SCHOOL LAUNCH · GEOGRAPHY K–12

Human Geography

An optional full-year, AP-style high-school course that studies where people live and why: Malthus counting mouths and harvests in 1798, Ravenstein reading his laws of migration to the Statistical Society in London in 1885, the steamers that brought millions through Ellis Island, von Thünen measuring the rings of his farm in Mecklenburg, Christaller mapping the market towns of southern Germany and Burgess drawing his circles over Chicago, each model worked with real numbers, tested against the evidence and weighed for what it explains and what it leaves out.

First edition

> *“And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;” (Acts 17:26, KJV)*

Course guide

This is an optional full-year elective for students in grades 10–12: 50 lessons in ten units of five, finished in about 34 weeks. It follows the broad shape of the AP Human Geography framework for students who want to sit the exam in May, and it stands on its own for those who do not. Unit 1 teaches the student to think geographically: maps and projections, spatial concepts, census data and layered maps, and scales of analysis. Then the course works through population, migration, language and religion, political geography, agriculture, cities, and industry and development, closes with a unit on resources and stewardship, and ends with a full exam-review unit in April. Every lesson has a historic map, painting or photograph, three worked examples, a practice set of twelve problems with answers and a written response. Each unit ends with a 100-point test and a unit project, the midterm closes Unit 5, and the final exam closes the course.

Every lesson begins with **the story**: a real person at a real place on a real date. Thomas Malthus publishes his *Essay on the Principle of Population* in 1798; E. G. Ravenstein reads "The Laws of Migration" to the Statistical Society in London in 1885; Johann Heinrich von Thünen sets out the rings of land use around a market town in *The Isolated State* in 1826; Walter Christaller maps the central places of southern Germany in 1933. Then comes **the model**: what the person claimed, stated clearly with its assumptions. Then **the numbers**: density, growth rates, doubling time, population pyramids, distance decay, location quotients and the simple arithmetic of each model, shown in worked examples. Finally comes **the test**: does the model fit the evidence, where does it break down and what did its critics say? Models are taught as models, useful tools to be weighed, not doctrines to be believed, and the course keeps ideological framing out.

Running through the course is the thread that runs through the whole School Launch Geography series, marked ⚙: technology overcoming geography. Census tabulating machines and layered digital maps let geographers see patterns no traveler could see; the seed drill, the tractor and the high-yield wheat of the Green Revolution changed what a field could feed; streetcars, railroads and highways reshaped the city; steamships and railways carried the great migrations. Each time the student asks what the land made hard, what the new technology changed and what distance, soil, water and climate still decide.

The faith thread runs underneath. Human geography is the study of the nations, and Scripture says plainly where they came from: "And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;" (Acts 17:26). Every people on the map is of one blood and made in God's image, every family and every city matters, and the earth is given to man to work and to keep: "And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it" (Genesis 2:15). The world's religions are described accurately and respectfully, the spread of Christianity from Jerusalem to the ends of the earth is told where it belongs in the story, and history is told candidly, with real achievements given their due and real wrongs named plainly.

WHO IT IS FOR

Written for students in grades 10–12, especially those who plan to take the AP Human Geography exam. No earlier geography course is required, though students who have done the School Launch Geography grades or Courses A and B will recognize many of the places and some of the content. The math is Algebra I level: rates, percentages, ratios, averages, the rule of 70 for doubling time and reading graphs and tables, with every method shown in a worked example first. Students work fairly independently, reading the lesson, studying the map or data and working the examples themselves; a parent or mentor checks the practice sets against the answers, discusses the written responses and helps with the projects. A world atlas, a calculator, graph paper and free public data from sources such as the U.S. Census Bureau are all that is needed. AP and Advanced Placement are trademarks of the College Board, which has not reviewed or endorsed this course.

HOW TO USE THIS COURSE

The weekly rhythm. Each lesson takes three sessions of about 50 minutes. Session 1: the warm-up, the story, the picture study and the core ideas. Session 2: the worked examples and map or data work in the map notebook. Session 3: the practice set, checked against the answers, and a written response in the style of an exam free-response question. Each unit ends with a test day and time to finish the unit project; the midterm closes Unit 5 and the final closes Unit 10, each with a review day. At five sessions a week the 50 lessons fill a school year of about 34 weeks. Students taking the AP exam in May should start in late August or early September so that Unit 10, the review unit, falls in April.

Models as models. Human geography is full of models: the demographic transition, von Thünen's rings, Christaller's hexagons, the Burgess, Hoyt and multiple-nuclei cities, Weber's triangle, Rostow's stages and Wallerstein's world-system. For each one, learn three things: what it claims, what it assumes, and where the real world departs from it. The exam asks for exactly this, and it is also simply good thinking. Contested questions, such as migration policy or land conservation, are presented factually and from more than one side.

The ⚙ thread and the map notebook. The ⚙ lessons, on GIS, the agricultural revolutions and transportation and the city, carry the series thread of technology overcoming geography; ask each time what barrier the technology crossed and what the land still decided. Use one bound notebook, ideally graph paper, for the whole year. Each unit has a main map or chart: a thematic map from census data, population pyramids, migration flows, language families and religions, boundary types, von Thünen's rings on a real region, an urban model fitted to a real city, an industrial map and a river-basin map. Draw them by hand with a title, a scale or axes, a key and a short note on what they show.

Worked examples and practice. Each lesson has three worked examples: population density, growth rates and doubling time, reading a population pyramid, distance decay, location quotients, rent at a distance from market in von Thünen's model, the range and threshold of a central place. Cover the solution, try it yourself, then compare line by line. The

practice set of twelve problems has answers; check them the same day and rework every miss.

Unit tests and unit projects. Each unit test is worth 100 points and mixes multiple-choice questions, map and data questions, short calculations and one free-response question scored the way the exam scores them. Each unit also has a project, from building a population pyramid of your own county to mapping the land use around your nearest town or fitting an urban model to a city you know. Record each project in the map notebook with a sketch, the data and what you learned.

Where it fits. This is Course E of the School Launch high-school Geography electives, and it is optional because it partly overlaps Course A, *Geography and History* (boundaries and states), and Course B, *Geography and Commerce* (trade and comparative advantage). Course C, *Technology Overcoming Geography*, makes the ⚙ thread the whole story, and Course D, *Geopolitics*, weighs the great theories of Mahan, Mackinder and Spykman. The course also sits beside the School Launch Engineering and Business high-school courses: Engineering explains how the tractor, the railway and the dam work, Business explains markets, trade and location costs, and this course shows where people, farms, cities and factories end up on the map and why.

SCOPE AND SEQUENCE

Unit 1: Thinking Geographically (Weeks 1–3)

Scale, projection and distortion; thematic maps; location, place, region, distance decay and diffusion; census data and layered maps in GIS; and how a pattern changes when it is studied at the local, national or global scale.

Unit 2: Population (Weeks 4–6)

Where the world’s people live and why, density and distribution, growth rates and doubling time, the demographic transition as a model with its limits, Malthus and the critics who pointed to invention and enterprise, and how to read the shape of a nation in its population pyramid.

Unit 3: Migration (Weeks 7–10)

Push and pull factors and Ravenstein’s laws of 1885, the great Atlantic crossings and Ellis Island, westward movement and the move to the cities, and migration policy presented factually with several views.

Unit 4: Culture: Language and Religion (Weeks 11–13)

Indo-European and the world’s great language families, the spread of Christianity from Jerusalem to the ends of the earth, the world’s religions on the map presented factually, and sacred places and pilgrimage at Jerusalem, Rome, Mecca and Varanasi.

Unit 5: Political Geography (Weeks 14–17)

States, nations and sovereignty since the Peace of Westphalia (1648), types of boundaries, federal and unitary states from the U.S. Constitution to France, and supranational organizations such as the UN, NATO and the EU, presented factually. The unit closes with the midterm on Units 1–5.

Unit 6: Agriculture (Weeks 18–20)

The first farms of the Fertile Crescent and the spread of farming, von Thünen's rings of land use around a market town (1826), the agricultural revolutions from the seed drill and the tractor to the Green Revolution, and the farming regions of the world from rice paddies to wheat belts.

Unit 7: Cities (Weeks 21–24)

Site and situation and why cities grow where they do, Christaller's central place theory (1933), the Burgess, Hoyt and multiple-nuclei models of the city, and how streetcars, railroads and highways reshaped it.

Unit 8: Industry and Development (Weeks 25–27)

Coal, iron and rivers in the geography of the Industrial Revolution, Weber's theory of where factories go (1909), Rostow's stages of growth and their critics, including Wallerstein's world-system, and trade, development and comparative advantage.

Unit 9: Geography and Stewardship (Weeks 28–30)

Dominion and stewardship (Genesis 1:28 and 2:15) and the use of resources, rivers, aquifers and dams, land use and conservation presented factually with several views, and natural hazards and the ways people prepare for and respond to them.

Unit 10: Exam Review (Weeks 31–34)

Timed free-response practice on models and on maps and data, a multiple-choice review of the whole course, a full practice exam under exam conditions, and the final exam. Students sitting the AP exam should reach this unit in April.

MATERIALS

- **A good world atlas**: A current atlas with physical, political and thematic maps (population, climate, land use). A library copy is fine.
- **A globe**: Any size, as long as it turns freely. Used for projections, scale and the great migration routes.
- **Map notebook**: One bound notebook, ideally graph paper, for every map, chart, worked example, project record and written response.
- **Graph paper, colored pencils, tracing paper and a ruler**: For population pyramids, thematic maps, tracing-paper overlays (a hand-made version of GIS layers) and the urban and land-use models.

- **A calculator**: Any scientific or phone calculator, for density, growth rates, doubling time, location quotients and model problems.
- **Free public data**: U.S. Census Bureau tables for your own state and county, and the population pyramids and tables published free online by national statistics offices. A free spreadsheet program is helpful but not required.
- **A local map**: A street map or printed online map of your own town or nearest city, for the site-and-situation, central place and urban-model projects.
- **Optional exam resources**: The College Board's free AP Human Geography course description and released free-response questions, and any current AP Human Geography review book. Useful for students sitting the exam; not required.
- **Optional reading**: Thomas Malthus, An Essay on the Principle of Population (1798), and E. G. Ravenstein, "The Laws of Migration" (1885), both free to read online in excerpt. Good background for older students; not required.

GRADING

Grades come from the practice sets and written responses, the map notebook, the unit projects, the unit tests, the midterm and the final. A calculation earns full credit when the setup, the numbers with their units and the answer are all shown. A written response earns full credit when it states the model or concept correctly, applies it to a specific place with real evidence and explains where the model fits and where it falls short.

- Practice sets and written responses (completed and corrected): 15%
- Map notebook (accuracy, neatness, notes): 10%
- Unit projects: 10%
- Unit tests: 35%
- Midterm exam: 15%
- Final exam: 15%

A 90–100, B 80–89, C 70–79, D 60–69, F below 60.

- Practice sets are graded for completion and correction, not first-try accuracy: a problem done, checked and correctly reworked earns full credit.
- Free-response questions are scored point by point, the way the exam scores them: each part earns its point for a correct, specific answer tied to a real place or example. Practice writing complete sentences that answer exactly what is asked.
- A map or chart earns full marks when it has a title, a scale or labeled axes, a key and a short note on what it shows, and when its data are plotted accurately.
- On tests, give partial credit for a correct setup even if the arithmetic slips. Answers on contested questions earn full credit when they present more than one view fairly and support each with evidence.
- For a high-school transcript this course is one full credit of social studies (human geography). Keep the map notebook, the unit projects and the tests as the record of the year. The AP exam score, if the student sits the exam, is reported separately by the College Board.

A NOTE TO PARENTS

This course is built to help a teenager understand where people live and why: why cities stand where they do, why people move, why farms and factories cluster, why languages and faiths spread along the routes they did. It also prepares students who wish to sit the AP Human Geography exam in May, with a full review unit, timed free-response practice and a practice exam. You do not need to be an expert. The lessons carry the content and the answers are provided; your part is to ask what each model claims and whether the evidence supports it, read the written responses and help with the projects. Population, migration, religion and development are treated factually with well-established figures and dates, family and marriage are presented as the norm, and contested questions are presented from more than one side without partisan or ideological framing. Figures that change from year to year are dated “as of 2026.”

A word about time. This course is written from a Christian view of creation (Genesis 1:1) and treats the Flood (Genesis 6–9) as history. It gives no ages of the earth or its rocks in the millions of years. Students will meet deep-time names such as “Ice Age” or “Neolithic” in museums, atlases, textbooks and on the exam, so the course teaches them as museum words: vocabulary to recognize and read, not claims the course makes. Where a long age unavoidably comes up, as it may in the lesson on the first farms, a “Thinking About Time” box separates what is actually measured from what is assumed and explains how Christians who read Genesis as history understand it. Recorded history, with dates from written sources, is given normally. Students should be able to read any sign, textbook or exam question with understanding and still say with confidence, “in the beginning God created the heaven and the earth” (Genesis 1:1).

Above all, we want students to see the peoples of the world as Scripture sees them: made “of one blood,” placed by a God who “hath determined the times before appointed, and the bounds of their habitation,” and given the earth to dress and to keep. A student who finishes this course should be able to read a population pyramid, a census map and an urban model with skill, weigh a theory against the evidence, and look at any town or nation with both clear eyes and charity.

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★ quarter path · ⚙ technology overcoming geography

UNIT 1

Thinking Geographically

Human geography asks a simple question with deep answers: **why are people and their works where they are?** Before we can study population, migration, language, religion, states, farms and cities, we need the geographer's tools. In this unit you will learn to read a map's scale and projection and to choose the right thematic map, to use the spatial concepts of location, place, region, distance decay and diffusion, to find and map census data with a geographic information system, and to move between local, national and global scales of analysis without being fooled by averages.

Every lesson begins with a real moment: Charles Joseph Minard's 1869 chart of Napoleon's march on Moscow, the spread of printing from Gutenberg's Mainz, John Snow's map of the Broad Street cholera outbreak of 1854 and Charles Booth's street-by-street map of London in 1889. Each one shows a person seeing something new by putting data on a map. You will compute scales, distortion factors, densities, rates, gravity-model predictions and location quotients, the same quantitative skills the AP Human Geography exam expects.

Throughout the course we keep in mind the series verse, Acts 17:26: God "hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation." The models and maps of human geography are tools for understanding how people dwell on God's earth. We use them carefully and test them against the evidence, remembering that behind every dot and every average are real families and neighbors.

BEFORE YOU BEGIN

- Can read latitude and longitude and use a bar scale on a map
- Can compute percentages, ratios and averages, and use square roots and exponents on a calculator
- Can convert between miles and kilometers and between square miles and square kilometers
- Has used an atlas or online map to locate countries and U.S. states

MASTERY CHECKLIST

- I can read and convert map scales and explain the difference between large-scale and small-scale maps.
- I can explain what each common projection preserves and distorts, and choose a suitable projection and thematic map type for a purpose.
- I can define and give examples of absolute and relative location, place, formal, functional and perceptual regions, and the four kinds of diffusion.
- I can apply distance decay, the gravity model and Reilly's law with real numbers.
- I can find census data, normalize it, compute densities, rates and location quotients, and describe how GIS layers work.

- I can analyze a question at more than one scale and recognize the modifiable areal unit problem and the ecological fallacy.

OPTIONAL BOOKS AND RESOURCES

- **U.S. Census Bureau data (data.census.gov)** (https://data.census.gov/): Free. Population, age, housing and economic data for the nation, states, counties, census tracts and blocks. Used in the Lesson 1.3 and 1.4 projects and the unit portfolio.
- **David Rumsey Map Collection** (https://www.davidrumsey.com/): Free. Hundreds of thousands of high-resolution historic maps, including many projections, thematic maps and atlases. Good for comparing projections (Lesson 1.1) and finding historic maps of your own state.
- **QGIS (free, open-source GIS software)** (https://qgis.org/): Free desktop GIS for Windows, Mac and Linux. Optional for the Lesson 1.3 layered-map project and the portfolio; a parent or teacher should help with installation and the first census download.

1.1 Maps and Projections

OBJECTIVES

- Read and convert map scale in its three forms (representative fraction, verbal scale and bar scale) and tell a large-scale map from a small-scale map.
- Explain why every flat map of the round earth distorts shape, area, distance or direction, and compare the Mercator, Gall–Peters, Robinson and Winkel Tripel projections by what each keeps and what each gives up.
- Identify the main kinds of thematic maps (choropleth, dot density, proportional symbol, isoline, flow and cartogram) and choose the right one for a set of data, using Charles Joseph Minard’s 1869 map of Napoleon’s Russian campaign as a model.

Warm-up. Take an orange (or a clementine) and draw a rough equator and a few continents on it with a marker. Now peel it in as few pieces as you can and try to press the peel flat on the table without tearing or stretching it. Write one sentence: what had to happen to the peel to make it lie flat? That is the mapmaker’s problem in one hand.

Watch. *Introduction to MAPS! [AP Human Geography Review—Unit 1 Topic 1]* (Heimler's History, 9:50). https://www.youtube.com/watch?v=iG3XQQ7lgBI
With the big idea: watch how the teacher explains why every flat map bends the round Earth somewhere, and listen for the Mercator, Robinson and equal-area projections the lesson names.
Note: Captions were not available to check; preview it first. This is a fast AP exam review from a teacher, so it may move quickly for younger students.

Backup video. *A Strange Map Projection (Euler Spiral) - Numberphile* (Numberphile, 12:55). https://www.youtube.com/watch?v=D3tdW9l1690
As review: watch a mathematician peel the globe into one long spiral strip, and notice why no flat map can show the round Earth without cutting or stretching it. Note: Captions were not available to check; preview it first. The description lists a Brilliant sponsor, so skip the sponsor message, and the video leans more toward math than the projections named in the lesson. Shows an unusual Euler spiral projection rather than the Mercator, Robinson or Winkel Tripel maps in the lesson.

KEY TERMS

map scale
The relationship between a distance on a map and the real distance on the ground, written as a representative fraction (1:24,000), a verbal scale (“one inch equals one mile”) or a bar scale.

large-scale and small-scale map

A large-scale map (such as 1:24,000) shows a small area in great detail; a small-scale map (such as 1:50,000,000) shows a large area with little detail. The larger the fraction, the larger the scale.

map projection
A mathematical method of transferring the curved surface of the earth onto a flat map. Every projection distorts at least one of shape, area, distance or direction.

conformal and equal-area projections
A conformal projection keeps the shapes of small areas and true angles (Mercator); an equal-area projection keeps the relative sizes of areas but bends shapes (Gall–Peters, Goode's homolosine). No projection can be both.

thematic map
A map that shows the pattern of one subject or theme, such as population, rainfall or religion, rather than general features like roads and rivers (a reference map).

choropleth map
A thematic map that shades whole areas (states, counties, tracts) by the value of a rate or ratio, such as people per square mile or percent over age 65.

CORE IDEAS

The story. In 1869 a retired French civil engineer named Charles Joseph Minard, then eighty-eight years old, published a map in Paris of a disaster that had happened when he was a young man. In June 1812 Napoleon led the Grand Army across the Niemen River into the Russian Empire. Minard drew the army as a broad tan band flowing east from the Niemen toward Moscow, its width showing the number of men, at one millimeter for every ten thousand. The band begins about 42 millimeters wide (422,000 men by Minard's figures) and narrows as men fell to battle, hunger, disease and desertion. A thin strand of 100,000 reaches Moscow in September. Then a black band shows the retreat west through the winter, with a line of temperatures beneath it, falling to 30 degrees below zero on the Réaumur scale in early December. At the Berezina River the black band is cut in half. About 10,000 men, by Minard's count, recrossed the Niemen. One sheet of paper shows six things at once: the size of the army, its route, its direction, the places it passed, the dates and the cold.

How it worked. Minard was not trying to make a beautiful map. He wanted readers to *see* numbers. His chart is a **flow map**, one kind of **thematic map**. A reference map shows where things are (rivers, roads, towns); a thematic map shows the pattern of one subject. Human geographers use a handful of standard types. A **choropleth map** shades whole areas by a rate, such as people per square mile. A **dot density map** puts one dot for every 1,000 people (or cattle, or churches), so clusters stand out. A **proportional symbol map** draws circles sized by a count, such as the population of each city. An **isoline map** joins points of equal value, such as temperature (isotherms) or elevation (contour lines). A **flow map** shows movement, like Minard's army or migrants and trade. A **cartogram** deliberately resizes each country by a value, such as its population, so that the shapes look strange but the sizes tell the story. A wise mapmaker picks the type that fits the data: counts belong in dots or proportional symbols, while rates and percentages belong in choropleths, because a big county will look important on a choropleth even when few people live there.

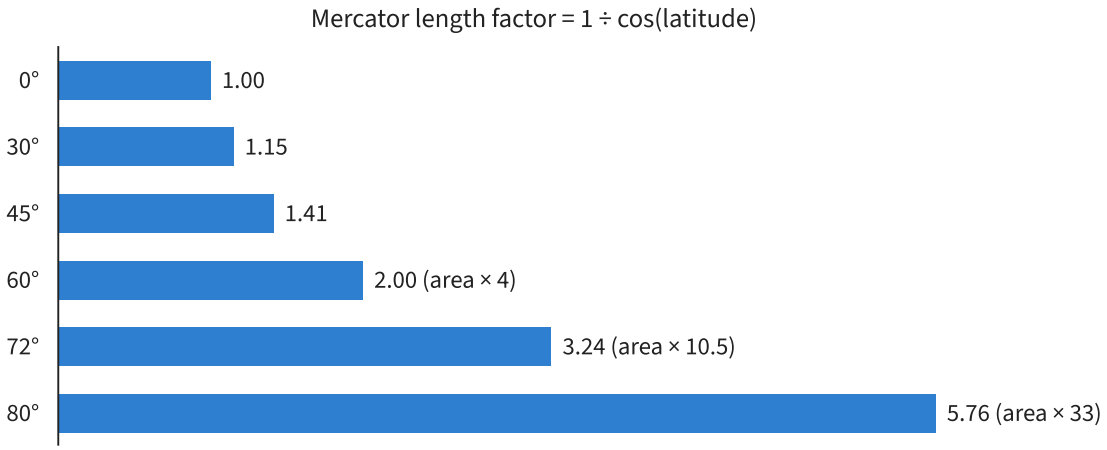
The big idea: scale. Every map is a reduction. **Map scale** tells how much. A U.S. Geological Survey topographic map at **1:24,000** means one inch on the map stands for 24,000 inches (2,000 feet) on the ground. That same scale can be written as a verbal scale ("one inch equals 2,000 feet") or drawn as a bar scale, which has the advantage of staying correct when the map is enlarged or shrunk on a copier or a screen. Geographers call 1:24,000 a **large-scale map** because the fraction 1/24,000 is larger than, say, 1/10,000,000; it shows a small area in great detail. A world map is a **small-scale map**. Students often get this backward, so remember: large scale, large detail, small area.

The big idea: projection. The earth is very nearly a sphere, and a sphere cannot be flattened without stretching or tearing, as your orange peel showed. A **map projection** is the rule that does the flattening, and each one must give something up. Gerardus Mercator's world map of 1569 was made "for the use of navigators." It is **conformal**: angles are true, so a line of constant compass bearing (a rhumb line) is straight, and a sailor can lay a ruler from port to port and read off a course. The price is area. On the Mercator map the stretching at any latitude equals 1 divided by the cosine of the latitude, so lengths at 60° are doubled and areas quadrupled. Greenland looks about as large as Africa, though Africa is about fourteen times larger. **Equal-area** projections keep sizes true but bend shapes. In 1973 the German historian Arno Peters promoted an equal-area map as fairer to the tropical countries; cartographers pointed out that the Scottish clergyman James Gall had described the same projection in 1855, and that its continents are badly stretched north and south. Hence the name Gall–Peters. **Compromise** projections bend everything a little to avoid bending anything a lot. Arthur Robinson designed one in 1963; the National Geographic Society used it for world maps from 1988 and switched in 1998 to the Winkel Tripel (published by Oswald Winkel in 1921). There is no perfect projection, only the right one for a purpose.

On the map. When you open any atlas or app, ask four questions. What is the **scale**, and is there a bar scale? What is the **projection**, and which property does it protect? Is this a **reference** or a **thematic** map, and if thematic, does the type fit the data (counts or rates)? And what has the mapmaker **left out**? Every map selects, simplifies and classifies. Minard left out mountains, roads and towns he did not need. A map is an argument made with symbols, and an honest map makes a true argument clearly.

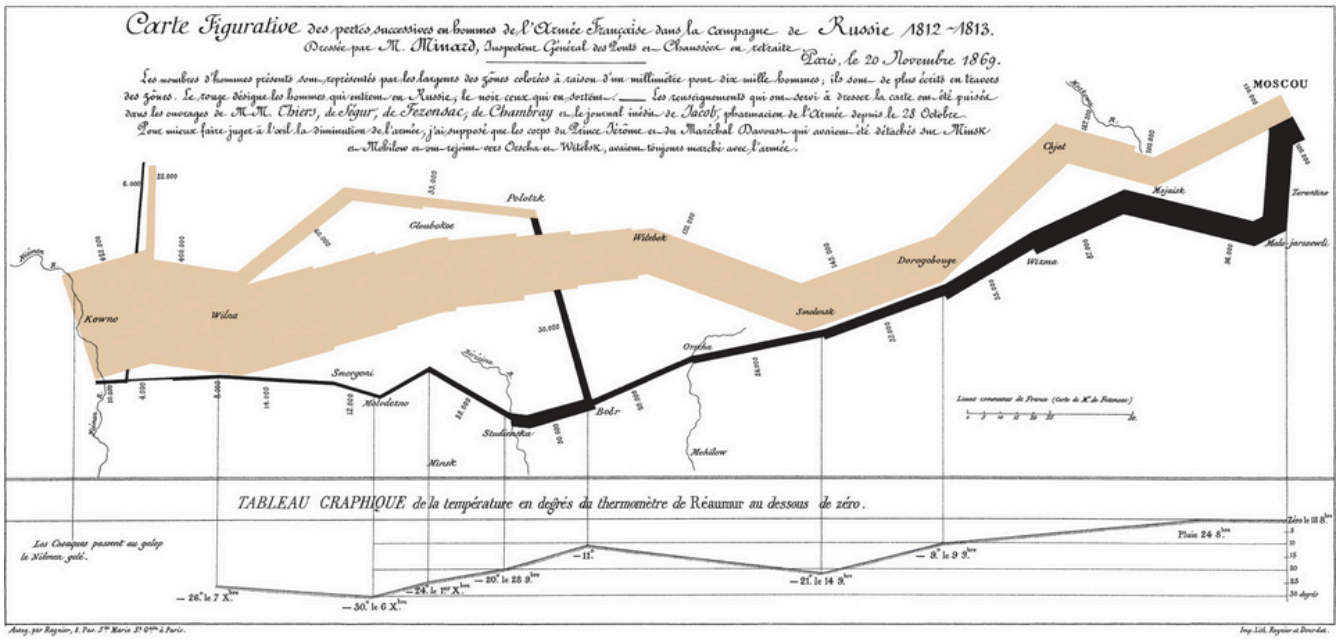
Why it matters. The psalmist wrote, "The earth is the LORD's, and the fulness thereof" (Psalm 24:1). A map is a small human attempt to describe a world we did not make. That calls for humility, because every map is partial, and for honesty, because a map can mislead as easily as it can teach. In the rest of this course you will read population maps, migration maps, language and religion maps and city maps. The habits of this lesson, checking scale, projection and map type, are the first tools of thinking geographically.

The route Minard drew: Napoleon's advance (June to September 1812) and retreat (October to December 1812).



How much the Mercator projection stretches lengths at each latitude (1 ÷ cosine of latitude). Areas are stretched by the square of these numbers.

PICTURE STUDY



Carte figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812–1813 (Figurative Map of the Successive Losses in Men of the French Army in the Russian Campaign, 1812–1813), Charles Joseph Minard, 1869 · Lithograph, printed in two colors (tan and black) · Published in Paris; copies are held at the library of the École nationale des ponts et chaussées and in other French libraries, and the chart is widely reproduced

Charles Joseph Minard (1781–1870) spent his career as an engineer building bridges, canals and roads for the French state. In retirement he made dozens of "figurative maps" that turned statistics into pictures: flows of wine, cotton, coal and travelers. This one, published in 1869 together with a map of Hannibal's march across the Alps, is the most famous.

Minard took his numbers from the memoirs and histories of men who had been on the campaign. Historians today give somewhat different totals, but nearly all agree with the shape of the story his band tells: most of the army that crossed into Russia never came back.

Look closely

- Follow the tan band from left to right. Where does it get much thinner suddenly? What happened at those places?
- Find the black band of the retreat and the temperature line beneath it. How did Minard connect the two?
- Look for the small branch that splits off from the main band. Why might part of an army march a different route?
- Notice what is missing: there are almost no rivers, roads or mountains. Why did Minard leave them out?

Talk about it

1. How many different kinds of information (variables) does this one chart show? List them.
2. Is this a reference map or a thematic map? Which type of thematic map is it?
3. A chart like this makes an argument without words. What is Minard’s argument, and is it fair to the evidence?

PROJECT: PEEL THE EARTH: MEASURING DISTORTION

You will measure the distortion of the Mercator projection with your own hands. Using a globe (or a ball with a grid drawn on it) and a Mercator world map, you will compare the true and mapped sizes of Greenland, Africa and South America, then build a small table of scale factors and test it against the formula from this lesson.

You will need

- A globe, or a large ball (playground ball or grapefruit) with lines of latitude every 15° and longitude every 15° drawn in marker
- A printed Mercator world map and, if possible, a Robinson or Winkel Tripel world map (free outline maps are easy to find in any atlas or online)
- A strip of paper or a flexible tape measure, a ruler, string, tracing paper, a pencil and a calculator

Steps

1. On the globe, measure the length of one degree of longitude along the equator (measure 15° and divide by 15). Then measure one degree of longitude along 30°, 45° and 60° north. Record each in a table.
2. Divide each measurement by the equator measurement. Compare your numbers with cos 30° = 0.866, cos 45° = 0.707 and cos 60° = 0.500. They should be close.
3. On the Mercator map, measure one degree of longitude at the equator and at 60° N. Notice that they are the same width: the Mercator map keeps every meridian parallel, so it stretches high latitudes east and west by 1 ÷ cos(latitude).
4. Trace Greenland and Africa from the Mercator map onto tracing paper and lay the tracings side by side. Then trace the same two landmasses from a Robinson or Winkel Tripel map. Write down your impression of how big each looks.
5. Look up the true areas (Greenland about 2.17 million km², 836,000 sq mi; Africa about 30.4 million km², 11.7 million sq mi) and compute how many Greenlands fit in Africa.
6. Peel your orange or grapefruit carefully into eight pieces from pole to pole (gores) and lay them flat. Sketch the result and label where the gaps are. This is how globe makers have printed globes since the 1500s.
7. Write a paragraph explaining which projection you would choose for (a) a ship’s chart, (b) a wall map comparing the sizes of countries and (c) a general classroom world map, and why.

Tips

- Measure along the curved surface, not straight through the ball: the tape must lie on the skin of the globe.
- If your measurements are a little off, that is normal. Ask whether the error is in the globe, the tape or your reading.
- Keep units the same throughout the table. Ratios have no units.

Check your work

- My table shows degree-of-longitude lengths at four latitudes, and my ratios are close to the cosines.
- I can show with tracings why Greenland looks too big on a Mercator map.
- My paragraph matches each purpose to a suitable projection and explains the trade-off.

MAP NOTEBOOK

1. Draw a bar scale for a 1:50,000 map that shows 0, 1, 2 and 3 kilometers (2 cm per kilometer). Underneath, write the same scale as a verbal scale.
2. Sketch the outline of Minard's chart from memory: the tan advance, the black retreat, Moscow at the right, the Niemen at the left and the temperature line. Label four places.
3. Make a two-column chart titled "Which Map for Which Data?" Write six kinds of thematic map on the left and one example of good data for each on the right.

> **From history.** Mercator drew his 1569 map by careful construction, but he never published the mathematics behind the spacing of his parallels. That was done by the English mathematician Edward Wright in *Certaine Errors in Navigation* (1599), who worked out tables of the stretching from latitude to latitude. With Wright's tables, any chartmaker could draw a true Mercator chart, and over the next century the projection became the standard for sea charts, as it still is today.

WORKED EXAMPLES

Example 1. On a U.S. Geological Survey topographic map at 1:24,000, a hiking trail measures 3.25 inches. How long is the trail in feet, miles and kilometers?

1. At 1:24,000, 1 inch on the map = 24,000 inches on the ground = 24,000 ÷ 12 = 2,000 feet.
2. Trail length = 3.25 × 2,000 = 6,500 feet.
3. In miles: 6,500 ÷ 5,280 = 1.23 miles.
4. In kilometers: 6,500 × 0.3048 = 1,981 meters, about 1.98 km.

Answer: 6,500 feet, about 1.23 miles (1.98 km).

Example 2. On the Mercator projection, lengths at latitude φ are stretched by a factor of 1 ÷ cos φ, and areas by (1 ÷ cos φ)². Greenland lies mostly between 60° and 83° N; take 72° N as its middle. Africa straddles the equator, where the stretching is small. Estimate how much the Mercator map enlarges Greenland's area, and explain why Greenland looks about as large as Africa although Africa is about 14 times larger.

(Use the map or drawing "Use the factor at 72° (3.24) and square it for area." shown earlier in this lesson.)

1. cos 72° = 0.309, so the length factor is 1 ÷ 0.309 = 3.24.
2. Area factor = 3.24² = 10.5. Greenland is drawn about 10 times too large (even more in its northern part).
3. Mapped Greenland ≈ 2.17 million km² × 10.5 ≈ 22.8 million km² equivalent.
4. Africa lies between about 37° N and 35° S; most of it is within 25° of the equator, where the area factor is under 1.25, so it appears near its true 30.4 million km².
5. So on the map the two look comparable (about 23 versus a little over 30), while in reality Africa ÷ Greenland = 30.4 ÷ 2.17 = 14.

Answer: Greenland is enlarged roughly tenfold in area (factor ≈ 10.5 at 72° N), while Africa is barely enlarged, so a landmass one-fourteenth the size of Africa appears about as large. This is an estimate using one central latitude.

Example 3. Minard's chart shows 422,000 men crossing the Niemen, 100,000 reaching Moscow and 10,000 recrossing the Niemen. His band width is 1 mm for every 10,000 men. Find the band widths at the start, at Moscow and at the end, the percentage of the army that reached Moscow and the percentage that was lost overall.

(Use the map or drawing "The route behind Minard's band." shown earlier in this lesson.)

1. Widths: 422,000 ÷ 10,000 = 42.2 mm; 100,000 ÷ 10,000 = 10 mm; 10,000 ÷ 10,000 = 1 mm.
2. Reached Moscow: 100,000 ÷ 422,000 = 0.237, or 23.7 percent.
3. Returned: 10,000 ÷ 422,000 = 0.0237, or 2.4 percent.
4. Lost overall: 100 − 2.4 = 97.6 percent.

Answer: 42.2 mm, 10 mm and 1 mm. About 23.7 percent reached Moscow, and about 97.6 percent of the force (by Minard's figures) did not return across the Niemen.

PRACTICE

1. EASY Which is the larger-scale map, 1:24,000 or 1:1,000,000? Which one would show a whole state, and which a single town?
2. EASY Write the representative fraction 1:63,360 as a verbal scale in inches and miles.

3. EASY What property does the Mercator projection preserve, why did that matter to sailors, and what does it distort most?
4. MEDIUM On a 1:50,000 map two churches are 7.2 cm apart. How far apart are they on the ground in kilometers and miles?
5. MEDIUM Use the figure. What is the Mercator length factor at 45°, and by how much is area enlarged there?
   (Use the map or drawing "Mercator stretching by latitude." shown earlier in this lesson.)
6. MEDIUM A degree of longitude is about 111.3 km (69.2 mi) at the equator. How long is it on the ground at 60° N, near Oslo and St. Petersburg?
7. MEDIUM Choose the best type of thematic map for each: (a) the number of people in each U.S. city of over 100,000; (b) the percent of each state's population over age 65; (c) average January temperatures across Canada; (d) the routes and numbers of immigrants arriving in the United States in 1900.
8. MEDIUM On Minard's chart, 1 mm of band width stands for 10,000 men. The main army at Smolensk on the advance is about 145,000 men by Minard's figures. How wide is the band there? How wide would a band of 28,000 men be?
9. HARD Minard's temperature line reads −30° Réaumur on December 6, 1812. On the Réaumur scale water freezes at 0° and boils at 80°. Convert −30° R to Celsius and Fahrenheit.
10. HARD South America covers about 17.8 million km² and Greenland about 2.17 million km². How many times larger is South America? Why does the Mercator map make them look much closer in size?
11. HARD Why did the National Geographic Society choose the Robinson projection (1988) and then the Winkel Tripel (1998) for its world maps instead of the Mercator or an equal-area projection?
12. CHALLENGE In a paragraph, recommend a projection for each purpose and justify it: (a) a ship's chart for plotting compass courses; (b) a world map of population density by country; (c) a map showing the shortest air routes from Chicago to cities around the world.

COMMON MISTAKES

- Reversing large and small scale. A large-scale map (1:24,000) shows a small area in great detail; a world map is small scale.
- Using a choropleth map for raw counts. Shading counties by total population makes large, empty counties look important; choropleths should show rates (per square mile, per 1,000 people, percent).
- Thinking some projection is "correct." Every projection distorts; the question is which property you need for your purpose.

> **Make it a game · Projection Detective.** Print or display four world maps without their titles: Mercator, Gall–Peters, Robinson (or Winkel Tripel) and an azimuthal map centered on the North Pole. Players race to name each one and give one clue that proves it (Greenland's size, stretched tropics, curved meridians, a round map with the pole in the

middle). Then a caller reads a purpose (“plot a course by compass,” “compare the sizes of countries,” “show airline routes over the Arctic”) and the first player to point to the best map scores a point. Play to ten.

Scripture. “The earth is the LORD’s, and the fulness thereof; the world, and they that dwell therein.” (Psalm 24:1, KJV)

Maps are human attempts to describe a world that belongs to God. Every map leaves things out and bends something, so a mapmaker must be humble about its limits and honest in what it shows.

Practice answers

1. 1:24,000 is the larger scale (1/24,000 is a larger fraction). It shows a small area such as a town in detail; 1:1,000,000 is a small-scale map suitable for a whole state.
2. There are 63,360 inches in a mile (5,280 × 12), so one inch equals one mile.
3. It is conformal: angles and local shapes are true, so a line of constant compass bearing (a rhumb line) is straight and a navigator can plot a course with a ruler. It badly distorts area toward the poles.
4. 7.2 × 50,000 = 360,000 cm = 3.6 km = 3.6 × 0.6214 = 2.24 miles.
5. Length factor 1 ÷ cos 45° = 1.41; area factor $1.41^2 = 2.0$. Areas at 45° are drawn twice their true size relative to the equator.
6. 111.3 × cos 60° = 111.3 × 0.5 = 55.7 km (69.2 × 0.5 = 34.6 mi).
7. (a) Proportional (graduated) symbol map, because these are counts at points. (b) Choropleth map, because these are rates for areas. (c) Isoline (isotherm) map. (d) Flow map.
8. 145,000 ÷ 10,000 = 14.5 mm; 28,000 ÷ 10,000 = 2.8 mm.
9. °C = °R × 100/80 = −30 × 1.25 = −37.5 °C. °F = −37.5 × 1.8 + 32 = −67.5 + 32 = −35.5 °F.
10. 17.8 ÷ 2.17 ≈ 8.2 times larger. South America lies mostly between about 12° N and 55° S, where most of it is stretched only modestly, while Greenland lies at 60–83° N, where the Mercator area factor is roughly 4 to 70 times. Greenland is therefore inflated far more.
11. Both are compromise projections: they are neither conformal nor equal-area, but they keep distortion of area, shape and distance moderate everywhere, so the world looks familiar and the polar regions are not wildly enlarged. The Winkel Tripel was judged to reduce overall distortion further than the Robinson. Mercator inflates high latitudes; equal-area maps stretch shapes.
12. (a) Mercator, because it is conformal and rhumb lines are straight, so a constant compass course can be read off with a ruler. (b) An equal-area projection (for example Gall–Peters, Mollweide or Goode’s homolosine), because a density map compares areas and inflating high-latitude countries would mislead the eye. (c) An azimuthal equidistant projection centered on Chicago, because straight lines from the center are great circles at true distance, showing both the shortest route and its length. A strong answer names the trade-off each choice accepts.

1.2 Spatial Concepts

OBJECTIVES

- Define and give examples of absolute and relative location, place, and the three kinds of region (formal, functional and perceptual).
- Explain distance decay and the gravity model, and compute gravity-model comparisons and a Reilly breaking point between two real cities.
- Classify diffusion as relocation, hierarchical, contagious or stimulus, using the spread of printing from Mainz after about 1450 as the case study.

Warm-up. On a scrap of paper, list the last ten places your family drove to (store, church, school, doctor, relatives). Beside each, write roughly how many miles away it is. Count how many are under 5 miles, 5 to 20 miles, and over 20 miles. What pattern do you notice?

Video. Coming soon. Gutenberg and the spread of the printing press across Europe, and the basic spatial concepts of geography (location, region, diffusion, distance decay): search Hillsdale Studios, The History Guy, Library of Congress (the Gutenberg Bible), Drive Thru History with Dave Stotts (the Reformation and printing); candidates (need vetting): AP Human Geography review channels from individual teachers (vet each carefully for ideological framing).

KEY TERMS

absolute and relative location

Absolute location is a position given by a precise reference system, such as latitude and longitude (Mainz: 50.0° N, 8.3° E). Relative location is a position described in relation to other places (“on the Rhine, opposite the mouth of the Main”).

region

An area that shares a common feature. A formal region shares a measurable trait (a language area); a functional region is organized around a center and linked by flows (a newspaper’s circulation area); a perceptual or vernacular region exists in people’s minds (“the Midwest”).

distance decay

The tendency for contact and interaction between two places to decline as the distance between them increases.

gravity model

A model that predicts the interaction between two places as proportional to the product of their populations divided by the square of the distance between them: $P_1 \times P_2 \div d^2$.

expansion diffusion

The spread of an idea or innovation outward while it stays strong at its source. Its forms are hierarchical (from larger or more important places to smaller ones), contagious (from

person to person nearby) and stimulus (the underlying idea spreads, but the form changes).

relocation diffusion
The spread of an idea or practice when the people who carry it move to a new place.

CORE IDEAS

The story. In the 1450s, in the Rhineland city of Mainz, Johannes Gutenberg and his partners printed a Latin Bible with movable metal type. The work was finished by about 1455, and some 180 copies were made, on paper and on vellum. Gutenberg's craft combined a hand mold for casting identical letters, an oil-based ink and a press adapted from the wine and paper presses of the region. For a few years the craft stayed mostly in Mainz, though a press was working in nearby Strasbourg by about 1460. Then, in 1462, during a war between two rival archbishops, Mainz was captured and sacked, and many of its workmen scattered. Printing spread faster with them. A press was working in Cologne by about 1466. In 1465 two German printers, Konrad Sweynheym and Arnold Pannartz, set up a press at the Benedictine monastery of Subiaco in the hills east of Rome, and moved to Rome itself in 1467. Johann of Speyer printed in Venice in 1469; a press was set up at the Sorbonne in Paris in 1470; William Caxton, an English merchant who had learned the craft on the Continent, opened his shop at Westminster in 1476. By 1500 presses had worked in more than 250 towns across Europe.

How to think about it: location, place and region. Why Mainz? Its **absolute location** is about 50.0° N, 8.3° E. Its **relative location** mattered more: on the Rhine, Europe's busiest river road, where the Main flows in, about 40 km (25 mi) from Frankfurt and its great trade fairs, in a region with paper mills, metalworkers and wealthy churchmen who wanted books. Geographers call the physical character of a spot its **site** and its connections its **situation** (Unit 7 returns to these). Every location is also a **place**, with its own human and physical character: Mainz was an archbishop's seat and a city of goldsmiths, which helps explain why a goldsmith there could invent precise type. A **region** groups places that share something. A **formal region** shares a measurable trait, such as the area where German was spoken. A **functional region** is tied together by flows around a center, such as the area that bought books at the Frankfurt fair. A **perceptual** or **vernacular region** exists in people's minds, such as "the Rhineland" or, today, "the South" or "the Midwest," whose edges people draw differently.

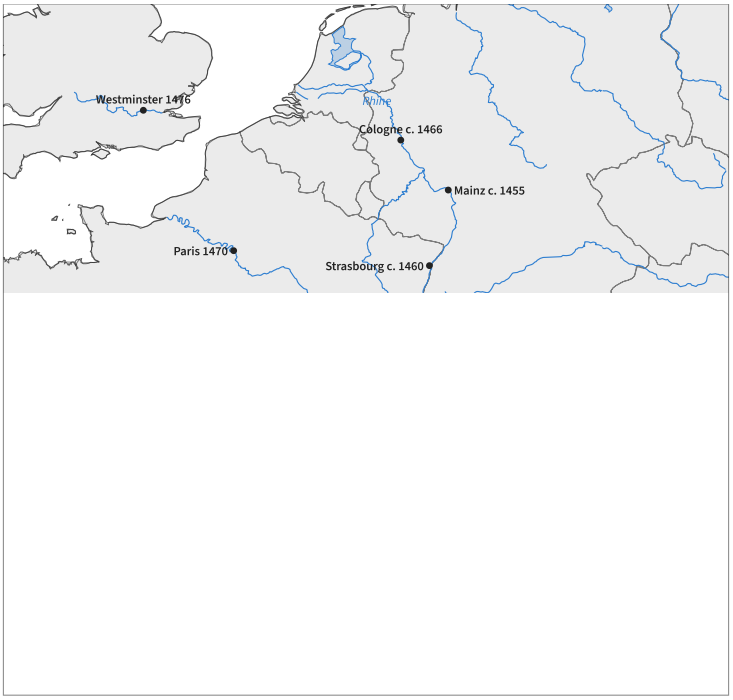
The big idea: diffusion. The spread of printing shows every type of **diffusion** geographers use. It was **relocation diffusion** when printers like Sweynheym and Pannartz carried their skill and type across the Alps. It was **hierarchical diffusion** because presses went first to large commercial cities, university towns and seats of church power (Cologne, Rome, Venice, Paris), skipping many small towns nearby. It became **contagious diffusion** as presses multiplied outward from each center to neighboring towns. And **stimulus diffusion** happens when the idea spreads but the form changes. The classic American example is Sequoyah, a Cherokee silversmith who saw that English-speakers could write down speech. He could not read English, but by 1821 he had created a syllabary for the Cherokee language, with its

own symbols, and within a few years many Cherokees could read and write in it. In 1953 the Swedish geographer Torsten Hägerstrand published a study of how farm innovations spread through a district of south-central Sweden. He showed that adoption followed an S-shaped curve (slow, then fast, then leveling off) and spread outward mainly by personal contact, and he built early computer-style models of the process.

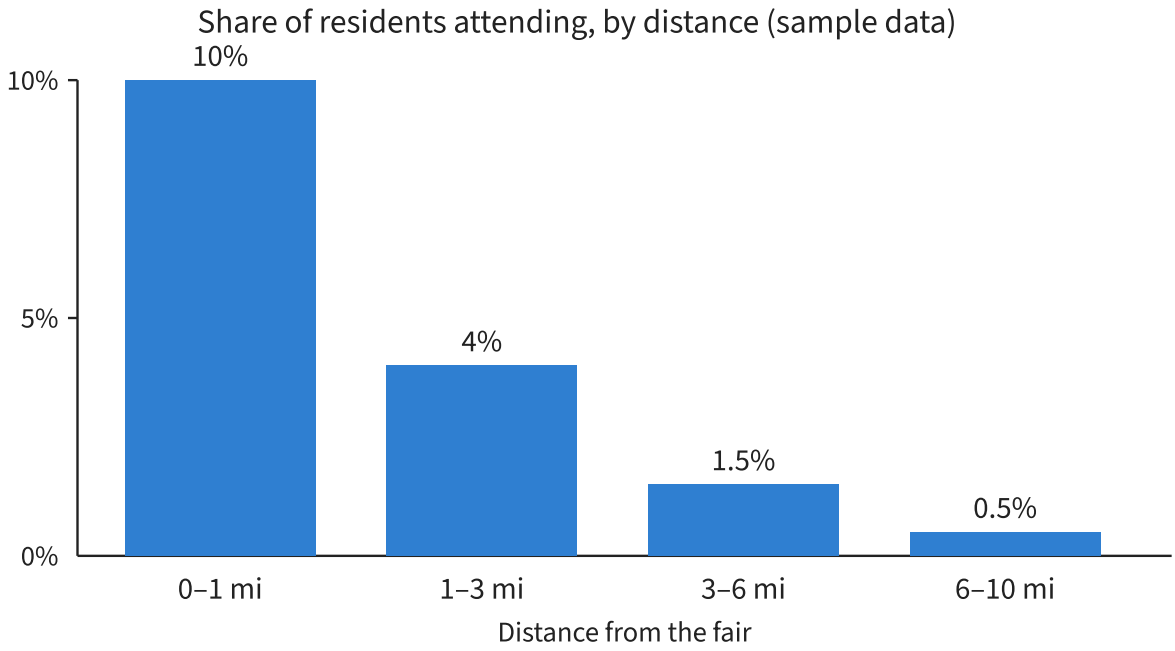
The big idea: distance decay. Why did the first presses cluster in the Rhineland and northern Italy? Partly because of **distance decay**: interaction falls off with distance. People shop, marry, worship, phone and visit more often near home than far away. In 1970 the geographer Waldo Tobler put it in a sentence that is now called the first law of geography: “Everything is related to everything else, but near things are more related than distant things.” The **gravity model** turns this into a formula. Like Newton’s law of gravitation, it says interaction between two places grows with their sizes and shrinks with the square of the distance: $P_1 \times P_2 \div d^2$. In 1931 the American marketing researcher William J. Reilly used the same reasoning to find the **breaking point** between two cities, where a shopper is equally drawn to either. These are models: they predict averages well, but real flows also depend on cost, culture, language, borders and personal ties.

Technology overcoming geography. Printing itself shrank distance. Before 1450, a book had to be copied by hand, and ideas spread at the pace of a copyist. After it, the same text could be printed in hundreds of identical copies and carried along trade routes. In 1517 Martin Luther’s Ninety-five Theses were posted in Wittenberg; within weeks printed copies were circulating across the German lands. Geographers call this shrinking of effective distance by faster travel and communication **time-space compression**. The steamship, the telegraph, the airplane and the internet have pressed the world closer still. Yet distance decay has not disappeared: most of your friends, purchases and visits are still near home, as your warm-up list probably showed.

On the map. The series verse, Acts 17:26, says that God “hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation.” Human geography studies those bounds and times: where people dwell, how places differ, and how ideas, goods and people move among them. In every lesson that follows, ask the spatial questions of this one. Where is it? What is this place like? What region is it part of? How did it get here, and how does distance shape it?



The first spread of printing from Mainz, with the year a press first worked in each city (round dates).



A distance-decay curve from a survey (sample data): the farther people live, the smaller the share who come.

PICTURE STUDY

Impressio Librorum (The Printing of Books), from the series Nova Reperta (New Inventions of Modern Times), Designed by Jan van der Straet (Stradanus); engraved in the Galle workshop (often credited to Theodoor Galle); published by Philips Galle, Antwerp, about 1580–1605 (the series is usually dated about 1590) · Engraving · British Museum, London (1948,0410.4.194), and many other print collections

Jan van der Straet, a Flemish painter who worked for the Medici in Florence and was known as Stradanus, designed a series of prints celebrating the great inventions of recent times, including the compass, gunpowder, the mechanical clock, the discovery of America and printing. The series, called *Nova Reperta*, was engraved and published in Antwerp, itself one of the great printing cities of Europe.

About 140 years after Gutenberg, this print shows that printing had become an ordinary trade carried on in shops across Europe. It lets us see every step of the work that carried ideas from city to city.

Look closely

- Find the compositors setting type from the cases. How many letters might it take to set one page?
- Find the press and the worker pulling its bar. Find the man with the two round ink balls.
- Look up at the sheets hanging to dry. What does that tell you about how many copies were made at once?
- Find any figure who seems to be checking or reading the work. Why would proofreading matter?

Talk about it

1. Which steps in this shop could be carried to a new city by a single skilled worker? What does that tell you about relocation diffusion?
2. Stradanus put printing in the same series as the compass and the discovery of America. Why did people of his time see printing as one of the inventions that changed the world?
3. How does printing illustrate time-space compression?

PROJECT: DISTANCE DECAY IN MY OWN TOWN

You will test distance decay with real data from your own community. Choose one place many people visit (your church, a library, a farmers' market, a store), survey where its visitors come from, and map the results in distance rings. Then compare what you find with the gravity model.

You will need

- A local street map or printed online map of your town with a bar scale
- A compass (drawing compass) or string and pin for drawing distance rings, a ruler and colored pencils
- A short survey sheet (ask only the nearest cross-streets or ZIP code, never full addresses), with permission from the place you survey
- Census population for your ZIP codes or town (data.census.gov) if you want to compute rates

Steps

1. With a parent and the permission of the church, library or business, ask 40 or more visitors one question: "About how far do you live from here, or what are your nearest cross-streets or ZIP code?" Do not collect names or addresses.
2. Mark the place on your map. Draw distance rings at 1, 3, 6 and 10 miles (or 2, 5, 10 and 15 km) using the bar scale.
3. Place one dot for each visitor in the correct ring (approximate is fine). Count the dots in each ring.
4. If you can, estimate the number of people living in each ring (from census data or a parent's help) and compute the visitors per 1,000 residents in each ring.
5. Make a bar chart like the figure in this lesson, with distance bands on one axis and visitors (or visitors per 1,000) on the other.
6. Write a paragraph: Does your chart show distance decay? Name at least two reasons besides distance (a highway, a river, family ties, a rival store or church) that bend the pattern.

Tips

- Count per 1,000 residents when you can. Raw counts can mislead if one ring holds many more people than another.
- A survey of 40 is small. Treat your result as a first test, not a proof.

- Be courteous and brief with the people you ask, and thank the place that let you survey.

Check your work

- My map shows the place, four distance rings drawn to scale and a dot for every response.
- My chart shows counts (and rates, if possible) for each ring.
- My paragraph states whether distance decay appears and names other factors that shape the pattern.

MAP NOTEBOOK

1. Write the absolute location of your home (latitude and longitude to one decimal place) and three sentences describing its relative location.
2. Draw three small maps: one formal region, one functional region and one perceptual region that include your town. Label each.
3. Draw a four-panel comic showing relocation, hierarchical, contagious and stimulus diffusion of one idea or invention.

> **From history.** Caxton printed the first book in English, *The Recuyell of the Historyes of Troye*, in Bruges around 1473–74, before he returned to England. At Westminster he printed Chaucer's *Canterbury Tales* in 1476 or 1477. Printing in English helped fix the spelling and grammar of the language, and some of the odd spellings we still use go back to choices made by early printers.

WORKED EXAMPLES

Example 1. Using the gravity model (interaction $\propto P_1 \times P_2 \div d^2$), compare Chicago's predicted interaction with Milwaukee and with St. Louis. Use round metropolitan populations: Chicago 9.6 million, Milwaukee 1.6 million, St. Louis 2.8 million. Straight-line distances: Chicago–Milwaukee about 82 miles (132 km), Chicago–St. Louis about 262 miles (422 km).

1. Chicago–Milwaukee: $9.6 \times 1.6 \div 82^2 = 15.36 \div 6{,}724 = 0.00228$.
2. Chicago–St. Louis: $9.6 \times 2.8 \div 262^2 = 26.88 \div 68{,}644 = 0.000392$.
3. Ratio: $0.00228 \div 0.000392 = 5.8$.
4. Check another way: $(1.6 \div 2.8) \times (262 \div 82)^2 = 0.571 \times 10.2 = 5.8$.

Answer: The model predicts about 5.8 times as much interaction between Chicago and Milwaukee as between Chicago and St. Louis, even though St. Louis is the larger city, because it is more than three times as far away and distance counts squared.

Example 2. Reilly's law gives the breaking point between two cities, measured from city A, as d ÷ (1 + √(P_B ÷ P_A)). Find the breaking point between Chicago (9.6 million) and Indianapolis (2.1 million), which are about 165 miles (265 km) apart.

1. P_B ÷ P_A = 2.1 ÷ 9.6 = 0.219.
2. √0.219 = 0.468.
3. Breaking point from Chicago = 165 ÷ 1.468 = 112 miles (265 ÷ 1.468 = 181 km).
4. Distance from Indianapolis = 165 − 112 = 53 miles (85 km).

Answer: About 112 miles (181 km) from Chicago and 53 miles (85 km) from Indianapolis. The larger city's pull reaches about twice as far.

Example 3. A survey of a town's Fourth of July fair (sample data) counted visitors by distance band. Within 1 mile: 2,000 residents, 200 visitors. 1–3 miles: 6,000 residents, 240 visitors. 3–6 miles: 12,000 residents, 180 visitors. 6–10 miles: 20,000 residents, 100 visitors. Compute the share of residents who came from each band and describe the pattern.

(Use the map or drawing "The rates from this example." shown earlier in this lesson.)

1. Within 1 mile: 200 ÷ 2,000 = 10 percent.
2. 1–3 miles: 240 ÷ 6,000 = 4 percent.
3. 3–6 miles: 180 ÷ 12,000 = 1.5 percent.
4. 6–10 miles: 100 ÷ 20,000 = 0.5 percent.
5. Notice that the 1–3 mile band sent the most visitors (240) but a much smaller share than the nearest band.

Answer: 10, 4, 1.5 and 0.5 percent. The rate falls steadily with distance, a clear case of distance decay, even though raw counts do not fall as neatly because the outer bands contain more people.

PRACTICE

1. EASY Give the absolute location of Mainz and one sentence describing its relative location.
2. EASY Classify each region as formal, functional or perceptual: (a) the area served by a city's newspaper delivery; (b) the area where Spanish is the majority language; (c) "Dixie"; (d) a public school district; (e) the area where annual rainfall exceeds 40 inches.
3. EASY State Tobler's first law of geography and explain it in your own words.
4. EASY Classify each as relocation, hierarchical, contagious or stimulus diffusion: (a) Sweynheym and Pannartz carry printing to Subiaco; (b) presses open first in Rome,

Venice and Paris before small towns; (c) Sequoyah creates a Cherokee syllabary after seeing English writing; (d) a rumor spreads through a school from friend to friend.

5. MEDIUM Use the map. How many years passed between the completion of the Gutenberg Bible (about 1455) and the first press at Westminster? Which city on the map received printing first after Mainz?
   (Use the map or drawing "Use this map for Problem 5." shown earlier in this lesson.)
6. MEDIUM Mainz is at about 50.0° N and Rome at about 41.9° N. One degree of latitude is about 111 km (69 mi). Find the north–south distance between them.
7. MEDIUM By the gravity model, if the distance between two cities doubles while their populations stay the same, what happens to the predicted interaction? If it is cut in half?
8. MEDIUM Town A has 400,000 people and town B 100,000; they are 60 miles (97 km) apart. Use Reilly's law to find the breaking point measured from town A.
9. HARD Use the gravity model to compare two pairs: cities of 2 million and 1 million that are 100 miles apart, and cities of 4 million and 3 million that are 300 miles apart. Which pair is predicted to interact more, and by how much?
10. HARD Define time-space compression and give two examples from different centuries.
11. HARD Hägerstrand found that innovations are adopted along an S-shaped curve. Describe the three phases of the curve and explain why contact between neighbors produces it.
12. CHALLENGE Write a paragraph explaining why the gravity model is useful but limited. Use at least two real examples of flows it would predict poorly.

COMMON MISTAKES

- Confusing hierarchical with contagious diffusion. Hierarchical diffusion skips from important place to important place; contagious diffusion spreads to neighbors regardless of rank.
- Calling every region with a boundary "formal." A school district or a delivery area is functional because it is organized around a center and its flows.
- Forgetting to square the distance in the gravity model. Doubling the distance cuts interaction to one-fourth, not one-half.

Make it a game · Diffusion Tag. Play in a yard or large room. One player is "Mainz" and holds an idea (a beanbag or a card). Round 1 (contagious): the idea passes only by tagging the nearest player. Round 2 (hierarchical): three players are "big cities" and must be reached first before anyone else can be tagged. Round 3 (relocation): the idea holder must run to a new corner and start there. Time each round. Afterward, discuss which kind of diffusion was fastest and which reached every player.

Scripture. "And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;" (Acts 17:26, KJV)

Paul spoke these words in Athens, a city famous for spreading ideas. Human geography studies the “bounds of their habitation”: where peoples live, how their places differ and how ideas travel among them. The gospel itself has spread by relocation (missionaries), hierarchy (cities first) and contact (neighbor to neighbor).

Practice answers

1. About 50.0° N, 8.3° E. Relative location: on the left bank of the Rhine opposite the mouth of the Main, a short way west of Frankfurt (any accurate description).
2. (a) Functional. (b) Formal. (c) Perceptual (vernacular). (d) Functional (organized around the schools it serves; it also has a legal boundary). (e) Formal.
3. “Everything is related to everything else, but near things are more related than distant things.” Places near each other tend to be more alike and to interact more than places far apart.
4. (a) Relocation. (b) Hierarchical. (c) Stimulus. (d) Contagious.
5. 1476 − 1455 = about 21 years. Strasbourg (about 1460) was first after Mainz.
6. 50.0 − 41.9 = 8.1°. 8.1 × 111 = 899 km (8.1 × 69 = 559 miles). The real distance is greater because Rome is also east of Mainz.
7. Doubling d multiplies d^2 by 4, so interaction falls to one-fourth. Halving d makes interaction 4 times as great.
8. √(100,000 ÷ 400,000) = √0.25 = 0.5. 60 ÷ 1.5 = 40 miles (about 64 km) from A, 20 miles from B.
9. Pair 1: 2 × 1 ÷ 100^2 = 2 ÷ 10,000 = 0.0002. Pair 2: 4 × 3 ÷ 300^2 = 12 ÷ 90,000 = 0.000133. Pair 1 interacts 0.0002 ÷ 0.000133 = 1.5 times as much.
10. The shrinking of effective distance between places as transportation and communication become faster and cheaper. Examples: the printing press spreading Luther’s theses across the German lands within weeks in 1517; the telegraph (1840s); the transatlantic cable (1866); jet airliners (1950s); the internet. Any two accurate examples.
11. Slow start (a few early adopters), rapid middle (many people adopt as they see neighbors use it), leveling off (few people are left to adopt). Because most people learn of a new thing from someone nearby, each adopter creates new adopters, so adoption accelerates until the pool of non-adopters runs low.
12. Answers will vary. The model predicts average interaction well using only population and distance, which makes it useful for planning roads, stores and phone networks. But it ignores borders, language, cost, culture, history and personal ties. Examples: two cities of similar size and distance interact far less when a closed or heavily guarded national border lies between them, or when their people speak different languages; immigrants often send money, letters and visits to a distant homeland rather than to nearby cities; a mountain range or a sea without a bridge can make a short distance costly, while a cheap airline route can make a long one easy. A good answer names the model’s assumptions and shows how real factors bend the result.

1.3 Data and GIS ⚙

OBJECTIVES

- Tell how John Snow used a map of deaths and water pumps in 1854 to reason about the cause of a cholera outbreak, and explain why his method is the ancestor of modern GIS.
- Describe the U.S. census (its constitutional basis, its history and its geographic units) and find and normalize census data correctly (density, rates and percentages).
- Explain how a geographic information system stores data in layers (points, lines, polygons and rasters), and compute population density, rates per 10,000 and location quotients.

Warm-up. Lay three sheets of clear plastic (sheet protectors or plastic wrap on cardboard) over a printed map of your town. On the first, mark every school; on the second, every church; on the third, every grocery store. Lift and lower the sheets one at a time. What patterns can you see only when two layers are down together?

Watch. *31st August 1854: Cholera outbreak in London leads to John Snow's work on germ-contaminated water* (HistoryPod, 2:44). https://www.youtube.com/watch?v=s8HyP9e2GfE
After the story: watch how John Snow marked each cholera death on a street map and found that the cases clustered around the Broad Street pump.
Note: Captions were not available to check; preview it first. It tells about the many deaths in the 1854 outbreak. The description says more than 120 died in the first three days; the lesson says more than a hundred.

KEY TERMS

census
An official count of a population, usually with information about each person and household. The U.S. Constitution (Article I, Section 2) requires one every ten years; the first was taken in 1790.

census tract
A small statistical area used by the U.S. Census Bureau, usually with 1,200 to 8,000 people (about 4,000 on average). Tracts are divided into block groups and blocks.

geographic information system (GIS)
Computer hardware and software that store, analyze and display data tied to locations on the earth, usually as layers that can be combined.

vector and raster data
Vector data stores features as points (a pump), lines (a street) and polygons (a census tract). Raster data stores a grid of cells, each with a value (a satellite image, an elevation model).

normalization
: Dividing a count by a base such as area or population (people per square mile, deaths per 10,000) so that places of different sizes can be compared fairly.

location quotient (LQ)
: A ratio that compares a local share with a larger share: (local share of an industry or group) ÷ (national share). An LQ above 1 means the place is more concentrated in it than the nation.

CORE IDEAS

The story. On the last night of August 1854, cholera broke out in Soho, a crowded district of London. Within three days more than a hundred people living near Broad Street were dead, and by the time the outbreak ended some 600 had died. Most doctors of the day believed cholera spread through *miasma*, bad air rising from filth, a theory that fit many observations of the time: disease was worst in the smelliest districts. A London physician named John Snow, already famous for giving chloroform to Queen Victoria in childbirth in 1853, had argued since 1849 that cholera was carried in water fouled by the waste of the sick. He went door to door, collected the addresses of the dead from the General Register Office, and marked each death on a street map. The deaths clustered around the public pump on Broad Street. On September 7 he presented his evidence to the parish Board of Guardians, and the next day the handle of the pump was removed.

How he figured it out. Snow's map made the cluster visible, but it was his reasoning about exceptions that made the case. A workhouse in Poland Street, close to the pump, had more than 500 inmates but only a handful of deaths; it had its own well. The men of the brewery on Broad Street drank beer and water from the brewery's own supply, and none of them died. A widow in Hampstead, miles away, died of cholera; her family said she liked the taste of Broad Street water and had a bottle carried to her every day. The local curate, the Reverend Henry Whitehead of St. Luke's, Berwick Street, at first doubted Snow's theory, then investigated it himself and found the likely first case: a baby at 40 Broad Street whose mother had washed the child's soiled cloths and emptied the water into a cesspool only a few feet from the well. Snow also compared the households of south London supplied by two water companies, one drawing from the Thames below the city's sewers and one from cleaner water upstream (see the worked example). His map was published in 1855 in the second edition of his book *On the Mode of Communication of Cholera*. In fairness to his critics, the outbreak was already declining when the handle came off, as Snow himself admitted, and the cholera bacterium, first described by the Italian Filippo Pacini in 1854, was not widely accepted as the cause until Robert Koch's work in 1883–84. Snow's achievement was to reason correctly from spatial evidence before the cause could be seen.

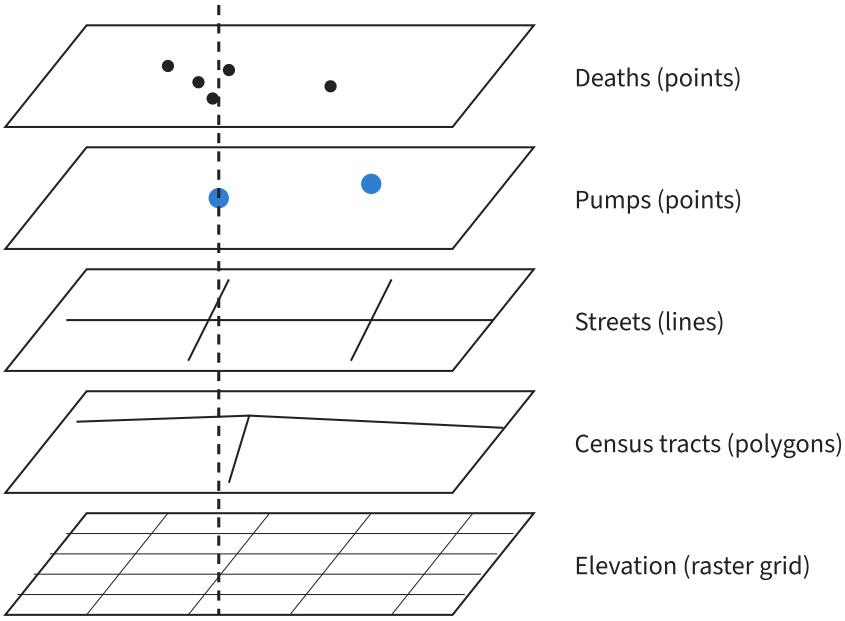
The big idea: data that has a place. Snow's map joined three **layers**: streets, pumps and deaths. A modern **geographic information system** does the same with any number of layers. **Vector** layers store points (pumps, churches, crimes), lines (streets, rivers, pipelines) and polygons (counties, census tracts, flood zones). **Raster** layers store grids of cells, like a satellite photograph or an elevation model. Because every layer shares the same

coordinates, a GIS can *overlay* them (which homes lie in the 100-year floodplain?), draw a *buffer* (which homes are within 400 meters of the pump?) and measure distance, density and pattern. Much of the human data in those layers comes from the **census**.

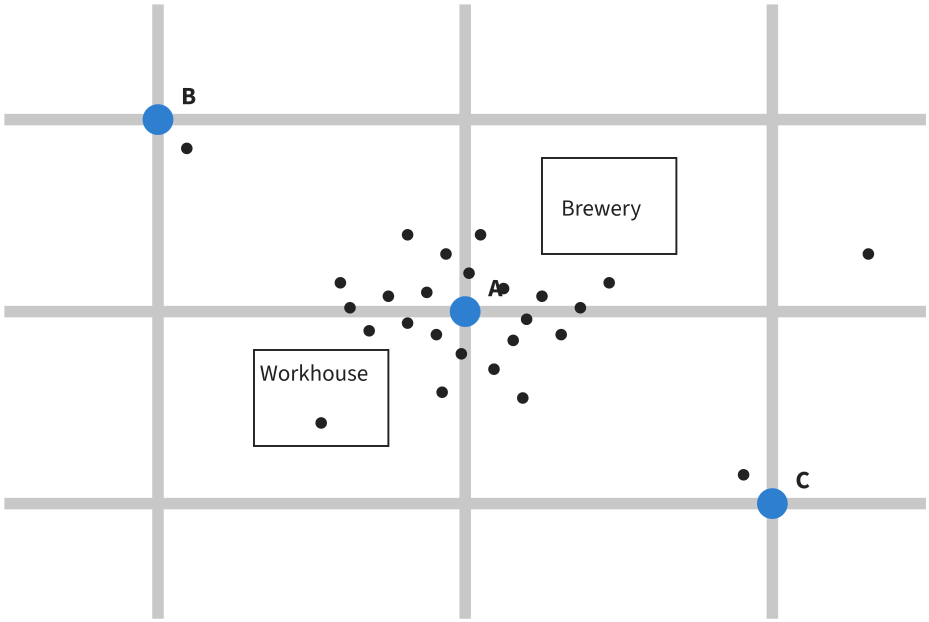
The census. The U.S. Constitution requires an "actual Enumeration" every ten years to divide seats in the House of Representatives among the states. The first census, in 1790, was taken by federal marshals on horseback under Secretary of State Thomas Jefferson and counted about 3.9 million people. The 2020 census counted 331,449,281. The Census Bureau publishes data for nested units: the nation, states, counties, **census tracts** (about 4,000 people each on average), block groups and blocks. Individual answers are confidential for 72 years; the 1950 records were released in April 2022. Since 2005 the American Community Survey has collected yearly samples on income, commuting, language and much else. All of this is free at data.census.gov. To compare places fairly, a geographer **normalizes** counts: people per square mile, deaths per 10,000, percent of workers in manufacturing. One useful normalized measure is the **location quotient**, which shows whether a place has more or less than its expected share of some activity.

Technology overcoming geography. In 1890 the Census Bureau used electric tabulating machines invented by Herman Hollerith, which read holes punched in cards; the 1880 count had taken most of a decade to tabulate by hand, and the 1890 count was finished far faster. Hollerith's company later became part of IBM. In the 1960s Roger Tomlinson led the building of the Canada Geographic Information System to inventory Canada's land, and he is often called the father of GIS. In 1969 Jack and Laura Dangermond founded the company Esri in Redlands, California, whose software became the most widely used GIS in the world. Landsat 1, launched in 1972, began a continuous record of the earth's surface from orbit, and the Global Positioning System, fully operational by 1995, gave every phone and surveyor exact coordinates. What once took Snow weeks of walking, a computer now does in seconds.

On the map. A GIS is a powerful servant and a poor master. It can only analyze the data put into it, and a careless choice of units, colors or classes can make a misleading map look scientific. Snow's example still teaches the right habits: collect the data carefully, map it, look hard at the exceptions, and test the pattern against other evidence before drawing a conclusion.



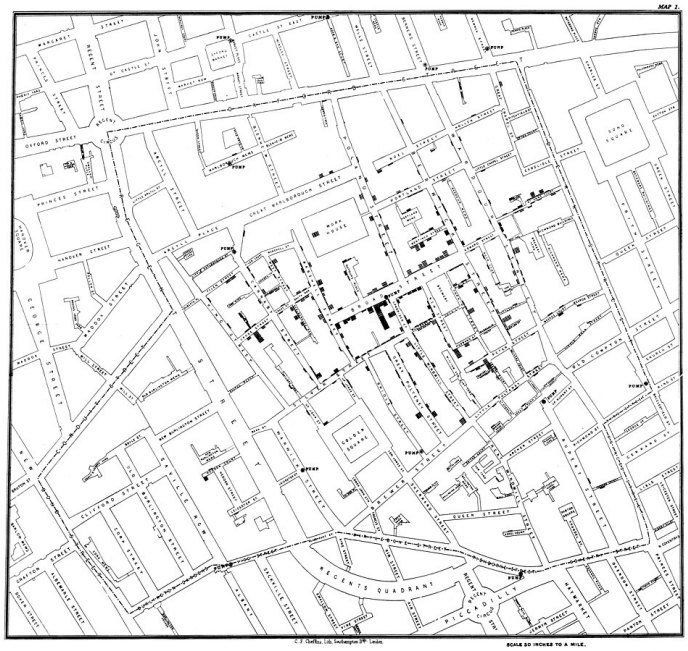
How a GIS stores data: separate layers that share one set of coordinates. A single location (dashed line) can be queried in every layer at once.



Blue circles = pumps; dots = deaths. Schematic, not to scale.

A simplified sketch of the pattern on Snow's map (schematic, not to scale; not the real street plan).

PICTURE STUDY



Map of the deaths from cholera around Broad Street and Golden Square, Soho, 1854, John Snow; lithographed by Charles F. Cheffins, London, 1854 (published 1855) · Lithographed map, in *On the Mode of Communication of Cholera*, second edition · Published in London; copies of the book survive in many libraries, and the map is widely reproduced

Snow marked each death as a short black bar at the address where it occurred, stacking the bars when more than one person died in the same house. The result looks like a bar chart laid onto a street plan. He also marked the public pumps of the district.

Later writers sometimes told the story as if Snow drew the map first and found the answer from it. In fact he already suspected the Broad Street pump from his interviews; the map was his way of showing the evidence to others. It remains one of the most famous maps ever made.

Look closely

- Find the Broad Street pump. Where are the tallest stacks of bars?
- Find the other pumps on the map. Are there many deaths around them?
- Look for blocks near the center with few or no bars. What might explain them?
- Notice that Snow drew the bars at addresses, not at the pump. Why was that the honest way to map the data?

Talk about it

1. Is this a dot density map, a proportional symbol map or something in between? Explain.
2. What layers would you add if you were making this map in a GIS today?
3. Snow’s critics thought bad air spread cholera. Could this map alone have proved them wrong? What other evidence did Snow need?

PROJECT: LAYERED MAP OF MY COUNTY

You will build a small geographic information system by hand, and then (if you can) on a computer. Using real census data for your county, you will make a choropleth base layer of census tracts and lay over it transparent layers of points and lines, then look for a relationship between the layers.

You will need

- A printed outline map of your county's census tracts (from the Census Bureau's free reference maps, or traced from data.census.gov)
- Three or four clear plastic sheets or tracing paper, cut to the size of the map, and fine markers in several colors
- Census data for each tract from data.census.gov (for example total population, land area, percent of residents age 65 and over, or median age)
- Optional: a computer with the free, open-source GIS program QGIS (qgis.org)

Steps

1. Choose one variable that is a rate or percentage (not a raw count), such as people per square mile or percent age 65 and over. Record it for every tract in a table.
2. Divide the values into four or five classes with a clear legend (for example equal intervals). Shade the tract map by class, light for low and dark for high. This is your base layer.
3. On the first clear sheet, mark points: schools, churches, hospitals or grocery stores (choose one kind).
4. On the second sheet, draw lines: the main highways and rail lines through the county.
5. On the third sheet, draw any physical feature that matters: a river, a floodplain, a ridge or a lake.
6. Stack the layers in different combinations and look for relationships. For example, do the dense tracts follow the highways? Are the stores where the people are? Write down three patterns you see.
7. Optional: load your county's tract boundaries and data into QGIS and repeat the choropleth on the computer. Compare the two versions.

Tips

- Never shade a choropleth by raw counts. Divide by area or population first.
- Keep north at the top of every sheet and line up two corner marks on each layer so they register exactly.
- A pattern on a map is a question, not an answer. Ask what else could explain it.

Check your work

- My base layer shows a normalized variable in clear classes with a legend and a source line ("Source: U.S. Census Bureau, year").

- My overlays line up correctly with the base map.
- I have written three patterns and one possible explanation for each, with a caution about what the map cannot prove.

MAP NOTEBOOK

1. Draw the five layers of the GIS figure from memory and give one real example of data for each layer.
2. Sketch a simple street grid with a pump in the middle, then draw a buffer circle of 400 m around it at the scale 1 cm = 100 m. What is the radius in centimeters?
3. List the nested census units from largest to smallest, beginning with the nation and ending with the block.

> **From history.** Because individual census records are kept confidential for 72 years, each new release is a great day for historians and families tracing their ancestors. The 1950 census records were opened to the public on April 1, 2022, through the National Archives, and volunteers and computers worked to index millions of handwritten pages. The 1960 records are due in 2032.

WORKED EXAMPLES

Example 1. In his study of the 1854 epidemic in south London, Snow counted, for the first seven weeks, 1,263 cholera deaths in 40,046 houses supplied by the Southwark and Vauxhall Company (which drew Thames water below the sewer outfalls) and 98 deaths in 26,107 houses supplied by the Lambeth Company (which had moved its intake upstream). Compute the deaths per 10,000 houses for each and compare.

1. Southwark and Vauxhall: 1,263 ÷ 40,046 × 10,000 = 315 deaths per 10,000 houses.
2. Lambeth: 98 ÷ 26,107 × 10,000 = 37.5 deaths per 10,000 houses.
3. Ratio: 315 ÷ 37.5 = 8.4.
4. The two companies’ pipes ran down the same streets, so the households were alike in nearly every way except their water. That made the comparison a natural experiment.

Answer: About 315 versus 37 deaths per 10,000 houses: households drinking the downstream water died at about 8.4 times the rate. Normalizing by houses was essential, because the raw counts alone (1,263 and 98) do not account for the different number of customers.

Example 2. The 2020 census counted 331,449,281 people in the United States, which has a land area of about 3,531,905 square miles (9,147,593 km²). Find the population density in people per square mile and per square kilometer.

1. Per square mile: 331,449,281 ÷ 3,531,905 = 93.8.
2. Per square kilometer: 331,449,281 ÷ 9,147,593 = 36.2.
3. Check: 1 square mile = 2.59 km², and 93.8 ÷ 2.59 = 36.2.

Answer: About 94 people per square mile (36 per km²). This is an average for the whole nation; Lesson 1.4 shows how much it hides.

Example 3. A county has 40,000 jobs, of which 6,000 are in manufacturing and 4,000 in health care. Nationally (round figures for this example), 8 percent of jobs are in manufacturing and 14 percent in health care. Compute the location quotient for each industry and interpret it.

1. County manufacturing share = 6,000 ÷ 40,000 = 0.15. LQ = 0.15 ÷ 0.08 = 1.88.
2. County health-care share = 4,000 ÷ 40,000 = 0.10. LQ = 0.10 ÷ 0.14 = 0.71.
3. LQ above 1 means more concentrated than the nation; below 1 means less.

Answer: Manufacturing LQ ≈ 1.88: the county has nearly twice the national concentration of factory jobs, likely a basic (export) industry. Health care LQ ≈ 0.71: the county has less than its share, so residents may travel elsewhere for some care.

PRACTICE

1. EASY Classify each as vector point, vector line, vector polygon or raster: (a) a satellite photograph; (b) the boundary of a census tract; (c) the location of a fire hydrant; (d) a railroad; (e) an elevation model of a mountain.
2. EASY Where in the Constitution is the census required, how often is it taken, what was its original purpose and when was the first one?
3. EASY Name the census unit that usually contains about 4,000 people, and the smallest unit the Census Bureau uses.
4. MEDIUM The 1790 census counted about 3.93 million people and the 2020 census about 331.4 million. By what factor did the population grow?
5. MEDIUM How many censuses were taken from 1790 through 2020?
6. MEDIUM A county has 125,000 people and a land area of 480 square miles. Find its density per square mile and per square kilometer (1 sq mi = 2.59 km²).
7. MEDIUM In a county with 30,000 jobs, 1,200 are in mining. Nationally, about 0.5 percent of jobs are in mining (round figure for this problem). Compute the location quotient and interpret it.

8. MEDIUM Use the schematic. Which pump has the most deaths around it? Why are the workhouse and brewery important to Snow's argument?
   (Use the map or drawing "Use this sketch for Problem 8." shown earlier in this lesson.)
9. HARD County A had 50 cases of a disease among 10,000 people; County B had 200 cases among 100,000 people. Which had more cases? Which had the higher rate per 10,000? Which number belongs on a choropleth map?
10. HARD U.S. population grew from about 3.93 million (1790) to about 331.4 million (2020). Find the average annual growth rate over the 230 years. (Hint: rate = (final ÷ start)^(1/230) − 1, or use natural logarithms.)
11. HARD A town plans a new elementary school and wants a site within 1 mile (1.6 km) of at least 2,000 children, outside the 100-year floodplain and on land zoned for public use. Describe the GIS layers and operations needed.
12. CHALLENGE The outbreak around Broad Street was already falling when the pump handle was removed on September 8, 1854. Does that weaken Snow's case? Write a paragraph weighing the evidence.

COMMON MISTAKES

- Mapping raw counts instead of rates. Big places will always have more of everything; normalize by area or population.
- Thinking a GIS proves causes. A GIS shows where things coincide; explaining why takes reasoning and other evidence, as Snow showed.
- Confusing a census tract with a county or a city. Tracts are small statistical units drawn by the Census Bureau, usually about 4,000 people.

Make it a game · Overlay Hunt. One player secretly chooses a location on a town map. Others ask yes-or-no questions using only layers: "Is it within half a mile of a school?" "Is it in a tract with more than 2,000 people per square mile?" "Is it north of the river?" Each answer lets players shade out areas on their own clear sheets. The first to find the location in ten questions or fewer wins. Then talk about which question cut away the most territory.

Scripture. "And it came to pass in those days, that there went out a decree from Cæsar Augustus, that all the world should be taxed." (Luke 2:1, KJV)

A Roman census, an act of government record-keeping, brought Joseph and Mary to Bethlehem, where the prophet Micah had said the Christ would be born. The Bible records other censuses too: God commanded Moses to number Israel (Numbers 1), while David's proud census brought judgment (2 Samuel 24). Counting people is not good or bad in itself; what matters is the purpose and the heart behind it.

Practice answers

1. (a) Raster. (b) Vector polygon. (c) Vector point. (d) Vector line. (e) Raster.

2. Article I, Section 2; every ten years; to divide seats in the House of Representatives among the states (apportionment); 1790.
3. The census tract (usually 1,200 to 8,000 people). The smallest is the census block.
4. 331.4 ÷ 3.93 = 84.3. The population grew about 84 times.
5. (2020 − 1790) ÷ 10 + 1 = 23 + 1 = 24 censuses.
6. 125,000 ÷ 480 = 260 people per sq mi. Area = 480 × 2.59 = 1,243 km^2; 125,000 ÷ 1,243 = 101 per km^2.
7. Local share = 1,200 ÷ 30,000 = 0.04 (4 percent). LQ = 0.04 ÷ 0.005 = 8.0. Mining is eight times as concentrated in this county as in the nation, a strong local specialty.
8. Pump A (the Broad Street pump). The workhouse and brewery stood very close to pump A but had their own water supplies and few or no deaths, so they were exceptions that supported the idea that the pump water, not the neighborhood air, carried the disease.
9. County B had more cases (200 versus 50). Rates: A = 50 per 10,000; B = 200 ÷ 100,000 × 10,000 = 20 per 10,000. County A has the higher rate. The rate belongs on a choropleth map.
10. Ratio = 84.3; ln 84.3 = 4.434; 4.434 ÷ 230 = 0.0193; e^0.0193 = 1.0195. About 1.95 percent (nearly 2 percent) per year on average (much faster early, slower recently).
11. Layers: candidate parcels with zoning (polygons); the floodplain (polygon); census blocks or block groups with the number of children (polygons, normalized or counted). Operations: select parcels zoned for public use; erase or exclude those that overlap the floodplain (overlay); draw a 1-mile buffer around each remaining parcel; sum the children in blocks inside each buffer; keep parcels with at least 2,000. A good answer names the layers and the overlay, buffer and query steps.
12. Answers will vary. A strong answer notes that the timing alone cannot prove the pump caused the outbreak, since deaths were already falling (many people had fled and the first infection may have passed). But Snow’s case did not rest on the handle. It rested on the clustering of deaths around the pump, the exceptions (workhouse and brewery with their own water, the Hampstead widow who drank Broad Street water), Whitehead’s discovery of the first case near the well and the much larger south London comparison of two water companies. Several independent lines of evidence pointing the same way made the conclusion strong, and later discovery of the bacterium confirmed it.

1.4 Scales of Analysis

OBJECTIVES

- Distinguish map scale from scale of analysis, and describe how a pattern can look different at the local, regional, national and global scales.
- Explain aggregation, the modifiable areal unit problem and the ecological fallacy, using Charles Booth's street-by-street poverty maps of London (1889) as the case study.
- Compute densities and shares at nested scales (world, nation, state) and show with numbers how averages hide differences.

Warm-up. Look at one square inch of a newspaper photograph with a magnifying glass, then at the whole picture from across the room. Describe what you see at each distance. Which view is "true"? Write one sentence about what each view shows that the other hides.

Video. Coming soon. Charles Booth's poverty maps of Victorian London and the idea of scale in geography (local, national, global): search Library of Congress, Hillsdale Studios, The History Guy (Victorian London), NASA Earth Observatory (the earth at night at different scales); candidates (need vetting): London School of Economics (Charles Booth's London project), AP Human Geography review channels from individual teachers (vet each carefully for ideological framing).

KEY TERMS

scale of analysis
The level at which a geographer gathers and studies data: local, regional, national or global. Different scales can show different patterns of the same thing.

aggregation
Combining data from smaller units into larger ones (households into tracts, counties into states). Aggregation simplifies, but it hides differences inside each unit.

modifiable areal unit problem (MAUP)
The fact that the patterns and results of an analysis can change when the same data are grouped into different-sized or differently drawn areas.

ecological fallacy
The error of assuming that what is true of a group or an area as a whole is true of each individual or household in it.

globalization
The growing connection of places worldwide through trade, travel, communication and investment, so that events at one scale affect others.

glocalization
Adapting a global product or idea to local customs and tastes, as when a worldwide restaurant chain changes its menu country by country.

CORE IDEAS

The story. In 1886 Charles Booth, a Liverpool-born shipowner who had built a successful steamship line, set out to learn how many Londoners were truly poor. Newspapers and reformers made bold claims, and one group had announced that a quarter of the people of London lived in extreme poverty. Booth suspected the figure was exaggerated and decided to count. With a team of investigators he drew on the notebooks of the School Board visitors, who called at every home with children to enforce school attendance, and later walked the streets with police officers on their beats. His results began to appear in 1889, with a *Descriptive Map of London Poverty* on which every street was colored by the condition of the people living on it, in seven classes from yellow (the wealthy) through red (middle class), pink (fairly comfortable), purple (mixed, some comfortable and others poor) and light blue (poor) to dark blue (very poor) and black (the lowest class). His conclusion surprised him: in the whole of London about 30 percent of the people lived in poverty, more than the figure he had expected to disprove. Booth kept working for seventeen years, revised the maps in 1898–99, and published his *Life and Labour of the People in London* in seventeen volumes, including a whole series on the churches, missions and religious life of the city.

How he figured it out. Booth's great insight was about **scale**. A single number for London, "30 percent poor," is true, but it tells you almost nothing about any particular street. His map showed that wealth and want lay side by side: a broad red or yellow street could have black and dark blue courts and alleys just behind it. At the scale of a whole borough, these differences averaged out; at the scale of the street, they leaped off the page. Booth chose the street because it was small enough to show the pattern and large enough to protect the privacy of families. Even so, he knew that a purple street contained both comfortable and poor households. To assume that every family on a purple street was comfortable, or that every family was poor, would be the **ecological fallacy**: reasoning from an area's average to its individuals.

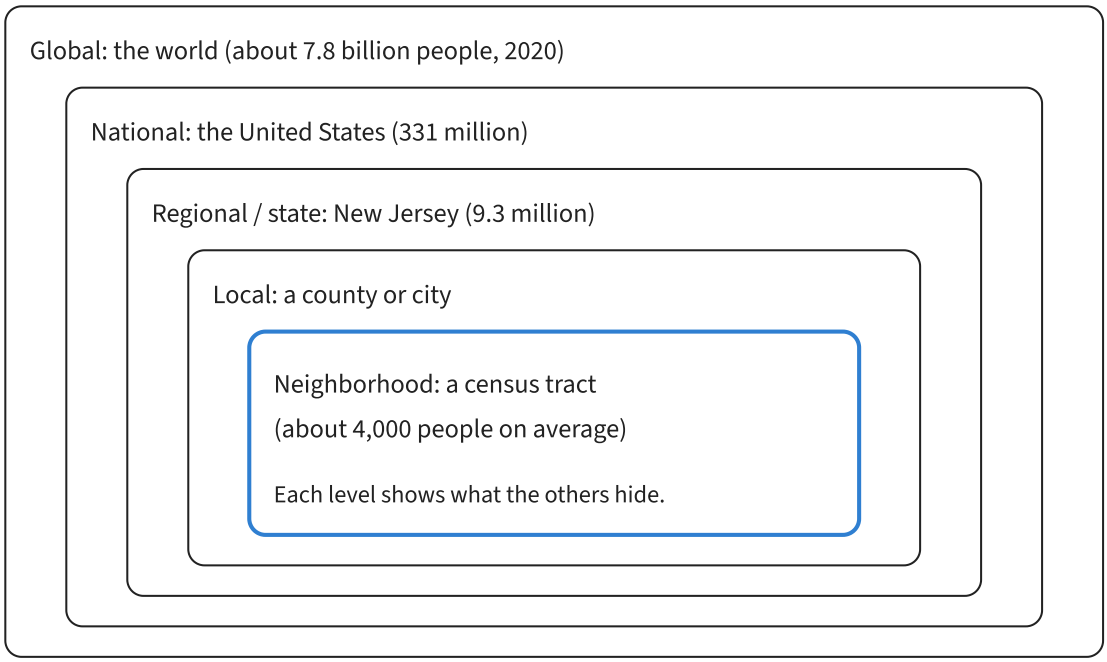
The big idea: scales of analysis. In Lesson 1.1 you learned **map scale**, the ratio of map distance to ground distance. **Scale of analysis** is something different: the level at which we ask a question and gather data. Geographers usually name four: **local** (a neighborhood, a town, a county), **regional** (a group of counties or states, or a region of the world), **national** and **global**. The same question gives different answers at different scales. The United States as a whole had about 94 people per square mile in 2020. New Jersey had about 1,263; Wyoming about 6. Inside New Jersey, the dense cities across the Hudson from Manhattan stand beside lightly settled pine forests in the south of the state. The national average is true, and it describes almost no actual place.

Aggregation and its traps. Data almost always reach us **aggregated**: households grouped into blocks, blocks into tracts, tracts into counties. Aggregation is necessary, but it smooths away differences, and the results depend on where the lines are drawn. This is the **modifiable areal unit problem**. Group the same households one way and a town looks uniform; group them another way and it looks sharply divided (see the worked example). Political boundaries can be drawn to exploit this, which is one reason the drawing of election districts is so hotly argued in many countries. A careful geographer reports the scale and the

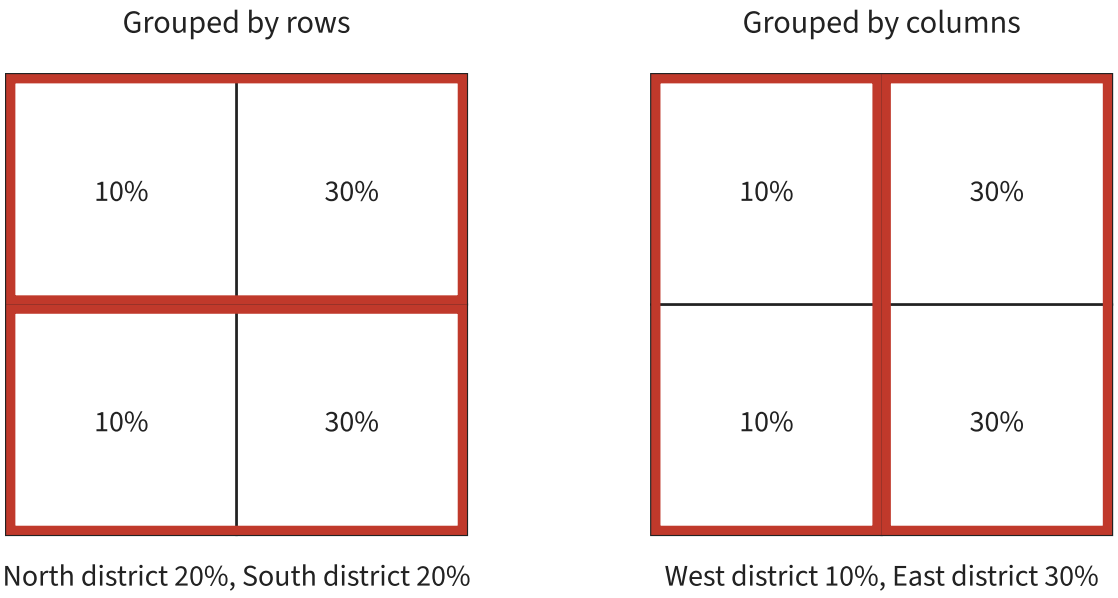
units of every analysis, tries more than one scale when possible, and never assumes an area's average describes each person in it.

Scales are linked. Events at one scale ripple into others. A drought in a wheat-growing region on another continent raises the world price of grain, and a family farm in Kansas earns more for its harvest. A local invention, Gutenberg's press in Mainz, became a continental and then a global change. Worldwide companies adapt to local places (**glocalization**): a restaurant chain sells different menus in India, Japan and Texas. Local choices also add up: millions of families deciding how many children to have, where to move or what to buy become the national and global patterns you will study in Units 2 and 3. Thinking geographically means moving up and down the scales and asking, at each level, what is visible here that was hidden before.

On the map. The prophet Isaiah describes God as one "that sitteth upon the circle of the earth, and the inhabitants thereof are as grasshoppers" (Isaiah 40:22): the global scale. Yet Jesus said, "the very hairs of your head are all numbered" (Matthew 10:30): the scale of one person. Human geographers must keep both in view. Behind every dot on a map and every shade on a choropleth are real families and neighbors, and no average, however accurate, tells the whole story of any one of them.



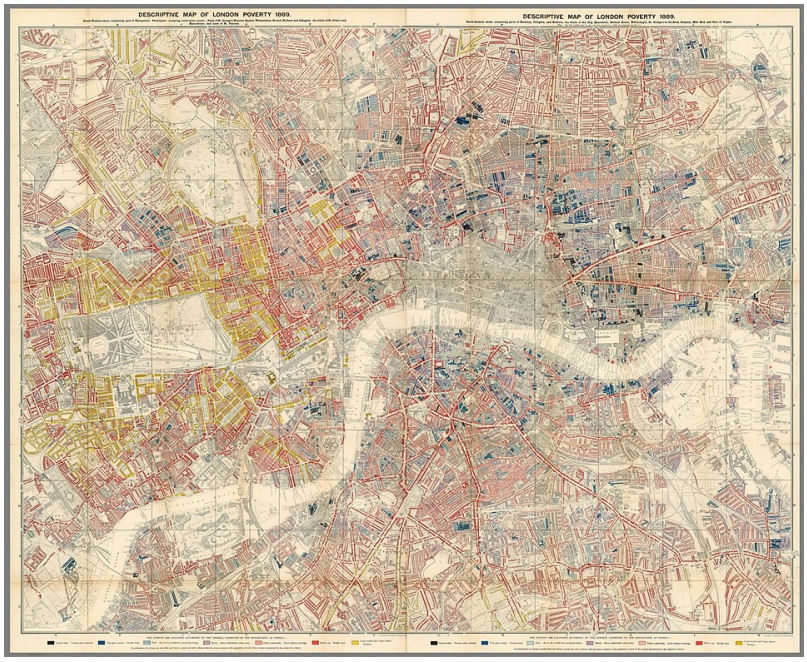
Scales of analysis nest inside one another. Each level shows patterns the others hide.



The modifiable areal unit problem: the same four tracts, grouped two ways, give two different pictures.

The same nation, two very different states (2020 census).

PICTURE STUDY



Descriptive Map of London Poverty, 1889, Charles Booth and his survey team, 1889 (four sheets issued 1889–1891; revised maps 1898–99) · Color-printed map in four sheets on a Stanford street map of London, colored street by street in seven classes · Charles Booth Archive, London School of Economics Library, London

Booth’s map was printed on a standard Stanford street map of London, with each street hand-classified and colored by the condition of its residents. The colors run from yellow for the wealthy to black for the very lowest class. The map was issued with his volumes on the life and labour of the people, and it startled readers who had never seen their own city drawn this way.

For his revised maps of 1898–99, Booth’s investigators walked nearly every street of London with police officers who knew the district, writing notebooks full of observations about houses, shops, churches, public houses and people. The notebooks survive alongside the maps.

Look closely

- Look at the main roads and then at the narrow streets behind them. Do the colors change? What does that tell you?
- Find a purple street. What does “mixed” mean about the families who lived there?
- Look for patches of yellow and red. Are they far from the black and dark blue streets, or close by?
- Notice the scale Booth chose: the street, not the household or the borough. What does that choice show and hide?

Talk about it

1. If Booth had colored whole boroughs instead of streets, what would his map have lost?

2. Booth set out to test a claim he thought was exaggerated and found the problem was larger. What does that say about how a good researcher should treat evidence?
3. Where on this map is the risk of the ecological fallacy greatest?

PROJECT: ONE QUESTION, THREE SCALES

You will investigate one question at three scales of analysis, using free census data, and show how the answer changes. For example: “How old are the people in my area?” or “How densely settled is my area?” You will make three small choropleth maps (nation by state, state by county, county by tract) and a short report comparing them.

You will need

- Three outline maps: the United States by state, your state by county and your county by census tract (free from the Census Bureau or traced from an atlas)
- Data from data.census.gov for one variable at all three scales (for example population density, median age or percent of homes owner-occupied)
- Colored pencils in one color family (light to dark), a ruler, a calculator

Steps

1. Choose one normalized variable (a rate, percentage, median or density, not a raw count).
2. Download or copy the values for all states, all counties in your state and all tracts in your county.
3. For each map, divide the values into five classes and shade from light (low) to dark (high). Use the same class breaks on all three maps if the ranges allow, and note it if they do not.
4. Mark your own county on the state map and your own tract on the county map.
5. Write the national value, your state’s value, your county’s value and your tract’s value in a column beside the maps.
6. Write a report of 300 to 400 words: How does the picture change as you zoom in? Which scale is most useful for which question (a federal program, a county road plan, a church choosing where to plant a new congregation)? Where could an ecological fallacy creep in?

Tips

- Medians cannot be averaged from smaller units, so use the published value for each scale rather than computing it yourself.
- Tracts with very few people can show extreme values. Note any tract with fewer than about 1,000 residents.
- Write the source and year on every map.

Check your work

- I have three choropleth maps of the same variable at three scales, each with a legend, source and year.
- My column of values traces my own place from nation to tract.
- My report explains what each scale shows and hides and names one possible ecological fallacy.

MAP NOTEBOOK

1. Draw five nested boxes like the figure and fill them in for your own home: world, nation, state, county, tract. Add one fact at each scale.
2. Draw a 3 × 3 grid of nine imaginary city blocks, give each a number (people per block), then group them two different ways and compute the averages to show the MAUP.
3. Write down one statement about your town that is true on average but false for some families, and explain why.

> **From history.** Booth's survey had lasting effects on public life. His careful figures on the poverty of the aged helped make the case for Britain's first old-age pensions, passed in the Old Age Pensions Act of 1908. His method of mapping social data street by street was copied in American cities, and the archive of his maps and notebooks at the London School of Economics is still used by historians and by families tracing where their ancestors lived.

WORKED EXAMPLES

Example 1. Using the 2020 census, compare population density at the national and state scales. United States: 331,449,281 people, 3,531,905 sq mi of land. New Jersey: 9,288,994 people, 7,354 sq mi. Wyoming: 576,851 people, 97,093 sq mi. Give densities per square mile and per square kilometer (1 sq mi = 2.59 km²) and compare New Jersey with Wyoming.

(Use the map or drawing "Two states, two very different densities." shown earlier in this lesson.)

1. United States: 331,449,281 ÷ 3,531,905 = 93.8 per sq mi; 93.8 ÷ 2.59 = 36.2 per km².
2. New Jersey: 9,288,994 ÷ 7,354 = 1,263 per sq mi; 1,263 ÷ 2.59 = 488 per km².
3. Wyoming: 576,851 ÷ 97,093 = 5.94 per sq mi; 5.94 ÷ 2.59 = 2.3 per km².
4. Ratio: 1,263 ÷ 5.94 = 213.

Answer: U.S. 94 per sq mi (36 per km²); New Jersey 1,263 (488 per km²); Wyoming about 6 (2.3 per km²). New Jersey is about 213 times as densely settled as Wyoming, and neither looks anything like the national average.

Example 2. A small town has four census tracts of 1,000 people each, arranged in a square. The percentage of residents over age 65 is 10 percent in the two western tracts and 30 percent in the two eastern tracts. Group the tracts into two districts first by rows (north and south) and then by columns (west and east). Find the share over 65 in each district both ways.

(Use the map or drawing "Same data, different boundaries, different picture." shown earlier in this lesson.)

1. By rows: the north district holds one western tract (10%) and one eastern tract (30%): (100 + 300) ÷ 2,000 = 20%. The south district is the same: 20%.
2. By columns: the west district holds both western tracts: (100 + 100) ÷ 2,000 = 10%. The east district: (300 + 300) ÷ 2,000 = 30%.
3. The whole town: (100 + 300 + 100 + 300) ÷ 4,000 = 20%.

Answer: Grouped by rows, both districts show 20 percent and the town looks uniform. Grouped by columns, the districts show 10 and 30 percent, a sharp east–west contrast. The data did not change; only the boundaries did. This is the modifiable areal unit problem.

Example 3. In 2020 the world's population was about 7.8 billion. What share of the world lived in the United States (331.4 million) and in New Jersey (9.29 million)? What share of the U.S. population lived in New Jersey?

1. U.S. share of world: 331.4 million ÷ 7,800 million = 0.0425, or 4.25 percent.
2. New Jersey share of world: 9.29 ÷ 7,800 = 0.00119, or 0.12 percent.
3. New Jersey share of the United States: 9.29 ÷ 331.4 = 0.028, or 2.8 percent.
4. Check: 2.8 percent of 4.25 percent = 0.028 × 4.25 = 0.12 percent.

Answer: About 4.25 percent of the world lived in the United States, about 0.12 percent in New Jersey, and New Jersey held about 2.8 percent of the U.S. population. A state that dominates a national map of density is a tiny dot at the global scale.

PRACTICE

1. EASY Name the four common scales of analysis and give one example of each that includes your home.
2. EASY Explain the difference between map scale and scale of analysis.
3. EASY On Booth's map, what did yellow, purple and black stand for?
4. MEDIUM The County of London had about 4.2 million people in 1891. If about 30 percent lived in poverty, about how many people was that?
5. MEDIUM Alaska had 733,391 people in 2020 and about 571,000 square miles of land. Find its density per square mile and per km², and compare it with the U.S. average of 94 per

square mile.

6. MEDIUM Which statement commits the ecological fallacy? (a) “This county has a high average income, so the Smith family who lives there must be well off.” (b) “This county has a higher average income than the state as a whole.”
7. MEDIUM Tract A has 3,000 people, 30 percent under age 18. Tract B has 1,000 people, 10 percent under 18. What percent of the combined area is under 18? Why is it not 20 percent?
8. MEDIUM Use the MAUP figure. If the four tracts were grouped into one district, what share would be over 65? Which grouping would a planner need to see that the eastern half of town is much older?
   (Use the map or drawing “Use this figure for Problem 8.” shown earlier in this lesson.)
9. HARD Give one example of a global process that affects a local place, and one example of local decisions that add up to a national or global pattern.
10. HARD Define glocalization and give an example.
11. HARD Why did Booth color streets rather than individual houses or whole boroughs? Give one advantage and one limitation of his choice.
12. CHALLENGE A church in your state wants to know where to start a new congregation and a federal agency wants to know how many Americans live in rural areas. Write a paragraph explaining which scale of analysis each should use, what data each would need and what mistakes each should avoid.

COMMON MISTAKES

- Confusing map scale with scale of analysis. A world map is small scale, but it presents a global scale of analysis.
- Treating an average as if it describes every place or person in the area (the ecological fallacy).
- Averaging percentages without weighting by population. A large tract’s rate should count more than a small tract’s.

Make it a game · Zoom In, Zoom Out. The caller names a fact at one scale (“The United States averages 94 people per square mile”). Players take turns zooming in or out by one scale and stating a true related fact at the new scale (“New Jersey averages 1,263”; “Our county averages…”; “The world averages…”), using an atlas or census printout. A player who states a fact that the previous one hid (a big difference from the average) scores two points; a correct fact scores one. A player who commits the ecological fallacy loses a point. Play five rounds.

Scripture. “It is he that sitteth upon the circle of the earth, and the inhabitants thereof are as grasshoppers; that stretcheth out the heavens as a curtain, and spreadeth them out as a tent to dwell in:” (Isaiah 40:22, KJV)

God sees the whole earth at once, and yet the Lord Jesus said that the very hairs of our heads are numbered (Matthew 10:30). No human map can hold both scales at once.

Geographers move between them, and the habit of remembering the person behind the average is part of loving our neighbor.

Practice answers

1. Local (my town, county or neighborhood), regional (a group of states such as New England, or a world region such as North America), national (the United States) and global (the world). Examples will vary.
2. Map scale is the ratio between a distance on a map and the distance on the ground (1:24,000). Scale of analysis is the level at which data are gathered and studied (local, regional, national, global).
3. Yellow: upper-middle and upper classes, the wealthy. Purple: mixed, some comfortable and others poor. Black: the lowest class.
4. 0.30 × 4.2 million = 1.26 million people, about 1.3 million.
5. 733,391 ÷ 571,000 = 1.28 per sq mi; 1.28 ÷ 2.59 = 0.50 per km². The U.S. average is 94 ÷ 1.28 = about 73 times as dense.
6. (a). It reasons from the county's average to one family. Statement (b) compares two averages at the area level and is valid.
7. Under 18: 900 + 100 = 1,000 of 4,000 = 25 percent. It is not the simple average (20 percent) because Tract A has three times as many people, so its rate counts three times as much (a weighted average).
8. (100 + 300 + 100 + 300) ÷ 4,000 = 20 percent. The west–east (column) grouping, which shows 10 percent and 30 percent.
9. Answers will vary. Global to local: a poor harvest overseas raises world grain prices, so a Kansas farmer earns more; the opening of the Suez Canal in 1869 shifted ships away from Cape Town. Local to global: millions of family decisions about having children add up to national birth rates; individual farmers adopting new seed varieties became the Green Revolution.
10. Adapting a global product, company or idea to local cultures and tastes. Example: a worldwide fast-food chain serves no beef in its restaurants in India and offers local dishes in other countries; a global news service publishes local-language editions.
11. Advantage: the street was small enough to show sharp differences that disappear at the borough scale (poor courts behind wealthy roads) and large enough to protect the privacy of individual families. Limitation: a single color still hid differences within a street (the purple "mixed" class shows this), so reasoning from the street's color to any one household risks the ecological fallacy.
12. Answers will vary. The church needs a local scale: tract or block-group data on population, growth, age and families, plus the locations of existing churches and roads, mapped to find growing areas underserved by congregations; it should avoid relying on county averages that hide fast-growing neighborhoods. The federal agency needs a national scale built up from consistent small units (Census urban and rural classifications by block), summed for the nation; it should avoid mixing definitions and should not assume that a mostly rural county has no urban residents. A strong answer matches the scale to the decision and names the MAUP or ecological fallacy as risks.

Unit 1 test

Answer every question. Show your work for all calculations, give units, and use complete sentences for explanations. A calculator is allowed. The test is worth 100 points.

1. (5 pts) A map has a scale of 1:100,000. Two towns are 8.4 cm apart on the map. How far apart are they on the ground in kilometers and miles? Is this a larger or smaller scale than a 1:24,000 map?
2. (6 pts) Name the property each projection preserves and one main distortion: (a) Mercator; (b) Gall–Peters; (c) Winkel Tripel.
3. (6 pts) On the Mercator projection, lengths are stretched by $1 \div \cos(\text{latitude})$. Find the length factor and the area factor at 50° N ($\cos 50° = 0.643$). What does this mean for how a country at 50° N appears compared with an equal-sized country on the equator?
4. (6 pts) Choose the best thematic map type for each and explain your choice in a phrase: (a) the number of Lutheran churches in each county of Minnesota; (b) the percent of each county's population born in another state; (c) lines of equal average July temperature across the United States.
5. (6 pts) Describe Minard's 1869 map of Napoleon's Russian campaign. Name at least four variables it shows and explain why it is considered a model of a good thematic map.
6. (6 pts) Classify each region as formal, functional or perceptual and explain one: (a) the area served by an airport's flights; (b) the Corn Belt, defined by the share of farmland in corn; (c) "the Heartland"; (d) the area where a majority of people are Catholic.
7. (8 pts) Classify each as relocation, hierarchical, contagious or stimulus diffusion: (a) German printers carry type and presses to Subiaco in 1465; (b) a new fashion appears first in New York, Los Angeles and Chicago before reaching small towns; (c) Sequoyah develops a Cherokee writing system after seeing English writing; (d) a farming practice spreads from neighbor to neighbor in a Swedish district, as Hägerstrand described.
8. (8 pts) Using the gravity model ($P_1 \times P_2 \div d^2$), city X (5 million) is 200 miles from city Y (2 million) and 400 miles from city Z (6 million). With which city is X predicted to interact more, and by what factor?
9. (7 pts) Two cities are 90 miles (145 km) apart. City A has 1,600,000 people and city B has 400,000. Use Reilly's law, $d \div (1 + \sqrt{(P_B \div P_A)})$, to find the breaking point measured from city A. Explain what the breaking point means.
10. (6 pts) In 1854 John Snow counted 1,263 cholera deaths among 40,046 houses served by one water company and 98 deaths among 26,107 houses served by another. Compute the deaths per 10,000 houses for each and explain why the comparison was so convincing.
11. (6 pts) Explain the difference between vector and raster data in a GIS and give two examples of each. Then name and describe one GIS operation (overlay or buffer).
12. (7 pts) A county has 50,000 jobs, of which 2,500 are in agriculture. Nationally, 1.25 percent of jobs are in agriculture (round figure for this problem). Compute the location quotient and interpret it. Then state why a choropleth map of the county's region should show LQ or percentages rather than the number of agricultural jobs.

13. (6 pts) State the constitutional purpose of the U.S. census, the year of the first census, and how the 1890 census was tabulated differently from earlier ones.
14. (7 pts) In 2020 New Jersey had 9,288,994 people on 7,354 square miles and Wyoming 576,851 people on 97,093 square miles; the U.S. average was about 94 people per square mile. Compute each state's density and explain what this shows about the national scale of analysis.
15. (10 pts) Charles Booth colored London street by street in 1889 and found that about 30 percent of Londoners lived in poverty. In a paragraph, explain (a) why his choice of the street as the unit of analysis revealed things a borough map would hide, (b) what the ecological fallacy is and how a reader of his map could commit it, and (c) how the modifiable areal unit problem could affect a study like his.

UNIT PROJECT: A GEOGRAPHER'S ATLAS OF MY COUNTY

Make a small atlas of your own county with four maps and a written introduction. Map 1 is a reference map with a bar scale, north arrow, the name of its projection and the main towns, roads and rivers. Map 2 is a choropleth map of one census variable by tract, normalized and classified with a clear legend and source. Map 3 is a distance-decay or diffusion map from your Lesson 1.2 survey, with distance rings drawn to scale. Map 4 is a three-scale comparison (nation, state, county) of one variable from your Lesson 1.4 project.

Bind the maps with a two-page introduction that explains, for each map, what it shows, what scale and projection it uses, what it leaves out and one pattern you discovered. Close with a paragraph on what you learned about your own home by mapping it, and one question you would like to investigate later in the course.

- **Map accuracy**: Places, boundaries, routes and distance rings are correct; every map has a title, legend, bar scale, north arrow, source and year.
- **Data and computation**: Census data are normalized correctly (densities, rates, percentages), classes are sensible, and all calculations are shown and correct.
- **Geographic reasoning**: The introduction correctly uses unit vocabulary (scale, projection, region, distance decay, diffusion, aggregation, ecological fallacy) and explains what each map shows and hides.
- **Craft and clarity**: The atlas is neat, readable and well organized, with consistent colors and lettering, and the writing is clear and complete.

Answer key

1. 8.4 × 100,000 = 840,000 cm = 8.4 km = 8.4 × 0.6214 = 5.2 miles. It is a smaller scale than 1:24,000 (1/100,000 is a smaller fraction), so it shows a larger area in less detail.
2. (a) Mercator: conformal (true angles and local shapes; rhumb lines straight); greatly enlarges areas toward the poles. (b) Gall–Peters: equal-area (true relative sizes); shapes stretched north–south near the equator and squashed near the poles. (c) Winkel Tripel: a compromise, preserving no property exactly but keeping area, shape and distance distortion moderate; slight distortion everywhere, with curved meridians.

3. Length factor = 1 ÷ 0.643 = 1.56. Area factor = 1.56^2 = 2.42. A country at 50° N is drawn about 2.4 times as large as an equal-sized country on the equator.
4. (a) Dot density or proportional symbol map, because these are counts (a choropleth of counts would mislead). (b) Choropleth map, because it is a percentage for each area. (c) Isoline (isotherm) map, because it joins points of equal value.
5. Minard drew the army as a band whose width is proportional to its size (1 mm per 10,000 men), tan for the advance to Moscow and black for the retreat, with a temperature graph below. Variables: number of men, location (route), direction of movement, place names, dates and temperature (any four). It is admired because it shows many variables at once clearly and honestly, letting the reader see the scale of the loss and its connection to the cold and the river crossings without needing a long explanation.
6. (a) Functional. (b) Formal. (c) Perceptual (vernacular). (d) Formal. Explanation example: an airport's service area is functional because it is organized around a central node and defined by flows of passengers to and from it.
7. (a) Relocation. (b) Hierarchical. (c) Stimulus. (d) Contagious.
8. X–Y: 5 × 2 ÷ 200^2 = 10 ÷ 40,000 = 0.00025. X–Z: 5 × 6 ÷ 400^2 = 30 ÷ 160,000 = 0.0001875. X–Y is greater by 0.00025 ÷ 0.0001875 = 1.33 times. Even though Z is three times as large as Y, it is twice as far away, which cuts interaction to one-fourth.
9. √(400,000 ÷ 1,600,000) = √0.25 = 0.5. 90 ÷ 1.5 = 60 miles (about 97 km) from A, 30 miles from B. At the breaking point a shopper is predicted to be equally drawn to either city; closer to B, B draws more trade, and closer to A, A does.
10. 1,263 ÷ 40,046 × 10,000 = 315; 98 ÷ 26,107 × 10,000 = 37.5. The first rate is about 8.4 times the second. It was convincing because the two companies' pipes served similar households on the same streets, so the main difference between the groups was the source of their water: a natural experiment.
11. Vector data stores features as points, lines and polygons with exact coordinates (examples: wells, roads, rivers, census tracts, county boundaries). Raster data stores a grid of cells with values (examples: satellite images, elevation models, land-cover grids). Overlay: combining layers to find where features coincide (homes inside a floodplain). Buffer: drawing a zone of set distance around a feature (all parcels within 1 mile of a school).
12. Local share = 2,500 ÷ 50,000 = 0.05. LQ = 0.05 ÷ 0.0125 = 4.0. Agriculture is four times as concentrated in this county as in the nation, a local specialty. A choropleth of raw job counts would make large or populous counties look most agricultural regardless of their share; normalized values compare places fairly.
13. To apportion seats in the House of Representatives among the states by population (Article I, Section 2). The first was in 1790. In 1890 the results were tabulated with Herman Hollerith's electric punched-card machines instead of by hand, which made the work far faster.
14. New Jersey: 9,288,994 ÷ 7,354 = 1,263 per sq mi. Wyoming: 576,851 ÷ 97,093 = 5.9 per sq mi. The national average of 94 describes neither state: New Jersey is about 13 times denser than the average and Wyoming about 16 times less dense. A national figure hides large differences that appear at the state (and smaller) scales.
15. (a) At the borough scale, rich and poor streets averaged together; at the street scale, the map showed poor courts and alleys lying right behind prosperous main roads, a pattern invisible in averages. (b) The ecological fallacy is assuming an area's average describes each individual in it; a reader would commit it by assuming every family on a purple (mixed) or red (middle-class) street was comfortable, or every family on a dark blue street was very poor. (c) If the same households were grouped into different units (larger areas, or lines drawn differently), the share of poverty in each unit and the visible pattern could change, making areas look

more uniform or more divided than they are. Full credit requires all three parts with accurate examples.

UNIT 2

Population

Where do the world's people live, why are there so many more of us than there were two centuries ago, and what will the shape of each nation look like a generation from now? Population geography answers those questions with a few powerful tools: density, the demographic transition, and the population pyramid. In this unit you will begin with the 1890 census and the "closing of the frontier," follow Sweden's parish books from 1749 to the modern age, weigh Thomas Malthus's famous warning of 1798 against two hundred years of evidence, and read the American baby boom in the bars of a pyramid.

Every model in this unit is taught as a model: a useful simplification built from real history, with real limits. You will calculate densities, growth rates, doubling times and dependency ratios from real and realistic data, and you will meet several thinkers who disagreed sharply (Malthus, Boserup, Simon, Sen) and judge their arguments by the evidence. Behind every number stands a family. Scripture tells us that God "hath made of one blood all nations of men for to dwell on all the face of the earth" (Acts 17:26) and calls children "an heritage of the LORD" (Psalm 127:3); good population geography keeps both the numbers and the people in view.

BEFORE YOU BEGIN

- Can compute a rate and a percentage and convert between square kilometers and square miles
- Can read a line graph and a bar graph and describe a trend
- Knows the main world regions and can locate major countries on a world map (Unit 1)
- Has used a scientific calculator for powers and, ideally, natural logarithms

MASTERY CHECKLIST

- I can calculate arithmetic, physiological and agricultural density and explain which one fits a given question.
- I can describe world population distribution, name its four great clusters and explain the physical and human factors behind them.
- I can calculate CBR, CDR, RNI and doubling time, and place a country on the demographic transition model.
- I can explain at least three limits of the demographic transition model with real examples.
- I can state Malthus's argument and evaluate it with evidence and the views of his critics.
- I can read a population pyramid, compute dependency and sex ratios, and project a cohort forward.

OPTIONAL BOOKS AND RESOURCES

- **U.S. Census Bureau International Database** (https://www.census.gov/data-tools/demo/idb/): Free. Population pyramids, birth and death rates, fertility and projections for every country, for the past and future. Ideal for Lessons 2.2 and 2.4 and the portfolio.
- **PopulationPyramid.net** (https://www.populationpyramid.net/): Free. Animated population pyramids for every country from 1950 with projections, drawn from United Nations data. Press play and watch a baby boom climb the pyramid.
- **Malthus, *An Essay on the Principle of Population* (free at Project Gutenberg)** (https://www.gutenberg.org/ebooks/search/?query=malthus+essay+population): Free. Read chapters 1 and 2 of the 1798 first edition, where Malthus states his two ratios and his checks, for Lesson 2.3. Older readers may compare one of the later, much longer editions.

UNIT 2 · LESSON 2.1 · 3 SESSIONS OF 50 MINUTES

2.1 Where People Live: Density and Distribution

OBJECTIVES

- Calculate arithmetic, physiological and agricultural density and explain what each one reveals and hides.
- Describe the world's population distribution, name its four great clusters and explain the physical and human reasons people gather where they do.
- Use the 1890 census, the "closing of the frontier" and the moving U.S. center of population to read change in density over time.

Warm-up. Pour a handful of dry rice onto a baking sheet and shake it gently. Then tilt the sheet a little and tap it. Where do the grains gather? Now draw a pencil "river" across a sheet of paper, sprinkle rice over the whole page, and slide the grains into a band along the river. Count roughly how many grains sit within one finger-width of the river and how many sit everywhere else. You have just made a population distribution: the same number of grains, but a very different pattern.

Watch. *Why do some places have a greater population density than others?* (Mr Gedge's Geography Channel, 3:39). https://www.youtube.com/watch?v=hMOat3MAxIw
With the big idea: watch for the natural reasons (climate, landforms, water) and the human reasons (jobs, cities) why people crowd into some places and leave others nearly empty.
Note: Captions were not available to check; preview it first. It's made by an Australian teacher, so it measures density in people per square kilometre and uses an Australian map as its example. Uses metric units (per square kilometre) and Australian examples instead of U.S. ones.

KEY TERMS

arithmetic density
The total number of people divided by the total land area, such as people per square kilometer or per square mile.

physiological density
The number of people per unit of arable land (land fit for growing crops). It shows the pressure of people on the land that feeds them.

agricultural density
The number of farmers per unit of arable land. A high figure usually means many small farms worked by hand; a low figure usually means machines and large farms.

population distribution
The pattern of where people live across an area: clustered, dispersed or strung out in a line (linear), such as along a river or a highway.

ecumene

The part of the earth’s land surface that is permanently lived on by people.

center of population

The point on which a flat, weightless map of a country would balance if every person weighed the same. The U.S. Census Bureau calculates it after each census.

CORE IDEAS

The story. On July 12, 1893, in Chicago, while crowds filled the World’s Columbian Exposition, a thirty-one-year-old history professor from the University of Wisconsin named Frederick Jackson Turner read a paper to the American Historical Association. He called it “The Significance of the Frontier in American History.” Turner opened with a dry sentence from a government bulletin. The superintendent of the 1890 census had written, in effect, that until 1880 the country had a frontier line of settlement, but that the unsettled land had now been so broken up by scattered settlements that there could hardly be said to be a frontier line any longer. Turner saw that this small statistical note marked the end of an era. For nearly three centuries, he argued, American life had been shaped by the edge of open land to the west. Historians have argued over Turner’s thesis ever since, but no one disputes the geography behind it: the frontier was defined by a number, and the number was **density**.

How they figured it out. The census office drew its “frontier line” where settlement thinned to fewer than **2 people per square mile** (about 0.8 per square kilometer). To find that line, clerks divided each county’s population by its land area and shaded the counties on maps in steps, from the nearly empty to the crowded. The 1890 count was also the first in which the Census Office used Herman Hollerith’s electric tabulating machines, which read holes punched in cards, so the huge task of sorting 63 million Americans by place, age and birthplace went faster than ever before. The maps were gathered in Henry Gannett’s *Statistical Atlas of the United States* (1898). Look at one and you can watch the dense East, the filling Midwest and the thin, broken settlement of the mountain West, all on one page.

The big idea. Geographers measure crowding in three ways. **Arithmetic density** is people divided by total land area. It is easy to find, but it treats a desert acre and a river-bottom acre as if they were the same. **Physiological density** divides people by *arable* land only, and so shows the pressure of people on the land that must feed them. **Agricultural density** divides the number of farmers by arable land; a high value usually means small farms worked largely by hand, and a low value means large, machine-worked farms. Density tells *how many*; **distribution** tells *where*. People cluster along rivers and coasts, on fertile lowlands and in middle-latitude climates, and they spread thinly across deserts, high mountains, polar lands and dense rainforest. About 90 percent of the human race lives in the Northern Hemisphere. Four great clusters hold well over half of all people: **East Asia** (above all China), **South Asia** (India, Pakistan and Bangladesh), **Europe**, and **Southeast Asia** (especially Indonesia, the Philippines and Vietnam). India and China alone each have about 1.4 billion people, together more than a third of a world population of about 8.2 to 8.3 billion (as of 2026).

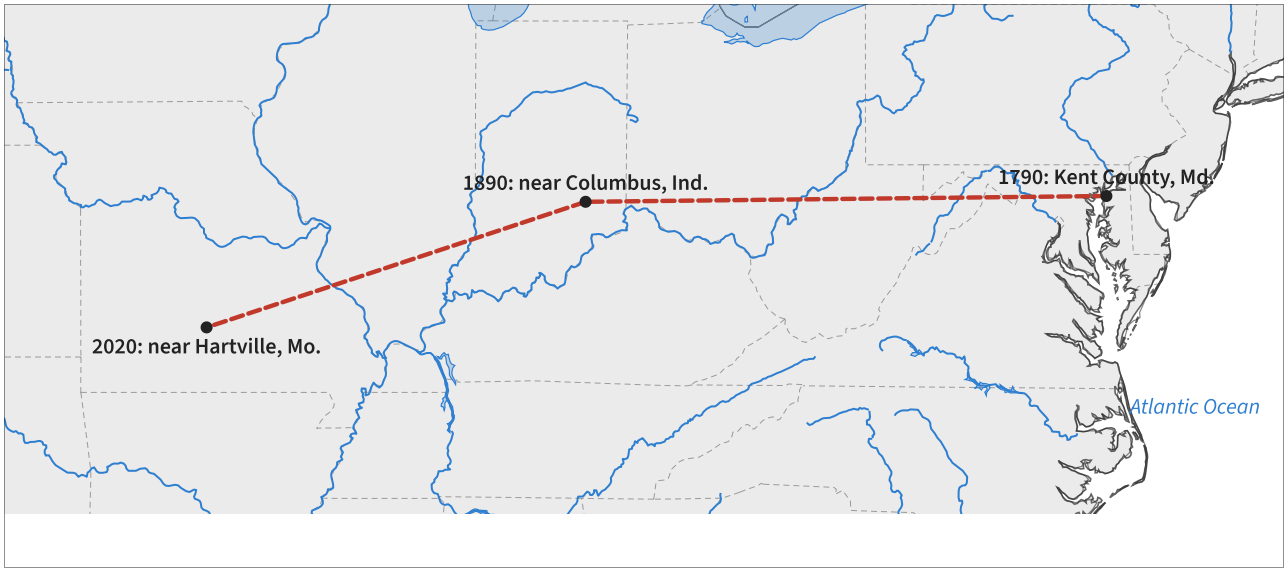
On the map. Egypt is the classic lesson in why arithmetic density can mislead. Egypt covers about 1 million km² (386,000 square miles), and its arithmetic density is only a little above

100 people per km². Yet roughly 95 percent of Egyptians live on about 5 percent of the land, in the narrow green ribbon of the Nile valley and the fan of the delta below Cairo (see the map). Divide Egypt's people by its arable land and the figure leaps to several thousand per km², one of the highest physiological densities on earth. Canada shows the same lesson in a colder setting: about three-quarters of Canadians live within about 160 km (100 miles) of the U.S. border, while the vast northern forests and tundra hold very few. The United States shows a third lesson, change over time. The Census Bureau's **center of population** stood in Kent County, Maryland, in 1790; by 1890 it had moved to near Columbus, Indiana; and in 2020 it stood near Hartville, Missouri. Its steady march west, and lately south, is the story of a whole nation's distribution shifting across a continent.

Limits of the numbers. Every density is an average, and averages hide. The arithmetic density of the United States is about 37 people per km² of land (about 96 per square mile), but that one number covers both Manhattan and the Nevada desert. Physiological density depends on how "arable" is defined, and arable land can be made: irrigation turned dry valleys in California and Israel into farmland, and Dutch dikes and polders made new land out of the sea. A high density is not the same as overcrowding. Singapore and the Netherlands are among the most densely settled countries and are also prosperous, while some thinly peopled lands are poor. Density measures how people fit on the land; what they do with the land depends on skill, trade, law and work.

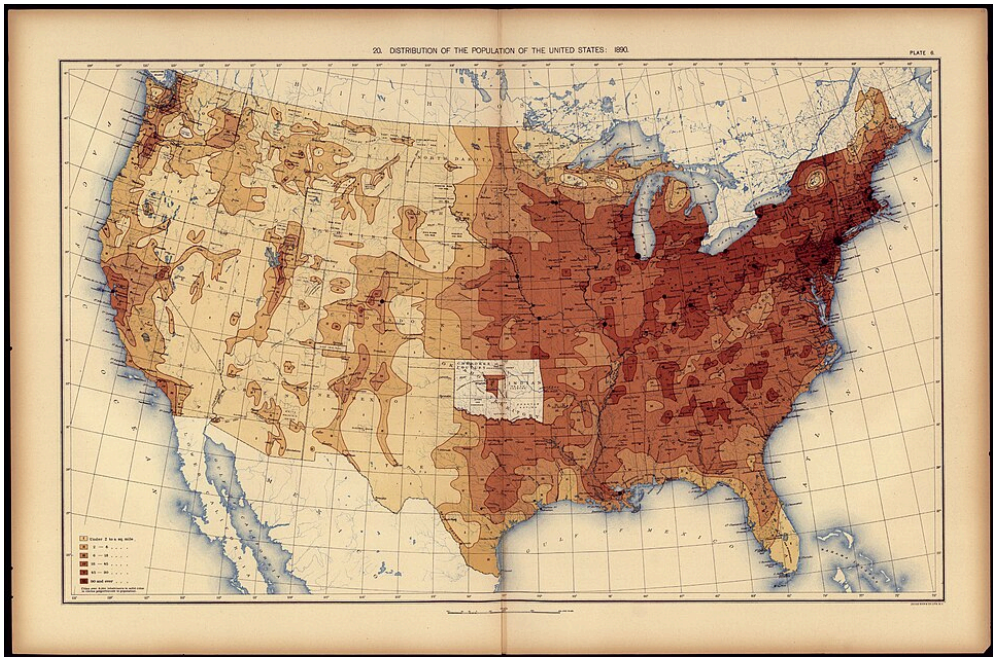
Why it matters. Scripture says that God "hath made of one blood all nations of men for to dwell on all the face of the earth" and has determined "the bounds of their habitation" (Acts 17:26). From the command to Noah's family to "replenish the earth" (Genesis 9:1) to the scattering at Babel, the Bible pictures people spreading across the lands God made. Geographers today map that spreading with censuses and satellites. The lights of cities seen from orbit at night trace the same clusters Gannett's clerks shaded by hand: the Nile like a glowing stem, the bright belts of Europe, India and eastern China, and the dark spaces of the Sahara, Siberia and the Amazon. Learning to read those patterns is the first step in all of human geography.

Egypt's people live along a thin ribbon: nearly all of them crowd into the Nile valley and delta, while the deserts on either side are almost empty.



The U.S. center of population, 1790, 1890 and 2020. Its westward and southward drift traces the changing distribution of Americans.

PICTURE STUDY



Distribution of the Population of the United States: 1890 (Map 20, Plate 6), from the Statistical Atlas of the United States, Henry Gannett, for the U.S. Census Office, 1898 (based on the 1890 census) · Color-printed map in a bound statistical atlas · Library of Congress, Geography and Map Division, Washington, D.C.

Henry Gannett (1846–1914) was the chief geographer of the U.S. Geological Survey and one of the founders of the National Geographic Society in 1888. For the 1890 census he directed the making of a great atlas of maps and charts. Its population maps shade the country in six steps, from under 2 people per square mile to 90 and over, using the county as the usual unit, and mark large cities with black dots.

This is the kind of map behind the famous statement that the frontier had closed. The darkest shades follow the Atlantic seaboard, the Ohio valley and the Great Lakes; lighter shades spread across the plains; and islands of settlement dot the West around mining towns, Salt Lake City, Denver and the Pacific valleys.

Look closely

- Find the darkest counties. Which rivers, coasts or lakes do they follow?
- Trace with your finger roughly where the shading fades to the lightest class. How straight is that “line”?
- Find the isolated patches of settlement in the West. What drew people there in the 1800s?
- Look at the map key. How many density classes are there, and are the steps between them equal?

Talk about it

1. Why did the census office say there was no longer a single frontier line, even though large parts of the West were still nearly empty?
2. Would a map of arithmetic density by state show the same pattern as this county map? What would be lost?
3. If you made this map for 2020, which areas would be darker, and which might be lighter?

PROJECT: A DENSITY MAP OF MY STATE

You will make the same kind of map Henry Gannett's clerks made in the 1890s: a county-by-county density map of your own state, colored by hand from real census numbers. Then you will compare it with a map of where the farmland and rivers are.

You will need

- A printed blank county outline map of your state (state government and university websites offer them free)
- County populations and land areas from the U.S. Census Bureau (data.census.gov) or a state almanac
- Calculator, ruler and pencil
- Colored pencils in five shades of one color, light to dark
- A physical map of your state showing rivers, highways and elevation

Steps

1. Make a table with columns: County, Population, Land area (sq mi), Density (people per sq mi), Density (people per km²).
2. Fill in at least 15 counties, including the most and least populous. If your state has fewer counties, do them all.
3. Divide population by land area for each. Convert to people per km² by dividing the per-square-mile figure by 2.59.
4. Choose five density classes. You may borrow Gannett's idea of steps that grow larger as density rises, for example under 18, 18–45, 45–90, 90–500 and over 500 people per square mile.
5. Shade each county on the blank map by its class. Add a title, a key, a north arrow and the source of your data.
6. Lay your map beside the physical map. Mark with a pencil line the main rivers and interstate highways.
7. Write a paragraph: Is your state's population clustered, dispersed or linear? What physical and human features explain the pattern?

Tips

- Use land area, not total area, when the census gives both; lakes and bays do not hold houses.

- If one city county is far denser than the rest, give it its own darkest class so it does not swamp the map.

Check your work

- My densities are correct to the nearest whole number in both units.
- My map has a title, key, north arrow and source.
- My paragraph names at least two physical and one human reason for the pattern.

MAP NOTEBOOK

1. Sketch a world outline and shade the four great population clusters: East Asia, South Asia, Europe and Southeast Asia. Label one major river in each.
2. Draw Egypt as a long rectangle of desert with the Nile as a thin green line and the delta as a fan. Write beside it: “about 95 percent of the people on about 5 percent of the land.”
3. Plot the U.S. center of population for 1790, 1890 and 2020 on a sketch map of the eastern half of the country and connect them with arrows.

> **From history.** Herman Hollerith, a young engineer who had worked on the 1880 census, won the contest to tabulate the 1890 count with his electric machine. A clerk placed each punched card in a press; wherever a hole let a pin dip into a cup of mercury, a circuit closed and a dial advanced. The first rough count of the population was announced in weeks rather than years. Hollerith’s Tabulating Machine Company later merged with other firms, and in 1924 the combined company took the name International Business Machines (IBM). Counting people was one of the first great jobs of the computing age.

WORKED EXAMPLES

Example 1. Egypt has about 110 million people on about 1,000,000 km² (386,000 sq mi). About 3 percent of the land is arable. Find the arithmetic and physiological densities in both units, and compare them. (Use these rounded figures.)

(Use the map or drawing "Egypt's arable land is almost all in the Nile valley and delta." shown earlier in this lesson.)

1. Arithmetic density: 110,000,000 ÷ 1,000,000 km² = 110 people per km². In square miles: 110,000,000 ÷ 386,000 ≈ 285 people per sq mi.
2. Arable land: 3 percent of 1,000,000 km² = 0.03 × 1,000,000 = 30,000 km². In square miles: 30,000 ÷ 2.59 ≈ 11,580 sq mi.
3. Physiological density: 110,000,000 ÷ 30,000 ≈ 3,670 people per km², or 110,000,000 ÷ 11,580 ≈ 9,500 people per sq mi.
4. Compare: 3,670 ÷ 110 ≈ 33. The physiological density is about 33 times the arithmetic density, because almost all of Egypt is desert.

Answer: Arithmetic: about 110 per km² (285 per sq mi). Physiological: about 3,700 per km² (9,500 per sq mi), roughly 33 times higher.

Example 2. Japan has about 124 million people on about 378,000 km². Canada has about 41 million people on about 9,985,000 km². Find each arithmetic density and how many times denser Japan is.

1. Japan: 124,000,000 ÷ 378,000 ≈ 328 people per km² (328 × 2.59 ≈ 850 per sq mi).
2. Canada: 41,000,000 ÷ 9,985,000 ≈ 4.1 people per km² (about 10.6 per sq mi).
3. Ratio: 328 ÷ 4.1 ≈ 80.

Answer: Japan about 328 per km² (850 per sq mi); Canada about 4.1 per km² (11 per sq mi). Japan is about 80 times denser by arithmetic density, though both countries have large thinly settled areas (Japan's mountains, Canada's north).

Example 3. The U.S. center of population was at about 39.3° N, 76.2° W in 1790 and about 37.4° N, 92.4° W in 2020. At a latitude near 38° N, one degree of longitude is about 87 km (54 miles). How far west did the center move, and what is the average westward shift per decade?

(Use the map or drawing "The center of population moved west across Maryland, Indiana and Missouri." shown earlier in this lesson.)

1. Difference in longitude: 92.4° − 76.2° = 16.2°.
2. Westward distance: 16.2 × 87 km ≈ 1,410 km. In miles: 16.2 × 54 ≈ 875 miles.
3. Years: 2020 − 1790 = 230 years = 23 decades.
4. Per decade: 1,410 ÷ 23 ≈ 61 km (about 38 miles).

Answer: About 1,410 km (875 miles) west, an average of about 61 km (38 miles) per decade. (The center also moved about 2° south, roughly 210 km, mostly in recent decades.)

PRACTICE

1. EASY Australia has about 27 million people on about 7.7 million km² (2.97 million sq mi). Find its arithmetic density in both units.
2. EASY Bangladesh has about 173 million people on about 148,000 km². Find its arithmetic density.
3. MEDIUM About 60 percent of Bangladesh's land is arable. Find its physiological density and compare it with Egypt's (about 3,700 per km²).
4. MEDIUM Country A has 2 million farmers working 50,000 km² of arable land. Country B has 500,000 farmers working 400,000 km². Find the agricultural density of each. Which country is more likely to farm with large machines? Explain.
5. EASY Name the four great clusters of world population and one country in each.
6. MEDIUM Convert a density of 100 people per km² to people per square mile. (1 sq mi = 2.59 km².)
7. MEDIUM The 1890 census frontier line marked settlement thinner than 2 people per square mile. Express that threshold in people per km².
8. MEDIUM Describe Canada's population distribution in one or two sentences and give two physical reasons for it.
9. HARD The center of population was at about 85.5° W in 1890 and 92.4° W in 2020. Using 87 km per degree of longitude, find the westward shift and the average per decade. Compare with the 1790–2020 average of about 61 km per decade.
10. HARD A country covers 200,000 km² and has 20 million people. Seventy percent of the people live on 10 percent of the land. Find the density in the crowded part and in the rest, and compare both with the arithmetic density.
11. CHALLENGE Egypt's arithmetic density is about 110 per km² and Bangladesh's about 1,170 per km², yet Egypt's physiological density is higher. Explain how both statements can

be true and what each measure tells a planner.

12. MEDIUM In a short paragraph, explain why the Sahara, Siberia, the Amazon basin and the Himalaya all have very low densities, naming a different physical limit for each.

COMMON MISTAKES

- Using arithmetic density to judge crowding or food pressure. A country can have a low average and still be crowded where people actually live, as Egypt shows.
- Mixing units: dividing by square miles and reporting per km², or forgetting that 1 sq mi = 2.59 km². Multiply a per-km² density by 2.59 to get per sq mi.
- Confusing density with distribution. Two countries can have the same density but very different patterns: one clustered on a river, the other spread evenly.

Make it a game · Denser or Sparser?. One player names two places (for example, Bangladesh and Mongolia, or New Jersey and Wyoming). The other says which is denser and gives one geographic reason within ten seconds. A correct answer scores a point; naming whether arithmetic or physiological density would change the answer scores a bonus point. Use an almanac or the Census Bureau website to settle disputes. Play to ten.

Scripture. “And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;” (Acts 17:26, KJV)

Paul spoke these words in Athens. The study of population begins with a simple fact Scripture states first: all peoples are one family, spread across the earth, and their dwelling places are not an accident of history but part of God’s providence.

Practice answers

1. 27,000,000 ÷ 7,700,000 ≈ 3.5 people per km²; 27,000,000 ÷ 2,970,000 ≈ 9.1 people per sq mi.
2. 173,000,000 ÷ 148,000 ≈ 1,170 people per km² (about 3,030 per sq mi), one of the highest of any large country.
3. Arable land ≈ 0.60 × 148,000 = 88,800 km². Physiological density ≈ 173,000,000 ÷ 88,800 ≈ 1,950 per km². Bangladesh has about ten times Egypt’s arithmetic density but only about half its physiological density, because so much of Bangladesh’s delta land can be farmed.
4. A: 2,000,000 ÷ 50,000 = 40 farmers per km². B: 500,000 ÷ 400,000 = 1.25 farmers per km². Country B, because each farmer works far more land (about 80 hectares each), which is possible only with tractors and combines.
5. East Asia (China, Japan); South Asia (India, Pakistan, Bangladesh); Europe (Germany, France, the United Kingdom); Southeast Asia (Indonesia, the Philippines, Vietnam). Any correct country in each is acceptable.
6. 100 × 2.59 = 259 people per square mile. (A square mile holds 2.59 km², so it holds 2.59 times as many people.)
7. 2 ÷ 2.59 ≈ 0.77 people per km².

8. Canada’s people are clustered in a band along the southern border, about three-quarters within roughly 160 km (100 miles) of the United States, especially along the St. Lawrence and the Great Lakes. Reasons: the south has a longer growing season and milder winters, and the north is covered by boreal forest, rocky Canadian Shield and tundra with poor soils and permafrost. (Trade ties to the U.S. are a human reason.)
9. 6.9° × 87 ≈ 600 km (about 373 miles) over 13 decades ≈ 46 km (29 miles) per decade. The westward drift slowed after 1890, once the West was settled; much of the later movement was toward the South and the Pacific coast.
10. Arithmetic: 20,000,000 ÷ 200,000 = 100 per km². Crowded part: 14,000,000 ÷ 20,000 = 700 per km². Rest: 6,000,000 ÷ 180,000 ≈ 33 per km². The single average of 100 describes neither area well.
11. Arithmetic density spreads people over all land, and Egypt’s land is mostly desert, so the average is low. Physiological density counts only farmland, and Egypt has very little (about 3 percent), so the pressure on each farmed km² is very high, while Bangladesh’s delta is mostly farmable. A planner worried about housing and roads looks at where people actually live; a planner worried about food supply looks at physiological density and at irrigation and imports.
12. The Sahara lacks water; Siberia’s long, bitter winters, short growing season and permafrost limit farming; the Amazon’s dense rainforest, heavy rain and leached soils make clearing and farming hard and travel slow; the Himalaya’s great height, steep slopes and thin air leave little flat, warm land. In each case people can live there (and some do), but the land supports few people without large imports or new technology.

2.2 Growth and the Demographic Transition

OBJECTIVES

- Calculate crude birth and death rates, the rate of natural increase and doubling time, and read a country's total fertility rate.
- Describe the five stages of the demographic transition model and place real countries on it.
- Explain where the model came from (Sweden's parish records, Thompson 1929, Notestein 1945) and evaluate at least three of its limits.

Warm-up. Fill a sink or bowl with an open drain and a running tap. Turn the tap high and leave the drain open: the water level holds steady. Now partly plug the drain: the level rises fast. Then turn the tap down to match the drain: the level steadies again, but higher. Write one sentence matching each step to births (the tap), deaths (the drain) and population (the water). You have just acted out the demographic transition.

Video. Coming soon. The demographic transition model, Sweden's population records and world population milestones: search Hillsdale Studios, The History Guy and Library of Congress; AP Human Geography review channels from individual teachers are candidates (needs vetting, check for ideological framing).

KEY TERMS

crude birth rate (CBR)
The number of live births in a year for every 1,000 people in the population.

crude death rate (CDR)
The number of deaths in a year for every 1,000 people in the population.

rate of natural increase (RNI)
The percentage by which a population grows in a year from births minus deaths, not counting migration: RNI = (CBR − CDR) ÷ 10.

total fertility rate (TFR)
The average number of children a woman would have in her lifetime at current birth rates. About 2.1 is "replacement level" in countries with low child mortality.

doubling time
The number of years a population takes to double at a steady growth rate; approximately 70 divided by the percent growth rate (the "rule of 70").

demographic transition model
A model describing how a country's birth and death rates change from high to low over time, producing a burst of growth in between.

CORE IDEAS

The story. In 1749 the Kingdom of Sweden began something no nation had done before: it started a continuous, nationwide record of its people. The work rested on the parish clergy of the Church of Sweden. Under the Church Law of 1686 every Lutheran pastor kept registers of baptisms, marriages and burials, and a household examination roll in which he recorded each family when he visited to test their knowledge of the catechism. From 1749 the pastors sent yearly summaries to Stockholm, where the astronomer Pehr Wargentin, secretary of the Royal Swedish Academy of Sciences, studied them and built some of the first reliable tables of how long people lived. Because of those faithful parish books, Sweden has the longest unbroken series of national birth and death figures in the world, and it became the textbook example of how a population changes as a nation grows healthier and richer.

How it worked. In the 1750s Sweden had about 1.8 million people. Births usually ran in the 30s per 1,000 people a year, and deaths in the high 20s, far higher in years of harvest failure or epidemic, as in the famine of 1772–1773. Then, through the 1800s, the death rate fell. Smallpox vaccination, discovered by Edward Jenner in England in 1796, was made compulsory in Sweden in 1816; the potato spread as a reliable field crop; and long years of peace followed the Napoleonic Wars. The poet and bishop Esaias Tegnér summed up the cause of Sweden’s growth in a famous phrase: “peace, vaccine and potatoes.” Births stayed high for decades after deaths fell, so the population surged, to about 5.1 million by 1900, even though hundreds of thousands of Swedes had emigrated, most of them to the American Midwest (more than a million left between 1850 and 1930). Only from the 1880s did the birth rate fall steadily, and by the 1930s it was among the lowest in the world.

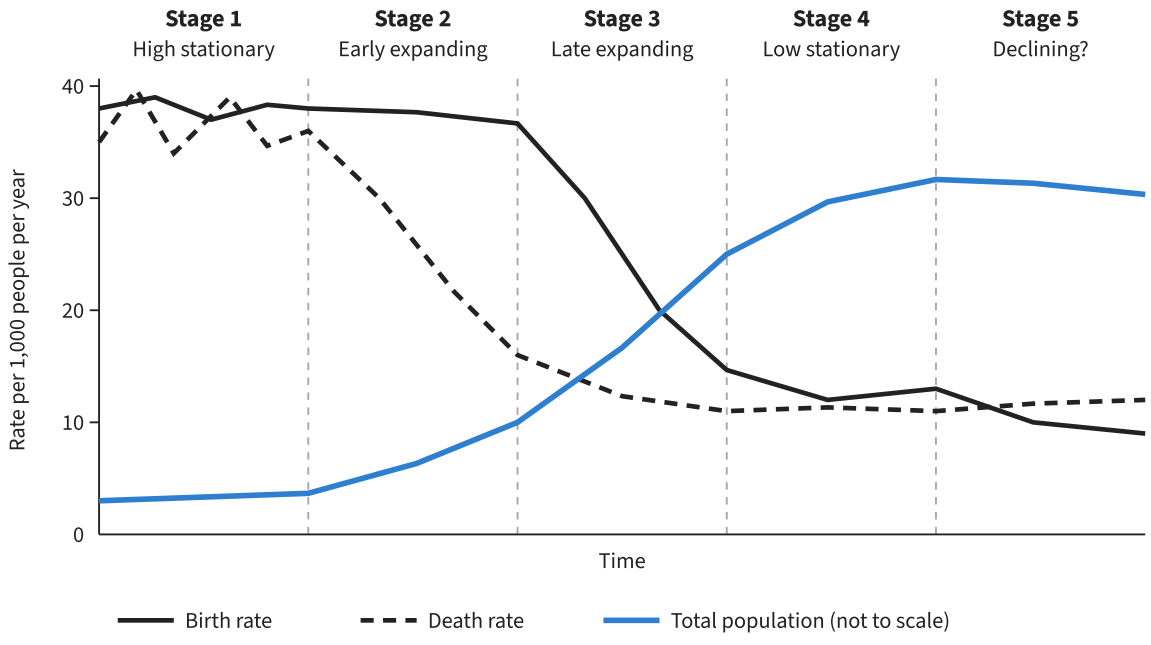
The big idea. In 1929 the American demographer Warren Thompson noticed that countries fell into groups by their birth and death rates, and in 1945 Frank Notestein of Princeton gave the pattern its name, the **demographic transition**. Textbooks now draw it in five stages (see the graph). **Stage 1 (high stationary):** high birth and death rates, slow and uneven growth; this was the condition of nearly every people before modern times. **Stage 2 (early expanding):** the death rate falls with better food supply, clean water and medicine, while births stay high, so growth is fast. **Stage 3 (late expanding):** the birth rate falls too, as families move to cities, children survive, schooling grows longer and children become more costly to raise. **Stage 4 (low stationary):** both rates are low and growth is slow. **Stage 5**, added later and still debated, describes countries where deaths exceed births and the native population shrinks. The tools for reading the stages are simple. The **rate of natural increase** is (CBR − CDR) ÷ 10, in percent. A population growing at a steady r percent doubles in about 70 ÷ r years. The **total fertility rate** tells how many children the average woman bears; about 2.1 replaces the parents where few children die young.

On the map. The world as a whole has passed through the fastest part of the transition. Humanity reached its first billion around 1804, its second in 1927 and its third in 1960; it then added a billion about every eleven to fourteen years, reaching 8 billion in November 2022. The world growth rate peaked a little above 2 percent a year in the 1960s and was below 1 percent by the 2020s. Today the map shows nearly every stage at once. Several countries of the Sahel, such as Niger, still have fertility near six children per woman and very

young populations, placing them in stage 2 or early stage 3. Most of Latin America, South Asia and the Middle East sit in late stage 3 or early stage 4. Japan, Italy, South Korea and much of Eastern Europe have entered what the model calls stage 5: South Korea's fertility fell below 0.8 in the early 2020s, and Japan has recorded more deaths than births every year since the late 2000s.

Limits of the model. The demographic transition is a description of what happened in Europe and North America, generalized into a model. It is useful, but it is not a law. First, *timing* differs. In Sweden the death rate fell over a century; in much of Asia, Africa and Latin America after 1945 it fell within a generation, because vaccines, antibiotics and clean water arrived from abroad, so stage 2 growth was much faster: Kenya grew close to 4 percent a year around 1980. Second, *causes* differ. France's birth rate began falling in the late 1700s, before it industrialized, and Bangladesh's fertility fell from nearly seven children per woman in the early 1970s to about two by the 2020s while it was still a poor country. Third, the model leaves out **migration**, which can make a stage 4 country grow or a stage 2 country shrink. Fourth, it assumes rich countries end with few children, yet culture and faith matter: Israel, a wealthy country, has a fertility rate near 3. Finally, it cannot say what comes after stage 5, because no country has lived through it yet.

Why it matters. A model that is honest about its limits is still a powerful tool. It explains why a young, fast-growing country must build schools and create jobs, and why an aging one must care for many elderly with fewer workers. Behind every rate are real families. Scripture calls children "an heritage of the LORD" (Psalm 127:3), and the Swedish pastors who recorded every baptism and burial knew that each line in the parish book was a soul. Good geography keeps both truths in view: the numbers are real, and so are the people behind them.



The demographic transition model. Population grows fastest where the gap between the birth-rate and death-rate lines is widest (stages 2 and 3).

PICTURE STUDY

The Census at Bethlehem, Pieter Bruegel the Elder, 1566 · Oil on oak panel · Royal Museums of Fine Arts of Belgium, Brussels

Pieter Bruegel the Elder painted the Bible story of the census that brought Joseph and Mary to Bethlehem: “And it came to pass in those days, that there went out a decree from Cæsar Augustus, that all the world should be taxed” (Luke 2:1). Like many painters of his time, he set the scene in his own country, a Brabant village in the depth of a hard winter, with people his viewers would recognize.

Mary and Joseph are easy to miss. They are just two more travelers in the crowd, arriving to be counted like everyone else. Bruegel shows what a count of people really is: an enormous effort to record every household, one name at a time.

Look closely

- Find the crowd at the inn window. What are the officials doing?
- Find the woman in the blue cloak on the donkey. Why might Bruegel have made the holy family so small?
- Count the different activities you can see: people working, playing, carrying, buying. What do they tell you about village life?
- Look at the season and the light. What would travel have been like for people summoned to register?

Talk about it

1. Why do rulers and governments count their people? List at least three reasons, ancient and modern.

2. The Swedish parish books and the census in Luke 2 were both kept by authorities. How might a count’s purpose (taxes, soldiers, church membership) affect its accuracy?
3. What would a geographer want to know from a census besides the total number of people?

PROJECT: BEANS THROUGH THE TRANSITION

You will run a whole country through the five stages of the demographic transition with a bowl of dried beans and a die, keep a ledger of births and deaths, and graph the result. Then you will compare your graph with the model and with real data.

You will need

- About 1 pound of dried beans (a few hundred beans) and a large bowl for the “country”
- A second bowl for the “graveyard” and a cup of extra beans for “births”
- One six-sided die
- Graph paper, ruler, pencil and two colored pencils
- Calculator

Steps

1. Put 100 beans in the country bowl. Each round stands for ten years.
2. Use these rates per 100 people per round. Stage 1: 30 births and 28 deaths, and roll the die; on a 1, a famine or epidemic adds 20 more deaths. Stage 2: 30 births, 12 deaths. Stage 3: 18 births, 9 deaths. Stage 4: 10 births, 9 deaths. Stage 5: 8 births, 11 deaths.
3. Each round, multiply the rates by (current population ÷ 100) and round to whole beans. Add the births from the cup and move the deaths to the graveyard bowl.
4. Play three rounds in each stage (15 rounds). In a ledger, record for each round: stage, starting population, births, deaths, ending population and the growth that round in percent.
5. Graph the population after each round with one color. On the same paper, with a second scale, graph the birth and death rates you used.
6. Find the round in which growth was fastest and the stage it belonged to.
7. Look up the crude birth and death rates of three real countries (one high-fertility, one middle, one aging) in an almanac or the Census Bureau International Database, and mark where each would fall on your graph.
8. Write a paragraph comparing your bean country with Sweden from 1750 to today, and name one thing the beans could not show (for example, emigration).

Tips

- Round births and deaths to whole beans; small rounding differences are fine.
- If two people play, give each a separate country and different luck with the die, then compare how famines in stage 1 change the ending population.

Check your work

- My ledger is complete for all 15 rounds and the arithmetic is correct.
- My graph shows the fastest growth in stages 2 and 3 and a slight decline in stage 5.
- My paragraph names a real country for at least three stages and one limit of the model.

MAP NOTEBOOK

1. Copy the demographic transition graph from memory, label all five stages and shade the gap that shows natural increase.
2. Make a timeline of world population milestones: 1 billion (about 1804), 2 (1927), 3 (1960), 4 (1974), 5 (1987), 6 (1999), 7 (2011), 8 (2022). Draw it to scale.
3. Sketch a map of Sweden and draw an arrow across the Atlantic labeled “more than a million emigrants, 1850–1930,” with a note on where most of them settled.

> **From history.** On May 14, 1796, the English country doctor Edward Jenner scratched material from a cowpox sore into the arm of eight-year-old James Phipps; weeks later, exposed to smallpox, the boy did not fall ill. Jenner named the method vaccination, from the Latin *vacca*, cow. Smallpox had been one of the great killers of children in every country, and as vaccination spread through Europe in the early 1800s, it became one of the first forces pushing death rates down and starting the demographic transition. Sweden made vaccination compulsory in 1816, and its parish registers show smallpox deaths falling sharply in the decades after.

WORKED EXAMPLES

Example 1. In the 1750s Sweden had a crude birth rate of about 35 and a crude death rate of about 27 per 1,000. Find the rate of natural increase and the doubling time at that rate.

1. RNI = (CBR − CDR) ÷ 10 = (35 − 27) ÷ 10 = 0.8 percent per year.
2. Rule of 70: doubling time ≈ 70 ÷ 0.8 = 87.5 years.

Answer: RNI 0.8 percent per year; doubling time about 88 years (in a normal year, before famines or epidemics).

Example 2. Sweden grew from about 1.8 million people in 1750 to about 5.1 million in 1900. Find the average annual growth rate over those 150 years.

1. Growth factor: 5.1 ÷ 1.8 ≈ 2.83.
2. Notice that $2.83 \approx 2^{1.5}$ (since 2 × 1.41 = 2.83). So the population doubled 1.5 times in 150 years, a doubling time of 150 ÷ 1.5 = 100 years.
3. Rule of 70 in reverse: r ≈ 70 ÷ 100 = 0.7 percent per year.
4. Check with logarithms: r = ln(2.83) ÷ 150 = 1.04 ÷ 150 ≈ 0.0069, or 0.69 percent.

Answer: About 0.7 percent per year, even though hundreds of thousands of emigrants left in the later decades.

Example 3. Place three countries on the demographic transition model and find each one's RNI. Country P: CBR 40, CDR 10. Country Q: CBR 20, CDR 7. Country R: CBR 7, CDR 12.

(Use the map or drawing "Compare each country's birth and death rates with the lines on the graph." shown earlier in this lesson.)

1. P: RNI = (40 − 10) ÷ 10 = 3.0 percent; doubling in about 70 ÷ 3 ≈ 23 years. Births high, deaths already low: stage 2.
2. Q: RNI = (20 − 7) ÷ 10 = 1.3 percent; doubling in about 54 years. Births falling, deaths low: stage 3.
3. R: RNI = (7 − 12) ÷ 10 = −0.5 percent. Deaths exceed births: stage 5 (some textbooks call this late stage 4).

Answer: P: stage 2, +3.0 percent. Q: stage 3, +1.3 percent. R: stage 5, −0.5 percent (shrinking without immigration).

PRACTICE

1. EASY A country has a CBR of 25 and a CDR of 8. What is its rate of natural increase?
2. EASY A population grows at 1.4 percent a year. About how long will it take to double?
3. EASY In the mid-2020s the world population was growing at about 0.9 percent a year. What is the doubling time at that rate, and how does it compare with the doubling time at the 1960s peak of about 2.1 percent?
4. MEDIUM A country of 3,000,000 people records 60,000 births and 27,000 deaths in a year. Find the CBR, CDR and RNI.
5. MEDIUM A country of 50 million grows steadily at 2 percent a year. About what will its population be in 35 years? In 70 years?
6. EASY In which stage of the model does the death rate fall while the birth rate stays high? Give two reasons the death rate falls.

7. MEDIUM Why is replacement-level fertility about 2.1 children per woman and not exactly 2?
8. MEDIUM A country records 1,800 deaths of infants under one year old and 60,000 live births in a year. What is its infant mortality rate (deaths under age one per 1,000 live births)?
9. HARD A country has a CBR of 9 and a CDR of 10, yet its total population rose last year. How is that possible, and what limit of the demographic transition model does it show?
10. HARD The world took about 123 years to go from 1 to 2 billion (about 1804 to 1927) but only about 11 years to go from 7 to 8 billion (2011 to 2022), even though the growth rate was lower in the 2010s than in the 1960s. Explain.
11. CHALLENGE A country of 10 million has an RNI of −0.5 percent a year and no migration. About how many people will it have after 20 years?
12. CHALLENGE In a paragraph, explain two limits of the demographic transition model, each with a real example.

COMMON MISTAKES

- Forgetting to divide by 10 when turning (CBR − CDR), which is per 1,000, into a percentage. A CBR of 30 and CDR of 10 give 2 percent, not 20 percent.
- Thinking population grows fastest in stage 4 because the country is richest. Growth is fastest where the gap between births and deaths is widest, in stages 2 and early 3.
- Treating the model as a law every country must follow on the same timetable. It is a generalization from European history, and real countries have moved through it at different speeds and for different reasons.

Make it a game · Name That Stage. One player reads out a country's crude birth rate and crude death rate (from an almanac or made up within realistic limits). The other must give the rate of natural increase, the doubling time by the rule of 70 and the stage of the demographic transition within twenty seconds. One point for each correct part. Switch roles every round and play to fifteen points.

Scripture. "Lo, children are an heritage of the LORD: and the fruit of the womb is his reward." (Psalm 127:3, KJV)

Birth rates and fertility rates are statistics, but every one of them counts children, whom Scripture calls a gift and a heritage. The demographic transition describes changes in how many children families have; the Bible reminds us what each of those children is worth.

Practice answers

1. (25 − 8) ÷ 10 = 1.7 percent per year.
2. 70 ÷ 1.4 = 50 years.
3. 70 ÷ 0.9 ≈ 78 years, compared with 70 ÷ 2.1 ≈ 33 years in the 1960s, more than twice as long.

4. CBR = 60,000 ÷ 3,000,000 × 1,000 = 20. CDR = 27,000 ÷ 3,000,000 × 1,000 = 9. RNI = (20 − 9) ÷ 10 = 1.1 percent.
5. Doubling time ≈ 70 ÷ 2 = 35 years. After 35 years about 100 million; after 70 years about 200 million.
6. Stage 2. Reasons include a steadier food supply, clean water and sewers, vaccines (such as smallpox vaccination) and antibiotics, and better care for mothers and infants.
7. Each couple needs two children to replace themselves, but slightly more boys than girls are born and some children die before they grow up and have families of their own, so a little more than 2 is needed. Where child mortality is high, replacement level is well above 2.1.
8. 1,800 ÷ 60,000 × 1,000 = 30 infant deaths per 1,000 live births.
9. Its natural increase was negative (−0.1 percent), so the growth must have come from immigration exceeding emigration. The model tracks only births and deaths and ignores migration, which can reverse its predictions.
10. A billion is a fixed amount, but growth is a percentage of the current total. One percent of 7 or 8 billion is 70 to 80 million people a year, while even a higher rate applied to 1 or 2 billion added far fewer people. A falling rate on a very large base can still add a billion quickly.
11. $10{,}000{,}000 \times 0.995^{20} \approx 10{,}000{,}000 \times 0.905 \approx 9.05$ million, a loss of about 950,000 people.
12. Any two well-supported limits, for example: (1) It was built on European history, but in many countries after 1945 death rates fell far faster because medicine was imported, so stage 2 growth was much faster (Kenya near 4 percent around 1980). (2) Birth rates do not always fall because of industry and wealth: France’s fell before industrialization and Bangladesh’s fell while it was poor. (3) It ignores migration (Sweden’s emigration; immigration into stage 4 and 5 countries). (4) Culture and faith matter: Israel is rich yet has fertility near 3. (5) It cannot predict what follows stage 5.

2.3 Malthus and His Critics

OBJECTIVES

- State Malthus's argument of 1798, distinguish geometric from arithmetic growth, and explain positive and preventive checks.
- Weigh the evidence of the two centuries since: rising food output, the Irish famine, the Haber–Bosch process, and the forecasts of the 1960s.
- Compare the views of Malthus, the neo-Malthusians, Ester Boserup, Julian Simon and Amartya Sen, and write a reasoned judgment of your own.

Warm-up. Take a sheet of paper and fold it in half, then in half again, as many times as you can, counting the layers each time (2, 4, 8, 16…). At the same time, have a partner stack one extra sheet on a pile for each of your folds. After six folds, compare: your folded stack has 64 layers; the partner's pile has 7 sheets. Which kind of growth would you rather have for your food, and which for the number of mouths to feed?

Video. Coming soon. Thomas Malthus and the Essay on the Principle of Population, the Irish famine, the Haber–Bosch process and the Simon–Ehrlich wager: search Hillsdale Studios, The History Guy and Library of Congress; candidates needing vetting: Tom Scott, Half as Interesting.

KEY TERMS

geometric (exponential) growth
Growth by a constant multiple in each period, as 1, 2, 4, 8, 16. Malthus said population, when unchecked, grows this way.

arithmetic (linear) growth
Growth by a constant amount in each period, as 1, 2, 3, 4, 5. Malthus said food supply could at best grow this way.

positive checks
In Malthus's terms, causes that raise the death rate and hold population down: famine, disease, war and misery.

preventive checks
In Malthus's terms, causes that lower the birth rate, above all later marriage, which he called "moral restraint" from his second edition (1803).

carrying capacity
The largest population an area can support with a given level of technology, trade and land use.

agricultural intensification
Getting more food from the same land by more labor, better tools, irrigation, fertilizer and new methods. Ester Boserup argued population growth drives it.

CORE IDEAS

The story. In the summer of 1798 the London bookseller Joseph Johnson published a short book with a long title and no author's name: *An Essay on the Principle of Population, as it Affects the Future Improvement of Society, with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers*. Its author was Thomas Robert Malthus, a thirty-two-year-old Cambridge graduate serving as curate of the little Anglican chapel at Okewood in Surrey. The book grew out of an argument with his own father. Daniel Malthus admired the hopeful thinkers of the age, such as William Godwin in England and the Marquis de Condorcet in France, who believed that reason and good government would soon free mankind from poverty. The son was not convinced: he believed a hard law of nature stood in the way.

How it worked. Malthus's argument fits in two sentences of his own: "Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio." Pointing to the American colonies, where he believed numbers had doubled about every twenty-five years, he supposed that an unchecked population would go 1, 2, 4, 8, 16 in successive quarter-centuries, while the best the land could do was add a fixed amount each time: 1, 2, 3, 4, 5. In two centuries, he wrote, population and food would stand as 256 to 9 (see the graph). Since that cannot actually happen, something must hold numbers down. Malthus called these the **checks**. **Positive checks** raise the death rate: famine, disease, war and misery. **Preventive checks** lower the birth rate, chiefly later marriage. In the much enlarged second edition of 1803, signed with his name, Malthus gave more hope to "moral restraint," the choice to delay marriage until one could support a family. As a clergyman he rejected contraception as a vice.

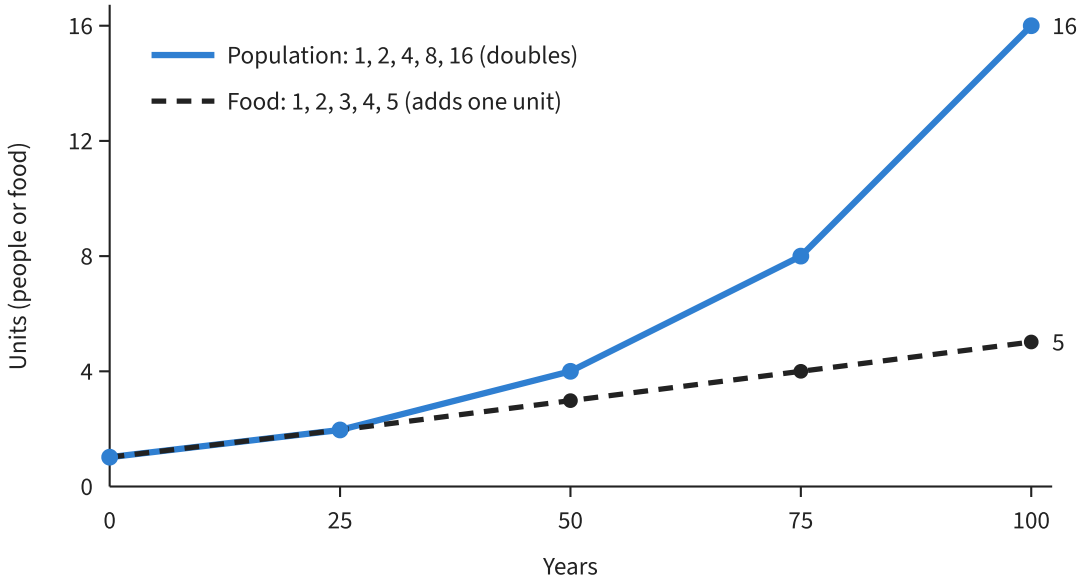
The big idea. Malthus described the world before the demographic transition well. For most of history, good harvests let numbers rise and bad harvests, plagues and wars cut them down, which is the jagged stage 1 line on the model. But the two centuries after he wrote did not follow his ratios. England and Wales grew from about 9 million people at the first census in 1801 to about 32.5 million in 1901, and most of them ate better at the end than at the beginning. Food production had not crawled upward by fixed steps. Farmers adopted new rotations, drained fields, and bred better livestock; railroads and steamships brought grain from the American prairies and the Russian steppe; refrigeration carried meat from Argentina and New Zealand. In 1909 the German chemist Fritz Haber found how to make ammonia from the nitrogen of the air, and Carl Bosch of the BASF company scaled the process up to a factory by 1913. Synthetic nitrogen fertilizer from the **Haber–Bosch process** became one of the foundations of modern farming; by some estimates, about half of the world's people today eat food grown with it. Haber himself is a sober reminder that inventors are not saints: the same chemist directed Germany's poison gas attacks in the First World War.

On the map. The great test case close to Malthus's own time was **Ireland**. Its population had climbed to about 8.2 million by 1841, many of them poor tenants living on small plots and depending almost entirely on the potato. When a blight destroyed the crop from 1845, about a million people died of hunger and disease and more than a million emigrated; by 1851 the population was about 6.5 million. Some at the time read the famine as a Malthusian

check. Critics then and since have pointed out that Ireland went on exporting grain and cattle during the famine years, that land tenure left families with no reserve, and that government relief was limited by a rigid belief in leaving the market alone. The geography of the twentieth century strengthened the critics' case. The deadliest famines of that century, in the Soviet Union in 1932–1933 and in China during the Great Leap Forward of 1959–1961, which killed tens of millions, were caused chiefly by the policies of Communist governments that seized grain and forced peasants into collective farms, not by too many people for the land. The economist **Amartya Sen**, writing in 1981, argued that modern famines usually come from a collapse in people's ability to obtain food, through war, policy or lost wages, rather than from a simple shortage of food.

The critics and the debate. In 1965 the Danish economist **Ester Boserup** turned Malthus upside down: in her view, population pressure is what pushes farmers to work the land more intensively, with shorter fallows, irrigation and new tools, so growth in numbers can cause growth in food. The economist **Julian Simon** argued in *The Ultimate Resource* (1981) that the human mind is the resource that does not run out. In 1968 the biologist Paul Ehrlich's *The Population Bomb* had predicted that hundreds of millions would starve in the 1970s; instead, new wheat and rice varieties of the Green Revolution (Unit 6) raised harvests sharply. In 1980 Simon bet Ehrlich that a basket of five metals would be cheaper in 1990; it was, and Ehrlich paid. **Neo-Malthusians** still answer that soils can wear out, aquifers can be pumped down and fisheries can be emptied, and that past success does not guarantee future success. Those are real questions about local resources, and they deserve careful, evidence-based answers rather than panic.

Why it matters. Malthus was wrong in his forecast but useful in his question: what limits the number of people a land can feed, and what can raise that limit? The answer of the last two centuries has been human work, invention and trade on a fruitful earth. God promised Noah after the Flood that "seedtime and harvest" would not cease while the earth remains (Genesis 8:22), and He set man in the garden "to dress it and to keep it" (Genesis 2:15). Stewardship means both: diligent work to make the land fruitful, and care so that it stays fruitful for our grandchildren.



Malthus's two ratios over a century: population doubling every 25 years (geometric) against food adding one unit every 25 years (arithmetic).

PICTURE STUDY

The Gleaners, Jean-François Millet, 1857 · Oil on canvas · Musée d'Orsay, Paris

Jean-François Millet was the son of a Norman farming family who painted the rural poor of France with great dignity. In *The Gleaners* three women gather the stray ears of wheat left on the ground after the harvest, the right of the poorest people in a village since ancient times. The law of Moses commanded it: "And when ye reap the harvest of your land, thou

shalt not wholly reap the corners of thy field, neither shalt thou gather the gleanings of thy harvest” (Leviticus 19:9), and Ruth gleaned in the field of Boaz.

Millet painted it in 1857, in the decades when French and English farmers were steadily raising their harvests. Behind the women lies abundance: tall stacks and a busy harvest crew. In front of them lies the thin margin on which the poor lived, the margin Malthus worried about.

Look closely

- Compare the foreground and the background. What has been harvested, and what is left for the gleaners?
- Look at the women’s postures. How does Millet show how hard and repetitive the work is?
- Find the figure on horseback at the right. Who might he be?
- Notice the color and light. Does the painting feel hopeful, sorrowful or both?

Talk about it

1. How does this painting show both of the facts debated in this lesson: growing harvests and continuing poverty?
2. Gleaning laws gave the poor a share of the harvest. What other ways have societies used to keep the poor from famine?
3. Would Malthus, Boserup or Sen each read this painting differently? How?

PROJECT: THE RACE: DOUBLING AGAINST ADDING

You will act out Malthus’s two ratios with grains of rice, then add Boserup’s and Simon’s answer: invention cards that can make the food line bend upward. At the end you will write your own verdict.

You will need

- A cup of uncooked rice and a cup of dried beans
- Two plates, labeled “People” and “Food”
- Eight index cards and a marker
- One six-sided die
- Graph paper, ruler and two colored pencils

Steps

1. Make eight invention cards, each with a real advance and its date: Norfolk four-course rotation (1700s), seed drill (Jethro Tull, about 1701), steel plow (John Deere, 1837), refrigerated shipping (1870s–1880s), Haber–Bosch fertilizer (1913), hybrid corn (1930s), semi-dwarf wheat (1960s), drip irrigation (1960s). Shuffle them face down.
2. Round 0: put 1 rice grain on the People plate and 1 bean on the Food plate. Each round is 25 years.

3. Malthus's race: for 8 rounds, double the rice each round and add 1 bean each round. Record both counts in a table (people: 1, 2, 4…; food: 1, 2, 3…). Count, or once the rice is too many, compute.
4. Graph both lines on the same axes. Mark the round when people first outnumber food units.
5. Boserup's race: start again. Each round, double the rice, add 1 bean, and roll the die. On a 5 or 6, turn over an invention card and double the food on the plate. Record which invention arrived when.
6. Graph the second race in another color on a new set of axes. Did the food line bend upward? Did it keep pace?
7. Write a one-page verdict: Was Malthus right about his own time? About ours? What makes the difference between the two races, and what in the real world might stop the inventions from coming?

Tips

- After 8 doublings the People plate needs 256 grains; you may compute rather than count once it is past 64.
- The die stands in for the uncertainty of invention. Run the second race twice and compare.

Check your work

- My table and graph show geometric and arithmetic growth correctly (256 to 9 after 8 rounds in Malthus's race).
- My second race records each invention with its real date.
- My verdict names at least one critic of Malthus and one neo-Malthusian concern.

MAP NOTEBOOK

1. Draw Malthus's two ratios side by side as stacks of squares: 1, 2, 4, 8, 16 and 1, 2, 3, 4, 5.
2. Sketch a map of Ireland and write the population in 1841 (about 8.2 million) and 1851 (about 6.5 million). Draw arrows for emigration to Britain and North America.
3. Make a four-box chart: Malthus, Boserup, Simon, Sen. In each box write the thinker's main claim in one sentence and one piece of evidence for it.

> **From history.** Britain had never counted its people when Malthus wrote, and debate over his essay helped persuade Parliament to pass the Census Act of 1800. The first census of Great Britain was taken on March 10, 1801, organized by a young parliamentary official named John Rickman, who went on to oversee the next three censuses as well. It found about 8.9 million people in England and Wales. Malthus used the new figures in his later editions, and Britain has taken a census every ten years since, except in 1941, during the Second World War.

WORKED EXAMPLES

Example 1. Using Malthus's assumptions (population doubles every 25 years; food grows by one original unit every 25 years), find the ratio of population to food after 100, 200 and 300 years.

(Use the map or drawing "The first century of Malthus's race." shown earlier in this lesson.)

1. 100 years = 4 periods. Population: $2^4 = 16$. Food: 1 + 4 = 5. Ratio 16 : 5.
2. 200 years = 8 periods. Population: $2^8 = 256$. Food: 1 + 8 = 9. Ratio 256 : 9.
3. 300 years = 12 periods. Population: $2^{12} = 4{,}096$. Food: 1 + 12 = 13. Ratio 4,096 : 13.

Answer: 16 : 5 after a century, 256 : 9 after two centuries and 4,096 : 13 after three, the very ratios Malthus gave in 1798.

Example 2. In a certain country, total food production grows 2.5 percent a year while population grows 1.5 percent a year. About how much does food per person change over 30 years?

1. Food per person grows by about the difference: 2.5% − 1.5% = 1.0% per year. (Exactly: 1.025 ÷ 1.015 ≈ 1.0099, or 0.99%.)
2. Over 30 years: $1.01^{30} \approx 1.35$.
3. Using the exact rate: $1.0099^{30} \approx 1.34$.

Answer: Food per person rises by about a third (roughly 34–35 percent) in 30 years, even though the population is also growing.

Example 3. Average U.S. corn yields were about 25 bushels per acre in the early 1930s and about 175 bushels per acre in the 2020s. How many times higher is the modern yield? Convert 175 bushels per acre to metric tons per hectare (1 bushel of corn = 25.4 kg; 1 hectare = 2.47 acres).

1. Ratio: 175 ÷ 25 = 7.
2. Kilograms per acre: 175 × 25.4 ≈ 4,445 kg.
3. Per hectare: 4,445 × 2.47 ≈ 10,980 kg ≈ 11.0 metric tons per hectare.
4. Meaning: to grow today's harvest at 1930s yields would take about seven times as much land.

Answer: About 7 times higher; 175 bushels per acre ≈ 11 metric tons per hectare. Hybrid seed, fertilizer and machinery bent Malthus's "arithmetic" line sharply upward.

PRACTICE

1. EASY Write the first six terms of Malthus's population series and his food series, starting at 1.
2. EASY Classify each as a positive or a preventive check: (a) a cholera epidemic, (b) couples marrying at 28 instead of 20, (c) a crop failure and famine, (d) a long war.
3. MEDIUM Ireland's population fell from about 8.2 million in 1841 to about 6.5 million in 1851. Find the loss and the percentage decline.
4. MEDIUM England and Wales grew from about 9 million people in 1801 to about 32.5 million in 1901. By what factor did the population grow, and what was its average annual growth rate?
5. MEDIUM State Ester Boserup's argument in two sentences and give one example of agricultural intensification.
6. MEDIUM What did the Haber–Bosch process make possible, and why is it important to the Malthus debate?
7. HARD In a country, food output grows 1.2 percent a year and population 2.0 percent a year. Approximately how much does food per person change in 25 years?
8. HARD A valley produces 6,000 metric tons of grain a year, and each person needs about 0.2 metric ton a year. What is its carrying capacity from local grain? If irrigation raises output by 50 percent, what is the new figure? Name one way the valley could support more people without growing more grain.
9. MEDIUM What did Paul Ehrlich predict in *The Population Bomb* (1968), and what happened instead?
10. HARD Explain Amartya Sen's view of famine and use one twentieth-century famine as an example.
11. CHALLENGE A region's food supply is 150 units and grows by 10 units a year (arithmetic). Its population needs 100 units and the need grows 3 percent a year (geometric). In about which year does need first exceed supply? What does this show, and what does it leave out?
12. CHALLENGE Write a paragraph judging Malthus: in what ways was he right, and in what ways was he wrong? Use at least two pieces of evidence.

COMMON MISTAKES

- Saying Malthus predicted the world would starve by a certain date. He made no such date prediction; he argued that checks would always hold population to the food supply.
- Treating every famine as proof of overpopulation. Many famines, especially in the twentieth century, were caused chiefly by war or by government policy.
- Mixing up the two series: geometric growth multiplies (1, 2, 4, 8), arithmetic growth adds (1, 2, 3, 4).

> **Make it a game · Malthus or Boserup?.** One player reads a short headline, real or invented, such as "New rice variety doubles yields," "Blight destroys the potato crop," or

"Farmers terrace hillsides as villages grow." The other must say whether it supports Malthus, Boserup or Sen, and explain why in one sentence. One point for a good reason, not just the right name. Take turns and play to ten.

Scripture. "While the earth remaineth, seedtime and harvest, and cold and heat, and summer and winter, and day and night shall not cease." (Genesis 8:22, KJV)

God gave this promise to Noah after the Flood. It does not promise that every harvest will be large or that no land will suffer famine, but it assures us that the earth was made to bear fruit, and that diligent, wise work on it is not in vain.

Practice answers

1. Population (geometric): 1, 2, 4, 8, 16, 32. Food (arithmetic): 1, 2, 3, 4, 5, 6.
2. (a) positive, (b) preventive, (c) positive, (d) positive.
3. Loss: $8.2 - 6.5 = 1.7$ million. Decline: $1.7 \div 8.2 \approx 0.207$, about 21 percent.
4. Factor: $32.5 \div 9 \approx 3.6$. Rate: $\ln(3.6) \div 100 \approx 1.28 \div 100 \approx 1.3$ percent per year (doubling about every 54 years).
5. Boserup argued that rising population is not just limited by food supply but pushes farmers to raise output from the same land. As numbers grow, people shorten fallow periods and invest more labor and better methods. Examples: terracing hillsides, irrigation, multiple cropping each year, manuring and new tools.
6. It made ammonia, and so nitrogen fertilizer, from the nitrogen in the air (Haber 1909; Bosch's factory 1913). Nitrogen was often the nutrient that limited crop growth, so synthetic fertilizer raised yields enormously, a major reason food supply outran Malthus's arithmetic ratio.
7. Per person: about $1.2\% - 2.0\% = -0.8\%$ per year. Over 25 years: $0.992^{25} \approx 0.82$, a fall of about 18 percent, unless trade, new methods or slower growth change the picture.
8. $6{,}000 \div 0.2 = 30{,}000$ people. With irrigation: $9{,}000 \div 0.2 = 45{,}000$ people. It could trade other goods (wool, timber, manufactured goods, services) for grain grown elsewhere, as Britain did in the 1800s.
9. He predicted that hundreds of millions would starve to death in the 1970s. Instead, Green Revolution wheat and rice varieties, fertilizer and irrigation raised harvests sharply, especially in India and Pakistan, and those mass famines did not occur. (Hunger remained in some places, chiefly where war or bad policy struck.)
10. Sen argued that famines usually come from people losing the ability to obtain food (through lost wages, high prices, war or policy) rather than from too little food existing. Example: the famine in China during the Great Leap Forward (1959–1961), when government policy collectivized farms, set false grain quotas and took grain from starving villages, causing tens of millions of deaths; or the Soviet famine of 1932–1933, caused by forced collectivization and grain seizures. Sen's own chief case, the Bengal famine of 1943 (about 2 to 3 million deaths), is also a good answer: food supply was not far below normal, but wartime inflation and government policy left laborers unable to buy food.
11. Need $= 100 \times 1.03^{t}$; supply $= 150 + 10t$. At $t = 73$: 865 vs 880. At $t = 74$: $1.03^{74} \approx 8.91$, so need ≈ 891 vs supply 890. Need first exceeds supply in year 74. It shows that steady geometric growth always overtakes steady arithmetic growth in the end. It leaves out the possibility that the supply line itself grows geometrically through invention and trade, and that population growth slows as the demographic transition proceeds.

12. A strong answer credits Malthus for describing the pre-industrial world accurately (stage 1 populations really were held down by famine and disease, and Ireland in the 1840s showed the danger of dependence on a single crop) and for asking a lasting question about limits. It shows he was wrong in his forecast: food output grew far faster than arithmetic (England fed nearly four times as many people in 1901 as in 1801, U.S. corn yields rose about sevenfold, Haber–Bosch fertilizer), and birth rates fell on their own as countries passed through the demographic transition. It may note neo-Malthusian concerns about local soils and water as fair questions.

2.4 Population Pyramids: Reading the Shape of a Nation

OBJECTIVES

- Read a population pyramid by age and sex, identify expansive, stationary and constrictive shapes, and link each to a stage of the demographic transition.
- Calculate the dependency ratio, youth and old-age dependency, sex ratio and the share of the population in an age group, and project a cohort forward in time.
- Explain how real events (the American baby boom, China's one-child policy, labor migration to the Gulf states) leave lasting marks on a nation's pyramid.

Warm-up. List everyone in your extended family (grandparents, parents, aunts, uncles, cousins, brothers and sisters) with their ages, or as close as you know. Sort them into ten-year groups (0–9, 10–19, 20–29 …) and make two tally columns, males on the left and females on the right. Draw a bar for each group. Is your family's shape wide at the bottom, straight-sided or narrow at the base?

Watch. *How to Read a Population Pyramid* (Mr Gedge's Geography Channel, 6:33).
https://www.youtube.com/watch?v=Cx7KFyasW6A
Before the project: watch how the teacher reads the bars for each age group, men on one side and women on the other, and how a young, aging or aged nation each gives the pyramid a different shape.
Note: Captions were not available to check; preview it first. It ties the pyramid shapes to the Demographic Transition Model, a term the lesson may not use.

KEY TERMS

population pyramid
A pair of back-to-back bar graphs showing the number or percentage of males and females in each age group, usually five-year bands, with the youngest at the bottom.

cohort
A group of people born in the same period, such as the five-year band born 1946–1950, who move up the pyramid together as they age.

dependency ratio
The number of people aged 0–14 and 65 and over for every 100 people aged 15–64: (young + old) ÷ working-age × 100.

sex ratio
The number of males for every 100 females in a population or age group. At birth it is naturally about 105.

population momentum

The tendency of a young population to keep growing for decades after fertility falls to replacement level, because so many people are entering the childbearing years.

baby boom

A period of unusually high births, especially in the United States from 1946 through 1964, after the Depression and the Second World War.

CORE IDEAS

The story. In 1946, the first full year of peace after the Second World War, about 3.4 million babies were born in the United States, nearly 20 percent more than in 1945. Soldiers and sailors had come home, couples who had waited through the Depression and the war married, and families moved into new houses in new towns. Births kept rising. They passed 4 million in 1954, peaked at about 4.3 million in 1957, and stayed above 4 million every year through 1964. Then they dropped. Demographers call the children born from 1946 to 1964 the **baby boom**, about 76 million Americans in all. On January 1, 2011, the oldest of them turned 65, and newspapers reported that about ten thousand Americans a day would reach that age for the next two decades. By 2030 every baby boomer will be at least 65. One generation's family decisions after a war have shaped schools, housing, jobs and pensions for eighty years.

How it worked. The tool that makes such a generation visible is the **population pyramid**. It is two bar graphs set back to back: males on the left, females on the right, and age groups stacked from birth at the bottom to old age at the top, usually in five-year bands. Each band is a **cohort**. Each year the whole picture slides upward, and the baby boom travels up the American pyramid like a swallowed meal moving up a snake. Look at a U.S. pyramid and you can still read the past: the thinner bands born in the low-birth years of the 1930s Depression (only about 2.3 million births in 1933), the broad bulge of the boomers, the narrower "baby bust" born in the late 1960s and 1970s, and the "echo" of the boomers' own children born in the 1980s and 1990s.

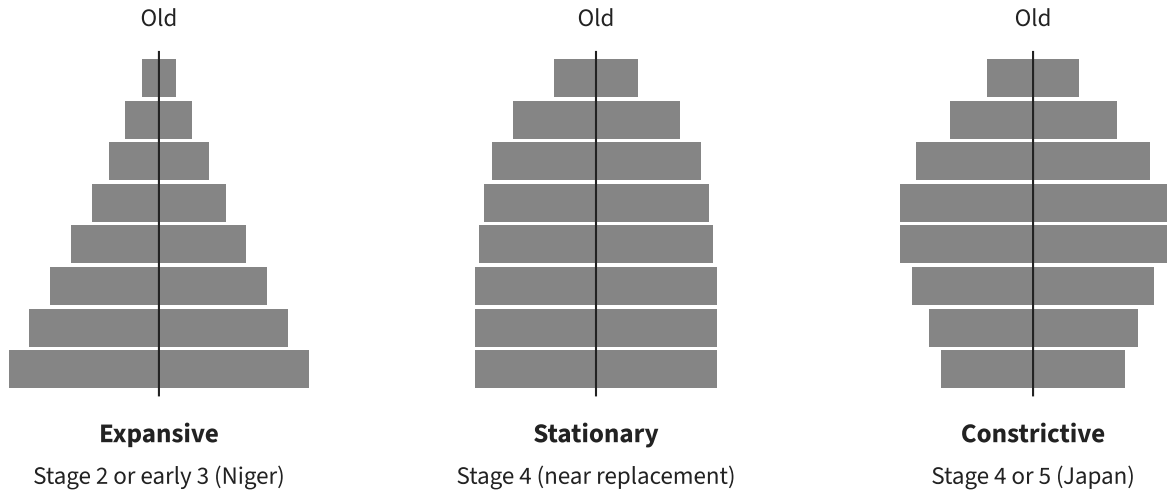
The big idea. Pyramids come in three basic shapes, each matching a stage of the demographic transition (see the shapes figure). An **expansive** pyramid has a broad base that narrows steadily: many children, fewer adults, few elderly. It belongs to stage 2 or early stage 3. Niger, where the median age is only about 15 and roughly half the people are children under 15, is a strong example. A **stationary** pyramid has nearly straight sides until old age: births have been near replacement for a long time, as in stage 4. A **constrictive** pyramid is narrower at the base than in the middle: births have fallen below replacement, the population is aging, and the country may be entering stage 5. Japan is the leading example; its population peaked around 2008 at about 128 million, its median age is near 49, and about 29 percent of its people are 65 or older. The shape is read with a few numbers. The **dependency ratio** compares the young (0–14) and the old (65+) with the working-age population (15–64). The **sex ratio** compares males with females; it is about 105 boys per 100 girls at birth, and it falls in old age because women on average live longer than men.

On the map. Real events carve pyramids in ways the textbook shapes do not predict. In 1980 China's Communist government imposed its **one-child policy**. It was enforced with

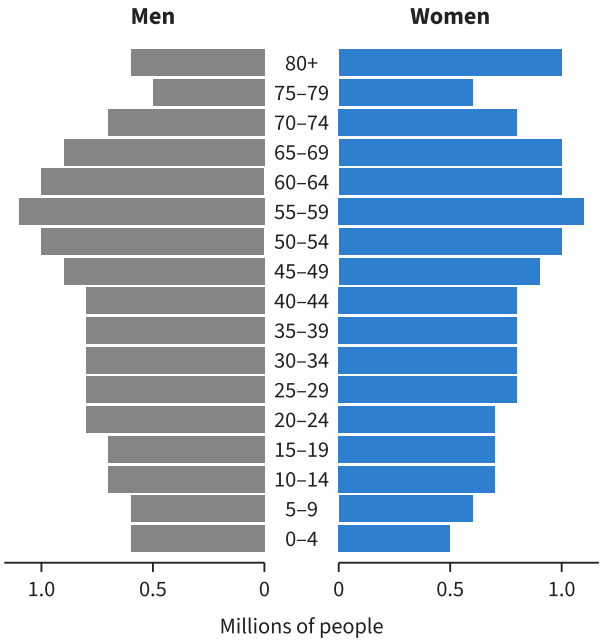
fines, loss of jobs and, in many places, forced abortions and sterilizations, a grave wrong done by the state to its own families. Because many families wanted a son, the sex ratio at birth climbed above 115 boys per 100 girls in the 2000s, leaving tens of millions more young men than young women. The policy was loosened to two children in 2016 and three in 2021, but births kept falling; China's population began to shrink in 2022, and India passed it as the world's most populous country in 2023. A very different mark appears in the Gulf states such as Qatar and the United Arab Emirates, where large numbers of foreign men come to work on construction and in oil fields. Their pyramids bulge hugely on the male side between about 25 and 50, with far more men than women. War leaves marks too: the pyramids of Russia and Germany long showed missing men in the generations who fought the World Wars and missing births during them.

Limits and uses. A pyramid is a snapshot, not a forecast, and its bands mix births, deaths and migration. A narrow base might mean few births or the emigration of young families; a bulge might be a baby boom or an influx of workers. Still, pyramids are the most useful single picture in population geography, because a cohort is predictable. Every child in the 0–4 band who lives will be in the 10–14 band in ten years, needing a school desk, and in the 20–24 band in twenty, looking for a job or a home. Planners use pyramids to decide how many schools, hospitals and nursing homes to build. A young pyramid also carries **population momentum**: even if every family had just two children from now on, the large cohorts already born would keep the population growing for decades as they marry and have children.

Why it matters. "So teach us to number our days," prays Moses in Psalm 90:12, "that we may apply our hearts unto wisdom." A pyramid literally numbers our days, showing each generation's place in the life of a nation. It reminds us that families are the building blocks of every society, that the elderly are to be honored and cared for (Exodus 20:12), and that the children counted in the bottom bar today will carry the nation's work and faith tomorrow.



The three basic shapes. Expansive (stage 2 or early stage 3), stationary (stage 4), constrictive (late stage 4 or stage 5).



Country X (hypothetical), an aging country with a large cohort aged 55–69. Values are in millions.

PICTURE STUDY

The Peale Family, Charles Willson Peale, begun about 1771–1773, finished 1808 · Oil on canvas · New-York Historical Society, New York

Charles Willson Peale (1741–1827) of Maryland and Philadelphia was a painter, soldier in the War for Independence, naturalist and founder of one of America’s first museums. He painted his own large household gathered around a table, several generations together, and kept working on the picture for decades, finishing it in 1808.

Peale was proud of his family and named many of his children after great painters and scientists. His painting is a kind of living population pyramid of one household in the early republic, when American families were large and the young far outnumbered the old.

Look closely

- Count the people in the painting and sort them roughly into children, adults and older people. What shape would their pyramid have?
- Find the painter himself. What is he holding, and what is he doing?
- Look at how the figures touch and lean toward each other. What does Peale want you to feel about family?
- Find the dog. Why might a painter include a family pet?

Talk about it

1. The United States in Peale's day had a very expansive pyramid. What would a portrait of a typical American family look like today?
2. How does a family's shape at home connect to the shape of the nation's pyramid?
3. What responsibilities do the generations in a family have toward each other?

PROJECT: THE PYRAMID OF MY COUNTY

You will draw a real population pyramid of your own county from census data, by hand, at a scale you choose, then read its history and forecast its needs. You can also build it in three dimensions with interlocking bricks.

You will need

- Census age and sex data for your county (data.census.gov, table S0101 "Age and Sex," or your state data center)
- Large graph paper (four squares per inch or finer), ruler, pencil and two colored pencils
- Calculator
- Optional: interlocking toy bricks in two colors and a baseplate

Steps

1. Copy the number of males and females in each five-year age group into a table, from 0–4 to 85 and over.
2. Convert each number to a percentage of the county's total population, so your pyramid can be compared with others.
3. Choose a scale (for example, one square = 0.5 percent). Draw a central age column and bars to the left for males and to the right for females. Label every age band.
4. Title the pyramid, give the source and year, and draw horizontal dashed lines at ages 15 and 65.
5. Calculate the dependency ratio, the youth and old-age ratios, the sex ratio for all ages and for 80 and over.

6. Find and label: the baby boom cohort, any narrow bands, and any bulge you think comes from migration (a college, a military base, a retirement community).
7. Optional: build the pyramid with bricks, one brick for each percentage point, males in one color and females in another.
8. Write a planning memo to your county commissioners: what will the county need in ten years for schools, jobs, housing and care for the elderly, based on your pyramid?

Tips

- Use the same scale on both sides; a pyramid with uneven sides misleads the eye.
- College towns show a sharp bulge at ages 18–24, and retirement areas a wide top. That is migration, not births.

Check your work

- My bars are drawn to scale and labeled, with title and source.
- My dependency and sex ratios are calculated correctly.
- My memo makes at least three predictions tied to specific cohorts.

MAP NOTEBOOK

1. Draw the three basic pyramid shapes and write beside each one its stage of the demographic transition and one real example country.
2. Sketch the U.S. pyramid from memory and mark the 1930s Depression notch, the baby boom and the echo boom with arrows and birth years.
3. Draw a timeline from 1946 to 2046 and mark where the oldest and youngest baby boomers will be on the pyramid in 1966, 1986, 2006, 2026 and 2046.

> **From history.** On January 31, 1940, Ida May Fuller, a retired legal secretary from Ludlow, Vermont, received the first monthly Social Security retirement check, for $22.54. When the program was young, the U.S. pyramid was still broad at the base, and in 1950 there were about 16 workers paying in for every person drawing benefits. As the baby boom moved up the pyramid and birth rates fell, that number dropped to under 3 by the 2020s. Few government programs show more clearly why the shape of a nation’s pyramid matters.

WORKED EXAMPLES

Example 1. Use the Country X pyramid. Its totals are: ages 0–14, 3.7 million; ages 15–64, 17.3 million; ages 65 and over, 6.1 million. Find the total population, the dependency ratio, and the youth and old-age dependency ratios.

(Use the map or drawing "Country X, values in millions." shown earlier in this lesson.)

1. Total: 3.7 + 17.3 + 6.1 = 27.1 million.
2. Dependency ratio = (3.7 + 6.1) ÷ 17.3 × 100 = 9.8 ÷ 17.3 × 100 ≈ 56.6.
3. Youth dependency = 3.7 ÷ 17.3 × 100 ≈ 21.4. Old-age dependency = 6.1 ÷ 17.3 × 100 ≈ 35.3.
4. Interpret: there are about 57 dependents for every 100 people of working age, and more of them are old than young.

Answer: Total 27.1 million; dependency ratio about 57; youth about 21, old-age about 35. Country X's burden of dependency is mainly an aging one, typical of a constrictive pyramid.

Example 2. In Country X, what percentage of the population is 65 or older? Find the sex ratio for the 80-and-over band (0.6 million men, 1.0 million women) and for the whole population (13.3 million men, 13.8 million women).

1. Share 65+: 6.1 ÷ 27.1 ≈ 0.225, or about 22.5 percent.
2. Sex ratio 80+: 0.6 ÷ 1.0 × 100 = 60 men per 100 women.
3. Sex ratio overall: 13.3 ÷ 13.8 × 100 ≈ 96.4 men per 100 women.

Answer: About 22.5 percent are 65 or older. Sex ratio 60 at ages 80+ and about 96 overall. Women outnumber men in old age because they live longer on average.

Example 3. In Country X, 2.2 million people (1.1 million men, 1.1 million women) are aged 55–59. Today the 65–69 band holds 1.9 million. If about 8 percent of the 55–59 cohort dies over the next ten years and there is no migration, how large will the 65–69 band be in ten years? What does this mean for the country?

1. In ten years the 55–59 cohort will be aged 65–69.
2. Survivors: 2.2 × (1 − 0.08) = 2.2 × 0.92 ≈ 2.02 million.
3. Compare: 2.02 − 1.9 = 0.12 million more than today's 65–69 band.

Answer: About 2.0 million, roughly 120,000 more people entering the 65–69 band than are in it now. The old-age group will keep growing for at least another decade, so Country X must plan for more pensions, health care and elder care, with a working-age population that is not growing.

PRACTICE

1. EASY Look at the three shapes in the figure. Which shape matches each country: (a) Niger, (b) Japan, (c) a country whose births have been near replacement level for fifty years?
   (Use the map or drawing "Expansive, stationary and constrictive pyramids." shown earlier in this lesson.)
2. EASY A country has 30 million people aged 0–14, 60 million aged 15–64 and 10 million aged 65 and over. Find its dependency ratio.
3. MEDIUM For the country in problem 2, find the youth and old-age dependency ratios. Which shape of pyramid is it likely to have?
4. MEDIUM In Country X the 0–4 band has 0.6 million boys and 0.5 million girls. Find the sex ratio. How does it compare with the natural ratio at birth, and what might explain the difference in a real country?
   (Use the map or drawing "Read the 0–4 band at the bottom." shown earlier in this lesson.)
5. MEDIUM In the Country X pyramid, which age band is widest? If the year is 2026, in what years were its members born, and what might have caused such a large cohort?
6. EASY American baby boomers were born from 1946 through 1964. How old are the oldest and youngest boomers in 2026?
7. HARD About 2.86 million babies were born in the United States in 1945 and about 4.3 million in 1957. Find the percentage increase. How would this show on the U.S. pyramid today?
8. HARD Explain population momentum. Why would a country with an expansive pyramid keep growing for decades even if its fertility rate dropped to 2.1 tomorrow?
9. MEDIUM Describe the pyramid of a Gulf state such as Qatar and explain its cause.
10. HARD A country has 12 million people under 15 out of a total of 26 million. What percentage is under 15? If the 0–4 band holds 4.4 million children, how many school places for ages 5–9 might be needed in five years if about 3 percent die and there is no migration?
11. CHALLENGE Suppose a country has a sex ratio at birth of 118 and 10 million babies are born in a year. How many are boys and how many are girls? About how many more boys than girls is that? What will this mean for that cohort in 25 years?
12. CHALLENGE In a paragraph, compare the pyramids of Niger and Japan and explain the different challenges each country faces.

COMMON MISTAKES

- Reading the bars as years instead of people. The width of a bar shows how many people (or what percentage) are in that age group; age runs up the vertical axis.
- Computing the dependency ratio with total population in the denominator. It is dependents per 100 people aged 15–64.
- Assuming every bulge or notch comes from births. Migration, war, famine and policy all reshape a pyramid.

Make it a game · Guess the Nation. Print or display several real population pyramids from the Census Bureau International Database or PopulationPyramid.net with the country names covered. Players take turns guessing the country, or at least its continent and its stage in the demographic transition, and must point to one feature of the shape that supports the guess. Two points for the right country, one for the right stage with a good reason.

Scripture. “So teach us to number our days, that we may apply our hearts unto wisdom.” (Psalm 90:12, KJV)

This psalm is titled “A Prayer of Moses the man of God.” A population pyramid numbers a whole nation’s days, generation by generation. Wisdom sees in it both the brevity of each life and the duty each generation has to those older and younger.

Practice answers

1. (a) Expansive. (b) Constrictive. (c) Stationary.
2. (30 + 10) ÷ 60 × 100 ≈ 66.7, about 67 dependents per 100 working-age people.
3. Youth: 30 ÷ 60 × 100 = 50. Old-age: 10 ÷ 60 × 100 ≈ 16.7. With dependency dominated by the young, it most likely has an expansive pyramid.
4. 0.6 ÷ 0.5 × 100 = 120 boys per 100 girls, far above the natural ratio of about 105. In a real country such a ratio usually points to sex-selective abortion where families strongly prefer sons, as happened in China under the one-child policy.
5. The 55–59 band (1.1 million men and 1.1 million women). They were born about 1967–1971. A large cohort usually means a period of high births, a baby boom, in those years (or in a real country, immigration of people now in that age group).
6. Oldest: 2026 − 1946 = 80. Youngest: 2026 − 1964 = 62. In 2026 the boomers occupy the bands from 60–64 to 80–84.
7. (4.3 − 2.86) ÷ 2.86 ≈ 1.44 ÷ 2.86 ≈ 0.50, about a 50 percent increase. Today the cohort born in 1957 (aged about 69 in 2026) forms part of a wide bulge in the 60s and 70s of the pyramid compared with the narrower bands born just before 1946.
8. In an expansive pyramid the youngest cohorts are the largest. As they grow up and marry, the number of couples having children will be much larger than today, so even at two children per couple, total births will exceed deaths (which are few, because there are few old people) for decades. Growth stops only when the age structure evens out.
9. It has a huge bulge on the male side, roughly from the mid-20s to about 50, with far more men than women in those ages and comparatively small bands of children and elderly. The cause is migration: large numbers of foreign men come for limited periods to work in construction, oil and services, usually without their families.
10. 12 ÷ 26 ≈ 0.46, about 46 percent under 15 (an expansive pyramid, like Niger’s). In five years: 4.4 × 0.97 ≈ 4.27 million children aged 5–9 will need places.
11. Boys = 10,000,000 × 118 ÷ 218 ≈ 5.41 million; girls = 10,000,000 × 100 ÷ 218 ≈ 4.59 million. About 0.83 million more boys. In 25 years, many of these young men will be unable to find wives in their own country, which can mean lower marriage rates, fewer births, and social strain.
12. Niger’s pyramid is strongly expansive: about half its people are under 15 and the median age is about 15. It must build schools, train teachers and create jobs for very large cohorts

entering adulthood, and it will keep growing through population momentum. Japan’s pyramid is constrictive: few children, a bulge in late middle age and old age, about 29 percent aged 65 or older and a shrinking population since about 2008. It must support many retirees with a shrinking workforce, through pensions, health care, automation, later retirement or immigration, and faces the closing of rural schools and villages. Both challenges come from the shape of the pyramid.

Unit 2 test

Answer each question. Show your work for every calculation, give units (and both metric and U.S. units where asked), and answer explanations in complete sentences. The test is worth 100 points.

1. (5 pts) Define arithmetic, physiological and agricultural density. Which one best measures the pressure of people on the land that feeds them?
2. (8 pts) A country has 60 million people on 500,000 km² of land, of which 12 percent is arable. Find its arithmetic and physiological densities per km² and per square mile (1 sq mi = 2.59 km²).
3. (6 pts) Name the four great clusters of world population. Then give two physical factors that draw people together and two physical features that keep large areas nearly empty.
4. (6 pts) The U.S. center of population moved from Kent County, Maryland (about 76.2° W) in 1790 to near Hartville, Missouri (about 92.4° W) in 2020. Using 87 km (54 miles) per degree of longitude, how far west did it move? What does the movement tell you about the American population?
5. (6 pts) A country of 5,000,000 people has 150,000 births and 50,000 deaths in a year. Find its CBR, CDR, RNI and doubling time.
6. (8 pts) Match each description with a stage of the demographic transition model (1–5): (a) birth rate falling, death rate low, growth still fairly fast; (b) both rates high, growth slow and uneven; (c) deaths exceed births; (d) death rate falling fast while the birth rate stays high; (e) both rates low, growth slow.
7. (8 pts) Explain two limits of the demographic transition model, each with a real example.
8. (6 pts) Why has Sweden become the textbook example of the demographic transition, and why did its population grow so much in the 1800s?
9. (6 pts) State Malthus’s two ratios (1798). Using his assumptions (population doubles every 25 years; food adds one original unit every 25 years), what is the ratio of population to food after 150 years?
10. (8 pts) Compare the views of Malthus and Ester Boserup on the relationship between population and food. Give one piece of historical evidence that supports Boserup and one event often cited for Malthus.
11. (6 pts) What was Amartya Sen’s argument about famine? Name one twentieth-century famine that supports it and its main cause.
12. (8 pts) A country has 18 million people aged 0–14, 50 million aged 15–64 and 7 million aged 65 and over. Find the dependency ratio, the youth and old-age dependency ratios, and the share of the population under 15. Which pyramid shape is most likely?
13. (6 pts) In a pyramid, the 80-and-over band has 0.4 million men and 0.7 million women. Find the sex ratio and explain the result. What is the usual sex ratio at birth?
14. (6 pts) American baby boomers were born from 1946 through 1964. In what age range will they be in 2036? Name two things a planner should expect in that year because of this cohort.

15. (7 pts) Describe how China's one-child policy (1980) changed the shape of China's population pyramid. Name two lasting effects.

UNIT PROJECT: A POPULATION ATLAS OF ONE NATION

Choose one country (not the United States) and make a short illustrated population atlas of it. Include a hand-drawn density map by province or state with a key and source; a graph of its birth and death rates over at least fifty years with the stage of the demographic transition marked; a hand-drawn population pyramid for the most recent year, with dependency and sex ratios calculated; and a two-page essay explaining where the country's people live and why, how its population has changed and what its pyramid predicts for the next twenty years. In the essay, apply the debate between Malthus and his critics to your country's food supply, presenting more than one view fairly.

- **Accuracy**: Data are real, current, cited and correctly mapped and graphed; places are placed and labeled correctly.
- **Calculations**: Densities, rates of natural increase, doubling time, dependency and sex ratios are correctly calculated with work shown.
- **Reasoning**: The essay uses the models as models, explains at least one way the country does not fit them, and weighs Malthus and his critics with evidence.
- **Craft**: Maps and graphs are neat, titled, keyed and to scale; the atlas is organized and easy to read.

Answer key

1. Arithmetic: people per unit of total land area. Physiological: people per unit of arable land. Agricultural: farmers per unit of arable land. Physiological density best measures the pressure of people on farmland.
2. Arithmetic: 60,000,000 ÷ 500,000 = 120 per km², or 120 × 2.59 ≈ 311 per sq mi. Arable land: 0.12 × 500,000 = 60,000 km². Physiological: 60,000,000 ÷ 60,000 = 1,000 per km², or about 2,590 per sq mi.
3. East Asia, South Asia, Europe and Southeast Asia. Drawing factors (any two): fresh water and rivers, fertile lowland soils, coasts and harbors, moderate middle-latitude climates. Empty areas (any two): deserts (Sahara), high mountains (Himalaya), cold polar or subarctic lands (Siberia, northern Canada), dense tropical rainforest (Amazon).
4. 16.2° × 87 ≈ 1,410 km (about 875 miles). It shows that the distribution of Americans shifted steadily westward as settlement spread across the continent, and in recent decades also southward toward the Sun Belt.
5. CBR = 150,000 ÷ 5,000,000 × 1,000 = 30. CDR = 50,000 ÷ 5,000,000 × 1,000 = 10. RNI = (30 − 10) ÷ 10 = 2.0 percent. Doubling time ≈ 70 ÷ 2 = 35 years.
6. (a) Stage 3. (b) Stage 1. (c) Stage 5. (d) Stage 2. (e) Stage 4.
7. Any two well-explained limits, for example: it is based on European history and many countries moved through stage 2 much faster after 1945 because medicine was imported (Kenya grew near 4 percent a year around 1980); birth rates fell for reasons other than industrialization (France in the late 1700s, Bangladesh while still poor); it ignores migration (Swedish emigration; immigration into aging countries); culture and faith keep some wealthy countries' fertility high (Israel near 3); it cannot predict what follows stage 5.

8. From 1749 Sweden kept continuous national records built from the parish registers of the Church of Sweden, the longest such series in the world. In the 1800s its death rate fell (smallpox vaccination, compulsory from 1816; the potato; long peace, Tegnér's "peace, vaccine and potatoes") while the birth rate stayed high until the 1880s, so the population grew from about 1.8 million in 1750 to about 5.1 million in 1900 despite heavy emigration.
9. Population, when unchecked, increases in a geometrical ratio; subsistence increases only in an arithmetical ratio. 150 years = 6 periods: population $2^6 = 64$; food $1 + 6 = 7$. Ratio 64 : 7.
10. Malthus: food supply limits population; when numbers outrun food, positive checks (famine, disease, war) or preventive checks (later marriage) hold them down. Boserup: population pressure drives farmers to intensify (shorter fallows, irrigation, new tools), so growing numbers can raise food output. Evidence for Boserup (any one): England and Wales grew from about 9 to 32.5 million in the 1800s while eating better; U.S. corn yields rose about sevenfold since the 1930s; the Green Revolution; Haber–Bosch fertilizer. Often cited for Malthus: the Irish famine of 1845–1852 (population about 8.2 million in 1841 to 6.5 million in 1851), though critics note exports, land tenure and limited relief.
11. Sen argued that modern famines usually come from people losing the ability to obtain food (through war, policy, lost wages or prices) rather than from a simple shortage of food. Examples: the Soviet famine of 1932–1933 (forced collectivization and grain seizures) or China's Great Leap Forward famine of 1959–1961 (collectivization, false quotas and grain requisitions); both were caused chiefly by Communist government policy. Sen's own chief case, the Bengal famine of 1943 (about 2 to 3 million deaths), is also acceptable: food supply was not far below normal, but wartime inflation and government policy left laborers unable to buy food.
12. Dependency: $(18 + 7) \div 50 \times 100 = 50$. Youth: $18 \div 50 \times 100 = 36$. Old-age: $7 \div 50 \times 100 = 14$. Total 75 million; under 15: $18 \div 75 = 24$ percent. With dependency mainly young but not extreme, the pyramid is mildly expansive, a country in stage 3.
13. $0.4 \div 0.7 \times 100 \approx 57$ men per 100 women. Women on average live longer than men, so women outnumber men more and more in old age. At birth the ratio is naturally about 105 boys per 100 girls.
14. $2036 - 1964 = 72$ and $2036 - 1946 = 90$, so ages 72 to 90. Expect (any two): high demand for health care, nursing homes and in-home care; large Social Security and Medicare costs paid by a smaller working-age group per retiree; more housing sold by older owners; many deaths, so an old-age band that begins to shrink.
15. The policy, enforced with fines, job loss and in many places forced abortions and sterilizations, narrowed the base of the pyramid sharply, giving it a constrictive shape, and because many families wanted sons the sex ratio at birth rose above 115 boys per 100 girls in the 2000s. Lasting effects (any two): many more young men than women, so many men cannot marry; a rapidly aging population with fewer workers to support retirees; low births even after the policy was loosened in 2016 and 2021; a shrinking population from 2022, with India passing China as the most populous country in 2023.

UNIT 3

Migration

From the first chapters of Genesis, people have been on the move. God “hath made of one blood all nations of men for to dwell on all the face of the earth” (Acts 17:26), and the way people spread across that face is one of the great subjects of human geography. In this unit you will study **migration**: why people leave one place for another, where they go, how far, and what happens to the places they leave and the places they reach.

You will begin in London in 1885, where Ernst Georg Ravenstein used the British census to show that migration follows patterns, and you will test his “laws” against your own family’s moves. You will cross the Atlantic in steerage and climb the staircase at Ellis Island, face plainly the forced migration of the slave trade, follow the westward movement and the Great Migration with the Census Bureau’s moving center of population, and watch the countryside empty into the cities. Finally you will study the laws by which nations decide who may enter, and learn to state several views on immigration fairly before forming your own.

Along the way you will use the tools of the field: the net migration rate, the demographic balancing equation, the gravity model and distance decay, growth rates and doubling times. As always, models are models: useful summaries of evidence, to be tested against real people and real places.

BEFORE YOU BEGIN

- Can compute percents, rates per 1,000 and percent change (Unit 2)
- Knows the demographic transition model and can read a population pyramid (Unit 2)
- Can use a map scale and read latitude and longitude (Unit 1)
- Knows the basic outline of U.S. history from colonial times to World War II

MASTERY CHECKLIST

- I can classify causes of migration as push or pull and as economic, political, cultural or environmental, and tell voluntary from forced migration.
- I can state Ravenstein’s laws, explain the evidence behind them and judge which still hold.
- I can compute a net migration rate, use the demographic balancing equation and apply the gravity model.
- I can describe the great Atlantic migrations, including the slave trade and the Ellis Island era, with correct dates and numbers.
- I can trace America’s internal migrations with the mean center of population and explain urbanization.
- I can explain the turning points of U.S. immigration law and present the main views on immigration policy fairly.

OPTIONAL BOOKS AND RESOURCES

- **Statue of Liberty National Monument and Ellis Island (National Park Service)** (https://www.nps.gov/elis/index.htm): Free. History of the immigration station, photographs and planning for a visit to the Ellis Island National Museum of Immigration (Lesson 3.2).
- **Immigration: classroom materials from the Library of Congress** (https://www.loc.gov/classroom-materials/immigration/): Free. Primary sources, photographs and cartoons on immigration to the United States, including materials useful for Lessons 3.2 and 3.4.
- **Centers of Population (U.S. Census Bureau)** (https://www.census.gov/geographies/reference-files/time-series/geo/centers-population.html): Free. Official locations of the mean center of population for every census since 1790, for the balancing project in Lesson 3.3.

3.1 Why People Move: Push, Pull and Ravenstein's Laws

OBJECTIVES

- Classify the causes of migration as push or pull factors and as economic, political, cultural or environmental, and distinguish voluntary from forced migration.
- State Ravenstein's laws of migration (1885, 1889), explain the evidence he built them on, and judge which still hold today.
- Use the net migration rate, the demographic balancing equation and the gravity model to make and check simple migration calculations.

Warm-up. Write down every place you have lived, or every place one of your parents has lived, in order. Beside each move write one reason for leaving and one reason for choosing the new place. Then estimate how far each move was. Were most of the moves long or short? Keep your list; you will test a 140-year-old law against it today.

Video. Coming soon. Ravenstein's laws of migration, push and pull factors, and the gravity model: search Library of Congress, The History Guy and Hillsdale Studios; candidates needing vetting: individual AP Human Geography teacher review channels (check each for ideological framing).

KEY TERMS

migration
A permanent or long-term change of residence from one place to another. International migration crosses a national border; internal migration stays within one country.

push factor
A condition at the place of origin that drives people away, such as famine, war, persecution or lack of work.

pull factor
A condition at a destination that attracts people, such as jobs, cheap land, freedom of worship or family already there.

intervening obstacle
A barrier between origin and destination that makes a move harder: distance, cost, mountains, seas, borders or laws (Everett Lee, 1966).

step migration
Migration made in stages, for example from farm to market town, then from town to a great city.

net migration rate
Immigrants minus emigrants in a year, per 1,000 people in the population.

CORE IDEAS

The story. In March 1885 a German-born mapmaker named Ernst Georg Ravenstein stood before the Statistical Society of London to read a long paper with a bold title: “The Laws of Migration.” Ravenstein had come to England from Frankfurt as a young man in 1852 and spent about twenty years in the topographical department of the War Office, drawing maps. The great medical statistician William Farr had once remarked that migration seemed to go on without any definite law. Ravenstein thought otherwise. The British census of 1881 had asked every person where he or she was born, and printed the answers county by county. Ravenstein set to work comparing birthplace with present residence for every county of England, Wales, Scotland and Ireland. If people moved at random, the tables would show no pattern. They showed a very strong one.

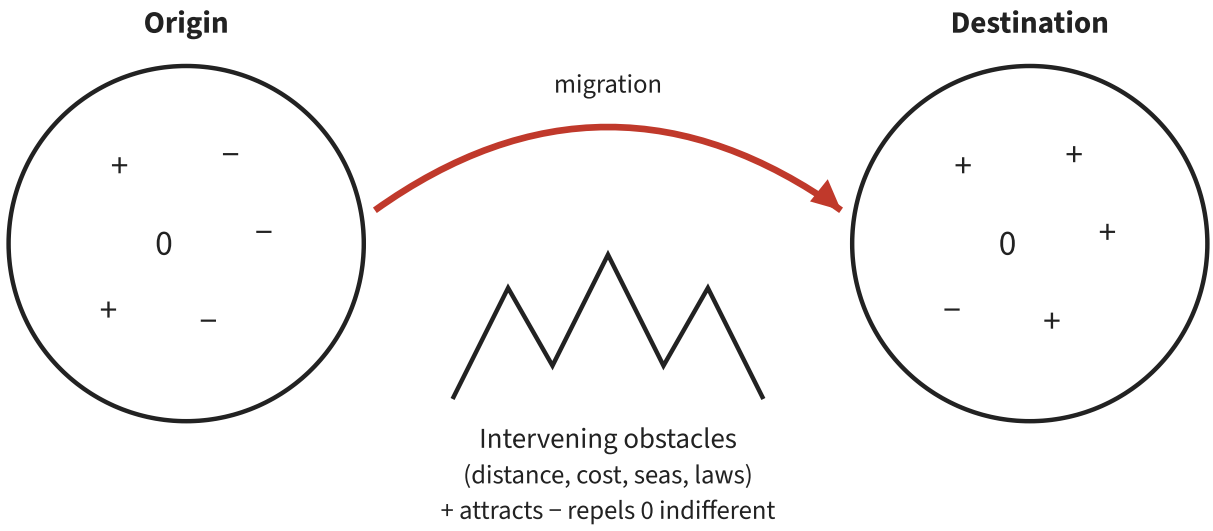
How he figured it out. Ravenstein noticed first that the number of people born in one county and living in another fell off steeply with distance. A growing town such as Manchester drew most of its newcomers from the counties around it, fewer from farther away, and only a trickle from the far end of the kingdom. He also saw that the counties just around a great city lost people to the city and were then filled in by people from counties farther out, as if a wave were moving inward. He published his findings in 1885 and added data from other countries in a second paper in 1889. Textbooks usually sum up his conclusions as a list of “laws.” *Most migrants move only a short distance. Migration proceeds step by step. Migrants who travel long distances generally go to great centers of commerce or industry. Each current of migration produces a smaller countercurrent. People born in towns move less than people born in the country. Within their own country women were the more frequent movers, while men more often went abroad. Most migrants are adults. Large towns grow more by migration than by natural increase. Migration increases as industry, commerce and transport improve. The main direction is from farming areas to centers of industry and trade. The chief causes are economic.* None of these were laws in the sense of the law of gravity; they were patterns in the evidence, and Ravenstein said so. But they gave geographers something to test.

The big idea. Every migration decision weighs two places against each other. A **push factor** drives people from home; a **pull factor** draws them to a destination. Geographers sort both into four families. *Economic* causes (work, wages, land) are the most common, as Ravenstein saw. *Political* causes include war, persecution and new borders. *Cultural* causes include religion, language and family. *Environmental* causes include drought, floods and good farmland. In 1966 the American demographer Everett Lee drew the idea as a diagram (see the figure): the origin and the destination each have pluses, minuses and neutral features, and between them stand **intervening obstacles** such as distance, cost, seas and laws. Personal factors decide the rest; two brothers on the same farm may weigh the same facts differently. In 1940 Samuel Stouffer added the idea of the **intervening opportunity**: a good job halfway to the big city may stop the migrant before he gets there. We also distinguish **voluntary migration**, where people choose to go, from **forced migration**, where they are driven or carried against their will, as in the Atlantic slave trade or the deportation of whole peoples.

Putting numbers on it. Geographers measure migration with a few simple tools. The **net migration rate** is immigrants minus emigrants per 1,000 people. The **demographic balancing equation** says that population change equals births minus deaths plus net migration, so if we know the census counts and the vital records, we can find migration even when no one counted the migrants. The **gravity model**, popularized by George Zipf in 1946, puts Ravenstein's distance pattern into a formula: the expected interaction between two places is proportional to the product of their populations divided by the distance between them, often squared. Big places attract more migrants; distant places attract fewer. This weakening of interaction with distance is **distance decay**, and it is Ravenstein's first law in modern dress. Like every model, the gravity model ignores things that matter: language, family ties, borders and laws can make a nearby place unreachable and a distant place familiar.

On the map. Migration is a geography of flows. Mapmakers draw it with arrows whose width shows the number of migrants, a style called a flow map. On such a map Ravenstein's patterns jump out: thick short arrows around every city, thin long arrows to the greatest centers, and smaller return arrows pointing back. Wilbur Zelinsky later argued (1971) in his *mobility transition* that the kind of migration changes as a country develops, much as birth and death rates change in the demographic transition model you studied in Unit 2: international and rural-to-urban moves first, then moves between cities. Like that model, it describes many countries well and some poorly.

Technology overcoming geography. Ravenstein wrote that migration grows as transport improves, and the century after him proved it. The steamship, the railroad, the automobile and the airliner all shrank the friction of distance, and the telephone and the cheap letter let migrants stay in touch with home, which made the next migrant's decision easier. Yet his first law has never been repealed. In recent U.S. Census surveys more than half of all people who move in a given year stay within the same county. God "hath made of one blood all nations of men for to dwell on all the face of the earth" (Acts 17:26), and the ways people spread out over that face still follow patterns we can study.



Everett Lee's model (1966): pluses attract, minuses repel, zeros leave people indifferent, and obstacles stand between.

PICTURE STUDY

The Last of England, Ford Madox Brown, 1852–1855 · Oil on panel · Birmingham Museum and Art Gallery, Birmingham, England

In the early 1850s, thousands of British families sailed for Australia, where gold had been found in 1851. Ford Madox Brown, a struggling London painter, was himself poor enough that he thought of emigrating to India. When his friend the sculptor Thomas Woolner sailed for the Australian goldfields in 1852, Brown began this painting. He used himself and his wife Emma as the models and painted much of it outdoors, so that the cold light and the wind-reddened faces would be true.

The painting is a study in push and pull. The couple are not adventurers; they are leaving because they must, and their faces show what it costs. Behind them, on the crowded deck, other emigrants show other feelings about the same journey.

Look closely

- Find the baby. How much of it can you see, and how is the mother protecting it?
- Look past the couple at the white cliffs. Which direction is the ship sailing, and how do you know?
- Find the cabbages hanging along the rail. Why would emigrants carry fresh vegetables on a voyage of several months?
- Look at the other passengers behind the couple. Can you find someone who seems angry and someone who seems cheerful?

Talk about it

1. What push factors might have driven a family like this one to leave England in 1852? What pull factors drew them to Australia?
2. Brown called the painting *The Last of England*. What does the title tell you about how the emigrants expected their journey to end?
3. Which of Ravenstein’s laws does this family break by going so far, and which does it keep?

PROJECT: TESTING RAVENSTEIN: A FAMILY MIGRATION SURVEY

Ravenstein built his laws from census tables of where people were born and where they lived. You will build a small census of your own from your family and friends, map it, and test his first two laws against it.

You will need

- A notebook and pencil
- A printed outline map of the United States (or your country) and a world map
- A ruler and the map’s scale bar, or an online distance tool used with a parent
- Colored pencils
- At least 8 people to interview (parents, grandparents, neighbors, church friends), by phone or in person

Steps

1. Make a survey sheet with columns: Name, Place of birth, Every later place lived (in order), Reason for each move, Push or pull, Economic / political / cultural / environmental.
2. Interview at least 8 people. Ask politely, and let people skip any question. Record every move, including moves within the same town.
3. Plot each person’s birthplace with a dot and each move with an arrow. Use one color per person.

4. Measure the straight-line distance of every move with the scale bar. Sort the moves into bands: under 25 miles (40 km), 25–100 miles (40–160 km), 100–500 miles (160–800 km), over 500 miles (800 km).
5. Make a bar graph of the number of moves in each band. Does the graph fall off with distance, as Ravenstein's first law predicts?
6. Look for step migration (farm to town to city) and for countercurrents (anyone who moved back toward home). Mark them on the map with a star.
7. Tally the reasons. What share of the moves were mainly economic? Compare your result with Ravenstein's last law.
8. Write a one-page report: which of Ravenstein's laws your survey supports, which it does not, and how a sample of 8 people limits what you can conclude.

Tips

- Count every move as one data point, not every person. A grandmother who moved five times gives five moves.
- If someone cannot remember an exact place, the county or nearest town is fine. Geographers work with the best data they can get, just as Ravenstein did.

Check your work

- My map shows every move as an arrow, with a key.
- I measured and graphed the distances in bands.
- I classified each reason as push or pull and by type.
- My report states which laws my data support and admits the limits of a small sample.

MAP NOTEBOOK

1. Copy Lee's model from the figure. In the origin circle write three pluses and minuses for your own town; in the destination circle write three for a city you might move to someday.
2. Draw a simple flow map of your family survey with arrow widths showing how many moves went in each direction.
3. List Ravenstein's laws in your own words in two columns: "Still true today" and "Weakened or changed." Give one example for each.

> **From history.** Ravenstein was honored in his own day. In 1902 the Royal Geographical Society awarded him the first Victoria Medal, given for research in geography. His fame rests now on the migration papers, which are still cited in nearly every human geography textbook more than 140 years after he read them.

WORKED EXAMPLES

Example 1. In one year a country of 10,000,000 people receives 85,000 immigrants and loses 60,000 emigrants. Find the net migration and the net migration rate per 1,000.

1. Net migration = immigrants − emigrants = 85,000 − 60,000 = +25,000.
2. Rate per 1,000 = net migration ÷ population × 1,000 = 25,000 ÷ 10,000,000 × 1,000.
3. 25,000 ÷ 10,000,000 = 0.0025; × 1,000 = 2.5.

Answer: Net migration is +25,000, a net migration rate of +2.5 per 1,000. The country gains people by migration.

Example 2. City A has 2,000,000 people. City B has 6,000,000 people and is 300 km (186 miles) from A. City C has 1,000,000 people and is 100 km (62 miles) from A. Use the gravity model, interaction = $P_1 \times P_2 \div d^2$, to decide whether A should have more migration with B or with C. Then repeat using $P_1 \times P_2 \div d$. What does the comparison teach about models?

1. A and B with d^2: 2,000,000 × 6,000,000 = 12×10^{12}. $d^2 = 300^2 = 90{,}000$. $12 \times 10^{12} \div 90{,}000 \approx 1.33 \times 10^8$.
2. A and C with d^2: 2,000,000 × 1,000,000 = 2×10^{12}. $d^2 = 100^2 = 10{,}000$. $2 \times 10^{12} \div 10{,}000 = 2.0 \times 10^8$.
3. With d^2, C (2.0×10^8) beats B (1.33×10^8), about 1.5 times as much interaction.
4. With d: A–B = $12 \times 10^{12} \div 300 = 4.0 \times 10^{10}$; A–C = $2 \times 10^{12} \div 100 = 2.0 \times 10^{10}$. Now B beats C, twice as much.
5. The answer flips depending on how strongly the model punishes distance. Real flows must be measured to find which exponent fits a given country and era.

Answer: With distance squared, A interacts more with nearby C; with plain distance, A interacts more with large B. A model’s result depends on its assumptions, so models must be tested against data.

Example 3. Two towns of equal size lie 50 km (31 miles) and 150 km (93 miles) from a growing city. (a) By an inverse-square distance decay rule, how many times as many migrants should come from the nearer town? (b) A census finds 600 migrants from the near town and 90 from the far one. Does distance decay in this case operate more or less strongly than inverse-square?

1. The far town is 150 ÷ 50 = 3 times as distant.
2. Inverse-square: interaction ∝ 1 ÷ d^2, so the ratio is $3^2 = 9$. The near town should send 9 times as many.
3. Observed ratio = 600 ÷ 90 ≈ 6.7.
4. 6.7 is less than 9, so the far town sends more migrants than the inverse-square rule predicts. Distance holds people back somewhat less strongly here.

Answer: (a) 9 times as many. (b) The observed ratio is about 6.7, so distance decay is weaker than inverse-square in this case (perhaps a railroad or family ties link the far town to the city).

PRACTICE

1. EASY Define push factor and pull factor and give one historical example of each.
2. EASY What source of data did Ravenstein use for his 1885 paper, and what question in it made his study possible?
3. EASY Classify each as push or pull and as economic, political, cultural or environmental: (a) a drought that ruins the crops; (b) high wages in a steel mill city; (c) a law forbidding a church to meet; (d) relatives who have already settled in a new country.
4. MEDIUM A country of 4,000,000 people has 30,000 immigrants and 42,000 emigrants in one year. Find the net migration rate per 1,000.
5. MEDIUM Town T (100,000 people) is 50 km from City X (500,000 people) and 200 km from City Y (2,000,000 people). Using $P_1 \times P_2 \div d^2$, which city should draw more of T's migrants, and by what factor?
6. MEDIUM In the inverse-square gravity model, what happens to the expected interaction between two places if the distance between them triples and their populations stay the same?
7. MEDIUM Explain the difference between step migration and chain migration, with an example of each.
8. MEDIUM Distinguish an intervening obstacle from an intervening opportunity, and name the scholar associated with each.
9. HARD A survey of 1,000 newcomers to an industrial town finds: 520 came from within 20 miles (32 km), 280 from 20–50 miles (32–80 km), 140 from 50–100 miles (80–160 km), and 60 from over 100 miles (160 km). What percent came from within 50 miles? Which of Ravenstein's laws does this support?
10. HARD Ravenstein said each current of migration produces a countercurrent. Give one historical and one modern example, and suggest why countercurrents exist.

11. HARD A region had 2,000,000 people on January 1. During the year there were 26,000 births and 18,000 deaths. On the next January 1 it had 2,011,000 people. Use the demographic balancing equation to find net migration.
12. CHALLENGE In a paragraph, judge Ravenstein's laws today. Choose one law that still holds well and one that has weakened, and give evidence for each.

COMMON MISTAKES

- Treating Ravenstein's "laws" like laws of physics. They are patterns found in data, true in general but not for every person.
- Confusing a migrant with a traveler or a seasonal worker. Migration is a long-term change of residence; a vacation or a daily commute is not migration.
- Plugging numbers into the gravity model and forgetting to square the distance (or squaring it when the version given uses plain distance). Always check which form the problem uses.

Make it a game · Push or Pull Lightning Round. One player reads a cause of migration from a card (a famine, a gold strike, a new railroad, a war, a letter from a cousin). The other has five seconds to call push or pull and the type: economic, political, cultural or environmental. Two points for both right, one for one. Bonus point for naming a real historical example. Play to 15.

Scripture. "And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;" (Acts 17:26, KJV)

Paul told the philosophers of Athens that God is the author of the spreading of peoples over the earth. Studying why people move is one way of tracing that providence in the patterns of real lives.

Practice answers

1. A push factor drives people away from their origin (example: the Irish potato famine of the 1840s). A pull factor attracts them to a destination (example: the discovery of gold in California in 1848).
2. The British census of 1881, which recorded each person's place of birth alongside his or her place of residence, so he could count how many people born in one county lived in another.
3. (a) Push, environmental (with economic effects). (b) Pull, economic. (c) Push, political (and cultural, since it concerns religion). (d) Pull, cultural (family ties).
4. Net migration = 30,000 − 42,000 = −12,000. Rate = −12,000 ÷ 4,000,000 × 1,000 = −3.0 per 1,000 (a net loss).
5. X: 100,000 × 500,000 ÷ 2,500 = 2×10^7. Y: 100,000 × 2,000,000 ÷ 40,000 = 5×10^6. City X, by a factor of 4.
6. It falls to one-ninth ($1 \div 3^2$) of its former value.
7. Step migration is a move made in stages, such as a farm boy moving to a market town and later to London. Chain migration is migration that follows earlier migrants from the same

family or village, such as a young man in Sicily sailing to New York because his brother had written that there was work.

8. An intervening obstacle (Everett Lee, 1966) is a barrier between origin and destination, such as an ocean, a mountain range, cost or immigration law. An intervening opportunity (Samuel Stouffer, 1940) is an attractive chance found before the planned destination, such as a good job in a town along the way, which stops the migrant short.
9. 520 + 280 = 800 of 1,000 = 80 percent. It supports his first law, that most migrants move only a short distance, and shows distance decay.
10. Historical: many Italian men who came to America around 1900 later returned to Italy with their savings. Modern: retirees who leave the city where they worked and return to their home region. Countercurrents exist because some migrants meant to stay only a while, some are disappointed, and some go home to family, land or familiar culture.
11. Total change = 2,011,000 − 2,000,000 = +11,000. Natural increase = 26,000 − 18,000 = +8,000. Net migration = 11,000 − 8,000 = +3,000.
12. A strong answer might say: the first law still holds, since in recent U.S. Census surveys more than half of people who move in a year stay within the same county. The law that most long-distance migrants go to great centers of commerce has weakened in some places, since cheap air travel and family networks now carry migrants straight to smaller cities and suburbs, and counterurbanization moves some people out of big cities. The answer should give evidence, not opinion only, and note that Ravenstein himself called his laws patterns, not iron rules.

3.2 Great Migrations of History: The Atlantic Crossings and Ellis Island

OBJECTIVES

- Describe the major waves of migration across the Atlantic from the 1600s to 1924, including the forced migration of the Atlantic slave trade, and explain the push and pull factors behind each wave.
- Explain how Ellis Island worked and what its records show about the scale and sources of immigration between 1892 and 1924.
- Calculate crossing speeds, rates of population change and processing rates from historical data, and read an Atlantic route map.

Warm-up. Pack a pretend trunk. You are leaving home for a new country in 1900 and will probably never return. Your trunk holds about as much as a large laundry basket. List the ten things you would take. Then cross out three, because the steamship company has weighed your trunk and it is too heavy. What did you keep, and why?

Watch. *17th April 1907: Ellis Island in New York Harbor has its busiest day, processing 11,747 immigrants* (HistoryPod, 2:36). https://www.youtube.com/watch?v=8BDHBSGfMD4
After the story: watch how arriving immigrants passed through inspection on Ellis Island's busiest day in 1907, fifteen years after Annie Moore became the first to register.
Note: Captions were not available to check; preview it first. It briefly mentions ethnic and religious violence that drove Jews to leave the Russian Empire.

KEY TERMS

steerage
The cheapest accommodation on a passenger ship, below decks, where most emigrants crossed the Atlantic.

Ellis Island
The federal immigration station in New York Harbor, open from 1892 to 1954, through which about 12 million immigrants passed.

forced migration
Movement in which people are compelled to leave or are carried away against their will, as in the Atlantic slave trade.

old and new immigration
Historians' terms for the earlier wave from northern and western Europe (Ireland, Germany, Britain, Scandinavia) and the later wave, after about 1880, from southern and eastern Europe (Italy, Austria-Hungary, the Russian Empire, Greece).

remittance

Money a migrant sends home to family in the country of origin.

ship manifest

The passenger list a steamship company prepared at the port of departure, recording each passenger's name, age, origin, destination and other details for inspectors at the port of arrival.

CORE IDEAS

The story. On the morning of January 1, 1892, the new federal immigration station on Ellis Island in New York Harbor opened its doors. The first passenger registered was a teenage girl named Annie Moore from County Cork, Ireland, who had crossed in steerage on the steamship *Nevada* with her two younger brothers to join their parents in New York. Officials gave her a ten-dollar gold piece to mark the occasion. Behind her came millions. On April 17, 1907, the busiest day in the station's history, inspectors processed 11,747 people, and more than a million immigrants entered the United States that year. By the time Ellis Island closed in 1954, about 12 million people had passed through it.

How it worked. Steamship companies prepared a **manifest** at the port of departure, listing every passenger. First- and second-class passengers were usually inspected on board. Steerage passengers were ferried to the island, where they climbed a staircase to the great Registry Room while doctors watched from the top for anyone who was short of breath or limping. Doctors marked suspected illnesses in chalk on a coat: E for the eyes (watching for trachoma, a contagious eye disease), L for lameness, H for the heart. Inspectors then asked the questions on the manifest: name, age, occupation, destination, whether the person had money and someone to meet him. For most immigrants the whole process took a few hours. Only about 2 percent were refused entry, usually for contagious disease or because officials judged them likely to become dependent on public charity. For those few, the island was called the Island of Tears.

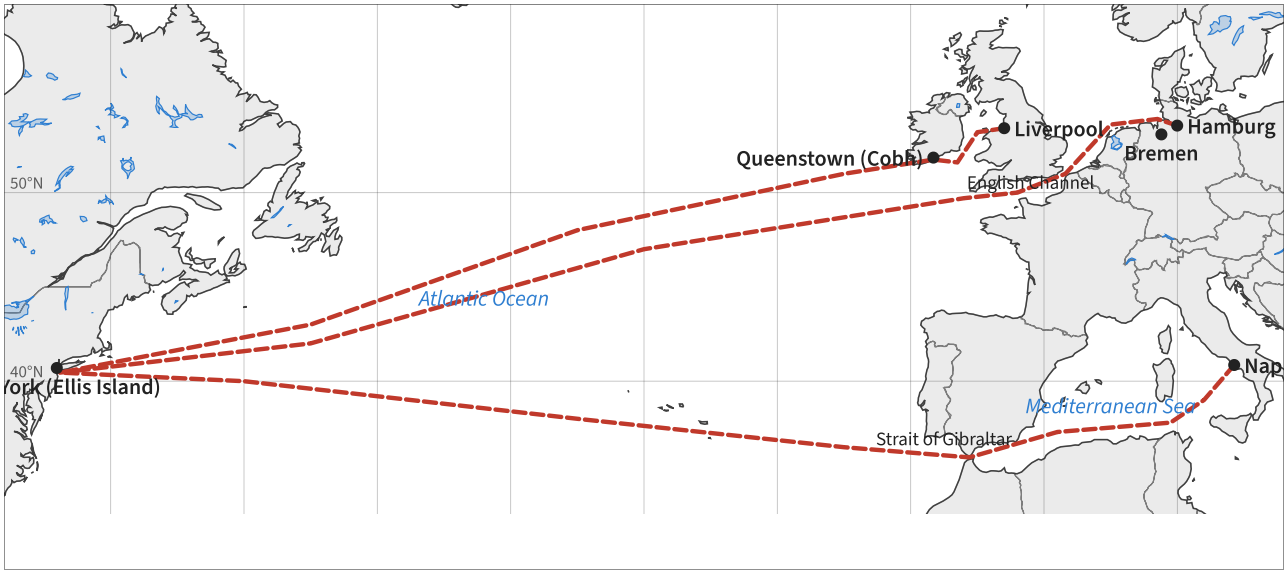
The big idea. Ellis Island stood at the peak of a long series of Atlantic migrations. The first English settlers came in the 1600s; about 20,000 Puritans sailed to New England in the "Great Migration" of the 1630s, pushed by religious conflict at home and pulled by the hope of a godly commonwealth. Alongside the free settlers came indentured servants who worked several years to repay their passage. Far larger, and of a different kind, was the **forced migration** of the Atlantic slave trade. Between the 1500s and the 1860s about 12.5 million Africans were carried onto slave ships, and about 10.7 million survived the Middle Passage to the Americas. Most went to Brazil and the Caribbean sugar colonies; about 400,000 were landed in mainland North America. It was a great and deliberate wrong, and its effects on the population map of the Americas are still plain. In the nineteenth century the free migration swelled. Ireland's potato famine (1845–1852) killed about a million people and sent more than a million abroad; the census counted about 8.2 million people in Ireland in 1841 and only about 6.6 million in 1851. Germans fleeing poor harvests and the failed revolutions of 1848 became the largest group of all. After about 1880 came the "new immigration": Italians from the poor villages of the south, Jews escaping the pogroms and

restrictions of the Russian Empire after 1881, Poles, Slovaks, Hungarians and Greeks. Between 1820 and 1920 more than 30 million immigrants came to the United States.

Technology overcoming geography. The ocean itself was the great intervening obstacle, and the steamship cut it down. A sailing ship from Liverpool to New York, a voyage of about 5,600 km (3,500 miles) by the usual route, took about six weeks westbound against the prevailing winds, and steerage passengers cooked their own food in cramped holds where disease spread easily. By the 1870s most emigrants crossed by steam, and by 1900 the largest liners made the trip in about a week. Cheaper, faster and safer crossings made migration possible for millions who could never have left before, and made return journeys possible too. Railroads carried emigrants to the ports (Hamburg, Bremen, Liverpool, Naples) and inland from New York to Chicago, Pittsburgh and Minnesota. The telegraph and the international postal system kept families in touch, and letters home describing work and wages pulled the next relatives across. This is **chain migration** on a continental scale.

On the map. Follow the routes on the map. Irish emigrants sailed from Queenstown (now Cobh); English, Scottish and many Scandinavian emigrants from Liverpool; Germans and eastern Europeans from Hamburg and Bremen; Italians from Naples and Palermo. All converged on New York, though millions also landed at Boston, Philadelphia, Baltimore, New Orleans and Galveston, and others sailed for Canada, Argentina, Brazil and Australia. Inland, the new arrivals clustered: Germans in the Midwest from Cincinnati to Milwaukee, Scandinavians in Minnesota and the Dakotas, Irish and Italians in the cities of the Northeast. Ravenstein’s countercurrent appears too. A large share of Italian men, by some estimates a third or more, eventually went home with their savings, and remittances sent back from America built houses in many Italian villages.

Judging fairly. These migrants faced hardship we should not soften: dangerous work, crowded tenements, and suspicion from earlier arrivals. They also built churches, parishes and schools, dug subways and canals, staffed the mills and mines, and raised children who served and led the nation. In 1883 the poet Emma Lazarus wrote “The New Colossus,” and in 1903 its lines were placed inside the pedestal of the Statue of Liberty: “Give me your tired, your poor, / Your huddled masses yearning to breathe free.” Many who passed the statue on their way to Ellis Island remembered the sight all their lives.



Main emigrant routes to New York around 1900. Routes are simplified.

PICTURE STUDY

The Steerage, Alfred Stieglitz, 1907 (photograph); published as a photogravure in 1911 · Photogravure · J. Paul Getty Museum, Los Angeles; Metropolitan Museum of Art, New York; and other collections

In June 1907 the American photographer Alfred Stieglitz sailed from New York to Europe on the large German liner *Kaiser Wilhelm II*. Walking the first-class deck, he looked down at the crowded steerage below, ran for his camera, and found he had one plate left. He later called it one of his finest pictures, and it became one of the most famous photographs of the twentieth century.

Notice which way the ship was sailing. These steerage passengers were leaving America, not arriving. Some were returning migrants going home for good, and others may have been

refused work or entry. The picture is a perfect illustration of Ravenstein's countercurrent.

Look closely

- Find the gangway that cuts across the picture. What does it separate?
- Compare the lower deck with the upper deck. What differences in clothing do you see?
- Find the laundry and the bare metal of the ship. What do they tell you about life in steerage?
- Find the round shapes and straight lines that Stieglitz said first caught his eye. How do they organize the crowd?

Talk about it

1. Why might thousands of immigrants each year sail back to Europe from America? List three possible reasons.
2. If you saw this photograph without knowing its story, would you guess the ship was arriving or leaving? What does that teach about reading historical photographs?

PROJECT: THE CROSSING: A STRING-AND-GLOBE VOYAGE AND A PASSENGER'S PAPERS

You will measure the Atlantic crossing on a globe with a piece of string, compare sailing and steam voyages, and then build the papers of a real or realistic immigrant of 1907, from manifest line to Ellis Island inspection card.

You will need

- A globe (a large one if possible) and a piece of thin string about 1 m long
- A ruler or tape measure and a marker
- Card stock or heavy paper, a pencil and colored pencils
- Optional, with a parent: free access to the passenger records of the Statue of Liberty–Ellis Island Foundation to find a real manifest

Steps

1. Find the globe's scale. Lay the string along the equator from 0° to 90° longitude, mark it, and measure the length. That length equals about 10,000 km (6,200 miles).
2. Stretch the string tight on the globe from Liverpool to New York. Mark the length and convert it to km and miles with your scale. Then measure Naples to New York and Hamburg to New York the same way.
3. Notice that a tight string on a globe curves north of a straight line drawn on a flat map. That is the great-circle route. Write one sentence on why ships could not always follow it (land, ice, storms, ports of call).
4. Make a table of travel time and speed: a sailing ship taking 40 days and a steamship taking 7 days on the 5,600 km route. Calculate km per day and km per hour for each.

5. Create a passenger card for one immigrant of 1907. Use a real ancestor or a well-researched realistic person: name, age, home village, port of departure, ship, occupation, money carried, person meeting him or her, final destination.
6. Make a small inspection card and a ticket stub. On the back, write the questions the inspector asked and how your passenger answered.
7. Trace your passenger's whole journey on an outline map: home village to port by rail, port to New York by sea, New York to final destination by rail. Measure each leg.

Tips

- If you search the Ellis Island records, remember that names were written down at the port of departure in Europe, not invented at Ellis Island. Spellings varied because clerks wrote what they heard.
- On a small globe, keep the string tight and check twice. Small errors in the string become large errors in kilometers.

Check your work

- I measured at least three crossings on the globe and converted them to km and miles.
- I calculated the speed of a sailing and a steam crossing.
- My passenger's papers are complete and historically realistic.
- My map shows every leg of the journey with distances.

MAP NOTEBOOK

1. Draw the floor plan of the Ellis Island process as a flow chart: ship, ferry, baggage room, staircase, medical inspection, Registry Room, legal inspection, money exchange and railroad ticket office, and the ferry to New York or New Jersey.
2. Make a timeline from 1620 to 1924 with five Atlantic migration waves, one push factor for each, and the approximate number of people involved.
3. Copy the route map and add arrows inland showing where Germans, Scandinavians, Irish and Italians mostly settled.

> **From history.** Before Ellis Island, New York's immigrants were received at Castle Garden, a former fort at the southern tip of Manhattan, which served as the state's immigration depot from 1855 to 1890. When the federal government took over immigration in the early 1890s, it chose the small island in the harbor so that arrivals could be inspected away from the city. The original wooden station burned in June 1897, and the brick and limestone building that stands there today opened in December 1900. It is now the Ellis Island National Museum of Immigration.

WORKED EXAMPLES

Example 1. The usual route from Liverpool to New York was about 5,600 km (3,500 miles). A westbound sailing ship took about 40 days; a steamship around 1900 took about 7 days. Find each average speed in km per day and km per hour, and how many times faster the steamship was.

(Use the map or drawing "The Liverpool route ran by way of Queenstown, Ireland." shown earlier in this lesson.)

1. Sailing ship: 5,600 km ÷ 40 days = 140 km per day. 140 ÷ 24 ≈ 5.8 km/h (about 3.6 mph).
2. Steamship: 5,600 km ÷ 7 days = 800 km per day. 800 ÷ 24 ≈ 33 km/h (about 21 mph).
3. Ratio: 800 ÷ 140 ≈ 5.7, or 40 days ÷ 7 days ≈ 5.7.

Answer: Sail: about 140 km/day (5.8 km/h). Steam: about 800 km/day (33 km/h). The steamship was nearly 6 times as fast.

Example 2. The census of Ireland counted 8,175,124 people in 1841 and 6,552,385 in 1851. Find the change and the percent change. Then explain why the decline cannot be blamed on deaths alone.

1. Change = 6,552,385 − 8,175,124 = −1,622,739.
2. Percent change = −1,622,739 ÷ 8,175,124 × 100 ≈ −19.8 percent.
3. Famine deaths were about 1 million. A loss of about 1.6 million, plus the births that would normally have added people over ten years, means that well over a million more people must have left. The balancing equation (change = births − deaths + net migration) shows large negative net migration.

Answer: A fall of about 1.62 million people, or about 19.8 percent (roughly one person in five). The gap between the loss and famine deaths reveals mass emigration.

Example 3. On its busiest day, April 17, 1907, Ellis Island processed 11,747 immigrants. If the inspectors worked a 10-hour day, how many people did they process per hour and per minute? If about 2 percent of arrivals were refused entry, how many of the roughly 12 million people who passed through Ellis Island would that be?

1. Per hour: 11,747 ÷ 10 ≈ 1,175 people.
2. Per minute: 1,175 ÷ 60 ≈ 19.6, about 20 people every minute.
3. Refused: 2 percent of 12,000,000 = 0.02 × 12,000,000 = 240,000.

Answer: About 1,175 people per hour, nearly 20 per minute. At 2 percent, roughly 240,000 people would have been refused over the station's history: a small share, but a great many individual sorrows.

PRACTICE

1. EASY When did Ellis Island open and close, and about how many immigrants passed through it?
2. EASY Who was Annie Moore?
3. EASY Name two push factors behind Irish emigration in the 1840s and two behind Jewish emigration from the Russian Empire after 1881.
4. EASY Distinguish the "old immigration" from the "new immigration" by source region and approximate dates.
5. MEDIUM About 12.5 million Africans were embarked on slave ships and about 10.7 million survived to land in the Americas. About how many died at sea, and what percent is that?
6. MEDIUM Of the roughly 10.7 million enslaved Africans landed in the Americas, about 400,000 came to mainland North America. What percent is that, and where did most of the rest go?
7. MEDIUM A steamship sailing from Naples to New York covers about 7,400 km (4,600 miles) in 12 days. Find its average speed in km per day and km/h.
8. MEDIUM Explain how the steamship changed migration in three ways.
9. MEDIUM Read the route map. Which strait did ships from Naples pass through, and which narrow sea did ships from Hamburg pass through, to reach the Atlantic?
   (Use the map or drawing "Use the map to trace each route." shown earlier in this lesson.)
10. HARD In 1907 about 1,285,000 immigrants entered the United States, whose population was about 87 million. Find immigration per 1,000 people. Compare it with a modern country receiving 1,000,000 immigrants with a population of 335 million.
11. HARD Explain why the Stieglitz photograph *The Steerage* illustrates one of Ravenstein's laws.
12. CHALLENGE Write a paragraph comparing the migration of Irish famine emigrants (1845–1855) with the forced migration of the Atlantic slave trade. Use the terms push factor, voluntary and forced, and be precise about what was similar and what was different.

COMMON MISTAKES

- Believing that officials at Ellis Island changed immigrants' names. Names came from the ship manifests written in Europe; many families later changed their own names in America.
- Treating the Atlantic slave trade as just another migration with push and pull factors. It was forced migration, and push–pull language does not fit it.
- Forgetting the countercurrent. Millions of immigrants went home again, especially in the new immigration after 1880.

Make it a game · Port of Departure. Write the names of ports (Liverpool, Queenstown, Hamburg, Bremen, Naples, Palermo) on cards, and the names of immigrant groups and decades on others (Irish 1850s, Germans 1880s, Italians 1905, Jews from the Russian Empire 1900s, Swedes 1880s). Players race to match each group with its most likely port and the strait or sea the ship would pass. One point per correct match; two if the player can name a push factor for that group.

Scripture. "By faith Abraham, when he was called to go out into a place which he should after receive for an inheritance, obeyed; and he went out, not knowing whither he went." (Hebrews 11:8, KJV)

Many who crossed the Atlantic carried their Bibles and prayed as Abraham did, going out not knowing what they would find. Their churches and parishes were often the first things they built in the new land.

Practice answers

1. It opened on January 1, 1892, and closed in 1954. About 12 million immigrants passed through it.
2. A teenage girl from County Cork, Ireland, who was the first immigrant registered at Ellis Island, on January 1, 1892. She came with her two younger brothers to join their parents.
3. Irish: the potato blight and famine; poverty and evictions from small rented farms. Jewish: pogroms (violent attacks); laws restricting where Jews could live and what work they could do.
4. Old immigration came mainly from northern and western Europe (Ireland, Germany, Britain, Scandinavia), especially before about 1880. New immigration came mainly from southern and eastern Europe (Italy, Austria-Hungary, the Russian Empire, Greece) from about 1880 to 1914.
5. 12.5 − 10.7 = about 1.8 million deaths. 1.8 ÷ 12.5 ≈ 0.144, about 14 percent.
6. 0.4 ÷ 10.7 ≈ 3.7 percent. Most of the rest went to Brazil and the Caribbean, chiefly to sugar plantations.
7. 7,400 ÷ 12 ≈ 617 km per day; 617 ÷ 24 ≈ 26 km/h (about 16 mph).
8. It shortened the crossing from about six weeks to about a week or two; it made the voyage cheaper and safer, with less disease, so poorer people could go; and it made return trips practical, so seasonal and temporary migration and countercurrents became common.

9. From Naples, the Strait of Gibraltar. From Hamburg, the Strait of Dover and the English Channel (though some ships went north around Scotland).
10. 1907: 1,285,000 ÷ 87,000,000 × 1,000 ≈ 14.8 per 1,000. Modern example: 1,000,000 ÷ 335,000,000 × 1,000 ≈ 3.0 per 1,000. Relative to population, the 1907 inflow was about five times as large.
11. The photograph shows steerage passengers on a liner sailing from New York to Europe. They were returning migrants, a countercurrent to the great westward flow. Ravenstein's fourth law says that every current of migration produces a countercurrent.
12. A strong answer notes that both involved crossing the Atlantic in dangerous, crowded ships with high death rates, and that both reshaped the population of the Americas. But the Irish were pushed by famine and poverty and chose, however desperately, to leave; they arrived free, could send for family, write home and move on. Enslaved Africans did not choose to go; they were captured, sold and carried in chains, and arrived as property, separated from family and denied freedom. One was voluntary migration under severe push factors; the other was forced migration and a grave moral wrong.

3.3 Internal Migration: Westward Movement and the Move to Cities

OBJECTIVES

- Trace the main internal migrations of American history (the westward movement, Indian removal, the Great Migration, the Dust Bowl exodus, suburbanization and the Sun Belt shift) and explain the push and pull factors behind each.
- Explain urbanization as the world's largest migration, and use the mean center of population and urban percentages to measure internal migration.
- Compute annual growth rates and doubling times (rule of 70) and the rate of movement of the mean center of population.

Warm-up. Balance a ruler on your finger. Now tape three coins near one end and one coin near the other. Where is the new balance point? Move the coins around and watch the balance point travel. Keep this in mind: the U.S. Census Bureau finds the "center of population" of the whole country in exactly this way, as if every person weighed the same on a flat map.

Watch. *Oregon Trails: History of American Westward Explained on Maps* (History on Maps, 9:10). https://www.youtube.com/watch?v=Yh2fHoTN80Y
After the story: watch the animated maps trace the Oregon Trail from Independence, Missouri, to Oregon City, and notice how many families moved west to get land of their own, the frontier Turner wrote about.
Note: Captions were not available to check; preview it first. The video covers only the Oregon Trail. It does not cover the Homestead Act, Turner's thesis or the move to cities, and the description mentions conflict with Native Americans along the trail. Covers only the mid-1800s Oregon Trail, not Turner's 1893 frontier thesis or the later move to cities.

KEY TERMS

internal migration
Permanent movement within one country. Interregional migration moves between major regions; intraregional migration moves within a region, as from city to suburb.

urbanization
The growth in the share of a population living in cities and towns, mainly through migration from the countryside.

mean center of population
The point on which a flat map of the country would balance if every person had the same weight. The Census Bureau computes it every ten years.

frontier

In the U.S. census of the 1800s, the line beyond which there were fewer than two settlers per square mile.

counterurbanization
Movement of people out of large cities to small towns and rural areas.

rule of 70
A shortcut for doubling time: a quantity growing at r percent per year doubles in about 70 ÷ r years.

CORE IDEAS

The story. On July 12, 1893, a young historian from the University of Wisconsin named Frederick Jackson Turner read a paper to the American Historical Association, meeting in Chicago during the World's Columbian Exposition. His title was "The Significance of the Frontier in American History." Turner began with a short statement buried in a bulletin of the 1890 census: the superintendent reported that the unsettled West had been so broken up by pockets of settlement that a frontier line could hardly be drawn any more. To Turner this was the end of an era. For three centuries Americans had been moving west, and he argued that the frontier, the meeting point of settlement and wilderness, had shaped the American character: self-reliant, practical, restless and democratic. Historians have argued about his "frontier thesis" ever since, but no one doubts the migration he described. It was one of the largest internal migrations in history.

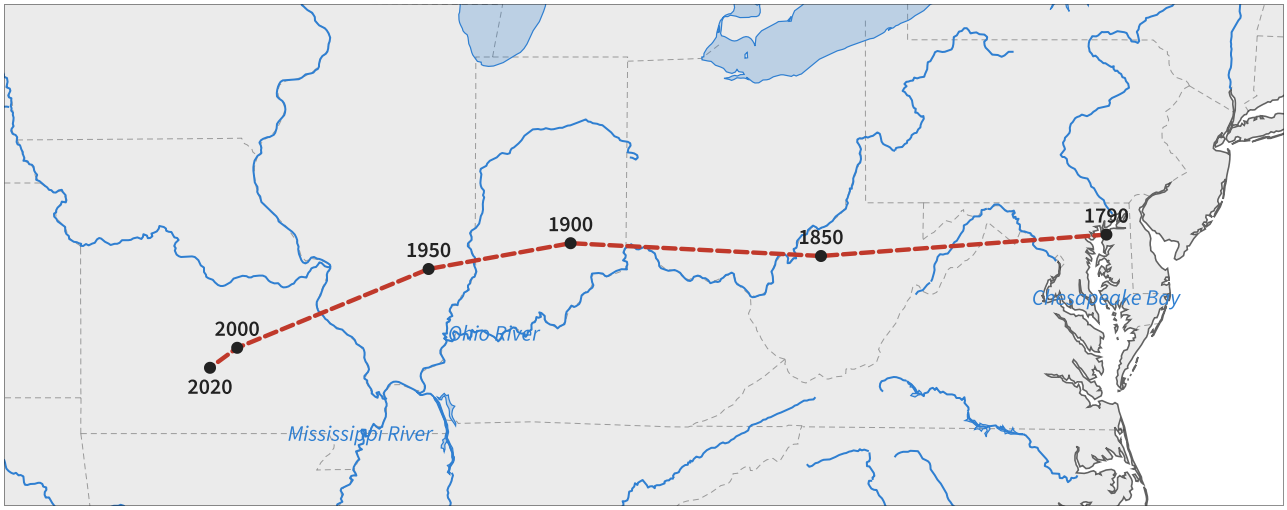
How it worked. Each westward step followed a route and was pulled by land. Settlers crossed the Appalachians through the Cumberland Gap and down the Ohio River after 1790; the Erie Canal (1825) opened the Great Lakes country; wagon trains carried perhaps 300,000 or more people over the Oregon, California and Mormon trails between the 1840s and 1860s; the gold rush of 1849 filled California in a few years. The Homestead Act of 1862 offered 160 acres of public land to a settler who lived on it and farmed it for five years, and the transcontinental railroad (1869) made the trip in about a week. On April 22, 1889, some 50,000 people raced into the Unassigned Lands of Indian Territory in the Oklahoma Land Run. This movement carried a real wrong with it. The Indian Removal Act of 1830 led to the forced removal of the Cherokee, Creek, Choctaw, Chickasaw and Seminole from the Southeast. In 1838–1839 about 16,000 Cherokee were marched west under army guard, and thousands died on the way, about 4,000 by a common estimate. The Cherokee called it the Trail Where They Cried. It was forced internal migration, and it should be named as such.

The big idea. The Census Bureau measures the whole story with one moving dot, the **mean center of population** (see the map). In 1790 it lay in Kent County, Maryland, east of Baltimore. It moved through Maryland and Virginia, crossed into what is now West Virginia, then Ohio, northern Kentucky (in 1880), Indiana and Illinois, and in 2020 it lay near Hartville, Missouri, roughly 880 miles (1,420 km) west and a little south of where it began. Its westward march shows the frontier; its turn to the southwest after 1950 shows a later migration to the **Sun Belt**. That later shift was pulled by mild winters, new industries, lower costs and military bases, and was made livable by a technology: air conditioning, invented by Willis Carrier in 1902 and widespread in homes by the 1960s.

The move to cities. The other great internal migration ran from farm to city. In 1790 only about 5 percent of Americans lived in places the census counted as urban. The census of 1920 was the first to find a majority (51.2 percent) in urban areas; today about 80 percent do. Machines pushed people off the land, since a farmer with a tractor could work many times the acres of a farmer with a mule, and factories pulled them to the cities. Chicago grew from about 30,000 people in 1850 to about 1.7 million in 1900. Within this flow ran the **Great Migration**: from about 1910 to 1970 roughly 6 million Black Southerners moved to the cities of the North and West. They were pushed by the poverty of sharecropping, by the boll weevil's ruin of cotton, and by segregation laws and lynching; they were pulled by factory jobs, especially in World War I, when European immigration nearly stopped and northern industry needed workers. Newspapers such as the *Chicago Defender* and letters home spread the news. In the 1930s drought and dust storms on the southern Plains, together with low farm prices, pushed hundreds of thousands of "Okies" west to California. After 1945, the automobile, the Interstate Highway Act (1956) and new tract towns like Levittown, New York (begun 1947), carried families from city to **suburb**: intraregional migration on a vast scale.

On the map, worldwide. Urbanization is now the largest migration on earth. The United Nations estimated that the world became more than half urban around 2007, and that about 55 percent of people lived in cities in 2018. China's cities have absorbed the largest rural-to-urban migration in history; its statisticians counted close to 300 million rural migrant workers in the early 2020s. Lagos, Dhaka and Delhi grow by thousands of newcomers a week. Ravenstein would recognize the pattern: farm to town, town to city, mostly for work. He would recognize the countercurrent too, in retirees leaving cities and in remote workers moving to small towns, a pattern geographers call **counterurbanization**.

Judging fairly. The westward movement was both a story of courage and hard work and a story of conquest. Homesteading families broke sod, built schools and churches, and turned the Plains into one of the world's great granaries; the same movement took the land of the peoples who were already there, often by broken treaties. A fair historian names both. Believers among the migrants often saw their journeys in biblical terms. When God's people were carried into Babylon, the prophet told them to build houses, plant gardens and seek the good of the city where they lived (Jeremiah 29:5–7). Millions who moved to American cities did just that.



The U.S. mean center of population, 1790–2020 (selected census years; positions approximate).

PICTURE STUDY

Across the Continent: "Westward the Course of Empire Takes Its Way", Frances Flora Bond Palmer, published by Currier & Ives, 1868 · Hand-colored lithograph · National Gallery of Art, Washington, D.C. (Paul Mellon Collection, 1985.64.160); other impressions at the Library of Congress

Fanny Palmer was an English-born artist who emigrated to New York in 1844 and became one of the most popular printmakers of Currier & Ives, a firm that sold inexpensive colored prints to millions of American homes. She drew this scene in 1868, the year before the transcontinental railroad was completed. Her title borrows a line from a poem by the eighteenth-century bishop George Berkeley, which Americans quoted as a motto for the westward movement.

The print is a work of persuasion as much as of record. It shows what many Americans of 1868 believed the railroad would bring: towns, schools, churches and farms spreading west.

It also shows, quietly, who would be pushed aside.

Look closely

- Follow the railroad track. Where does it begin, and where does it lead your eye?
- Find the schoolhouse in the frontier town. Why do you think the artist included it?
- Find the Native horsemen. Where are they placed, and how is the train's smoke drawn in relation to them?
- Look at the settlers in the foreground. What work are they doing?

Talk about it

1. What pull factors for westward migration does this print advertise?
2. What does the print leave out about the westward movement? Use what you learned about Indian removal and the Plains.
3. Would a farm family in Ohio in 1868 have found this print encouraging? Why?

PROJECT: BALANCING THE NATION: FINDING THE CENTER OF POPULATION

The Census Bureau describes the mean center of population as the point where a map of the country would balance if every person had the same weight. You will build exactly that: a cardboard map, weighted with coins for the population of cities, balanced on a pencil point for two different census years.

You will need

- A printed outline map of the contiguous United States, about 11 by 17 inches if possible
- A sheet of stiff, flat cardboard or foam board the same size, and glue
- About 60 pennies (or washers) and tape
- A sharpened pencil standing in a lump of clay, or a pushpin head
- Census figures for state populations in 1850 and in 2020 (from the Census Bureau website, with a parent)

Steps

1. Glue the map to the cardboard and trim the cardboard to the outline of the country. The trimmed board is your "unweighted" country.
2. Using 1850 state populations, give each state one penny per 500,000 people (round to the nearest whole penny; give at least one to any state that had people counted). Tape each state's pennies near its largest population cluster.
3. Find the balance point by resting the board on the pencil point and moving it until it balances (or hang it from two corners with string and mark where the plumb lines cross). The weight of the board itself adds error; keep the board light and the pennies heavy.
4. Mark the 1850 balance point. Compare it with the real 1850 center (Wirt County, in what is now West Virginia).

5. Remove the pennies and repeat with 2020 state populations, using one penny per 6,000,000 people (round, minimum one).
6. Mark the 2020 balance point. Measure the distance between your two points with the map scale and compare it with the real shift.
7. Write a paragraph: Which migrations moved the balance point? Why is your result only approximate?

Tips

- Placing each state's pennies at its biggest cities, not in the middle of the state, gives a much better answer, because people are not spread evenly.
- Hanging the board from two different holes with a weighted string is often easier than balancing it on a pencil.

Check your work

- My weighted map balances, and I marked two balance points.
- I measured the shift with the map scale and compared it with the census.
- My paragraph names specific migrations that moved the center.
- I explained at least two sources of error.

MAP NOTEBOOK

1. Copy the mean center map and label each point with one migration that helped move it.
2. Draw a flow map of the Great Migration with arrows from the Deep South to Chicago, Detroit, Cleveland, New York, Philadelphia and Los Angeles. Note the main railroad lines that carried migrants north.
3. Make a line graph of the urban percentage of the United States: about 5 percent (1790), 15 percent (1850), 40 percent (1900), 51 percent (1920), 64 percent (1950) and about 80 percent (2020).

> **From history.** Dorothea Lange's photograph *Migrant Mother*, taken in March 1936 at a pea-pickers' camp in Nipomo, California, for the federal Resettlement Administration, became the best-known image of the 1930s migration west. Its subject, Florence Owens Thompson, had been born in Indian Territory, in what is now Oklahoma. The original negatives are in the Library of Congress, which holds many thousands of the government photographs that recorded American internal migration in those years.

WORKED EXAMPLES

Example 1. Chicago had 29,963 people in 1850 and 1,698,575 in 1900. Find the average annual growth rate and the doubling time using the rule of 70.

1. Growth factor over 50 years = 1,698,575 ÷ 29,963 ≈ 56.7.
2. Annual factor = 56.7^(1/50). Using logarithms: ln 56.7 ≈ 4.04; 4.04 ÷ 50 ≈ 0.0808; e^0.0808 ≈ 1.084.
3. Annual growth rate ≈ 8.4 percent.
4. Rule of 70: doubling time ≈ 70 ÷ 8.4 ≈ 8.3 years.
5. Check: 50 years ÷ 8.3 ≈ 6 doublings; $2^6 = 64$, close to 56.7. (The rule of 70 is an approximation; the exact doubling time is ln 2 ÷ 0.0808 ≈ 8.6 years.)

Answer: About 8.4 percent per year, doubling roughly every 8 to 9 years. Most of that growth came from migration, as Ravenstein's law about large towns predicts.

Example 2. The mean center of population moved about 880 miles (1,420 km) between 1790 and 2020. Find its average speed in miles and km per year and per decade. Then find the speed between 1950 (near Olney, Illinois) and 2020 (near Hartville, Missouri), about 235 miles (380 km) apart.

(Use the map or drawing "Use the dated points to see when the center moved fastest and when it changed di" shown earlier in this lesson.)

1. 1790 to 2020 is 230 years, or 23 decades.
2. 880 ÷ 230 ≈ 3.8 miles per year; 1,420 ÷ 230 ≈ 6.2 km per year.
3. Per decade: 880 ÷ 23 ≈ 38 miles (62 km).
4. 1950 to 2020 is 70 years: 235 ÷ 70 ≈ 3.4 miles per year (380 ÷ 70 ≈ 5.4 km per year), or about 34 miles (54 km) per decade.

Answer: About 3.8 miles (6.2 km) per year over the whole period, about 38 miles (62 km) per decade. Since 1950 the center has moved a little more slowly, about 3.4 miles (5.4 km) per year, and it has turned southwest toward the Sun Belt.

Example 3. In 1790 the United States had 3,929,214 people, about 5.1 percent urban. In 1920 it had 106,021,537 people, 51.2 percent urban. Find the urban population each year and how many times larger it became. Compare with the growth of the whole population.

1. 1790 urban: 0.051 × 3,929,214 ≈ 200,000.
2. 1920 urban: 0.512 × 106,021,537 ≈ 54,300,000.
3. Urban growth factor: 54,300,000 ÷ 200,000 ≈ 270.
4. Total population growth factor: 106,021,537 ÷ 3,929,214 ≈ 27.

Answer: About 200,000 urban residents in 1790 and about 54.3 million in 1920, roughly 270 times as many, while the whole population grew about 27 times. Cities grew ten times faster than the nation, which shows massive movement from countryside to city (plus immigrants who settled in cities).

PRACTICE

1. EASY Distinguish interregional from intraregional migration, with an American example of each.
2. EASY What did the Homestead Act of 1862 offer, and on what condition?
3. EASY What was Turner’s frontier thesis, and what census report prompted it?
4. EASY Give two push factors and two pull factors of the Great Migration (about 1910–1970).
5. MEDIUM A city grows at 3.5 percent per year. Using the rule of 70, how long will it take to double? To quadruple?
6. MEDIUM Read the mean center map. In which state was the center in 1900? Between which two years shown did the center move from moving almost due west to moving southwest?
   (Use the map or drawing “Read the dated points.” shown earlier in this lesson.)
7. MEDIUM Why did air conditioning matter to the geography of American migration?
8. MEDIUM In 1838–1839 about 16,000 Cherokee were forcibly removed, and about 4,000 died. What percent is that? Classify this migration.
9. HARD A country has 50 million people, 40 percent urban. Twenty years later it has 65 million, 60 percent urban. How many more urban residents are there? If the rural population’s natural increase would have raised it by 6 million with no migration, about how many people moved from countryside to city (assume no international migration and that births in cities explain the rest)?
10. HARD Explain how the tractor acted as both a push factor and a technology overcoming geography in the move to cities.
11. HARD Name two features of the Dust Bowl migration of the 1930s that fit Ravenstein’s laws and one that does not.
12. CHALLENGE In a paragraph, weigh Turner’s frontier thesis. Give one strength and one criticism, and explain what geographic evidence supports the migration he described.

COMMON MISTAKES

- Thinking the westward movement ended in 1890. The census frontier line vanished, but westward migration continued strongly, and the center of population has moved west in every census since.
- Confusing the Great Migration of the 1630s (Puritans to New England) with the Great Migration of 1910–1970 (Black Southerners to northern and western cities). Always give the dates.
- Assuming cities grow mainly by births. Until recent times, cities grew mostly by migration; in the 1800s many cities had more deaths than births.

Make it a game · Move the Center. Draw a large outline of the United States on poster board and place a coin at the 1790 center in Maryland. Players draw cards naming a migration (Erie Canal opens, Gold Rush, Homestead Act, Great Migration, air conditioning spreads, retirees to Florida). For each card, the player moves the coin a short distance in the direction that migration would push the center and explains why. The others vote whether the move is right. Finish by comparing the coin's position with the real 2020 center in Missouri.

Scripture. "And seek the peace of the city whither I have caused you to be carried away captives, and pray unto the LORD for it: for in the peace thereof shall ye have peace." (Jeremiah 29:7, KJV)

The exiles in Babylon had not chosen to move, yet God told them to work and pray for the good of their new city. Every migrant, willing or not, is called to seek the peace of the place where God has set him.

Practice answers

1. Interregional migration moves between major regions, such as the Great Migration from the South to northern cities. Intraregional migration moves within one region, such as families moving from New York City to suburban Long Island after 1945.
2. 160 acres of public land to a settler who lived on it and farmed it for five years (after which, for a small fee, the land was his).
3. Turner argued in 1893 that the westward-moving frontier had shaped the American character and institutions. He was prompted by the 1890 census report that a continuous frontier line could no longer be drawn.
4. Push: sharecropping poverty and the boll weevil's damage to cotton; segregation laws and racial violence including lynching. Pull: factory jobs in northern and western cities, especially when World War I cut off European immigration; letters and newspapers such as the *Chicago Defender* describing better wages and more freedom.
5. Doubling time ≈ 70 ÷ 3.5 = 20 years. Quadrupling takes two doublings, about 40 years.
6. Indiana in 1900. The turn comes between 1950 and 2000: through 1950 (Illinois) the center moved almost due west, and from 1950 to 2000 and 2020 (Missouri) it moved southwest.
7. It made the hot, humid summers of the South and the desert Southwest comfortable for homes, offices and factories, removing an environmental obstacle and helping pull millions to

Sun Belt cities such as Houston, Phoenix, Atlanta and Miami after 1950.

8. 4,000 ÷ 16,000 = 25 percent, about one in four (by a common estimate). It was forced internal migration carried out under the Indian Removal Act of 1830.
9. Urban: 0.40 × 50 = 20 million at first; 0.60 × 65 = 39 million later; an increase of 19 million. Rural: 30 million at first; 26 million later. Without migration it would have been 30 + 6 = 36 million, so about 36 − 26 = 10 million people moved from countryside to city.
10. The tractor let one farmer work far more land, so fewer farm workers were needed, which pushed rural people to look for work in towns. At the same time it overcame the limits of animal power and distance on the farm, raising output so that a shrinking farm population could feed a growing urban one.
11. Fits: the main causes were economic (failed crops and low prices); the migration ran from a farming area toward places with work (California's farms and cities). Does not fit well: many migrants moved long distances (over 1,000 miles) to farm regions rather than short distances or to great centers of commerce; and many traveled as whole families rather than as single adults.
12. A strong answer might say: a strength is that it took geography seriously, linking the availability of cheap land in the West to American habits of self-government, mobility and self-reliance. A criticism is that it underplayed the Native peoples already living in the "wilderness," the role of the federal government and the army, and the importance of cities and of the South. The geographic evidence includes the steady westward march of the mean center of population, census density maps showing the frontier line, and the Homestead Act's land entries.

3.4 Migration and Policy: Laws, Borders and Several Views

OBJECTIVES

- Trace the major turning points of U.S. immigration law from 1790 to 1990 and compare them with the policies of other countries (guest-worker programs, points systems, free-movement zones).
- Explain the arguments that thoughtful people make for more open and for more restrictive immigration policies, and the effects of migration on sending countries, fairly and in their strongest form.
- Calculate quotas, foreign-born shares and remittance shares from data, and read a bar graph of the foreign-born population over time.

Warm-up. Your family is deciding whether to let a new family stay in your home for a month. List three good reasons to say yes and three honest questions or concerns you would want answered first. Notice that a person can hold all six thoughts at once. Nations face the same kind of question on a larger scale.

Video. Coming soon. The history of U.S. immigration law (Chinese Exclusion Act, the 1924 quota act, the 1965 act) presented factually: search Library of Congress, The History Guy and Hillsdale Studios; vet any newer explainer carefully for partisan framing before use.

KEY TERMS

immigration policy
The laws and rules by which a country decides who may enter, how many, for how long, and on what path to citizenship.

quota
A numerical limit on the number of immigrants admitted, often by country of origin, as in the U.S. laws of 1921 and 1924.

refugee
Under the 1951 UN Refugee Convention, a person outside his or her country who cannot return because of a well-founded fear of persecution for race, religion, nationality, membership in a particular social group or political opinion.

guest worker
A foreign worker admitted for a limited time to fill labor needs, usually without a direct path to citizenship, as in West Germany’s program from 1955 or the U.S. Bracero Program (1942–1964).

brain drain

The emigration of educated and skilled people (doctors, engineers, nurses) from a country, which may weaken the country they leave.

naturalization

The legal process by which an immigrant becomes a citizen.

CORE IDEAS

The story. On May 26, 1924, President Calvin Coolidge signed the Immigration Act of 1924, often called the Johnson–Reed Act after its sponsors. It set a yearly limit of about 165,000 immigrants from outside the Western Hemisphere and divided them by nationality: each country received 2 percent of the number of people born in that country who were living in the United States in the census of 1890. Choosing 1890 rather than a later census was deliberate, because the "new immigrants" from Italy, Poland, Russia and Greece had come mostly after that year. The law cut immigration from southern and eastern Europe to a trickle and barred almost all immigration from Asia. Forty-one years later, on October 3, 1965, President Lyndon Johnson signed a new law at the foot of the Statue of Liberty. The Immigration and Nationality Act of 1965, called the Hart–Celler Act, abolished the national-origins quotas and put in their place a system of preferences for relatives of citizens and residents and for workers with needed skills. Johnson said at the signing that he did not consider it a revolutionary bill. It changed the map of American immigration more than almost anyone expected.

How it worked. For its first century the United States had few limits on immigration. The Naturalization Act of 1790 limited citizenship to an alien who was a "free white person" of good character, but entry itself was largely open. The first major federal restriction aimed at a single nationality was the Chinese Exclusion Act of 1882, which barred Chinese laborers, was extended in 1892 and 1902, and was repealed only in 1943, when China was an ally in World War II. Most Americans of 1882 approved it; it was nonetheless a law that judged people by their ancestry, and it is fair to name it as a wrong. Federal inspection began in the 1890s (Ellis Island, 1892). A literacy test followed in 1917, temporary quotas in 1921 and the permanent quotas of 1924. Then came the reforms: 1965 ended national origins; the Refugee Act of 1980 set up a regular system for admitting refugees; the Immigration Reform and Control Act of 1986 gave legal status to about 2.7 million people who had entered or stayed unlawfully while making it illegal for employers knowingly to hire unauthorized workers; and the Immigration Act of 1990 raised the overall limits. The graph shows the result: the foreign-born share of Americans, near 15 percent around 1890 and 1910, fell to under 5 percent by 1970, then rose to about 14 percent in recent years.

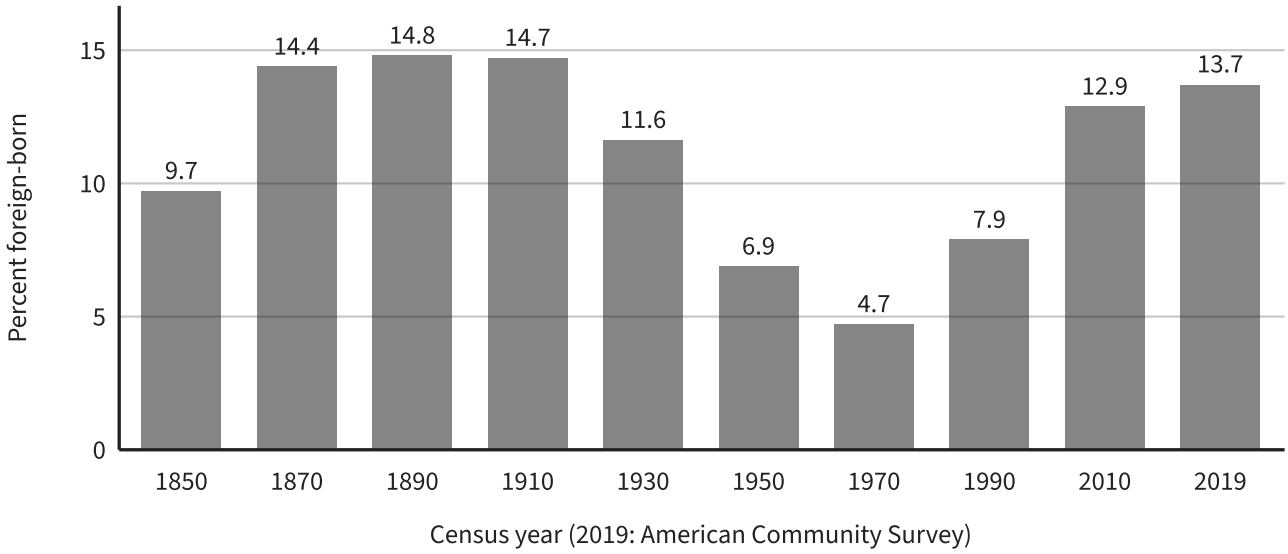
The big idea. Every country decides who may enter, and the choices vary widely. Canada adopted a **points system** in 1967, scoring applicants on education, language ability, age and job skills; Australia later did the same. West Germany signed **guest-worker** agreements with Italy in 1955 and Turkey in 1961, expecting workers to go home; many stayed and brought families. The European Union allows its citizens to live and work in any member state, and most members belong to the Schengen Area, with no routine passport checks at shared borders. The Persian Gulf states rely heavily on temporary foreign workers; in the United

Arab Emirates close to nine in ten residents are foreign nationals. By the count of the UN's International Organization for Migration, about 281 million people, roughly 3.6 percent of humanity, lived outside their country of birth in 2020.

Several views. Immigration is debated in every country that receives migrants, and serious people disagree. Those who favor more open policies argue that immigrants fill labor shortages and start businesses, that they slow the aging of a population with low birth rates (recall the population pyramids of Unit 2), that refugees fleeing persecution deserve shelter, and that America's own history shows newcomers becoming loyal citizens. Those who favor more restrictive policies argue that a nation has the right and the duty to control its borders and enforce its laws, that large inflows of low-wage labor may hold down the wages of the least-skilled citizens, that public services and housing have limits, and that newcomers need time to learn the language and civic customs of their new country, so that the pace of immigration matters. Economists study these questions with real data and still disagree on the size of the wage effects; one famous case, the arrival of about 125,000 Cubans in Miami during the Mariel boatlift of 1980, has been analyzed by different scholars with different conclusions. In 1893 Puck magazine's cartoonist, himself an immigrant, mocked restrictionists, while the American Federation of Labor under Samuel Gompers soon came to support restriction (endorsing a literacy test in 1897) to protect workers' wages. The same debate runs through American history.

On the map: the sending side. Migration changes the countries people leave as well. Migrants' **remittances** to low- and middle-income countries totaled more than 600 billion dollars a year in the early 2020s by World Bank estimates, more than those countries received in foreign aid. In a few small countries, such as Tonga and Tajikistan, remittances have exceeded a third of the whole economy in some recent years. But a country that trains doctors and nurses only to see them emigrate suffers a **brain drain**, and villages emptied of young men must be farmed by the old. Here, too, the effects are mixed.

A Christian frame. Scripture speaks to both sides of this question without writing a policy. The law of Moses commanded Israel to love the stranger, "for ye were strangers in the land of Egypt" (Leviticus 19:34). Every migrant bears the image of God (Genesis 1:27). Scripture also teaches that God "hath determined the times before appointed, and the bounds of their habitation" (Acts 17:26) and that rulers bear real authority to keep order (Romans 13:1–4). Christians who hold all of these truths still reach different conclusions about how many to admit and how; the task of a geographer is to get the facts right and present each view fairly.



Foreign-born share of the U.S. population, 1850–2019 (U.S. Census Bureau; 2019 from the American Community Survey).

PICTURE STUDY

Looking Backward, Joseph Keppler, 1893 (Puck, January 11, 1893) · Chromolithograph (color printed cartoon) · Published in Puck, January 11, 1893; impressions at the Library of Congress, Washington, D.C.

Joseph Keppler was born in Austria in 1838 and emigrated to the United States, where he founded *Puck*, the most famous humor magazine of its day. In 1893, as Congress debated new restrictions, Keppler drew this cartoon. Prosperous men block a newcomer, but behind each of them stands the shadow of the poor immigrant he, or his father, had been. The caption asks, in effect, whether they would close behind others the door that had let them in.

A cartoon is an argument in a picture. Keppler made his point sharply, and it is worth learning to read his method. A good student of geography and history should also be able to state, just as clearly, what the people he was mocking would have said in reply.

Look closely

- Find the newcomer. How does Keppler show that he is poor and has traveled far?
- Look at the shadows behind the prosperous men. What do their clothes tell you about who they used to be?
- Look at the men’s faces and gestures. How does Keppler want you to feel about them?
- Find any labels or words in the cartoon. How do they sharpen the argument?

Talk about it

1. State Keppler’s argument in one sentence.
2. Write the best one-sentence reply a supporter of restriction in 1893, such as a labor union member worried about wages, might have made.
3. Why might a cartoonist who was himself an immigrant feel strongly about this question?

PROJECT: A POLICY TIMELINE AND A FAIR BRIEF

You will build a large wall timeline of U.S. immigration law with a hand-drawn graph of the foreign-born share beneath it, so you can see how laws and numbers moved together. Then you will write a short policy brief that presents two views fairly before stating and defending your own.

You will need

- A long strip of butcher paper or several sheets of paper taped together (about 1.5 m long)
- A ruler, pencil, markers and graph paper
- Sticky notes in two colors
- The data from the figure in this lesson

Steps

1. Draw a timeline from 1780 to 2020 along the paper, with 1 cm for every 2 years (120 cm in all). Mark every decade.
2. Above the line, mark the laws: 1790, 1882, 1892 (Ellis Island opens), 1917, 1921, 1924, 1943, 1952 (the McCarran–Walter Act, which kept the quotas but ended racial bars to naturalization), 1965, 1980, 1986, 1990. Write one sentence for each.
3. Below the line, using the same horizontal scale, draw the bar graph of the foreign-born share from the figure. Use 1 cm for each percentage point.
4. Look for patterns. Draw arrows connecting laws to changes in the graph, but be careful: wars, the Great Depression and economic changes also moved the numbers.

Use one sticky-note color for laws and one for other events (World War I, the Depression, World War II).

5. Choose one policy question, such as how many refugees a country should admit each year or whether a points system is better than a family-based system.
6. Write a one-page brief: (1) the facts, with numbers; (2) the strongest case for one answer; (3) the strongest case for another; (4) your own view, with reasons, written in a way a person who disagrees would call fair.
7. Read your brief aloud to a parent and ask whether each side was presented as its own supporters would present it.

Tips

- Correlation is not cause. The foreign-born share fell after 1924, but it also fell because the Depression and World War II stopped most migration.
- A fair brief uses each side's best argument, not its weakest. If you cannot state the other view well, you do not yet understand the question.

Check your work

- My timeline has all twelve laws and events, correctly dated.
- My graph uses a consistent scale and matches the data.
- My brief states facts with numbers and presents two views fairly.
- My own view is clearly reasoned and courteous to those who disagree.

MAP NOTEBOOK

1. Draw a world map and shade three examples of different policy systems: Canada (points), the Schengen Area (free movement), and the Gulf states (temporary workers). Add a key.
2. Make a two-column chart titled "Effects on Sending Countries" with columns for benefits (remittances, returning skills) and costs (brain drain, aging villages).
3. Copy the foreign-born bar graph and label the three periods: high immigration (1850–1910), restriction and decline (1924–1970), renewed immigration (after 1965).

> **From history.** Ellis Island closed in November 1954, and its last detainee, a Norwegian merchant seaman named Arne Peterssen, was released and allowed to enter the United States. By then most immigrants were inspected at their ports of departure or on arrival by air. The empty buildings decayed for decades until a large restoration, and the main building reopened as a museum of immigration in 1990.

WORKED EXAMPLES

Example 1. The 1890 census counted 182,580 people born in Italy living in the United States. Under the 1924 rule of 2 percent of the 1890 foreign-born, what would Italy's quota be? In 1907 about 285,000 Italians had entered the United States. What percent of the 1907 inflow does the quota represent?

1. Quota = 0.02 × 182,580 = 3,651.6, about 3,650 per year.
2. Share of 1907 inflow = 3,650 ÷ 285,000 ≈ 0.0128.
3. As a percent: about 1.3 percent.

Answer: About 3,650 per year (the quota actually set for Italy was 3,845, after technical adjustments), only about 1.3 percent of the number who came in 1907. The 1924 law cut Italian immigration by roughly 98 percent from its peak.

Example 2. The 1910 census counted 13,515,886 foreign-born people in a population of 92,228,496. The 1970 census counted 9,619,302 foreign-born in a population of 203,211,926. Find the foreign-born share each year. Then check your answers against the bar graph.

(Use the map or drawing "Compare the 1910 and 1970 bars." shown earlier in this lesson.)

1. 1910: 13,515,886 ÷ 92,228,496 ≈ 0.1466, or 14.7 percent.
2. 1970: 9,619,302 ÷ 203,211,926 ≈ 0.0473, or 4.7 percent.
3. The graph shows bars of 14.7 percent for 1910 and 4.7 percent for 1970.

Answer: 14.7 percent in 1910 and 4.7 percent in 1970. The number of foreign-born fell by about 3.9 million, while the total population more than doubled, so the share fell by about two-thirds.

Example 3. Country R (a teaching example) has a gross domestic product of 40 billion dollars a year. About 1.2 million of its citizens work abroad and send home a total of 8 billion dollars a year. Find remittances as a percent of GDP and the average remittance per migrant per year and per month.

1. Share of GDP = 8 ÷ 40 = 0.20, or 20 percent.
2. Per migrant per year = 8,000,000,000 ÷ 1,200,000 ≈ 6,667 dollars.
3. Per month = 6,667 ÷ 12 ≈ 556 dollars.

Answer: Remittances equal 20 percent of GDP, about 6,700 dollars per migrant per year, or about 560 dollars a month. For such a country, emigration is a major source of income, which is one reason sending governments often encourage it even while they worry about brain drain.

PRACTICE

1. EASY What did the Immigration Act of 1924 do, and why did it use the census of 1890?
2. EASY What did the Immigration and Nationality Act of 1965 replace the quota system with?
3. EASY When was the Chinese Exclusion Act passed and when was it repealed? Why was it repealed then?
4. EASY Define refugee as the 1951 UN Convention does. How does a refugee differ from an economic migrant?
5. MEDIUM Read the bar graph. In which census year shown was the foreign-born share highest? Lowest? About how many percentage points did it rise from 1970 to 2019? *(Use the map or drawing "Read the values above each bar." shown earlier in this lesson.)*
6. MEDIUM Under the 1924 rule, the 1890 census counted about 2,785,000 German-born residents. What would Germany's quota be? Compare it with Italy's (about 3,650).
7. MEDIUM About 281 million people lived outside their country of birth in 2020. If the world population was about 7.8 billion, what percent is that? Is international migration the experience of most people?
8. MEDIUM Compare a points system (Canada, 1967) with a family-preference system (the U.S. after 1965). Give one argument made for each.
9. HARD West Germany's guest-worker program began in 1955. Explain what the government expected and what actually happened, and what lesson geographers draw from it.
10. HARD State the strongest argument for more open immigration and the strongest argument for more restrictive immigration in one sentence each, as a supporter of each would put it.
11. HARD A country of 5 million people loses 2,000 of its 10,000 doctors to emigration over a decade but receives remittances equal to 15 percent of its GDP. Describe one benefit and one cost to the country, and explain why economists disagree about whether emigration helps it overall.
12. CHALLENGE Write a paragraph explaining how the foreign-born share of Americans fell from 14.7 percent in 1910 to 4.7 percent in 1970. Name at least three causes and explain why the 1924 law alone does not explain it.

COMMON MISTAKES

- Confusing a percentage with a number. The foreign-born share in recent years is about the same as in 1910, but the number of foreign-born people is more than three times as large because the population is larger.
- Treating the views in an immigration debate as simply good versus bad. Thoughtful people weigh real goods (mercy, family, prosperity, rule of law, shared culture) differently.
- Assuming every international migrant is a refugee. Most migrants move for work or family; refugees are a specific legal category.

Make it a game · Name That Law. Make cards with one clue each (“2 percent of the 1890 census,” “signed at the Statue of Liberty,” “repealed in 1943,” “gave legal status to about 2.7 million,” “created the diversity visa,” “first federal immigration station in New York Harbor”). Players race to name the law or event and its year. Two points for both, one for either. For a bonus, the player must state one argument that was made for the law and one that was made against it at the time.

Scripture. “But the stranger that dwelleth with you shall be unto you as one born among you, and thou shalt love him as thyself; for ye were strangers in the land of Egypt: I am the LORD your God.” (Leviticus 19:34, KJV)

God reminded Israel that they had once been strangers themselves. The verse governs how believers treat the stranger who dwells among them; questions of how many to admit and how are left to wise and lawful government, on which Christians may differ.

Practice answers

1. It set national-origins quotas of 2 percent of each nationality’s foreign-born population in 1890, with a total of about 165,000 a year from outside the Western Hemisphere, and barred almost all Asian immigration. It used 1890 because most immigrants from southern and eastern Europe had arrived after that year, so their quotas would be small.
2. A system of preferences based mainly on family ties to U.S. citizens and permanent residents and on needed job skills, without quotas by national origin.
3. Passed in 1882; repealed in 1943, during World War II, when China was an American ally.
4. A refugee is a person outside his or her country who cannot return because of a well-founded fear of persecution for race, religion, nationality, membership in a particular social group or political opinion. An economic migrant moves mainly for work or better wages and could return home safely.
5. Highest: 1890 (14.8 percent). Lowest: 1970 (4.7 percent). Rise: 13.7 − 4.7 = 9.0 percentage points.
6. 0.02 × 2,785,000 = 55,700, about 15 times Italy’s quota. (The quota actually set for Germany was 51,227, after technical adjustments.) The 1890 base favored the older immigrant groups from northern and western Europe.
7. 281 ÷ 7,800 ≈ 0.036, about 3.6 percent. No: more than 96 percent of people live in the country where they were born, which fits Ravenstein’s first law.
8. A points system selects immigrants by education, language, age and skills; supporters argue it matches immigration to the economy’s needs and helps newcomers succeed. A family-preference system admits relatives of citizens and residents; supporters argue it keeps families together and gives newcomers a ready support network. (Either system has critics as well.)
9. The government expected workers from Italy, Turkey and other countries to work for a few years and go home. Many stayed, brought their families and settled permanently, forming large communities. Geographers draw the lesson that temporary labor migration often becomes permanent settlement, and chain migration follows.
10. Open: immigrants bring work, enterprise and youth to an aging nation, refugees deserve refuge, and history shows newcomers becoming loyal and productive citizens. Restrictive: a nation must control its borders and enforce its laws, and limiting the pace and kind of

immigration protects the wages of its least-skilled workers, the capacity of its public services and its shared civic culture. (Answers will vary; each should be stated fairly and in its strongest form.)

11. Benefit: remittances support families, build houses and businesses and bring in foreign currency. Cost: losing 20 percent of its doctors weakens health care and wastes public money spent training them. Economists disagree because the effects are of different kinds and fall on different people, and because some emigrants return with skills and capital, so the overall result depends on the country and the time span.
12. A strong answer names: the 1921 and 1924 quota laws, which sharply cut immigration from Europe and Asia; World War I, which nearly halted Atlantic crossings; the Great Depression, when few wanted to come and some went home; World War II; the aging and death of the immigrants who had arrived before 1914; and the growth of the native-born population through births. The law set limits, but wars and the Depression kept arrivals even below the quotas in some years, and natural increase raised the denominator.

Unit 3 test

Answer each question. Show your work for every calculation, give units, and use complete sentences for explanations. Where a question asks for several views, state each one fairly, as its own supporters would. The test is worth 100 points.

1. (5 pts) Define push factor and pull factor. Give one historical example of each, and classify each as economic, political, cultural or environmental.
2. (6 pts) What data did Ravenstein use for “The Laws of Migration” (1885)? State three of his laws.
3. (8 pts) A country of 6,000,000 people has 45,000 immigrants and 27,000 emigrants in a year. During the same year there are 66,000 births and 54,000 deaths. (a) Find the net migration rate per 1,000. (b) Use the demographic balancing equation to find the population at the end of the year.
4. (8 pts) City A has 3,000,000 people. City B has 1,500,000 people and lies 150 km (93 miles) from A. City C has 6,000,000 people and lies 450 km (280 miles) from A. Using interaction $= P_1 \times P_2 \div d^2$, which city should have more migration with A, and by about what factor? Name the concept the d^2 term represents.
5. (6 pts) Explain Everett Lee’s idea of intervening obstacles and Samuel Stouffer’s idea of intervening opportunities, with an example of each.
6. (6 pts) Describe the inspection process at Ellis Island. About how many people passed through it between 1892 and 1954, and about what percent were refused entry? Name two common reasons for refusal.
7. (8 pts) About 12.5 million Africans were carried onto slave ships and about 10.7 million survived to land in the Americas. (a) About what percent died at sea? (b) Why is this migration classified differently from the Irish famine emigration, even though both crossed the Atlantic under terrible conditions?
8. (8 pts) The route from Hamburg to New York by way of the English Channel is about 6,600 km (4,100 miles). A steamship around 1905 made it in 9 days; a sailing ship of the 1840s took about 50 days. Find each average speed in km per day and km/h, and explain one way faster crossings changed the pattern of migration.
9. (6 pts) Distinguish the “old” from the “new” immigration, naming two source countries and one push factor for each. What Ravenstein law does Stieglitz’s photograph *The Steerage* (1907) illustrate, and how?
10. (8 pts) A city of 1,000,000 people grows at 2.8 percent per year. (a) Use the rule of 70 to find its doubling time. (b) About how long until it reaches 8,000,000? (c) Name two reasons such growth comes mostly from migration in a rapidly urbanizing country.
11. (8 pts) The U.S. mean center of population was in Kent County, Maryland, in 1790; in Indiana in 1900; near Olney, Illinois, in 1950; and near Hartville, Missouri, in 2020. (a) What is the mean center of population? (b) Its total movement 1790–2020 was about 880 miles (1,420 km). Find its average speed in miles per decade. (c) Why did its direction turn toward the southwest after 1950?

12. (6 pts) Give the dates, approximate size, and two push and two pull factors of the Great Migration of Black Southerners.
13. (8 pts) Under the Immigration Act of 1924, each nationality's quota was 2 percent of its foreign-born population counted in the 1890 census. (a) If a nationality numbered 150,000 in 1890 and sent 120,000 immigrants in 1910, what would its quota be, and what percent of its 1910 inflow is that? (b) Why did Congress choose 1890 rather than 1910 as the base year? (c) What law replaced the national-origins system, and when?
14. (9 pts) Write a well-organized paragraph on immigration policy. (a) State the strongest argument for more open immigration and the strongest argument for more restrictive immigration, each as its supporters would put it. (b) Name one benefit and one cost of emigration for a sending country. (c) Explain how a Christian might draw on Leviticus 19:34 and Romans 13 in thinking about the question, without claiming that Scripture settles a particular policy.

UNIT PROJECT: A MIGRATION ATLAS

Assemble a small atlas of at least six pages that tells the story of migration at three scales: your own family, your nation and the world. Include your family migration map and distance graph from Lesson 3.1 with your test of Ravenstein's laws; a map of one Atlantic crossing from Lesson 3.2 with your passenger's papers; your balanced-map record of the center of population from Lesson 3.3; and your policy timeline, foreign-born graph and fair brief from Lesson 3.4.

Open the atlas with a one-page introduction that answers the unit's central question in your own words: Why do people move, and what changes when they do? Close it with a short reflection on Acts 17:26 and what it means that God has "determined the times before appointed, and the bounds of their habitation."

- **Accuracy**: Places, routes, dates and figures are correct; maps have a title, key, scale and north arrow.
- **Quantitative reasoning**: Calculations (distances, rates, doubling times, shares) are shown, correct and clearly explained.
- **Fairness and judgment**: Historical wrongs are named plainly, achievements are given their due, and policy views are stated as their own supporters would state them.
- **Craft and clarity**: The atlas is neat, well organized and readable, with careful hand-drawn maps and graphs.

Answer key

1. A push factor drives people from their origin; a pull factor draws them to a destination. Example push: the Irish potato famine of 1845–1852 (environmental and economic). Example pull: factory jobs in Chicago during World War I (economic). Other correct examples accepted.
2. The British census of 1881, which recorded each person's birthplace and residence by county. Any three: most migrants move short distances; migration proceeds step by step; long-distance migrants go to great centers of commerce or industry; each current produces a

countercurrent; town-dwellers migrate less than rural people; most migrants are adults; large towns grow more by migration than by natural increase; migration increases as industry and transport improve; the main flow is from farming areas to industrial centers; the chief causes are economic.

3. (a) Net migration = 45,000 − 27,000 = +18,000; rate = 18,000 ÷ 6,000,000 × 1,000 = +3.0 per 1,000. (b) Change = (66,000 − 54,000) + 18,000 = 12,000 + 18,000 = +30,000; end population = 6,030,000.
4. A–B: 3,000,000 × 1,500,000 = 4.5×10^{12}; ÷ 22,500 = 2.0×10^{8}. A–C: 3,000,000 × 6,000,000 = 1.8×10^{13}; ÷ 202,500 ≈ 8.9×10^{7}. City B, by a factor of about 2.25. The d^2 term represents distance decay (the friction of distance).
5. Intervening obstacles (Lee, 1966) are barriers between origin and destination, such as the Atlantic Ocean, the cost of a ticket or an immigration law. Intervening opportunities (Stouffer, 1940) are attractive chances found before the intended destination, such as a factory job in Pittsburgh that keeps a migrant bound for Chicago from going farther.
6. Steerage passengers were ferried to the island, climbed to the Registry Room under the eyes of doctors, received medical inspection (with chalk marks for suspected conditions), and then answered an inspector's questions from the ship's manifest (name, age, work, money, destination). About 12 million passed through; about 2 percent were refused, mainly for contagious disease (such as trachoma) or for being judged likely to become a public charge.
7. (a) 1.8 million ÷ 12.5 million ≈ 14 percent. (b) The slave trade was forced migration: Africans were captured, sold and carried against their will and arrived enslaved. The Irish, though pushed by famine, chose to leave and arrived free, able to work, move, write home and send for family.
8. Steam: 6,600 ÷ 9 ≈ 733 km per day, ÷ 24 ≈ 31 km/h (about 19 mph). Sail: 6,600 ÷ 50 = 132 km per day, ÷ 24 = 5.5 km/h (about 3.4 mph). Faster, cheaper, safer crossings let poorer people emigrate and made return trips practical, so seasonal migration and countercurrents grew.
9. Old (to about 1880): Ireland and Germany, for example; push: famine (Ireland) or poor harvests and the failed revolutions of 1848 (Germany). New (about 1880–1914): Italy and the Russian Empire, for example; push: rural poverty (southern Italy) or pogroms and legal restrictions on Jews (Russia). *The Steerage* shows steerage passengers on a ship sailing from New York to Europe, illustrating the law that every current produces a countercurrent.
10. (a) 70 ÷ 2.8 = 25 years. (b) 8,000,000 is three doublings, about 75 years. (c) Mechanization and poverty push rural people off the land; city jobs and services pull them in; historically cities had lower natural increase than the countryside, so migration supplied most of the growth.
11. (a) The point on which a flat map of the country would balance if every person had equal weight. (b) 880 ÷ 23 decades ≈ 38 miles (62 km) per decade. (c) Migration to the Sun Belt (the South and Southwest), pulled by mild winters, new industries, lower costs and military bases, and made comfortable by air conditioning, together with the growth of California and Texas.
12. About 1910–1970; roughly 6 million people. Push: sharecropping poverty and the boll weevil; segregation laws and racial violence including lynching. Pull: factory jobs in northern and western cities (especially when World War I cut off European immigration); higher wages and greater freedom reported in letters and newspapers such as the *Chicago Defender*.
13. (a) 0.02 × 150,000 = 3,000; 3,000 ÷ 120,000 = 2.5 percent of the 1910 inflow. (b) Most immigrants from southern and eastern Europe arrived after 1890, so an 1890 base gave them small quotas and favored northern and western Europe. (c) The Immigration and Nationality

Act of 1965 (Hart–Celler), signed at the Statue of Liberty, which replaced national origins with preferences for family ties and skills.

14. A full-credit answer (3 points per part): (a) Open: immigrants bring work, enterprise and youth to an aging nation, refugees deserve refuge, and history shows newcomers becoming loyal citizens. Restrictive: a nation must control its borders and enforce its laws, and limiting the pace and kind of immigration protects the wages of its least-skilled workers, its public services and its shared civic culture. (b) Benefit: remittances (more than 600 billion dollars a year to low- and middle-income countries in the early 2020s). Cost: brain drain of trained doctors, nurses and engineers. (c) Leviticus 19:34 commands love for the stranger and reminds God’s people they were once strangers; Romans 13 teaches that rulers have authority to keep order. A Christian holds both: treating every migrant with dignity and supporting lawful government, while recognizing that believers may reach different conclusions about specific policies.

UNIT 4

Culture: Language and Religion

Language and religion are the two cultural traits that most deeply divide and unite the peoples of the earth, and both have a geography. In this unit you will start in Calcutta in 1786, where Sir William Jones noticed that Sanskrit was a cousin of Greek and Latin, and learn how linguists group the world's roughly 7,100 languages into families. You will follow the gospel from a crowded Jerusalem at Pentecost along Roman roads, across the steppes and seas, to its present center in the Global South. Then you will map the hearths and regions of the world's religions and visit four great sacred cities: Jerusalem, Rome, Mecca and Varanasi.

The models of this unit (language trees and waves, relocation, hierarchical and contagious diffusion, location quotients, growth rates and the gravity model) are tools to be tested against the evidence, not laws. Religions are described as their own followers would recognize them, accurately and with real numbers, because false witness is no part of good scholarship. Through it all runs the series verse that Paul preached in Athens: God "hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation" (Acts 17:26).

The unit test (Lesson 4.5) is worth 100 points and covers all four lessons, including calculations, map reading and written explanation.

BEFORE YOU BEGIN

- Can explain relocation and expansion diffusion and distance decay (Unit 1)
- Can compute percentages, growth rates and doubling times with the rule of 70 (Unit 2)
- Can read latitude and longitude and explain why a great circle is the shortest route on a globe
- Knows the basic outline of the book of Acts

MASTERY CHECKLIST

- I can name the world's major language families, place them on a map, and list the main branches of Indo-European.
- I can use regular sound correspondences such as Grimm's law to show that languages are related, and explain the tree and wave models with their limits.
- I can trace the spread of Christianity from Jerusalem to the present and identify relocation, hierarchical and contagious diffusion in that history.
- I can describe the hearth, beliefs, branches and present distribution of the world's major religions accurately and classify them as universalizing or ethnic.
- I can compute location quotients, growth rates, doubling times and gravity-model comparisons from religious and linguistic data and explain what the numbers leave out.
- I can describe the sacred sites of Jerusalem, Rome, Mecca and Varanasi and explain pilgrimage from a biblical perspective.

OPTIONAL BOOKS AND RESOURCES

- **Pew Research Center: Religion** (https://www.pewresearch.org/religion/): Free. Reports and country tables on the size and distribution of the world's religious groups, the source of most figures in Lessons 4.2 and 4.3. Use the country tables for the Lesson 4.3 mapping project.
- **Ethnologue: Languages of the World** (https://www.ethnologue.com/): The standard catalog of the world's living languages and families. Some pages are free; full country profiles require a subscription. Useful for checking language counts in Lesson 4.1.
- **Library of Congress, Geography and Map Division** (https://www.loc.gov/maps/): Free. Thousands of historic maps, including Holy Land maps, pilgrim maps and missionary maps, which can be downloaded for the portfolio atlas.

4.1 Language Families

OBJECTIVES

- Define language family, branch, dialect, lingua franca and language isolate, and locate the world's major language families on a world map.
- Explain how William Jones, Franz Bopp and Jacob Grimm showed that languages from Ireland to India share a common source, and use Grimm's law to predict English cognates of Latin words.
- Compare the tree model and the wave model of language change, and explain how migration, empire, trade and mission spread languages across the map.

Warm-up. Take five minutes and write the words for "father," "mother," "three" and "night" in as many languages as you can find in your house (a Spanish or French textbook, a Bible in another language, a grandparent who speaks German, a dictionary app). Line them up in columns. Circle the words that look alike. Are there any languages on your list whose words look nothing like English? Make one guess about why some languages resemble each other and others do not.

Watch. *Latin and Its Indo-European Language Family* (latintutorial, 5:35). https://www.youtube.com/watch?v=TPh03KsGrAA
With the big idea: watch the family tree that traces Spanish, French and Italian back to Latin, and Latin back to an older lost parent language.
Note: Captions were not available to check; preview it first. The video says it leaves out some languages, such as Romanian, for lack of space.

Backup video. *Evolution of the Indo-European Languages - Ancient Civilizations DOCUMENTARY* (Kings and Generals, 18:07). https://www.youtube.com/watch?v=VpXgMdvLUXw
As review: watch the animated map showing how the Indo-European languages spread and split into branches, and look for Sanskrit, Latin and the Germanic tongues. Note: Captions were not available to check; preview it first. It opens with a sponsor message for a translation tool, which you can skip, and it likely tells the story through prehistoric migration theories rather than the lesson's Tower of Babel discussion.

KEY TERMS

language family
A group of languages that descend from one common ancestor language, shown by regular likenesses in basic words and grammar (for example, Indo-European).

language branch
A large division within a family whose languages share a closer common ancestor (for example, the Germanic branch of Indo-European, which includes English and German).

cognate
A word in one language that comes from the same ancestral word as a word in another language (Latin *pater* and English *father*).

dialect
A regional or social form of a language with its own pronunciation, words or grammar, whose speakers can still largely understand speakers of other forms.

lingua franca
A language used for communication between people whose native languages differ (Latin in medieval Europe, Swahili in East Africa, English in aviation and science today).

language isolate
A language with no proven relatives in any known family, such as Basque in the western Pyrenees.

CORE IDEAS

The story. On 2 February 1786, in Calcutta (now Kolkata), a British judge named Sir William Jones rose to give his third annual address to the Asiatic Society of Bengal, a learned society he had founded two years before. Jones had come to India in 1783 to sit on the Supreme Court at Fort William, and he had set himself to learn Sanskrit, the ancient language of Hindu scripture and law, so that he would not have to trust interpreters. What he found astonished him. Sanskrit, he told the society, resembled Greek and Latin so closely, both in the roots of its verbs and in the forms of its grammar, that the likeness could not be an accident. No scholar, he said, could study all three without believing that they had sprung from some common source, which perhaps no longer existed. He added that Gothic (an old Germanic tongue), the Celtic languages and old Persian probably belonged to the same family. A judge in Bengal had found the distant cousins of English.

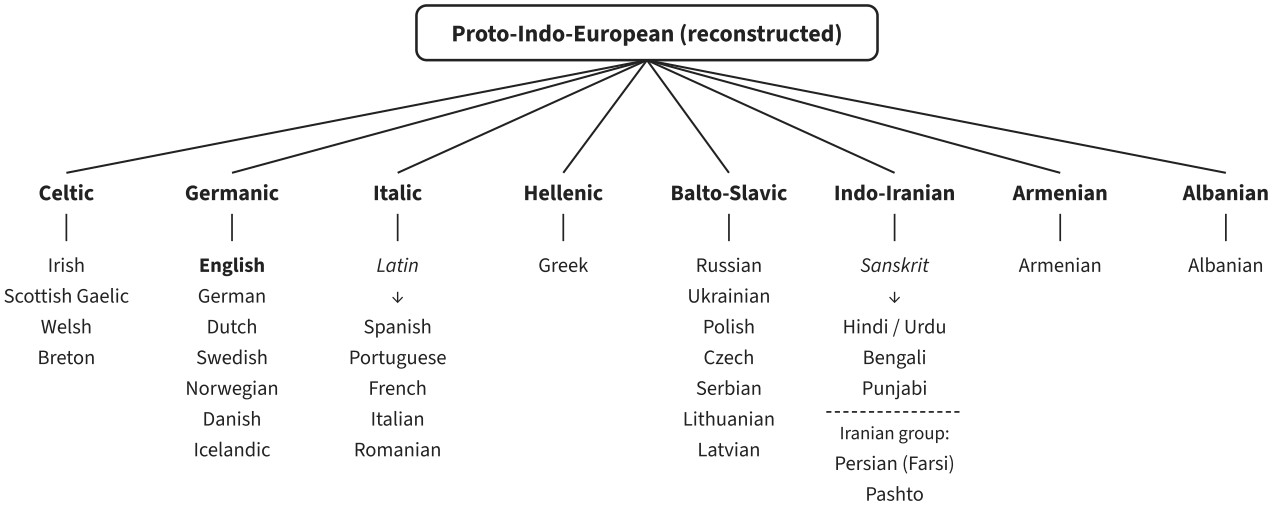
How they figured it out. Others had noticed likenesses before, but Jones's address set scholars to work. They compared the words a people rarely borrows: numbers, family members, parts of the body. Sanskrit *pitṛ*, Greek *patēr*, Latin *pater*, Gothic *fadar* and English *father* plainly belong together. In 1816 the German scholar Franz Bopp compared the verb endings of Sanskrit, Greek, Latin, Persian and Germanic, and the Danish scholar Rasmus Rask did similar work. In 1822 Jacob Grimm, the same Grimm who collected fairy tales with his brother Wilhelm, set out regular sound shifts now called **Grimm's law**: where Latin and Greek have *p*, *t* and *k*, the Germanic languages usually have *f*, *th* and *h*. So Latin *pater* answers to *father*, *tres* to *three* and *cornu* to *horn*. The key is regularity. Two words that merely look alike prove little, but hundreds of words that change by the same rules prove a common ancestry. Borrowed words do not follow the old rules: English *beef* came from French after the Norman Conquest of 1066, long after the Germanic sound shift, which is why it looks nothing like its native cousin *cow*.

The big idea. A **language family** is a set of languages descended from one ancestor. Ethnologue, the standard catalog, lists about 7,100 living languages in the mid-2020s, grouped into a few hundred families and isolates. **Indo-European** has the most native speakers, more than 3 billion, about two people in every five on earth. Its main branches are

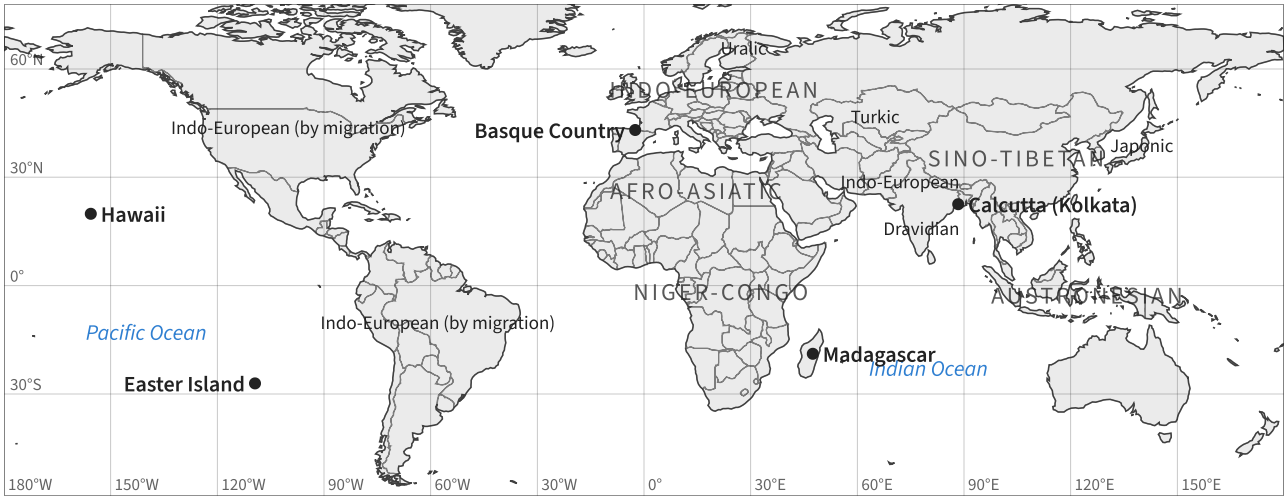
Germanic (English, German, Dutch, the Scandinavian languages), Italic or Romance (Latin and its daughters Spanish, Portuguese, French, Italian and Romanian), Balto-Slavic (Russian, Ukrainian, Polish, Lithuanian), Indo-Iranian (Hindi, Bengali, Punjabi, Persian), Celtic (Irish, Welsh, Breton), Hellenic (Greek), and the single languages Armenian and Albanian (see the tree in the figure). **Sino-Tibetan** (Mandarin, Cantonese, Tibetan, Burmese) has about 1.4 billion speakers. **Niger-Congo** has the most languages, about 1,500, including Yoruba, Igbo and the Bantu languages such as Swahili and Zulu. **Afro-Asiatic** includes Arabic, Hebrew, Amharic and Hausa. **Austronesian** stretches from Madagascar to Hawaii and Easter Island and includes Malay, Indonesian, Tagalog and Maori. **Dravidian** (Tamil, Telugu) fills southern India, **Turkic** runs from Turkey to western China, and **Uralic** includes Finnish, Estonian and Hungarian. Japanese and Korean are usually placed in small families of their own, and Basque is a true isolate. All such counts are estimates, because experts disagree about where a dialect ends and a separate language begins.

Models and their limits. In the 1860s August Schleicher drew Indo-European as a branching **family tree**, each language splitting cleanly from its parent. In 1872 his student Johannes Schmidt proposed a **wave model**: changes spread outward like ripples among neighboring dialects, so the edges between languages blur. Both are useful, and both are incomplete. English is Germanic in its grammar and most common words, yet a large share of its dictionary comes from French and Latin; a tree alone cannot show that. Neither can scholars agree where the ancestor, Proto-Indo-European, was first spoken. The **steppe hypothesis**, set out by Marija Gimbutas in 1956, places it among horse-riding herders north of the Black and Caspian Seas; the **Anatolian hypothesis**, argued by Colin Renfrew in 1987, has it spreading with the first farmers out of Anatolia. Recent studies of ancient DNA have strengthened the steppe view for Europe, but the debate continues. Scripture gives the deeper frame. Genesis 11 records that the whole earth was once “of one language,” and that at Babel the LORD confounded their language and scattered them abroad. Linguists can trace families backward for some thousands of years, but their methods fade out before they reach one proven ancestor of all the families, which is consistent with the great families beginning in a sudden dividing of tongues.

On the map. Languages travel the same ways people do. **Relocation diffusion** carried English to North America and Australia and Spanish and Portuguese to Latin America after 1492, the latter by conquest as well as settlement. **Expansion diffusion** spread Latin through the Roman Empire, Arabic with the Muslim conquests from the 600s, and Swahili along the trade routes of the East African coast. Mission has shaped the map too. In 863 the brothers Cyril and Methodius went to Great Moravia and devised an alphabet for the Slavs, and Bible translators since have reduced hundreds of languages to writing for the first time. A **lingua franca** bridges language borders: Latin did so for medieval Europe, and English does so today in science, business and international aviation. Place names, or **toponyms**, keep older layers alive: *Massachusetts* is Algonquian, *Los Angeles* Spanish, and English towns ending in *-chester* recall the Latin *castra*, a camp. Many small languages are now spoken only by the old, yet decline is not always final: Hebrew, long used chiefly in worship and study, was revived as an everyday spoken language in the late 1800s and is now spoken by millions in Israel.



The Indo-European family drawn as a tree (Schleicher's model). Real languages also borrow sideways, which a tree cannot show.



The great language families on the map (simplified; each label marks the core region of a family).

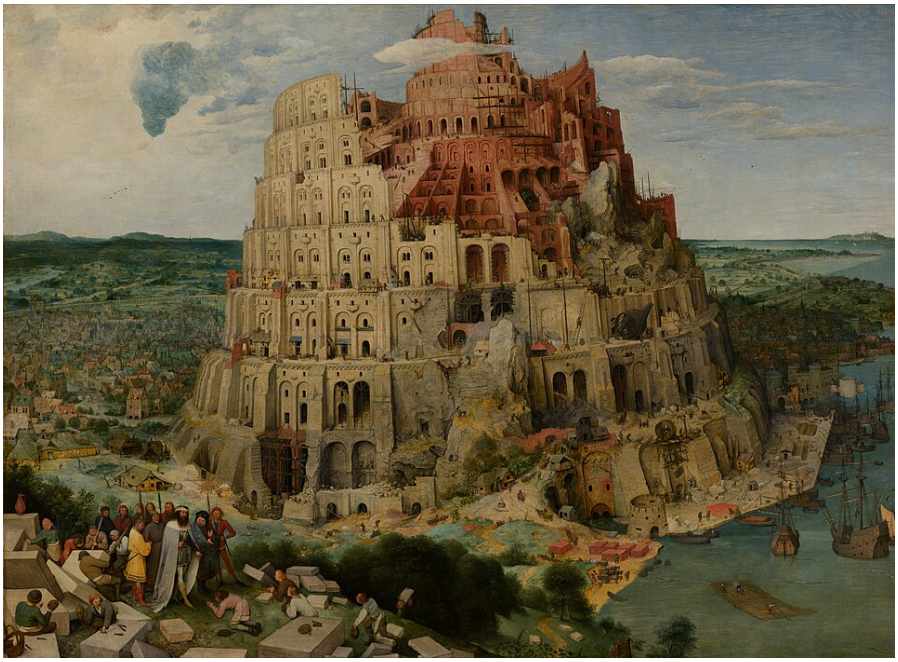
Thinking About Time

What the sign says. Proto-Indo-European was never written down; it is reconstructed from its daughter languages.

What we observe. What is measured is the written record: the oldest Indo-European texts, in Hittite, come from Anatolia in the second millennium BC. Dates offered for the parent language before writing rest on assumed rates of language change and on radiocarbon dates from archaeological sites, both of which depend on assumptions that cannot be checked against written records.

> **How Christians read it.** Christians who read Genesis 11 as history place the dividing of languages at Babel, after the Flood, and hold reconstructed dates beyond the written record loosely.

PICTURE STUDY



The Tower of Babel, Pieter Bruegel the Elder, 1563 · Oil on oak panel · Kunsthistorisches Museum, Vienna

Pieter Bruegel the Elder painted this scene in Antwerp, then one of the busiest ports in Europe, where merchants and sailors spoke Dutch, French, Spanish, German, Italian and English in the same streets. He had traveled to Rome, and his tower borrows the stacked arches of the Roman Colosseum. In the lower left, the king traditionally linked with Babel, Nimrod, inspects the work while stonecutters kneel.

Bruegel shows the moment before the confusion of tongues in Genesis 11. Look closely and you will see that the tower is already failing: its layers are not level, some arches are unfinished while higher ones go up, and the whole mass leans on a natural crag. Bruegel painted a smaller version of the subject too, now in Rotterdam.

Look closely

- Find the harbor at the right. What does it tell you about how the builders brought stone and supplies?
- Look at the tiers of the tower. Are they level? What does that suggest about the plan?
- Find the cranes and treadwheels on the tower. These were real machines of Bruegel’s own day.
- Find the king and the kneeling stonecutters. How does Bruegel show pride?

Talk about it

1. Bruegel lived in a city where many languages met. How might that have shaped the way he imagined Babel?
2. Genesis 11:4 says the builders wanted to make themselves a name. How does the painting show ambition, and how does it show weakness?
3. Why might a geographer care about a story of people being scattered “upon the face of all the earth”?

PROJECT: A LANGUAGE FAMILY TREE AND COGNATE MAP

You will build a large family tree of the Indo-European languages with yarn and index cards, test it with real cognates, and then color a world map of the great language families. By the end you will see with your own eyes why Jones, Bopp and Grimm were convinced.

You will need

- A large poster board or a sheet of butcher paper
- Yarn in three colors, glue or tape, about 30 index cards
- A printed blank world map with country borders (Library of Congress or any free outline map)
- Colored pencils (at least 10 colors)
- Bilingual dictionaries or a reliable online dictionary for at least eight languages

Steps

1. Write “Proto-Indo-European (reconstructed)” on a card and tape it at the top center of the board.
2. Make eight branch cards: Celtic, Germanic, Italic, Hellenic, Balto-Slavic, Indo-Iranian, Armenian, Albanian. Connect each to the top card with yarn.
3. Make language cards (at least 16) and connect them to the right branch: for example English, German, Dutch and Swedish under Germanic; Latin, then Spanish, Portuguese, French, Italian and Romanian under Italic.
4. On the back of each language card, write the words for “father,” “mother,” “three,” “night” and “new.” Use a dictionary; write the spelling and, if you can, the pronunciation.
5. Lay out the cards of one branch side by side. Underline the sound that changes regularly. Then compare Latin with English and look for Grimm’s p-to-f, t-to-th and k-to-h shifts.
6. Add two cards from outside the family, such as Finnish (Uralic) and Swahili (Niger-Congo). Do their words fit the pattern? Tape them off to the side with a note.
7. Color the world map by family, following the lesson figure. Use one color per family and make a key. Shade lightly where a family arrived by migration after 1492.
8. Write a paragraph at the bottom of the board explaining what a family tree shows well and what it misses (borrowing, blurred borders between dialects).

Tips

- Use basic words. Words for computers or coffee were borrowed recently and will mislead you.
- Spelling can hide sound. French *nuit* and English *night* look different on paper but come from the same root.
- Hindi and Persian are Indo-European; Arabic and Hebrew are not, even though they are spoken nearby.

Check your work

- My tree shows all eight Indo-European branches with correct sample languages.
- My cognate cards show at least three regular sound changes.
- My map has a key and correctly places at least eight families.
- My paragraph names one strength and one limit of the tree model.

MAP NOTEBOOK

1. Copy the Indo-European tree into your map notebook from memory, then check it against the figure and correct it in red.
2. Draw a small outline of the Indian and Pacific Oceans and mark the farthest corners of the Austronesian family: Madagascar, Taiwan, Hawaii, New Zealand and Easter Island.
3. List five place names near your home. For each, find the language it came from (English, Spanish, French, a Native American language, Dutch, Latin, Greek) and the meaning.

> **From history.** Hebrew had been used for centuries mainly in prayer, Scripture and scholarship. Eliezer Ben-Yehuda, who settled in Jerusalem in 1881, resolved to speak only Hebrew at home and raised his son as one of the first native speakers of the language in modern times. He coined new words for modern things and labored for decades on a great Hebrew dictionary. Schools of the Jewish settlements in the land took up Hebrew as their language of teaching, and when the British Mandate began in 1922 Hebrew was recognized as an official language alongside English and Arabic. It is one of the very few languages ever brought back to everyday speech.

WORKED EXAMPLES

Example 1. Use Grimm's law (Latin *p, t, k, d* usually answer to Germanic *f, th, h, t*) to predict the native English cognates of these Latin words: *piscis* (fish), *pes, pedis* (foot), *tres* (three), *cornu* (horn) and *dens, dentis* (tooth).

1. *piscis*: the first sound p becomes f. Expect an English word beginning with f meaning the same thing: *fish*.
2. *pedis*: p becomes f, and d becomes t. The pattern f-t gives *foot*.
3. *tres*: t becomes th. The pattern th-r gives *three*.
4. *cornu*: the k sound (written c) becomes h. The pattern h-r-n gives *horn*.
5. *dentis*: d becomes t and t becomes th. The pattern t-th gives *tooth* (English lost the n, as it did in other words).
6. Check: each English word means the same as its Latin partner, and every change follows the same rules. The English words are cognates, not borrowings. English also borrowed the Latin forms later, which is why we have both *tooth* and *dentist*, *foot* and *pedal*.

Answer: fish, foot, three, horn, tooth. The regular shifts p→f, t→th, k→h and d→t show inheritance from a common ancestor.

Example 2. A **location quotient** (LQ) compares how concentrated something is in one place with its share in a larger area. About 29% of Texans age 5 and older speak Spanish at home, compared with about 13% of all Americans age 5 and older. Find the LQ for Spanish at home in Texas and explain what it means.

1. Formula: LQ = (local share) ÷ (national share).
2. LQ = 29% ÷ 13% = 29 ÷ 13 ≈ 2.2.
3. An LQ of 1.0 would mean Texas has exactly the national share. An LQ above 1 means more concentration than the nation; below 1 means less.
4. Geographic reason: Texas borders Mexico, was part of New Spain and Mexico before 1836, and has received many migrants from Mexico and Central America (relocation diffusion).

Answer: LQ ≈ 2.2: Spanish at home is a little more than twice as concentrated in Texas as in the United States as a whole.

Example 3. Before 1500, the Austronesian family was the most widely spread language family on earth. Its westernmost language, Malagasy, is spoken on Madagascar (Antananarivo, about 47.5° E); its easternmost, Rapa Nui, on Easter Island (about 109.4° W). How many degrees of longitude does the family span, going east across the Indian Ocean and the Pacific? What fraction of the globe is that, and about how far is it along the parallel of 20° S?

(Use the map or drawing "Find Madagascar and Easter Island at the two ends of the Austronesian label." shown earlier in this lesson.)

1. From 47.5° E east to the 180° meridian: 180 − 47.5 = 132.5°.
2. From 180° on east to 109.4° W: 180 − 109.4 = 70.6°.
3. Total span: 132.5 + 70.6 = 203.1°.
4. Fraction of the globe: 203.1 ÷ 360 ≈ 0.56, a little more than half.
5. One degree of longitude at latitude 20° measures about 111 km × cos 20° = 111 × 0.940 ≈ 104 km.
6. Distance: 203.1 × 104 ≈ 21,100 km, or about 13,100 miles (21,100 × 0.621).

Answer: About 203° of longitude, roughly 56% of the way around the earth, or about 21,000 km (13,000 miles) along the 20° S parallel.

PRACTICE

1. EASY Explain the difference between a language family and a language branch, using English as your example.
2. EASY Which language family has the most native speakers? Which has the largest number of separate languages?
3. EASY Place each language in its Indo-European branch: Portuguese, Swedish, Hindi, Polish, Welsh, Persian.
4. EASY What is a language isolate? Name one and say where it is spoken.
5. MEDIUM Using Grimm's law (p→f, t→th, k→h, d→t, g→k), predict the native English cognates of Latin *tu* (you, singular), *cor, cordis* (heart) and *genu* (knee).
6. MEDIUM Latin *bos* and French *bœuf* mean "ox." English has both *cow* and *beef*. Which is the inherited Germanic word, which is a borrowing, and how does history explain it?
7. MEDIUM Suppose 6% of the people age 5 and older in a California county speak Vietnamese at home, compared with about 0.5% in the United States as a whole. Find the location quotient and interpret it.
8. MEDIUM Using the language-family map, which family is spoken both on Madagascar, off the coast of Africa, and in Hawaii? Which family surrounds Madagascar on the African mainland?
   (Use the map or drawing "Use the labels on the map." shown earlier in this lesson.)
9. MEDIUM Give one example of relocation diffusion and one of expansion diffusion of a language, and explain the difference.

10. HARD Why is English, rather than the language with the most native speakers, the lingua franca of international aviation, science and business? Give two geographic or historical reasons.
11. HARD English has roughly 1.5 billion speakers in all, of whom roughly 380 million are native speakers. About what percent of English speakers learned it as a second language? Why does this matter for a map of “where English is spoken”?
12. CHALLENGE In a paragraph, compare Schleicher’s tree model with Schmidt’s wave model. Use English to show where the tree model fits and where it fails, and explain how a Christian geographer might relate the language families to Genesis 11.

COMMON MISTAKES

- Treating any two look-alike words as proof of kinship. Kinship is shown by regular sound correspondences across many basic words; chance resemblances and borrowings do not count.
- Assuming languages spoken near each other are related. Hindi and Persian are Indo-European, but neighboring Arabic is Afro-Asiatic and Tamil is Dravidian; Hungarian, in the middle of Europe, is Uralic.
- Confusing the number of speakers with the number of languages. Indo-European leads in speakers, Niger-Congo in languages, and the island of New Guinea alone holds hundreds of languages spoken by small populations.

Make it a game · Cognate Detective. One player writes a basic word (water, mother, night, two, star, new) in four or five languages on slips of paper, mixing in one language from outside Indo-European, such as Finnish, Swahili or Arabic. The other players must sort the slips into “family” and “outsider” and name the sound change that ties the family words together. Score 2 points for finding the outsider and 1 point for each correct branch named. First to 15 points wins.

Scripture. “Therefore is the name of it called Babel; because the LORD did there confound the language of all the earth: and from thence did the LORD scatter them abroad upon the face of all the earth.” (Genesis 11:9, KJV)

The map of languages is also a map of a scattering. The God who divided the tongues at Babel later gathered “every nation under heaven” to hear the gospel in their own languages at Pentecost (Acts 2), the story that opens the next lesson.

Practice answers

1. A family is the whole set of languages descended from one ancestor (English belongs to Indo-European). A branch is a closer subgroup inside the family (English belongs to the Germanic branch, with German, Dutch and the Scandinavian languages).
2. Indo-European has the most native speakers (roughly 3 billion). Niger-Congo has the most languages (about 1,500).
3. Portuguese: Italic (Romance). Swedish: Germanic. Hindi: Indo-Iranian. Polish: Balto-Slavic. Welsh: Celtic. Persian: Indo-Iranian.

4. A language with no proven relatives in any family. Basque, spoken in the western Pyrenees of northern Spain and southwestern France.
5. *tu* → *thou* (t→th). *cordis* → *heart* (k→h, d→t). *genu* → *knee* (g→k; the k is still written though no longer spoken).
6. *Cow* is the inherited Germanic word. *Beef* was borrowed from Norman French after the Norman Conquest of 1066, long after the Germanic sound shifts, so it does not follow Grimm's law. English kept the native word for the animal and took the French word for its meat.
7. LQ = 6 ÷ 0.5 = 12. Vietnamese at home is twelve times as concentrated in that county as in the nation, a strong cluster created by relocation diffusion (many Vietnamese families settled there after 1975).
8. Austronesian is spoken on both Madagascar and Hawaii. The nearby African mainland is Niger-Congo (Bantu languages such as Swahili).
9. Relocation: English carried by settlers to North America and Australia (the speakers themselves moved). Expansion: Arabic spreading across North Africa after the 600s, or Latin through the Roman Empire, as peoples already living there adopted the language of rulers, faith and trade. In relocation people move; in expansion the language spreads through a population that largely stays put.
10. Possible reasons: the British Empire spread English across every continent by the 1800s; the United States became the leading economic, scientific and aviation power after 1945; English was already the language of many airlines and of leading scientific journals. Mandarin has more native speakers but is concentrated in one region, while English is spread across many countries and is learned as a second language worldwide. International aviation rules require pilots and controllers on international flights to be able to use English.
11. Second-language speakers ≈ 1,500 − 380 = 1,120 million; 1,120 ÷ 1,500 ≈ 75%. A map of native speakers shows only Britain, Ireland, North America, Australia, New Zealand and a few others, but most English speakers live elsewhere (India, Nigeria, the Philippines, Europe), so a native-speaker map understates the reach of English.
12. A good answer says: the tree model shows inheritance, with each language descending from a parent (English from Proto-Germanic, from Proto-Indo-European), and it fits English grammar and its basic words (father, three, horn). The wave model shows changes spreading among neighboring dialects and borrowing across branches; English fits this too, since a large share of its vocabulary came from French and Latin after 1066, which a clean tree cannot show. Both are models, simplifications that reveal some things and hide others. A Christian geographer reads Genesis 11 as history: the LORD confounded the one language at Babel and scattered the peoples, and the great families may be understood as the branches that grew from that dividing; linguists can trace families back for some thousands of years but have not shown one common ancestor of all of them.

4.2 The Spread of Christianity

OBJECTIVES

- Trace the spread of Christianity from Jerusalem across the Roman world and beyond, naming key places, people and dates from Pentecost to the modern missionary era.
- Distinguish relocation, hierarchical and contagious diffusion and identify each in the history of the Church, including the barriers that slowed or reversed its spread.
- Calculate growth rates and doubling times from historical estimates, and explain how the center of the Christian world shifted from Europe toward the Global South in the twentieth century.

Warm-up. Tell one piece of news (for example, “Grandma is coming on Saturday”) to one person in your house and ask that person to pass it on to one more. Time how long it takes to reach everyone. Then try a second way: tell the news to the one person who will see everyone else first, like a parent at the dinner table. Which way was faster? Which way reached the most distant person? Keep your answer for the lesson on diffusion.

Watch. *Did Nero Help Spread Christianity?* (Drive Thru History with Dave Stotts, 4:34). https://www.youtube.com/watch?v=5H1FNEPr5sM
After the story: watch Dave Stotts explain how persecution under Nero scattered believers and helped carry the gospel farther across the Roman world.
Note: Captions were not available to check; preview it first. The channel itself warns that this clip describes the persecution of early Christians, so younger students may need a parent nearby.

Backup video. *13th June 313: The Edict of Milan formally ends the persecution of Christians in the Roman Empire* (HistoryPod, 2:26). https://www.youtube.com/watch?v=TU96JsSfdPc
As review: watch this short summary of the Edict of Milan in AD 313 and listen for how Constantine and Licinius ended the persecution of Christians across the empire. Note: Captions were not available to check; preview it first.

KEY TERMS

universalizing religion
A religion that seeks converts among all peoples everywhere (Christianity, Islam, Buddhism), in contrast to an ethnic religion tied to one people and land.

hearth
The place where a cultural trait, such as a religion or language, began and from which it spread. Christianity’s hearth is Jerusalem and Judea.

relocation diffusion

Spread of a trait by people who move and carry it with them (believers scattered by persecution, merchants, soldiers, migrants).

hierarchical diffusion
Spread from one important place or person to others of similar rank first: from city to city, or from a ruler to his people.

contagious diffusion
Spread from person to person and place to neighboring place, outward through a population like ripples.

missionary
A person sent to carry the faith to another people or place, often crossing a language or cultural boundary to do so.

CORE IDEAS

The story. Fifty days after the Passover at which Jesus was crucified, in about AD 30, Jerusalem was crowded with pilgrims for the feast of Pentecost. The book of Acts names where they came from: “Parthians, and Medes, and Elamites, and the dwellers in Mesopotamia,” and Judea, Cappadocia, Pontus, Asia, Phrygia and Pamphylia, Egypt and Libya near Cyrene, “strangers of Rome,” Cretes and Arabians (Acts 2:9–11). A geographer reading the list sees a map: a great ring of peoples from Persia to Italy, all gathered in one city. Peter preached, and about three thousand were baptized that day (Acts 2:41). Weeks before, Jesus had given His followers a route as much as a command: they would be witnesses “both in Jerusalem, and in all Judæa, and in Samaria, and unto the uttermost part of the earth” (Acts 1:8). The book of Acts follows that very order outward, and it closes with Paul preaching in Rome, the capital of the known world.

How it worked. The early Church used the geography of the Roman Empire. Roman roads and sea lanes tied the Mediterranean together, the Pax Romana made travel fairly safe, and koine Greek was understood from Syria to Italy, which is why the New Testament was written in it. Jewish synagogues scattered across the cities of the Diaspora gave Paul his first hearers in town after town. When persecution broke out in Jerusalem, believers fled, and “they that were scattered abroad went every where preaching the word” (Acts 8:4): **relocation diffusion**. At Antioch, the third city of the Empire, “the disciples were called Christians first” (Acts 11:26), and from there Paul set out on his journeys between about AD 46 and 57. He went deliberately to cities: Ephesus, Philippi, Thessalonica, Athens, Corinth and at last Rome. That is **hierarchical diffusion**, leaping from city to city along the routes of trade and government, followed by **contagious diffusion** as the faith passed from neighbor to neighbor into the countryside. The faith grew in spite of persecution, under Nero after the fire of Rome in AD 64 and in Diocletian’s Great Persecution from 303. Then the emperor Constantine’s Edict of Milan in 313 granted toleration, and in 380 Theodosius made Nicene Christianity the religion of the Empire.

Beyond the Empire. The gospel also crossed Rome’s borders. Armenia became the first kingdom to adopt Christianity, traditionally in 301 through Gregory the Illuminator. King Ezana of Aksum, in what is now Ethiopia, was converted in the 300s through Frumentius, a

Syrian Christian who had been carried there as a captive. The Church of the East spread across Persia and along the Silk Road, and a monk named Alopen reached the Chinese capital Chang'an in 635. In the West, Patrick preached in Ireland in the 400s, Columba founded the monastery of Iona in 563, Augustine landed in Kent in 597, and Boniface worked among the Germans in the 700s. Cyril and Methodius carried the faith to the Slavs in 863, and Prince Vladimir of Kyiv was baptized in 988. Here hierarchical diffusion often worked through rulers: when a king like Clovis of the Franks (about 496) or Vladimir was baptized, his people followed. Barriers rose as well. The Arab conquests of the 600s brought Syria, Egypt and North Africa, once Christian heartlands, under Muslim rule, and over centuries their populations became mostly Muslim. The East-West Schism of 1054 and the Reformation of 1517 divided the Church into the three main branches on today's map: Catholic, Orthodox and Protestant.

Honest history. The record holds real wrongs. Charlemagne forced baptism on the conquered Saxons, and in 782 at Verden, according to the Frankish annals, some 4,500 Saxons were put to death. The Spanish conquest of the Americas brought the faith together with war, forced labor under the encomienda system and the death of millions, chiefly from new diseases. Yet the loudest protest came from inside the Church: the Dominican friar Bartolomé de las Casas, judging by the standard of the gospel he preached, denounced the cruelty of the conquerors in his *Short Account of the Destruction of the Indies* (1552). Missionaries also gave much. Francis Xavier reached Japan in 1549; Matteo Ricci, who learned Chinese and Confucian learning, entered Beijing in 1601; William Carey sailed for India in 1793 and, with his colleagues at Serampore, translated Scripture into dozens of languages. Hudson Taylor founded the China Inland Mission in 1865, and Samuel Ajayi Crowther, rescued from a slave ship as a boy, was consecrated in 1864 as the first African bishop of the Anglican Church. Many of the most effective evangelists in Africa and Asia were local believers whose names are rarely recorded.

On the map. According to the Pew Research Center, about two-thirds of the world's Christians lived in Europe in 1910; by 2010 only about a quarter did. In the same century the number of Christians in sub-Saharan Africa rose from fewer than 9 million to more than 500 million. The Center for the Study of Global Christianity calculates that the statistical center of the world's Christians, which moved north and west from Jerusalem into Europe over many centuries, had swung south by 2010 to West Africa, near Timbuktu in Mali. Today Christianity is the largest religion, with about 2.3 billion adherents in 2020, roughly 29% of humanity, and the most widely spread across the globe. The countries with the most Christians are the United States, Brazil and Mexico, and fast-growing churches in Nigeria, Brazil, China, India and the Philippines now send missionaries of their own. The word that began in one city among pilgrims from a dozen lands has reached the uttermost parts of the earth.

The early Church in the Roman world, with Paul's voyage to Rome (Acts 27–28).

PICTURE STUDY

St Paul Preaching in Athens, Raphael (Raffaello Sanzio), 1515–1516 · Bodycolor on paper, mounted on canvas (a full-size design, or cartoon, for a tapestry) · Royal Collection, on loan to the Victoria and Albert Museum, London

Pope Leo X ordered from Raphael ten designs for tapestries to hang in the Sistine Chapel, showing the deeds of Peter and Paul. Raphael painted full-size cartoons, and weavers in Brussels used them as patterns. Seven cartoons survive. They have belonged to the English Crown since 1623 and have hung in the Victoria and Albert Museum since 1865.

This cartoon shows Acts 17, when Paul stood on the Areopagus in Athens and told the philosophers that God “hath made of one blood all nations of men for to dwell on all the face of the earth,” the verse that runs through this whole geography series. At the right, a man and a woman step forward: Dionysius the Areopagite and Damaris, who believed (Acts 17:34).

Look closely

- Find Paul. How do his arms and stance show that he is speaking with conviction?
- Look at the crowd. Which listeners seem persuaded, which are thinking hard, and which are turning away?
- Find the statue behind Paul and the round temple. What do they tell you about the city where he was preaching?
- Find Dionysius and Damaris at the right. How does Raphael show that they are responding?

Talk about it

1. Paul quoted the Athenians’ own poets to them (Acts 17:28). Why might a missionary study the culture of the people he hopes to reach?
2. Athens was a center of learning but not of government or trade by Paul’s day. Why might Paul still have chosen to preach there?
3. How does this picture connect the spread of Christianity with Acts 17:26, a verse about geography?

PROJECT: DIFFUSION ON A GRID

You will model the spread of an idea across a map of towns, first by contagious diffusion and then by hierarchical diffusion, and compare how fast each one reaches the far corner. Then you will lay the spread of the early Church on a real map with pins and string.

You will need

- Two sheets of graph paper (at least 20 by 20 squares)
- One six-sided die, colored pencils, a ruler
- A printed outline map of the Mediterranean world
- Map pins or small stickers and string in two colors
- A Bible (Acts 2, 8, 11, 13–28)

Steps

1. On the first sheet, mark a 20 × 20 block of squares. Each square is a village. Draw five larger squares to stand for cities, spread across the grid; mark one city in a corner as Jerusalem.
2. Contagious round: color Jerusalem. Each round, every colored square tries to pass the idea to one neighbor: roll the die (1 north, 2 east, 3 south, 4 west, 5 or 6 nothing

happens) and color that neighbor. Keep a tally of colored squares after each round. Stop after 10 rounds or when the far corner is reached.
3. Hierarchical round: on the second sheet draw the same grid and cities. Each round, a colored city first passes the idea to the nearest uncolored city (no die roll; travel along roads is reliable), and every colored square also tries one contagious roll. Tally again.
4. Graph both tallies (round on the horizontal axis, colored squares on the vertical) on one set of axes.
5. On the Mediterranean map, pin Jerusalem, Antioch, Damascus, Ephesus, Philippi, Thessalonica, Athens, Corinth, Alexandria and Rome. Use string of one color for Paul's journeys and of another for his voyage to Rome (follow the lesson map).
6. Add pins for five later places from the lesson (for example Armenia, Aksum, Iona, Kyiv, Chang'an), each labeled with its date.
7. Write a paragraph: Which model better matches what you see in Acts? Where did the real spread use both kinds of diffusion?

Tips

- Real diffusion has barriers. Try adding a "mountain range" of squares that blocks contagious spread but not travel between cities.
- A good model is simple enough to run by hand but still captures one real pattern.

Check your work

- My grids and tallies show both kinds of diffusion.
- My graph compares the two models on one set of axes.
- My map shows at least ten early Church cities in the right places and five later sites with dates.
- My paragraph uses evidence from Acts.

MAP NOTEBOOK

1. Draw a simple map of Acts 1:8 as four nested rings: Jerusalem, Judea, Samaria, the uttermost part of the earth. In each ring write the chapter of Acts where the gospel reaches it (1–7, 8, 8, 9–28).
2. Make a timeline strip from AD 30 to 1000 and mark ten dates from the lesson with a tiny map symbol for each place.
3. Sketch a pie chart of where the world's Christians lived in 1910 and another for 2010, using the Pew figures in the lesson and worked examples.

> **From history.** In about 1625 workers digging near Xi'an, the old Chinese capital of Chang'an, uncovered a stone tablet nearly ten feet tall. Its inscription, in Chinese with names in Syriac, tells how a monk named Alopen came from the West in 635 bringing scriptures, how the emperor Taizong received him and allowed the faith to be taught, and how monasteries were founded across the land. The stone was set up in 781. Jesuit missionaries in China sent copies of its text to Europe, where it caused a sensation, for it

proved that Christians had reached China nearly a thousand years before them. The Nestorian Stele, as it is often called, stands today in the Beilin Museum (the Forest of Stone Steles) in Xi'an.

WORKED EXAMPLES

Example 1. The sociologist Rodney Stark, in *The Rise of Christianity* (1996), proposed a simple model: suppose there were about 1,000 Christians in AD 40 and the number grew about 40% every ten years. (a) How many Christians does the model give for AD 300? (b) What is the doubling time? (c) Name one limit of the model.

1. From AD 40 to 300 is 260 years, or 26 decades.
2. Each decade multiplies the number by 1.4, so $N = 1{,}000 \times 1.4^{26}$.
3. 1.4^{26}: $\ln 1.4 \approx 0.3365$, and $26 \times 0.3365 \approx 8.75$; $e^{8.75} \approx 6{,}300$. So $N \approx 1{,}000 \times 6{,}300 \approx 6.3$ million.
4. Doubling time: solve $1.4^{t} = 2$, so $t = \ln 2 \div \ln 1.4 = 0.693 \div 0.3365 \approx 2.06$ decades, about 21 years.
5. Check with the rule of 70: 40% per decade is about 3.4% per year ($1.4^{0.1} \approx 1.034$), and $70 \div 3.4 \approx 21$ years.
6. Limits: the starting number and growth rate are estimates, not counts; no ancient census of Christians exists; and real growth surely sped up and slowed down (persecutions, plagues, peace).

Answer: (a) About 6.3 million in AD 300, roughly a tenth of the Empire's people. (b) About 21 years. (c) The inputs are estimates, and a steady rate is a simplification; the model shows that steady, ordinary growth can explain a large result.

Example 2. According to the Pew Research Center, the number of Christians in sub-Saharan Africa grew from fewer than 9 million in 1910 to about 516 million in 2010. Find the average annual growth rate and the doubling time.

1. Growth factor over 100 years: $516 \div 9 \approx 57.3$.
2. Annual factor: $57.3^{1/100}$. $\ln 57.3 \approx 4.05$, and $4.05 \div 100 = 0.0405$, so the annual factor $\approx e^{0.0405} \approx 1.041$.
3. Average growth rate $\approx 4.1\%$ per year.
4. Doubling time: $0.693 \div 0.0405 \approx 17$ years (rule of 70: $70 \div 4.1 \approx 17$).
5. Interpret: the growth combines conversions with Africa's rapid natural population increase during the same century.

Answer: About 4.1% per year on average, doubling roughly every 17 years for a century.

Example 3. Pew estimates about 600 million Christians worldwide in 1910, with 66% in Europe, and about 2.18 billion in 2010, with 26% in Europe. Find the number of European Christians in each year. Did Europe's Christian population shrink?

1. 1910: 0.66 × 600 million ≈ 396 million, about 400 million.
2. 2010: 0.26 × 2,180 million ≈ 567 million.
3. Change: 567 − 396 ≈ 171 million more, an increase of about 43%.
4. Europe's share fell from about two-thirds to about one-quarter because Christianity grew much faster elsewhere.

Answer: About 400 million (1910) and about 567 million (2010). The number in Europe rose; it was Europe's share of the world total that fell. Always distinguish a count from a share.

PRACTICE

1. EASY What is the hearth of Christianity, and what verse in Acts sets out the order of its spread?
2. EASY Name three features of the Roman world that helped the gospel spread in the first century.
3. EASY Classify each as relocation, hierarchical or contagious diffusion: (a) believers scattered from Jerusalem by persecution preach where they settle; (b) Paul plants churches in Ephesus, Corinth and Rome; (c) a farmer tells his neighbor, who tells hers.
4. EASY Match each date with its event: 313, 380, 863, 988, 1054.
5. MEDIUM Using the map of the early Church, list in order the islands Paul passed or stopped at on his voyage to Rome, and name the port where he landed in Italy.
   (Use the map or drawing "Follow the dashed line west from Caesarea." shown earlier in this lesson.)
6. MEDIUM Why is the baptism of a ruler like Clovis or Vladimir an example of hierarchical diffusion? Give one strength and one weakness of faith spreading this way.
7. MEDIUM Name two regions where Christianity was once the majority faith but later became a minority, and explain the geographic process.
8. MEDIUM In Stark's model, Christians grew 40% per decade. At that rate, how many Christians would there be in AD 100 if there were 1,000 in AD 40?
9. MEDIUM A church movement grows at 5% per year. Use the rule of 70 to estimate its doubling time, then find how many times larger it would be after 70 years.
10. HARD In 2010 Pew estimated that about 63% of the people of sub-Saharan Africa were Christian, compared with about 32% of the world's population. Find the location quotient and interpret it.
11. HARD Explain in three or four sentences why the statistical center of the world's Christians moved from Europe toward West Africa between 1910 and 2010, even though Europe's Christian population did not shrink.
12. CHALLENGE Write a paragraph evaluating the role of conquest in the spread of Christianity. Give one example of coercion, one example of a Christian who opposed coercion in his

own day, and one example of spread without any state power.

COMMON MISTAKES

- Thinking Christianity began as a European religion. Its hearth is in western Asia, and for its first centuries its strongest centers were Jerusalem, Antioch, Alexandria, Asia Minor and Persia as well as Rome.
- Confusing a share with a count. Europe's share of the world's Christians fell sharply after 1910, but the number of European Christians still rose for decades.
- Treating diffusion types as exclusive. The real spread usually combined relocation, hierarchical and contagious diffusion at once.

> **Make it a game · Pentecost Passport.** Write the places named in Acts 2:9–11 on cards (Parthia, Media, Elam, Mesopotamia, Judea, Cappadocia, Pontus, Asia, Phrygia, Pamphylia, Egypt, Libya near Cyrene, Rome, Crete, Arabia). Draw a card and point to the region on a map of the ancient Near East, then name the modern country that lies there. A correct region earns 1 point and a correct modern country 1 more. Bonus point: name a church or Christian figure later linked to that region (Cappadocia and Basil the Great, Egypt and Athanasius, Rome and Peter and Paul).

> **Scripture.** "But ye shall receive power, after that the Holy Ghost is come upon you: and ye shall be witnesses unto me both in Jerusalem, and in all Judæa, and in Samaria, and unto the uttermost part of the earth." (Acts 1:8, KJV)

This verse reads like a geographer's plan of diffusion, moving outward ring by ring from a hearth. The rest of Acts, and the twenty centuries since, are the record of that plan on the map.

Practice answers

1. Jerusalem and Judea. Acts 1:8: "in Jerusalem, and in all Judæa, and in Samaria, and unto the uttermost part of the earth."
2. Any three: Roman roads and sea lanes; the relative peace of the Pax Romana; koine Greek as a common language; Jewish synagogues in cities across the Diaspora; large cities linked by trade.
3. (a) Relocation. (b) Hierarchical (city to city). (c) Contagious.
4. 313: Edict of Milan (toleration under Constantine). 380: Theodosius makes Nicene Christianity the religion of the Empire. 863: Cyril and Methodius go to the Slavs. 988: Baptism of Vladimir of Kyiv. 1054: East-West Schism.
5. Cyprus (sailed past it), Crete (Fair Havens), Malta (shipwrecked), Sicily (Syracuse); he landed at Puteoli and went on to Rome by land.
6. The faith passes first to the person at the top of the hierarchy and then down to his people. Strength: it can open a whole kingdom quickly to churches, teaching and Scripture. Weakness: people may conform outwardly without personal conviction, and coercion can creep in, as with Charlemagne's forced baptisms of the Saxons.

7. Any two of Syria, Egypt, North Africa (the region of Augustine’s Hippo), Asia Minor (modern Turkey). After the Arab conquests of the 600s (and the Turkish conquest of Asia Minor later), Muslim rulers governed these lands; over centuries, through conversion, taxes and laws favoring Muslims, and migration, the population became mostly Muslim. This is a barrier to diffusion and a case of one religion replacing another in a region.
8. Six decades: $1{,}000 \times 1.4^{6} = 1{,}000 \times 7.53 \approx 7{,}500$ Christians.
9. Doubling time $\approx 70 \div 5 = 14$ years. 70 years is 5 doublings, so $2^{5} = 32$ times larger (exact: $1.05^{70} \approx 30.4$).
10. LQ $= 63 \div 32 \approx 2.0$. Christians are about twice as concentrated in sub-Saharan Africa as in the world as a whole.
11. The center of gravity is a kind of average location of all Christians. Between 1910 and 2010 the number of Christians in Europe rose only modestly (about 400 to 567 million), while Christians in sub-Saharan Africa rose from under 9 million to over 500 million and Latin America and Asia also grew. Because so many more of the world’s Christians now live in Africa and the Americas, the average location shifted south and a little west. A falling share does not mean a falling count.
12. A strong answer names, for example, Charlemagne’s forced baptisms of the Saxons and the executions at Verden in 782, or the Spanish conquest and the encomienda; names Bartolomé de las Casas, who denounced the conquerors’ cruelty in 1552 by the standard of the gospel itself (Alcuin also urged Charlemagne that faith cannot be forced); and gives an example of spread without state power, such as the first three centuries under Roman persecution, the Church of the East in Persia and China, or the growth of the church in China after 1949 or in Africa after independence. It concludes that conquest sometimes accompanied the faith, but that much of its growth, then and now, came without it, and it judges these people by the Christian standard they themselves professed.

4.3 The World's Religions on the Map

OBJECTIVES

- Describe accurately the hearth, founding events, main beliefs, branches and present-day distribution of Judaism, Christianity, Islam, Hinduism, Buddhism and Sikhism.
- Distinguish universalizing from ethnic religions and explain how each kind spreads (or does not spread) across space.
- Read and calculate with religious data (shares, location quotients, growth rates) and explain the limits of censuses, surveys and majority-religion maps.

Warm-up. Look at the buildings you pass on the way to church or the store, or picture your own town. Make a quick list of every place of worship you can name, and what kind it is (Baptist church, Catholic parish, synagogue, mosque, temple). Mark them on a hand sketch of your town. Are they spread out evenly, or clustered? What might explain the pattern?

Watch. *The Silk Road Network - UNESCO World Heritage Site* (World Heritage Journey, 4:35). https://www.youtube.com/watch?v=bU8cmkShC-s
With On the map: watch this tour of Xi'an, the eastern end of the Silk Road, and look for the places where trade routes also carried faiths such as Buddhism into China.
Note: Captions were not available to check; preview it first. This is a travel video about Silk Road heritage sites, so it may say little about religion itself. The video focuses on Silk Road trade and sightseeing in Xi'an rather than on where the world's religions began and how they spread.

KEY TERMS

ethnic religion
A religion closely tied to one people, land or culture, which does not actively seek converts from other peoples (Hinduism, Judaism, Shinto).

universalizing religion
A religion that claims to be true for all people and seeks converts everywhere (Christianity, Islam, Buddhism, Sikhism).

branch (of a religion)
A large, basic division within a religion: Catholic, Orthodox and Protestant in Christianity; Sunni and Shia in Islam; Theravada, Mahayana and Vajrayana in Buddhism.

denomination
An organized body within a branch, such as the Baptists, Lutherans, Presbyterians or Methodists within Protestant Christianity.

diaspora
A people scattered from their homeland and living in many other places, such as the Jewish diaspora after AD 70 or the Indian diaspora today.

religiously unaffiliated

Survey term for people who do not identify with any religion. It includes atheists and agnostics but also many who believe in God without belonging to a religious body.

CORE IDEAS

The story. On 11 September 1893, in a great hall of the new Art Institute building in Chicago, a gathering opened that no one had attempted before. Alongside the World's Columbian Exposition, the World's Parliament of Religions brought together, for seventeen days, speakers from the world's faiths. It was chaired by John Henry Barrows, a Presbyterian pastor of Chicago. Protestant, Catholic and Orthodox Christians spoke, along with Jewish rabbis; Swami Vivekananda spoke for Hinduism; Anagarika Dharmapala of Ceylon (Sri Lanka) for Buddhism; Virchand Gandhi for the Jains; Japanese speakers for Shinto and Buddhism; and Mohammed Alexander Russell Webb, an American who had become a Muslim, for Islam. For many Americans it was the first time they had heard these faiths described by their own followers. Behind each speaker lay a geography: a hearth where his faith began, routes along which it spread, and the region where its people lived.

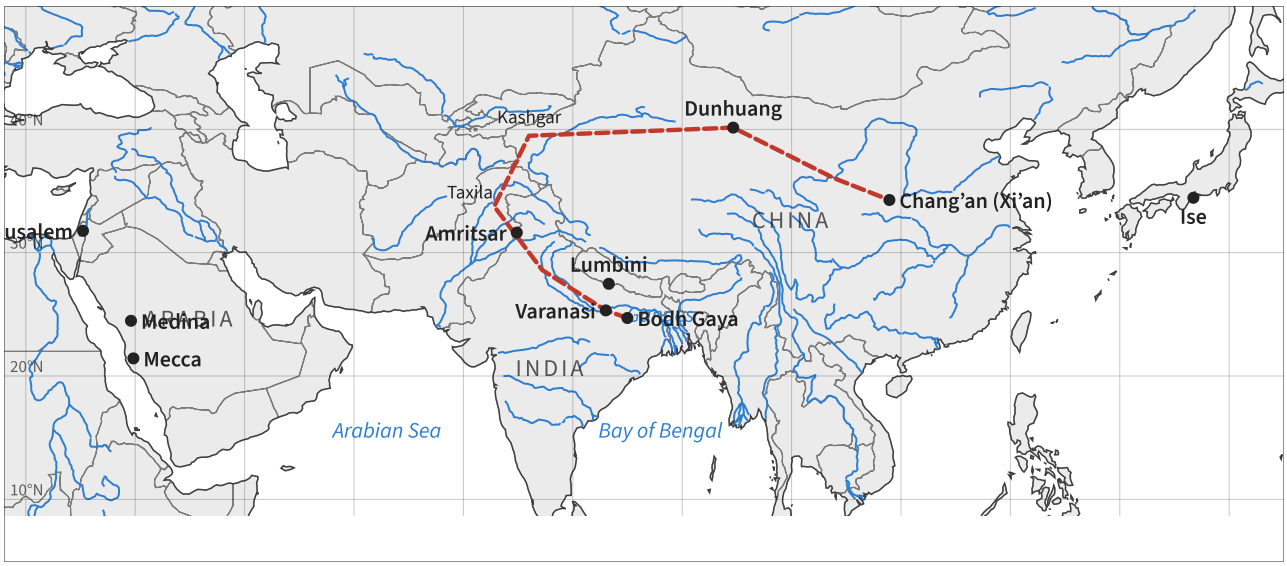
The big idea. Geographers sort religions by how they spread. **Universalizing religions** claim to be true for all people and seek converts everywhere: Christianity, Islam, Buddhism and Sikhism. **Ethnic religions** are bound to one people and land and grow mostly by birth: Hinduism, Judaism and Shinto. The Pew Research Center estimates that in 2020 there were about 2.3 billion Christians (29% of the world's people), about 2.0 billion Muslims (26%), about 1.2 billion Hindus (15%), about 320 million Buddhists (4%) and about 15 million Jews (0.2%), with folk religions and smaller faiths making up the rest. About 1.9 billion people (24%) were religiously unaffiliated, about two-thirds of them in China, where decades of officially atheist rule have shaped the answers people give.

Hearths and routes. Judaism traces itself to God's call of Abraham and the covenant with Israel in the land of Canaan. After the Romans destroyed the Temple in AD 70, Jews scattered in a long diaspora; today the large majority of the world's Jews live in Israel or the United States. **Christianity** began in Jerusalem with Jesus Christ (Lesson 4.2). **Islam** began with Muhammad in Mecca, who Muslims believe received revelations from 610. In 622 he moved to Medina, the Hijra, which begins the Islamic calendar. Within a century Arab armies carried Muslim rule from Spain (711) to the Indus valley, and later merchants and teachers spread Islam by trade to East Africa, Malaysia and Indonesia, now the country with the most Muslims. A dispute over who should lead after Muhammad split Islam into Sunni (roughly 85 to 90% of Muslims) and Shia, who are the majority in Iran, Iraq, Azerbaijan and Bahrain. **Hinduism** has no single founder; it grew on the plains of the Indus and Ganges, from the Vedas and later writings, with beliefs in dharma (duty), karma and rebirth. About 94% of Hindus live in India, and Nepal is the other Hindu-majority country. **Buddhism** began with Siddhartha Gautama, born at Lumbini in what is now Nepal, who taught after his enlightenment at Bodh Gaya, in northeastern India, in about the 400s BC. The emperor Ashoka sent teachers abroad in the 200s BC; Theravada Buddhism took root in Sri Lanka and mainland Southeast Asia, Mahayana traveled the Silk Road to China, Korea and Japan, and Vajrayana grew in Tibet and Mongolia. Buddhism later nearly vanished from India, its

own hearth. **Sikhism** was founded in the Punjab by Guru Nanak (1469–1539), and its holiest site is the Golden Temple at Amritsar.

On the map. The patterns are clear. Christianity predominates in the Americas, Europe, Oceania, much of sub-Saharan Africa and the Philippines. Islam holds a broad belt from Morocco through the Middle East and Central Asia to Pakistan and Bangladesh, and on to Malaysia and Indonesia. Hinduism centers on India and Nepal, Buddhism on Southeast and East Asia. Religious boundaries have sometimes become lines of great suffering. When British India was partitioned in 1947 into a mostly Hindu India and a mostly Muslim Pakistan, some 14 to 15 million people fled across the new borders, and hundreds of thousands were killed in riots and massacres. Ideological tyranny drew its own map: the Soviet Union closed most churches, mosques and synagogues, and China's Cultural Revolution (1966–1976) attacked temples, churches and believers of every faith.

Reading the data honestly. Religious figures come from censuses, which some countries do not take, and from surveys, which measure what people say rather than what they practice. A map that colors each country by its majority religion hides large minorities. India is about 80% Hindu, yet its roughly 200 million Muslims make it one of the largest Muslim populations on earth; Nigeria is roughly half Christian and half Muslim, divided broadly between a Muslim north and a Christian south. Scale matters too: a county, a state and a nation can show very different pictures. Accuracy is also a matter of conscience. The ninth commandment forbids false witness, and that includes misrepresenting what other people believe. When Paul came to Athens he first walked the city and studied its altars, then spoke plainly of the one true God (Acts 17:23). Christians confess that Jesus Christ is "the way, the truth, and the life" (John 14:6), and they can describe other faiths fairly and exactly because the truth needs no caricature.



Hearths of the world's major religions, with the Silk Road route by which Buddhism reached China.

PICTURE STUDY

The Diamond Sutra (frontispiece), Unknown Chinese woodblock carver; printed for Wang Jie, 868 · Ink on paper, printed from carved wooden blocks; a scroll more than 16 feet (about 5 m) long · British Library, London

This scroll is the oldest complete printed book that carries a date. A note at its end says that Wang Jie had it made for free distribution on behalf of his two parents, in the year we call AD 868. It contains the Diamond Sutra, a Mahayana Buddhist scripture translated into Chinese from Sanskrit, and its picture shows the Buddha teaching his aged disciple Subhuti.

The scroll was found in 1900 in a cave at Dunhuang, a Silk Road oasis town in western China, where thousands of manuscripts had been sealed up about nine hundred years earlier. The explorer Aurel Stein acquired it in 1907 and brought it to London. It is a map in one object: a religion born in India, carried by monks and merchants across Central Asia, translated into Chinese and multiplied by Chinese printing technology.

Look closely

- Find the Buddha on his throne and the kneeling old man. Which one is teaching?
- Look at the fine lines of the clothing and the canopy. Remember that all of this was carved backward into a block of wood.
- Find the lions or guardian figures. Why might a book begin with such a grand picture?
- Compare this to a printed Bible page from Gutenberg’s Bible (about 1455). Which is older, and by how much?

Talk about it

1. How does this scroll show diffusion along the Silk Road? Name every “move” it represents (place, language, technology).

2. Why would printing help a universalizing religion spread? What did printing later do for the Reformation in Europe?
3. Why might a Christian geographer take care to describe the Buddhist meaning of this object accurately?

PROJECT: A WORLD RELIGION MAP: CHOROPLETH AND DOTS

You will make two maps of the same data and discover what each one hides. The first colors each country by its majority religion (a choropleth map). The second uses dots for the people of each faith, so that large minorities appear.

You will need

- Two printed blank world maps with country borders
- Colored pencils (six colors) and a fine black pen
- The data table your parent or teacher prepares from the Pew Research Center's religious-composition tables for at least 30 countries (include India, Indonesia, Nigeria, China, the United States, Brazil, Egypt, Iran, Thailand, Japan, Israel, Germany, Russia, the Philippines)
- A calculator and ruler

Steps

1. Choose a color for each group: Christian, Muslim, Hindu, Buddhist, Jewish, unaffiliated or folk religion. Make a key.
2. Map 1 (choropleth): color each of your 30 countries by its largest religious group. Shade darker if the majority is above 80%.
3. Map 2 (dot map): let one dot equal 10 million people. For each country, compute how many dots each group gets (round to the nearest dot) and draw them inside the country.
4. Compare: list three countries where Map 1 hides a large minority that Map 2 shows (for example India, Nigeria, Egypt's Coptic Christians).
5. Add the hearths of the six religions from the lesson figure to Map 2 with a star.
6. Draw arrows for at least three diffusion routes: Christianity from Jerusalem, Islam from Mecca, Buddhism from Bodh Gaya.
7. Write a paragraph: Which map is more honest for which question? What kind of map would you need to show practice or attendance rather than identity?

Tips

- Countries with very large populations (China, India) will need many dots; plan space before you draw.
- Small countries may not get even one dot at this scale. Note them instead of forcing a dot.

Check your work

- Both maps have a key and correct data for 30 countries.
- My dot counts are correctly computed and rounded.
- My hearths and diffusion arrows are placed correctly.
- My paragraph compares the two maps fairly.

MAP NOTEBOOK

1. Draw a two-column chart titled “Universalizing / Ethnic” and place at least seven religions in it with their hearths.
2. Sketch the route of Buddhism from Bodh Gaya to Japan and of Islam from Mecca to Indonesia on one outline map of Asia.
3. Draw a simple floor plan of three houses of worship (a church, a mosque, a synagogue) from pictures or a visit, and mark the direction each faces or the focus of its worship.

> **From history.** In the 200s BC the Mauryan emperor Ashoka, who ruled most of the Indian subcontinent, turned to Buddhism after a bloody war against the kingdom of Kalinga. He had edicts carved on rock faces and on tall polished stone pillars across his empire, urging moral conduct, and he sent teachers abroad; tradition holds that his son Mahinda carried Buddhism to Sri Lanka. The edicts are among the oldest deciphered writings of India; they were first read in modern times by the British scholar James Prinsep in 1837. The lion capital from Ashoka’s pillar at Sarnath, where the Buddha first preached, is the national emblem of India today.

WORKED EXAMPLES

Example 1. Indonesia had about 280 million people in the mid-2020s, and its census reports that about 87% are Muslim. About how many Muslims live in Indonesia? About how many of the world’s 2.0 billion Muslims is that, as a percent?

1. Muslims in Indonesia: 0.87 × 280 million ≈ 244 million.
2. Share of the world’s Muslims: 244 ÷ 2,000 ≈ 0.12.
3. So roughly one Muslim in eight lives in Indonesia, far from Islam’s Arabian hearth.
4. Geographic reason: Islam came to the islands mainly through merchants and teachers on the Indian Ocean trade routes from the 1200s onward (expansion diffusion by trade, not conquest).

Answer: About 244 million Muslims, roughly 12% of all Muslims, the largest number in any country.

Example 2. In Nepal's 2021 census about 81% of the people were Hindu. Hindus are about 15% of the world's population, and about 1% of the U.S. population. Find the location quotient (LQ) of Hindus in Nepal and in the United States, using the world as the base.

1. LQ = local share ÷ base share.
2. Nepal: 81 ÷ 15 = 5.4.
3. United States: 1 ÷ 15 ≈ 0.07.
4. An LQ above 1 shows concentration; far below 1 shows scarcity. Hinduism, an ethnic religion, is strongly concentrated in its hearth region.

Answer: Nepal: LQ ≈ 5.4 (more than five times the world share). United States: LQ ≈ 0.07.

Example 3. Using rounded Pew figures, the world's Muslim population grew from about 1.7 billion in 2010 to about 2.0 billion in 2020. Find the average annual growth rate and the doubling time at that rate. Give one reason the projection may not hold.

1. Ten-year growth factor: 2.0 ÷ 1.7 ≈ 1.176.
2. Annual factor: $1.176^{1/10}$. ln 1.176 ≈ 0.163, ÷ 10 = 0.0163, so about 1.6% per year.
3. Doubling time: 0.693 ÷ 0.0163 ≈ 43 years (rule of 70: 70 ÷ 1.6 ≈ 44).
4. Main cause: Muslims have a younger population and higher fertility on average than the world as a whole, so most of the growth comes from births, not conversion.
5. Limit: fertility is falling in many Muslim-majority countries (Iran, Turkey, Bangladesh), so the rate is likely to slow; a constant-rate model ignores the demographic transition (Unit 2).

Answer: About 1.6% per year, a doubling time of about 43 years, but falling fertility makes it unlikely the rate will stay constant.

PRACTICE

1. EASY Classify each as universalizing or ethnic: Christianity, Hinduism, Islam, Judaism, Buddhism, Shinto, Sikhism.
2. EASY Name the hearth city or region of Christianity, Islam, Buddhism and Sikhism.
3. EASY Rank the three largest religions in the world in 2020 by number of adherents (do not count the religiously unaffiliated), and give the rounded number for each.
4. EASY What event in 622 begins the Islamic calendar, and what is it called?
5. MEDIUM Name the three main branches of Buddhism and one country or region where each predominates.
6. MEDIUM Name four countries with Shia Muslim majorities. Roughly what share of the world's Muslims are Sunni?

7. MEDIUM Using the hearth map, which hearth lies farthest east? Which two Buddhist sites lie closest to Varanasi? Through which oasis city on the map did Buddhism pass just before reaching Chang’an?
   (Use the map or drawing “Use the points and the dashed Silk Road route.” shown earlier in this lesson.)
8. MEDIUM India has about 1.4 billion people, of whom about 14% are Muslim. About how many Muslims live in India? Why does a map coloring India by its majority religion mislead on this point?
9. MEDIUM A Pew survey counts someone as “religiously unaffiliated.” Does that mean the person is an atheist? Explain.
10. HARD Buddhism began in India but is a small minority there today, while Christianity began in Judea and is a small minority in Israel and the Palestinian territories. Give one historical reason for each.
11. HARD In 1947 the partition of British India along religious lines displaced some 14 to 15 million people. Explain, as a geographer, why drawing a border by religion caused such large movements.
12. CHALLENGE Write a paragraph explaining why a Christian geographer should describe other religions accurately, and how Acts 17 models doing so while still speaking plainly of the gospel.

COMMON MISTAKES

- Equating Arabs with Muslims. Most Muslims are not Arabs; Indonesia, Pakistan, India and Bangladesh have the largest Muslim populations, and there are Arab Christians in Egypt, Lebanon, Syria and elsewhere.
- Assuming every person in a country shares the majority religion shown on a choropleth map. Minorities can number in the tens or hundreds of millions.
- Treating “unaffiliated” as the same as “atheist,” or treating a survey answer as proof of practice. Surveys measure identity, not depth of belief or attendance.

> **Make it a game · Hearth and Route.** Make three sets of cards: religions (Judaism, Christianity, Islam, Hinduism, Buddhism, Sikhism, Shinto), hearths (Land of Israel, Jerusalem, Mecca, Indus and Ganges plains, Bodh Gaya, Punjab, Japan) and “where today” facts (Indonesia, India and Nepal, Thailand, Brazil, Iran, Amritsar, Israel and the U.S.). Shuffle each set face down in rows. Players turn over one card from each row; a correct three-card match of religion, hearth and region scores 3 points and the player keeps the cards. Play until all matches are made.

> **Scripture.** “And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation; That they should seek the Lord, if haply they might feel after him, and find him, though he be not far from every one of us:” (Acts 17:26–27, KJV)

Paul spoke these words in Athens, a city full of altars. The religious map is a map of the human search for God, and Paul’s answer is that the Creator has set the nations in their

places so that they might seek Him and find Him.

Practice answers

1. Universalizing: Christianity, Islam, Buddhism, Sikhism. Ethnic: Hinduism, Judaism, Shinto.
2. Christianity: Jerusalem and Judea. Islam: Mecca (and Medina) in Arabia. Buddhism: northeastern India (Bodh Gaya), with the Buddha's birthplace at Lumbini in Nepal. Sikhism: the Punjab (Amritsar).
3. Christians (about 2.3 billion), Muslims (about 2.0 billion), Hindus (about 1.2 billion). The unaffiliated (about 1.9 billion) are not a religion but would fall between Muslims and Hindus.
4. The Hijra, Muhammad's move from Mecca to Medina.
5. Theravada: Sri Lanka, Myanmar, Thailand, Laos or Cambodia. Mahayana: China, Korea, Japan or Vietnam. Vajrayana: Tibet, Mongolia or Bhutan.
6. Iran, Iraq, Azerbaijan, Bahrain. Roughly 85 to 90% of Muslims are Sunni.
7. Ise in Japan (Shinto) lies farthest east. Bodh Gaya and Lumbini lie closest to Varanasi. Buddhism passed through Dunhuang before reaching Chang'an.
8. 0.14 × 1,400 million ≈ 196 million, about 200 million, one of the largest Muslim populations in the world. A majority-religion map colors all of India Hindu and hides this huge minority.
9. No. "Unaffiliated" means the person does not identify with any religion. The group includes atheists and agnostics, but many unaffiliated people say they believe in God or practice folk religion without belonging to a religious body.
10. Buddhism in India: it was absorbed and outcompeted by a revived Hinduism over many centuries, and Muslim invasions around 1200 destroyed great monasteries such as Nalanda, its centers of learning. Christianity in its hearth: Roman suppression after the Jewish revolts, the Arab conquest of the 600s and centuries of Muslim rule shrank the Christian population, and in modern times many Christians emigrated.
11. Hindus, Muslims and Sikhs were intermixed across much of the Punjab and Bengal, so any line left millions on the "wrong" side. Fear and violence pushed them to cross to the state of their own faith (forced relocation migration), producing one of the largest migrations of the twentieth century and hundreds of thousands of deaths. Religion did not fall into neat regions, so a political boundary drawn by religion cut through mixed communities.
12. A strong answer says that the ninth commandment forbids false witness, so misrepresenting others' beliefs is a sin as well as bad scholarship; that accurate description is needed to understand a region and to love one's neighbors; and that Paul in Acts 17 observed the Athenians' altars carefully, quoted their own poets and began from what they knew (the altar "TO THE UNKNOWN GOD") before proclaiming the Creator who "hath made of one blood all nations of men" and calling them to repent. Accuracy and conviction go together: the Christian describes fairly and then says plainly what he believes is true (John 14:6).

4.4 Sacred Places and Pilgrimage

OBJECTIVES

- Describe the sacred sites of Jerusalem, Rome, Mecca and Varanasi, the faiths that honor them, and the history that shaped each place.
- Explain pilgrimage as a form of circulation and use simple spatial models (distance decay and the gravity model) and calendar reasoning to analyze pilgrim flows.
- Explain how transportation technology changed pilgrimage, and evaluate pilgrimage from a biblical perspective (Psalm 122; John 4:21–24).

Warm-up. Think of a place your family has traveled to because it meant something, not just for fun: a grandparent's grave, the church where your parents were married, a battlefield, a historic church. On a scrap of paper, write how far away it was, how you traveled and how long it took. Then guess how long the same trip would have taken on foot in AD 400 at about 20 miles (30 km) a day.

Watch. *Pilgrimage Church of Wies - UNESCO World Heritage Site* (World Heritage Journey, 3:36). https://www.youtube.com/watch?v=mQhu7KP2OS8
After the story: tour this Bavarian pilgrimage church and notice how a place becomes a destination that over a million pilgrims still travel to each year.
Note: Captions were not available to check; preview it first. The church was built to house a wooden statue of Jesus said to have wept, and the video presents that devotion without comment.

Backup video. *The Importance of Capernaum in the Bible | Bible Backroads | Drive Thru History with Dave Stotts* (Drive Thru History with Dave Stotts, 5:11).
https://www.youtube.com/watch?v=rrt7JPBha18
With the big idea: visit Capernaum with Dave Stotts and look for why this town by the Sea of Galilee became a place pilgrims still come to see. Note: Captions were not available to check; preview it first.

KEY TERMS

pilgrimage
A journey to a sacred place for religious reasons, such as worship, a vow, thanksgiving or devotion.

sacred space
A place set apart and given special religious meaning by a faith community, such as a temple site, a tomb, a river or a mountain.

circulation
Short-term, repeated or round-trip movement (commuting, seasonal travel, pilgrimage), as distinct from migration, which is a permanent move.

distance decay
The decline in interaction between two places as the distance between them grows.

gravity model
A model that predicts the interaction between two places to be proportional to the product of their populations divided by the square of the distance between them.

Hajj
The pilgrimage to Mecca, held each year in the Islamic month of Dhu al-Hijjah, which Muslims are to make once in their lives if they are able.

CORE IDEAS

The story. In about AD 381 a Christian woman named Egeria, probably from the far west of the Roman Empire, perhaps Gallaecia in northwest Spain, set out on a journey that lasted about three years. She climbed Mount Sinai at dawn, visited Egypt and Edessa, and spent long months in Jerusalem, and she wrote it all down in a long letter to her "sisters" at home. Her letter is our best eyewitness account of worship in fourth-century Jerusalem. She describes the bishop leading the people down from the Mount of Olives on Palm Sunday with branches in their hands, and the great services of Holy Week in the churches Constantine had built over Golgotha and the tomb of Christ. She even notes the geography of language: the bishop preached in Greek, and a presbyter translated into Syriac for those who knew only that tongue. The only surviving copy of her letter, missing its beginning and end, was discovered in 1884 in a library in Arezzo, Italy.

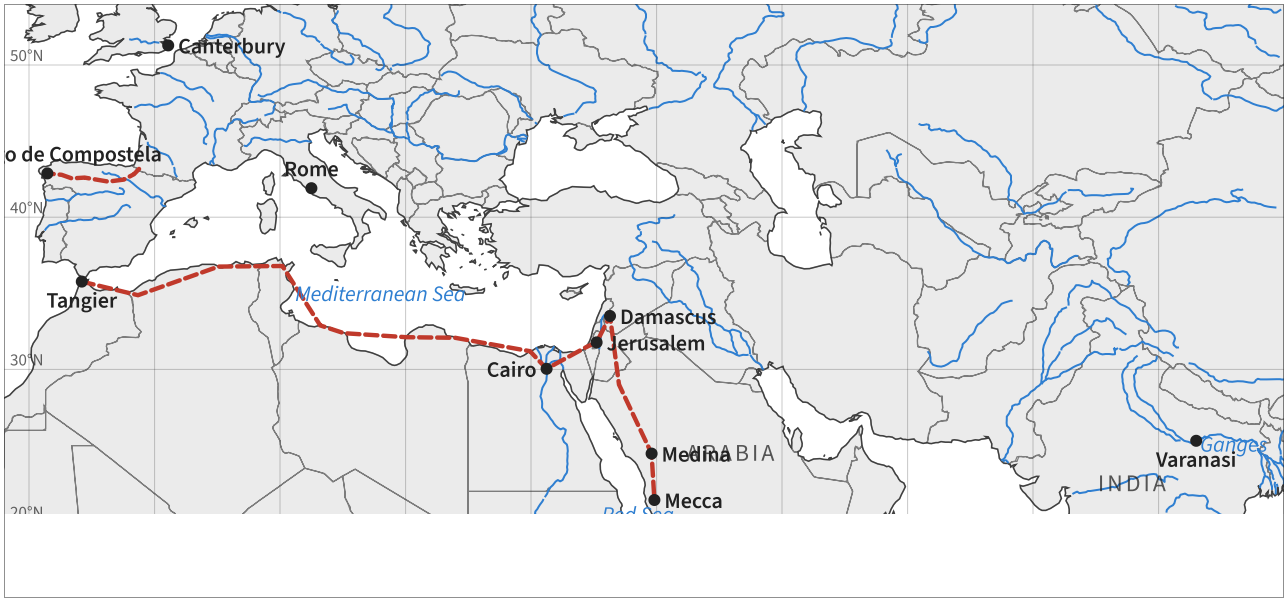
How it worked. Geographers call pilgrimage a form of **circulation**, round-trip movement rather than permanent migration. Like any flow, it obeys **distance decay**: most pilgrims to a shrine come from nearby, and fewer from far away, unless the shrine is of the very highest rank. Medieval Europe built a whole network for pilgrims, with roads, bridges, hospices run by monks, and guidebooks. The road across northern Spain to Santiago de Compostela, where the tomb of the apostle James was said to have been found in the early 800s, became one of the great routes of Christendom, and its scallop-shell badge still marks the way. In England, after Archbishop Thomas Becket was murdered in his cathedral in 1170, Canterbury drew so many pilgrims that Geoffrey Chaucer framed *The Canterbury Tales* (late 1300s) around a company riding there from London.

Jerusalem and Rome. Jerusalem is sacred to three faiths within a walled Old City of less than one square kilometer, its present walls built by the Ottoman sultan Suleiman the Magnificent between 1537 and 1541. For Jews, the Western Wall is a remaining retaining wall of the Temple Mount that Herod enlarged, near the site of the Temple destroyed by Rome in AD 70. For Christians, the Church of the Holy Sepulchre, first dedicated under Constantine in 335, covers the places of the crucifixion and the empty tomb; six Christian communities share it under an old Ottoman arrangement called the Status Quo, so strictly that a wooden ladder has stood on a ledge above the entrance since at least the 1700s. For Muslims, the Dome of the Rock, completed in 691–692, and the Al-Aqsa Mosque stand on the platform above the Western Wall. The city has known terrible violence: the First Crusade took it in 1099 and massacred many of its Muslim and Jewish inhabitants, and Saladin retook

it in 1187. Since 1967 Israel has governed the whole city; its status remains disputed internationally, and as of 2026 most countries keep their embassies in Tel Aviv, though the United States moved its embassy to Jerusalem in 2018. Rome became a pilgrim city because of the tombs of the apostles Peter and Paul, both martyred there by tradition under Nero. Constantine raised a basilica over Peter's grave, replaced by the present St. Peter's Basilica between 1506 and 1626. Pope Boniface VIII proclaimed the first Jubilee Year in 1300, and Jubilees still draw vast crowds, as in 2025. A young monk named Martin Luther visited Rome as a pilgrim in 1510–1511 and was troubled by what he saw; seven years later his Ninety-five Theses against the sale of indulgences began the Reformation.

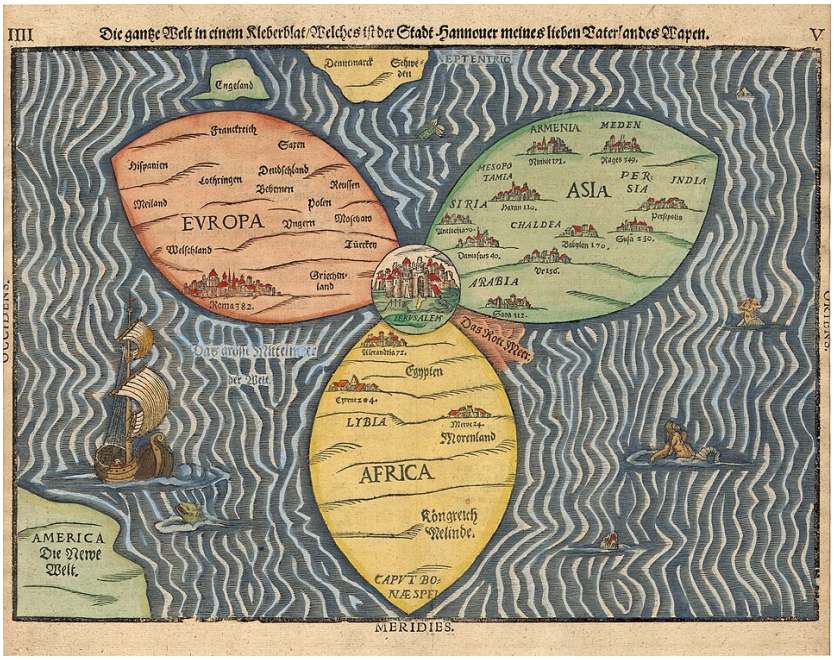
Mecca and Varanasi. Mecca, in a dry valley of western Arabia, holds the Kaaba, the cube-shaped shrine that Muslims believe Abraham and Ishmael built. Muslims everywhere face it in prayer, so the direction of Mecca (the *qibla*) is fixed in every mosque; from North America the shortest, great-circle direction points northeast, not southeast as a flat map suggests. The Hajj is one of the Five Pillars of Islam. Saudi law closes Mecca to non-Muslims. Because the Islamic calendar is lunar, about 354 days long, the Hajj comes about eleven days earlier each year; about 1.8 million pilgrims took part in 2024. Varanasi, also called Kashi or Benares, stands on the west bank of the Ganges, the river Hindus revere above all others. Long stone stairways called *ghats* line the river for miles; pilgrims bathe at dawn, and at the burning ghats the dead are cremated, since many Hindus believe that dying in Kashi brings release from the cycle of rebirth. Its history too is candid: the Mughal emperor Aurangzeb destroyed the Kashi Vishwanath temple in 1669 and built a mosque on part of its site; the temple that stands today was built nearby in 1780 by the Maratha queen Ahilyabai Holkar. Just outside the city lies Sarnath, where the Buddha preached his first sermon.

The big idea. Sacred places shape maps far beyond themselves: roads, inns, trade, city economies and even borders. Technology has changed pilgrimage more than anything since Egeria. Steamships and the Suez Canal (1869) carried tens of thousands of pilgrims to Arabia each year, and jet travel now brings millions, so that Saudi Arabia sets national quotas to manage the crowds. The Bible honors pilgrimage in its place: Israelite men were to go up to the place the LORD chose for three feasts each year, and the Psalms of Ascent (Psalms 120–134) were sung on the road. Yet Jesus told the woman at the well, "the hour cometh, when ye shall neither in this mountain, nor yet at Jerusalem, worship the Father" (John 4:21), for "God is a Spirit: and they that worship him must worship him in spirit and in truth" (John 4:24). The Reformers rejected pilgrimage as a way to earn merit, though Christians of every tradition still travel to the Holy Land to walk the places of Bible history and come home reading Scripture with new eyes.



Sacred cities and two pilgrim routes: the Camino Francés to Santiago and Ibn Battuta's journey to Mecca (1325–1326).

PICTURE STUDY



The World in a Cloverleaf (Die ganze Welt in einem Kleberblat), Heinrich Bünting, 1581 · Woodcut, often hand-colored, printed in Bünting's *Itinerarium Sacrae Scripturae* (Travels through Holy Scripture), first published at Helmstedt in 1581, with many later editions, including Magdeburg · Copies in many libraries, including the National Library of Israel, Jerusalem

Heinrich Bünting was a German Lutheran pastor who wrote a geography of the Bible, tracing the travels of everyone from Abraham to the apostles and measuring them in German miles. Among its woodcut maps is this famous one, which draws the three continents of the Old World as the leaves of a clover with Jerusalem at the center. It is said to honor the arms of Hanover, Bünting's home city, whose emblem was a cloverleaf.

Bünting knew perfectly well that the world was not shaped like a clover; his book also had ordinary maps. This one is a picture of meaning rather than measurement, following the old Christian habit of placing Jerusalem at the center of the world, as the Hereford map had done around 1300. A large mosaic copy of it is set in the pavement of Safra Square, beside Jerusalem's city hall.

Look closely

- Find Jerusalem in the center. How does Bünting make it look important?
- Name the three leaves. Which continent is on top?
- Find England, Scandinavia and the piece of America in the corners. Why are they drawn outside the clover?
- Look at the sea around the clover. What ships or creatures can you find?

Talk about it

1. What is the difference between a map that shows where places are and a map that shows what places mean? Is one more "true" than the other?
2. Why would a pastor who was writing about Bible journeys put Jerusalem at the center?
3. If a Muslim mapmaker or a Hindu mapmaker drew a "map of meaning," what might be at the center?

PROJECT: A PILGRIM'S ROUTE PLANNER

You will plan a real pilgrimage route of the past, measure it on a map with string, and work out how long it took on foot, by sailing ship, by steamship and by airplane. You will finish with a short pilgrim's journal written in the voice of Egeria, Ibn Battuta or a medieval walker on the Camino.

You will need

- A printed map of Europe, North Africa and the Middle East with a scale bar
- String, a ruler and a fine marker
- A calculator
- A notebook for the journal
- Optional: a pedometer or phone step counter

Steps

1. Choose one route: (a) Egeria, from northwest Spain to Jerusalem; (b) Ibn Battuta, from Tangier to Mecca by way of Cairo and Damascus; (c) the Camino Francés from Saint-Jean-Pied-de-Port to Santiago.
2. Lay the string along the route, following coasts and valleys as a traveler would, not a straight line. Mark the string at the end, straighten it along the scale bar and record the distance in km and miles.
3. Compute travel time at four speeds: walking 30 km (about 19 miles) a day; a medieval sailing ship averaging 80 km (50 miles) a day on the sea legs; a steamship of about

1900 averaging 400 km (250 miles) a day; a jet at 800 km/h (500 mph) on a straight-line flight.
4. Make a table of your results and a bar graph comparing the four times.
5. Walk one measured mile (or 1.6 km) and time yourself. How many hours a day would you need to walk to cover 19 miles? What would slow a real pilgrim?
6. Write three journal entries (each about 150 words) in the voice of your pilgrim: setting out, a hard day on the road, and arriving. Use real places and real details from the lesson.

Tips

- A string route is always longer than a straight line; that is the point of measuring it.
- Real pilgrims waited for caravans, ships and good weather. Ibn Battuta's trip from Tangier to Mecca took about a year and a half.

Check your work

- My route is drawn on the map with correct cities in order.
- My distances are measured with the scale bar and given in both km and miles.
- My travel-time table is correctly calculated for all four modes.
- My journal entries use accurate historical details.

MAP NOTEBOOK

1. Draw a plan of Jerusalem's Old City as a rough rectangle divided into four quarters (Christian, Muslim, Jewish, Armenian) and mark the Church of the Holy Sepulchre, the Western Wall and the Dome of the Rock in their approximate places.
2. On a sketch of a globe, draw the great-circle route from your home to Mecca and the straight line on a flat Mercator map. Label which way the qibla really points.
3. Draw a scallop shell, the badge of Santiago pilgrims, and beside it the symbol of a pilgrimage in another faith from the lesson.

> **From history.** In June 1325 a young legal scholar of twenty-one named Ibn Battuta left his home in Tangier, Morocco, to make the Hajj. He traveled along the North African coast to Alexandria and Cairo, tried to reach Arabia by way of the Red Sea, turned back, and finally went north through Palestine, where he visited Jerusalem, to Damascus, and then south with the great pilgrim caravan to Medina and Mecca, which he reached in the autumn of 1326. He did not go home for nearly a quarter century. His travels took him to Persia, East Africa, Anatolia, the Central Asian steppe, India, the Maldives and China, a distance usually estimated at about 75,000 miles. After his return he dictated his account, the *Rihla*, to the scholar Ibn Juzayy in Fez in the 1350s.

WORKED EXAMPLES

Example 1. The Camino Francés runs about 780 km (485 miles) from Saint-Jean-Pied-de-Port in the French Pyrenees to Santiago de Compostela. A pilgrim walks 25 km (about 15.5 miles) a day and takes one rest day after every six walking days. How many days does the journey take? How long would it take at 20 miles (32 km) a day?

(Use the map or drawing "The Camino Francés runs west across northern Spain." shown earlier in this lesson.)

1. Walking days: 780 ÷ 25 = 31.2, so 32 walking days (the last day is short).
2. Rest days: one after each 6 walking days. 32 ÷ 6 = 5.33, so 5 full blocks of six days, each followed by rest: 5 rest days.
3. Total: 32 + 5 = 37 days, a little over five weeks.
4. At 20 miles a day: 485 ÷ 20 = 24.25, so 25 walking days, plus 4 rest days (25 ÷ 6 = 4.2) = 29 days.

Answer: About 37 days at 25 km a day with rest days; about 29 days at 20 miles a day.

Example 2. The Islamic calendar has 12 lunar months, about 354 days. In 2024 the Hajj began on about 14 June. (a) About when did it begin in 2025? (b) After how many years does the Hajj move through all the seasons and return to about the same date?

1. Difference between solar and lunar years: 365 − 354 = 11 days.
2. (a) 14 June − 11 days ≈ 3 June 2025. (It actually began on 4 June 2025; months begin with the sighting of the new moon, so the shift is 10 to 12 days.)
3. (b) To move back a full solar year: 365 ÷ 11 ≈ 33 years.
4. Consequence: in some decades the Hajj falls in the extreme heat of an Arabian summer and in others in the milder winter, which changes how authorities plan for the pilgrims' safety.

Answer: (a) About 3–4 June 2025. (b) About 33 years for the Hajj to cycle through all the seasons.

Example 3. Use the gravity model, interaction $\propto (P_1 \times P_2) \div d^2$, to compare pilgrim flows to the same shrine from two cities. City A has 4 million people and lies 400 km from the shrine. City B has 10 million people and lies 1,000 km away. Which sends more pilgrims, and by what factor?

1. The shrine's own size (P_2) is the same for both, so compare $P \div d^2$.
2. City A: $4{,}000{,}000 \div 400^2 = 4{,}000{,}000 \div 160{,}000 = 25$.
3. City B: $10{,}000{,}000 \div 1{,}000^2 = 10{,}000{,}000 \div 1{,}000{,}000 = 10$.
4. Ratio: $25 \div 10 = 2.5$.
5. Limits: the model ignores cost and ease of travel, the share of each city that belongs to the faith, visa quotas and the special pull of the highest-rank shrines (the Hajj draws from every continent).

Answer: City A, the smaller but nearer city, sends about 2.5 times as many pilgrims. Distance decay outweighs size here.

PRACTICE

1. EASY Why do geographers classify pilgrimage as circulation rather than migration?
2. EASY Match each site to its city and faith: the Kaaba; the Western Wall; St. Peter's Basilica; the ghats on the Ganges; the Church of the Holy Sepulchre; the Dome of the Rock.
3. EASY Who was Egeria, and why is her letter valuable to historians?
4. MEDIUM The straight-line distance from Jerusalem to Mecca is about 1,240 km (770 miles). A caravan of the Middle Ages covered about 30 km (19 miles) a day. How many days would the trip take at that pace? Why would the real trip take longer?
5. MEDIUM Using the map of sacred cities, which of the marked cities lies farthest east? Which lies farthest west? Which pairs of marked cities are less than 400 km apart? *(Use the map or drawing "Compare the positions of the marked cities." shown earlier in this lesson.)*
6. MEDIUM Many pilgrims walk only the last 100 km of the Camino, the minimum distance on foot for the certificate called the Compostela. From Sarria it is about 115 km to Santiago. At 20 km (12.4 miles) a day, how many walking days is that?
7. MEDIUM Use the gravity model to compare two source cities for the same shrine: City X has 2 million people at 200 km; City Y has 8 million people at 800 km. Which sends more pilgrims, and by what factor?
8. MEDIUM The Hajj began on about 14 June 2024. Estimate when it began in 2026.
9. HARD Explain why Jerusalem's sacred sites have so often been places of conflict. Use at least two historical examples from the lesson and keep your answer factual.
10. HARD Explain how technology changed the geography of the Hajj between 1300 and today. Name three technologies and their effect.
11. HARD A Muslim in Chicago prays facing Mecca. On a flat Mercator map, Mecca appears to the east-southeast of Chicago, yet mosques in Chicago face northeast. Explain why.

12. CHALLENGE Write a paragraph explaining how the Bible treats sacred places and pilgrimage. Use Psalm 122 and John 4:21–24, and explain why many Christians still visit the Holy Land.

COMMON MISTAKES

- Thinking pilgrimage belongs to only one religion. Jews, Christians, Muslims, Hindus, Buddhists and Sikhs all have sacred places and journeys, though they understand them differently.
- Reading a straight line on a Mercator map as the shortest route. Pilgrim flights and the Muslim qibla follow great circles, which look curved on a Mercator map.
- Forgetting that the Islamic calendar is lunar. The Hajj and Ramadan move about 11 days earlier each year against our calendar.

Make it a game · Which City Am I?. One player secretly chooses a sacred city from the lesson (Jerusalem, Rome, Mecca, Medina, Varanasi, Santiago, Canterbury, Amritsar, Bodh Gaya). The others ask yes-or-no questions about its geography only: “Are you on a river?” “Are you north of 35° N?” “Are you in Asia?” “Do pilgrims reach you by an ancient road?” Guess the city in ten questions or fewer to score a point; the player who stumps the group with only geography questions scores two.

Scripture. “I was glad when they said unto me, Let us go into the house of the LORD. Our feet shall stand within thy gates, O Jerusalem.” (Psalm 122:1–2, KJV)

This is one of the Psalms of Ascent, sung by pilgrims on the road up to Jerusalem for the feasts. Its joy is in meeting God among His people. Jesus later taught that true worship is “in spirit and in truth” in every place, but the gladness of going up together to worship is the same in any church on the Lord’s Day.

Practice answers

1. Pilgrims make a round trip and return home; migration is a permanent (or long-term) change of residence.
2. Kaaba: Mecca, Islam. Western Wall: Jerusalem, Judaism. St. Peter’s Basilica: Rome, Christianity (Catholic). Ghats: Varanasi, Hinduism. Church of the Holy Sepulchre: Jerusalem, Christianity. Dome of the Rock: Jerusalem, Islam.
3. A Christian woman, probably from the western Roman Empire (perhaps northwest Spain), who traveled to Sinai, Egypt and Jerusalem around AD 381–384. Her letter is the best eyewitness account of worship in fourth-century Jerusalem, including Palm Sunday and Holy Week.
4. 1,240 ÷ 30 ≈ 41 days (770 ÷ 19 ≈ 41). The real trip was longer because caravans followed wells and oases rather than a straight line, rested, and waited to travel in large, protected groups.
5. Varanasi is farthest east; Santiago de Compostela is farthest west. Two pairs are less than 400 km apart: Mecca and Medina (about 340 km) and Jerusalem and Damascus (about 220 km).
6. 115 ÷ 20 = 5.75, so 6 walking days.

7. X: 2,000,000 ÷ 200^2 = 2,000,000 ÷ 40,000 = 50. Y: 8,000,000 ÷ 800^2 = 8,000,000 ÷ 640,000 = 12.5. City X sends 50 ÷ 12.5 = 4 times as many.
8. Two years earlier by about 11 days each: 14 June − 22 days ≈ 23 May 2026. (It began on about 25 May 2026; moon sighting shifts the date by a day or two.)
9. The same small area is sacred to Jews, Christians and Muslims, so control of it carries deep meaning for all three, and sites sit literally on top of one another (the Dome of the Rock and Al-Aqsa on the Temple Mount above the Western Wall). Examples: Rome destroyed the Temple in AD 70; the First Crusade took the city in 1099 with a massacre of Muslim and Jewish inhabitants; Saladin retook it in 1187. Even among Christians, the six communities sharing the Holy Sepulchre need the strict Status Quo arrangement. Since 1967 Israel has governed the city, and its status remains disputed internationally.
10. In Ibn Battuta's day pilgrims walked or rode in caravans for many months, so the Hajj drew mostly from nearby lands and the journey was dangerous. The steamship and the opening of the Suez Canal in 1869 cut sea voyages from India, Southeast Asia and North Africa to weeks and multiplied the numbers. Railways (such as the Hejaz Railway to Medina, opened 1908) and later motor roads helped overland pilgrims. Jet aircraft now bring pilgrims from every continent in hours, so the numbers reach millions and Saudi Arabia limits them by national quotas. Technology overcame distance decay, though not completely: cost and quotas still limit who can go.
11. The qibla is the direction of the shortest path over the globe, the great-circle route. Great circles between distant points in the Northern Hemisphere bend poleward on a Mercator map, so the shortest route from Chicago to Mecca sets off toward the northeast, over the North Atlantic, rather than following the straight Mercator line (a rhumb line), which is longer.
12. A strong answer says that God commanded Israel to go up to the place He chose for the three great feasts and that pilgrims sang Psalms such as Psalm 122 ("I was glad when they said unto me, Let us go into the house of the LORD") on the road to Jerusalem; that Jesus told the Samaritan woman that the hour was coming when the Father would be worshiped neither on Gerizim nor at Jerusalem but "in spirit and in truth," because God is a Spirit, so no place on earth is needed for true worship or for salvation; that the Reformers therefore rejected pilgrimage as a way of earning merit; and that Christians still visit the Holy Land to see the real places where the events of Scripture happened, which strengthens their understanding of Bible history and geography.

Unit 4 test

Answer every question. Show your work for calculations, give units, and use complete sentences for explanations. A calculator is allowed. The test is worth 100 points.

1. (6 pts) Define *language family*, *cognate* and *lingua franca*, and give an example of each.
2. (6 pts) Place each language in its family (and, for Indo-European, its branch): Russian, Arabic, Tamil, Swahili, Finnish, Bengali.
3. (8 pts) Using Grimm's law (Latin p, t, k, d usually answer to English f, th, h, t), give the native English cognates of Latin *pater*, *tres*, *cornu* and *pes, pedis*. Then explain why English *paternal* does not follow the rule.
4. (8 pts) In a certain state, 18% of residents age 5 and older speak Spanish at home; nationally the figure is about 13%. In another state the figure is 2%. Find the location quotient for each state and interpret both.
5. (6 pts) The Austronesian family stretches from Madagascar (about 47.5° E) east to Easter Island (about 109.4° W). How many degrees of longitude is that? Name one other region where Austronesian languages are spoken.
6. (6 pts) Give one example from the history of the Church of each kind of diffusion: relocation, hierarchical and contagious.
7. (8 pts) In Rodney Stark's model the number of Christians grew 40% per decade. (a) Find the doubling time. (b) If there were 1,000 Christians in AD 40, about how many would the model give for AD 200? (c) Name one limit of the model.
8. (6 pts) In 1910 about 66% of the world's roughly 600 million Christians lived in Europe; in 2010 about 26% of roughly 2.18 billion did. Did the number of Christians in Europe go up or down? Show your work and explain the difference between a count and a share.
9. (8 pts) Classify Christianity, Islam, Hinduism, Judaism and Buddhism as universalizing or ethnic, and name the hearth of each.
10. (8 pts) Nigeria has about 230 million people, roughly half Christian and half Muslim. (a) About how many Christians and how many Muslims is that? (b) Describe the broad regional pattern of the two faiths within Nigeria. (c) Explain why a map coloring each country by its majority religion would mislead a reader about Nigeria.
11. (6 pts) Name the three branches of Buddhism and the two main branches of Islam, with one country where each branch predominates. Which branch of Islam is larger?
12. (8 pts) The Islamic year is about 354 days. (a) Why does the Hajj come about 11 days earlier each year on our calendar? (b) If the Hajj begins on 25 May one year, about when will it begin three years later? (c) After about how many years does it return to the same season?
13. (6 pts) Use the gravity model (interaction $\propto P \div d^2$ for the same destination) to compare two cities sending pilgrims to the same shrine: City P has 3 million people at 300 km; City Q has 12 million at 900 km. Which sends more, and by what factor? Name one thing the model leaves out.

14. (10 pts) Essay. Jerusalem is sacred to three faiths. In one or two paragraphs, name the chief sacred site of each faith in the Old City and explain why it matters to that faith; give one historical example of conflict over the city; and explain how John 4:21–24 shapes a Christian's view of sacred places.

UNIT PROJECT: AN ATLAS OF LANGUAGE AND FAITH

Assemble a four-plate atlas, each plate a hand-drawn map on its own sheet with a title, key, scale bar and north arrow: (1) the world's major language families, with the Indo-European tree in an inset; (2) the spread of Christianity from Jerusalem, with Paul's journeys and at least ten later dated sites; (3) the world's religions, as a majority-religion map with dot symbols for major minorities and the hearths starred; (4) four sacred cities and two historic pilgrim routes. Include your cognate cards, diffusion-grid graphs and pilgrim's journal from the lesson projects.

Finish with a one-page essay explaining what these maps show about how God has "determined the times before appointed, and the bounds of their habitation" (Acts 17:26), and what the maps cannot show (belief, practice, the movement of the heart), using at least four numbers from the unit.

- **Accuracy**: Families, branches, hearths, cities, routes and dates are placed and labeled correctly; numbers are rounded and sourced.
- **Cartography**: Each plate has a clear title, key, scale bar and north arrow, readable labels and a sensible choice of map type (choropleth, dot, flow).
- **Analysis**: The essay uses at least four figures from the unit, names the limits of the models and data, and describes other faiths fairly and exactly.
- **Care and conviction**: The atlas is neat and complete, and the essay connects the maps thoughtfully to Acts 17:26–27 without forcing the text.

Answer key

1. Language family: languages descended from one ancestor (Indo-European). Cognate: words in different languages from the same ancestral word (Latin *pater*, English *father*). Lingua franca: a language used between people with different native languages (English in aviation; Swahili in East Africa; Latin in medieval Europe). 2 points each.
2. Russian: Indo-European, Balto-Slavic. Arabic: Afro-Asiatic. Tamil: Dravidian. Swahili: Niger-Congo (Bantu). Finnish: Uralic. Bengali: Indo-European, Indo-Iranian. 1 point each.
3. *father*, *three*, *horn*, *foot* (1.5 points each). *Paternal* was borrowed from Latin (through French) long after the Germanic sound shift, so it keeps the Latin p (2 points).
4. First state: $18 \div 13 \approx 1.4$, Spanish at home is about 40% more concentrated than in the nation. Second state: $2 \div 13 \approx 0.15$, Spanish at home is much less common than the national share. 4 points each (2 for computation, 2 for interpretation).
5. $(180 - 47.5) + (180 - 109.4) = 132.5 + 70.6 = 203.1°$, a little more than half the globe (4 points). Any of: Indonesia, Malaysia, the Philippines, Taiwan, Hawaii, New Zealand, Polynesia, Micronesia (2 points).
6. Relocation: believers scattered from Jerusalem by persecution "went every where preaching the word" (Acts 8:4); also migrants and missionaries. Hierarchical: Paul planting churches in

the great cities (Antioch, Ephesus, Corinth, Rome), or the baptism of rulers such as Clovis (about 496) or Vladimir (988). Contagious: the faith passing from neighbor to neighbor into the countryside around the cities. 2 points each.

7. (a) $\ln 2 \div \ln 1.4 \approx 0.693 \div 0.336 \approx 2.06$ decades, about 21 years (3 points). (b) 16 decades: $1{,}000 \times 1.4^{16} \approx 1{,}000 \times 218 \approx 218{,}000$ (3 points). (c) The starting number and rate are estimates with no census behind them, and real growth was not steady (2 points).
8. 1910: $0.66 \times 600 \approx 396$ million. 2010: $0.26 \times 2{,}180 \approx 567$ million (3 points). The number went up by about 170 million, but Europe's share fell because Christianity grew much faster in Africa, Latin America and Asia. A count is how many; a share is what fraction of the whole (3 points).
9. Christianity: universalizing, Jerusalem and Judea. Islam: universalizing, Mecca and Medina in Arabia. Hinduism: ethnic, the Indus and Ganges plains of India. Judaism: ethnic, the Land of Israel. Buddhism: universalizing, northeastern India (Bodh Gaya), with the Buddha's birthplace at Lumbini, Nepal. 1 point for each correct classification (5 points) and 3 points for the five hearths (subtract 1 for each wrong or missing hearth).
10. (a) About 115 million of each (2 points). (b) Muslims predominate in the north and Christians in the south (3 points). (c) A single color for the whole country hides the fact that about half the population belongs to the other faith and that the two are regionally divided; scale matters (3 points).
11. Theravada (Thailand, Sri Lanka, Myanmar), Mahayana (China, Japan, Korea, Vietnam), Vajrayana (Tibet, Mongolia, Bhutan); Sunni (Saudi Arabia, Egypt, Indonesia, Pakistan, Turkey), Shia (Iran, Iraq, Azerbaijan, Bahrain). Sunni is larger, roughly 85 to 90% of Muslims. 1 point for each branch with a correct country (5 points) and 1 point for naming Sunni as larger.
12. (a) The Islamic calendar is lunar; 12 lunar months are about 354 days, 11 days shorter than the solar year (2 points). (b) 25 May − 33 days ≈ 22 April (3 points). (c) $365 \div 11 \approx 33$ years (3 points).
13. P: $3{,}000{,}000 \div 90{,}000 \approx 33.3$. Q: $12{,}000{,}000 \div 810{,}000 \approx 14.8$. City P sends about 2.25 times as many (4 points). Left out: cost or ease of transport, the share of each city that belongs to the faith, quotas, the special pull of a top-ranked shrine (2 points).
14. Judaism: the Western Wall, a retaining wall of the Temple Mount near the site of the Temple destroyed in AD 70 (2 points). Christianity: the Church of the Holy Sepulchre, over the sites of the crucifixion and the empty tomb, first dedicated under Constantine in 335 and shared by six Christian communities (2 points). Islam: the Dome of the Rock (691–692) and Al-Aqsa Mosque on the Temple Mount platform (2 points). Conflict: the Roman destruction of AD 70, the Crusader capture and massacre of 1099, Saladin's reconquest of 1187, or the disputed modern status since 1967, stated neutrally (2 points). John 4: Jesus taught that true worshipers worship the Father "in spirit and in truth," not tied to Gerizim or Jerusalem, so Christians value the Holy Land as the real setting of Bible history but do not need any place to meet God or earn merit (2 points).

UNIT 5

Political Geography

The world map is covered with lines, and every one of them was drawn by someone, for some reason, at some date. Political geography asks how the land surface of the earth came to be divided into about two hundred sovereign states, why their borders fall where they do, how each state divides power inside its own territory, and why states join together in larger organizations. Scripture tells us that God “hath determined the times before appointed, and the bounds of their habitation” (Acts 17:26); this unit studies how those bounds have been drawn, defended, argued over and redrawn in recorded history.

You will begin in 1648 in the Westphalian towns of Münster and Osnabrück, where exhausted diplomats ended the Thirty Years’ War and set the pattern of sovereign states that still shapes the map. You will follow the Tordesillas line of 1494 across the Atlantic and see why Brazil speaks Portuguese, measure the 49th parallel, and learn the zones of the Law of the Sea. You will sit with the delegates in Philadelphia in 1787 as they invented American federalism and compare their answer with unitary France and Japan. Finally you will stand in San Francisco in 1945, Washington in 1949 and Paris in 1950, at the births of the United Nations, NATO and the European Union, and weigh fairly what states gain and give up when they pool their sovereignty.

As in every unit of this course, models and categories (the Westphalian system, Hartshorne’s boundary types, centripetal and centrifugal forces) are taught as tools to be tested against real cases, not as laws. Current affairs are dated “as of 2026” and presented neutrally. Lesson 5.5 is the course **midterm examination**, covering Units 1–5, which is published separately; the unit test below may be given in the session before it or used as midterm review.

BEFORE YOU BEGIN

- Can read latitude and longitude and use a map scale (Unit 1)
- Can calculate population density and percent change (Units 1–2)
- Knows the outline of European and American history from about 1500 to 1950
- Is comfortable writing a reasoned paragraph that presents more than one view

MASTERY CHECKLIST

- I can define state, nation, nation-state and sovereignty, and explain why the Peace of Westphalia (1648) is a milestone of the modern state system.
- I can classify the shape of a state and calculate its density and elongation.
- I can classify boundaries as antecedent, subsequent, superimposed or relic, and as physical, cultural or geometric, with real examples.
- I can convert the zones of the Law of the Sea between nautical miles, kilometers and miles and find a median line.

- I can explain the difference between unitary, federal and confederal states and calculate representation in the U.S. Congress and Electoral College.
- I can describe the founding and purpose of the UN, NATO and the EU and present the arguments for and against pooling sovereignty fairly.

OPTIONAL BOOKS AND RESOURCES

- **The Avalon Project, Yale Law School** (https://avalon.law.yale.edu/): Free. Full texts of the Treaty of Westphalia, the U.S. Constitution, the Federalist Papers, the North Atlantic Treaty and the UN Charter. Use it to read the actual words of Article 5, the Tenth Amendment and *Federalist* Nos. 45 and 51.
- **The Constitution of the United States, National Archives** (https://www.archives.gov/founding-docs/constitution): Free. High-resolution images and a transcript of the Constitution as signed in 1787, with the Bill of Rights and later amendments (Lesson 5.3).
- **Charter of the United Nations** (https://www.un.org/en/about-us/un-charter): Free. The full text of the 1945 Charter. Read the Preamble and Chapter V (the Security Council) for Lesson 5.4.

5.1 States, Nations and Sovereignty

OBJECTIVES

- Define state, nation, nation-state, multinational state, multistate nation and stateless nation, and classify real examples correctly.
- Explain what the Peace of Westphalia (1648) settled, why it is called the starting point of the modern state system, and where that label goes too far.
- Describe the shapes of states (compact, elongated, prorupted, perforated, fragmented, landlocked) and calculate the population density and elongation of real states.

Warm-up. Take a sheet of paper and write two headings: **Things that make a country** and **Things that make a people**. In five minutes, sort these words under the headings: army, language, border, flag, shared history, passport, favorite songs, tax collector, church traditions, embassy. Which words could go under both? Keep the list; by the end of the lesson you will have the proper names for your two headings: *state* and *nation*.

Watch. *24th October 1648: Peace of Westphalia ends the Thirty Years' War that ravaged Europe* (HistoryPod, 2:27). https://www.youtube.com/watch?v=uS-jBe8Tpww
After the story: watch how the Peace of Westphalia ended the Thirty Years' War in 1648, and listen for how the treaties redrew borders and recognized the sovereignty of states.
Note: Captions were not available to check; preview it first. The video says the war took up to eight million lives through battle, hunger and disease.

Backup video. *Ten Minute History - The Thirty Years' War (Short Documentary)* (History Matters, 9:59). https://www.youtube.com/watch?v=EBLVzdvp8qE
As review: follow the Thirty Years' War from the revolt in Bohemia to the peace of 1648, and listen for why it laid the foundations of modern diplomacy. Note: Captions were not available to check; preview it first. It is a fast-paced ten-minute overview of a long and deadly war.

KEY TERMS

state
A politically organized territory with a permanent population, defined borders, a government and sovereignty, able to deal with other states. In everyday speech, a "country."

nation
A large group of people who see themselves as one people because of a shared language, history, faith, customs or ancestry. A nation is a people, not a territory.

nation-state
A state whose territory closely matches the homeland of one nation, such as Japan or Iceland.

sovereignty
Final authority over a territory and its people, free from control by any outside power.

stateless nation
A nation without a state of its own, such as the Kurds, whose homeland lies across Turkey, Iraq, Iran and Syria.

multistate nation
A nation whose people live in two or more states, such as the Koreans in North and South Korea.

CORE IDEAS

The story. On May 23, 1618, a group of Protestant nobles in Prague climbed to a high window of Prague Castle and threw two of the Catholic emperor's officials and their secretary out of it. All three survived the fall. That "Defenestration of Prague" lit the fuse of the **Thirty Years' War**, which began as a quarrel over religion and rule inside the Holy Roman Empire and grew into a struggle among the great powers of Europe: the Habsburg emperor and Spain on one side; Sweden, France, the Dutch and many German Protestant princes on the other. Armies lived off the land, burned villages and spread disease and hunger. By common estimates the German lands lost between a fifth and a third of their people. Peace talks opened in the mid-1640s in two Westphalian towns about 30 miles (45 km) apart: Catholic powers met at **Münster**, Protestant powers at **Osnabrück**. In 1648 the treaties were finally signed. Together they are called the **Peace of Westphalia**.

What the treaties settled. The peace ended the Thirty Years' War, and the Peace of Münster between Spain and the Dutch Republic ended the Eighty Years' War (1568–1648). Spain recognized the Dutch Republic as independent, and the Swiss Confederation was recognized as free of the Empire. Sweden gained lands on the Baltic and North Sea coasts, and France gained the bishoprics of Metz, Toul and Verdun and most of Alsace. Inside the Empire, the rule of the Peace of Augsburg (1555), that a prince decided the official church of his land, was confirmed and extended to Calvinists, with 1624 set as the "normal year" for deciding which churches held which property. The roughly three hundred German princes and free cities gained the right to make alliances with foreign powers, as long as those alliances were not aimed at the emperor. In practice, the emperor could no longer command the princes as a single ruler, and no pope or emperor could overrule the kings of Europe in their own lands.

The big idea. Geographers and historians call the system that grew out of 1648 the **Westphalian state system**: the world is divided into territories, each ruled by a **sovereign** government that is legally equal to the others and has final authority inside its borders. That is still the basic plan of the world map. Its modern legal checklist comes from the Montevideo Convention of 1933: a state has a permanent population, a defined territory, a government and the capacity to enter into relations with other states. As of 2026 the United Nations has 193 member states, and two more, the Holy See and Palestine, are non-member observer states. A few territories, such as Taiwan and Kosovo, govern themselves but are recognized as states by only part of the world, which shows that recognition is a political act

as well as a legal one. Like every model in this course, the Westphalian model has limits. The treaties hardly used the word sovereignty; the Holy Roman Empire survived until 1806; and the tidy picture of equal, independent states was built up over the next two centuries. “Westphalia” is best understood as a convenient milestone, not a single switch that turned on the modern world.

State and nation are not the same. A **state** is a territory with a government; a **nation** is a people. When the two match closely we have a **nation-state**: Japan, where about 97 percent of the people are Japanese and the language and history are shared, or Iceland, settled by Norse families in the 800s and still almost entirely Icelandic. Most states are **multinational**. The United Kingdom joins the English, Scots, Welsh and Northern Irish; Switzerland joins German, French, Italian and Romansh speakers. Some nations are split across several states: the Koreans have lived in two states since 1948. Some have no state at all: the Kurds, estimated at 30 million or more, live mostly where Turkey, Iraq, Iran and Syria meet. The idea that every nation should have its own state, called **self-determination**, spread after the French Revolution and helped redraw the map after both World Wars. It has united some peoples and divided others, because almost no line on the ground separates peoples cleanly.

On the map. The territory of a state also has a **shape**, and shape affects how hard a state is to govern and defend. A **compact** state, such as Poland or Uruguay, has its borders at roughly equal distance from the center. An **elongated** state, such as Chile, is long and thin, so its far ends are hard to connect. A **prorupted** state has a long arm sticking out, such as Thailand’s strip down the Malay Peninsula or Afghanistan’s Wakhan Corridor. A **perforated** state completely surrounds another: South Africa surrounds Lesotho, and Italy surrounds both San Marino and Vatican City. A **fragmented** state is broken into pieces, such as Indonesia, spread over more than 17,000 islands, or the United States with Alaska and Hawaii apart from the other 48 states. A **landlocked** state, such as Bolivia or Switzerland, has no sea coast and depends on neighbors for ports. Pieces of a state cut off by foreign land, such as Russia’s Kaliningrad, are called **exclaves**. Size does not change sovereignty: Russia and Vatican City are equally sovereign in law.

A Christian reading. Scripture teaches that God “hath made of one blood all nations of men” and “hath determined the times before appointed, and the bounds of their habitation” (Acts 17:26). Nations and their borders are not accidents; they rise and fall under His providence. Yet no state is ultimate. The men of Westphalia, exhausted by thirty years of war fought partly in the name of faith, chose to let each ruler settle religion inside his own borders as the price of peace. Christians may weigh that settlement honestly: it ended a terrible war and laid the groundwork for later ideas of toleration, yet it also tied the church closely to the power of the prince. Either way, sovereignty on earth is always a borrowed authority, answerable to the King of kings.

The peace congress met in two towns: Catholic powers at Münster and Protestant powers at Osnabrück. Modern borders are shown for reference.

PICTURE STUDY

The Swearing of the Oath of Ratification of the Treaty of Münster, 15 May 1648, Gerard ter Borch, 1648 · Oil on copper · National Gallery, London (NG896); on long-term loan to the Rijksmuseum, Amsterdam

Gerard ter Borch was a young Dutch painter who traveled to Münster during the peace talks and was there when the Spanish and Dutch envoys swore to keep the Peace of Münster on May 15, 1648, in the town hall. He painted the scene on a small copper plate, only about 18 by 23 inches, and filled it with careful portraits of the real delegates.

The painting records the moment when Spain, after eighty years of war, recognized the Dutch Republic as a free and sovereign state. It is one of the few paintings of a real diplomatic event made by an eyewitness in the very year it happened.

Look closely

- Find the men with raised right hands. Two delegations, Spanish and Dutch, are swearing the oath. Can you find clues that tell the two groups apart?
- Look at the documents on the table. What do you think is written on them?
- Count how many faces you can see. Why might the painter have taken such care to make each face a real portrait?
- Notice the dark clothing and plain room. Does this look like a celebration, or like a solemn promise?

Talk about it

1. Why would the Dutch want an eyewitness painting of this moment?
2. An oath is a promise made before God. Why might both sides have chosen to seal a peace treaty with an oath rather than only with signatures?
3. What does this painting show about sovereignty: who is recognizing whom?

PROJECT: EUROPE IN 1648: AN OVERLAY MAP

You will draw the main political pieces of Europe as the Peace of Westphalia left them, then lay a modern map underneath to see which lines survived and which disappeared. This is the oldest trick in political geography: compare two maps of the same place at two dates.

You will need

- A printed outline map of modern Europe (free from many atlas sites) or a page traced from an atlas
- Tracing paper or baking parchment the same size
- Colored pencils and a fine black pen
- A historical atlas or a reliable online map of Europe in 1648 (ask a parent to help you find one)

Steps

1. Tape the tracing paper over the modern outline map so the coastlines show through. Trace the coasts and the main rivers (Rhine, Elbe, Danube, Oder).
2. Using the historical map, draw the outer border of the Holy Roman Empire in 1648 with a heavy line. Shade it lightly.
3. Color the Dutch Republic and the Swiss Confederation in their own colors, and label them “sovereign, recognized 1648.”
4. Mark Sweden’s new German lands (Western Pomerania at the mouth of the Oder, and Bremen and Verden near the mouth of the Elbe and Weser) in Sweden’s color.

5. Mark the lands France gained (Metz, Toul, Verdun and most of Alsace) in France's color.
6. Put a star at Münster and Osnabrück, and draw a dotted line between them. Measure the line with your map scale and write the distance.
7. Lift the tracing paper and lay it over the modern map again. With a green pen, circle three 1648 borders that still exist today in about the same place, and with a red pen circle three that have disappeared.
8. On the back, write a paragraph: Which of the states on your 1648 map were nation-states, and which were multinational?

Tips

- Do not try to draw all three hundred little German states. Shade the Empire as one region and let the big pieces tell the story.
- The Swiss and Dutch borders of 1648 are close to their modern borders, which makes them good anchors for lining up the two maps.

Check your work

- I can show on a map what the Peace of Westphalia changed.
- I can find at least one border from 1648 that survives today.
- I can explain why the Holy Roman Empire was not a nation-state.

MAP NOTEBOOK

1. Draw a Venn diagram with one circle labeled State and one labeled Nation. Place Japan, the Kurds, the Koreans, the United Kingdom and Iceland where they belong, and write one sentence explaining each placement.
2. Sketch the outlines of six states from an atlas, one for each shape: compact (Poland), elongated (Chile), prorupted (Thailand), perforated (South Africa), fragmented (Indonesia) and landlocked (Bolivia). Label each shape.
3. Copy the four Montevideo criteria for a state into your notebook. Beside each, give one example of what can go wrong when a would-be state lacks it.

> **From history.** Pope Innocent X objected to the religious terms of the peace and issued a formal protest, the bull *Zelo domus Dei*, dated November 1648, declaring the articles harmful to the Catholic Church null and void. The signing powers, Catholic France and Catholic Austria among them, went ahead anyway. Historians often point to this moment as a sign that the papacy's old role as an arbiter among Christian princes had ended, and that the rulers of Europe now treated questions of war and peace as matters for sovereign states alone.

WORKED EXAMPLES

Example 1. Monaco covers about 2.0 km² (0.78 sq mi) and has about 38,000 residents. Vatican City covers about 0.44 km² (0.17 sq mi) and has about 800 residents. Find the population density of each in people per km² and per square mile, and say how many times denser Monaco is.

1. Density = population ÷ area.
2. Monaco: 38,000 ÷ 2.0 km² = 19,000 people per km². Per square mile: 38,000 ÷ 0.78 ≈ 48,700 people per sq mi.
3. Vatican City: 800 ÷ 0.44 km² ≈ 1,800 people per km². Per square mile: 800 ÷ 0.17 ≈ 4,700 people per sq mi.
4. Ratio: 19,000 ÷ 1,800 ≈ 10.5.

Answer: Monaco ≈ 19,000 per km² (≈ 48,700 per sq mi); Vatican City ≈ 1,800 per km² (≈ 4,700 per sq mi). Monaco is about 10 times as dense. Both are fully sovereign states despite their tiny size.

Example 2. The United Nations had 51 original member states in 1945. As of 2026 it has 193. By what factor has membership grown, and what is the percent increase? In 1960 alone 17 states joined, most of them newly independent African states, bringing the total to 99. How many members were there at the start of 1960?

1. Growth factor = 193 ÷ 51 ≈ 3.78.
2. Percent increase = (193 − 51) ÷ 51 × 100 = 142 ÷ 51 × 100 ≈ 278%.
3. Members before the 1960 admissions = 99 − 17 = 82.

Answer: Membership grew by a factor of about 3.8, an increase of about 278%. There were 82 members at the start of 1960. Most of the growth came from the end of European overseas empires, which multiplied the number of sovereign states on the map.

Example 3. Chile is about 4,300 km (2,670 mi) long from north to south but averages under 180 km (110 mi) wide. Poland is roughly 650 km (400 mi) from west to east and 650 km from north to south. Compute the elongation ratio (length ÷ average width) of each and classify their shapes.

1. Chile: 4,300 ÷ 180 ≈ 24. (In miles: 2,670 ÷ 110 ≈ 24.)
2. Poland: 650 ÷ 650 = 1.
3. A ratio near 1 means compact; a large ratio means elongated.

Answer: Chile's ratio is about 24, an elongated state; Poland's is about 1, a compact state. Chile's capital, Santiago, is over 1,200 miles (about 2,000 km) by road from its far north and farther still from its far south, which is why Chile depends on sea and air links to hold together.

PRACTICE

1. EASY Define sovereignty in one sentence.
2. EASY In what year was the Peace of Westphalia signed, in which two towns was it negotiated, and which two wars did it end?
3. EASY List the four qualities of a state named in the Montevideo Convention of 1933.
4. MEDIUM Classify each as a nation-state, multinational state, multistate nation or stateless nation: (a) Japan (b) the Kurds (c) the Koreans (d) the United Kingdom.
5. MEDIUM Iceland covers about 103,000 km² (39,800 sq mi) and has about 380,000 people. Find its density per km² and per square mile.
6. MEDIUM Name the shape of each state: (a) Chile (b) Indonesia (c) South Africa (d) Thailand (e) Poland (f) Bolivia.
7. MEDIUM Use the map (he-westphalia-map). In which direction would a courier ride from Münster to Osnabrück, and roughly how far?
   (Use the map or drawing "Münster and Osnabrück, the two towns of the peace congress." shown earlier in this lesson.)
8. MEDIUM Lesotho covers about 30,000 km² (11,600 sq mi) and lies entirely inside South Africa. Name two geographic facts that make Lesotho's position unusual, and one way it depends on its neighbor.
9. HARD Russia covers about 17.1 million km² and Vatican City about 0.44 km². How many Vatican Cities would fit inside Russia? What does international law say about the sovereignty of the two?
10. HARD Explain the principle confirmed from the Peace of Augsburg (1555) at Westphalia, and two ways Westphalia changed it.
11. HARD Why are Taiwan and Kosovo hard cases for the Montevideo checklist? Answer neutrally.
12. CHALLENGE Write a short paragraph (5–7 sentences) weighing this claim: "The modern world of sovereign states began in 1648." Give evidence for and against.

COMMON MISTAKES

- Using “nation” and “state” as if they meant the same thing. A state is a governed territory; a nation is a people. The Kurds are a nation without a state.
- Thinking Westphalia created nation-states. It recognized sovereign rulers and territories; most of the states of 1648 were dynastic and multinational, and the nation-state ideal came later.
- Assuming a small state has less sovereignty than a large one. Monaco and Russia are equally sovereign in law, though very unequal in power.

Make it a game · State, Nation or Both?. Make twenty index cards, each with one name: Japan, Iceland, the Kurds, the Koreans, the United Kingdom, Switzerland, Vatican City, the Basques, Poland, Lesotho, and ten more from an atlas. Shuffle. Players take turns drawing a card and must say within ten seconds whether it is a nation-state, a multinational state, a multistate nation or a stateless nation, and why. A correct answer with a reason scores 2 points; a correct answer without a reason scores 1. Bonus point: name the shape of the state (compact, elongated, prorupted, perforated, fragmented or landlocked).

Scripture. “And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;” (Acts 17:26, KJV)

Paul spoke these words in Athens. Nations (peoples) come from one human family, and their times and boundaries lie under God’s providence. States rise and fall, but none is ultimate.

Practice answers

1. Sovereignty is final authority over a territory and its people, free from control by any outside power.
2. 1648; Münster and Osnabrück; the Thirty Years’ War (1618–1648) and the Eighty Years’ War between Spain and the Dutch (1568–1648).
3. A permanent population, a defined territory, a government, and the capacity to enter into relations with other states.
4. (a) Nation-state. (b) Stateless nation. (c) Multistate nation (North and South Korea). (d) Multinational state (English, Scots, Welsh, Northern Irish).
5. 380,000 ÷ 103,000 ≈ 3.7 people per km²; 380,000 ÷ 39,800 ≈ 9.5 people per sq mi.
6. (a) Elongated. (b) Fragmented. (c) Perforated (it surrounds Lesotho). (d) Prorupted. (e) Compact. (f) Landlocked.
7. Northeast, about 30 miles (45 km).
8. It is landlocked, and it is an enclave completely surrounded by one other state (making South Africa a perforated state). It depends on South Africa for access to ports, trade routes and much of its commerce and employment.
9. 17,100,000 ÷ 0.44 ≈ 38.9 million Vatican Cities. Under international law both are equally sovereign states; size does not change legal sovereignty.

10. The ruler of each land decided its official church. Westphalia extended the rule to include Calvinists (not only Lutherans and Catholics) and set 1624 as the “normal year” for deciding which church held which property, which gave some protection to religious minorities against later changes by their prince.
11. Each has a permanent population, territory and its own government, but neither is a UN member and each is recognized as a state by only part of the world. This shows that, in practice, statehood depends partly on recognition by other states, which is a political decision.
12. A strong answer notes evidence for: the peace recognized Dutch and Swiss independence, gave German princes the right to make alliances, ended the claim of emperor or pope to overrule rulers in their own lands, and treated Catholic and Protestant powers as negotiating equals. Evidence against: the treaties hardly use the word sovereignty; the Holy Roman Empire continued until 1806; most of the world was not organized as sovereign states for centuries more; and the idea of equal sovereign states developed gradually. A balanced conclusion calls 1648 an important milestone rather than a single beginning.

5.2 Boundaries

OBJECTIVES

- Classify boundaries by origin (antecedent, subsequent, superimposed, relic) and by form (physical, cultural, geometric), using real examples.
- Explain the four stages of making a boundary and the four common types of boundary dispute.
- Calculate distances along parallels and convert the zones of the Law of the Sea between nautical miles, kilometers and miles.

Warm-up. Look at a fence, hedge, curb or property line near your home. Who decided where it goes? Is it marked on the ground, only on paper, or both? Now think of a line between two rooms in your house that “belong” to different people. Is it a wall (a physical line) or an agreement (an invisible line)? In five minutes, sketch the boundary and write how you would settle a quarrel about it.

Watch. *Tordesillas - How the Pope divided the world between Spain and Portugal* (Kings and Generals, 18:50). https://www.youtube.com/watch?v=o1Qllx4YH9A
After the story: watch the animated maps show the pope's 1493 line and how Spain and Portugal moved it in the Treaty of Tordesillas, and look for where the final line fell.
Note: Captions were not available to check; preview it first. The video is about 19 minutes long and very likely opens with an Audible sponsor message; skip it.

KEY TERMS

antecedent boundary
A boundary drawn before the area was heavily settled, such as the 49th parallel between the western United States and Canada.

subsequent boundary
A boundary drawn after settlement, often to follow differences of language or religion that already existed, such as the India–Pakistan border of 1947.

superimposed boundary
A boundary imposed on an area by outside powers, with little regard for the peoples living there, such as most borders drawn in Africa after the Berlin Conference of 1884–85.

relic boundary
A boundary that no longer functions but can still be seen in the landscape, such as the remains of the Berlin Wall.

geometric boundary
A straight-line boundary drawn along a line of latitude or longitude or between two points, ignoring the land beneath it.

exclusive economic zone (EEZ)

The sea area up to 200 nautical miles from a state's coast in which it controls fishing, oil, gas and other resources, under the UN Convention on the Law of the Sea (1982).

CORE IDEAS

The story. In March 1493 Christopher Columbus sailed home from the Caribbean with news of lands across the Atlantic, and Spain and Portugal, the two great seafaring powers of the day, nearly came to blows over who could claim them. Pope Alexander VI drew a line in 1493 running from pole to pole 100 leagues west of the Azores and Cape Verde Islands, giving Spain the lands to the west. The Portuguese king, John II, protested that the line left too little sea room for his ships on the long voyage to Africa and India. So the two crowns negotiated directly, and on June 7, 1494, at the town of **Tordesillas** in Castile, they signed a treaty moving the line to 370 leagues west of the Cape Verde Islands, somewhere near 46 to 47 degrees west longitude. No one in 1494 knew that South America bulged east across that line. In April 1500 the Portuguese captain Pedro Álvares Cabral, swinging far west on his way to India, struck the coast of Brazil and claimed it for Portugal. That is why the largest country in South America speaks Portuguese while nearly all its neighbors speak Spanish.

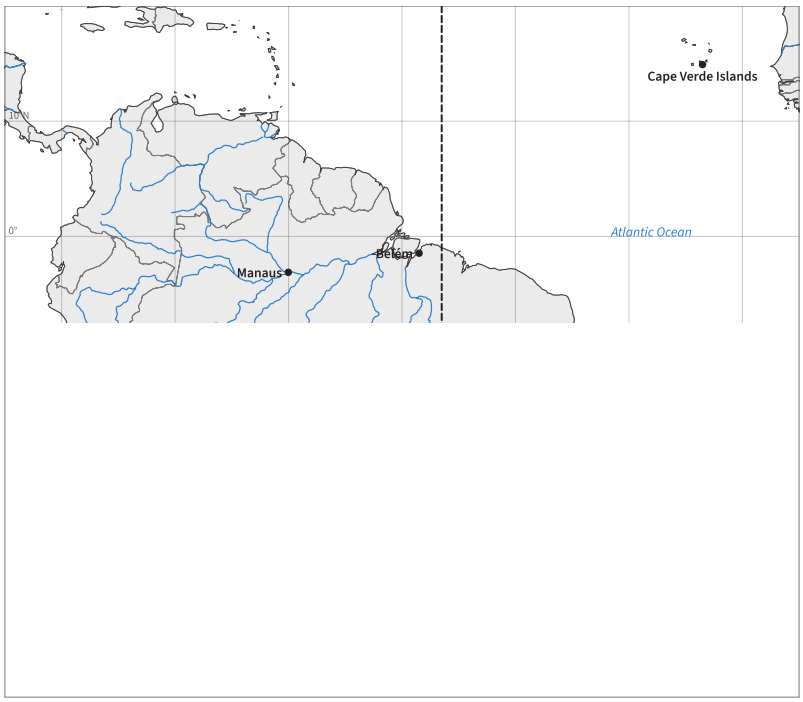
How it worked out. The Tordesillas line was a **geometric** and **superimposed** boundary: a straight line drawn by distant powers across lands they had never seen, ignoring the many native peoples who lived there. Nobody could measure longitude accurately at sea for another two and a half centuries, so the line could never be marked on the ground. Instead, settlers pushed past it. Portuguese explorers and slave-raiding expeditions from São Paulo, the **bandeirantes**, moved deep into the interior hunting for gold and capturing native people to sell, and missionaries, ranchers and traders followed. By the Treaty of Madrid in 1750, Spain and Portugal abandoned the old line and agreed instead that each would keep the lands its people actually held. Brazil's western border today lies more than 1,000 miles (1,600 km) west of the line of 1494.

The big idea. A **boundary** is the vertical plane where one state's sovereignty ends and another's begins; it runs up into the airspace and down beneath the ground. In the 1930s the American geographer Richard Hartshorne classified boundaries by when they were drawn. An **antecedent** boundary came before most settlement: the 49th parallel, agreed by Britain and the United States in 1818 east of the Rockies and extended west to the Pacific in the Oregon Treaty of 1846, crossed prairie and mountain where few settlers yet lived. A **subsequent** boundary came after settlement and tries to follow the peoples already there, as the India–Pakistan border of 1947 tried, with great bloodshed, to separate Muslim-majority from Hindu-majority districts. A **superimposed** boundary is forced on a region by outside powers, as most African borders were after the Berlin Conference of 1884–85 (studied in Course A). A **relic** boundary no longer works as a border but survives in the landscape, like the stretches of the Berlin Wall left standing after it was opened on November 9, 1989. Boundaries can also be classed by form: **physical** boundaries follow rivers, mountain crests or lakes (the Rio Grande, the Pyrenees); **cultural** boundaries follow differences of language or religion; and **geometric** boundaries follow straight lines, such as the 22nd parallel north between Egypt and Sudan.

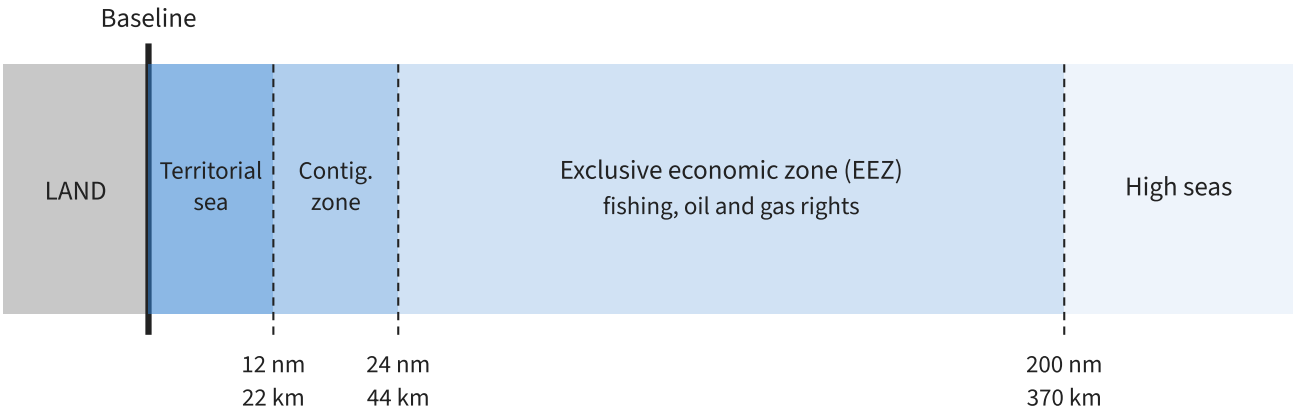
How lines are made and argued over. A boundary is built in four stages. It is **defined** in a treaty in words; **delimited** by drawing it on a map; **demarcated** on the ground with pillars, fences or buoys; and finally **administered** by border posts and officials. Disputes come in four kinds. A **definitional** dispute argues over the treaty's wording. A **locational** dispute argues over where the line actually lies, as when the Rio Grande shifted its bed at El Paso in the 1800s and left the Chamizal tract in doubt until the United States and Mexico settled it in 1963. An **operational** dispute argues over how the border works: migration, smuggling, trade. An **allocational** dispute argues over resources that cross the line, such as an oil field or a river's water.

On the map: the sea. Boundaries also run out to sea. Under the UN Convention on the Law of the Sea (1982), a coastal state measures its zones from a baseline along the coast in **nautical miles** (1 nautical mile = 1.852 km, about 1.15 statute miles). Its **territorial sea** reaches 12 nautical miles and is fully sovereign, though foreign ships may pass through peacefully. A **contiguous zone** reaches 24 nautical miles for customs and immigration control. The **exclusive economic zone** reaches 200 nautical miles, giving the state control of fishing, oil and gas but not of ordinary shipping. Where two coasts lie less than 400 nautical miles apart, their zones overlap, and states usually draw a **median line** halfway between. Because a single small island can claim a circle of sea about 166,000 square miles (431,000 km²), islands that look tiny on a globe can be worth a great deal.

Course A connection. In Course A (Geography and History) you studied why rivers, mountains and deserts so often become borders, and how surveyors ran the Mason–Dixon line and the 49th parallel. Human geography adds a hard lesson: no border is "natural" in itself. Rivers shift, mountain crests are disputed, and peoples straddle every line. A border lasts when the people on both sides, and the states behind them, accept it. Scripture honors that kind of settled line: "Remove not the ancient landmark, which thy fathers have set" (Proverbs 22:28).

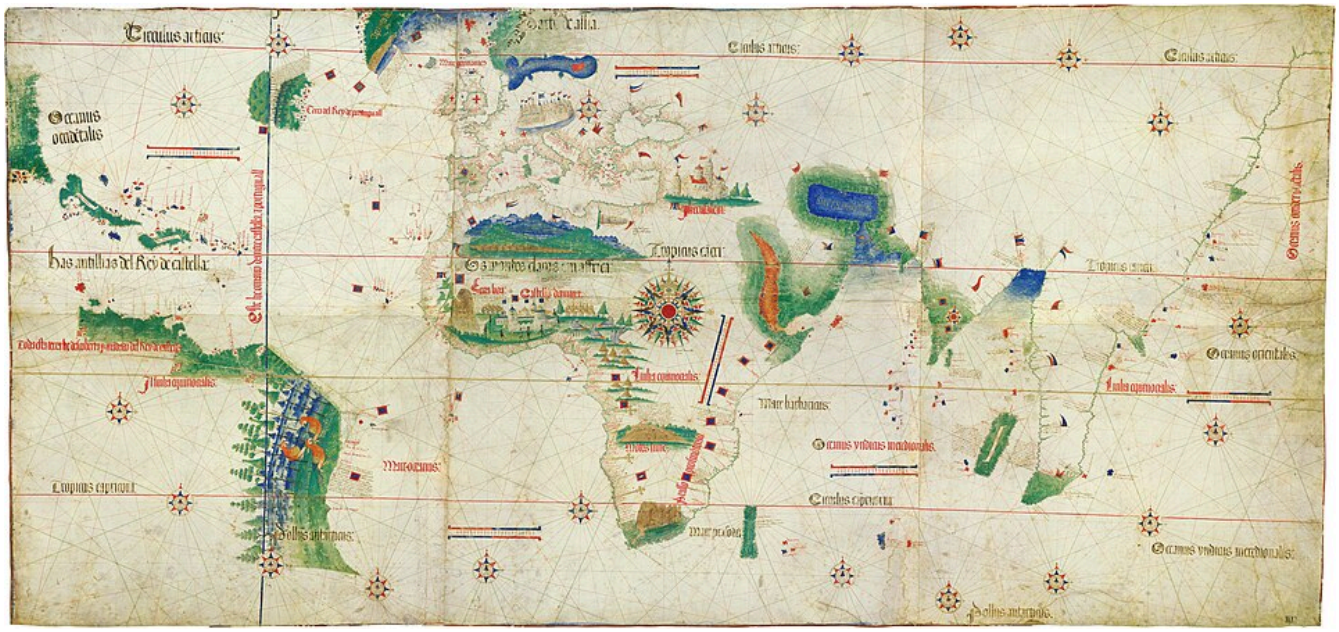


The approximate line of the Treaty of Tordesillas (1494), about 370 leagues west of the Cape Verde Islands. Experts disagree about its exact longitude because the league was not standardized.



Maritime zones under the UN Convention on the Law of the Sea (1982). Not to scale.

PICTURE STUDY



The Cantino Planisphere, Unknown Portuguese cartographer, 1502 · Ink, color and gold leaf on parchment (vellum) · Biblioteca Estense Universitaria, Modena, Italy

In 1502 an Italian agent named Alberto Cantino, working for the Duke of Ferrara, had this map smuggled out of Portugal, where the newest charts of the voyages were closely guarded state secrets. It is one of the oldest surviving maps to show the coast of Brazil, reached by Cabral only two years before, and it shows the Tordesillas line as a straight meridian running down the Atlantic.

The map is a picture of a boundary being imagined before anyone knew what lay behind it. The Portuguese side is decorated with flags and the riches they hoped to find; the line itself crosses ocean and an unknown coast.

Look closely

- Find the straight line running from top to bottom through the Atlantic. Which lands lie on each side of it?
- Look at the coast of Brazil. What did the mapmaker draw to show the new land? Why trees and birds rather than towns?
- Compare Africa’s outline with a modern map. Which parts are drawn well, and which are not?
- Find the compass roses and the lines spreading from them. How would a pilot have used them?

Talk about it

1. Why would Portugal keep its maps secret, and why would other rulers pay to steal them?

2. What does this map show about the difference between delimiting a boundary on paper and demarcating it on the ground?
3. Who lived in the lands the line divided, and were they asked?

PROJECT: DRAW, DELIMIT, DEMARCATE: A BACKYARD BOUNDARY

You will carry a boundary through all four stages, from words in a treaty to markers on the ground, and discover why border-makers argue.

You will need

- A partner (a sibling or parent)
- Ball of string, about 20 stakes or clothespins, and a tape measure
- A compass (or a phone compass app)
- Paper, ruler and pencil for the map
- A small “resource,” such as a bucket of marbles or a potted plant

Steps

1. Define: With your partner, write a one-paragraph “treaty” in words only, dividing a yard or park area between you. Use at least one physical feature (a path, a tree line) and one geometric line (for example, “due north from the oak tree”). Both sign it.
2. Delimit: Each of you, separately and without talking, draws the boundary on a sketch map of the area using only the treaty’s words. Compare maps. Mark every place where they disagree.
3. Demarcate: Walk the line together and place stakes or clothespins every few yards, using the compass for the geometric part. Settle any differences by talking and amending the treaty.
4. Administer: Place the “resource” bucket exactly on the line. Write a rule for who may use it and how.
5. Now have a parent “move the river”: shift the path or feature your treaty used (move a rope or a garden hose). Decide whether the boundary moves with it. You have just met a locational dispute.
6. Measure the length of your boundary with the tape measure and draw a final map at a stated scale (for example, 1 inch = 10 feet).

Tips

- Vague words like “near” and “along” cause most of the trouble. Real treaty writers learned to use coordinates and measured distances.
- Keep both original sketch maps. The differences between them are the best part of the project.

Check your work

- I can name and explain the four stages of boundary-making.
- I can show where a definitional or locational dispute appeared in my own boundary.

- I can draw a boundary map to scale.

MAP NOTEBOOK

1. Make a four-box chart for antecedent, subsequent, superimposed and relic boundaries. In each box, sketch a tiny map of one real example and write its date.
2. Draw the maritime zones diagram from memory, labeling 12, 24 and 200 nautical miles and the kilometer equivalent of each.
3. Trace the outline of Africa and draw three straight-line (geometric) borders you can find in an atlas. Next to each, name the two countries it separates.

> **From history.** The 49th parallel was demarcated by joint British and American survey parties. West of the Rockies the boundary commission of 1857–1861 cut a clearing through the forest and set iron and stone monuments; east of the Rockies, a second commission in 1872–1876 marked the prairie with stone cairns and earth mounds. Today the International Boundary Commission, created by treaty in 1908 and made permanent in 1925, still keeps a cleared strip about 20 feet (6 m) wide along much of the forested border, called “the Slash,” so that the line can be seen.

WORKED EXAMPLES

Example 1. Convert the three main Law of the Sea zones (12, 24 and 200 nautical miles) into kilometers and statute miles. Use 1 nautical mile = 1.852 km = 1.151 statute miles.

(Use the map or drawing “Maritime zones under the UN Convention on the Law of the Sea.” shown earlier in this lesson.)

1. Territorial sea: 12 × 1.852 = 22.2 km; 12 × 1.151 = 13.8 mi.
2. Contiguous zone: 24 × 1.852 = 44.4 km; 24 × 1.151 = 27.6 mi.
3. Exclusive economic zone: 200 × 1.852 = 370.4 km; 200 × 1.151 = 230.2 mi.

Answer: Territorial sea ≈ 22 km (14 mi); contiguous zone ≈ 44 km (28 mi); EEZ ≈ 370 km (230 mi).

Example 2. Key West, Florida, lies about 90 statute miles (145 km) from the nearest coast of Cuba. Convert to nautical miles. Do the two countries' territorial seas overlap? Do their EEZs? Where would a median line fall?

1. 90 ÷ 1.151 ≈ 78 nautical miles.
2. Two territorial seas need 12 + 12 = 24 nm. Since 78 > 24, the territorial seas do not overlap; about 54 nm of water lies between them.
3. Two full EEZs would need 200 + 200 = 400 nm. Since 78 < 400, the EEZs overlap completely in the strait.
4. A median line lies halfway: 78 ÷ 2 = 39 nm (about 45 statute miles, 72 km) from each coast.

Answer: About 78 nm. Territorial seas do not overlap, but the EEZs do, so the boundary is drawn as a median line about 39 nm (45 mi, 72 km) from each coast. The United States and Cuba signed a maritime boundary agreement along such a line in 1977.

Example 3. The U.S.–Canada boundary follows the 49th parallel from Lake of the Woods (about 95.15° W) to the Strait of Georgia (about 123.0° W). Estimate its length. One degree of longitude spans about 111.32 × cos(latitude) km.

1. Difference in longitude: 123.0 − 95.15 = 27.85°.
2. Length of 1° of longitude at 49° N: 111.32 × cos 49° = 111.32 × 0.6561 ≈ 73.0 km.
3. Length: 27.85 × 73.0 ≈ 2,034 km.
4. In miles: 2,034 ÷ 1.609 ≈ 1,264 mi.

Answer: About 2,030 km (about 1,260 miles) of straight-line geometric boundary, one of the longest in the world, drawn across land that was thinly settled when the line was agreed (1818 and 1846).

PRACTICE

1. EASY Define antecedent, subsequent, superimposed and relic boundaries in one phrase each.
2. EASY Classify by origin: (a) the 49th parallel west of the Great Lakes (b) the remains of the Berlin Wall (c) most borders of Africa drawn after 1884–85 (d) the India–Pakistan border of 1947.
3. EASY Put the four stages of boundary-making in order and give a one-word description of each.
4. MEDIUM The Strait of Gibraltar is about 14 km (9 statute miles) wide at its narrowest. Convert to nautical miles. Do Spain's and Morocco's 12-nm territorial seas overlap there? Where would a median line lie?

5. MEDIUM A small island lies more than 400 nm from any other land. Estimate the area of its EEZ (ignore the island's own size) in km² and square miles.
6. MEDIUM The Rio Grande shifted its course at El Paso in the 1800s, leaving the Chamizal tract on the "wrong" side of the river. Which kind of boundary dispute was this, and how was it settled?
7. MEDIUM At 49° N, one degree of longitude is about 73.0 km. How long is the stretch of the 49th parallel between 110° W and 120° W, in km and miles?
8. MEDIUM The Korean Demilitarized Zone, set by the armistice of 1953, is about 250 km (155 mi) long and 4 km (2.5 mi) wide. Estimate its area. What kind of boundary is the line through its middle?
9. HARD Use the map (he-tordesillas-map). The line is drawn at about 46.5° W. Which of these cities lie on the Portuguese (east) side: Recife (34.9° W), Rio de Janeiro (43.2° W), Belém (48.5° W), Manaus (60.0° W)? What does this tell you about Brazil's growth?
   (Use the map or drawing "The approximate Tordesillas line of 1494." shown earlier in this lesson.)
10. HARD Before invading Kuwait in 1990, Iraq accused Kuwait of drawing oil from the Rumaila field, which lies across their border. What kind of boundary dispute is this? Give one other example of the same kind.
11. HARD Why can a line of latitude or longitude make a clear boundary on a map yet be hard to demarcate in 1494, but easy to demarcate in 1846?
12. CHALLENGE In 1964 the Organization of African Unity resolved that its members would respect the borders they had at independence, even though most were superimposed in the colonial era. Write a paragraph (5–7 sentences) weighing the reasons for and against that decision.

COMMON MISTAKES

- Mixing up the two ways of classifying boundaries. Antecedent, subsequent, superimposed and relic describe *when and how* a line was drawn; physical, cultural and geometric describe *what it follows*. One border can be both, such as the 49th parallel (antecedent and geometric).
- Treating rivers and mountains as perfect "natural" borders. Rivers move, crests are hard to fix, and people live on both sides.
- Confusing nautical and statute miles. A nautical mile (1.852 km) is about 15 percent longer than a statute mile (1.609 km).

Make it a game · Border Detectives. One player opens an atlas or online map and secretly picks a real international border, then gives clues one at a time: its form (physical, cultural or geometric), its origin (antecedent, subsequent, superimposed or relic), the continent, a feature it follows, and a date. The others guess after each clue. Guessing after one clue scores 5 points, after two scores 4, and so on. Bonus point: name one dispute or event connected with that border.

Scripture. "Remove not the ancient landmark, which thy fathers have set." (Proverbs 22:28, KJV)

In ancient Israel, boundary stones marked each family's inheritance, and moving one was a form of theft. A settled, honest boundary keeps the peace between neighbors, whether they are farmers or nations.

Practice answers

1. Antecedent: drawn before most settlement. Subsequent: drawn after settlement, usually following existing cultural differences. Superimposed: forced on an area by outside powers. Relic: no longer functions but is still visible in the landscape.
2. (a) Antecedent (also geometric). (b) Relic. (c) Superimposed. (d) Subsequent.
3. Definition (words in a treaty), delimitation (drawn on a map), demarcation (marked on the ground), administration (managed by officials and posts).
4. 14 ÷ 1.852 ≈ 7.6 nm. Yes, they overlap heavily (24 nm would be needed). A median line lies about 3.8 nm (7 km, 4.4 mi) from each shore. Ships still pass freely under the rule of transit passage through international straits.
5. Radius 370.4 km: area = π × 370.4^2 ≈ 431,000 km^2. Radius 230.2 mi: π × 230.2^2 ≈ 166,000 sq mi.
6. A locational dispute (where exactly the line lies). It was settled by the Chamizal Convention between the United States and Mexico in 1963, which divided the tract and moved the river into a concrete-lined channel.
7. 10 × 73.0 = 730 km; 730 ÷ 1.609 ≈ 454 miles.
8. 250 × 4 = 1,000 km^2 (155 × 2.5 ≈ 390 sq mi). It is a superimposed boundary (a cease-fire line between armies, roughly along the 38th parallel, dividing one nation into two states).
9. Recife and Rio de Janeiro lie east of the line; Belém and Manaus lie west of it. Brazil grew far beyond the 1494 line as Portuguese-speaking settlers, traders and missionaries pushed inland, and the Treaty of Madrid (1750) recognized the lands they actually held.
10. An allocational dispute (over a resource that crosses the boundary). Other examples: disputes over sharing a river's water, such as the Nile among Egypt, Sudan and Ethiopia, or fishing rights in overlapping sea zones.
11. In 1494 no one could measure longitude accurately at sea or on land, and the Tordesillas line was a meridian, so it could not be found on the ground. Latitude could be found by measuring the sun or the North Star, and by the 1800s surveyors had good instruments (and later chronometers and telegraph time signals for longitude), so the 49th parallel could be measured and marked with monuments.
12. A strong answer notes that superimposed borders split some peoples and joined rivals, which has fed some conflicts and secession movements. But redrawing them would have opened claims and counterclaims across the whole continent, with no clean line available because peoples overlap. Accepting existing borders gave new states a stable starting point and made interstate wars of conquest rarer. A balanced answer concludes that the decision traded the injustice of some lines for the danger of reopening all of them, and that most African states have kept their borders since.

5.3 Federal and Unitary States

OBJECTIVES

- Define unitary, federal and confederal systems, and classify the United States, France, Japan, the United Kingdom, Germany, Canada, Switzerland and India correctly.
- Explain how the U.S. Constitution (1787) divides power between the nation and the states, using the Tenth Amendment and the Federalist Papers.
- Calculate representation in the U.S. House, Senate and Electoral College, and explain centripetal and centrifugal forces and devolution with real examples.

Warm-up. Your family is planning a week. Some decisions belong to the whole household (where to go to church, the budget, the vacation). Others belong to each person (how to arrange a desk, which book to read). In five minutes, list four decisions of each kind. Then ask: who should decide whether the family gets a dog? There is your first lesson in dividing power between the center and the parts.

Watch. *Objections To The Federal Constitution – 1787* (The Appendix, 6:49). https://www.youtube.com/watch?v=Qz8mR1be8c4
With the big idea: listen to two New York delegates explain why they refused to sign the Constitution, and notice that their main fear was a strong central government swallowing up the states.
Note: Captions were not available to check; preview it first. The channel reads old documents aloud and its narration may be computer-generated, and the 1787 language will be hard for younger students. The video reads one Anti-Federalist letter aloud; it does not explain federal and unitary systems or compare the United States with France or Japan.

Backup video. *Jefferson's Opinion On The Constitutionality Of The Bank – February 15, 1791* (The Appendix, 11:53). https://www.youtube.com/watch?v=x-VGtgoA3Ww
As review: listen to Jefferson argue that Congress may use only the powers the Constitution lists and that the rest are reserved to the states, the idea behind the Tenth Amendment. Note: Captions were not available to check; preview it first. The channel reads old documents aloud and its narration may be computer-generated, and the 1791 language is dense for students. The video covers the 1791 debate over a national bank, not the 1787 Convention or a comparison of federal and unitary states.

KEY TERMS

unitary state
A state in which the national government holds final power and local governments have only the powers it grants them, as in France, Japan and the United Kingdom.

federal state

A state in which a written constitution divides power between a national government and regional governments (states, provinces, Länder or cantons), each with powers of its own, as in the United States, Canada, Germany and Switzerland.

confederation

A loose union of sovereign states that keep most power for themselves and give the central body only limited tasks, as under the American Articles of Confederation (1781–1789).

devolution

The transfer of some powers from a national government to regional governments, as when the United Kingdom created a Scottish Parliament in 1999.

centripetal force

Anything that pulls the people of a state together, such as a shared language, faith, history, national symbols or good transportation.

centrifugal force

Anything that pulls a state apart, such as deep regional differences of language or religion, great distance, or a sense of unfair treatment.

CORE IDEAS

The story. In the hot summer of 1787, fifty-five delegates from twelve of the thirteen states met behind closed windows in the Pennsylvania State House in Philadelphia, the same room where the Declaration of Independence had been signed eleven years before. (Rhode Island refused to send anyone.) They had come to fix the **Articles of Confederation**, the loose league that had governed since 1781. Under the Articles, Congress could not tax, could not regulate trade between the states and could not raise an army without begging the states for money and men. The states printed their own money and taxed one another's goods. George Washington, chosen to preside, had watched his soldiers go hungry for lack of supplies during the war. Instead of patching the Articles, the delegates wrote a new constitution, and on **September 17, 1787**, thirty-nine of them signed it.

How they figured it out. The great problem was geography and size. The large states, such as Virginia, wanted representation by population; the small states, such as Delaware and New Jersey, feared being swallowed and wanted one vote per state. The **Connecticut Compromise** gave both: a House of Representatives apportioned by population and a Senate with two members per state. The deeper answer was **federalism**. The word comes from the Latin *foedus*, a covenant or treaty. The Constitution gave the national government a list of powers (to tax, to coin money, to regulate commerce among the states and with foreign nations, to make war and treaties) and left the rest to the states. James Madison explained in *Federalist* No. 45: "The powers delegated by the proposed Constitution to the federal government are few and defined. Those which are to remain in the State governments are numerous and indefinite." The Tenth Amendment, ratified in 1791, made the point law: "The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people." The framers did not trust any single center of power. As Madison wrote in *Federalist* No. 51, "If men were angels, no government would be necessary." Their Constitution also left slavery in

place and counted three-fifths of enslaved people for representation; that compromise with a great wrong was settled only by the Civil War and the Thirteenth Amendment (1865).

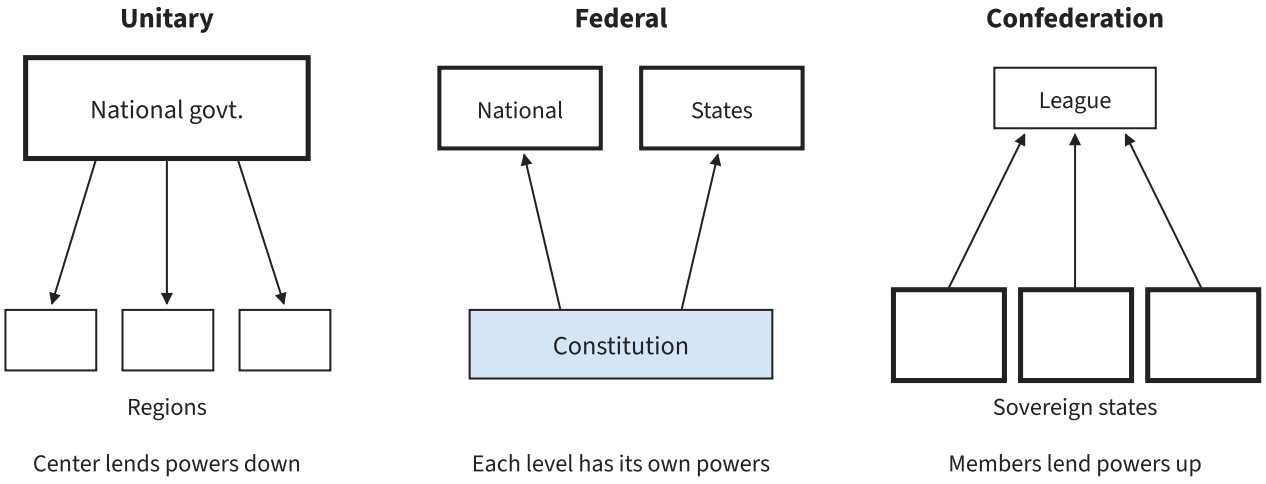
The big idea. Every state must decide how power is shared between the center and the regions. In a **unitary state** the national government is supreme, and provinces or counties exercise only the powers it lends them. France is the classic case: in 1790 the revolutionaries abolished the old provinces and drew new **départements**, it is often said, so that a rider could reach the chief town of each from anywhere within about a day. Paris still sets the school curriculum and appoints a prefect in each department. Japan, with 47 prefectures governed under laws made in Tokyo, is unitary too. In a **federal state**, a written constitution gives the regions powers the center cannot take away. Besides the United States, federal states include Canada (10 provinces and 3 territories), Mexico, Brazil, Germany (16 *Länder*), Switzerland (26 cantons), Australia (6 states), India (28 states and 8 union territories as of 2026) and Nigeria. A **confederation** is looser still, a league of sovereign states.

On the map. Geography helps explain which system a country chooses. Large states and those with many peoples tend to be federal: it is hard to govern the Swiss cantons, with four national languages (German, French, Italian and Romansh), or India, with hundreds of languages, entirely from one capital. Small, compact states with one main people, such as Denmark, Portugal or Japan, are usually unitary. But the rule has exceptions: China is huge and unitary, and Belgium, though small, became a federal state in 1993 to give Dutch-speaking Flanders and French-speaking Wallonia their own governments. Political geographers speak of **centripetal forces** that hold a state together (a shared language and faith, national holidays, a capital city, a highway or rail network such as the U.S. Interstate system begun in 1956) and **centrifugal forces** that pull it apart (regional languages, distance, rival religions, a sense that one region pays and another benefits). When centrifugal pressure grows, a unitary state may answer with **devolution**, handing powers to regions. Spain’s constitution of 1978 opened the way for 17 autonomous communities, set up between 1979 and 1983; the United Kingdom set up a Scottish Parliament and a Welsh Assembly (now the Senedd) in 1999 after referendums in 1997.

Drawing the districts. Federal and unitary states alike must draw lines inside the country for elections. In the United States, each census (every ten years since 1790) leads to **reapportionment**: the 435 House seats are divided among the states by population, and then each state redraws its district lines, called **redistricting**. After the 2020 census the average district held about 761,000 people. Drawing district lines to favor one party or group is called **gerrymandering**, a word coined in 1812 and still debated in every party and every decade. Geographers measure districts by their compactness and contiguity, the same tools you used for the shapes of states in Lesson 5.1.

A Christian reading. Long before Philadelphia, Moses’ father-in-law Jethro told him that one man could not judge all Israel alone and advised him to set “rulers of thousands, and rulers of hundreds, rulers of fifties, and rulers of tens” (Exodus 18:21). The idea that decisions belong as close to the people as wisdom allows, with the center handling only what the parts cannot, has deep roots in Scripture and in Christian political thought. Federal and

unitary systems are both lawful forms of government; each must be judged by how well it restrains the sinful use of power and serves justice and the common good.



Where power flows in unitary, federal and confederal systems.

PICTURE STUDY

Washington as Statesman at the Constitutional Convention, Junius Brutus Stearns, 1856 · Oil on canvas · Virginia Museum of Fine Arts, Richmond

Junius Brutus Stearns was an American painter who made a series of paintings of George Washington's life in the 1840s and 1850s: as farmer, soldier, statesman and Christian at his deathbed. This one imagines the Constitutional Convention in Philadelphia, with Washington presiding from the front of the room.

Stearns painted about seventy years after the convention, so the scene is a reconstruction, not a record. No pictures were made during the secret sessions. The painting shows how

Americans of the 1850s, a time when sectional quarrels were pulling the Union apart, remembered the founding as a moment of national unity.

Look closely

- Find Washington. How has the painter set him apart from the other delegates?
- Look at the light coming through the windows. Where does it fall?
- Find the papers on the tables and in the delegates' hands. What part of the convention's work do they suggest?
- Look at the delegates' faces and poses. Do they seem to agree, or are some still debating?

Talk about it

1. Why might a painter in 1856, just a few years before the Civil War, choose to paint the moment the Constitution was made?
2. The convention met in secret. What are the advantages and disadvantages of making a constitution behind closed doors?
3. How is this painting a centripetal force?

PROJECT: A CONSTITUTION FOR THREE ISLANDS

You will design a government for an imaginary island country, decide whether it should be unitary or federal, and draw its internal map and election districts.

You will need

- Large sheet of paper or poster board, colored pencils, ruler
- A grid of 100 small squares (10 by 10) drawn on graph paper for the population map
- About 100 dried beans or buttons (each one stands for 1,000 people)
- A notebook for the written constitution

Steps

1. Draw three islands of different sizes. Give each a landform (mountains, plains, a river delta), a main town and a people with its own customs. Decide whether they share a language.
2. On the graph-paper grid, scatter the beans to show where people live: crowded in the delta town, thin in the mountains. Count the people on each island.
3. List the centripetal forces (things that hold the islands together) and centrifugal forces (things that pull them apart).
4. Decide: unitary, federal or confederal? Write a short constitution (one page) with at least five articles: what the national government may do, what the islands may do, and how laws are made.
5. Your parliament has 10 seats. Apportion them among the islands by population, rounding sensibly so the total is 10.

6. Draw the election districts on the grid, each with about one tenth of the population. Make them compact and contiguous. Then, on a copy, draw them a second way to show how district lines can change who wins.
7. Present your constitution to your family and defend your choice of system in three minutes.

Tips

- If one island is much smaller, think about how the Connecticut Compromise protected the small states.
- Contiguous means every part of a district touches the rest; compact means it is roughly round or square rather than long and twisted.

Check your work

- I can explain why I chose a unitary, federal or confederal system for my islands.
- I can apportion seats by population and check that they add up.
- I can draw compact, contiguous districts of equal population.

MAP NOTEBOOK

1. Copy the power diagram (he-power-diagram) from memory, then add one real country under each of the three systems.
2. Draw a T-chart of centripetal and centrifugal forces for the United States in 1860 and again for today. What changed?
3. Sketch the 13 original states along the Atlantic coast and number them in the order they ratified the Constitution.

> **From history.** In 1812 the Massachusetts legislature redrew the state senate districts, and Governor Elbridge Gerry signed the bill. One district north of Boston curled into such a strange shape that a cartoon printed in the *Boston Gazette* in March 1812 gave it wings, claws and a head and called it “The Gerry-Mander,” a salamander named for the governor. The word has outlived nearly everything else about Gerry, who went on to become vice president of the United States under James Madison.

WORKED EXAMPLES

Example 1. The 2020 census apportionment population of the United States was 331,108,434. The House has 435 seats. Find the average number of people per House district. Wyoming has one representative and about 577,000 people. How does Wyoming's district compare with the average?

1. Average district = 331,108,434 ÷ 435 ≈ 761,169 people.
2. Wyoming ratio = 577,000 ÷ 761,169 ≈ 0.76.
3. Every state gets at least one seat by the Constitution, however small its population.

Answer: About 761,169 people per district. Wyoming's single district has about 76% of the average population, because the Constitution guarantees each state at least one representative.

Example 2. After the 2020 census, California had about 39.6 million of the nation's 331.1 million people, 52 of 435 House seats, 2 of 100 Senate seats and 54 of 538 electoral votes. Compute each share as a percent and explain the differences.

1. Population: 39.6 ÷ 331.1 × 100 ≈ 12.0%.
2. House: 52 ÷ 435 × 100 ≈ 12.0%.
3. Senate: 2 ÷ 100 × 100 = 2.0%.
4. Electoral College: 54 ÷ 538 × 100 ≈ 10.0% (52 House seats + 2 senators = 54).

Answer: Population 12.0%, House 12.0%, Senate 2.0%, Electoral College 10.0%. The House follows population; the Senate gives every state equal weight; the Electoral College blends the two. This is the Connecticut Compromise still at work in the map of American power.

Example 3. The Constitution was signed on September 17, 1787, and needed 9 of the 13 states to ratify it. New Hampshire became the ninth on June 21, 1788. What fraction of the states had to agree, as a percent? How many days passed between signing and the ninth ratification?

1. $9 \div 13 \approx 0.692$, or about 69%.
2. Days remaining in September after the 17th: $30 - 17 = 13$.
3. October 31 + November 30 + December 31 + January 31 + February 29 (1788 was a leap year) + March 31 + April 30 + May 31 = 244.
4. Add June 1–21: 21. Total = 13 + 244 + 21 = 278 days.

Answer: About 69% of the states (a supermajority), reached after 278 days. Virginia (June 25, 1788) and New York (July 26, 1788) soon followed, and the new government began in 1789.

PRACTICE

1. EASY Define unitary state, federal state and confederation in one sentence each.
2. EASY Classify: (a) France (b) Germany (c) Japan (d) Canada (e) the United Kingdom (f) Switzerland.
3. EASY Restate the Tenth Amendment in your own words.
4. MEDIUM After the 2020 census Texas received 38 House seats. What percent of the House is that? How many electoral votes does Texas have, and what percent of 538 is that?
5. MEDIUM Explain why the Electoral College has 538 votes and how many are needed to win.
6. MEDIUM Florida had about 21.5 million people in 2020. Using an average district of 761,169, about how many House seats would you expect it to receive? (Florida actually received 28.)
7. MEDIUM Name the first state to ratify the Constitution, the ninth, and the last of the original thirteen, with dates.
8. MEDIUM Sort into centripetal or centrifugal: (a) a national language taught in all schools (b) a region with its own language and a separate history (c) a national railway network (d) a long distance between a region and the capital (e) a shared national holiday.
9. HARD Explain what Madison meant in *Federalist* No. 45 when he called federal powers “few and defined” and state powers “numerous and indefinite.” Give two examples of each kind as the framers saw them.
10. HARD Switzerland has four national languages and 26 cantons; Belgium became federal in 1993. Explain, using the idea of centrifugal forces, why both chose federalism.
11. HARD Metropolitan France covers about 551,500 km² (213,000 sq mi) and has 96 departments. Find the average area of a department. If a rider covers about 40 miles (64 km) in a day, about how far is it from the center of an average department (treated as a circle) to its edge?

12. CHALLENGE Write a paragraph (6–8 sentences) weighing the advantages and disadvantages of a federal system for a large country with many regions.

COMMON MISTAKES

- Thinking a federal state is weaker or less sovereign than a unitary one. Both are fully sovereign abroad; the difference is how power is divided at home.
- Calling the United Kingdom federal. It is a unitary state that has devolved some powers; Parliament in Westminster can in law change or end the devolved bodies.
- Confusing reapportionment (dividing House seats among states after a census) with redistricting (redrawing district lines within a state).

Make it a game · Who Decides?. One player reads out a decision, such as printing money, setting a school calendar, declaring war, issuing driver's licenses, signing a trade treaty or fixing a local road. The others hold up a card: N for national government, S for state government, or B for both. Score 1 point for each correct answer under the U.S. Constitution, then play a second round as if you lived in unitary France, where Paris decides more. Talk about the answers that changed.

Scripture. "Moreover thou shalt provide out of all the people able men, such as fear God, men of truth, hating covetousness; and place such over them, to be rulers of thousands, and rulers of hundreds, rulers of fifties, and rulers of tens:" (Exodus 18:21, KJV)

Jethro saw that Moses would wear himself out judging every case alone. Layers of trustworthy rulers, each handling what it could, gave Israel justice close to home and left only the hard cases for the center.

Practice answers

1. Unitary: the national government holds final power and lends powers to local governments. Federal: a constitution divides power between the national government and regional governments, each with its own powers. Confederation: a loose league of sovereign states that give a weak central body only a few tasks.
2. (a) Unitary. (b) Federal. (c) Unitary. (d) Federal. (e) Unitary, with devolved governments in Scotland, Wales and Northern Ireland. (f) Federal (its official name is still the Swiss Confederation, but it has been a federal state since 1848).
3. Any power the Constitution does not give to the national government, and does not forbid to the states, belongs to the states or to the people.
4. 38 ÷ 435 ≈ 8.7%. Electoral votes: 38 + 2 = 40; 40 ÷ 538 ≈ 7.4%.
5. 435 (House) + 100 (Senate) + 3 (for the District of Columbia, under the Twenty-third Amendment, 1961) = 538. A majority is 270.
6. 21,500,000 ÷ 761,169 ≈ 28.2, so about 28 seats, which matches.
7. First: Delaware, December 7, 1787. Ninth: New Hampshire, June 21, 1788. Last: Rhode Island, May 29, 1790.
8. Centripetal: (a), (c), (e). Centrifugal: (b), (d).

9. The national government could do only what the Constitution listed; the states kept a broad, general authority over everything else. Federal examples: coining money, making treaties, declaring war, regulating interstate and foreign commerce. State examples (as Madison described them): the ordinary affairs of life, property, local order, internal improvement and prosperity of the state, such as schools, roads, courts, police and marriage and property law.
10. Both contain peoples with different languages concentrated in different regions (German, French, Italian and Romansh speakers in Switzerland; Dutch-speaking Flanders and French-speaking Wallonia in Belgium). Giving each region its own government over schools, culture and local matters reduces the pressure of these centrifugal forces and helps keep the state together.
11. 551,500 ÷ 96 ≈ 5,745 km² (about 2,220 sq mi). Radius r = √(5,745 ÷ π) ≈ √1,829 ≈ 43 km (about 27 mi). That is well within a day's ride, which fits the story that departments were drawn so the chief town could be reached in a day.
12. Advantages: decisions are made closer to the people affected; regions can try different policies and learn from one another; power is divided, so no single government can easily abuse it; regional peoples feel respected, reducing centrifugal pressure. Disadvantages: laws differ from region to region, which can confuse trade and travel; government is duplicated and may cost more; national action may be slow; and strong regions may resist the common good or even seek to leave, as eleven Southern states tried in 1860–61. A strong answer gives a reasoned conclusion and at least one real example.

5.4 Supranational Organizations

OBJECTIVES

- Describe the founding, purpose, membership and headquarters of the United Nations, NATO and the European Union, with correct dates.
- Explain how supranational organizations pool or limit sovereignty, and present the main arguments for and against them fairly.
- Apply the voting rules of the UN Security Council, and calculate membership growth and defense-spending guidelines from real figures.

Warm-up. Imagine your street forms a club. Each family keeps its own house and rules, but everyone pays a little into a fund to plow snow and agrees to help any neighbor whose house is threatened by fire. In five minutes, write down: What does each family gain? What does it give up? What should happen if one family refuses to pay? You have just described the bargain behind every supranational organization.

Watch. *NATO vs. the European Union* (Historia Civilis, 2:30).
https://www.youtube.com/watch?v=f-Ti18wP6tc
After the story: watch this short explainer to see how two groups formed after the UN, NATO and the European Union, differ in who belongs and what each one does.
Note: Captions were not available to check; preview it first. It covers NATO and the EU, not the founding of the UN in San Francisco that the story tells. Covers NATO and the EU rather than the 1945 UN Charter in the story.

KEY TERMS

supranational organization
An association of three or more states that agree to work together and accept some shared rules or institutions above the level of a single state.

United Nations (UN)
The worldwide organization of states founded in 1945 to keep international peace and promote cooperation; 193 member states as of 2026, headquartered in New York.

North Atlantic Treaty Organization (NATO)
A military alliance founded in 1949 under which members agree that an armed attack on one is an attack on all (Article 5); 32 members as of 2026, headquartered in Brussels.

European Union (EU)
A political and economic union of 27 European states (as of 2026), grown from the Coal and Steel Community of 1951 and the European Economic Community of 1957; created under its present name by the Maastricht Treaty (1992).

veto
The power of a single member to block a decision. Each of the five permanent members of the UN Security Council holds a veto.

collective security
An arrangement in which states agree to defend one another, so that an aggressor faces the combined strength of all.

CORE IDEAS

The story. On June 26, 1945, while war still raged in the Pacific, delegates of fifty nations gathered in the Veterans War Memorial Building in San Francisco to sign the **Charter of the United Nations**. The conference had lasted two months, and the Charter was prepared in five equally official languages: Chinese, French, Russian, English and Spanish. President Harry Truman flew in to address the closing session. Poland, whose government was still in dispute, signed a few months later as the fifty-first original member. The Charter came into force on October 24, 1945. Its opening words were meant to answer two world wars in a single generation: the peoples of the United Nations were "determined to save succeeding generations from the scourge of war." The UN replaced the **League of Nations** (1920), which had failed to stop aggression in the 1930s, partly because the United States never joined it and the great powers would not enforce its decisions.

How it works: the United Nations. The UN is a meeting place of sovereign states, not a world government. In the **General Assembly**, every member has one vote, so Tuvalu, with about 11,000 people, counts the same as India, with about 1.4 billion. The **Security Council** holds the real power to order sanctions or authorize force. It has 15 members: five permanent members, the victors of 1945 (the United States, the United Kingdom, France, Russia and China), and ten elected for two-year terms. A decision on any important matter needs nine votes and no veto from a permanent member. That rule was the price of getting the great powers to join, and it means the Council can act only when they agree. During the Cold War the veto often froze it. The UN also runs agencies for food, refugees, aviation and shipping, and it hosts treaties such as the Law of the Sea you studied in Lesson 5.2. Its headquarters stand on land along New York's East River bought for the UN with a gift of $8.5 million from John D. Rockefeller Jr.

How it works: NATO. By 1948 Soviet forces controlled Eastern Europe and the blockade of West Berlin had begun. On April 4, 1949, in Washington, twelve states signed the **North Atlantic Treaty**: the United States, Canada, the United Kingdom, France, Belgium, the Netherlands, Luxembourg, Denmark, Norway, Iceland, Italy and Portugal. Its heart is **Article 5**: an armed attack against one member in Europe or North America shall be considered an attack against them all. Article 5 has been invoked only once, after the attacks of September 11, 2001, on the United States. NATO is an alliance, not a union: members keep full control of their own armies, and decisions are made by consensus. It has grown to 32 members as of 2026, most recently Finland (2023) and Sweden (2024). In 2014 members pledged to move toward spending 2 percent of their gross domestic product (GDP) on defense, and at The Hague in 2025 they agreed to a higher target to be reached by 2035. Supporters credit NATO with deterring war in Europe for decades; critics in several member countries have argued over burden-sharing and over enlargement eastward. Students should know both arguments.

How it works: the European Union. On May 9, 1950, the French foreign minister Robert Schuman proposed placing all French and German coal and steel production under a common High Authority, so that war between the old enemies would become, in his words, “not merely unthinkable, but materially impossible.” He added that “Europe will not be made all at once, or according to a single plan.” Schuman was a devout Catholic, and the other founders he worked with, Konrad Adenauer of West Germany and Alcide De Gasperi of Italy, were also Christian statesmen. The European Coal and Steel Community (Treaty of Paris, 1951) joined six states: France, West Germany, Italy, Belgium, the Netherlands and Luxembourg. The Treaty of Rome (1957) created the European Economic Community, a common market. The Maastricht Treaty (signed 1992, in force 1993) created the European Union. The EU is the most **supranational** of the three: its laws apply directly inside member states, its Court of Justice in Luxembourg can overrule national courts on EU matters, and 21 of its 27 members share a single currency, the euro, issued by the European Central Bank in Frankfurt. The Schengen Agreement removed passport checks at most internal borders. The European Parliament meets in Strasbourg and Brussels.

On the map: weighing sovereignty. Each organization asks states to give up a different amount of sovereignty. The UN asks little beyond keeping the Charter; NATO asks a promise of mutual defense; the EU asks members to share lawmaking, trade policy and, for most, money itself. Supporters argue that pooled sovereignty has kept peace in Western Europe since 1945, widened markets and made small states stronger together. Critics argue that it moves decisions away from voters to distant officials, that common rules fit some regions poorly, and that a nation should govern itself. Both arguments were heard when voters in the United Kingdom chose in a 2016 referendum, 51.9 percent to 48.1 percent, to leave the EU; the UK departed on January 31, 2020. Other regional bodies follow the same pattern on a smaller scale: the African Union (2002, successor to the Organization of African Unity of 1963), the Association of Southeast Asian Nations (ASEAN, 1967) and the United States–Mexico–Canada Agreement (2020, which replaced NAFTA of 1994).

A Christian reading. Across the street from the UN headquarters, a stone wall in a small park carries words adapted from Isaiah 2:4: “They shall beat their swords into plowshares.” In Isaiah the promise belongs to the day when the Lord Himself “shall judge among the nations.” Christians can honor every honest effort to keep peace between nations, for “Blessed are the peacemakers” (Matthew 5:9), while remembering that no treaty or organization can change the human heart. Lasting peace is God’s gift, and human institutions, however useful, remain limited and answerable to Him.

Cities of European cooperation: treaties (Paris 1951, Rome 1957, Maastricht 1992, Lisbon 2007) and institutions (Brussels, Strasbourg, Luxembourg, Frankfurt). NATO's headquarters is also in Brussels.

PICTURE STUDY

President Truman Signing the Proclamation That Put the North Atlantic Treaty into Force, Abbie Rowe, National Park Service photographer at the White House, August 24, 1949 · Black-and-white photograph · U.S. National Archives and Records Administration; prints also at the Harry S. Truman Presidential Library and Museum, Independence, Missouri

The North Atlantic Treaty was signed by the foreign ministers of twelve nations in Washington, D.C., on April 4, 1949. A treaty does not take effect when it is signed, though.

Each country's government had to ratify it first, which in the United States means a two-thirds vote of the Senate. When enough nations had deposited their ratifications, President Truman signed a proclamation declaring the treaty in force on August 24, 1949. Ambassadors of the member nations crowded into his office to watch.

Abbie Rowe, a National Park Service photographer who recorded the White House for more than twenty years, took this picture. Because it was made by a government employee as part of his work, it belongs to the public. It records the moment when the United States, which had avoided permanent alliances since the days of Washington's Farewell Address, bound itself in peacetime to defend Western Europe.

Look closely

- Find President Truman. What is he doing, and where are the others looking?
- Look at the crowd behind the desk. Why would ambassadors from many countries want to be present for an American president's signature?
- Look at the room: the desk, the flags, the papers. Does this feel like a celebration or like solemn business?
- Compare this photograph with Ter Borch's painting of the oath at Münster in 1648 (Lesson 5.1). What is the same about the two ceremonies, and what is different?

Talk about it

1. George Washington warned in 1796 against permanent alliances with foreign nations. Why do you think American leaders decided in 1949 that the situation had changed?
2. Why does a treaty need to be ratified by each nation's government before it takes effect? What does that show about sovereignty?
3. What does each member nation give up by joining an alliance like NATO, and what does it gain?

PROJECT: A SECURITY COUNCIL IN THE LIVING ROOM

You will hold a mock session of the UN Security Council on a real historical crisis, vote under the real rules and then map the result.

You will need

- Fifteen name cards (family members may hold two or three each), labeled with the five permanent members and ten elected members
- A short account of a real crisis the Council considered, such as the Korean War vote of June 1950 (when the Soviet delegate was absent) or the Gulf crisis of 1990, from an encyclopedia or the UN's own website
- A blank world map, colored pencils
- A sheet for the vote tally

Steps

1. Read the crisis account aloud. Mark the countries involved on the blank map.
2. Assign the five permanent members (United States, United Kingdom, France, Russia or the Soviet Union, China) and ten elected members from the year of the crisis. Give each “ambassador” two minutes to state their country’s interest in the matter.
3. Write a short resolution (three or four sentences) stating what the Council will do.
4. Vote. Record each yes, no and abstention. Apply the rule: 9 yes votes and no veto from a permanent member.
5. Compare your result with what actually happened. Did the real Council act? Why or why not?
6. On the map, color the countries that voted yes in one color and those that voted no or abstained in another. Add a legend and a title.
7. Write a paragraph: Did the veto help or hurt the Council in this crisis? What does that show about the limits of supranational power?

Tips

- An abstention by a permanent member is not a veto. Only a no vote blocks a resolution.
- In June 1950 the Soviet Union was boycotting the Council, so it could not veto the resolutions on Korea. That is a good case for discussion.

Check your work

- I can apply the Security Council voting rule correctly.
- I can explain why the five permanent members were given a veto.
- I can map a real vote and explain its outcome.

MAP NOTEBOOK

1. Draw three concentric circles labeled UN, NATO and EU, and write in each a phrase describing how much sovereignty members give up.
2. On an outline map of Europe, shade NATO members in one pattern and EU members in another. Name three countries that belong to NATO but not the EU and three that belong to the EU but not NATO.
3. Make a timeline from 1945 to 2026 marking at least eight events from this lesson.

> **From history.** When the Security Council voted in June 1950 to help South Korea resist the invasion from the North, the Soviet Union could have vetoed the resolutions, but its delegate, Yakov Malik, had been boycotting the Council since January in protest that China’s seat was held by the Nationalist government on Taiwan rather than the Communist government in Beijing. In his absence the resolutions passed, and sixteen nations sent combat forces under the UN flag. The Soviet delegate returned to the Council in August 1950. The episode shows both the power of the veto and how much the Council depends on the great powers taking part.

WORKED EXAMPLES

Example 1. A Security Council draft resolution receives 11 yes votes, 3 no votes and 1 abstention. One of the no votes is from a permanent member. Does it pass? What if the permanent member had abstained instead of voting no?

1. A substantive resolution needs at least 9 yes votes out of 15, and no negative vote from any of the five permanent members.
2. 11 yes votes clear the threshold of 9.
3. But a permanent member voted no. That is a veto, so the resolution fails.
4. If that permanent member had abstained, the count would be 11 yes, 2 no, 2 abstentions. By long practice an abstention is not a veto, so 11 ≥ 9 and the resolution passes.

Answer: It fails because of the veto. With an abstention instead, it would pass with 11 votes.

Example 2. Trace the growth of the European communities and the EU: 6 founding members (1951/1957); +3 in 1973 (UK, Ireland, Denmark); +1 in 1981 (Greece); +2 in 1986 (Spain, Portugal); +3 in 1995 (Austria, Finland, Sweden); +10 in 2004; +2 in 2007 (Bulgaria, Romania); +1 in 2013 (Croatia); −1 in 2020 (UK). Find the total after each step and the percent growth from 6 to the peak.

1. 6 → 9 (1973) → 10 (1981) → 12 (1986) → 15 (1995) → 25 (2004) → 27 (2007) → 28 (2013) → 27 (2020).
2. The peak was 28 members (2013–2020).
3. Percent growth from 6 to 28: (28 − 6) ÷ 6 × 100 ≈ 367%.

Answer: Totals: 9, 10, 12, 15, 25, 27, 28, then 27. Peak growth from 6 to 28 is about 367%. The largest single jump, ten states in 2004, mostly brought in former communist states of Central and Eastern Europe.

Example 3. Under the 2014 NATO pledge, members aimed to spend at least 2% of GDP on defense. A member has a GDP of $600 billion and spends $9 billion on defense. What percent of GDP is that? How much more would it need to spend to reach 2%?

1. Percent = 9 ÷ 600 × 100 = 1.5%.
2. 2% of $600 billion = 0.02 × 600 = $12 billion.
3. Shortfall = 12 − 9 = $3 billion.

Answer: 1.5% of GDP; it would need about $3 billion more per year to reach 2%. (In 2025 the allies agreed to a higher goal to be reached by 2035, so the same method applies with a larger percentage.)

PRACTICE

1. EASY Define a supranational organization and give three examples.
2. EASY Name the five permanent members of the UN Security Council.
3. EASY What does Article 5 of the North Atlantic Treaty say, and when has it been invoked?
4. MEDIUM A Security Council vote ends 8 yes, 2 no (neither a permanent member) and 5 abstentions. Does the resolution pass?
5. MEDIUM NATO grew from 12 members in 1949 to 32 as of 2026. Find the percent increase.
6. MEDIUM Name the six founding members of the European Coal and Steel Community (1951).
7. MEDIUM As of 2026, 21 of the 27 EU members use the euro. How many do not, and what percent of members is that?
8. MEDIUM Use the map (he-europe-institutions). Which city hosts the European Central Bank, which hosts the EU Court of Justice, and in which cities were the 1957 and 1992 treaties signed?
   (Use the map or drawing "Cities of European cooperation." shown earlier in this lesson.)
9. HARD In the 2016 UK referendum on EU membership, turnout was about 72.2% and 51.9% of those voting chose to leave. What percent of all registered voters voted to leave?
10. HARD In the UN General Assembly, Tuvalu (about 11,000 people) and India (about 1.4 billion) each have one vote. How many people does India have for every person in Tuvalu? Give one argument for and one against the one-state-one-vote rule.
11. HARD Rank the UN, NATO and the EU from least to most supranational, and justify the ranking.
12. CHALLENGE Apply the Montevideo criteria from Lesson 5.1 to the European Union. Is the EU a state? Write a paragraph.

COMMON MISTAKES

- Calling the UN a world government. It cannot tax, has no army of its own, and depends on its member states to carry out its decisions.
- Confusing the EU and NATO. The EU is an economic and political union; NATO is a military alliance. Many states belong to both, but not all: Norway and Turkey are in NATO but not the EU; Austria and Ireland are in the EU but not NATO.
- Thinking an abstention by a permanent member is a veto. Only a negative vote blocks a Security Council resolution.

Make it a game · UN, NATO or EU?. Write thirty fact cards, such as “Article 5,” “193 members,” “the euro,” “Treaty of Rome,” “San Francisco, 1945,” “Security Council veto,” “Schengen,” “Washington, 1949,” “Maastricht,” “Brussels headquarters” (careful: that one fits two). Players draw a card and name the organization in five seconds. Score 1 point for each correct answer and 2 points for catching a card that fits more than one organization and naming both.

Scripture. “And he shall judge among the nations, and shall rebuke many people: and they shall beat their swords into plowshares, and their spears into pruninghooks: nation shall not lift up sword against nation, neither shall they learn war any more.” (Isaiah 2:4, KJV)

These words are carved, in adapted form, on a wall across from the UN in New York. In Isaiah the peace comes when the Lord Himself judges the nations. Human efforts at peace are good and worth honoring, but the full promise waits for Him.

Practice answers

1. An association of three or more states that cooperate under shared rules or institutions above the level of a single state. Examples: the UN, NATO, the EU (also the African Union, ASEAN).
2. The United States, the United Kingdom, France, Russia and China.
3. An armed attack against one member in Europe or North America is considered an attack against all. It has been invoked once, after the September 11, 2001, attacks on the United States.
4. No. It needs at least 9 yes votes; 8 is not enough, even without a veto.
5. (32 − 12) ÷ 12 × 100 ≈ 167%.
6. France, West Germany, Italy, Belgium, the Netherlands and Luxembourg.
7. 27 − 21 = 6 members (Denmark, Sweden, Poland, Czechia, Hungary and Romania); 6 ÷ 27 ≈ 22%.
8. Frankfurt (European Central Bank); Luxembourg (Court of Justice); Rome (1957) and Maastricht (1992).
9. 0.722 × 0.519 ≈ 0.375, about 37.5% of registered voters. (This shows the difference between a majority of votes cast and a majority of the whole electorate; referendums are decided by votes cast.)
10. 1,400,000,000 ÷ 11,000 ≈ 127,000. For: states are legally equal and sovereign, so each deserves an equal voice. Against: the votes of a few small states can outweigh the wishes of

most of the world’s people, which is one reason real power was placed in the Security Council.

11. NATO and the UN ask the least: NATO is a defensive alliance run by consensus, and members keep control of their armies; the UN’s General Assembly only recommends, though Security Council decisions bind members. The EU is the most supranational: its laws apply directly in member states, its court can overrule national courts on EU matters, and most members share a currency. (Students may reasonably place either NATO or the UN first if they give reasons.)
12. The EU has a population (its members’ citizens), a territory (its members’ territories), institutions that function like a government, and it signs some trade treaties with other states. But its members remain the sovereign states: they keep their own armies, foreign ministries and UN seats, they can leave (as the UK did under Article 50), and EU power rests on treaties the members agreed to. So the EU is best described as a supranational union of sovereign states, not a state itself.

Unit 5 test

Answer each question. Show your work for every calculation and use complete sentences for explanations and the essay. Use 1 nautical mile = 1.852 km = 1.151 statute miles where needed. The test is worth 100 points.

1. (5 pts) Define state, nation and nation-state, and give one real example of a nation-state.
2. (5 pts) Name the year of the Peace of Westphalia, the two towns where it was negotiated, and two things it settled.
3. (6 pts) Classify each: (a) the Kurds (b) the United Kingdom (c) the Koreans (d) Iceland.
4. (6 pts) Name the shape of each state and give one problem or advantage that shape brings: (a) Chile (b) Indonesia (c) South Africa.
5. (6 pts) Singapore covers about 735 km² (284 sq mi) and has about 6.0 million people. Find its density per km² and per square mile.
6. (6 pts) Classify each boundary by origin: (a) the remains of the Berlin Wall (b) the line through the Korean DMZ (c) the 49th parallel across the western prairie (d) the India–Pakistan border of 1947.
7. (6 pts) Convert the contiguous zone (24 nautical miles) and the exclusive economic zone (200 nautical miles) into kilometers and statute miles. What rights does a state have in its EEZ?
8. (6 pts) Name the four types of boundary dispute and match one to each case: (a) a river changes its course, leaving land in doubt (b) two states quarrel over an oil field under the border (c) the wording of a treaty is unclear (d) states disagree over controlling migration across a border.
9. (8 pts) At 49° N, one degree of longitude spans about 111.32 × cos 49° km. Find the length of the 49th parallel between 100° W and 110° W, in km and miles.
10. (6 pts) Explain the difference between a unitary state and a federal state, and give two real examples of each.
11. (8 pts) After the 2020 census the average House district held about 761,169 people. Ohio had about 11.8 million people. About how many seats would you expect Ohio to receive? (It received 15.) How many electoral votes does Ohio have?
12. (6 pts) Define devolution and give one real example. Then name one centripetal and one centrifugal force at work in that example.
13. (6 pts) Match each organization (UN, NATO, EU) with its founding year, its headquarters city and its main purpose.
14. (6 pts) A Security Council resolution receives 10 yes votes, 4 no votes and 1 abstention. One no vote is from China. Does it pass? Explain the rule.
15. (14 pts) Essay (8–12 sentences). Since 1648 the map of the world has been organized around sovereign states, yet since 1945 many states have joined organizations that limit or pool their sovereignty. Using at least three specific examples from this unit, weigh the gains and the costs of supranational cooperation. Present more than one view fairly and end with your own reasoned conclusion.

UNIT PROJECT: A POLITICAL ATLAS OF ONE COUNTRY

Choose one country (not the United States) and build a four-page political atlas of it. Page 1: a hand-drawn map of the country with its capital, main regions and shape labeled, and its population density calculated. Page 2: a map of its land and sea boundaries, with each land boundary classified by origin and form, its maritime zones sketched, and at least one past or present boundary dispute described. Page 3: a diagram of its government (unitary, federal or confederal), its first-level regions, and the centripetal and centrifugal forces at work. Page 4: a list of the supranational organizations it belongs to, with founding dates and what membership requires. Finish with a one-page essay explaining how geography has shaped this country's political life.

- **Accuracy**: Maps, boundaries, regions, dates and memberships are correct and clearly labeled; the density calculation is shown and correct.
- **Use of the unit's concepts**: The atlas correctly applies the terms of the unit: state shape, boundary types, boundary disputes, maritime zones, unitary or federal structure, centripetal and centrifugal forces, and supranationalism.
- **Fairness and reasoning**: The essay presents disputes and debates neutrally, gives more than one view where views differ, and reaches a reasoned conclusion supported by evidence.
- **Care**: Maps are neat, have titles, legends, scales and north arrows; the atlas is organized and easy to read.

Answer key

1. A state is a politically organized territory with a permanent population, defined borders, a government and sovereignty. A nation is a people who see themselves as one because of shared language, history, faith or customs. A nation-state is a state whose territory closely matches the homeland of one nation. Examples: Japan, Iceland.
2. 1648; Münster and Osnabrück. Any two: ended the Thirty Years' War; ended the Eighty Years' War and recognized Dutch independence; recognized Swiss independence from the Empire; confirmed each prince's right to decide the official church of his land and extended it to Calvinists; gave German princes the right to make foreign alliances; gave territory to Sweden and France.
3. (a) Stateless nation. (b) Multinational state. (c) Multistate nation. (d) Nation-state.
4. (a) Elongated: the far ends are hard to connect and govern from the capital. (b) Fragmented: thousands of islands make transport, defense and national unity difficult. (c) Perforated: it surrounds Lesotho, which depends on South Africa for access to the sea and trade.
5. 6,000,000 ÷ 735 ≈ 8,200 people per km²; 6,000,000 ÷ 284 ≈ 21,100 people per sq mi.
6. (a) Relic. (b) Superimposed. (c) Antecedent. (d) Subsequent.
7. 24 nm ≈ 44.4 km ≈ 27.6 mi; 200 nm ≈ 370.4 km ≈ 230.2 mi. In its EEZ a state controls fishing, oil, gas and other resources of the sea and seabed, but other states' ships may still pass freely.
8. (a) Locational. (b) Allocational. (c) Definitional. (d) Operational.
9. 111.32 × 0.6561 ≈ 73.0 km per degree; 10 × 73.0 = 730 km; 730 ÷ 1.609 ≈ 454 miles.
10. In a unitary state the national government holds final power and grants powers to local governments; in a federal state a constitution divides power between national and regional

governments, each with powers of its own. Unitary: France, Japan (also the UK, China). Federal: the United States, Germany (also Canada, Switzerland, India, Australia, Brazil, Mexico).

11. 11,800,000 ÷ 761,169 ≈ 15.5, so about 15 or 16 seats. Ohio received 15, because the official method (equal proportions) uses an adjusted divisor, so a state near the halfway mark can go either way. Electoral votes: 15 + 2 = 17.
12. Devolution is the transfer of powers from a national government to regional governments. Example: the United Kingdom created a Scottish Parliament in 1999. Centripetal: shared monarchy, language, history and economy. Centrifugal: a distinct Scottish history, legal system and national identity. (Spain’s autonomous communities or Belgium’s regions are also acceptable.)
13. UN: 1945, New York, international peace and cooperation among nearly all states. NATO: 1949, Brussels, collective defense (Article 5). EU: created under that name by the Maastricht Treaty of 1992 (roots in 1951 and 1957), main institutions in Brussels, economic and political union with shared laws and, for most members, a shared currency.
14. No. A resolution needs at least 9 yes votes and no negative vote from any of the five permanent members. China’s no vote is a veto, so the resolution fails despite 10 yes votes.
15. Scoring guide: thesis that answers the question (2 points); at least three accurate, specific examples, such as the Westphalian principle of sovereignty, the UN Security Council veto, NATO’s Article 5, the Schuman Declaration and the EU’s common laws and currency, the UK’s 2016 referendum and 2020 departure, or the Law of the Sea (6 points); fair presentation of at least two views, such as peace, security and wider markets versus distant decision-making, loss of self-government and rules that fit some regions poorly (4 points); a clear, reasoned conclusion (2 points).

UNIT 6

Agriculture

Every civilization stands on a field. In the second chapter of the Bible, God puts the first man in the garden “to dress it and to keep it” (Genesis 2:15), and the long story of farming has been the story of people learning to do that well. In this unit you will look at agriculture the way a geographer does: where it began, why each crop grows where it does, how inventions changed what the land could yield, and how the world divides into great farming regions, from the hand-built rice terraces of Asia to the wheat belts of the plains.

You will follow Nikolai Vavilov hunting for the homelands of crops and Robert Braidwood digging at Jarmo in the hills of the Fertile Crescent. You will sit with Johann Heinrich von Thünen over his account books at Tellow and build his model of land use around a market town (1826), calculating where each crop pays best. You will travel with Norman Borlaug between two Mexican valleys and watch the Green Revolution reach India and Pakistan, and you will walk the fields of China and Japan with F. H. King in 1909. Along the way you will compute densities, rents, growth rates, doubling times, irrigated areas and location quotients.

As with every model in this course, von Thünen’s rings, Diamond’s axis argument and Whittlesey’s regions are taught as models: useful simplifications to be tested against the evidence, with their limits stated plainly. The unit closes with a 100-point unit test and a portfolio project, a farm atlas of your own county.

BEFORE YOU BEGIN

- Can read latitude and longitude and convert degrees of latitude to distance (Unit 1)
- Can compute arithmetic density and growth rates, and use the rule of 70 (Unit 2)
- Understands relocation and expansion diffusion and distance decay (Units 1 and 3)
- Can read a climate map and knows the main Köppen climate groups

MASTERY CHECKLIST

- I can locate the Fertile Crescent and at least six other agricultural hearths and name their crops, and explain how domestication is recognized.
- I can explain the first, second and third agricultural revolutions with people, places and dates.
- I can state the assumptions of von Thünen’s model, draw its rings, and calculate locational rent, margins and ring boundaries.
- I can explain how technology, from the steel plow to the center pivot, has overcome geography in farming, and weigh the benefits and costs of the Green Revolution.
- I can describe the world’s main farming regions, classify a region from climate data, and calculate a location quotient and agricultural or physiological density.
- I can present each model with its strengths and its limits.

OPTIONAL BOOKS AND RESOURCES

- **USDA Census of Agriculture** (https://www.nass.usda.gov/AgCensus/): Free. County profiles give the number of farms, farm sizes, main crops and livestock for every U.S. county. Essential for the portfolio project and for real location-quotient practice.
- **Farm Security Administration / Office of War Information photographs, Library of Congress** (https://www.loc.gov/pictures/collection/fsa/): Free. Thousands of public-domain photographs of American farms, the Dust Bowl, sharecroppers, wheat harvests and dairies from the 1930s and 1940s. Good for picture studies and for the portfolio.
- **NASA Earth Observatory** (https://earthobservatory.nasa.gov/): Free. Search for “center pivot,” “rice,” or “Kansas crops” to find satellite images of farm landscapes around the world, with captions.

6.1 The First Farms

OBJECTIVES

- Define domestication, agricultural hearth and the first agricultural revolution, and locate the Fertile Crescent, its early village sites and its founder crops on a map.
- Explain how Nikolai Vavilov, James Henry Breasted and Robert Braidwood helped geographers find where farming began, and name at least six other hearths with their crops.
- Calculate a rate of agricultural diffusion, a physiological density and a north–south distance from latitude, and weigh Jared Diamond's east–west axis model with its limits.

Warm-up. Raid the kitchen. Set out six foods: flour, rice, dried lentils or beans, a potato, cornmeal or popcorn, and coffee or chocolate. For each one, write down which continent you think the plant was first grown on and why you think so. Seal the list in an envelope. At the end of the lesson, open it and score yourself.

Watch. *Early farmers, and nomads of the Fertile Crescent.* (Home-Ed History, 2:52).
https://www.youtube.com/watch?v=ozPEgAGnUnQ
With the big idea: watch this short clip to see where the Fertile Crescent lies and why its rivers and soil let early farmers settle down while nomads kept moving.
Note: Captions were not available to check; preview it first. Early-farming videos often give dates like '10,000 years ago', which may differ from how your family dates early history. Does not mention Vavilov or centers of origin. It covers only the Fertile Crescent.

KEY TERMS

domestication
The change of a wild plant or animal, through human selection over many generations, into a form that lives with people and depends on them (for example, wheat whose ripe ears no longer shatter).

agricultural hearth
A place where farming began independently, with its own set of domesticated plants and animals.

first agricultural revolution
The change from gathering and hunting to growing crops and herding animals; museum signs call it the Neolithic Revolution.

Fertile Crescent
The arc of well-watered land from the Persian Gulf up the Tigris and Euphrates valleys and down the eastern Mediterranean coast; named by James Henry Breasted in 1916.

founder crops
The first crops domesticated in the Fertile Crescent: emmer wheat, einkorn wheat, barley, lentils, peas, chickpeas, bitter vetch and flax.

physiological density
: The number of people per unit of arable (farmable) land, a better measure of pressure on farmland than arithmetic density (people per unit of total land).

CORE IDEAS

The story. In 1926 a young Russian botanist named Nikolai Vavilov published a short book with a large claim: the world's crops did not come from everywhere, but from a handful of *centers of origin*. His rule was simple. Go where a crop shows the greatest number of varieties and where its wild relatives still grow in the hills, and you are probably standing near its homeland. To test the rule he led seed-collecting expeditions across Asia, Africa, Europe and the Americas, and he built in Leningrad one of the largest seed collections in the world. His end was bitter. Stalin's government favored Trofim Lysenko, who rejected the science of genetics, and in 1940 Vavilov was arrested on false charges. He died of starvation in a prison in Saratov in January 1943. During the siege of Leningrad, the scientists of his institute guarded his collection through the starving winters, and several of them died at their posts rather than eat the seeds in their care.

How they figured it out. Vavilov's map agreed with what historians suspected about Southwest Asia. In 1916 the American historian James Henry Breasted, of the University of Chicago, named the arc of good land from the Persian Gulf up the Tigris and Euphrates valleys and down the eastern Mediterranean coast the **Fertile Crescent**. But where in the crescent did farming start? In 1948 Breasted's Oriental Institute sent the archaeologist Robert Braidwood to dig at Jarmo, a village mound in the Zagros foothills of northern Iraq. Braidwood's hypothesis was that farming began not on the hot river floodplains but on the "hilly flanks" above them, where wild wheat, wild barley, wild sheep and wild goats lived side by side. At Jarmo his team found mud-walled houses, stone sickle blades, charred wheat and barley, and the bones of goats. The signs of **domestication** are physical. Wild wheat has a brittle ear that shatters when ripe and scatters its seed. Farmers who cut ripe stalks with sickles kept, without meaning to, the rare plants whose ears held together, and sowed them again. In time the crop could no longer spread its own seed; it depended on the farmer.

The big idea. The change from gathering and hunting to growing and herding is called the **first agricultural revolution**; museum signs call it the Neolithic Revolution, a term made famous by the archaeologist V. Gordon Childe. In the Fertile Crescent the **founder crops** were emmer wheat, einkorn wheat, barley, lentils, peas, chickpeas, bitter vetch and flax, and the first herd animals were sheep, goats, cattle and pigs. Farming produced a surplus, and a surplus made possible settled villages, stored grain, specialists who did not farm, and at last the cities and writing of Sumer. Scripture places the first farmers in the same part of the world: "Abel was a keeper of sheep, but Cain was a tiller of the ground" (Genesis 4:2). After the Flood, Noah, whose ark rested on the mountains of Ararat just north of the crescent, "began to be an husbandman" (Genesis 9:20).

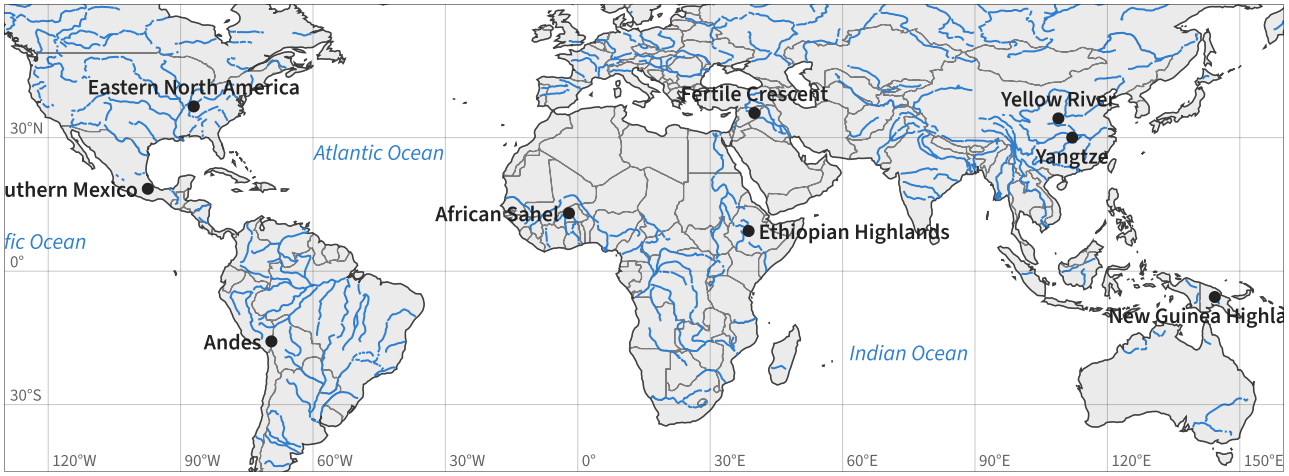
On the map. The Fertile Crescent was not the only **agricultural hearth**. Most geographers now recognize several places where farming began on its own: the Yellow and Yangtze river valleys of China (millet, rice and pigs); southern Mexico (maize, beans and squash); the

Andes (potatoes, quinoa and llamas); the highlands of New Guinea (taro and bananas); the Sahel and savanna of Africa south of the Sahara (sorghum in the eastern Sahel, in today's Sudan; pearl millet, African rice and yams farther west); the Ethiopian highlands (teff and coffee); and the eastern woodlands of North America (sunflower and squash). In 1952 the geographer Carl Sauer proposed that the earliest hearth lay in Southeast Asia, where people planted root crops from cuttings rather than seed. His particular claim is still debated, but his larger point stands: different peoples, in different places, learned to farm the plants God had set around them. Maize shows how far domestication can go. Its wild ancestor, a Mexican grass called teosinte, bears a tiny ear of a few hard kernels.

How farming spread. From the hearths, farming spread by diffusion. Sometimes farmers themselves moved into new land (*relocation diffusion*); sometimes neighbors adopted crops and animals they saw working next door (*expansion diffusion*). Mapping the earliest farm sites of Europe, the archaeologist Albert Ammerman and the geneticist Luca Cavalli-Sforza described a slow "wave of advance" of roughly one kilometer a year, from Anatolia and Greece up the Danube and on to Britain. Ancient DNA has since shown that Europe's first farmers descended largely from Anatolian farmers, so much of that spread was relocation. In 1997 Jared Diamond argued that Eurasia's long east–west axis helped, because places at the same latitude share day length, seasons and climate. The Americas run north and south, so maize had to adapt again and again as it spread. Diamond's model explains a good deal, but critics warn that it slides toward geographic determinism: mountains, deserts and human choices mattered too, and maize did spread across both continents in the end.

The great exchange. The largest diffusion of all followed 1492, in the **Columbian Exchange**. Wheat, cattle, horses, pigs and sugarcane crossed to the Americas; maize, potatoes, cassava, tomatoes and cacao crossed to Europe, Africa and Asia. By the 1700s the potato was feeding much of northern Europe, and maize was grown from Italy to China. The exchange also carried smallpox and other diseases that killed a very large share of the native peoples of the Americas, and the sugar plantations of Brazil and the Caribbean drove the Atlantic slave trade, which carried millions of Africans across the ocean in chains. Both the blessing and the wrong belong in the story.

The Fertile Crescent as Breasted described it in 1916, with early farming villages (Jericho, Jarmo, Çatalhöyük), the temple site of Göbekli Tepe, the Sumerian city of Ur, and Mount Ararat to the north.



The main agricultural hearths recognized by most geographers. Compare how many lie at similar latitudes in Eurasia with how far apart Mexico and the Andes are from north to south.

Thinking About Time

What the sign says. Textbooks and museum signs say farming began in the Fertile Crescent about 9500 BC and reached Britain about 4000 BC.

What we observe. These dates come from radiocarbon tests on charred seeds and bones: what is measured is the amount of carbon-14 left in a sample, while what is assumed is how much carbon-14 the air held when the plant grew and that the sample was never disturbed.

How Christians read it. Christians who read Genesis as history place the first farming with Cain and Abel and its new beginning after the Flood with Noah, and many think radiocarbon dates for this early period run too old because the Flood upset the balance of carbon in the world. Either way, the order of events is the same: farming began in a few hearths, the Fertile Crescent among the first, and spread outward from them.

PICTURE STUDY

The Standard of Ur (the "Peace" side), Unknown Sumerian craftsmen, about 2600–2400 BC · Wooden box inlaid with shell, red limestone and lapis lazuli · British Museum, London

The British archaeologist Leonard Woolley found this object in the Royal Cemetery at Ur, in southern Iraq, during his excavations of the late 1920s. No one knows exactly what it was for. Woolley guessed it had been carried on a pole like a banner, so he called it a "standard," and the name stuck. One side shows war; the other side, shown here, shows peace and plenty.

Ur stood near the mouth of the Euphrates at the southern end of the Fertile Crescent. The panel shows what long centuries of farming had made possible: herds of domesticated animals, loads of produce, and a city rich enough to feast and make music. The blue stone, lapis lazuli, came from the mountains of Afghanistan, more than 2,000 km (1,250 miles) away, so trade is in the picture too.

Look closely

- Start at the bottom row and read upward, as the Sumerians intended. What are the men carrying on their backs?
- Find the animals in the middle row. Which ones were among the first animals domesticated in the Fertile Crescent?

- In the top row, find the seated figures with cups and the musician with a lyre. Who might the largest figure be?
- Look at the materials: white shell, red stone, blue lapis lazuli. Which of these had to be traded from far away?

Talk about it

1. How does this panel show the idea of an agricultural surplus?
2. Why could a city like Ur support musicians, metalworkers and scribes when a band of hunters could not?
3. What does the panel tell us about the link between farming and trade?

> **Safety first.** Raw sprouts can carry bacteria. Look at, measure and draw your sprouts, but do not eat them unless an adult cooks them first.

PROJECT: VAVILOV'S SEED TABLE

Vavilov learned geography from seeds. You will gather seeds and foods from your own kitchen, trace each one to its hearth, sprout two founder crops of the Fertile Crescent, and build a world seed map that shows where farming began and how it spread.

You will need

- Twelve kinds of seeds or seed foods (for example: wheat berries, pearl barley, lentils, dried peas, chickpeas, flaxseed, rice, popcorn, dried beans, sunflower seeds, a small potato, coffee beans)
- Two clean glass jars, cheesecloth or a paper towel, and rubber bands
- Poster board, a world outline map or atlas, glue and colored pencils
- Ruler marked in millimeters, notebook

Steps

1. Lay out your twelve seeds on index cards. On each card write the crop's name and your guess at its hearth.
2. Check each guess against the lesson and the hearth map (figure he-hearths). Correct any cards and note which ones surprised you.
3. Soak a spoonful of wheat berries in one jar and a spoonful of lentils in the other overnight. Drain, cover with cloth held by a rubber band, and lay the jars on their sides out of direct sun.
4. Rinse and drain both jars twice a day for four days. Each evening, measure the longest sprout in each jar in millimeters and record it in a table.
5. On the poster board, draw or trace the world. Glue a few dry seeds at each hearth and label it with its crops.
6. Draw arrows to show three diffusions: the founder crops from the Fertile Crescent into Europe, maize from Mexico into North and South America, and the Columbian Exchange across the Atlantic after 1492.

7. Under the map, write a paragraph answering: Why did Vavilov look for the place with the most varieties and the wild relatives? What might fool that rule?

Tips

- Wheat sends up one narrow shoot; lentils, a legume, grow differently. Sketch the difference.
- Some foods have tangled histories. Oats began as a weed in fields of wheat and barley before people farmed them on purpose. Note any crop like this on its card.

Check your work

- I placed at least ten crops at the correct hearth.
- My sprout table has eight measurements with units.
- My map shows three diffusions with arrows and a date for the Columbian Exchange.
- My paragraph explains Vavilov’s rule and one weakness of it.

MAP NOTEBOOK

1. Trace the Fertile Crescent from figure he-fertile-crescent. Label the Tigris, Euphrates, Zagros Mountains, Jericho, Jarmo, Ur and Mount Ararat, and shade the arc lightly in green.
2. Draw a wild wheat ear shattering and a domesticated ear holding its grain. Under them, write two sentences explaining how sickle harvesting changed the plant.
3. Make a two-column chart titled “The Columbian Exchange” with arrows: Old World to New World, and New World to Old World. List at least five items in each column and one disease.

> **From history.** Vavilov’s idea of saving seeds lives on. The Svalbard Global Seed Vault, cut into a mountainside on the Norwegian island of Spitsbergen, opened in 2008 and holds backup copies of more than a million seed samples from gene banks around the world. In 2015 it made its first withdrawal: the International Center for Agricultural Research in the Dry Areas, whose gene bank near Aleppo had been cut off by the Syrian civil war, asked for its seeds back to rebuild the collection in Lebanon and Morocco. Many of those seeds were wheats, barleys and lentils of the Fertile Crescent itself.

WORKED EXAMPLES

Example 1. Textbooks date the first farming villages of Thessaly, in Greece (near Larissa, 39.6°N, 22.4°E), to about 6500 BC and the first farming in southern England (near London, 51.5°N, 0.1°W) to about 4000 BC. The great-circle distance between the two is about 2,200 km (1,350 miles). Using these textbook dates, find the average rate of spread in kilometers and miles per year. (See the time_note on how such dates are measured.)

1. Time between the two dates: 6500 BC to 4000 BC is 6,500 − 4,000 = 2,500 years.
2. Rate in kilometers: 2,200 km ÷ 2,500 years = 0.88 km per year.
3. Rate in miles: 1,350 miles ÷ 2,500 years = 0.54 miles per year.
4. Compare with Ammerman and Cavalli-Sforza's "wave of advance" of about 1 km per year: the answer is close to their figure.

Answer: About 0.9 km (0.5 miles) per year, close to the "wave of advance" of roughly 1 km per year. At that pace, farming moved only about 150 m (a football field and a half) every two months: slow, steady diffusion, mostly by farming families moving into new land.

Example 2. Test Diamond's axis model with latitude. Wheat spread west from Jericho (31.9°N) to Valencia, Spain (39.5°N). Maize spread south from the Tehuacán Valley of Mexico (18.5°N) to Cuzco, Peru (13.5°S). For each route, find the change in latitude and the north–south distance it represents (1° of latitude ≈ 111 km ≈ 69 miles).

1. Wheat route: both places are in the Northern Hemisphere, so subtract: 39.5° − 31.9° = 7.6°.
2. North–south distance: 7.6 × 111 km ≈ 840 km (7.6 × 69 ≈ 520 miles).
3. Maize route: the places are on opposite sides of the equator, so add: 18.5° + 13.5° = 32.0°.
4. North–south distance: 32.0 × 111 km ≈ 3,550 km (32 × 69 ≈ 2,210 miles).
5. Compare: 32.0 ÷ 7.6 ≈ 4.2, so the maize route crosses about four times as much latitude, and it crosses the equator, where seasons reverse and day length changes.

Answer: Wheat route: 7.6° (about 840 km or 520 miles north to south). Maize route: 32.0° (about 3,550 km or 2,210 miles) and across the equator. The numbers support Diamond's point that maize had to adapt to far greater changes in day length and season, though they do not prove that latitude was the only reason for slower spread.

Example 3. Egypt has always farmed along the Nile. Using rounded figures, Egypt has about 110 million people, a total area of about 1,000,000 km² (386,000 sq mi), and about 30,000 km² (11,600 sq mi) of arable land. Find its arithmetic density and its physiological density, and explain what the difference shows.

1. Arithmetic density = people ÷ total area = 110,000,000 ÷ 1,000,000 km² = 110 people per km² (about 285 per sq mi).
2. Physiological density = people ÷ arable land = 110,000,000 ÷ 30,000 km² ≈ 3,670 people per km².
3. In square miles: 110,000,000 ÷ 11,600 sq mi ≈ 9,480 people per sq mi.
4. Ratio: 3,670 ÷ 110 ≈ 33. Only about 3% of the land is arable, so the farmland is about 33 times as crowded as the arithmetic density suggests.

Answer: Arithmetic density about 110 per km² (285 per sq mi); physiological density about 3,670 per km² (9,480 per sq mi). Nearly all Egyptians live on and are fed by the narrow Nile valley and delta, so the pressure on farmland is far higher than the arithmetic density shows.

PRACTICE

1. EASY What is domestication? Name one physical change that shows a wheat plant has been domesticated.
2. EASY Name four founder crops and three animals first domesticated in the Fertile Crescent.
3. EASY Match each crop to its hearth: (a) maize, (b) potato, (c) sorghum, (d) coffee, (e) rice. Hearths: Andes, Ethiopian highlands, southern Mexico, China, African Sahel.
4. EASY Who named the Fertile Crescent, and in what year? Which two rivers run through its eastern half?
5. MEDIUM State Robert Braidwood's "hilly flanks" hypothesis. Why was Jarmo a good place to test it?
6. MEDIUM If a wave of farming advanced 1.1 km per year, how many years would it take to spread 1,650 km (about 1,025 miles) up the Danube valley?
7. MEDIUM A country has 50 million people and 400,000 km² of land, of which 20% is arable. Find its arithmetic density and physiological density in people per km².
8. MEDIUM Mexico City lies at 19.4°N and Lima, Peru, at 12.0°S. Find the change in latitude and the north–south distance between them (1° ≈ 111 km ≈ 69 miles). What happens to the seasons along the way?
9. MEDIUM Name three plants or animals that crossed from the Old World to the Americas in the Columbian Exchange, three that crossed the other way, and one tragic result of the exchange.
10. HARD Region A has 48 varieties of a bean and wild relatives of the bean growing in its hills. Region B, a busy trading port 1,500 km away, has 61 varieties but no wild

relatives. Using Vavilov's rule, which is more likely the bean's homeland? Why must we be careful?

11. HARD Evaluate Jared Diamond's east–west axis model. Give one piece of evidence that supports it and one limit or criticism.
12. CHALLENGE In a paragraph, explain how archaeologists and geneticists can tell relocation diffusion from expansion diffusion in the spread of farming into Europe, and what the evidence shows.

COMMON MISTAKES

- Thinking farming began in one place and spread to everyone. Several hearths arose independently, each with its own crops.
- Confusing tamed with domesticated. A tamed animal is a wild animal used to people; a domesticated breed has been changed by many generations of selection.
- Mixing up arithmetic density (people per total land) with physiological density (people per arable land).

Make it a game · Hearth Hunt. Write twenty crops and animals on cards (wheat, barley, lentils, sheep, rice, millet, maize, beans, squash, potatoes, llamas, quinoa, sorghum, yams, teff, coffee, taro, bananas, sunflowers, flax). Lay a world map on the table. Players take turns drawing a card and placing it on its hearth within 20 seconds. Correct placement scores a point; naming a country where the crop is grown today scores a bonus point. The first to ten points wins.

Scripture. "And Noah began to be an husbandman, and he planted a vineyard:" (Genesis 9:20, KJV)

After the Flood, the Bible's story of farming begins again in the mountains of Ararat, just north of the Fertile Crescent. Husbandry, the patient care of soil, plants and animals, is one of the oldest kinds of work God gave people.

Practice answers

1. Domestication is the change of a wild plant or animal, through human selection over many generations, into a form that lives with and depends on people. Domesticated wheat has an ear that does not shatter when ripe (it holds its grain until threshed); its grains are also larger.
2. Any four of: emmer wheat, einkorn wheat, barley, lentils, peas, chickpeas, bitter vetch, flax. Any three of: sheep, goats, cattle, pigs.
3. (a) southern Mexico; (b) Andes; (c) African Sahel (most likely the eastern Sahel, in today's Sudan); (d) Ethiopian highlands; (e) China (Yangtze valley).
4. James Henry Breasted of the University of Chicago, in 1916. The Tigris and the Euphrates.
5. Braidwood proposed that farming began in the foothills above the river valleys, where wild wheat, barley, sheep and goats lived naturally, rather than on the river floodplains. Jarmo lies in the Zagros foothills of northern Iraq, exactly in that zone, so finding early farming there (houses, sickle blades, charred grain, goat bones) was evidence for the idea.

6. 1,650 ÷ 1.1 = 1,500 years.
7. Arithmetic: 50,000,000 ÷ 400,000 = 125 per km². Arable land: 0.20 × 400,000 = 80,000 km². Physiological: 50,000,000 ÷ 80,000 = 625 per km² (about 1,620 per sq mi).
8. 19.4 + 12.0 = 31.4°; 31.4 × 111 ≈ 3,490 km (about 2,170 miles). The route crosses the equator, so the seasons are reversed: Lima's summer comes in December–February.
9. Old to New: any three of wheat, cattle, horses, pigs, sheep, sugarcane, coffee. New to Old: any three of maize, potatoes, cassava, tomatoes, cacao, peppers, tobacco. Tragic result: smallpox and other diseases killed a very large share of the native peoples of the Americas; or sugar plantations drove the Atlantic slave trade.
10. Region A, because the wild relatives grow there, which is what a hearth requires. Region B has more varieties, but a trading center can collect varieties from many places; Vavilov himself recognized such "secondary centers." Variety alone can mislead; wild relatives and archaeological remains are stronger evidence.
11. Support: the founder crops of the Fertile Crescent spread quickly across Eurasia at similar latitudes, while maize needed a long time to adapt as it moved north and south through the Americas across many degrees of latitude. Limit: the model can become geographic determinism; mountains, deserts, trade routes and people's choices also governed spread, and maize did in the end spread across both American continents.
12. If farming spread by expansion diffusion, local hunters would have adopted crops and animals, so the first farmers would be genetically like the earlier people and might keep their old tools and customs. If it spread by relocation, the first farmers would be newcomers whose ancestry, pottery and house styles match the source region. Ancient DNA shows that Europe's first farmers descended largely from farmers of Anatolia, and their villages, pottery and crops came with them, so much of the spread was relocation diffusion, with some mixing with local hunters over time.

6.2 Von Thünen's Model

OBJECTIVES

- State the assumptions of von Thünen's model (1826) and draw and explain its rings of land use around a market town.
- Calculate locational rent with the formula $R = Y(p - c) - Yfd$, find the margin of cultivation for a crop, and find the distance where one crop gives way to another.
- Test the model against the real world: explain how rivers, railroads, refrigeration and government policy bend the rings, and where the pattern still shows.

Warm-up. Look in the refrigerator and the pantry. Find one food that spoils in a few days (milk, lettuce, berries) and one that keeps for a year (flour, dry beans, rice). Weigh or estimate a dollar's worth of each. Which would you rather haul 300 miles by wagon, and which would you want grown close to your house? Write one sentence explaining why.

Video. Coming soon. Search for Johann Heinrich von Thünen, "The Isolated State" and the bid-rent curve, and for farmers' markets, milksheds and truck farming near cities: Hillsdale Studios, The History Guy, Library of Congress, The Henry Ford; AP Human Geography teacher channels explaining von Thünen are candidates that need careful vetting (never CrashCourse).

KEY TERMS

von Thünen model
A model, published by Johann Heinrich von Thünen in 1826, that predicts rings of agricultural land use around a single market town, based on the cost of transporting each product.

locational rent (bid rent)
The profit a unit of land can earn for a given use at a given distance from market; the most a farmer could pay for that land and still break even. $R = Y(p - c) - Yfd$.

margin of cultivation
The distance from market at which a crop's locational rent falls to zero; beyond it, growing that crop for market loses money.

intensive agriculture
Farming that puts much labor and capital on each acre to get high output per acre (market gardens, dairies).

extensive agriculture
Farming that uses large areas of land with little labor and capital per acre (ranching, grazing).

milkshed
The area around a city from which fresh milk can be delivered before it spoils; it widens as transport and refrigeration improve.

CORE IDEAS

The story. In 1810 a young German landowner named Johann Heinrich von Thünen bought an estate called Tellow, near the small town of Teterow in Mecklenburg, on the flat plain south of the Baltic Sea. He farmed it for the rest of his life, and he kept accounts that few farmers in history have matched: what every field yielded, what every worker and horse cost, what it cost to haul a wagonload of grain to market and how much of the load the horses ate on the way. Out of more than ten years of these figures he wrote a book. The first volume of *The Isolated State* appeared in Hamburg in 1826. Its question sounds simple. If a farmer can grow anything, what should he grow on each piece of land? Von Thünen's answer, worked out with pencil and ledger, became the first great model of economic geography, and it is still taught a full two centuries later.

How he figured it out. Von Thünen cleared away everything but distance. Imagine, he wrote, one large town in the middle of a fertile plain, with no navigable river or canal; the soil is the same everywhere; the plain ends in an untilled wilderness that cuts it off from the rest of the world; farmers carry their goods to the town by wagon, by the shortest road; and every farmer tries to earn the most he can. On such a plain, the only thing that differs from one field to the next is the cost of reaching the market. A farmer near town pays little for hauling and can pay a high rent for his land; a farmer far away pays heavily for hauling, so his land is worth less. Von Thünen expressed this as **locational rent**: $R = Y(p - c) - Yfd$, where Y is the yield per unit of land, p the market price per unit of product, c the cost of producing a unit, f the freight cost per unit per kilometer, and d the distance to market. Each product has its own rent line, falling with distance. Products that are heavy, bulky or perishable have steep lines; their rent drops fast.

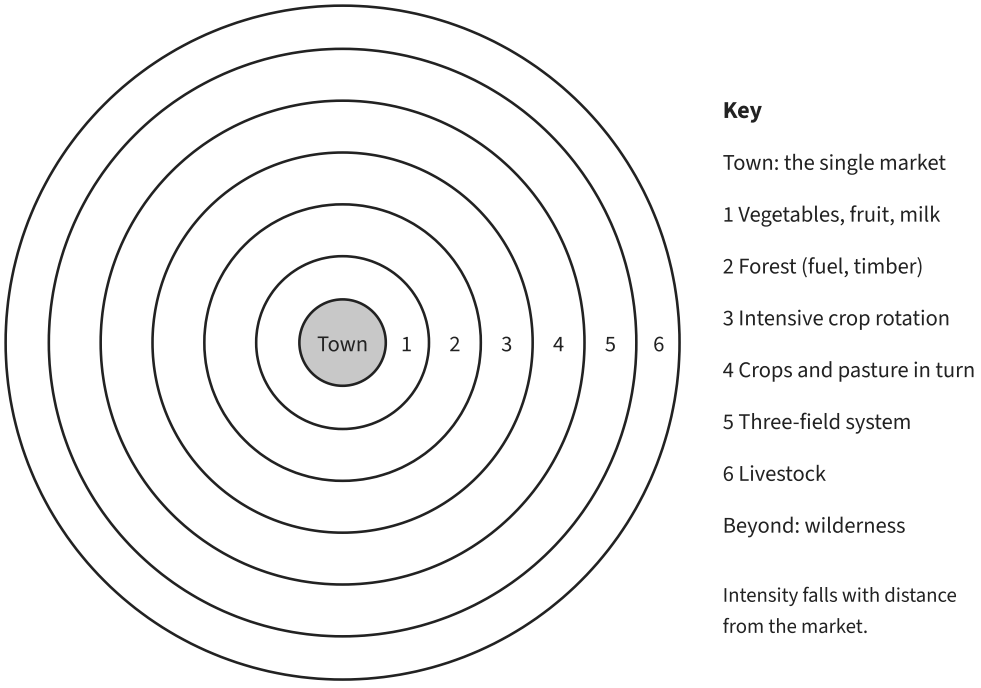
The big idea. On each piece of land, the use that can pay the highest rent wins, so the plain sorts itself into rings. In von Thünen's own scheme there were six. (1) Next to the town, "free cultivation": vegetables, fruit and fresh milk, which spoil quickly and earn much per acre, fed with manure carted back from the town's stables. (2) Forest, which surprises modern readers, because the town of the 1820s burned huge amounts of firewood and built with timber, and wood is so heavy and bulky that hauling it far was ruinous. (3) Grain in an intensive crop rotation with no fallow. (4) Grain in an "improved" system alternating crops and pasture. (5) Grain in the old three-field system, with one field fallow. (6) Livestock, because animals can walk to market on their own legs, and butter, cheese and wool are worth much for their weight. Beyond lay wilderness. The pattern teaches a rule that holds far beyond Mecklenburg: **intensity of land use falls with distance from market**.

Bending the rings. Von Thünen tested his own model. He added a navigable river and showed that, because shipping by water is cheaper than hauling by wagon, the rings stretch into long bands along the river. He added a second, smaller town and showed it would grow its own small set of rings. Every real landscape bends the rings in the same way. Railroads after the 1830s, refrigerated rail cars after the 1870s, trucks, highways and finally air freight lowered f, the freight rate, again and again, so perishable goods could come from farther away. Differences in soil, slope and climate, which the model holds constant, matter greatly on real land. Government subsidies, tariffs and zoning change what crops pay. Near modern

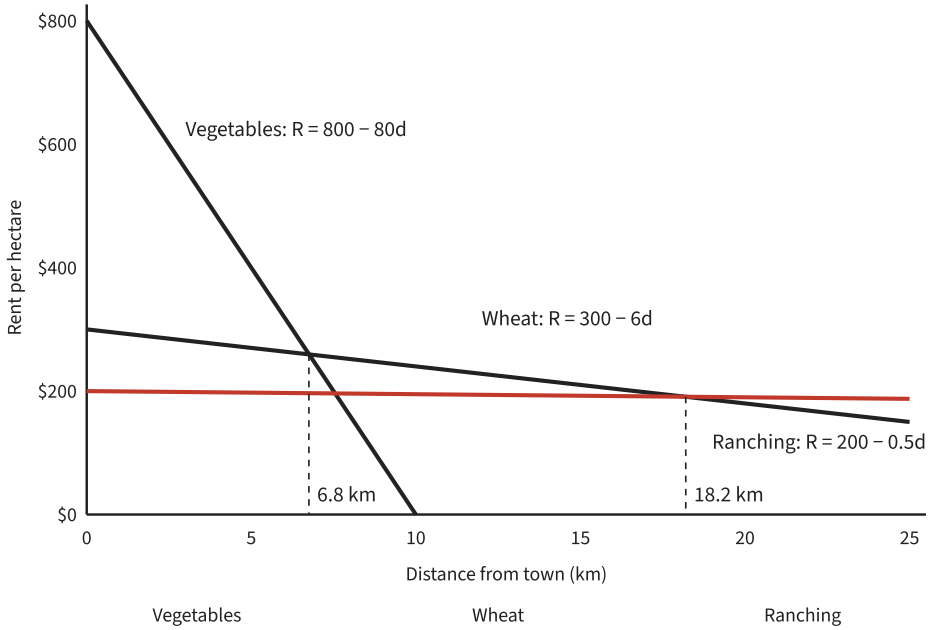
cities, suburban houses often bid more for land than any farm can, so market gardens are pushed outward.

On the map. Is the model therefore wrong? A model is a simplification meant to isolate one cause, and the logic of transport cost still shows. In 1969 the geographer Richard Peet argued that nineteenth-century Britain stood at the center of a world-sized "isolated state": dairy and vegetables came from near home and nearby Europe, grain from the American plains and the Russian steppe, and wool and meat from Argentina, Australia and New Zealand, the outermost ring. In the United States, the **milksheds** around early twentieth-century cities ran along rail lines exactly as von Thünen's river did. Truck farms crowded the edges of Northeastern cities, and the great ranches lay far out on the Great Plains. Economists later applied the same bid-rent logic to land inside cities, which you will meet in Unit 7.

The man behind the model. Von Thünen was not only a calculator. He thought hard about what a fair wage for farm workers would be, and late in his life he gave the workers at Tellow a share of the estate's profits. His careful bookkeeping fits the old wisdom of Proverbs: "Be thou diligent to know the state of thy flocks, and look well to thy herds" (Proverbs 27:23).



Von Thünen's six rings around the town of the "isolated state" (1826). The rings are a model of what pays best at each distance, not a map of any real place.



Bid-rent lines for the three crops in the worked examples. On each stretch of land, the highest line wins, and the crossover points become ring boundaries.

PICTURE STUDY

The Harvesters, Pieter Bruegel the Elder, 1565 · Oil on wood · The Metropolitan Museum of Art, New York

Bruegel painted *The Harvesters* as one of a series of pictures of the seasons for Niclaes Jonghelinck, a wealthy merchant of Antwerp. Five of the series survive. This one shows the wheat harvest of late summer in the Low Countries, the busy, crowded farmland that fed some of the largest cities of sixteenth-century Europe.

Look past the workers and you will see a whole landscape of land use: grain fields, orchards, pasture, a village, roads, and at the far horizon a harbor with ships. Bruegel painted the countryside not as a wilderness but as the working hinterland of a trading world, very much the kind of landscape von Thünen would later try to explain.

Look closely

- Find the workers cutting wheat with scythes and the ones tying sheaves. How many different jobs can you count?
- Look at the group eating under the pear tree. What food have they brought to the field?
- Follow the road and paths from the field toward the village and the distant water. How would this grain reach a town?
- Look at the far distance. What land uses do you see beyond the wheat field?

Talk about it

1. Which of von Thünen’s rings do you think this field belongs to, and why?
2. How does the harbor in the distance change the problem of distance to market that von Thünen studied?
3. What does the painting show about how much human labor one wheat harvest took in 1565?

PROJECT: RINGS AROUND MY TOWN

You will build a working von Thünen model, calculate its ring boundaries in a spreadsheet, bend it with a river, and then test it against the real farms around your own town.

You will need

- A large sheet of paper or poster board, a compass for drawing circles (or a string and pencil), ruler, colored pencils
- A length of blue yarn
- A spreadsheet program or graph paper and calculator
- A road map or online map of your county, and a notebook for a grocery-store or farmers’ market survey

Steps

1. Use the three crops from the worked examples (vegetables, wheat, ranching). In a spreadsheet, list distances from 0 to 30 km in steps of 1 km and compute R for each crop at each distance.
2. Graph all three rent lines on one chart. Mark the crossover points where the highest line changes. These are your ring boundaries.
3. Choose a scale (for example, 1 cm = 1 km) and draw the town and its rings on the poster. Color each ring and make a key.
4. Lay the blue yarn across the plain as a navigable river. Suppose river freight costs one-fifth of wagon freight. Recompute the rent lines for land along the river and redraw the

rings there as long bands.

5. Visit a grocery store or farmers' market. For ten fresh foods, record where each was grown and estimate its distance from your town with the map.
6. Mark on your county map where you find dairies, vegetable farms, grain fields, pasture and woodland (from the map, a drive, or the USDA Census of Agriculture county profile).
7. Write a page: Where do your real farms fit von Thünen's pattern, and where do they break it? Name at least two causes of the differences.

Tips

- Freight rate f is per unit of product per kilometer, so multiply it by the yield Y to get the cost per hectare per kilometer.
- Look for the "highest line wins" rule. A crop can have the highest rent at the town and still lose land farther out because its line is steeper.

Check your work

- My spreadsheet or table computes R correctly for all three crops.
- My ring boundaries match the crossover points (about 6.8 km and 18.2 km).
- My river version shows bands stretched along the river.
- My essay names real examples that fit and real causes that bend the rings.

MAP NOTEBOOK

1. Copy figure he-thunen-rings and color it. Beside each ring, write one product and the reason it belongs there (perishable, heavy, high value per weight, can walk).
2. Draw a second version of the rings with a river running east from the town, showing the bands stretched along it.
3. Sketch a bid-rent graph with two lines that cross. Label the axes, the margin of cultivation of each crop, and the ring boundary.

> **From history.** Von Thünen worked for years on a formula for the "natural wage" of a farm laborer, which he wrote as the square root of ap, where a is what a worker needs to live and p is what his labor produces. He was so attached to the result that he asked for it to be carved on his gravestone, and it was. Economists still debate his formula, but his main model of land use outlived him by two centuries.

WORKED EXAMPLES

Example 1. A market gardener near von Thünen's town grows vegetables with yield Y = 20 tonnes per hectare, price p = $100 per tonne, production cost c = $60 per tonne, and freight f = $4 per tonne per km. (These are illustrative numbers.) Find the locational rent at 4 km and the margin of cultivation.

1. Write the formula: $R = Y(p - c) - Yfd$.
2. Profit per hectare at the town gate: $Y(p - c) = 20 \times (100 - 60) = 20 \times 40 = \$800$.
3. Freight per hectare per km: $Yf = 20 \times 4 = \$80$. So $R = 800 - 80d$.
4. At $d = 4$ km: $R = 800 - 80 \times 4 = 800 - 320 = \$480$ per hectare.
5. Margin of cultivation: set $R = 0$, so $800 = 80d$ and $d = 10$ km (about 6.2 miles).

Answer: R = $480 per hectare at 4 km. The margin of cultivation is 10 km (6.2 miles); beyond it, vegetables for this market lose money.

Example 2. A wheat farmer has Y = 3 tonnes per hectare, p = $200 per tonne, c = $100 per tonne and f = $2 per tonne per km. Find the wheat rent line and its margin, then find the distance at which wheat begins to out-earn the vegetables of Example 1.

(Use the map or drawing "The vegetable and wheat lines cross at about 6.8 km." shown earlier in this lesson.)

1. Wheat: $Y(p - c) = 3 \times (200 - 100) = \$300$; $Yf = 3 \times 2 = \$6$ per km. So $R = 300 - 6d$.
2. Margin: $300 = 6d$, so $d = 50$ km (about 31 miles).
3. Crossover with vegetables: set $800 - 80d = 300 - 6d$.
4. Rearrange: $800 - 300 = 80d - 6d$, so $500 = 74d$ and $d \approx 6.8$ km (about 4.2 miles).
5. Check: at 6.76 km, vegetables earn $800 - 80 \times 6.76 \approx \$259$ and wheat earns $300 - 6 \times 6.76 \approx \$259$. They match.

Answer: Wheat rent $R = 300 - 6d$, with a margin of 50 km. Vegetables win inside about 6.8 km (4.2 miles); wheat wins beyond it, even though vegetables are still profitable out to 10 km, because the wheat line is higher there.

Example 3. Cattle ranching gives Y = 0.5 tonne of beef per hectare, p = $1,500 per tonne, c = $1,100 per tonne, and f = $1 per tonne per km (the cattle walk to market). Combine all three crops into a full ring pattern: find each ring boundary and the outer edge of farming.

(Use the map or drawing "The highest line on each stretch of distance determines the land use." shown earlier in this lesson.)

1. Ranching: Y(p − c) = 0.5 × 400 = $200; Yf = 0.5 × 1 = $0.50 per km. So R = 200 − 0.5d.
2. Margin of ranching: 200 = 0.5d, so d = 400 km (about 249 miles).
3. Crossover of wheat and ranching: 300 − 6d = 200 − 0.5d, so 100 = 5.5d and d ≈ 18.2 km (about 11.3 miles).
4. From Example 2, vegetables give way to wheat at about 6.8 km.
5. Ring pattern: vegetables 0–6.8 km; wheat 6.8–18.2 km; ranching 18.2–400 km; wilderness beyond 400 km.

Answer: Vegetables from the town to 6.8 km (4.2 mi), wheat from 6.8 to 18.2 km (4.2–11.3 mi), ranching from 18.2 to 400 km (11.3–249 mi), then wilderness. The flattest rent line (ranching) takes the outermost and widest ring, just as von Thünen predicted.

PRACTICE

1. EASY Who wrote *The Isolated State*, when was its first volume published, and on what estate did he collect his data?
2. EASY List four assumptions of von Thünen's isolated state.
3. EASY Name von Thünen's six rings in order from the town outward.
4. MEDIUM Why did von Thünen place forest in the second ring, so close to the town?
5. MEDIUM Using the vegetable rent line R = 800 − 80d from Worked Example 1, find the rent at 7 km.
6. MEDIUM A crop has Y = 4 t/ha, p = $150/t, c = $90/t and f = $3 per tonne per km. Write its rent line and find its margin of cultivation in km and miles.
7. MEDIUM Crop A has R = 600 − 50d and Crop B has R = 200 − 10d. At what distance do they cross? Which crop is grown nearer the town?
8. MEDIUM Describe how a navigable river running through the plain changes the ring pattern, and explain why.
9. HARD In Problem 6, suppose bad roads double the freight rate to f = $6 per tonne per km. Find the new margin and explain what happens to the ring.
10. HARD Name two modern developments that weaken von Thünen's pattern, and one place or scale where the pattern can still be seen.
11. HARD In a short paragraph, explain how the same bid-rent idea can explain why downtown land holds office towers and the urban edge holds houses with yards.

12. CHALLENGE In the worked examples, suppose the price of wheat rises from $200 to $260 per tonne while everything else stays the same. Find the new wheat rent line, its margin, and the new boundaries with vegetables and with ranching. Describe the change in the wheat ring.

COMMON MISTAKES

- Treating the rings as a map of a real place. They are a model of what pays best at each distance under stated assumptions.
- Forgetting to multiply the freight rate by the yield. Freight per hectare per km is Yf, not f.
- Thinking the crop with the most profit per hectare at the town must win everywhere it is profitable. Each stretch of land goes to the crop with the highest rent there.

Make it a game · Bid for the Land. Draw a road with five plots marked 1, 5, 10, 20 and 50 km from town. Give each player a product card (vegetables R = 800 − 80d, wheat R = 300 − 6d, ranching R = 200 − 0.5d, or make your own). The banker calls out a plot; each player quickly computes his product's rent there and bids it. The highest correct bid wins the plot. A wrong calculation forfeits the turn. When all plots are sold, check that the winners form von Thünen's rings.

Scripture. "Be thou diligent to know the state of thy flocks, and look well to thy herds." (Proverbs 27:23, KJV)

Von Thünen's model grew out of years of careful records on one estate. Diligent knowledge of the land in our care is part of the stewardship God asks of every farmer and every householder.

Practice answers

1. Johann Heinrich von Thünen; 1826 (in Hamburg); his estate of Tellow, near Teterow in Mecklenburg, Germany.
2. Any four: a single market town in the center; a flat plain; the same soil and climate everywhere; no navigable rivers or canals (transport by wagon only); farmers travel by the shortest route; farmers seek the greatest profit; the state is cut off from the outside world by wilderness.
3. (1) Free cultivation: vegetables, fruit and milk; (2) forest; (3) intensive crop rotation; (4) improved system of crops alternating with pasture; (5) three-field system; (6) livestock raising. Wilderness lies beyond.
4. Towns of his day burned large amounts of firewood and built with timber. Wood is heavy and bulky for its value, so its freight cost per hectare was very high; grown far away, it would cost too much to haul. Its rent line is steep, so it wins land close to town.
5. R = 800 − 80 × 7 = 800 − 560 = $240 per hectare.
6. Y(p − c) = 4 × 60 = $240; Yf = 12. R = 240 − 12d. Margin: 240 = 12d, d = 20 km (about 12.4 miles).

7. 600 − 50d = 200 − 10d gives 400 = 40d, so d = 10 km (6.2 miles). Crop A, with the higher and steeper line, is grown inside 10 km; Crop B beyond it.
8. The rings stretch into long bands along the river. Freight by water is much cheaper than by wagon, so land along the river is effectively “closer” to market; each crop’s rent falls more slowly along the river and its zone extends farther out there.
9. Yf = 4 × 6 = 24; R = 240 − 24d; margin = 240 ÷ 24 = 10 km (6.2 miles). The margin is cut in half, so the crop’s ring shrinks toward the town. Better roads (lower f) do the opposite and widen the ring.
10. Weakening (any two): refrigerated rail and trucks, highways and air freight lowering transport costs; government subsidies and tariffs; zoning and suburban housing bidding up land near cities; differences in soil, slope and climate. Still seen (any one): milksheds and truck farms around cities; the nineteenth-century world pattern around Britain described by Richard Peet (1969), with dairy near and grain, wool and meat far away.
11. Businesses that need to be reachable by many people (offices, stores) earn much more from a central location, so their bid-rent line is high and steep; they outbid other users for downtown land and use it intensively by building tall. Households value space more than centrality, so their line is lower and flatter, and they win land farther out where it is cheaper. The economist William Alonso developed this urban version of von Thünen’s model in 1964.
12. R = 3 × (260 − 100) − 6d = 480 − 6d. Margin: 480 ÷ 6 = 80 km. With vegetables: 800 − 80d = 480 − 6d gives 320 = 74d, d ≈ 4.3 km. With ranching: 480 − 6d = 200 − 0.5d gives 280 = 5.5d, d ≈ 50.9 km. The wheat ring grows in both directions, from 6.8–18.2 km to about 4.3–50.9 km (2.7–31.6 miles), taking land from both market gardens and ranches.

6.3 The Agricultural Revolutions ⚙

OBJECTIVES

- Describe the second agricultural revolution (seed drill, crop rotation, steel plow, reaper, tractor, synthetic fertilizer, hybrid seed) and the third (the Green Revolution of Norman Borlaug and IR8 rice), with places and dates.
- Explain how farm technology overcame geography: short seasons, dry plains, sticky sod and distance to market.
- Calculate yield growth rates, doubling times, the area watered by a center pivot and the land spared by higher yields, and weigh the benefits and costs of the revolutions.

Warm-up. Take a handful of dry beans or rice. Stand up and scatter them by hand across a sheet of newspaper on the floor, the way farmers sowed for thousands of years. Now lay out the same number in straight rows with even spacing. Which method wastes fewer seeds, and which would make weeding between plants easier? Write down two observations.

Video. Coming soon. Search for Jethro Tull's seed drill, the McCormick reaper and John Deere plow, the Fordson tractor, Norman Borlaug and the Green Revolution, and center-pivot irrigation seen from space: The Henry Ford, Smithsonian, Hillsdale Studios, The History Guy, NASA Earth Observatory, Library of Congress; Practical Engineering for irrigation; AP Human Geography teacher channels are candidates that need careful vetting (never CrashCourse).

KEY TERMS

second agricultural revolution
The improvement and mechanization of farming that began in Britain in the 1700s alongside the Industrial Revolution: seed drills, crop rotation, selective breeding, enclosure, and later steel plows, reapers and tractors.

Green Revolution (third agricultural revolution)
The spread, mainly from the 1960s, of high-yielding semi-dwarf wheat and rice together with fertilizer, irrigation and pest control to developing countries; the name was coined by William Gaud in 1968.

mechanization
Replacing human and animal labor with machines, such as reapers, tractors and combines.

Haber–Bosch process
The industrial method of making ammonia from the nitrogen of the air (Haber 1909; Bosch's factory 1913), the basis of synthetic nitrogen fertilizer.

center-pivot irrigation

A long sprinkler pipe on wheeled towers that rotates around a central well, watering a circular field; patented by Frank Zybach in 1952.

doubling time

The time for a quantity growing at a steady rate to double; approximately 70 divided by the percentage growth rate (the rule of 70).

CORE IDEAS

The story. In 1944 a young plant scientist from Iowa named Norman Borlaug arrived in Mexico to work in a wheat program supported by the Rockefeller Foundation and the Mexican government. Mexican wheat was being ruined by stem rust, a fungus that turns the stalks rusty red and shrivels the grain. Breeding a resistant variety normally took ten years or more, because a breeder got only one generation a year. Borlaug broke the rule of one season. He grew a summer crop in the cool, high Toluca Valley near Mexico City, then carried the seed about 1,400 km (850 miles) northwest to sow a winter crop in the irrigated Yaqui Valley of Sonora, near sea level. Experts objected that seed needed to rest after harvest; Borlaug persisted, and two generations a year cut the breeding time in half. The "shuttle" had a bonus no one planned: wheat that thrived at both latitudes and altitudes was no longer fussy about day length, so it could be grown across much of the world. In the 1950s he crossed his wheats with a Japanese dwarf variety, Norin 10, to make short, stiff-stemmed wheat that could carry heavy heads of grain on heavy fertilizer without falling over.

How they figured it out. Borlaug stood at the end of a long chain of inventions. Historians speak of a **second agricultural revolution**, beginning in Britain in the 1700s and running alongside the Industrial Revolution. Jethro Tull, an English gentleman farmer, built a horse-drawn seed drill around 1701 that dropped seed in straight rows at an even depth instead of scattering it by hand, and he described his methods in *The New Horse-Houghing Husbandry* (1731). Charles Townshend, nicknamed "Turnip" Townshend, promoted the Norfolk four-course rotation of wheat, turnips, barley and clover, which ended the idle fallow year: clover enriched the soil and turnips fed livestock through the winter. Robert Bakewell bred sheep and cattle selectively. Enclosure turned scattered open-field strips into compact private farms. In America, John Deere's polished steel plow of 1837 cut the sticky prairie sod that clogged iron plows, Cyrus McCormick's mechanical reaper, first demonstrated in Virginia in 1831, let one man and a team harvest what had taken a crew with scythes, and railroads and grain elevators carried the harvest to Chicago and the world.

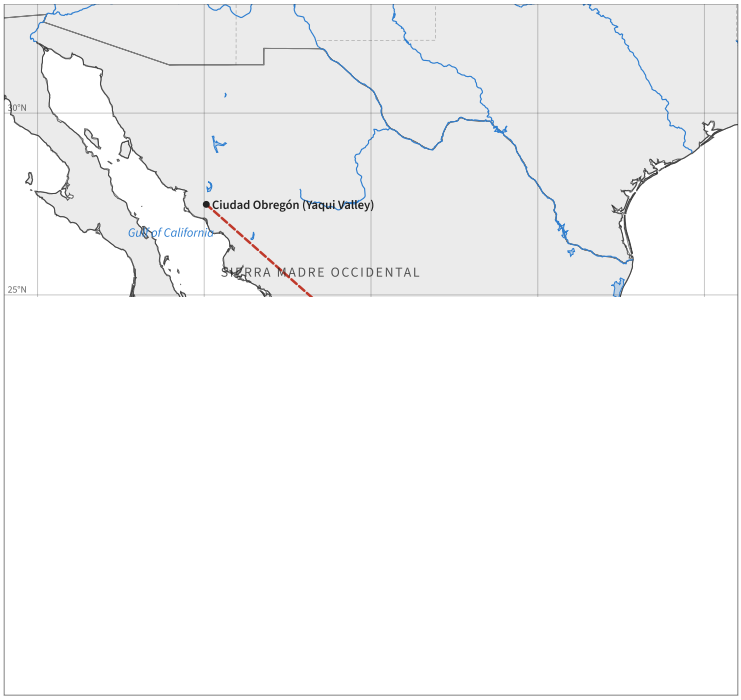
Power and chemistry. The twentieth century added engines and chemistry. Gasoline tractors spread after Henry Ford's cheap Fordson of 1917. U.S. farms kept more than 25 million horses and mules around 1920; by the mid-1950s tractors outnumbered them, and the millions of acres once planted in oats for horse feed could grow food. In Germany, Fritz Haber learned in 1909 how to make ammonia from the nitrogen of the air, and Carl Bosch scaled the process up to a factory by 1913; synthetic nitrogen fertilizer from the Haber–Bosch process now underlies a large share of the world's food supply. Hybrid corn, sold commercially in Iowa from the late 1920s, spread so fast that most Iowa corn acres were hybrid within about a decade. The sociologists Bryce Ryan and Neal Gross studied it in 1943

as a classic case of diffusion: a few innovators, then their neighbors, then nearly everyone, tracing an S-shaped curve.

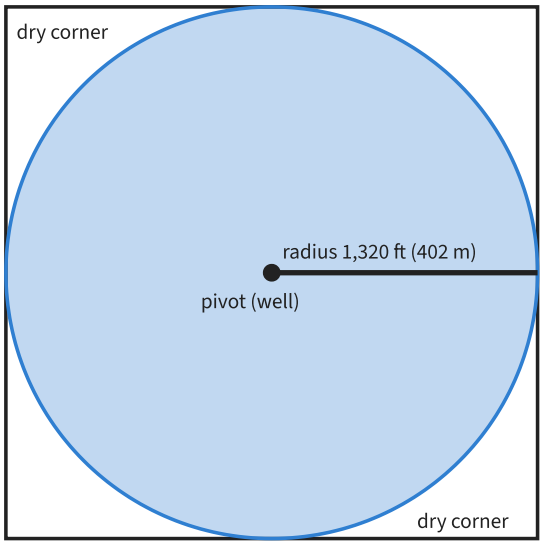
The Green Revolution. The third agricultural revolution carried these tools to the developing world. In the mid-1960s, with famine feared in South Asia, India and Pakistan imported thousands of tons of Borlaug's Mexican semi-dwarf wheat seed. At the International Rice Research Institute in Los Baños, in the Philippines, breeders released IR8 in 1966, a short-stemmed rice that farmers soon called "miracle rice." Wheat yields in India and Pakistan nearly doubled between 1965 and 1970. In 1968 William Gaud of the U.S. Agency for International Development called the change a "green revolution," and in 1970 Borlaug received the Nobel Peace Prize. The new seeds worked as a package with fertilizer, irrigation and pest control; seed alone did little.

Technology overcoming geography. Each revolution let farmers grow food where geography had said no. Marquis wheat, released in Canada in 1909, ripened about a week earlier than older varieties, early enough to beat the first frost on the northern prairies, and it helped turn Saskatchewan and Alberta into wheat country. Gustavus Swift's refrigerated rail cars of the late 1870s let beef dressed in Chicago reach the cities of the East, stretching von Thünen's rings across a continent. Center-pivot irrigation, patented by the Colorado farmer Frank Zybach in 1952, swings a long sprinkler pipe around a central well, watering a circle of semi-arid land from the Ogallala Aquifer beneath the High Plains; from an airplane, western Kansas and Nebraska are dotted with green circles. Today GPS-guided tractors plant within a few centimeters of the planned line and vary fertilizer across a single field, a practice called precision agriculture.

The big idea. The result is the most productive farming in history. In 1900 about two in five American workers farmed; by 2000 about one in fifty did, and the country fed itself and exported grain besides. The revolutions also had costs, and a careful student weighs them. Heavy pumping has lowered water tables in India's Punjab and in parts of the Ogallala; fertilizer runoff feeds algae in rivers and bays; farmers planted fewer local varieties, which is why seed banks matter; and farmers with irrigation, credit and roads gained more than those without, so the rain-fed sorghum, millet and cassava farms of much of sub-Saharan Africa benefited less at first. Genetically engineered crops, planted widely since 1996, are the newest chapter: supporters point to higher yields and fewer insecticide sprays, while critics raise concerns about seed patents and herbicide-resistant weeds. Borlaug himself said his work had bought the world time, not ended hunger. Scripture gives the frame: man is set in the garden "to dress it and to keep it" (Genesis 2:15), using every good invention with care, and the prophet credits the farmer's skill to God's own teaching (Isaiah 28:26).



Borlaug's shuttle breeding: a summer crop in the high Toluca Valley and a winter crop in the irrigated Yaqui Valley, two generations a year.



Quarter section: 160 acres

Square: 2,640 ft on a side

Irrigated circle:
about 125.7 acres (50.9 ha)
78.5% of the square

Four dry corners:
about 34.3 acres in all

A center pivot in a quarter section. The circle waters about 78.5% of the square; the corners stay dry unless a corner arm is added.

PICTURE STUDY

The Sower, Jean-François Millet, 1850 · Oil on canvas · Museum of Fine Arts, Boston

Jean-François Millet grew up in a farming family in Normandy and later settled in the village of Barbizon near Paris, where he painted the hard work of French peasants. *The Sower* was shown at the Paris Salon of 1850–51 and caused a stir: critics were startled to see a common field worker painted on a grand scale, like a hero.

The sower is broadcasting seed, throwing it by hand in wide arcs, exactly as farmers had done since the first fields of the Fertile Crescent and as Jesus described in the parable of the sower. A century and a half before Millet, Jethro Tull had built a drill to plant in rows, but in 1850 most of the world's grain was still sown this way.

Look closely

- Follow the sower's right arm. Where is the seed going, and how evenly do you think it will land?
- Find the bag of seed. How is he carrying it, and how much do you think it holds?
- Look at the background on the hillside. What other farm work is going on?
- Notice the light and the colors. What time of day is it, and what mood does Millet create?

Talk about it

1. Compare broadcasting with Tull's seed drill. What three problems of hand sowing did the drill solve?
2. Why might Millet have chosen to make a single farm worker so large and strong in the picture?

3. How many people would it take to sow a 1,000-acre Kansas wheat farm this way? What does that tell you about mechanization?

PROJECT: BROADCAST OR DRILL? A PLANTING TRIAL

Jethro Tull claimed that sowing in rows at an even depth saved seed and gave stronger plants. You will test his claim with radishes, which sprout in a few days, and build a simple row-marking tool like the business end of a seed drill.

You will need

- Two shallow trays or boxes of the same size (about 30 by 45 cm), filled with potting soil
- Radish seeds (count out 150)
- A scrap board about 30 cm long and four short dowels or thick pencils
- Duct tape, ruler, spray bottle, notebook

Steps

1. Build a row marker: tape four dowels upright to the board, 7.5 cm apart, each sticking out 1 cm. Pressed into soil, it makes four furrows of equal spacing and depth, as Tull's drill did.
2. Tray A (broadcast): stand up, and scatter 100 seeds by hand over the tray from shoulder height. Rake the surface lightly with your fingers to cover them.
3. Tray B (drill): press the marker into the soil, drop 50 seeds evenly along the four furrows (about 12 or 13 per row), and cover them.
4. Water both trays the same way with the spray bottle and keep them in the same light.
5. On days 3, 5 and 7, count the seedlings in each tray. On day 7, measure the height of ten seedlings in each tray and find the average.
6. Compute for each tray: the germination rate (seedlings ÷ seeds × 100) and the seeds used per surviving plant.
7. Try to "hoe" each tray with a pencil, removing imaginary weeds between plants. Note which tray is easier.
8. Write a one-page report answering Tull's question: Did drilling save seed and make stronger plants? Include your data table and one weakness of your test.

Tips

- Broadcast seed often lands too deep, too shallow or in clumps, so some never sprout or crowd one another. Look for clumps.
- A fair test changes only one thing. Keep soil, water and light the same for both trays.

Check your work

- My row marker makes even furrows at a set spacing.
- My table has counts for days 3, 5 and 7 and average heights for day 7.
- I calculated germination rate and seeds per plant for both trays.

- My report states a conclusion supported by my numbers and names one weakness.

MAP NOTEBOOK

1. Make a timeline of farm technology from 1701 to 1996 with at least ten inventions and dates from this lesson. Mark the second and third agricultural revolutions.
2. Copy figure he-shuttle-breeding. Label both valleys with their seasons and approximate elevations, and draw the shuttle route.
3. Sketch a bird’s-eye view of a section of land (one square mile) holding four center-pivot circles. Shade the irrigated circles and the dry corners.

> **From history.** Borlaug did not retire when the Nobel Prize came. In 1986, past the age of seventy, he joined the Japanese philanthropist Ryoichi Sasakawa in a program to bring the same package of better seed and fertilizer to farmers in sub-Saharan Africa, where the Green Revolution had largely passed by. In 2014 the state of Iowa placed a bronze statue of him in National Statuary Hall in the U.S. Capitol, where he stands among the nation’s great figures as a farm boy who became, in the eyes of many, a man who helped feed the world.

WORKED EXAMPLES

Example 1. In the 1930s, before hybrid seed spread, U.S. corn averaged about 25 bushels per acre. In 2023 the national average reached a record of about 177 bushels per acre. Taking 1935 as the starting year, find the average annual growth rate of yield and its doubling time. Then convert 177 bushels per acre to tonnes per hectare (1 bushel of corn = 56 lb = 25.4 kg; 1 acre = 0.4047 ha).

1. Number of years: 2023 − 1935 = 88.
2. Growth factor: 177 ÷ 25 = 7.08.
3. Annual rate: r = 7.08^(1/88) − 1. Since ln 7.08 ≈ 1.957, divide by 88: 0.02224. Then e^0.02224 ≈ 1.0225, so r ≈ 2.25% per year.
4. Doubling time by the rule of 70: 70 ÷ 2.25 ≈ 31 years (exactly, ln 2 ÷ ln 1.0225 ≈ 31.2 years).
5. Convert: 177 × 25.4 kg ≈ 4,496 kg per acre; 4,496 ÷ 0.4047 ≈ 11,110 kg per hectare, or about 11.1 tonnes per hectare.

Answer: About 2.25% per year, doubling roughly every 31 years; the yield rose about sevenfold. 177 bu/acre ≈ 11.1 t/ha.

Example 2. A quarter section of the Public Land Survey is a square half a mile (2,640 ft) on a side, or 160 acres. A center pivot set at its center has a radius of 1,320 ft. How many acres does it water, what percent of the quarter section is that, and how large are the dry corners? (1 acre = 43,560 sq ft.)

(Use the map or drawing "The circle touches all four sides, so it covers π/4 of the square." shown earlier in this lesson.)

1. Area of the circle: $A = \pi r^2 = 3.1416 \times 1{,}320^2 = 3.1416 \times 1{,}742{,}400 \approx 5{,}473{,}900$ sq ft.
2. In acres: 5,473,900 ÷ 43,560 ≈ 125.7 acres.
3. Percent of the square: 125.7 ÷ 160 ≈ 0.785, or 78.5%. (This is π ÷ 4 for any circle in a square that it just touches.)
4. Dry corners: 160 − 125.7 = 34.3 acres, about 8.6 acres in each corner.
5. In metric: 125.7 acres × 0.4047 ≈ 50.9 hectares; the radius is about 402 m.

Answer: About 125.7 acres (50.9 ha), or 78.5% of the quarter section; the four dry corners total about 34.3 acres.

Example 3. Land sparing. A country needs 20 million tonnes of wheat a year. At the old yield of 0.8 tonne per hectare, how much land would it need? At a Green Revolution yield of 2.0 tonnes per hectare? How much land is spared, in hectares, square kilometers and square miles? (1 km² = 100 ha; 1 sq mi = 2.59 km².)

1. Old yield: 20,000,000 t ÷ 0.8 t/ha = 25,000,000 ha.
2. New yield: 20,000,000 t ÷ 2.0 t/ha = 10,000,000 ha.
3. Land spared: 25,000,000 − 10,000,000 = 15,000,000 ha.
4. In km²: 15,000,000 ÷ 100 = 150,000 km².
5. In square miles: 150,000 ÷ 2.59 ≈ 57,900 sq mi, nearly the size of the state of Georgia.

Answer: 25 million ha at the old yield versus 10 million ha at the new; 15 million ha (150,000 km², about 57,900 sq mi) are spared for forest, pasture or other crops. This is the "land sparing" argument Borlaug often made for higher yields.

PRACTICE

1. EASY Name the three agricultural revolutions and one invention or change that belongs to each.
2. EASY What did Jethro Tull's seed drill do differently from broadcast sowing?
3. EASY Give the four crops of the Norfolk four-course rotation and explain what the turnips and clover did.

4. EASY Who coined the term “Green Revolution” and in what year? Who received the Nobel Peace Prize for this work, and when?
5. MEDIUM Borlaug’s two stations were the Yaqui Valley near Ciudad Obregón (27.5°N, near sea level) and the Toluca Valley (19.3°N, about 2,600 m). Find the difference in latitude and the north–south distance it represents (1° ≈ 111 km), and the difference in elevation in feet (1 m = 3.28 ft). Why did using both places help?
6. MEDIUM A district’s wheat yield rises from 1.0 to 2.0 tonnes per hectare in 5 years. What average annual growth rate does this represent?
7. MEDIUM If farm output grows at a steady 3% per year, about how long will it take to double? Use the rule of 70, then check with logarithms.
8. MEDIUM A center pivot has a radius of 400 m. How many hectares and acres does it water? (1 ha = 10,000 m^2; 1 ha = 2.471 acres.)
9. MEDIUM A country needs 6 million tonnes of rice. How much land does it need at 1.5 t/ha and at 4.0 t/ha? How much land is spared, in km^2 and square miles?
10. HARD Describe the S-shaped diffusion curve Ryan and Gross found for hybrid corn in Iowa. Why did the curve start slowly and then rise steeply?
11. HARD Give two benefits and two costs of the Green Revolution, each supported by a specific fact or example.
12. CHALLENGE Write a paragraph explaining how farm technology has “overcome geography.” Use three specific examples from the lesson and name one way geography still limits farming.

COMMON MISTAKES

- Thinking the Green Revolution was only new seeds. The high-yield varieties needed fertilizer, irrigation and pest control to pay off.
- Treating each revolution as a single event. Each unfolded over decades and spread unevenly, following an S-curve of diffusion.
- Using the rule of 70 with the rate written as a decimal. Divide 70 by the percentage (3, not 0.03).

Make it a game · Inventor’s Timeline. Write fifteen farm inventions and changes on cards without dates (seed drill, Norfolk rotation, steel plow, reaper, refrigerated rail car, Marquis wheat, Haber–Bosch, Fordson tractor, hybrid corn, center pivot, semi-dwarf wheat, IR8 rice, the term “Green Revolution,” GPS tractors, engineered crops). Shuffle and deal. Players take turns placing a card in the right spot on a growing timeline on the table. If another player challenges and the card is out of order, the placer loses the card; if it is right, the challenger loses a turn. Most cards placed correctly wins.

Scripture. “For his God doth instruct him to discretion, and doth teach him.” (Isaiah 28:26, KJV)

Isaiah describes the plowman who knows how to plow, sow and thresh each crop in its own way, and says his skill comes from God. Seed drills, hybrid corn and new wheats are fruits of

the minds God gave people, to be used with wisdom and care.

Practice answers

1. First (Neolithic): domestication of plants and animals, such as wheat or sheep. Second: for example the seed drill, Norfolk rotation, steel plow, reaper or tractor. Third (Green Revolution): for example semi-dwarf wheat, IR8 rice, or the package of fertilizer and irrigation.
2. It placed seed in straight rows at an even depth and spacing instead of scattering it by hand. This saved seed, covered it properly, and left room to hoe weeds between the rows.
3. Wheat, turnips, barley, clover. Clover enriched the soil with nitrogen and made hay or pasture; turnips fed livestock through the winter. Together they ended the need for an idle fallow year.
4. William Gaud of USAID, in 1968. Norman Borlaug, in 1970.
5. 27.5 − 19.3 = 8.2°; 8.2 × 111 ≈ 910 km (about 565 miles). Elevation difference about 2,600 m ≈ 8,500 ft. Using both gave two growing seasons a year (halving breeding time) and produced wheat adapted to different day lengths and conditions, so it could grow widely.
6. r = 2^(1/5) − 1 ≈ 1.149 − 1 = 0.149, about 14.9% per year (rule of 70 check: 70 ÷ 14.9 ≈ 4.7 years to double, close to 5).
7. 70 ÷ 3 ≈ 23 years. Exactly: ln 2 ÷ ln 1.03 ≈ 0.693 ÷ 0.0296 ≈ 23.4 years.
8. A = π × 400² = 3.1416 × 160,000 ≈ 502,700 m² ≈ 50.3 ha ≈ 124 acres.
9. 6,000,000 ÷ 1.5 = 4,000,000 ha; 6,000,000 ÷ 4.0 = 1,500,000 ha. Spared: 2,500,000 ha = 25,000 km² ≈ 9,650 sq mi.
10. A few innovators planted hybrid corn first, so adoption rose slowly at the start. As neighbors saw the higher yields with their own eyes and talked with those farmers, adoption spread rapidly (contagious diffusion), making the curve rise steeply. It leveled off near the top when almost every farmer had switched, leaving only a few late adopters.
11. Benefits (any two): wheat yields in India and Pakistan nearly doubled from 1965 to 1970; famine feared in South Asia in the 1960s was averted; higher yields spared land from the plow; IR8 and later rice varieties raised rice output across Asia. Costs (any two): heavy irrigation lowered water tables in Punjab; fertilizer runoff causes algae growth in rivers and bays; local varieties were abandoned (loss of genetic diversity); farmers without irrigation or credit, including much of rain-fed Africa, gained less.
12. Strong answers name three examples, such as: Marquis wheat (1909) ripened early enough to escape frost on the Canadian prairies; John Deere’s steel plow (1837) broke the tough prairie sod; center pivots (Zybach, 1952) brought water from the Ogallala Aquifer to semi-arid plains; refrigerated rail cars (late 1870s) let perishable meat travel across the continent; shuttle-bred wheat ignored day length and grew across many latitudes. A limit: water (aquifers can be drawn down and rainfall cannot be manufactured), the length of the frost-free season, steep slopes and poor soils, and the cost of distance still shape what can be grown where.

6.4 Farming Regions of the World

OBJECTIVES

- Distinguish subsistence from commercial and intensive from extensive agriculture, and describe the main world farming regions from rice paddies to wheat belts, with their climates and places.
- Explain how climate, soil, slope, distance to market, population and history shape where each kind of farming is found, including Boserup's view of intensification.
- Calculate a location quotient and the people fed per hectare, and classify a farming region from climate data.

Warm-up. Pull five foods from the pantry or refrigerator that have a country or state of origin on the label (rice, bananas, coffee, olive oil, cheese, oranges, pasta). For each, guess the climate it was grown in: hot and wet all year, dry in summer, cold winters, or dry grassland. Keep your guesses for the project.

Watch. *The Dust Bowl: How America Plowed Its Way to Black Sunday* (The Photographed Past, 5:10). https://www.youtube.com/watch?v=h8U4QlIH3jQ
With the big idea: watch how plowing up the native shortgrass and then years of drought turned the southern Plains wheat country into the Dust Bowl, and notice what the grass roots had been doing for the soil.
Note: Captions were not available to check; preview it first. This is a small, unfamiliar channel, so listen for a robotic or AI-sounding narrator. The film shows hard times, with farms auctioned and families leaving their homes.

Backup video. *How a Combine Works | Harvesting Corn with Modern Farming Technology* (MissouriCorn, 5:24). https://www.youtube.com/watch?v=AyQB77Tihaw
With On the map: watch a modern combine cut corn and separate the grain, then compare it with the small hand-worked fields of Asia in the story. Note: Captions were not available to check; preview it first. It comes from a farm group (Missouri Corn Growers) and may close with a membership pitch. The video shows a corn harvest; the lesson talks about the U.S. wheat harvest and custom combine crews.

KEY TERMS

subsistence agriculture
Farming mainly to feed the farmer's own family, with little sold for cash.

commercial agriculture
Farming mainly to sell crops and animals off the farm, usually on a larger scale with machines.

intensive subsistence agriculture

Farming of small plots with much labor per acre to feed a dense population, as in the wet-rice lands of East, South and Southeast Asia.

pastoral nomadism
Herding domesticated animals by moving with them seasonally across dry lands in search of pasture and water.

shifting cultivation
Clearing a patch of tropical forest (often by slash and burn), farming it for a few years, then leaving it to regrow while clearing a new patch.

location quotient (LQ)
A ratio comparing a region's share of an activity with the national share: LQ = (local share) ÷ (national share). Above 1 means the region specializes in it.

CORE IDEAS

The story. Early in 1909 Franklin Hiram King, a soil scientist who had taught at the University of Wisconsin and worked for the U.S. Department of Agriculture, crossed the Pacific to Asia. Over the next several months he walked the fields of Japan, China and Korea with a notebook and a camera. What amazed him was not machinery, for there was little, but how many people small fields could feed, and how long they had done it. He watched farmers carry mud from canals onto their fields, compost every scrap, grow two or three crops a year on the same ground, and set out rice seedlings by hand in flooded paddies. King died in 1911 before he finished his book, and it was published that year as *Farmers of Forty Centuries*. To a man from the wheat and dairy country of the American Midwest, it was a different farming world, and the contrast between those two worlds is the subject of this lesson.

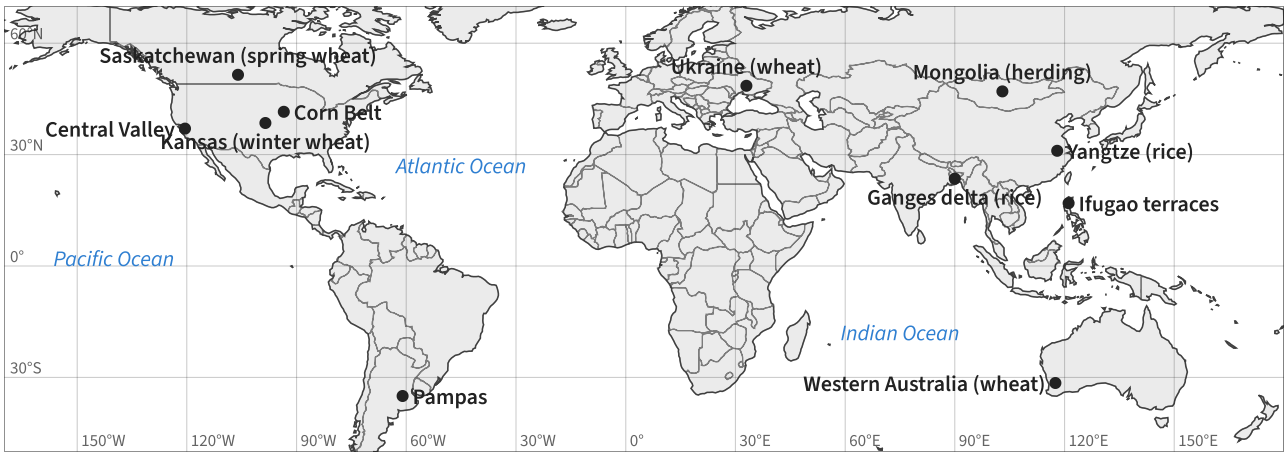
How geographers sort farms. In 1936 the Harvard geographer Derwent Whittlesey published the map of world agricultural regions that most textbooks still follow. He sorted farming by the mix of crops and livestock, the methods used, the intensity of labor and capital put into the land, whether the harvest is eaten at home or sold, and the farm buildings. Two divisions do most of the work. **Subsistence agriculture** feeds the farm family; **commercial agriculture** sells to the market. **Intensive** farming puts much labor or capital on each acre; **extensive** farming spreads little effort over much land. Physical geography sets the outer limits (Köppen climate, soil and slope), and markets, population, technology and history decide what is grown inside them.

From rice paddies. In the warm, wet monsoon lands of East, South and Southeast Asia, **intensive subsistence agriculture** centers on wet rice. Asia grows about nine-tenths of the world's rice, and China and India are the two largest producers. Seedlings are raised in a nursery bed, transplanted by hand or machine into flooded paddies whose low walls hold water, and harvested after the fields are drained. Where the season is long, two crops a year come off the same field. On steep slopes, families have carved terraces, like the rice terraces of the Ifugao people in the mountains of northern Luzon, named a UNESCO World Heritage Site in 1995. Where it is too dry or too cold for paddy rice, as on the North China Plain and much of India, the same intensive methods grow wheat, millet and sorghum. Farms are small and agricultural density is very high.

To wheat belts. In the semi-arid grasslands of the middle latitudes, **commercial grain farming** is extensive. Winter wheat is sown in the fall and harvested in early summer in Kansas, Oklahoma and Nebraska; spring wheat, sown in spring where winters are too harsh, fills the Dakotas, Saskatchewan and the steppes of Russia and Kazakhstan. The black chernozem soils of Ukraine and southern Russia, the Pampas of Argentina and the wheat belt of southern Australia complete the map. One family with large machines may farm thousands of acres, and custom combine crews follow the ripening wheat north from Texas toward Canada each summer. In the early 2020s Russia was the world's largest wheat exporter; the other leading exporters included the European Union, Canada, Australia, the United States, Ukraine and Argentina.

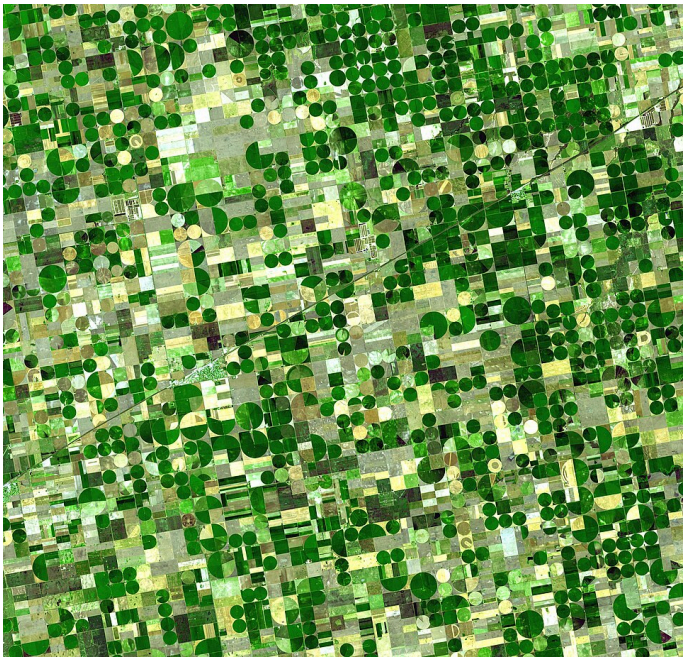
On the map. Between and beyond these lie the other regions. *Mixed crop and livestock* farming fills the U.S. Corn Belt and much of Europe, where corn and soybeans are fed to hogs and cattle. *Dairy* farms crowd near cities in von Thünen's first ring, while butter and cheese come from farther off, as in Wisconsin and New Zealand. *Mediterranean agriculture*, with olives, grapes, citrus and winter wheat, belongs to dry-summer climates: the Mediterranean basin, California, central Chile, the Cape of South Africa and southern Australia. *Plantations* grow one cash crop (sugar, coffee, cocoa, bananas, rubber, palm oil) in the tropics; the sugar plantations of Brazil, the Caribbean and the American South were worked by enslaved Africans, a great wrong now abolished. *Livestock ranching* spreads across semi-arid lands too dry for crops; *pastoral nomads* such as Bedouin, Mongolian herders and the Maasai move with their animals; and *shifting cultivation* clears and rests patches of tropical forest in turn.

The big idea. Farming regions are models too: real boundaries blur, and one farm can mix several types. Why does a region farm intensively? Malthus (Unit 2) feared that population would outrun food. The Danish economist Ester Boserup argued in 1965 that the arrow can point the other way: growing population pushes farmers to work land harder, with shorter fallows, terraces, irrigation and more labor, so that intensification follows population. Both forces are real, and King's Asian farmers show the second at work. Behind every region stands the promise God made to Noah when he came out of the ark: "While the earth remaineth, seedtime and harvest, and cold and heat, and summer and winter, and day and night shall not cease" (Genesis 8:22).



Sample places for the main farming regions. Note that the wheat regions lie in mid-latitude grasslands of both hemispheres, while the rice regions cluster in monsoon Asia.

PICTURE STUDY



Crop Circles in Finney County, Kansas, ASTER instrument on NASA's Terra satellite, June 24, 2001 · Satellite image · NASA Earth Observatory, image 5772, "Crop Circles in Kansas" (public domain)

From space, the High Plains of southwest Kansas look like a sheet of coins. Each circle is a field watered by a center pivot, set inside the square grid of the Public Land Survey. The larger circles are about 1.6 km (1 mile) across and the smaller about 800 m (half a mile). The image was taken in late June, near the start of the winter wheat harvest.

This is one picture of a wheat belt and of commercial agriculture at work: big fields, machines, groundwater from the Ogallala Aquifer, and crops grown for distant markets. Compare it in your mind with a hillside of hand-built rice terraces, the other end of the farming world.

Look closely

- Find the square grid. What does it tell you about how the land was surveyed and divided?
- Compare the colors of the circles. Why might neighboring fields look so different on the same day?
- Look at the corners between circles. Why are they a different color from the circles?
- Find any fields that are not circles. What might be grown there, or why might they lack a pivot?

Talk about it

1. Is the farming in this image intensive or extensive, subsistence or commercial? Defend your answer.
2. What would happen to this landscape if the aquifer below it could no longer supply water?
3. How would a satellite image of a rice-growing valley in Asia look different, and why?

PROJECT: GROCERY BAG ATLAS

Your kitchen is a map of the world's farming regions. You will trace twenty foods to where they were grown, place each one in its farming region and climate, and measure how far your dinner traveled.

You will need

- Twenty food items or labels from your kitchen or a grocery store (include fresh produce stickers, coffee, rice, olive oil, cheese, bread or pasta, meat, bananas or other tropical fruit)
- A world outline map, an atlas or online map with a distance tool, and colored pencils
- A world climate (Köppen) map from an atlas or textbook
- Notebook or spreadsheet

Steps

1. For each item, record the food, the country or state of origin from the label, and the nearest large city in that place.
2. Using the lesson, assign each food to a farming region: intensive subsistence, commercial grain, mixed crop and livestock, dairy, Mediterranean, commercial gardening, plantation, ranching or another.
3. Look up the Köppen climate of each origin. Check whether the climate fits the region you chose; correct any that do not.
4. Measure the straight-line distance from each origin to your town, in miles and kilometers. Find the average and the longest trip.
5. Plot all twenty origins on the world map with symbols for each farming region, and draw lines to your town.
6. Sort the foods by distance. Do the perishable foods (milk, lettuce, eggs) come from closer than the durable ones (rice, coffee, flour)? Compare with von Thünen's rings

from Lesson 6.2.

7. Write a page explaining what your atlas shows about farming regions, climate and transportation. Name the region you depend on most.

Tips

- Labels like “packed in” or “distributed by” name a company’s office, not the farm. Look for “product of” or “grown in.”
- Bananas, coffee and cocoa almost always come from tropical plantations or smallholders; olive oil from dry-summer lands. Use these as anchors.

Check your work

- I traced twenty foods with origins and distances in two units.
- Each food is assigned to a farming region whose climate fits.
- My map uses a clear key and shows the lines to my town.
- My essay links perishability and distance to von Thünen and names my most important region.

MAP NOTEBOOK

1. On a blank world map, shade and label at least eight farming regions using a key with a different color for each.
2. Draw a cross-section of a rice terrace hillside: the steps, the walls holding water, the water flowing down from one paddy to the next.
3. Make a two-column chart comparing a Kansas wheat farm and a Chinese rice farm: size, labor, machines, crops per year, yield per acre, yield per worker.

> **From history.** The wheat belt has its own warning. In the 1920s farmers plowed up millions of acres of the southern Great Plains grassland for wheat. When drought struck in the 1930s, the bare soil blew away in great dust storms, and on “Black Sunday,” April 14, 1935, a huge black cloud of dust rolled across Oklahoma and Texas. That same month Congress created the Soil Conservation Service, led by Hugh Hammond Bennett, which taught contour plowing, cover crops and strip cropping. Between 1934 and 1942 a federal shelterbelt project planted more than 200 million trees in windbreaks across the Plains. Many of those windbreaks still stand.

WORKED EXAMPLES

Example 1. A Great Plains county has 400,000 acres of cropland, of which 120,000 acres are in wheat. Nationwide, roughly 45 million of 300 million cropland acres are in wheat. (Rounded, illustrative figures.) Find the county's location quotient for wheat and interpret it.

1. Local share: 120,000 ÷ 400,000 = 0.30, or 30%.
2. National share: 45,000,000 ÷ 300,000,000 = 0.15, or 15%.
3. LQ = local share ÷ national share = 0.30 ÷ 0.15 = 2.0.
4. Interpret: an LQ above 1 means the activity is more concentrated here than in the nation as a whole.

Answer: LQ = 2.0. The county devotes twice the national share of its cropland to wheat, so it specializes in wheat, as expected of a commercial grain region.

Example 2. Compare food per hectare and food per worker. A family rice farm in a warm monsoon valley harvests two crops a year of 3.0 tonnes of milled rice per hectare each, on 1 hectare, with 4 workers. A Kansas wheat farm harvests one crop of 3.0 tonnes per hectare on 1,000 hectares with 2 workers. If a person eats about 150 kg of grain a year, how many people can each hectare feed, and how much grain does each worker produce? (Illustrative figures.)

1. Rice per hectare per year: 2 × 3.0 t = 6.0 t = 6,000 kg. People fed per hectare: 6,000 ÷ 150 = 40.
2. Wheat per hectare per year: 3.0 t = 3,000 kg. People fed per hectare: 3,000 ÷ 150 = 20.
3. Rice per worker: 6.0 t ÷ 4 workers = 1.5 t per worker.
4. Wheat per worker: (3.0 t × 1,000 ha) ÷ 2 workers = 3,000 t ÷ 2 = 1,500 t per worker.
5. Compare: rice feeds twice as many people per hectare; wheat produces 1,500 ÷ 1.5 = 1,000 times as much per worker.

Answer: Rice: 40 people per hectare, 1.5 t per worker. Wheat: 20 people per hectare, 1,500 t per worker. Intensive farming wins per unit of land; extensive, mechanized farming wins per worker. This is the core difference between the two farming worlds King saw.

Example 3. Station A has these rounded climate data: coldest month (January) 11°C with 65 mm of rain; hottest month (July) 28°C with 1 mm; wettest month (December) 90 mm; annual precipitation 550 mm; mean annual temperature 19°C. Classify its Köppen climate and name the farming region it suits. (Köppen rules: C if the coldest month is between 0°C and 18°C; "s" if the driest summer month has under 30 mm and less than one-third of the wettest winter month; "a" if the hottest month is 22°C or warmer. Check first that it is not arid: for a winter-rain climate, arid if annual precipitation in mm is less than 20 × the mean annual temperature.)

1. Arid check: 20 × 19 = 380 mm. Annual precipitation 550 mm is more than 380, so it is not a B (arid) climate.
2. Coldest month 11°C lies between 0°C and 18°C, so the first letter is C.
3. Driest summer month: 1 mm, under 30 mm and less than 90 ÷ 3 = 30 mm, so the second letter is s (dry summer).
4. Hottest month 28°C is at least 22°C, so the third letter is a.
5. Csa is the hot-summer Mediterranean climate.

Answer: Csa (hot-summer Mediterranean). It suits Mediterranean agriculture: olives, grapes, citrus and winter wheat, with irrigation for summer crops. Southern Spain (Seville is a close match), California's Central Valley and southern Italy have climates like this.

PRACTICE

1. EASY Define subsistence and commercial agriculture, and intensive and extensive agriculture. Give one example of each.
2. EASY Who published the classic map of world agricultural regions, and when? Name three of the criteria he used.
3. EASY Match each farming type to a place: (a) Mediterranean, (b) plantation, (c) pastoral nomadism, (d) commercial grain, (e) dairy. Places: Saskatchewan, Mongolia, Wisconsin, central Chile, Ghana's cocoa farms.
4. MEDIUM In a county, 30% of cropland is in soybeans; nationally the share is 25%. Find the location quotient and interpret it.
5. MEDIUM Region X has 6% of its cropland in cotton and Region Y has 1.5%; the national share is 3%. Find each LQ and explain what an LQ below 1 means.
6. MEDIUM A rice farm harvests two crops a year of 3.5 tonnes of milled rice per hectare each. If a person eats 140 kg of rice a year, how many people can one hectare feed?
7. MEDIUM Explain the difference between winter wheat and spring wheat, and name one region for each.
8. MEDIUM Station B: every month averages 25–28°C, and every month has more than 150 mm of rain. What Köppen climate is it, and which two farming types are most likely there?

9. HARD Compare the views of Malthus and Boserup on population and farming. Which view do King's Asian farmers illustrate?
10. HARD Why are fluid-milk dairies usually close to cities, while much butter and cheese comes from distant places such as New Zealand? Use von Thünen's logic.
11. HARD Describe the plantation system: its climate, crops and history, and how it differs from intensive subsistence farming.
12. CHALLENGE Country A has 2 million farmers working 40,000 km² of arable land; Country B has 30,000 farmers working 60,000 km². Find each country's agricultural density (farmers per km² of arable land) and explain what the difference suggests about farming in each.

COMMON MISTAKES

- Equating intensive with modern. Rice terraces worked by hand are highly intensive; a mechanized ranch is extensive.
- Calling every large farm a plantation. A plantation is a tropical or subtropical estate growing a cash crop, usually for export.
- Reading an LQ of 2.0 as "twice as much as the nation." It means twice the national share, not twice the national amount.

> **Make it a game · Name That Farm.** One player describes a farm in three clues without naming the region (for example: "dry summers; olives and grapes; the hills of central Chile"). The others race to name the farming region and one place where it is found. A correct answer on the first clue scores 3 points, on the second 2 and on the third 1. Rotate until every region (intensive subsistence, commercial grain, mixed, dairy, Mediterranean, plantation, ranching, pastoral nomadism, shifting cultivation, commercial gardening) has been used.

> **Scripture.** "While the earth remaineth, seedtime and harvest, and cold and heat, and summer and winter, and day and night shall not cease." (Genesis 8:22, KJV)

God gave this promise to Noah after the Flood. Every farming region on the map, from monsoon rice to winter wheat, depends on the faithful round of seasons He set in place.

Practice answers

1. Subsistence: farming to feed one's own family (a wet-rice family farm in Bangladesh). Commercial: farming to sell (a Kansas wheat farm). Intensive: much labor or capital per acre (rice paddies, dairies, market gardens). Extensive: little labor or capital spread over much land (ranching, pastoral nomadism).
2. Derwent Whittlesey, in 1936. Any three: the combination of crops and livestock; the methods of farming; the intensity of labor and capital applied to the land; whether products are consumed on the farm or sold; the farm buildings and structures.
3. (a) central Chile; (b) Ghana's cocoa farms; (c) Mongolia; (d) Saskatchewan; (e) Wisconsin.
4. LQ = 0.30 ÷ 0.25 = 1.2. The county is somewhat more specialized in soybeans than the nation.

5. X: 6 ÷ 3 = 2.0. Y: 1.5 ÷ 3 = 0.5. An LQ below 1 means the activity is less concentrated in that region than in the nation as a whole; Y is not a cotton-specializing region.
6. 2 × 3.5 = 7.0 t = 7,000 kg; 7,000 ÷ 140 = 50 people per hectare.
7. Winter wheat is sown in the fall, grows a little, survives winter and is harvested in early summer; it suits regions with milder winters, such as Kansas. Spring wheat is sown in spring and harvested in late summer where winters are too harsh for wheat to survive, such as North Dakota, Saskatchewan or the Russian and Kazakh steppes.
8. Af, tropical rain forest (coldest month above 18°C, no dry month). Likely farming: shifting cultivation and plantations (such as cocoa, rubber, palm oil or bananas).
9. Malthus argued that population tends to grow faster than food, so hunger checks population. Boserup (1965) argued that growing population pushes farmers to intensify, with shorter fallows, terraces, irrigation, more crops per year and more labor per acre, so food supply rises in response. King's farmers, who fed dense populations by double cropping, composting and terracing, illustrate Boserup's view, though both forces have operated in history.
10. Fresh milk is heavy, bulky and perishable, so its transport cost per unit of value is high and its rent line is steep; it wins land in the innermost ring (the milkshed). Butter and cheese are concentrated, keep longer and are worth more per kilogram, so their transport cost is relatively low and they can be made far away where land and pasture are cheap and shipped to market.
11. Plantations are large commercial farms in tropical and subtropical lands, growing one cash crop (sugar, coffee, cocoa, bananas, rubber, palm oil) for export, often with outside capital. Historically the sugar plantations of Brazil, the Caribbean and the American South were worked by enslaved Africans; slavery has since been abolished and plantations today use paid labor. Unlike intensive subsistence farms, which are small family plots growing food to eat, plantations are large, specialized and market-oriented.
12. A: 2,000,000 ÷ 40,000 = 50 farmers per km². B: 30,000 ÷ 60,000 = 0.5 farmers per km². A's agricultural density is 100 times higher, which suggests small, labor-intensive farms, probably subsistence or semi-subsistence, in a less industrialized economy. B's low density suggests large, mechanized commercial farms where few workers farm much land, typical of a developed country.

Unit 6 test

Answer each question. Show your work for every calculation, with units, and write complete sentences for explanations. Give distances and areas in both metric and U.S. units where asked. The test is worth 100 points.

1. (6 pts) Define domestication and agricultural hearth. Then name four founder crops of the Fertile Crescent.
2. (6 pts) Who named the Fertile Crescent, and when? State Robert Braidwood's "hilly flanks" hypothesis and the evidence he found at Jarmo.
3. (8 pts) A country has 80 million people and a land area of 500,000 km² (193,000 sq mi), of which 15% is arable. Calculate its arithmetic density and physiological density in people per km², and explain which better measures pressure on farmland.
4. (8 pts) (a) Using textbook dates, farming spread about 1,800 km (1,120 miles) in 2,000 years. Find the average rate in km and miles per year. (b) Name two items that crossed from the Old World to the Americas and two that crossed the other way in the Columbian Exchange.
5. (6 pts) Explain Jared Diamond's east–west axis model of crop diffusion and give one criticism of it.
6. (6 pts) List three assumptions of von Thünen's isolated state and name his rings in order from the town outward.
7. (8 pts) A crop has yield Y = 10 t/ha, price p = \$50/t, cost c = \$30/t and freight f = \$1 per tonne per km. Write its rent line R = Y(p − c) − Yfd, find R at 5 km, and find its margin of cultivation in km and miles.
8. (8 pts) Crop A has R = 500 − 40d and Crop B has R = 240 − 8d. Find the distance where they cross, say which crop is grown nearer the town, and find the outer edge of Crop B.
9. (6 pts) Explain how (a) a navigable river and (b) refrigerated transport each change von Thünen's rings.
10. (8 pts) A country's wheat yield rose from 1.2 to 3.6 tonnes per hectare in 30 years. Find the average annual growth rate and the doubling time at that rate.
11. (8 pts) A center pivot with a radius of 800 m sits in a square field 1,600 m on a side. Find the irrigated area in hectares and acres and the percent of the square it covers. (1 ha = 10,000 m²; 1 ha = 2.471 acres.)
12. (6 pts) Match each to its date or inventor: Tull's seed drill; McCormick's reaper; Deere's steel plow; Haber's ammonia synthesis; IR8 rice; the term "Green Revolution." Then name one cost of the Green Revolution.
13. (8 pts) Nationally, 12% of cropland is in corn. County P has 18% of its cropland in corn and County Q has 4%. Find each county's location quotient and interpret both.
14. (8 pts) In a well-organized paragraph, compare wet-rice farming in monsoon Asia with commercial wheat farming on the Great Plains. Address climate, intensity, farm size, labor and machines, output per hectare and per worker, and whether the harvest is mainly eaten or sold.

UNIT PROJECT: A FARM ATLAS OF MY COUNTY

Make a four-page atlas of farming in your own county (or a farming county near you). Page 1: a hand-drawn map of the county with towns, main roads, rivers and the major farm land uses, colored by type (cropland, pasture, woodland, dairy, orchards). Page 2: a data page from the USDA Census of Agriculture county profile, with the number and average size of farms, the top crops and livestock, and location quotients for at least three crops compared with the nation. Page 3: a test of von Thünen's model, drawing rings around the largest town and marking where your county fits the pattern and where it breaks it, with reasons. Page 4: a one-page essay naming your county's farming region, the climate and soil that support it, one technology that changed it, and one way farmers there practice stewardship of the land (Genesis 2:15). If possible, interview a farmer or extension agent and quote him or her accurately.

- **Map**: The county map is accurate, neat and readable, with a key, scale and north arrow, and shows the main land uses in the right places.
- **Data**: Census figures are correctly copied and cited; location quotients are calculated correctly with work shown and interpreted.
- **Model test**: The von Thünen page applies the model fairly and explains real departures from it with specific causes (roads, rivers, soils, terrain, policy, technology).
- **Essay**: The essay classifies the region correctly, connects it to climate and technology, and treats stewardship thoughtfully, with clear and accurate writing.

Answer key

1. Domestication: the change of a wild plant or animal, through human selection over many generations, into a form that lives with and depends on people. Agricultural hearth: a place where farming began independently. Founder crops (any four): emmer wheat, einkorn wheat, barley, lentils, peas, chickpeas, bitter vetch, flax.
2. James Henry Breasted, in 1916. Braidwood proposed that farming began in the foothills above the river valleys, where wild wheat, barley, sheep and goats lived together. At Jarmo, in the Zagros foothills of northern Iraq (from 1948), he found mud-walled houses, stone sickle blades, charred wheat and barley, and goat bones.
3. Arithmetic: 80,000,000 ÷ 500,000 = 160 per km². Arable land: 0.15 × 500,000 = 75,000 km². Physiological: 80,000,000 ÷ 75,000 ≈ 1,067 per km² (about 2,760 per sq mi). Physiological density is better, because it counts only the land that can grow food.
4. (a) 1,800 ÷ 2,000 = 0.9 km per year; 1,120 ÷ 2,000 = 0.56 miles per year. (b) Old to New (any two): wheat, cattle, horses, pigs, sheep, sugarcane. New to Old (any two): maize, potatoes, cassava, tomatoes, cacao, peppers.
5. Diamond argued that crops spread more easily along Eurasia's east–west axis because places at the same latitude share day length, seasons and climate, while crops in the north–south Americas had to adapt to changing conditions. Criticism: it risks geographic determinism; mountains, deserts, trade and human choices also mattered, and maize did eventually spread across both American continents.
6. Assumptions (any three): one central market town; flat plain; uniform soil and climate; no navigable rivers (wagon transport only); shortest routes; profit-seeking farmers; surrounded

by wilderness. Rings: (1) vegetables, fruit and milk; (2) forest; (3) intensive crop rotation; (4) crops alternating with pasture; (5) three-field system; (6) livestock; wilderness beyond.

7. $Y(p - c) = 10 \times 20 = \$200$; $Yf = \$10$ per km; $R = 200 - 10d$. At 5 km: $R = 200 - 50 = \$150$ per hectare. Margin: $200 = 10d$, $d = 20$ km (about 12.4 miles).
8. $500 - 40d = 240 - 8d$ gives $260 = 32d$, $d \approx 8.1$ km (about 5.0 miles). Crop A, with the higher and steeper line, is grown inside 8.1 km; Crop B beyond it. Crop B's margin: $240 = 8d$, $d = 30$ km (about 18.6 miles).
9. (a) Water freight is cheaper, so each ring stretches into a band along the river, where land is effectively closer to market. (b) Refrigeration lowers the cost and risk of moving perishable goods, flattening their rent lines, so milk, meat and vegetables can come from much farther away and the inner rings spread outward or break apart.
10. Growth factor $3.6 \div 1.2 = 3$. $r = 3^{(1/30)} - 1$: $\ln 3 \approx 1.0986$; $\div 30 = 0.0366$; $e^{0.0366} \approx 1.0373$, so $r \approx 3.7\%$ per year. Doubling time $\approx 70 \div 3.7 \approx 19$ years (exactly about 18.9 years).
11. Circle: $\pi \times 800^2 = 3.1416 \times 640{,}000 \approx 2{,}010{,}600$ m² ≈ 201 ha ≈ 497 acres. Square: $1{,}600^2 = 2{,}560{,}000$ m² $= 256$ ha. Percent: $201 \div 256 \approx 78.5\%$ ($\pi/4$).
12. Seed drill: about 1701 (Jethro Tull). Reaper: demonstrated 1831 (Cyrus McCormick). Steel plow: 1837 (John Deere). Ammonia synthesis: 1909 (Fritz Haber). IR8: 1966 (International Rice Research Institute). "Green Revolution": 1968 (William Gaud). Cost (any one): falling water tables from heavy irrigation; fertilizer runoff; loss of local crop varieties; uneven benefits for farmers without irrigation or credit.
13. P: $18 \div 12 = 1.5$, more specialized in corn than the nation. Q: $4 \div 12 \approx 0.33$, much less specialized in corn than the nation.
14. A strong answer: Wet rice grows in warm, wet monsoon climates, often with two crops a year; farms are small family plots worked with much hand labor (intensive subsistence), output per hectare is very high, output per worker is low, and much of the harvest feeds the farm family or local market. Commercial wheat grows in semi-arid mid-latitude grasslands with cold or mild winters, one crop a year; farms are very large, worked by few people with large machines (extensive commercial), output per hectare is lower but output per worker is enormous, and the harvest is sold to distant and world markets.

UNIT 7

Cities

For most of history most people lived on farms, but cities have always held a large share of a people's trade, learning, government and worship. Scripture records the first city builder in its fourth chapter (Genesis 4:17), and its last book ends with a city. In this unit you will ask the geographer's questions about cities: why they stand where they do, why some grow great and others stay small, how their land is arranged from the center to the edge, and how each new way of getting around has reshaped them.

You will stand with young George Washington at the Forks of the Ohio in 1753 and see why a point of land between two rivers became Pittsburgh. You will follow Walter Christaller across the market towns of southern Germany as he built his theory of central places (1933), and face honestly the use made of it in conquered Poland. You will walk the streets of Chicago with Ernest Burgess, Homer Hoyt, Chauncy Harris and Edward Ullman as they drew rings, wedges and nuclei on the map. Finally you will ride Frank Sprague's electric streetcars in Richmond in 1888 and drive the Interstate highways of 1956, and measure how speed has stretched the city.

As in every unit of this course, the models (site and situation, the rank-size rule, central place theory, the urban models, the density gradient) are taught as tools to be tested against real places, with their strengths and their limits. Debates about how cities should grow are presented with more than one view. Lesson 7.5 is the **unit test** below, worth 100 points.

BEFORE YOU BEGIN

- Can calculate percent change, density and average annual growth rates (Units 1–2)
- Can use the rule of 70 and simple logarithms or a calculator's e^x and ln keys
- Understands von Thünen's model and bid-rent lines (Lesson 6.2)
- Can read a map scale and convert between miles and kilometers

MASTERY CHECKLIST

- I can explain the difference between a city's site and its situation and use both to explain why real cities grew where they did.
- I can calculate percent urban and growth rates, apply the rank-size rule, and identify a primate city.
- I can explain threshold, range, the order of goods and Christaller's hexagonal hierarchy, and calculate a market radius and a breaking point.
- I can draw and explain the concentric zone, sector and multiple-nuclei models and use bid-rent lines and Clark's density gradient.
- I can trace how walking, streetcars, railroads, automobiles and highways reshaped the American city, and calculate how speed sets the area within commuting reach.
- I can state the limits of each model and present more than one view fairly on how cities should grow.

OPTIONAL BOOKS AND RESOURCES

- **U.S. Census Bureau QuickFacts** (https://www.census.gov/quickfacts/): Free. Population, density, housing and commuting figures for every state, county and city of 5,000 or more. Use it for the city projects in Lessons 7.1, 7.2 and 7.3.
- **Sanborn Fire Insurance Maps, Library of Congress** (https://www.loc.gov/collections/sanborn-maps/): Free. Detailed maps of thousands of American towns from the late 1800s to the mid-1900s, showing every building, its use and its material. Excellent for seeing a town's original site and its old streetcar and rail lines.
- **Panoramic Maps, Library of Congress** (https://www.loc.gov/collections/panoramic-maps/): Free. Bird's-eye views of American cities drawn in the 1800s and early 1900s. Find your own town or a nearby city and compare it with a modern satellite view.

7.1 Why Cities Grow

OBJECTIVES

- Distinguish a city's site from its situation and classify real location factors (defense, water, fords, harbors, break-of-bulk points, resources, routes) as one or the other.
- Calculate percent urban, percent change and average annual growth rates of cities, and test a set of cities against the rank-size rule and the idea of the primate city.
- Explain, using Pittsburgh and Chicago, how a city's situation can change while its site stays the same, and how basic and nonbasic jobs drive urban growth and decline.

Warm-up. Lay a towel on the table and scrunch it into hills and a valley. Pour a few spoonfuls of rice to stand for a river running down the valley, and add a second "river" joining it. Now place three coins where you would build a town. Write one sentence for each coin: why there? Keep your reasons; by the end of the lesson you will sort them into "site" and "situation."

Watch. *Why Pittsburgh Exists | Unboxing The Point* (Pittsburgh Unboxed, 8:21). https://www.youtube.com/watch?v=fzRvyDBE4fE
After the story: walk around the Point with the host to see where the Allegheny and Monongahela meet to form the Ohio, and why forts and then a city grew up on that spot. **Note:** Captions were not available to check; preview it first. The description mentions "Native homelands and continued connections," so check how that part is framed.

Backup video. *The Forks of the Ohio (Fort Duquesne & Fort Pitt)* (Bobblehead George, 1:08). https://www.youtube.com/watch?v=iSV9i48a9K4
After the story: this one-minute clip from a teacher-run nonprofit shows the Forks of the Ohio and the sites of Fort Duquesne and Fort Pitt that Washington's ride led to. Note: Captions were not available to check; preview it first.

KEY TERMS

site
The physical character of the ground a city stands on: landforms, elevation, water supply, soil, harbor and natural defenses.

situation
A city's location relative to other places: the rivers, routes, resources, markets and other cities it is connected to.

break-of-bulk point
A place where goods must be moved from one kind of carrier to another (ship to barge, barge to rail), which creates work in handling, storing and trading and so tends to grow a city.

urbanization

The growth in the share of a population living in cities and towns, and the process by which places become urban.

rank-size rule
An observed pattern in which the nth-largest city of a country has about 1/n the population of the largest ($P_n = P_1/n$).

primate city
A city more than twice as large as the next-largest city of its country and far more important in its economy and culture (Mark Jefferson, 1939).

CORE IDEAS

The story. In November 1753 a twenty-one-year-old Virginia militia officer named George Washington rode into the Ohio Country carrying a letter from Lieutenant Governor Robert Dinwiddie, warning the French to leave land that Virginia claimed. Along the way he came to the point where the Allegheny River, flowing down from the north, meets the Monongahela, flowing up from the south, and the two become the Ohio. In the journal he published the next year he wrote: “I spent some Time in viewing the Rivers, and the Land in the Fork; which I think extremely well situated for a Fort, as it has the absolute Command of both Rivers.” Two empires agreed with him. Virginians began a stockade at the Forks early in 1754; a French force drove them off and built Fort Duquesne; in 1758 a British army under General John Forbes advanced over the mountains and the French burned the fort and withdrew. The British built Fort Pitt, named for the statesman William Pitt, and the town that grew beside it became Pittsburgh.

How it worked: site and situation. Geographers explain where a city stands with two ideas. Its **site** is the ground itself: the shape of the land, the water, the soil, the harbor, the natural defenses. Its **situation** is its place in the wider world: what rivers, roads, resources, markets and other cities it connects to. Pittsburgh’s site was a narrow point of land guarded by water on two sides, with high bluffs across the rivers. Its situation was far greater. From the Forks the Ohio flows 981 miles (1,579 km) to the Mississippi at Cairo, Illinois, so whoever held the point held the gateway from the Atlantic seaboard, over the Appalachians, into the whole Ohio and Mississippi valleys (figure he-ohio-situation). In the 1800s its situation grew richer still. The hills around it held the thick Pittsburgh coal seam; rivers and then railroads brought iron ore from the Lake Superior country; and after Andrew Carnegie opened his Edgar Thomson steel works at nearby Braddock in 1875, the city became the steel capital of America.

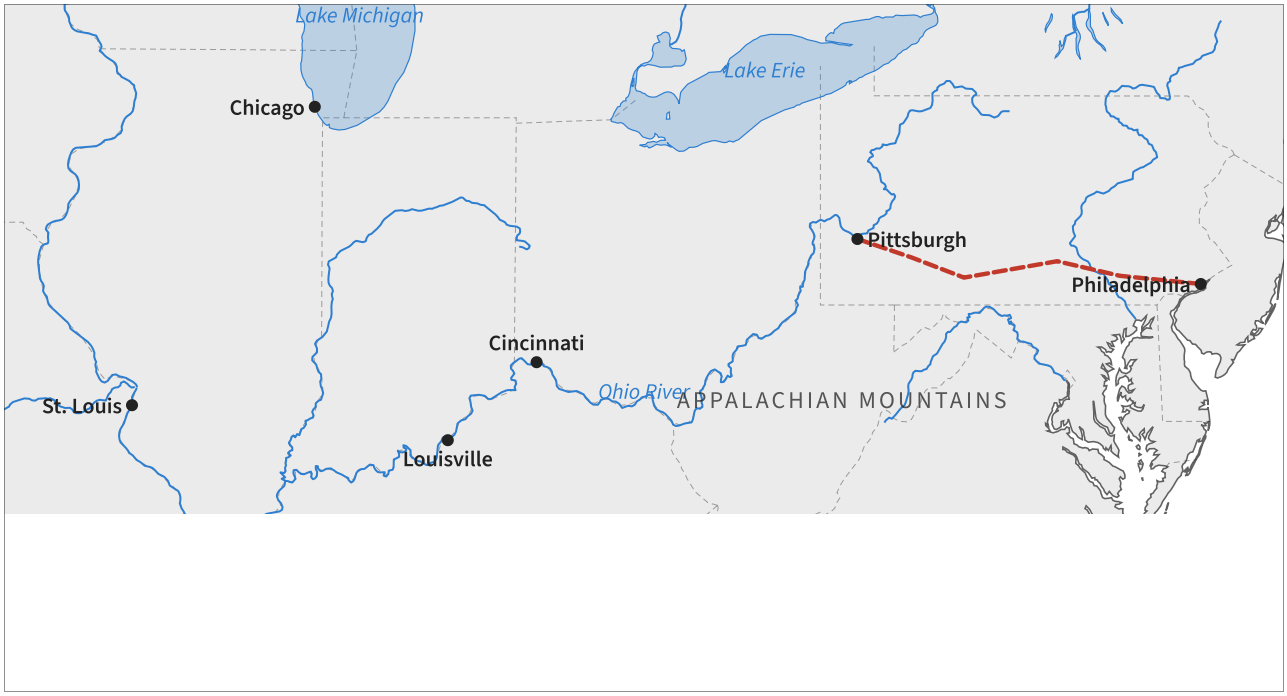
The big idea. Cities grow where something is gathered, made, defended or exchanged. The classic *site* factors are defense (Venice on its lagoon islands, Paris on the Île de la Cité in the Seine), fresh water, a ford or the lowest place a river can be bridged (the Romans bridged the Thames at London soon after their conquest of AD 43), and a sheltered harbor. The classic *situation* factors are routes and resources. A **break-of-bulk point**, where cargo must change from ship to barge or barge to railcar, creates work in loading, storing, financing and trading; New Orleans, Chicago and Rotterdam all grew this way. Along the eastern seaboard, the fall-line cities (Baltimore, Washington, Richmond) rose where ships could sail no farther

upstream and falling water could turn mill wheels. Once a city is planted, its growth depends on its **economic base**. *Basic* jobs sell goods and services to people outside the city (a steel mill shipping rails across the country) and bring money in; *nonbasic* jobs serve people inside the city (grocers, barbers, teachers). Every basic job supports some number of nonbasic jobs, a ratio called the **multiplier**. When basic industries grow, the city grows twice over; when they close, the loss multiplies too.

Cities in history and the urban hierarchy. Scripture records that Cain “builded a city” (Genesis 4:17), and the oldest cities known from archaeology and the first written records, such as Ur and Uruk, stood in Mesopotamia between the Tigris and Euphrates. Yet for nearly all of history most people lived on farms. The first U.S. census, in 1790, counted only about 5 percent of Americans as urban. The census of 1920 was the first to find a majority (51.2 percent) in urban places, and in 2020 the figure was 80 percent. By United Nations estimates the world as a whole passed the halfway mark around 2007, though countries define “urban” differently, so such figures must be read with care. Within a country, cities form a hierarchy of sizes. In 1913 the German physicist Felix Auerbach noticed, and in 1949 the American linguist George Zipf made famous, the **rank-size rule**: the second city tends to have about half the people of the first, the third about a third, and so on. Where one city far outstrips all the rest, as Paris does in France or Lima in Peru, geographers call it a **primate city**, a term coined by Mark Jefferson in 1939.

On the map: when situation changes. A city’s site rarely changes, but its situation can be transformed by new technology, new trade or new borders. Chicago is the textbook case. Its site was poor: low, wet prairie so swampy that in the 1850s and 1860s the city raised its streets and jacked up whole buildings to install sewers. But its situation was superb, at the short portage between Lake Michigan and the rivers draining to the Mississippi. The Illinois and Michigan Canal (1848) and then the railroads made it the meeting place of East and West, and it grew from about 4,500 people in 1840 to over a million in 1890. Pittsburgh shows the reverse. The city reached about 677,000 people in 1950, but when much of American steelmaking closed in the 1970s and 1980s, its basic jobs vanished and the multiplier ran backward. By 2020 the city held about 303,000, though its wider metropolitan area remained much larger and it rebuilt its economy around hospitals, universities and technology.

Limits of the explanation. Site and situation explain much, but people still decide. Washington, D.C., stands where it does because Congress chose a site on the Potomac in the Residence Act of 1790. Brazil built Brasília on its empty interior plateau and made it the capital in 1960 to draw settlement inland. Geography offers the opportunities and sets the costs; human choices, and in the Christian view the providence of the God who “hath determined the times before appointed, and the bounds of their habitation” (Acts 17:26), settle the rest.



The situation of Pittsburgh: the Forbes Road (1758) crossed the Appalachians to the Forks of the Ohio, and the Ohio River carried traffic 981 miles to the Mississippi at Cairo.

PICTURE STUDY

View of Delft, Johannes Vermeer, about 1660–1661 · Oil on canvas · Mauritshuis, The Hague

Johannes Vermeer spent his whole life in Delft, a prosperous town in the Dutch province of Holland. Here he painted it from the south, looking across the harbor basin where the Schie canal reached the city. The water in the foreground was the town's link to Rotterdam, the Maas and the sea, and the gates and walls show that a seventeenth-century city still had to think about defense.

The painting is famous for its light: shadowed walls in front, sunlit roofs and the tower of the New Church behind. For a geographer it is also a lesson in site and situation. Delft stood on low, flat, wet land that the Dutch had to drain and manage, but it was joined by water to the trade of half the world through the Dutch East India Company, which kept one of its chambers in the city.

Look closely

- Find the boats along the near quay. What do they tell you about how goods reached the city?
- Find the gates and walls. What do they show about the town's site and its need for defense?
- Look at how flat the land is and how much of the scene is water and sky. What problems and advantages would this site bring?
- Find the sunlit church tower. Why might a church stand at the center of an old European city?

Talk about it

1. Which features in the painting belong to Delft's site, and which point to its situation?
2. Delft was a busy trading town, but in later centuries nearby Rotterdam grew far larger. What changes in situation might explain that?
3. How does Vermeer make an ordinary town view feel peaceful and worth looking at?

PROJECT: THE SITE AND SITUATION OF MY TOWN

You will build a relief model of the ground your nearest city or town stands on, then draw a situation map that shows how it connects to the wider world, and write a short history explaining why it grew where it did.

You will need

- Salt dough (2 cups flour, 1 cup salt, about 3/4 cup water) or modeling clay, and a piece of stiff cardboard about 12 by 16 inches
- A USGS topographic map of your town (free from the USGS topoView website) or an online terrain map
- A historic map of your town if you can find one (the Library of Congress Sanborn and panoramic map collections are free)
- Paints or colored pencils, toothpicks and paper flags, ruler, a large sheet of paper for the situation map

Steps

1. Study the topographic map. Find the oldest part of town (often marked by the courthouse, the oldest church or the main street) and note the rivers, hills, harbor or crossroads near it.

2. Choose a scale so your town center fills most of the cardboard. Sketch the main rivers, hills and roads lightly in pencil.
3. Build the land with salt dough, making hills higher and valleys lower. Exaggerate the height about five times so the shape shows. Let it dry for a day or two, then paint water blue and land green or brown.
4. Mark with toothpick flags the original settlement and at least three site features (ford, bluff, spring, harbor, high ground, fall line).
5. On the large sheet, draw a situation map covering about 300 miles (500 km) around your town. Show the rivers, railroads, highways and larger cities it connects to, and any resource (coal, timber, farmland) that fed its growth.
6. Look up your town's population in the census for 1900, 1950 and 2020. Calculate the percent change between each pair of years.
7. Write one page: What first brought people here (site)? What made the town grow or shrink later (situation and economic base)? Name at least one basic industry.

Tips

- Many towns began at a river crossing, a mill seat, a railroad junction or a county seat. Look at the oldest street names for clues (Mill Street, Ferry Street, Depot Street).
- Remember that city limits change. If your city annexed land, part of its growth may be on paper. Note this in your history.

Check your work

- My model shows the real landforms and water of my town's site, with the original settlement marked.
- My situation map shows routes, resources and neighboring cities, with a title, scale and north arrow.
- My percent-change calculations are correct and shown.
- My history clearly separates site factors from situation factors.

MAP NOTEBOOK

1. Draw the Forks of the Ohio as Washington saw them: the Allegheny, the Monongahela and the Ohio, with the point of land between. Mark where Fort Duquesne and Fort Pitt stood and label one site advantage and one situation advantage.
2. Make a two-column chart titled "Site and Situation" and sort eight cities into it by their best-known advantage: Venice, Paris, London, New Orleans, Chicago, Pittsburgh, Singapore, Richmond.
3. Graph the U.S. percent urban for 1790 (5 percent), 1920 (51 percent) and 2020 (80 percent). Mark the year the line crosses 50 percent.

> **From history.** One building from the age of the forts still stands at the Forks. The Fort Pitt Block House, a small brick redoubt built in 1764 to guard the fort, survived the city's

growth around it and is preserved today in Point State Park, where the Allegheny and Monongahela meet to form the Ohio. It is the oldest surviving building in Pittsburgh.

WORKED EXAMPLES

Example 1. The 1920 census counted about 106.0 million Americans, of whom about 54.3 million lived in urban places. What percent of Americans were urban? Was the country majority urban?

1. Percent urban = urban population ÷ total population × 100.
2. 54.3 ÷ 106.0 = 0.512.
3. 0.512 × 100 = 51.2 percent.
4. 51.2 is more than 50, so the urban population was a majority.

Answer: About 51.2 percent urban. The 1920 census was the first to show a majority of Americans living in urban places.

Example 2. Pittsburgh had about 677,000 people in 1950 and about 303,000 in 2020. Find the percent change, and the average annual rate of change over the 70 years.

1. Percent change = (new − old) ÷ old × 100 = (303,000 − 677,000) ÷ 677,000 × 100.
2. −374,000 ÷ 677,000 = −0.552, so the change is about −55.2 percent.
3. Average annual rate r solves $677{,}000 \times (1 + r)^{70} = 303{,}000$, so $(1 + r)^{70} = 303 \div 677 = 0.4476$.
4. Take the 70th root: $1 + r = 0.4476^{1/70}$. Using logarithms, ln 0.4476 = −0.804, and −0.804 ÷ 70 = −0.0115, so $1 + r = e^{-0.0115} \approx 0.9886$.
5. $r \approx -0.0114$, about −1.1 percent per year.

Answer: Pittsburgh’s city population fell about 55 percent, an average decline of about 1.1 percent per year from 1950 to 2020.

Example 3. At the 2020 census the five largest U.S. metropolitan areas had about these populations: New York 20.1 million, Los Angeles 13.2 million, Chicago 9.6 million, Dallas–Fort Worth 7.6 million, Houston 7.1 million. Use the rank-size rule to predict the populations of ranks 2 to 5 and compare them with the real figures.

1. Rank-size rule: $P_n = P_1 \div n$, with $P_1 = 20.1$ million.
2. Rank 2: 20.1 ÷ 2 = 10.1 million (actual 13.2 million).
3. Rank 3: 20.1 ÷ 3 = 6.7 million (actual 9.6 million).
4. Rank 4: 20.1 ÷ 4 = 5.0 million (actual 7.6 million).
5. Rank 5: 20.1 ÷ 5 = 4.0 million (actual 7.1 million).
6. Every real figure is larger than predicted, so the top of the American hierarchy is "flatter" than the rule: no single city dominates.

Answer: Predicted: 10.1, 6.7, 5.0 and 4.0 million. The actual cities are all bigger, so the United States has several large rival centers and is the opposite of a primate-city country.

PRACTICE

1. EASY Define site and situation. Then classify each as a site or situation factor: (a) Venice was built on islands in a lagoon for safety. (b) Singapore lies at the southern entrance to the Strait of Malacca. (c) A spring of fresh water on a hilltop. (d) Chicago lies where Lake Michigan comes closest to the rivers draining to the Mississippi.
2. EASY What did Washington mean in 1753 when he wrote that the Forks of the Ohio had "the absolute Command of both Rivers"? Name the French and British forts later built there.
3. EASY Define break-of-bulk point and give two real examples.
4. MEDIUM The 1790 census counted about 3.93 million people, of whom about 202,000 lived in urban places. Find the percent urban.
5. MEDIUM A city of 2 million grows steadily at 3.5 percent per year. Use the rule of 70 to find its doubling time, and estimate its population after 40 years.
6. MEDIUM Metropolitan Paris has about 13 million people and metropolitan Lyon, France's second city, about 2.3 million. Find the ratio of the two. What does the rank-size rule predict, and what term describes Paris?
7. MEDIUM A country's largest city has 12 million people. If the country follows the rank-size rule exactly, how large are its 4th and 10th cities?
8. MEDIUM A new factory hires 2,000 workers who make goods sold all over the country. In this region each basic job supports 1.5 nonbasic jobs. How many total jobs does the factory create? What happens if it closes?
9. HARD Using figure he-ohio-situation, which city stands where the Ohio meets the Mississippi? A steamboat travels the 981 river miles from Pittsburgh to that city at an average of 8 miles per hour. How long does the trip take in hours and days? Give the distance in km.

(Use the map or drawing "Follow the Ohio River from Pittsburgh to its mouth." shown earlier in this lesson.)

10. HARD Chicago's site was poor but its situation was excellent. Explain both, with at least one specific fact for each.
11. HARD In a short paragraph, explain why Pittsburgh's city population fell by more than half between 1950 and 2020 even though its site did not change.
12. CHALLENGE Chicago grew from about 4,470 people in 1840 to about 1,099,850 in 1890. Find its average annual growth rate and the doubling time at that rate.

COMMON MISTAKES

- Treating nearby resources or routes as site factors. Site is the ground itself; anything about connections to other places is situation.
- Comparing city populations without checking the boundary. City limits, metropolitan areas and urban areas give very different numbers for the same place.
- Reading the rank-size rule as a law. It is an observed tendency that many countries follow roughly and some, with primate cities, do not follow at all.

Make it a game · Site or Situation?. One player reads a clue about a real city (for example, "built on islands in a lagoon," "at the mouth of the Mississippi," "where two rivers meet to form a third," "on the lowest bridging point of the Thames"). The other players race to call out "Site!" or "Situation!" and then name the city. A correct call scores one point, the right city scores a second. A player who can explain a city that has both a strong site and a strong situation earns a bonus point. Play to fifteen.

Scripture. "Ye are the light of the world. A city that is set on an hill cannot be hid." (Matthew 5:14, KJV)

Jesus drew on a fact of site that every listener knew: a city on a hill is seen from far away. Cities are planted where the land gives them strength and reach, and Christians are called to be just as visible in the places God sets them.

Practice answers

1. Site is the physical character of the place itself; situation is its location relative to other places. (a) Site. (b) Situation. (c) Site. (d) Situation.
2. A fort on the point could control all traffic on the Allegheny and the Monongahela, and so on the Ohio they form. The French built Fort Duquesne (1754); the British built Fort Pitt (1758 onward).
3. A place where cargo must be moved from one kind of carrier to another, creating work in handling, storage and trade. Examples: New Orleans (river barges to ocean ships), Chicago (lake ships to railroads), Rotterdam (ocean ships to Rhine barges).
4. 202,000 ÷ 3,930,000 = 0.051, about 5.1 percent urban.
5. Doubling time ≈ 70 ÷ 3.5 = 20 years. After 40 years it doubles twice: 2 → 4 → 8 million.
6. 13 ÷ 2.3 ≈ 5.7, so Paris is nearly six times as large as Lyon. The rank-size rule predicts a ratio of 2. Paris is a primate city.

7. 4th: 12 ÷ 4 = 3 million. 10th: 12 ÷ 10 = 1.2 million.
8. Nonbasic jobs: 2,000 × 1.5 = 3,000. Total: 2,000 + 3,000 = 5,000 jobs. If it closes, the multiplier works in reverse and roughly 5,000 jobs could be lost, not just 2,000.
9. Cairo, Illinois. 981 ÷ 8 ≈ 122.6 hours, about 5.1 days of steady travel. 981 miles × 1.609 ≈ 1,579 km.
10. Site: low, flat, swampy prairie with poor drainage; in the 1850s and 1860s the city had to raise its street level and jack up buildings to install sewers. Situation: it stood at the short portage between Lake Michigan and the Des Plaines and Illinois rivers leading to the Mississippi; the Illinois and Michigan Canal (1848) and the railroads made it the meeting point of eastern and western trade.
11. Pittsburgh grew on its situation: coal in the surrounding hills, river and rail access to iron ore and markets, and a huge steel industry that provided basic jobs. When much of American steelmaking closed in the 1970s and 1980s, those basic jobs disappeared and the multiplier ran backward, taking nonbasic jobs with them. Many families also moved to suburbs outside the city limits. The site was the same; the situation and the economic base had changed. (The city later rebuilt around hospitals, universities and technology.)
12. Ratio: 1,099,850 ÷ 4,470 ≈ 246. ln 246 ≈ 5.505; 5.505 ÷ 50 = 0.110, so $1 + r = e^{0.110} \approx 1.116$, about 11.6 percent per year. Doubling time ≈ ln 2 ÷ 0.110 ≈ 6.3 years (the rule of 70 with 11.6 percent gives about 6 years). Chicago doubled roughly every six years for half a century.

7.2 Central Place Theory

OBJECTIVES

- State the assumptions of Walter Christaller's central place theory (1933) and explain threshold, range, market area, the order of goods and the hexagonal pattern of central places.
- Calculate the market radius a business needs to reach its threshold, the area of hexagonal market areas in a K = 3 system, and the breaking point between two cities with Reilly's law and the gravity model.
- Test the theory against real landscapes (southern Germany, the American Midwest, the Dutch polders) and give an honest account of its limits and of the use made of it in Nazi-occupied Poland.

Warm-up. Make a list of six places your family goes: the gas station, the grocery store, a hardware store, a hospital, a furniture store, a major-league ballpark. Beside each, write about how far away the nearest one is and how often you go. What do you notice about the things you buy often and the things you buy rarely?

Video. Coming soon. Search for Walter Christaller and central place theory, threshold and range, hexagonal market areas and the gravity model of retail: Hillsdale Studios, The History Guy, Library of Congress; Wendover Productions and Jay Foreman (Map Men) are candidates that need vetting; AP Human Geography teacher channels explaining central place theory need careful vetting for framing (never CrashCourse).

KEY TERMS

central place
A settlement that provides goods and services to the people of the surrounding area (its hinterland or market area).

threshold
The minimum number of customers (or amount of spending) a business needs within its market area to stay in business.

range
The maximum distance people are willing to travel to obtain a good or service.

order of goods
The rank of a good or service: low-order goods (bread, gasoline) are bought often and have small thresholds and ranges; high-order goods (heart surgery, pianos, opera) are bought rarely and need large thresholds and long ranges.

market area (hinterland)
The area surrounding a central place from which people come to buy its goods and services; in Christaller's model, a hexagon.

gravity model

A model predicting that interaction between two places rises with the product of their populations and falls with the square of the distance between them: $I \propto P_1P_2/d^2$.

CORE IDEAS

The story. In 1933 a German geographer named Walter Christaller published the doctoral thesis he had written at the University of Erlangen, *Die zentralen Orte in Süddeutschland* (*The Central Places of Southern Germany*). He had spent years with maps of Bavaria, Württemberg and Baden and had asked a question that sounds almost childlike: why are there so many villages, fewer market towns, fewer still regional cities, and only a handful of great cities like Munich, Nuremberg, Stuttgart and Frankfurt? And why are they spaced across the land in such a regular way? His answer, translated into English in 1966, became one of the founding models of urban geography.

How he figured it out. Christaller saw that a town's importance is not the same as its size. A town of 5,000 that serves a wide farming region with a courthouse, a bank, doctors and shops matters more to the map than an industrial suburb of 5,000 that serves only itself. To measure this "centrality" he counted telephones. In the early 1930s telephones were found mainly in businesses and offices that served the public, so a town with far more telephone connections than its population alone would predict was serving a large surrounding region. Then he built a model. Imagine a flat, uniform plain with farm families spread evenly across it, all with the same purchasing power; travel costs the same in every direction; buyers go to the nearest place offering what they want; and sellers seek a profit. Every good then has a **threshold**, the minimum number of customers needed to stay in business, and a **range**, the farthest people will travel to get it. A business survives only where its range is longer than the radius needed to gather its threshold.

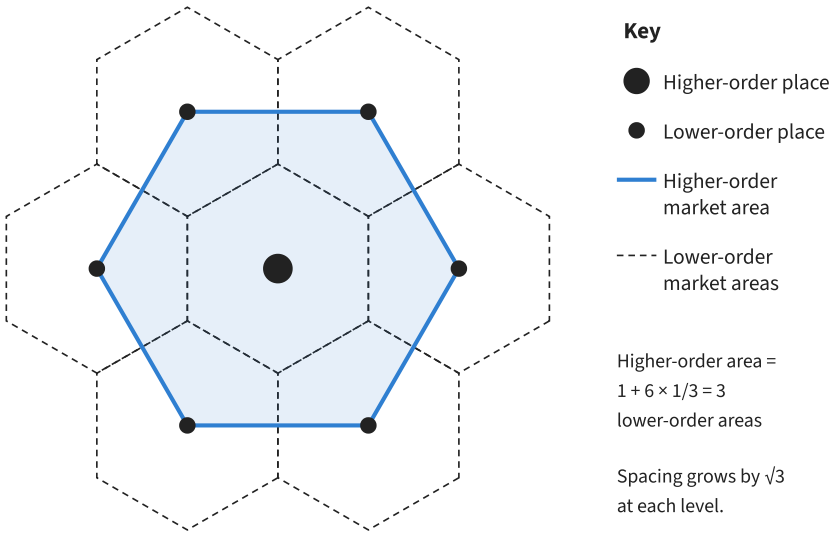
The big idea: hexagons and hierarchy. If every seller drew a circle of customers around himself, the circles would either leave gaps (people unserved) or overlap (customers shared). The figure closest to a circle that covers a plane with no gaps or overlaps is the hexagon, so Christaller's market areas are hexagons (figure he-central-place). Goods also come in an **order**. Low-order goods like bread and gasoline are bought often, have small thresholds and short ranges, and are offered in every village. High-order goods like a cathedral, a university or a specialist hospital need a huge threshold and are found only in a few large places, which also offer all the lower-order goods. The result is a **hierarchy**: many small central places close together, fewer large ones far apart, each larger place serving the market areas of several smaller ones. In his "marketing principle" ($K = 3$), each higher-order place serves the equivalent of three lower-order market areas, and the spacing between places grows by a factor of $\sqrt{3}$ at each step. Christaller reported that the smallest market places of southern Germany lay about 7 km apart, the next level about 12 km, then 21, 36, 62, 108 and 186 km, almost exactly that ratio. He also described a "transport principle" ($K = 4$), in which places line up along main roads, and an "administrative principle" ($K = 7$), in which each district falls wholly under one center.

On the map. Real landscapes bend the hexagons, as real rivers bent von Thünen's rings, but the hierarchy shows. In 1958 the American geographers Brian Berry and William Garrison

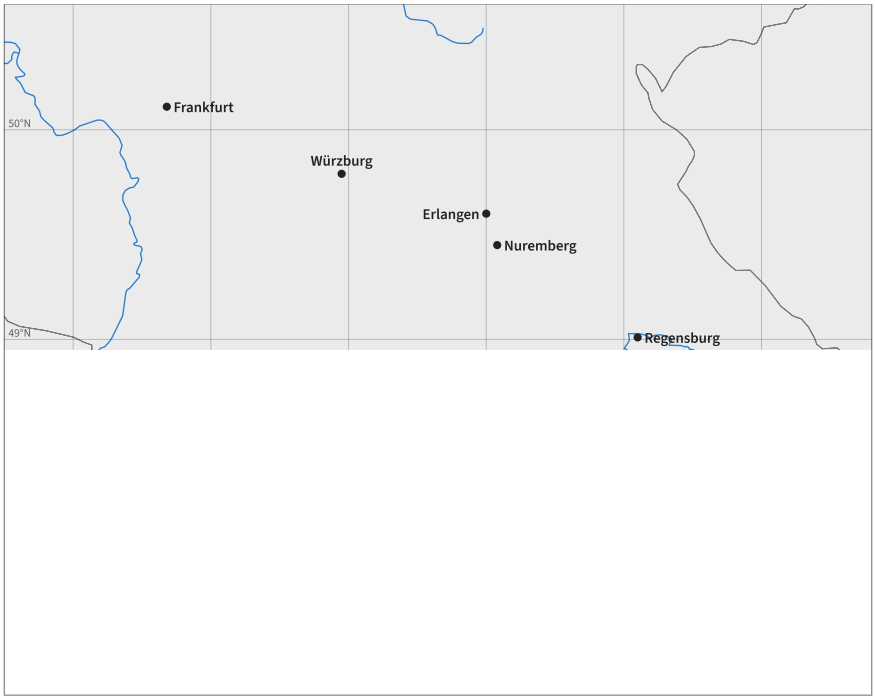
measured the thresholds of businesses in Snohomish County, Washington, and found a clear ladder of hamlets, villages and towns offering nested sets of goods. In the even farmland of the American Midwest, county seats often stand at fairly regular intervals. When the Dutch drained the Noordoostpolder from the IJsselmeer in the 1940s, its planners placed a central town, Emmeloord, with a ring of smaller villages around it, close enough for farm families to reach by bicycle. Geographers measure a city's pull on its neighbors with the **gravity model**, and in 1931 William J. Reilly used the same reasoning to find the "breaking point" between two cities, where shoppers are equally drawn to each: from the smaller city B, the distance is $d_{AB} \div (1 + \sqrt{(P_A/P_B)})$.

A hard chapter. The history of the model includes a real wrong that should be named plainly. Christaller joined the Nazi Party in 1940 and worked in the planning office directed by Konrad Meyer under Heinrich Himmler, drawing settlement plans for conquered western Poland. Those plans assumed the expulsion of Polish families from their farms and towns to make room for German settlers, and many were driven out. A model is a tool; it can be used to plan a just and orderly settlement or an unjust one, and the moral responsibility lies with those who use it. Students of geography should learn both the elegance of Christaller's reasoning and the warning in its history.

Limits of the model. The model assumes an even plain, even population and buyers who always go to the nearest place. Real buyers combine trips, travel farther for lower prices, and since the coming of the automobile have stretched the range of nearly every good. Regional shopping malls and big-box stores skipped levels of the hierarchy, and online shopping now delivers many high-order goods to the door. Yet the core logic still holds: a rural county can support a gas station and a grocery store but not a heart surgeon, and when farm population thins, small-town businesses fall below their thresholds and close.



Christaller's marketing principle (K = 3). The higher-order place serves its own lower-order market area plus one-third of each of the six around it: 1 + 6 × 1/3 = 3.



The region Christaller studied: the large cities of southern Germany and the Danube.

PICTURE STUDY

The Market Place and the Grote Kerk at Haarlem, Gerrit Adriaensz. Berckheyde, 1674 · Oil on canvas · The National Gallery, London

Gerrit Berckheyde lived and worked in Haarlem, a prosperous town in Holland, and painted its great market square many times. Here the Grote Markt opens before the enormous church of St. Bavo, the Grote Kerk. On market days farmers and traders came in from the surrounding countryside to buy and sell; the town hall, the meat hall and the church stood around the square.

For a geographer this is the very picture of a **central place**: the open square where the people of a hinterland met to trade, worship, settle disputes and hear news. Christaller's theory began with the observation that such places exist at every level, from a village green to a great city's central square.

Look closely

- Find the people and carts in the square. What business might bring them here from the countryside?
- Look at the great church. How does its size compare with the houses around the square? What does that say about its place in the town's life?
- Notice how much open space the square holds. Why does a market town need such a space at its center?
- Follow the light and shadow across the paving. What time of day do you think it is?

Talk about it

1. Which goods and services in this square would be low-order and which high-order in Christaller's terms?

2. How far do you think a farm family would travel to come to this market, and what would limit that range in 1674?
3. Why do you think Berckheyde, and the people who bought his paintings, cared so much about pictures of their own town square?

PROJECT: CENTRAL PLACES OF MY COUNTY

You will survey the towns of your own county or region, rank them by the goods and services they offer, map the hierarchy, and lay a hexagon grid over it to see where Christaller's model fits and where the land bends it.

You will need

- A road map or online map of your county and the counties around it
- A list of 12 to 15 goods and services of different orders (gas station, grocery, pharmacy, bank, hardware store, high school, hospital, furniture store, car dealer, college, specialist surgeon, airport with airline service)
- Tracing paper or clear plastic sheet, ruler, fine marker, colored pencils
- Population figures for each town (U.S. Census Bureau QuickFacts)

Steps

1. List every town and village within about 50 miles (80 km) of your home, with its population.
2. For each town, use the map or a phone directory search to check which goods on your list it offers. Make a table with towns as rows and goods as columns; put an X where a good is offered.
3. Count the Xs for each town. Rank the towns into three or four levels (hamlet, village, town, regional city) by the number and order of the goods they offer.
4. Mark the towns on your map with symbols sized by level. Measure the average distance between neighboring places of the same level.
5. On tracing paper, draw a grid of hexagons with a spacing equal to your lowest-level average, and a second, larger grid with spacing √3 (about 1.73) times larger. Lay them over the map.
6. Note where real towns fit the hexagon pattern and where rivers, mountains, highways or county lines bend it.
7. Write one page: Does your region show a central place hierarchy? Which assumptions of the model fail here, and why?

Tips

- Rank towns by what they offer, not just by population, as Christaller did with his telephones.
- Highways often pull central places into lines (Christaller's transport principle). Look for them.

Check your work

- My table shows at least ten towns and twelve goods, with clear levels.
- My map uses graduated symbols and has a title, key, scale and north arrow.
- My hexagon overlay is drawn to scale.
- My essay names at least two assumptions that fail in my region and gives the real reason.

MAP NOTEBOOK

1. Copy figure he-central-place. Shade the higher-order market area in one color and label the threshold and range of one low-order and one high-order good.
2. Draw three circles of customers around three stores and show why circles leave gaps or overlap. Then redraw them as hexagons.
3. Make a ladder diagram of the central place hierarchy for your region, from hamlet to regional city, listing three goods offered at each level.

> **From history.** Christaller's theory became widely known in English only in the 1950s and 1960s, when American geographers such as Brian Berry and William Garrison began testing it with numbers. In 1940 the German economist August Lösch published a more general version of the theory in a book translated as *The Economics of Location*, letting the hexagons of different goods rotate and overlap to form rich and poor "sectors" around a city.

WORKED EXAMPLES

Example 1. A grocery store needs a threshold of 3,000 customers, and its range is 8 km. In a farming region with 40 people per km², what market radius does it need to reach its threshold? Can it survive? What if the density falls to 10 people per km²?

1. Area needed = threshold ÷ density = 3,000 ÷ 40 = 75 km².
2. For a circular market area, A = πr², so r = √(A ÷ π) = √(75 ÷ 3.1416) = √23.87 ≈ 4.9 km (about 3.0 miles).
3. The range (8 km) is longer than the radius needed (4.9 km), so the store can survive.
4. At 10 people per km²: area = 3,000 ÷ 10 = 300 km²; r = √(300 ÷ 3.1416) = √95.5 ≈ 9.8 km (about 6.1 miles).
5. Now the radius needed (9.8 km) is longer than the range (8 km). Customers will not travel that far, so the store cannot reach its threshold.

Answer: At 40 per km² it needs a radius of about 4.9 km (3.0 mi), within its 8 km range, so it survives. At 10 per km² it needs about 9.8 km (6.1 mi), beyond its range, so it fails.

Example 2. In a K = 3 system the smallest central places are 7 km apart. A hexagonal market area whose centers are s km apart has area $A = (\sqrt{3}/2)s^2$. Find the market area of the smallest places, then the spacing and market area at the next two levels.

(Use the map or drawing "Each step up the hierarchy triples the market area and multiplies the spacing by" shown earlier in this lesson.)

1. Lowest level: $A = 0.866 \times 7^2 = 0.866 \times 49 \approx 42.4$ km² (about 16.4 sq mi).
2. In K = 3 the spacing grows by $\sqrt{3} \approx 1.732$ at each level: $7 \times 1.732 \approx 12.1$ km.
3. Second level area: $0.866 \times 12.12^2 \approx 0.866 \times 147.0 \approx 127.3$ km², which is 3×42.4. Each higher place serves three lower-order market areas.
4. Third level spacing: $12.1 \times 1.732 \approx 21.0$ km; area $0.866 \times 21^2 = 0.866 \times 441 \approx 381.9$ km² $= 3 \times 127.3$.
5. Compare Christaller's observed spacings in southern Germany: 7, 12 and 21 km.

Answer: Market areas of about 42.4, 127.3 and 381.9 km² (16.4, 49.2 and 147.5 sq mi), with spacings of 7, 12.1 and 21.0 km, matching Christaller's observed 7, 12 and 21 km.

Example 3. St. Louis (metro population about 2.8 million in 2020) and Kansas City (about 2.2 million) are about 250 miles (400 km) apart. Use Reilly's law to find the breaking point between them.

1. Reilly's breaking point, measured from city B, is $d_{AB} \div (1 + \sqrt{(P_A/P_B)})$.
2. Measure from Kansas City (B), with St. Louis as A: $P_A/P_B = 2.8 \div 2.2 = 1.273$; $\sqrt{1.273} \approx 1.128$.
3. Distance from Kansas City $= 250 \div (1 + 1.128) = 250 \div 2.128 \approx 117.5$ miles.
4. Distance from St. Louis $= 250 - 117.5 = 132.5$ miles. Check from the other side: $250 \div (1 + \sqrt{(2.2/2.8)}) = 250 \div 1.886 \approx 132.5$ miles.
5. In km: $132.5 \times 1.609 \approx 213$ km from St. Louis.

Answer: The breaking point lies about 132 miles (213 km) from St. Louis and 118 miles (189 km) from Kansas City, a little west of Columbia, Missouri. The larger city pulls the line toward the smaller one.

PRACTICE

1. EASY Define threshold and range. Which must be larger, the range or the radius needed to reach the threshold, for a business to survive?
2. EASY Why did Christaller draw market areas as hexagons rather than circles?
3. EASY Match each principle to its K value and description: marketing, transport, administrative. Descriptions: (a) each district falls wholly under one center; (b) places line up along main roads; (c) each higher place serves three lower-order market areas.

4. MEDIUM A pharmacy needs 12,000 customers. The population density is 150 people per square mile. What market radius does it need, in miles and km?
5. MEDIUM Rank these from lowest order to highest order and explain your reasoning: furniture store, gas station, heart-surgery center, grocery store, symphony orchestra.
6. MEDIUM Central places of one level are 10 km apart. Using $A = (\sqrt{3}/2)s^2$, find the area of each hexagonal market area in km² and square miles.
7. MEDIUM In a K = 3 system, how many lowest-order market areas fit within the market area of a place three levels higher? Within one five levels higher?
8. MEDIUM Use the gravity model $I = P_1P_2/d^2$. City A (1,000,000) is 100 km from City B (500,000) and 200 km from City C (2,000,000). Which pair interacts more?
9. HARD Town A has 90,000 people and Town B has 10,000. They are 40 miles apart. Find Reilly's breaking point.
10. HARD On figure he-south-germany, Munich and Nuremberg are about 150 km (93 mi) apart in a straight line. Between which two of Christaller's spacings (7, 12, 21, 36, 62, 108, 186 km) does this fall, and what does that suggest about the two cities?
    (Use the map or drawing "Compare the spacing of the largest cities with Christaller's ladder." shown earlier in this lesson.)
11. HARD In a short paragraph, name three assumptions of central place theory and explain how the automobile, big-box stores or online shopping have changed the pattern it predicts.
12. CHALLENGE A hardware store needs 2,500 customers and has a range of 6 km. Find the minimum population density at which it can survive. A farm county's density falls from 30 to 12 people per km² as farms consolidate. What happens to the store, and why does this explain the decline of many small farm towns?

COMMON MISTAKES

- Confusing threshold (a number of customers) with range (a distance). The business survives only if the range reaches far enough to gather the threshold.
- Ranking towns by population alone. Christaller ranked them by the goods and services they offer to a surrounding region.
- Expecting real maps to show perfect hexagons. The hexagons are the result of the model's assumptions; rivers, mountains, roads and history bend them.

Make it a game · Threshold Race. On a large sheet of graph paper, scatter 60 dots for farm families. Each player is a business with a card showing its threshold (gas station 5 families, grocery 10, hardware 15, hospital 40) and its range in squares (3, 4, 5, 10). In turn, players place their store on the grid and count the families within range that are closer to them than to any rival. A store that cannot reach its threshold goes out of business. The player whose businesses survive with the most customers wins. Then remove 20 families and play again to see which stores close first.

Scripture. "Thou shalt prepare thee a way, and divide the coasts of thy land, which the LORD thy God giveth thee to inherit, into three parts, that every slayer may flee thither."

> (Deuteronomy 19:3, KJV)

The law of Moses commanded cities of refuge spaced through the land and roads prepared to them, so that one who had killed a man by accident could reach safety before the avenger caught him. It is an ancient example of placing a central place so that its range covers everyone who needs it.

Practice answers

1. Threshold is the minimum number of customers a business needs; range is the farthest people will travel for a good. The range must be at least as large as the radius needed to gather the threshold.
2. Circles laid side by side either leave unserved gaps or overlap. The hexagon is the figure closest to a circle that covers a plane completely with no gaps or overlaps.
3. Marketing: K = 3, (c). Transport: K = 4, (b). Administrative: K = 7, (a).
4. Area = 12,000 ÷ 150 = 80 sq mi. r = √(80 ÷ π) = √25.5 ≈ 5.0 miles (about 8.1 km).
5. Gas station, grocery store, furniture store, heart-surgery center, symphony orchestra (the last two may be swapped with good reasons). Lower-order goods are bought often, have small thresholds and short ranges; higher-order goods are bought rarely and need very large thresholds and long ranges.
6. A = 0.866 × 100 = 86.6 km²; 86.6 ÷ 2.59 ≈ 33.4 sq mi.
7. Three levels: $3^3 = 27$. Five levels: $3^5 = 243$.
8. A–B: 1,000,000 × 500,000 ÷ 100^2 = $5 \times 10^{11} \div 10^4 = 5 \times 10^7$. A–C: 1,000,000 × 2,000,000 ÷ 200^2 = $2 \times 10^{12} \div 4 \times 10^4 = 5 \times 10^7$. They are equal: C's larger size exactly offsets its doubled distance.
9. From B: 40 ÷ (1 + √(90,000/10,000)) = 40 ÷ (1 + 3) = 10 miles from B, so 30 miles from A (about 16 km and 48 km).
10. Between 108 and 186 km, closer to 186 km. This suggests both are among the highest-order centers of the region, each serving a very large market area, as Christaller's hierarchy predicts for the largest cities.
11. Assumptions (any three): a flat, uniform plain; evenly spread population with equal purchasing power; equal travel cost in all directions; buyers go to the nearest place offering a good; sellers seek profit. The automobile lengthened the range of nearly every good, so shoppers bypass small towns for larger ones. Big-box stores and regional malls offer many goods at one location and draw from wide areas, skipping levels of the hierarchy. Online shopping delivers many high-order goods to rural homes, weakening the link between buying and travel. The hierarchy remains visible but is flatter and less regular.
12. Minimum density = threshold ÷ (π × range²) = 2,500 ÷ (3.1416 × 36) = 2,500 ÷ 113.1 ≈ 22.1 people per km². At 30 per km² it survives (needed radius √(83.3/π) ≈ 5.2 km). At 12 per km² the needed radius is √(208.3/π) ≈ 8.1 km, beyond the 6 km range, so it closes. As farms grow larger and fewer families live on the land, more and more small-town businesses fall below their thresholds.

7.3 Urban Models

OBJECTIVES

- Draw and explain the concentric zone model (Burgess, 1925), the sector model (Hoyt, 1939) and the multiple-nuclei model (Harris and Ullman, 1945), and name the evidence and reasoning behind each.
- Use bid-rent lines to find zone boundaries, calculate population density with Clark's density gradient, and find the area and population of a sector.
- Test the three models against real cities in America and abroad, and explain their limits, including how they were shaped by the industrial American city and how neighborhood ratings were misused in the 1930s.

Warm-up. Drop a spoonful of water into the middle of a paper towel and watch it spread in rings. Then lay a strip of string across the towel and drip water along it. Sketch both patterns. Which looks more like the way a city grows outward from its downtown, and which like the way it grows along a road or rail line?

Video. Coming soon. Search for the Chicago school of sociology and Ernest Burgess, Homer Hoyt and the sector model, the 1909 Plan of Chicago and Daniel Burnham, and the growth of American downtowns: The History Guy, Hillsdale Studios, Library of Congress, The Henry Ford; The B1M and Wendover Productions are candidates that need vetting; AP Human Geography teacher channels explaining urban models need careful vetting for framing (never CrashCourse).

KEY TERMS

central business district (CBD)
The commercial heart of a city, with the highest land values, tallest buildings and greatest concentration of offices and stores.

concentric zone model
Ernest Burgess's model (1925) of a city as five zones: the CBD at the center and four rings around it (zone in transition, workingmen's homes, residential zone and commuters' zone).

sector model
Homer Hoyt's model (1939) in which land uses, especially high-rent housing, form wedges that grow outward from the CBD along transportation lines and attractive land.

multiple-nuclei model
The model of Chauncy Harris and Edward Ullman (1945) in which a city grows around several separate centers (nuclei), such as a port, an industrial district or an outlying business district, as well as the CBD.

bid-rent curve
A line showing how much each land user is willing to pay for land at each distance from the center; the highest bidder at each distance wins the land.

density gradient

The rate at which population density falls with distance from the city center; Colin Clark (1951) described it as $D = D_0 e^{-bx}$.

CORE IDEAS

The story. No city on earth had grown as fast as Chicago. It held about 4,500 people in 1840, burned in the Great Fire of 1871, and still passed a million by 1890 and 2.7 million by 1920. At the University of Chicago, founded in 1890, a group of sociologists led by Robert Park decided to treat their own city as a laboratory. In 1923 one of them, Ernest W. Burgess, read a paper on "The Growth of the City" to the American Sociological Society, and in 1925 it appeared in the book *The City*. On a map of Chicago he drew a set of rings around the Loop, the downtown circled by the elevated railway. Because Lake Michigan lies on the east, his rings were half-circles. Every geography textbook since has reproduced them.

How he figured it out: the concentric zones. Burgess saw the city as growing outward from its center like the rings of a tree. Zone 1 was the **central business district**: offices, department stores, banks, hotels and theaters. Zone 2 was the **zone in transition**, where warehouses and light factories pushed into old houses that had been divided into cheap rooms; here newly arrived immigrants first settled. Zone 3 held the homes of working families who had moved one step out to be near their jobs. Zone 4 was a residential zone of better apartments and single-family houses. Zone 5, the commuters' zone, lay beyond the city limits, where people rode the trains in to work. Borrowing words from plant ecology, Burgess said each zone tended to grow by *invasion and succession* into the next, as families who prospered moved outward and newcomers took their places. Economists later explained the rings with **bid-rent curves**, applying von Thünen's reasoning to city land (figure he-urban-bid-rent): stores and offices gain most from a central location and outbid everyone downtown; industry bids next; households, who want space more than centrality, win the land farther out.

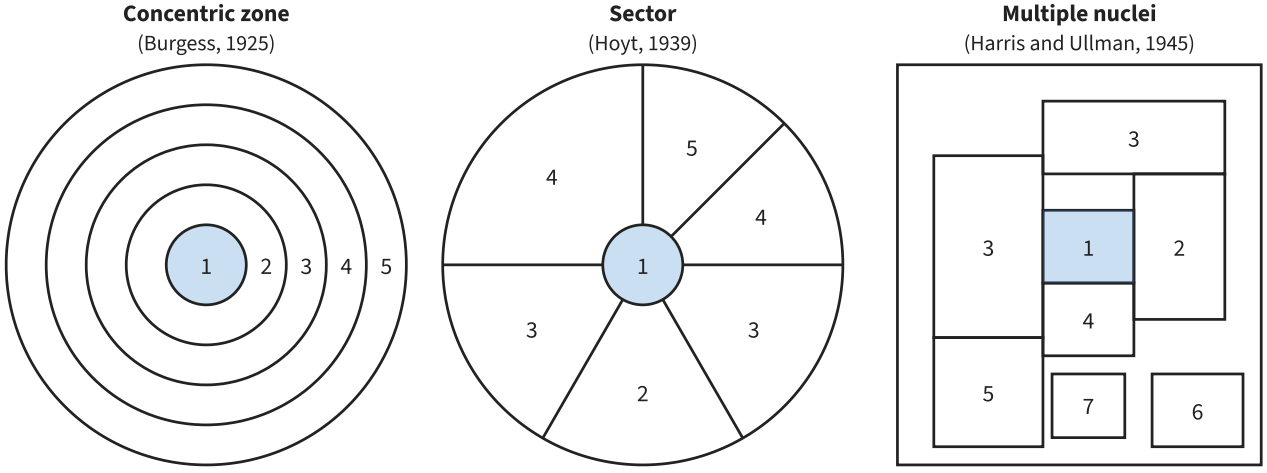
The sector model. Homer Hoyt was a land economist who had written a history of a century of land values in Chicago. Working for the new Federal Housing Administration, he studied block-by-block rent data for 142 American cities and published *The Structure and Growth of Residential Neighborhoods in American Cities* in 1939. He found that rents formed not rings but **sectors**, wedges running outward from downtown. Once a high-rent area began on one side of town, it kept growing outward in the same direction: along the fastest transportation lines, toward high ground, along lakefronts and rivers free of industry, and toward the homes of the city's leading families. Industrial and low-rent sectors likewise followed rail lines and rivers. Chicago's high-income North Shore along the lake, and Philadelphia's Main Line suburbs along the Pennsylvania Railroad, fit his pattern well.

The multiple-nuclei model. In 1945 the geographers Chauncy Harris and Edward Ullman argued in "The Nature of Cities" that many cities grow around several centers, not one. They gave four reasons. Some activities need special facilities, such as a port or a rail yard. Similar activities gain by clustering, as financial firms or furniture stores do. Some activities repel each other, so fine homes are not built beside steel mills. And some uses, such as

wholesaling and storage, cannot afford the rents of the best sites. Their model (figure he-urban-models) shows a CBD, a wholesale and light-manufacturing district, a heavy-industry district, an outlying business district, residential districts of several kinds, and suburbs. The car age, which you will study in Lesson 7.4, made the pattern stronger still.

The big idea: density falls with distance. All three models agree that land values and density are highest near the center and fall outward. In 1951 the British economist Colin Clark showed, from data on many cities, that population density tends to fall off exponentially: $D = D_0 e^{-bx}$, where D_0 is the density at the center, x the distance and b the density gradient. As transport improved, b grew smaller in nearly every city; the city flattened and spread.

Limits of the models. Each model describes the American industrial city of the early twentieth century, and each leaves things out: hills, rivers, laws, history and the choices of families. In many European cities, such as Paris, wealthy families have long preferred the center, and the poorer districts lie on the edge. Geographers have built other models for other regions, such as the Latin American city model of Ernest Griffin and Larry Ford (1980), with a wealthy "spine" running out from the center, and T. G. McGee's model of the Southeast Asian port city (1967). The models were also used in policy, sometimes unjustly. In the 1930s, federal mortgage agencies rated neighborhoods for lending risk, and the ratings often marked down neighborhoods because of the race or immigrant origin of their residents, making loans there hard to get; the Fair Housing Act of 1968 outlawed such discrimination. Taught honestly, the models are useful lenses: each shows a real force at work in the city, and none shows all of them.

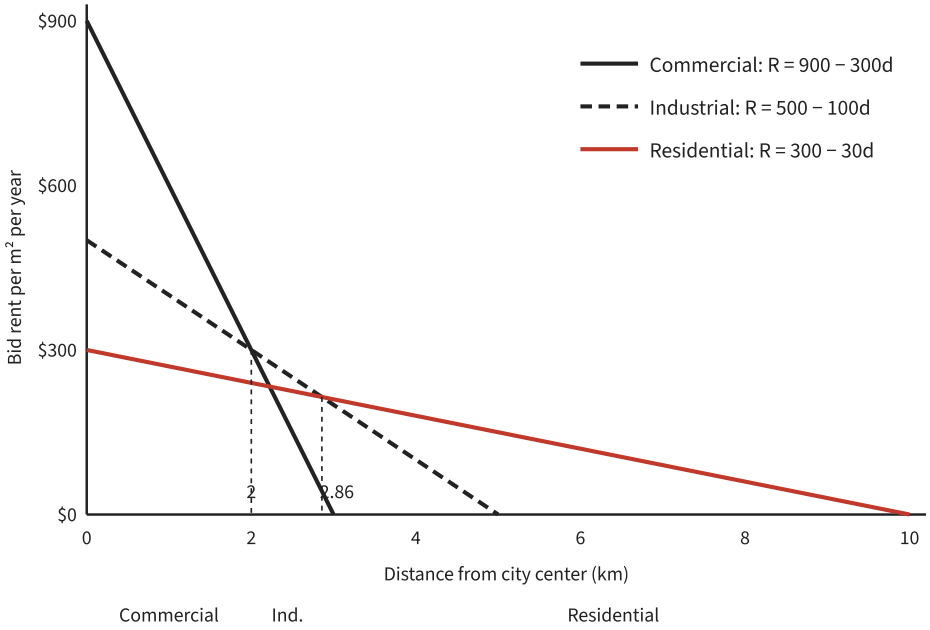


Burgess: 1 central business district (the Loop); 2 zone in transition; 3 workingmen's homes; 4 residential zone; 5 commuters' zone.

Hoyt and Harris–Ullman: 1 central business district; 2 wholesale and light manufacturing; 3 low-income housing; 4 middle-income housing; 5 high-income housing; 6 heavy manufacturing; 7 outlying business district.

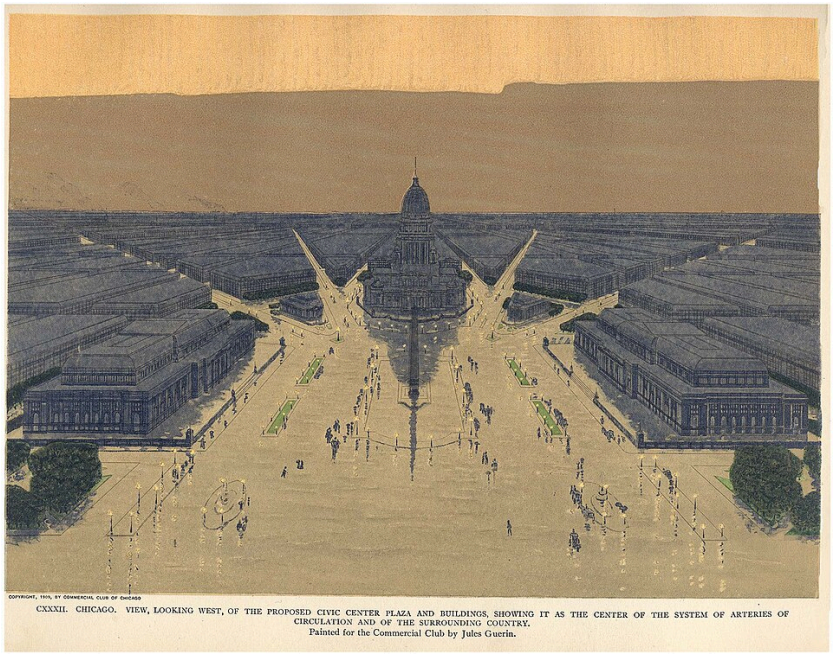
Unnumbered space in the multiple-nuclei diagram is mainly middle-income housing.

The three classic models of the American city. The numbers follow each author's own key, given beneath the diagrams.



Bid-rent lines for city land (illustrative numbers from Worked Example 1). The highest bidder at each distance wins, and the crossovers become Burgess's rings.

PICTURE STUDY



Chicago: View, Looking West, of the Proposed Civic Center Plaza and Buildings, Showing It as the Center of the System of Arteries of Circulation and of the Surrounding Country (from the Plan of Chicago), Jules Guérin, for Daniel H. Burnham and Edward H. Bennett, 1908 (published 1909) · Graphite and watercolor on paper, reproduced as a color plate in the *Plan of Chicago* (1909) · Art Institute of Chicago (on permanent loan from the City of Chicago)

In 1909 the architect Daniel Burnham and his partner Edward Bennett published the *Plan of Chicago*, paid for by the city's Commercial Club. It proposed lakefront parks, widened

boulevards, consolidated railroad stations and a ring of forest preserves. The painter Jules Guérin made its most famous illustrations, glowing bird’s-eye views of a city that did not yet exist.

This plate shows Burnham’s proposed civic center, a domed hall at the heart of the city, with avenues radiating outward across the prairie like the spokes of a wheel. The civic center was never built, but the picture captures the idea behind every model in this lesson: a city organized around a center, with its land uses arranged by distance and by the routes that lead out from it.

Look closely

- Find the domed building at the center. How does the artist make it the most important thing in the picture?
- Follow the diagonal avenues outward. Where do they lead, and what lies between them?
- Look at how flat the land is to the horizon. How does Chicago’s site make rings and spokes easy to draw?
- Notice the colors and the time of day. What feeling about the city’s future did Guérin want to give?

Talk about it

1. Which urban model does this picture most resemble, and why?
2. How might radiating avenues create the sectors that Hoyt described?
3. Burnham is remembered for urging planners to think big. What are the strengths and dangers of planning a whole city from the center?

PROJECT: TESTING THE MODELS ON A REAL CITY

You will map the land uses of a real city (your own or one you can study online), overlay transparent sheets drawn with each of the three models, and judge which fits best.

You will need

- A printed map of a city of at least 100,000 people (a street map, or a screenshot of an online map with satellite view)
- Three sheets of clear plastic or tracing paper, fine markers in several colors
- Census tract data on median household income or median home value for the city (data.census.gov or the Census Bureau’s mapping tools)
- A historic map of the same city, if available (Library of Congress Sanborn or panoramic maps)

Steps

1. Mark the CBD on your base map. Then color in the main land uses you can identify: industry and rail yards, port or river frontage, major shopping districts outside

downtown, parks, and residential areas.
2. Using census data, shade residential areas in three levels (lower, middle and higher median income or home value).
3. On the first clear sheet, draw Burgess's five rings centered on the CBD. On the second, draw Hoyt's sectors along the main rail lines, highways and waterfronts. On the third, draw Harris and Ullman's nuclei around every separate center you found.
4. Lay each sheet over the map in turn. Count how many of your colored areas each model places correctly.
5. Compare with the historic map. Has the city's high-income sector moved outward in one direction, as Hoyt predicted?
6. Write one to two pages: Which model fits your city best? Where does each fail, and what local features of site, situation or history explain the failures?

Tips

- Most real cities show a little of all three models. Look for the strongest pattern, and name the others.
- Rivers, hills and highways are often the hidden lines that bend the rings into sectors.

Check your work

- My land-use map has a title, key, scale and north arrow.
- Each overlay is drawn correctly for its model.
- I scored each model against the map and explained the result.
- My essay uses specific places in the city as evidence.

MAP NOTEBOOK

1. Copy the three diagrams in figure he-urban-models side by side, label every zone, and write the author and year beneath each.
2. Draw Burgess's rings as half-circles against a lake, as he did for Chicago, and mark the Loop.
3. Sketch a bid-rent graph for a city with three users (offices, factories, houses), and shade the three zones beneath it.

> **From history.** The 1909 *Plan of Chicago* shaped the city for a century. Its most lasting gift was the lakefront: the plan urged that the shore of Lake Michigan be kept for parks and public use, and today Chicago has miles of public beaches and parkland along the lake, including Grant Park and Burnham Park. The forest preserves around the city, another of its proposals, protect tens of thousands of acres of woods and prairie.

WORKED EXAMPLES

Example 1. In a model city, the bid rents for land (in dollars per square meter per year, illustrative) are: commercial R = 900 − 300d, industrial R = 500 − 100d and residential R = 300 − 30d, where d is the distance from the center in km. Find where each use wins and compare with Burgess's rings.

(Use the map or drawing "The highest line at each distance wins the land." shown earlier in this lesson.)

1. At the center (d = 0): commercial $900, industrial $500, residential $300. Commercial wins.
2. Commercial and industrial cross where 900 − 300d = 500 − 100d, so 400 = 200d and d = 2 km.
3. Industrial and residential cross where 500 − 100d = 300 − 30d, so 200 = 70d and d ≈ 2.86 km.
4. Check that residential is below commercial at 2 km: residential 300 − 60 = $240, commercial and industrial $300. Correct.
5. Residential margin: 300 − 30d = 0 gives d = 10 km. Beyond it, land stays in farm use.

Answer: Commercial from 0 to 2 km (1.2 mi), industrial from 2 to about 2.86 km (1.2–1.8 mi), residential from 2.86 to 10 km (1.8–6.2 mi). The pattern matches Burgess: a CBD, a ring of industry and transition, then homes.

Example 2. A city's density follows Clark's model $D = D_0 e^{-bx}$ with D_0 = 20,000 people per km² and b = 0.2 per km. Find the density at 5 km and at 10 km, and the distance at which density falls to half its central value.

1. At 5 km: $D = 20{,}000 \times e^{-0.2 \times 5} = 20{,}000 \times e^{-1} = 20{,}000 \times 0.368 \approx 7{,}360$ per km².
2. At 10 km: $D = 20{,}000 \times e^{-2} = 20{,}000 \times 0.135 \approx 2{,}710$ per km².
3. Half the central density: $e^{-0.2x} = 0.5$, so $-0.2x = \ln 0.5 = -0.693$, and $x = 0.693 \div 0.2 \approx 3.47$ km.
4. In miles: 3.47 km ÷ 1.609 ≈ 2.2 miles. In people per square mile, multiply by 2.59: the center has about 51,800 per sq mi.

Answer: About 7,360 per km² (19,100 per sq mi) at 5 km and about 2,710 per km² (7,000 per sq mi) at 10 km. Density halves every 3.47 km (2.2 miles).

Example 3. In a Hoyt-style city, a high-income sector forms a wedge of 45° running from 2 km to 10 km from the center. Find its area. If its average density is 3,000 people per km², about how many people live in it?

(Use the map or drawing "Sector 5 in Hoyt's diagram is a wedge like the one in this example." shown earlier in this lesson.)

1. The wedge is part of a ring between radii 2 km and 10 km. The full ring has area $\pi(10^2 - 2^2) = \pi \times 96 \approx 301.6$ km².
2. A 45° wedge is 45 ÷ 360 = 1/8 of the ring: 301.6 ÷ 8 ≈ 37.7 km².
3. In square miles: 37.7 ÷ 2.59 ≈ 14.6 sq mi.
4. Population: 37.7 × 3,000 ≈ 113,100 people.

Answer: About 37.7 km² (14.6 sq mi), home to about 113,000 people.

PRACTICE

1. EASY Name Burgess's five zones in order from the center outward.
2. EASY Match each model with its author or authors and year: concentric zone, sector, multiple nuclei.
3. EASY Give the four reasons Harris and Ullman offered for why cities develop several nuclei.
4. MEDIUM Which model best fits each description? (a) A wealthy district stretches 10 miles outward along a lakeshore and a commuter railroad. (b) A city has a downtown, an airport business district and a separate industrial suburb. (c) Land uses form rings that move outward as the city grows.
5. MEDIUM Retail bid rent is R = 1,200 − 400d and residential bid rent is R = 400 − 40d (d in km). Where do they cross, and which use is found nearer the center?
6. MEDIUM A city has D_0 = 15,000 people per km² and b = 0.3 per km. Find the density at 3 km.
7. MEDIUM A low-income industrial sector is a 60° wedge running from 1 km to 8 km from the center. Find its area in km² and square miles.
8. MEDIUM Chicago grew from about 1.10 million people in 1890 to about 2.70 million in 1920. Find the percent increase.
9. HARD Explain why Hoyt's high-income sectors grow along transportation lines and waterfronts, and give one real example.
10. HARD How does the Griffin–Ford model of the Latin American city differ from Burgess's model in where wealthy families live?
11. HARD In a paragraph, name three limits of the classic urban models.
12. CHALLENGE In a city that follows Clark's model, density is 12,000 people per km² at 2 km and 5,400 per km² at 6 km. Find the gradient b and the central density D_0.

COMMON MISTAKES

- Treating a model as a map of a real city. Each model isolates one force (distance, direction or multiple centers) and simplifies the rest.
- Mixing up the numbering. Burgess's zone 2 is the zone in transition; in Hoyt's and Harris and Ullman's keys, 2 is wholesale and light manufacturing.
- Assuming every city in the world has wealthy suburbs and a poorer inner city. That pattern is typical of many American cities, but many European and Latin American cities show the reverse.

Make it a game · Model Match. Make 24 cards, each describing a real place or pattern ("steel mills along the river," "mansions along the lakeshore," "an airport office park," "rooming houses beside downtown warehouses," "a ring of commuter suburbs"). Draw three large diagrams of the models on the table. Players take turns drawing a card and placing it on the model and zone it best fits, explaining why. Other players may challenge; if the challenger gives a better reason, they take the card. Most cards wins.

Scripture. "And seek the peace of the city whither I have caused you to be carried away captives, and pray unto the LORD for it: for in the peace thereof shall ye have peace." (Jeremiah 29:7, KJV)

Jeremiah wrote to the exiles in Babylon, the greatest city of their world, telling them to build houses, plant gardens, raise families and seek the good of the city where God had placed them. Studying how a city is arranged is one way to love its people wisely.

Practice answers

1. (1) Central business district (the Loop); (2) zone in transition; (3) zone of workingmen's homes; (4) residential zone; (5) commuters' zone.
2. Concentric zone: Ernest Burgess, 1925 (paper read in 1923). Sector: Homer Hoyt, 1939. Multiple nuclei: Chauncy Harris and Edward Ullman, 1945.
3. Some activities need specialized facilities (a port, rail yards); similar activities benefit from clustering; some activities repel each other (heavy industry and fine housing); some activities cannot afford the rents of the best sites (wholesaling, storage).
4. (a) Sector (Hoyt). (b) Multiple nuclei (Harris and Ullman). (c) Concentric zone (Burgess).
5. $1{,}200 - 400d = 400 - 40d$ gives $800 = 360d$, so $d \approx 2.22$ km (1.4 miles). Retail, with the higher and steeper line, wins inside 2.22 km; residential beyond.
6. $D = 15{,}000 \times e^{-0.9} = 15{,}000 \times 0.407 \approx 6{,}100$ people per km² (about 15,800 per sq mi).
7. Ring area $\pi(8^2 - 1^2) = 63\pi \approx 197.9$ km². A 60° wedge is 1/6 of it: ≈ 33.0 km², or 33.0 ÷ 2.59 ≈ 12.7 sq mi.
8. (2.70 − 1.10) ÷ 1.10 × 100 ≈ 145 percent.
9. Families who could afford it wanted quick travel to downtown and pleasant surroundings, so the most desirable new land lay along the fastest rail or streetcar lines, on high ground and along lakes or rivers free of industry. Once a high-income area began in one direction, new building extended it outward in the same direction. Examples: Chicago's North Shore along

Lake Michigan and the commuter lines; Philadelphia's Main Line along the Pennsylvania Railroad.

10. In Burgess's model, wealthier families live in the outer rings and commute in. In the Griffin–Ford model (1980), the wealthy live near the center and along a "spine" of fine avenues, shops and amenities running outward from the CBD, while the poorest districts often lie on the outer edge of the city.
11. They were built from American industrial cities of the early twentieth century and fit other times and places poorly (for example, Paris, where the wealthy have long preferred the center); they ignore physical features such as hills and rivers, and the effects of laws, zoning and history; they treat the city as having one center, or a few, while modern metropolitan areas have many centers spread by the automobile. They also say little about the choices of families and the role of faith, ethnicity and culture in neighborhoods.
12. $5{,}400 \div 12{,}000 = 0.45 = e^{-4b}$. $\ln 0.45 \approx -0.799$, so $b \approx 0.799 \div 4 \approx 0.20$ per km. Then $D_0 = 12{,}000 \times e^{0.2 \times 2} = 12{,}000 \times e^{0.4} \approx 12{,}000 \times 1.492 \approx 17{,}900$ people per km².

7.4 Transportation and the City ⚙

OBJECTIVES

- Trace the shape of the American city through four transportation eras (walking city, streetcar and railroad suburbs, automobile city, freeway metropolis), with real dates, people and places.
- Calculate how commuting speed sets the radius and area of a city, compare the carrying capacity of roads and rail, and compare journey times before and after the Interstate highways.
- Explain how transportation produced streetcar suburbs, star-shaped cities, suburbs, beltways and edge cities, and present more than one view fairly on how cities should grow.

Warm-up. Set a timer for 5 minutes and walk at a normal pace from your front door, then turn around when it rings at the halfway point. Note how far you got. Multiply by 6 to estimate how far you could walk in 30 minutes. Now think of a place 10 miles away. How long would it take on foot, by bicycle and by car? Write down which places in your life you could not reach in a day without wheels.

Watch. *The Lost Street Cars of New York City | The Story of American trolleys - IT'S HISTORY* (IT'S HISTORY, 12:18). https://www.youtube.com/watch?v=lwExk32mXjM
After the story: watch how electric trolleys like Sprague's spread across New York City and shaped its neighborhoods, then look for why the city later tore the lines out for buses and cars.
Note: Captions were not available to check; preview it first. The channel calls the loss of the trolleys 'a great American crime'. Historians still debate this claim that companies deliberately killed the streetcars, and the video may include a sponsor message. Focuses on New York's trolleys and their decline, not Sprague's 1888 Richmond line.

KEY TERMS

walking city
A compact city of the era before mechanized transit, in which nearly everything lay within a walk of about 30 minutes, so homes, shops and workplaces were mixed close together.

streetcar suburb
A residential district built along an electric streetcar or horsecar line in the late 1800s and early 1900s, with houses within a short walk of the tracks.

suburbanization
The movement of people, homes and later jobs and shopping from the central city to the surrounding communities.

beltway

A limited-access highway that circles a city, linking its suburbs to one another without passing through downtown.

edge city
Journalist Joel Garreau's term (1991) for a large concentration of offices and shopping that grows at a suburban highway junction, outside the old downtown (for example, Tysons, Virginia).

megalopolis
Geographer Jean Gottmann's term (1961) for a chain of metropolitan areas grown together, especially the corridor from Boston to Washington, D.C.

CORE IDEAS

The story. In 1887 a thirty-year-old engineer named Frank J. Sprague, a graduate of the U.S. Naval Academy who had worked briefly for Thomas Edison, signed a contract that many people thought would ruin him. He promised to build a complete electric street railway in Richmond, Virginia: about 12 miles of track, 40 cars, and a power station, on a city of steep hills where horses struggled. Motors burned out, cars stalled on grades, and Sprague and his men worked through the winter redesigning them. Early in 1888 regular service began, and it worked. Within a few years electric streetcars were replacing horsecars across the country, and the shape of the American city changed with them.

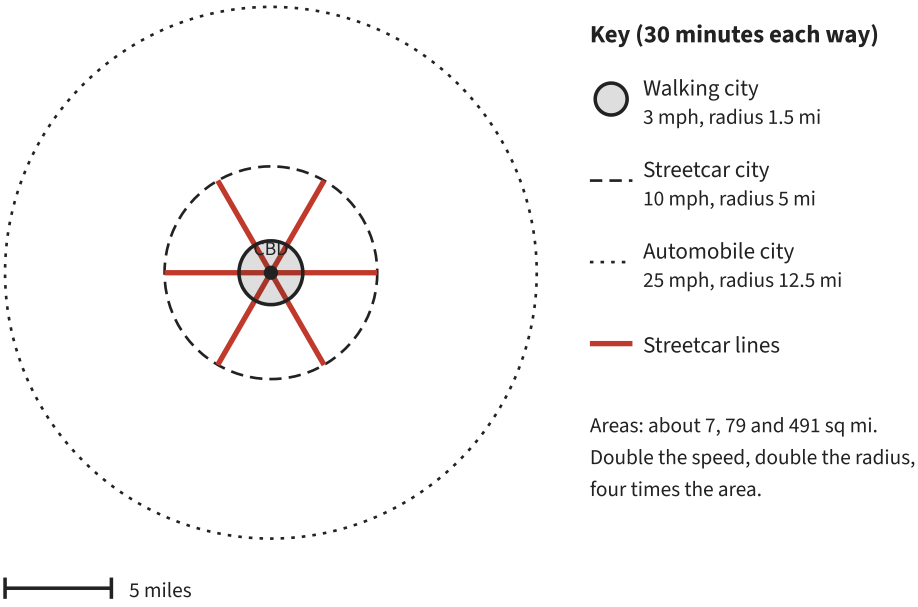
Technology overcoming geography: the walking city. Distance inside a city is measured in time. People walk about 3 miles an hour, and across history most have been willing to spend about an hour a day getting to and from work, a pattern the Italian physicist Cesare Marchetti described in 1994 and which has been called "Marchetti's constant." So before mechanized transit, cities were **walking cities**: dense, compact and mixed, rarely more than 2 or 3 miles across. Merchants lived above their shops, the wealthy lived near the center, and the poor crowded wherever they could. Horse-drawn omnibuses and then horsecars on rails (New York's first ran in 1832) stretched the city a little. Steam railroads let the well-to-do live in "railroad suburbs" along the lines, such as the towns along the Pennsylvania Railroad's Main Line west of Philadelphia. London opened the world's first underground railway, the Metropolitan, in 1863.

How it worked: the streetcar city. Sprague's electric streetcar ran at 10 to 15 miles an hour, three or four times walking speed, and a single fare carried a clerk or a factory hand from downtown to the edge of the countryside. Developers bought farmland at the end of the lines, laid out lots and built rows of houses; sometimes the streetcar company and the land company were the same. Because riders still had to walk to the tracks, the new **streetcar suburbs** stretched in narrow fingers along each line, and the city took the shape of a star, its points following the routes out of downtown. This is exactly the pattern Homer Hoyt's sectors describe (Lesson 7.3). The historian Sam Bass Warner traced it in detail for Boston in *Streetcar Suburbs* (1962). In the largest cities, elevated railways and subways moved still more people: Chicago's Loop elevated was completed in 1897, Boston opened America's first subway the same year, and New York's first subway line opened in 1904.

The automobile and the highway. Henry Ford's Model T (1908), built on a moving assembly line from 1913, brought the car within reach of ordinary families; by the mid-1920s a new one cost less than $300. Cars could go anywhere there was a road, so the spaces between the streetcar fingers filled in, and the star became a broad disk. After the Second World War, millions of returning servicemen started families, and builders like William Levitt mass-produced houses for them; his first Levittown on Long Island, begun in 1947, held more than 17,000 houses. In 1919 a young Army officer named Dwight Eisenhower had crossed the country in a military truck convoy that took 62 days; in Germany in 1945 he saw the autobahns. As president he signed the Federal-Aid Highway Act of 1956, which funded a 41,000-mile national network of Interstate highways. Beltways circled the cities, and offices and shopping followed homes outward, forming the multiple nuclei of Harris and Ullman, and later Joel Garreau's **edge cities**. Most American streetcar systems were gone by the 1950s and 1960s.

The big idea. Each new technology lowered the time-cost of distance, and each time the city spread to fill the same commuting time at the new speed. In the language of Lesson 7.3, the density gradient flattened. A 30-minute commute on foot reaches about 1.5 miles; by streetcar about 5; by car on city streets about 12; by freeway 25 or more, and the area within reach grows with the square of the radius (figure he-commute-radius). Where metropolitan areas grew together, as along the Atlantic coast from Boston to Washington, Jean Gottmann in 1961 saw a single **megalopolis**.

What technology has not overcome. The hour-a-day travel budget has hardly changed; faster travel was spent on distance, not on saved time. Congestion slows freeways at rush hour, and rivers, bays and mountains still force cities to spend heavily on bridges and tunnels. Americans weigh the results differently. Many families value the space, privacy, ownership and safety of suburban life and the freedom of the car. Others value walkable neighborhoods, shorter trips and the lower cost per household of serving compact areas with pipes, roads and transit, and as of 2026 a number of cities are building light rail or reviving streetcars. Both views draw on real goods; the geographer's task is to measure the trade-offs honestly.



The same 30-minute commute at three speeds. The radius grows with speed; the area within reach grows with the square of the radius.

PICTURE STUDY

La Gare Saint-Lazare (The Saint-Lazare Station), Claude Monet, 1877 · Oil on canvas · Musée d'Orsay, Paris

The Gare Saint-Lazare was the busiest station in Paris, the terminus of the line to Saint-Germain-en-Laye that had opened in 1837 as the first passenger railway in the Paris region, and of the lines to Normandy. Every day it carried thousands of passengers between the city and the growing towns to the west. In 1877 Claude Monet rented a small apartment nearby

and received permission to paint inside the station. He made about a dozen pictures of it, and several were shown at the Impressionists' exhibition that spring.

Monet painted the station as a place of light, smoke and movement. For a geographer it is also a picture of a node: a point where a city's web of streets meets the long lines of the railroad, where the suburb and the countryside are linked to the center every hour of the day.

Look closely

- Find the locomotives and the smoke. How does Monet show movement and noise without drawing every detail?
- Look at the iron and glass roof. Why would a station need such a high, open shed?
- Look through the open end of the station. What can you see of the city beyond?
- Find the people on the platforms. Where do you think they are going?

Talk about it

1. How did stations like Saint-Lazare change where people in Paris could live and work?
2. Why do railroad stations and the streets around them become centers of business in a city?
3. Is a railroad station a beautiful subject for a painting? Why did Monet think so?

PROJECT: AN ISOCHRONE MAP OF MY CITY

An **isochrone** is a line connecting all the places you can reach in the same amount of time. You will build a string-and-pin isochrone map showing how far you can travel from your city's downtown in 30 minutes on foot, by bicycle, by bus or rail, and by car, and compare it with the city's growth over time.

You will need

- A printed map of your city and its suburbs, mounted on corkboard or foam board
- Push pins and yarn in four colors
- An online map service with travel times for walking, cycling, transit and driving
- A historic map of the city around 1900 or 1920 showing streetcar or rail lines (Library of Congress map collections or a local historical society)
- Ruler and calculator

Steps

1. Mark the center of downtown with a pin.
2. Choose eight directions (N, NE, E, SE, S, SW, W, NW). In each direction, use the online map to find the point you can reach in 30 minutes on foot. Push a pin there.
3. Connect the eight walking pins with yarn of one color. Repeat for cycling, transit and driving, each in its own color.

4. Measure the average radius of each isochrone with the map scale. Estimate each area with $A = \pi r^2$ and record it in a table.
5. Compare the transit isochrone with the historic streetcar or rail map. Do the old lines still shape the routes and neighborhoods?
6. Note where rivers, rail yards, highways or hills stretch or pinch your isochrones.
7. Write one page: How has transportation shaped where people in my city live and work? What is one place that is close in miles but far in time, or far in miles but close in time?

Tips

- Check driving times at the same hour for every direction; rush-hour traffic changes the results greatly.
- Isochrones are rarely circles. The bulges show the fast routes, just as streetcar lines once made the city a star.

Check your work

- My map shows four isochrones in four colors with a key, scale and north arrow.
- My table gives the radius and area for each mode, with the calculations shown.
- I compared the present map with a historic one.
- My essay explains at least two ways transportation shaped the city.

MAP NOTEBOOK

1. Draw the four stages of the American city side by side as small diagrams: the compact walking city, the star-shaped streetcar city, the filled-in automobile city and the freeway metropolis with a beltway and edge cities.
2. Sketch figure he-commute-radius and label each circle with its mode, speed, radius and area.
3. Draw a timeline from 1832 to 1991 with these events: first New York horsecar line, London’s Metropolitan Railway, Sprague’s Richmond streetcars, Boston’s first subway, the Model T, Levittown, the Federal-Aid Highway Act, Gottmann’s *Megalopolis* and Garreau’s *Edge City*.

> **From history.** Sprague’s greatest gift to the big city came nine years after Richmond. In 1897 he demonstrated multiple-unit control on Chicago’s South Side elevated railway: each car of a train carried its own motors, but a motorman in the front car controlled them all. Trains could now be made longer or shorter as needed without a locomotive, and every subway and electric commuter train in the world still works on his principle.

WORKED EXAMPLES

Example 1. Assume a 30-minute commute each way. Find the radius and the area within reach of downtown for walking (3 mph), an electric streetcar (10 mph average with stops), a car on city streets (25 mph) and a freeway (50 mph). Give areas in square miles and km².

(Use the map or drawing "The 30-minute circles of the walking, streetcar and automobile cities." shown earlier in this lesson.)

1. Radius = speed × time = speed × 0.5 hour. Walking: 1.5 mi; streetcar: 5 mi; car: 12.5 mi; freeway: 25 mi.
2. Area = πr². Walking: $3.1416 \times 1.5^2 = 3.1416 \times 2.25 \approx 7.1$ sq mi.
3. Streetcar: $3.1416 \times 25 \approx 78.5$ sq mi. Car: $3.1416 \times 156.25 \approx 491$ sq mi. Freeway: $3.1416 \times 625 \approx 1{,}963$ sq mi.
4. Convert with 1 sq mi = 2.59 km²: about 18.3, 203, 1,271 and 5,085 km².
5. Compare: the freeway area is $1{,}963 \div 7.1 \approx 278$ times the walking area, because $(50 \div 3)^2 \approx 278$.

Answer: Walking: 1.5 mi, about 7.1 sq mi (18 km²). Streetcar: 5 mi, 78.5 sq mi (203 km²). Car: 12.5 mi, 491 sq mi (1,271 km²). Freeway: 25 mi, 1,963 sq mi (5,085 km²). Multiplying speed by about 17 multiplied the reachable area by about 278.

Example 2. Engineers commonly use round figures of about 2,000 vehicles per hour for one freeway lane, with about 1.1 people per car at rush hour. A busy urban rail line can carry about 30,000 passengers per hour in one direction. How many freeway lanes in one direction would carry as many people as the rail line?

1. People per lane per hour = $2{,}000 \times 1.1 = 2{,}200$.
2. Lanes needed = $30{,}000 \div 2{,}200 \approx 13.6$.
3. Round up: 14 lanes in one direction.

Answer: About 14 freeway lanes in one direction. This is why the densest city centers (Manhattan, central London) still depend on rail, while lower-density metropolitan areas, where trips go in many directions, depend on roads.

Example 3. In 1919 an Army convoy crossed the country from Washington, D.C., to San Francisco, about 3,250 miles, in 62 days. Today the trip by Interstate is about 2,800 miles. Find the convoy's average distance per day and estimate how many days the modern trip takes if a driver averages 60 mph for 10 hours a day.

1. Convoy: 3,250 ÷ 62 ≈ 52 miles per day (about 84 km per day).
2. Modern driving time: 2,800 ÷ 60 ≈ 46.7 hours.
3. Days at 10 hours per day: 46.7 ÷ 10 ≈ 4.7 days, so about 5 days.
4. Compare: 62 ÷ 4.7 ≈ 13 times faster.

Answer: The convoy averaged about 52 miles (84 km) per day. A modern driver could make the trip in about 5 days, roughly 13 times faster.

PRACTICE

1. EASY Who built the electric street railway in Richmond, Virginia, when did it open, and why was it important?
2. EASY Put these in order and give an approximate date for each: Federal-Aid Highway Act; London's Metropolitan Railway; Model T; first New York horsecar line; Richmond electric streetcars.
3. EASY Define edge city and megalopolis and give one example of each, with the person who named it.
4. MEDIUM A streetcar averages 12 mph. How far can a commuter ride in 30 minutes, and what area lies within that radius, in square miles and km²?
5. MEDIUM A walking city has a radius of 1.5 miles and an average density of 25,000 people per square mile. About how many people does it hold?
6. MEDIUM The 1956 act planned a 41,000-mile Interstate system. As of the 2020s the system is more than 48,000 miles long. By what percent did it exceed the original plan?
7. MEDIUM A streetcar line runs one car every 3 minutes, and each car carries 50 passengers. How many passengers per hour can it carry in one direction? How does that compare with one freeway lane carrying about 2,200 people per hour?
8. MEDIUM Levittown, New York, held more than 17,000 houses. If there were 17,400 houses with an average of 4 people each, about how many people lived there?
9. HARD On figure he-commute-radius, the walking city has a radius of 1.5 miles and the streetcar city 5 miles. How many times larger is the streetcar city's area? Why is the real streetcar city smaller than the full circle?
   (Use the map or drawing "Compare the walking circle with the streetcar circle." shown earlier in this lesson.)
10. HARD Explain how the streetcar city and the automobile city each match one of the urban models from Lesson 7.3.
11. HARD In a paragraph, present two views on suburban growth fairly, with at least two reasons for each.

12. CHALLENGE Suppose Marchetti's travel budget holds: people spend 30 minutes each way. If average commuting speed rises from 3 mph to 30 mph, by what factor does the reachable area grow? If density stays at 10,000 people per square mile, how many people could live within reach of downtown at each speed?

COMMON MISTAKES

- Thinking the area within reach grows in step with speed. Doubling the speed doubles the radius but quadruples the area.
- Assuming suburbs began with the automobile. Railroad and streetcar suburbs grew decades before the car.
- Assuming faster travel saves time. History shows people mostly keep about the same travel time and use the extra speed to live farther away.

Make it a game · Commute Race. Draw a city grid of 15 by 15 squares with downtown in the middle. Each player begins at a random home square and must reach downtown in as few turns as possible. Walking moves 1 square per turn anywhere. Streetcar lines (draw four straight lines from downtown) move 4 squares per turn but only along the line. A car moves 3 squares per turn anywhere on roads, but rolls a die each turn: a 1 means a traffic jam and no move. Play several rounds starting from different homes and record which mode wins from near, middle and far squares. Discuss where each mode is best.

Scripture. "The voice of him that crieth in the wilderness, Prepare ye the way of the LORD, make straight in the desert a highway for our God." (Isaiah 40:3, KJV)

The prophet used the picture of a road builder leveling and straightening a highway so a king could come swiftly. Every road, rail line and bridge that shortens distance is a small picture of how people prepare the way for those they are waiting for.

Practice answers

1. Frank J. Sprague; regular service began early in 1888. It proved that electric streetcars could work on a large scale, even on steep hills, and within a few years electric streetcars replaced horsecars in American cities, allowing them to spread outward.
2. First New York horsecar line (1832); London's Metropolitan Railway (1863); Richmond electric streetcars (1888); Model T (1908); Federal-Aid Highway Act (1956).
3. Edge city: a large cluster of offices and shopping at a suburban highway junction, outside the old downtown (Joel Garreau, 1991; example: Tysons, Virginia). Megalopolis: a chain of metropolitan areas grown together (Jean Gottmann, 1961; example: Boston to Washington, D.C.).
4. 12 × 0.5 = 6 miles. Area = π × 36 ≈ 113 sq mi, or 113 × 2.59 ≈ 293 km².
5. Area ≈ 7.07 sq mi; 7.07 × 25,000 ≈ 177,000 people.
6. (48,000 − 41,000) ÷ 41,000 × 100 ≈ 17 percent.
7. 60 ÷ 3 = 20 cars per hour; 20 × 50 = 1,000 passengers per hour, a little under half the people carried by one freeway lane at the round figure given.
8. 17,400 × 4 = 69,600, about 70,000 people.

9. $(5 \div 1.5)^2 = 3.33^2 \approx 11.1$ times larger. But riders had to walk to the lines, so building spread mainly in narrow strips along the tracks; the real streetcar city was star-shaped, covering only part of the 5-mile circle.
10. The streetcar city grew in fingers along the lines radiating from downtown, so its neighborhoods formed wedges, matching Hoyt's sector model. The automobile and freeway city filled the gaps between the fingers and let offices, factories and shopping move to suburban highway junctions, creating several centers, matching Harris and Ullman's multiple-nuclei model (and later edge cities).
11. One view values suburban growth: families gain space, yards, privacy, home ownership and often safer, quieter neighborhoods and well-regarded schools, and the car gives freedom to travel anywhere at any hour. Another view prefers compact growth: walkable neighborhoods allow shorter trips and independence for children and the elderly who cannot drive, and serving dense areas with roads, pipes and transit costs less per household, while long commutes take time from family life. A fair answer gives both views real reasons and does not caricature either.
12. Radius grows from 1.5 to 15 miles, a factor of 10, so area grows by $10^2 = 100$. Areas: $\pi \times 1.5^2 \approx 7.07$ sq mi and $\pi \times 15^2 \approx 707$ sq mi. Population within reach: about 70,700 and about 7,070,000. Faster travel, not more time spent traveling, made the multimillion metropolis possible.

Unit 7 test

Answer each question. Show your work for every calculation and use complete sentences for explanations and the essay. Use $\pi \approx 3.1416$, 1 mile = 1.609 km and 1 square mile = 2.59 km². A calculator is allowed. The test is worth 100 points.

1. (5 pts) Define site and situation. Then classify each: (a) Paris began on an island in the Seine that was easy to defend; (b) New Orleans lies near the mouth of the Mississippi, where river barges meet ocean ships.
2. (6 pts) A county has 250,000 people, of whom 185,000 live in urban places. What percent is urban? In 1920 the U.S. was about 51.2 percent urban; in 2020 about 80 percent. By how many percentage points did the share rise?
3. (6 pts) A country's largest city has 8.4 million people. What populations does the rank-size rule predict for its 3rd and 6th cities? If its second city actually has 1.2 million, what term describes the largest city, and why?
4. (6 pts) A steel mill employs 3,000 basic workers. Each basic job supports 2 nonbasic jobs. How many total jobs depend on the mill? Explain what happens to the city if it closes, using Pittsburgh as an example.
5. (6 pts) Define threshold and range. Explain why a small town has a gas station but not a heart-surgery center.
6. (8 pts) A clothing store needs 6,000 customers and has a range of 5 km. The density is 60 people per km². What market radius does it need? Can it survive? Give the radius in km and miles.
7. (6 pts) City A has 400,000 people and City B has 100,000. They are 60 miles apart. Find Reilly's breaking point.
8. (6 pts) Why are Christaller's market areas hexagons? In a K = 3 system, how many lowest-order market areas fall within a market area two levels higher? Name one real event in the history of the theory that should be remembered as a warning.
9. (6 pts) Name the author and year of each model and the model each describes: (a) wedges of land use along transport lines; (b) rings around the CBD; (c) several separate centers of activity.
10. (8 pts) Office bid rent is $R = 1{,}000 - 250d$ and residential bid rent is $R = 400 - 50d$ (d in km). Find where they cross, which use wins near the center, and where residential use ends.
11. (6 pts) Using Clark's model $D = D_0 e^{-bx}$ with $D_0 = 18{,}000$ per km² and $b = 0.25$ per km, find the density at 4 km. What happens to b as transportation improves?
12. (8 pts) A commuter will spend 20 minutes each way. Find the radius and area within reach on foot at 3 mph and by bicycle at 12 mph. How many times larger is the bicycle area?
13. (6 pts) Match each person to a contribution and date: Frank Sprague, Henry Ford, Dwight Eisenhower, William Levitt.
14. (6 pts) Explain why streetcar cities were star-shaped and how the automobile changed that shape. Define edge city in your answer.

15. (11 pts) Essay (8–12 sentences). Choose one real American city (other than Chicago or Pittsburgh). Explain its site and situation, its place in the urban hierarchy, which urban model best describes its layout, and how transportation technology has shaped its growth. End with a fair account of one debate about how the city should grow, giving more than one view.

UNIT PROJECT: AN URBAN GEOGRAPHY OF MY CITY

Assemble a five-part study of your own city or the nearest city of at least 50,000 people. Part 1: your site model and situation map, with a one-page history of why the city grew where it did. Part 2: a central place study of the towns around it, with your hierarchy table and hexagon overlay. Part 3: a land-use map with your three model overlays and your judgment of which fits best. Part 4: your isochrone map comparing walking, cycling, transit and driving, beside a historic map of the city's streetcar or rail lines. Part 5: a two-page essay explaining how site, situation, the urban hierarchy, land values and transportation together have shaped the city, ending with one question about its future presented from more than one point of view.

- **Accuracy**: Maps, populations, dates and calculations are correct and sourced; every map has a title, key, scale and north arrow.
- **Use of the unit's models**: The study correctly applies site and situation, the rank-size rule, central place theory, the three urban models, bid rent or density gradients, and the transportation eras, and states where each fits and fails.
- **Reasoning and fairness**: The essay connects the evidence into a clear explanation and presents any debate about the city's future fairly, with more than one view.
- **Care**: The portfolio is neat, organized and easy to follow, with the hands-on models and maps well made.

Answer key

1. Site is the physical character of the place itself; situation is its location relative to other places, routes and resources. (a) Site. (b) Situation (New Orleans is a break-of-bulk point).
2. 185,000 ÷ 250,000 × 100 = 74 percent urban. The U.S. share rose 80 − 51.2 = 28.8 percentage points.
3. 3rd: 8.4 ÷ 3 = 2.8 million; 6th: 8.4 ÷ 6 = 1.4 million. The second city should have about 4.2 million but has only 1.2 million, so the largest is 7 times the second: a primate city.
4. Nonbasic: 3,000 × 2 = 6,000; total 9,000 jobs. If the mill closes, the multiplier runs in reverse and nonbasic jobs disappear too. Pittsburgh lost much of its steel industry in the 1970s and 1980s, and its city population fell from about 677,000 (1950) to about 303,000 (2020).
5. Threshold is the minimum number of customers a business needs; range is the farthest people will travel for a good. A gas station is a low-order good with a small threshold that a small town can supply. Heart surgery is a high-order good needing a huge threshold, found only in large central places, and people will travel far for it, so it has a long range.
6. Area = 6,000 ÷ 60 = 100 km². r = √(100 ÷ π) = √31.83 ≈ 5.64 km (about 3.5 miles). The needed radius is longer than the 5 km range, so it cannot reach its threshold and will not survive.

7. From B: 60 ÷ (1 + √(400,000/100,000)) = 60 ÷ (1 + 2) = 20 miles from B, so 40 miles from A (about 32 km and 64 km).
8. Hexagons are the shape closest to circles that fill a plane with no gaps or overlaps. Two levels higher: $3^2 = 9$ market areas. Warning: Christaller joined the Nazi Party in 1940 and drew settlement plans for conquered western Poland that assumed the expulsion of Polish families.
9. (a) Sector model, Homer Hoyt, 1939. (b) Concentric zone model, Ernest Burgess, 1925. (c) Multiple-nuclei model, Chauncy Harris and Edward Ullman, 1945.
10. 1,000 − 250d = 400 − 50d gives 600 = 200d, d = 3 km (about 1.9 miles). Offices win inside 3 km; residential wins beyond. Residential ends where 400 − 50d = 0, at d = 8 km (about 5.0 miles).
11. $D = 18{,}000 \times e^{-1} \approx 18{,}000 \times 0.368 \approx 6{,}620$ per km². As transportation improves, b gets smaller: the density gradient flattens and the city spreads out.
12. Walking: 3 × 1/3 = 1 mile; area $\pi \times 1^2 \approx 3.14$ sq mi (8.1 km²). Bicycle: 12 × 1/3 = 4 miles; area $\pi \times 16 \approx 50.3$ sq mi (130 km²). The bicycle area is $4^2 = 16$ times larger.
13. Frank Sprague: the Richmond electric street railway, 1888. Henry Ford: the Model T (1908) and the moving assembly line (1913). Dwight Eisenhower: signed the Federal-Aid Highway Act creating the Interstate system, 1956 (after the 1919 Army convoy). William Levitt: mass-produced suburban houses at Levittown, New York, begun 1947.
14. Streetcar riders had to walk to the line, so houses were built within a short walk of tracks radiating from downtown, giving the city star-shaped fingers. Cars could use any road, so the gaps between the fingers filled in and the city spread as a broad disk; offices and shopping moved to suburban highway junctions, forming edge cities, large clusters of offices and stores outside the old downtown (Joel Garreau, 1991; for example, Tysons, Virginia).
15. Scoring guide: accurate site and situation with specific features (2 points); correct use of the urban hierarchy or central place ideas (2 points); a model chosen and supported with specific districts or routes (2 points); transportation eras applied with real examples such as rail lines, streetcars, interstates or beltways (3 points); a debate presented fairly with at least two views and a reasoned conclusion (2 points).

UNIT 8

Industry and Development

Why are factories where they are, and why are some nations rich and others poor? These are two of the largest questions in human geography, and they are tied together. God set man in the garden "to dress it and to keep it" (Genesis 2:15), and He placed coal, iron, fertile soils, harbors and rivers unevenly across the earth. He "hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation" (Acts 17:26). This unit studies how people have used those gifts: where they built mills and furnaces, how some countries grew from farming villages into industrial nations, and how trade lets each people serve others with what it does best.

You will stand in the Severn gorge in 1709, where Abraham Darby first smelted iron with coke, and follow industry from the waterfalls of Derbyshire to the coalfields of Lancashire, the Ruhr and Pittsburgh. You will watch U.S. Steel raise the city of Gary on the shore of Lake Michigan in 1906 and use Alfred Weber's model of 1909 to explain why. You will read W. W. Rostow's Cold War "Non-Communist Manifesto" of 1960 and test his five stages against South Korea, Argentina and the oil states, alongside his critics: Gerschenkron, the dependency school, Wallerstein and the institutions economists. Finally you will work through David Ricardo's famous cloth-and-wine example of 1817 and weigh, fairly, the long debate between free trade and the protection of home industry.

As throughout this course, the models (Weber's least-cost theory, Rostow's stages, world-systems theory, comparative advantage) are taught as models: simplified pictures to be tested against real cases, with their strengths and their limits. Real wrongs of industrial history, such as child labor, slave-grown cotton, the opium trade and the famines caused by Stalin's and Mao's forced industrialization, are named plainly, and real achievements are given their due. Current debates are dated "as of 2026" and presented neutrally. Lesson 8.5 is the **unit test** below.

BEFORE YOU BEGIN

- Can calculate percentages, ratios and growth rates, and use the rule of 70 (Unit 2)
- Can read a map scale and convert between miles and kilometers (Unit 1)
- Knows site and situation and the idea of a simple spatial model such as von Thünen's or Christaller's (Units 6–7)
- Is comfortable writing a reasoned paragraph that presents more than one view

MASTERY CHECKLIST

- I can explain how coal, iron ore, water power and water transport decided where the first industrial regions grew, and trace the diffusion of industry from Britain to Europe and America.
- I can calculate and interpret a location quotient, an average growth rate and a doubling time for an industrial region.

- I can use Weber’s locational triangle, material index and isodapanes to predict where a factory will go, and name the limits of the model.
- I can describe Rostow’s five stages and his take-off test, place real countries on the model, and explain the criticisms of Gerschenkron, dependency theory, Wallerstein and the institutions view.
- I can calculate opportunity costs and the gains from trade in Ricardo’s example and explain comparative advantage.
- I can compare import substitution and export-oriented development and present fairly the arguments for free trade and for protecting home industry.

OPTIONAL BOOKS AND RESOURCES

- **Ironbridge Gorge Museum Trust** (https://www.ironbridge.org.uk/): The museums of Coalbrookdale and the Iron Bridge (Lesson 8.1). The website has pictures and short histories of Darby’s furnace, the bridge and the gorge’s industries.
- **FRED economic data, Federal Reserve Bank of St. Louis** (https://fred.stlouisfed.org/): Free. Search for GDP per capita and other series by country to build the development chart in Lesson 8.3 and the unit portfolio. Graphs can be drawn on screen and copied by hand.
- **Econ Lowdown, Federal Reserve Bank of St. Louis** (https://www.econlowdown.org/): Free. Short lessons and videos on opportunity cost, comparative advantage and trade for Lesson 8.4. Parents and students can browse without an account.

8.1 The Industrial Revolution's Geography

OBJECTIVES

- Explain how coal, iron ore, running water and navigable rivers and canals decided where the first industrial regions of Britain grew, using Coalbrookdale, Cromford and Manchester as cases.
- Trace the diffusion of industry from Britain to Belgium, the Ruhr, New England and Pittsburgh, and explain why each new region had the same kinds of site advantages.
- Calculate transport savings, average growth rates with doubling time, and location quotients for industrial regions.

Warm-up. Fill a pitcher with water and pour it slowly onto the blades of a pinwheel or a plastic spoon held loosely by its handle. Now pour from twice as high. What changes? Next, picture a mill owner in 1770 who needs that turning force all day, every day. Write one sentence: where on a map must he build? Then write a second sentence: what would set him free to build anywhere he liked?

Watch. *Iron Bridge | 10 Places That Made England with Dan Snow* (English Heritage, 8:14). https://www.youtube.com/watch?v=bUbYMGwOA84
After the story: visit the Iron Bridge at Coalbrookdale with Dan Snow and look for how coke-smelted iron from the Severn valley made a bridge built entirely of cast iron possible.
Note: Captions were not available to check; preview it first. This is an English Heritage video with a well-known presenter, and it may use British terms. The bridge went up in 1779 and was built by Abraham Darby III, the grandson of the Abraham Darby who first smelted iron with coke in 1709 in the story.

KEY TERMS

Industrial Revolution
The change, beginning in Britain about 1760–1830, from making goods by hand at home to making them by machines in factories powered first by water and then by steam fueled with coal.

coke
Coal that has been baked to drive off its gases and tars, leaving nearly pure carbon. Abraham Darby used it in place of charcoal to smelt iron at Coalbrookdale in 1709.

coalfield
A region where workable seams of coal lie near enough to the surface to be mined. The great industrial regions of the 1800s grew on or beside coalfields.

power site
A place where nature supplies usable energy, such as a waterfall or a fast stream that can turn a water wheel. Early mills were tied to power sites.

industrial region
A cluster of related industries, workers, suppliers and transport links in one area, such as Lancashire’s cotton district or Germany’s Ruhr.

location quotient (LQ)
A ratio that compares an industry’s share of jobs in a region with its share in the whole nation. An LQ above 1 means the region specializes in that industry.

CORE IDEAS

The story. In 1709, in a narrow wooded valley that runs down to the River Severn in Shropshire, a Quaker ironmaster named Abraham Darby tried something new in his blast furnace at Coalbrookdale. For centuries English iron had been smelted with charcoal, and the forests that made charcoal were being cut faster than they could grow back. Darby baked the local coal into **coke** and smelted his iron ore with that instead. It worked. Coalbrookdale had everything an ironmaster could wish for within a few miles: coal and iron ore in the hillsides, limestone for flux, streams to drive the bellows, and the Severn, then one of the busiest rivers in Europe, to float the finished pots and pans down to Bristol. Seventy years later his grandson, Abraham Darby III, cast the parts of the world’s first great iron bridge across the Severn gorge. The Iron Bridge, spanning about 100 feet (30 m), was raised in 1779 and opened to traffic in 1781. It still stands.

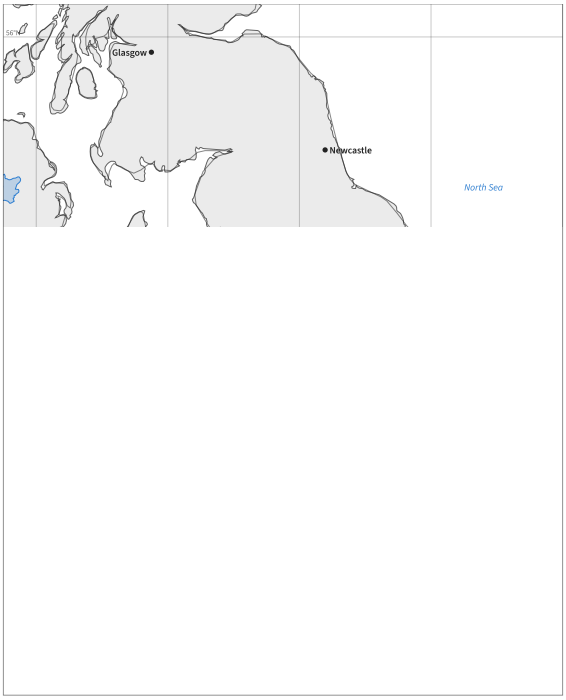
How it worked. The first factories were chained to **power sites**. When Richard Arkwright built his cotton-spinning mill at Cromford in Derbyshire in 1771, he chose a spot where a steady stream fed the River Derwent and could turn his water wheels. Mills crowded into the steep valleys of the Pennines for the same reason. Two inventions loosened the chain. Thomas Newcomen’s steam engine, first set to work near Dudley in 1712, pumped water out of coal mines so that miners could dig deeper. James Watt’s separate condenser, patented in 1769, made the steam engine far more efficient, and by the 1780s Watt and his partner Matthew Boulton were building engines that turned wheels. Now a mill could stand anywhere coal could reach cheaply. The best place became *on* the coalfield or beside a canal that came from it. In 1761 the Duke of Bridgewater opened a canal, engineered by James Brindley, from his mines at Worsley into Manchester, and the price of coal in Manchester fell by about half. Manchester grew into the world’s first great factory city, nicknamed Cottonopolis.

The big idea. Early industry was *resource-oriented*: it went to the heavy things it needed, because moving coal and ore over bad roads cost more than moving finished goods. Look at a map of Britain’s nineteenth-century industrial regions and you are looking at a map of its coalfields: Northumberland and Durham, Yorkshire, Lancashire, the Black Country around Birmingham, South Wales and the Central Lowlands of Scotland. Each coalfield developed its own specialty: cotton in Lancashire, wool in Yorkshire, iron and metal goods in the Black Country, iron and coal export in South Wales, shipbuilding on the Tyne and the Clyde. Geographers measure that specialization with the **location quotient**. By the 1851 census, for the first time in any large country, more than half the people of England and Wales lived in towns. Industry had redrawn the map of where people live.

On the map. The Industrial Revolution then **diffused**, and it spread to places that looked like Lancashire. John Cockerill opened ironworks at Seraing, near Liège, on the coalfield of the Meuse valley in 1817, and Belgium became the first industrial nation on the Continent. In Germany the Ruhr valley, where coal lay beside the Rhine, became Europe's greatest heavy-industry district, home of the Krupp works at Essen. Across the Atlantic, Samuel Slater, who had memorized the design of Arkwright's machines, built a water-powered mill at Pawtucket, Rhode Island, in 1793 on the falls of the Blackstone River. New England's fall-line rivers, the Merrimack at Lowell among them, became America's first textile belt. Pittsburgh, where the Allegheny and Monongahela join to form the Ohio, sat on one of the richest coal seams in the world and became the iron and steel capital of the United States. The pattern repeated: energy, raw materials and cheap water transport together.

The cost and the gift. Industry brought hardship that people of the time saw and named. Children worked long hours in mills and mines; Parliament's Factory Act of 1833 barred children under nine from textile mills, and the Mines Act of 1842 banned women, girls and boys under ten from working underground. Christian reformers such as Lord Ashley, later Earl of Shaftesbury, led those campaigns. Much of Lancashire's raw cotton was grown in the American South by enslaved people, a wrong that tied the mills to slavery across an ocean. Yet the same revolution, over a few generations, ended the old cycle of famine in industrial lands, made cloth, tools and books cheap, and raised ordinary wages as never before. God told Moses that the land He was giving Israel was one "whose stones are iron" (Deuteronomy 8:9), and He set man in the garden "to dress it and to keep it" (Genesis 2:15). Coal and iron are gifts to be used with skill and cared for wisely.

Technology overcoming geography. Each step of the story is technology loosening geography's grip. Coke freed iron from the forests. The steam engine freed the mill from the waterfall. The canal and then the railroad, after the Liverpool and Manchester line opened in 1830, freed the factory from the river. Yet geography did not vanish; it changed its terms. The new question was no longer "Where is the waterfall?" but "Where are coal, ore and market, and what does it cost to bring them together?" In the next lesson Alfred Weber turned that question into a model.



Early industrial Britain. Most of the great factory districts of the 1800s grew on or beside coalfields, and the earliest sites were on rivers.

PICTURE STUDY

Coalbrookdale by Night, Philip James de Loutherbourg, 1801 · Oil on canvas · Science Museum, London

Philip James de Loutherbourg was a French-born painter who settled in London and became famous for stage scenery and dramatic landscapes. Around 1800 travelers came to the Severn gorge to see the furnaces at night, as they might visit a volcano. In this painting he shows the Bedlam Furnaces at Madeley Wood, just downstream from Coalbrookdale, glowing against the night sky.

Notice that he painted it as a scene of awe, almost terror, in the style called the Sublime. People of his day did not yet know whether to see the new industry as a wonder, a danger or both.

Look closely

- Find the source of the light. What is burning, and why would a furnace run through the night?
- Look at the road in the foreground. What are the horses hauling, and what does this tell you about how goods moved before the railroad?
- Find the cottages and the moon. How does the painter set the old, quiet world beside the new one?
- Look for the hillsides. Why does a steep valley make sense for an ironworks of 1801?

Talk about it

1. What site advantages of Coalbrookdale can you find or infer from the painting?
2. Does the painter seem to admire the furnaces, fear them, or both? Give evidence.
3. How would a painting of a modern factory district look different, and why?

PROJECT: A WATER WHEEL AND A POWER-SITE MAP

You will build a small working water wheel, test how the height of falling water changes the work it can do, and then use what you learn to place mills, furnaces and canals on a map of an imaginary valley in two eras: 1770, before steam, and 1830, after it.

You will need

- A round plastic lid (from a yogurt or coffee container), 8 plastic spoons, hot glue or strong tape
- A pencil or wooden skewer for an axle and two tall cups or blocks to hold it
- About 2 feet (60 cm) of thread and a metal washer or small binder clip
- A pitcher or a kitchen faucet, a baking pan to catch the water
- A large sheet of paper, colored pencils and a ruler

Steps

1. Glue the 8 spoons evenly around the rim of the lid, bowls all facing the same way. Push the axle through the center and rest it across two cups in the baking pan so the wheel can turn freely.
2. Tape one end of the thread to the axle and tie the washer to the other end. Pour water onto the spoons from about 4 inches (10 cm) above the wheel and time how long it takes to wind up the thread and lift the washer.
3. Repeat from about 12 inches (30 cm). Record both times. Explain in one sentence why mill builders searched for falls and fast streams.
4. On the large sheet, draw an imaginary valley with a river that drops over falls, hills with a coal seam and an iron ore outcrop, a forest and a market town on navigable

water 20 miles away. Add a scale bar.

5. Map 1, the year 1770: place a cotton mill, a charcoal iron furnace and a coke iron furnace. Write a one-line reason beside each.
6. Map 2, the year 1830: steam engines and a canal now exist. Redraw the valley and move whatever would move. Draw the canal where it would save the most hauling.
7. Under the maps, write a paragraph comparing them, using the words power site, coalfield and resource-oriented.

Tips

- If the wheel will not turn, check that all the spoon bowls face the falling water and that the axle hole is not too tight.
- In 1830 not everything moves. A mill already built beside a stream might add a steam engine instead of moving.

Check your work

- I measured how the height of falling water changed the lifting time.
- I placed each industry with a clear geographic reason in both eras.
- I explained how the steam engine and the canal changed the map.

MAP NOTEBOOK

1. Sketch the Iron Bridge from a photograph or from memory, and label the river, the gorge and the abutments. Note the date it opened.
2. Draw an outline of Great Britain and shade its six main coalfields. Write the specialty of each region beside it.
3. Make a three-column chart: Water era, Steam era, Railroad era. In each, write what decided where a factory could stand.

> **From history.** The Iron Bridge was so famous that artists and tourists came from all over Europe to see it, and the town that grew beside it took the name Ironbridge. The Ironbridge Gorge, including Coalbrookdale and the Bedlam Furnaces, was named one of the first World Heritage Sites in the United Kingdom in 1986. Darby’s Old Furnace, rebuilt and enlarged over the years, can still be seen in Coalbrookdale, sheltered under a modern roof.

WORKED EXAMPLES

Example 1. Before the canals, coal often traveled on packhorses, each carrying about one-eighth of a ton. A single horse towing a canal boat could move a load of about 30 tons. How many packhorses would it take to carry one canal boat's load? If each packhorse needed one handler for every five horses, how many men did one boat with one horse and one boatman replace?

1. Packhorses needed: 30 tons ÷ 1/8 ton per horse = 30 × 8 = 240 horses.
2. Handlers needed: 240 horses ÷ 5 horses per handler = 48 men.
3. The canal boat needs 1 horse and 1 boatman (often with a boy to lead the horse), so it replaced about 239 horses and about 47 men for the same load.

Answer: About 240 packhorses and 48 handlers, replaced by one horse and one or two people. This is why the Bridgewater Canal cut the price of coal in Manchester by about half.

Example 2. Historians estimate that British coal output was about 30 million tons in 1830. In 1913, its peak year, it was about 287 million tons. Find the average annual growth rate and the doubling time.

1. Growth factor: 287 ÷ 30 = 9.57 over 1913 − 1830 = 83 years.
2. Average annual rate: r = 9.57^(1/83) − 1. Using logarithms, ln 9.57 = 2.259, and 2.259 ÷ 83 = 0.0272, so r ≈ e^0.0272 − 1 ≈ 0.028, about 2.8 percent per year.
3. Doubling time by the rule of 70: 70 ÷ 2.8 ≈ 25 years.
4. Check: 30 million doubled three times (75 years) is 240 million, and a little more growth carries it near 287 million by 83 years.

Answer: About 2.8 percent per year, doubling about every 25 years.

Example 3. Use these illustrative figures for a cotton county in the mid-1800s. The county has 200,000 workers, of whom 40,000 work in cotton textiles. The nation has 8,000,000 workers, of whom 400,000 work in cotton textiles. Find the location quotient for cotton and interpret it.

1. Regional share: 40,000 ÷ 200,000 = 0.20 (20 percent).
2. National share: 400,000 ÷ 8,000,000 = 0.05 (5 percent).
3. LQ = regional share ÷ national share = 0.20 ÷ 0.05 = 4.0.

Answer: LQ = 4.0. The county has four times as large a share of its workers in cotton as the nation does, so it is strongly specialized in cotton and almost certainly exports cloth to the rest of the country and the world.

PRACTICE

1. EASY What did Abraham Darby do at Coalbrookdale in 1709, and why did it matter?
2. EASY Name four site advantages that Coalbrookdale had for ironmaking.
3. EASY Why did Arkwright build his mill at Cromford in 1771 rather than in a large city?
4. MEDIUM Explain how James Watt’s improved steam engine changed the location of cotton mills.
5. MEDIUM A region has 15,000 of its 300,000 workers in steelmaking. The nation has 600,000 of its 60,000,000 workers in steelmaking. Find the location quotient.
6. MEDIUM A town has an LQ of 0.4 for textiles. What does that tell you?
7. EASY Match each region with its nineteenth-century specialty: Lancashire, Yorkshire (West Riding), the Clyde, the Ruhr. Choices: wool, cotton, shipbuilding, coal and heavy industry.
8. MEDIUM Liverpool and Manchester are about 31 miles (50 km) apart. Suppose a stagecoach of 1830 took about 4 hours for the trip and an early train on the new railroad about 1.5 hours. Find the average speed of each in miles per hour and km per hour.
9. MEDIUM Why did Pittsburgh become America’s iron and steel center in the 1800s? Give a site reason and a situation reason.
10. HARD A city grows from 75,000 people to 300,000 people in 50 years. Find its average annual growth rate and doubling time.
11. HARD Explain why the first industrial regions of Belgium, Germany and the United States looked geographically like those of Britain.
12. CHALLENGE Write a short paragraph (5–7 sentences) weighing the costs and achievements of the Industrial Revolution as people of the time saw them, naming at least one law passed to correct a wrong.

COMMON MISTAKES

- Thinking the steam engine came first and mills followed. The first great mills ran on water; steam freed them to move later.
- Reading a location quotient as a count of workers. It is a ratio of shares; a small town can have a very high LQ.
- Treating the coalfield pattern as permanent. Once transport costs fell and fuel use per ton of product dropped, industry began moving toward ports and markets, as the next lesson shows.

Make it a game · Coal, Ore or River?. One player names a real industrial place from the lesson (Coalbrookdale, Cromford, Manchester, Liverpool, Liège, Essen, Pawtucket, Lowell, Pittsburgh, Merthyr Tydfil, Glasgow). The other must say within ten seconds which advantage mattered most: coal, ore, water power, navigable water, or a canal or railroad, and give one sentence of evidence. Two points for a correct answer with evidence, one for the right advantage alone. Switch roles; first to fifteen points wins.

> **Scripture.** “A land wherein thou shalt eat bread without scarceness, thou shalt not lack any thing in it; a land whose stones are iron, and out of whose hills thou mayest dig brass.” (Deuteronomy 8:9, KJV)

Moses described the promised land as rich in metals as well as bread. Ores and coal lie where God placed them, and the geography of industry begins with those gifts and with people who learn to use them well.

Practice answers

1. He smelted iron ore using coke made from coal instead of charcoal. It freed ironmaking from shrinking forests and tied it instead to coalfields, which Britain had in abundance.
2. Any four: coal for coke, iron ore, limestone for flux, streams for water power to work the bellows, and the navigable River Severn to ship products.
3. His machines were driven by water wheels, so the mill had to stand at a power site with a steady flow of falling water. Cities rarely had such sites free.
4. Once steam engines could turn machinery efficiently (from the 1780s), mills no longer had to sit at waterfalls. They moved to places where coal was cheap and workers and markets were near, especially coalfield towns and canal-side cities like Manchester.
5. Regional share 15,000/300,000 = 0.05. National share 600,000/60,000,000 = 0.01. LQ = 0.05/0.01 = 5.0, a strong specialization in steel.
6. Textiles make up a smaller share of the town’s jobs than of the nation’s (only 40 percent of the national share), so the town is not specialized in textiles and probably buys cloth from elsewhere.
7. Lancashire: cotton. Yorkshire: wool. The Clyde: shipbuilding. The Ruhr: coal and heavy industry.
8. Stagecoach: 31 ÷ 4 ≈ 7.8 mph (50 ÷ 4 = 12.5 km/h). Train: 31 ÷ 1.5 ≈ 20.7 mph (50 ÷ 1.5 ≈ 33 km/h). The train was more than two and a half times as fast.
9. Site: it lay on a rich seam of coal suitable for coke. Situation: it stood where the Allegheny and Monongahela join to form the Ohio, giving cheap water transport down the Ohio and Mississippi to the growing West, and later railroads to eastern markets.
10. Growth factor 4 = two doublings in 50 years, so the doubling time is 25 years. Rate ≈ 70 ÷ 25 = 2.8 percent per year (exactly, 4^(1/50) − 1 ≈ 2.8 percent).
11. The same technology needed the same inputs: coal for steam and coke, iron ore, water for power and processing, and cheap water transport. So industry diffused to places with those advantages: the Meuse coalfield around Liège, the Ruhr beside the Rhine, the fall-line rivers of New England and the coal-and-river site of Pittsburgh. Skilled people who carried the knowledge, such as Cockerill and Slater, moved it there.
12. A strong answer names real costs (child labor in mills and mines, dangerous work, crowded towns, and the link between Lancashire’s cotton and slave-grown cotton in the American South), names a reform such as the Factory Act of 1833 or the Mines Act of 1842 and reformers such as Lord Ashley (later Earl of Shaftesbury), and gives real achievements their due (cheaper cloth, tools and food, the end of recurring famine in industrial lands, rising wages over generations). It judges people by what they knew and did in their own time.

8.2 Weber's Location Theory

OBJECTIVES

- State the assumptions of Alfred Weber's least-cost model (1909) and use the locational triangle and the material index to predict where a factory will go.
- Distinguish weight-losing from weight-gaining industries and explain the pull of labor costs, agglomeration and break-of-bulk points.
- Test the model against real cases (Pittsburgh, Gary, copper smelters, bottling plants, modern footloose industry) and name its limits.

Warm-up. Put a 1-pound bag of flour (or a can of beans) and a slice of bread on the table. Imagine you run a bakery. Every loaf you sell weighs about the same as the flour that went into it, but the water in the dough comes out of any tap. Now imagine you run a sugar mill, and 8 pounds of sugar beets make about 1 pound of sugar. Write one sentence for each: should the factory stand near the field or near the customer? Why?

Video. Coming soon. Industrial location and the steel industry: Gary, Indiana, Great Lakes ore boats and the Soo Locks, Pittsburgh steel. Search The History Guy, Practical Engineering (locks and bulk shipping), Smithsonian and The Henry Ford; candidates (need vetting): Wendover Productions (logistics), The B1M (industrial sites).

KEY TERMS

least-cost theory
Alfred Weber's model (1909): a factory will locate where the total cost of transport, labor and agglomeration is lowest, with transport cost usually the strongest pull.

locational triangle
Weber's diagram with two raw-material sources and a market at its corners; the least-cost factory site lies at a corner or inside the triangle, pulled toward whichever input or output weighs most.

material index
The weight of localized raw materials divided by the weight of the finished product. Above 1 means weight-losing (locate near materials); below 1 means weight-gaining (locate near market).

ubiquitous material
An input found nearly everywhere, such as water or air, which adds weight to a product without pulling the factory toward any one source.

isodapane
A line on a map joining points of equal extra transport cost compared with the least-cost site; used to judge whether cheap labor elsewhere is worth the extra freight.

break-of-bulk point

A place where goods must be transferred from one kind of carrier to another (ship to rail, for example), such as a port. Industry often locates there to avoid an extra handling cost.

CORE IDEAS

The story. In 1906 the United States Steel Corporation, then the largest company in the world, bought several thousand acres of sand dunes and marsh at the southern tip of Lake Michigan and built a city from nothing. They named it Gary, after the company's chairman, Elbert H. Gary, and within about three years its first furnaces were at work. Why there? Iron ore came from the Mesabi Range in Minnesota by rail to Duluth and then by great lake freighters all the way to the mill's own docks. Coal and coke came by rail from the Appalachian fields of Pennsylvania and West Virginia. And Chicago, next door, was the hub of the nation's railroads and the heart of a booming Midwest that wanted steel for rails, bridges, farm machines and skyscrapers. Gary sat where ore, coal and market could meet at the lowest total cost. In 1909 a German economist published a book explaining exactly that kind of decision.

The model. Alfred Weber (1868–1958), younger brother of the sociologist Max Weber, published *Über den Standort der Industrien* (On the Location of Industries) in 1909. Like von Thünen and Christaller, he began with simplifying assumptions: a single product and a known market; raw materials at known points; transport cost that rises in proportion to weight and distance; a uniform plain where any direction is as easy as any other; and owners who seek the lowest cost. Under those assumptions he drew the **locational triangle**: two material sources and a market at its corners. Each corner pulls the factory toward itself with a force equal to the tons that must be hauled from or to it. The least-cost site is where the total ton-miles, and so the total freight bill, is smallest.

How it worked. Weber's most useful tool is the **material index**: the weight of localized materials divided by the weight of the product. Copper ore in the great open-pit mines of the American West holds roughly 1 percent copper or less, so about 100 tons of ore yield 1 ton of metal; the index is about 100, and the concentrators and smelters stand beside the mines, as at Garfield next to Utah's Bingham Canyon. Sugar beets, paper pulp and canned vegetables are also **weight-losing** and are processed near the fields and forests. A soft-drink or beer bottler is the opposite. Its heaviest input is water, a **ubiquitous material** found nearly everywhere, so the product weighs far more than the localized inputs (syrup, hops, cans). It is **weight-gaining**, and bottling plants sit near the people who drink the product. Steel shows the model changing over time. In the 1800s a ton of iron needed several tons of coal, more than the weight of ore, so mills were drawn to the coalfields: Pittsburgh. As furnaces burned less fuel per ton, the pull of coal weakened, and new mills rose where lake ships delivered ore and where markets lay: Gary, Cleveland and Chicago.

The distortions. Weber knew that transport was not the whole bill. Cheaper **labor** might draw a factory away from the least-cost transport site. He drew **isodapanes**, rings of equal added freight cost around the least-cost point. If a site with cheaper labor lies inside the *critical isodapane*, the ring where added freight equals the labor saving, the factory should move there. **Agglomeration** could pull too: firms that cluster share skilled workers,

suppliers, repair shops and ideas, as automobile makers did around Detroit in the early 1900s. Later geographers added the **break-of-bulk point**. Where cargo must be moved from ship to rail anyway, building the factory right there saves a whole handling and hauling step. The Sparrows Point mill near Baltimore, later run by Bethlehem Steel, was built on tidewater in the 1880s to receive ore by sea.

The limits. Weber's model fits heavy, bulky, single-product industries of his day well. It fits a smartphone maker or a software company poorly, because their products are light and valuable and transport is a tiny share of cost; such industries are called **footloose**. The model treats the market as one point, when in fact markets are spread out and competitors react to one another. In 1929 the American economist Harold Hotelling showed how rival sellers choosing locations can cluster together for that reason alone. Real transport costs are not straight lines: they taper with distance (long hauls are cheaper per mile), jump at each transfer, and follow rivers, rails and highways. Governments shape location with taxes, tariffs, regulations and incentives. And in modern just-in-time manufacturing, pioneered by Toyota in Japan, parts suppliers locate within a short drive of the assembly plant so that parts arrive hours before they are needed. Weber still asks the right first question; the answer simply has more terms.

Technology overcoming geography. Every cut in freight cost weakens the pull of raw materials. The giant lake freighters, the locks at Sault Ste. Marie, unit trains of coal, ocean bulk carriers and, after Malcom McLean's first container voyage in 1956, the shipping container, all made it cheaper to move heavy things far. As transport fell from a large share of cost to a small one, labor costs, skills, markets and agglomeration became the deciding forces. Our Lord asked, "For which of you, intending to build a tower, sitteth not down first, and counteth the cost, whether he have sufficient to finish it?" (Luke 14:28). Weber's model is a careful way of counting the cost of where to build.

Why Gary? Iron ore came down the lakes from Minnesota, coal came by rail from Appalachia, and Chicago's market lay next door.

PICTURE STUDY

The Iron Rolling Mill (Modern Cyclopes), Adolph Menzel, 1872–1875 · Oil on canvas · Alte Nationalgalerie, Berlin

Adolph Menzel, one of the greatest German painters of the 1800s, traveled in 1872 to the ironworks at Königshütte in Upper Silesia, a coal-mining district now in southern Poland (the town is today called Chorzów). He filled sketchbooks with drawings of men and machines

and spent about three years on this large canvas, which shows a shift of workers making railroad rails.

Menzel painted the mill without making it either a hell or a paradise. He shows the danger, heat and teamwork of heavy industry exactly as he saw it, and even the shift change, the meal break and the washing up.

Look closely

- Find the glowing bar of iron. How many men does it take to guide it into the rollers?
- Look at the right side of the painting. What are the men there doing, and what does it tell you about a working day?
- Find the machinery: the flywheel, the rollers, the overhead shafts. What do you think is driving them?
- Look at the light. Where does it come from, and how does Menzel use it to lead your eye?

Talk about it

1. Königshütte stood on the Upper Silesian coalfield. Using Weber's model, explain why an ironworks of the 1870s would be located there.
2. What would this mill need to bring in, and what would it send out? Which flows would be heaviest?
3. Why might a painter in 1875 call ironworkers "modern Cyclopes"?

PROJECT: BUILD A VARIGNON FRAME: WEBER'S TRIANGLE IN STRINGS AND WEIGHTS

Location theorists long ago borrowed a device from the French mathematician Pierre Varignon (1654–1722) to find Weber's least-cost point without any arithmetic. You will build one. Three strings run over the edge of a table or through holes in a board, each pulling with a weight equal to the tons that must travel to or from that corner. The knot where they meet slides to the spot of least total ton-miles.

You will need

- A sheet of stiff cardboard or thin plywood about 18 by 18 inches (45 × 45 cm), propped between two chairs so weights can hang below it
- Three short pieces of drinking straw (to line the holes so string slides smoothly) and a pencil or awl
- Three pieces of string, each about 3 feet (1 m), tied together in one knot
- Identical metal washers or coins (about 15) and three small paper cups or bags to hold them
- Ruler, marker and a printed or traced copy of the locational triangle figure

Steps

1. Draw a triangle on the board with corners labeled O (ore), C (coal) and M (market), about 12 inches (30 cm) on the long side. Poke a hole at each corner and push a straw piece into it.
2. Thread one string through each hole so the knot rests on top of the board and the strings hang below. Tie a cup to each hanging end.
3. Load the cups to match the worked example: 2 washers at O (2 tons of ore), 3 at C (3 tons of coal), 1 at M (1 ton of steel). Tap the board gently and mark where the knot comes to rest.
4. Now model a modern steel mill that uses much less coal: 2 washers at O, 1 at C, 1 at M. Mark the new resting point. Which way did it move?
5. Model a weight-gaining industry: 1 washer at O, 1 at C, 5 at M. Mark the point.
6. Model a case where one corner outweighs the other two combined, such as 6 at C, 2 at O and 2 at M. What happens to the knot? (Weber showed that the factory then goes right to that corner.)
7. On your copy of the triangle, mark all four resting points and write one sentence explaining each.

Tips

- Friction is the enemy. Smooth the holes, use thin string, and tap the board lightly so the knot settles.
- The frame finds the least ton-mile point on a uniform plain. Real freight follows rails and waterways, so the real site may differ.

Check your work

- I built a frame whose knot moves when the weights change.
- I recorded and explained four resting points.
- I can explain why a heavy input pulls the factory toward its source.

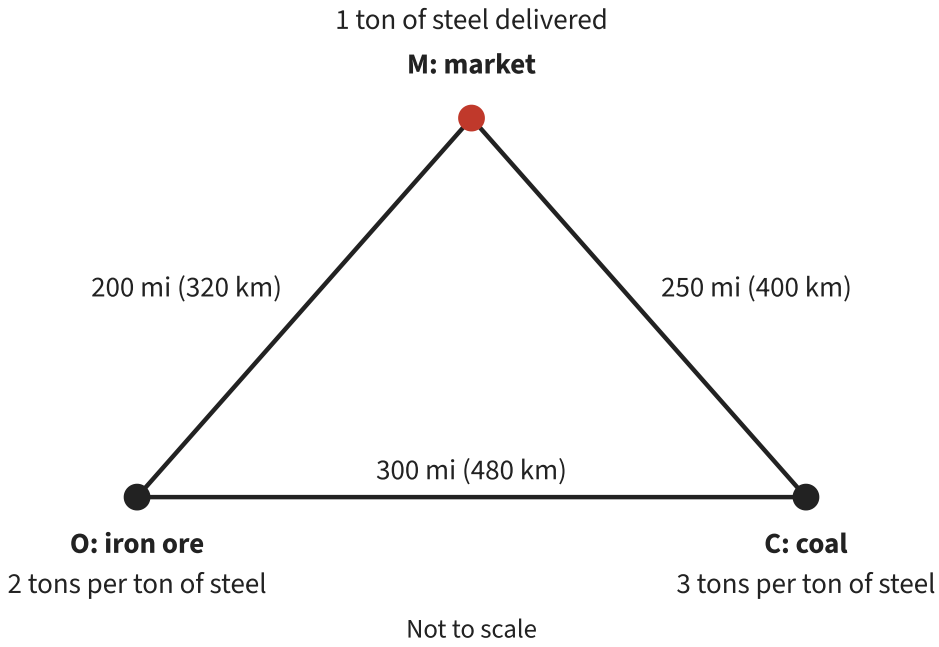
MAP NOTEBOOK

1. Draw the Great Lakes and trace the path of iron ore from the Mesabi Range to Gary, labeling Duluth, Sault Ste. Marie and the Straits of Mackinac.
2. Make a two-column chart, Weight-losing and Weight-gaining, with at least four industries in each column.
3. Draw a least-cost point with three isodapanes around it labeled $5, $10 and $15, and mark a cheap-labor town that lies inside the $15 ring.

> **From history.** Alfred Weber taught for most of his career at the University of Heidelberg. In 1933, after the National Socialists came to power, he protested when the Nazi flag was raised over his institute and soon left his post; he remained in Heidelberg through the war and returned to teaching after 1945, when he was in his late seventies. His least-cost model was translated into English in 1929 as *Theory of the Location of Industries*, which is how most geographers first read it.

WORKED EXAMPLES

Example 1. A simplified steel mill needs 2 tons of iron ore and 3 tons of coal for each ton of steel. The ore deposit O is 300 miles (480 km) from the coal field C and 200 miles (320 km) from the market M. The coal field is 250 miles (400 km) from the market. Freight costs the same per ton-mile everywhere. Which corner is the least-cost site?



Weber's locational triangle for the worked example (not to scale).

1. At O: bring 3 tons of coal 300 miles and ship 1 ton of steel 200 miles: 900 + 200 = 1,100 ton-miles.
2. At C: bring 2 tons of ore 300 miles and ship 1 ton of steel 250 miles: 600 + 250 = 850 ton-miles.
3. At M: bring 2 tons of ore 200 miles and 3 tons of coal 250 miles: 400 + 750 = 1,150 ton-miles.
4. The smallest total is at C.

Answer: The coal field, at 850 ton-miles per ton of steel. Coal is the heaviest input, so it pulls the mill toward itself, just as nineteenth-century mills were drawn to Pittsburgh.

Example 2. Find the material index and predict the location for (a) a copper concentrator and smelter using ore that is 1 percent copper, and (b) a soft-drink bottler that uses 0.1 ton of localized inputs (syrup, sugar, cans) for every ton of bottled drink, the rest being local tap water.

1. (a) 1 percent copper means 100 tons of ore yield 1 ton of copper. Material index = 100 ÷ 1 = 100.
2. An index far above 1 means the industry is strongly weight-losing, so it should locate at the material source.
3. (b) Material index = 0.1 ÷ 1 = 0.1.
4. An index below 1 means the industry is weight-gaining (water is ubiquitous), so it should locate at the market.

Answer: (a) Index 100: build at the mine, as at Bingham Canyon and Garfield, Utah. (b) Index 0.1: build near the customers; this is why bottling plants are found near nearly every large city.

Example 3. A garment factory's least-cost transport site costs $40 per unit in freight. Town L would cost $52 per unit in freight, but its labor costs are $18 per unit lower. Town K would cost $63 per unit in freight, with labor $18 per unit lower. Using Weber's isodapanes, where should the factory go?

1. The labor saving at either town is $18, so the critical isodapane is the $18 ring around the least-cost point.
2. Town L: added freight = $52 − $40 = $12. Since $12 < $18, L lies inside the critical isodapane. Net saving = $18 − $12 = $6 per unit.
3. Town K: added freight = $63 − $40 = $23. Since $23 > $18, K lies outside the critical isodapane. Net loss = $5 per unit.

Answer: Move to Town L, which saves $6 per unit overall. Town K is not worth it: the extra freight is more than the labor saving.

PRACTICE

1. EASY Who was Alfred Weber, and what did he publish in 1909?
2. EASY List four assumptions of Weber's model.
3. EASY Classify each as weight-losing or weight-gaining: (a) lumber sawmill, (b) beer brewery, (c) sugar beet refinery, (d) ready-mix concrete plant.
4. MEDIUM A pulp mill uses 4 tons of logs to make 1 ton of pulp. Find the material index and predict the location.
5. MEDIUM In the worked-example triangle (O–C 300 mi, O–M 200 mi, C–M 250 mi), suppose improved furnaces need only 1 ton of coal and 2 tons of ore per ton of steel. Compute

the ton-miles at each corner and find the least-cost corner.

6. MEDIUM Convert the distances in the worked-example triangle to kilometers (1 mile ≈ 1.609 km) and recompute the ton-kilometers at the coal corner C.
7. MEDIUM Give two reasons U.S. Steel chose the site of Gary, Indiana, in 1906.
8. MEDIUM What is a break-of-bulk point? Give an example of an industry that would choose one.
9. HARD A factory's least-cost site costs $25 per unit in freight. A site with skilled, lower-wage labor saves $9 per unit in labor but costs $31 per unit in freight. Is it inside the critical isodapane? Should the factory move? By how much does total cost change?
10. HARD Explain why the American steel industry's center shifted from Pittsburgh toward the Great Lakes and the coasts between about 1900 and 1950.
11. HARD Why does Weber's model explain the location of a smartphone design firm poorly? Name two forces that matter more.
12. CHALLENGE Write a paragraph (5–7 sentences) evaluating Weber's model as a model: what it explains well, what it leaves out, and why geographers still teach it.

COMMON MISTAKES

- Thinking a weight-losing industry locates near its market. It locates near its heaviest material, because hauling waste is expensive.
- Forgetting that ubiquitous materials like water do not pull a factory anywhere; they make a product weight-gaining and push it toward the market.
- Treating isodapanes as distances. They join points of equal extra freight cost, which on a real map follows roads, rails and water, not perfect circles.

> **Make it a game · Field or Customer?.** Write twenty industries on cards (copper smelter, bakery, brewery, sawmill, cannery, cement, ready-mix concrete, soft drinks, cheese, furniture, car assembly, aircraft, jewelry, software, frozen vegetables, oil refinery, flour mill, newspaper printing, ice, pulp). Draw a card and call out "Field!" (near materials), "Customer!" (near market), "Port!" (break-of-bulk) or "Footloose!" and give a one-sentence reason. A partner may challenge; if the challenger gives a better Weber reason, they take the point.

> **Scripture.** "For which of you, intending to build a tower, sitteth not down first, and counteth the cost, whether he have sufficient to finish it?" (Luke 14:28, KJV)

Jesus used a builder's planning to teach about the cost of following Him. Prudent planning, counting every cost before building, is also the heart of Weber's model.

Practice answers

1. A German economist (1868–1958), brother of Max Weber, who published Über den Standort der Industrien (On the Location of Industries), the least-cost theory of industrial location.
2. Any four: one product with a known market point; raw materials at known points; transport cost proportional to weight and distance; a uniform plain with equal movement in all

directions; firms seek least cost; labor available at fixed locations at fixed wages; perfect competition (no one firm controls the market).

3. (a) Weight-losing (bark, sawdust and scraps removed). (b) Weight-gaining (water added). (c) Weight-losing. (d) Weight-gaining (water and heavy, perishable product), so it sits near building sites.
4. Material index = 4 ÷ 1 = 4. It is weight-losing, so it should locate near the forests, often beside a river or rail line.
5. At O: 1 × 300 + 1 × 200 = 500. At C: 2 × 300 + 1 × 250 = 850. At M: 2 × 200 + 1 × 250 = 650. The least-cost corner is now O, the ore deposit, because ore is now the heaviest input.
6. 300 mi ≈ 483 km; 250 mi ≈ 402 km. At C: 2 × 483 + 1 × 402 = 966 + 402 = 1,368 ton-km (850 ton-miles × 1.609 ≈ 1,368).
7. Any two: iron ore from the Mesabi Range could arrive cheaply by lake freighter at its own docks; Appalachian coal could arrive by rail; Chicago, next door, was the nation’s rail hub and a huge market; flat, cheap lakeshore land was available for a vast mill.
8. A place where cargo must be transferred between carriers, such as a seaport or a lake port where ships meet railroads. A steel mill using imported ore (like Sparrows Point near Baltimore) or an oil refinery using crude oil delivered by tanker would choose one, avoiding an extra transfer.
9. Added freight = \$31 − \$25 = \$6, which is less than the \$9 saving, so it lies inside the critical isodapane. The factory should move; total cost falls by \$9 − \$6 = \$3 per unit.
10. As furnaces used less coal per ton, the pull of coal weakened relative to ore and markets. Cheap lake shipping brought Mesabi ore to lake ports, which were also break-of-bulk points and close to the Midwest market, so mills grew at Gary, Chicago and Cleveland. Later, imported ore by sea favored tidewater mills such as Sparrows Point.
11. The product is light and valuable, so freight is a tiny share of cost; the industry is footloose. More important are skilled labor (engineers, designers), agglomeration with other tech firms and universities, access to investors, and quality of life that attracts workers.
12. A strong answer says it explains bulky, weight-losing and weight-gaining industries well (copper, pulp, steel, bottling) and gives clear tools (triangle, material index, isodapanes). It leaves out real transport networks and tapering rates, competitors’ reactions (Hotelling), spread-out markets, government policy, multi-plant firms, just-in-time supply chains and footloose industries. Geographers still teach it because it isolates the key trade-off between freight and other costs and can be tested and extended, the purpose of any good model.

8.3 Rostow's Stages and Their Critics

OBJECTIVES

- Name and describe W. W. Rostow's five stages of economic growth (1960), including his test for the take-off, and place real countries on the model.
- Explain the main criticisms and rival models (Gerschenkron, dependency theory, Wallerstein's world-systems theory, and the institutions view of Bauer, North and de Soto), with the strengths and limits of each.
- Measure development with GDP per capita, purchasing power parity, the Human Development Index and sector shares of employment, and calculate growth with the rule of 70.

Warm-up. Draw a staircase of five steps on a sheet of paper. On the bottom step write "a village where almost everyone farms"; on the top step write "a country where most people work in offices, shops and hospitals and most families own a car." In five minutes, write what you think happens on the three steps between. Then ask yourself: does every country have to climb the same stairs in the same order?

Video. Coming soon. Economic development and the Cold War; Rostow's stages of growth; the Korean economic story; Ford's Highland Park assembly line (1913). Search Hillsdale Studios (lectures on economics and the Cold War), The Henry Ford (assembly line), The History Guy and Federal Reserve Bank of St. Louis; AP review channels from individual teachers are candidates (need careful vetting for ideological framing).

KEY TERMS

economic development
A lasting rise in a country's productive capacity and its people's standard of living, usually measured by output per person, health, education and the shift of work out of farming.

GDP per capita (PPP)
Gross domestic product, the value of all final goods and services produced in a country in a year, divided by its population. At purchasing power parity it is adjusted for what money actually buys in that country.

take-off
Rostow's third stage, a period of about twenty years in which investment rises above about 10 percent of national income, leading industries grow fast and growth becomes self-sustaining.

Human Development Index (HDI)
A summary measure published by the United Nations Development Programme since 1990 that combines life expectancy, years of schooling and income per person into one number between 0 and 1.

dependency theory

The view, associated with Raúl Prebisch and Andre Gunder Frank, that poor countries stay poor because their trade ties to rich countries keep them exporting raw materials on unfavorable terms.

world-systems theory
Immanuel Wallerstein's model (1974) of a single world economy divided into a core, a semi-periphery and a periphery, linked by trade and the division of labor.

CORE IDEAS

The story. In 1960 an American economic historian named Walt Whitman Rostow published a slim book with a bold subtitle: *The Stages of Economic Growth: A Non-Communist Manifesto*. It grew out of lectures he gave at the University of Cambridge in England. The subtitle was a deliberate answer to Karl Marx, whose *Communist Manifesto* of 1848 had claimed that history marched through fixed stages toward communism. The Cold War was then a contest for the newly independent nations of Asia and Africa, and Moscow offered them a road to modern industry through central planning. Rostow argued that the history of Britain, the United States, Germany and Japan showed another road, through private investment, trade and enterprise, and that any nation could travel it. He later served in the Kennedy and Johnson administrations, and from 1966 to 1969 he was President Johnson's national security adviser. Few academic models have had so direct a line to power.

The model. Rostow described five stages. (1) The **traditional society**: most people farm with methods that change slowly, and output per person has a ceiling. (2) The **preconditions for take-off**: new ideas in science and farming spread, banks and merchants appear, roads and ports are built, and a government able to keep order and enforce contracts emerges. (3) The **take-off**, about twenty years when investment rises from about 5 percent of national income to more than 10 percent and one or two leading sectors grow very fast. He dated Britain's take-off to 1783–1802 with cotton and iron, the United States' to 1843–1860 with railroads, Germany's to 1850–1873 and Japan's to 1878–1900. (4) The **drive to maturity**: industry spreads to steel, chemicals, machinery and electricity. (5) The **age of high mass consumption**: ordinary families buy cars, appliances and houses. For Rostow, the cheap mass-produced automobile, made possible by Henry Ford's moving assembly line at Highland Park in 1913, was the great symbol of America's arrival at the fifth stage.

On the map. Test the model on a real case. In 1960 South Korea, wrecked by war and with few natural resources, had an output per person of under $200 a year, poorer than many countries of Latin America and Africa. Over the next decades it invested heavily, educated nearly every child, and built export industries in sequence: textiles and wigs, then ships, steel (the Pohang mill made its first steel in 1973), cars and electronics. By the 2020s its output per person was more than $30,000. That path looks a great deal like Rostow's staircase. North Korea, sharing the same peninsula, language and history, chose a Soviet-style command economy, and its people remain among the poorest in Asia as of 2026. On the other hand, Rostow dated Argentina's take-off to 1935, yet Argentina has spent much of the time since in cycles of inflation and crisis. And several oil states on the Persian Gulf reached high incomes from one resource without passing through his stages at all. Geographers

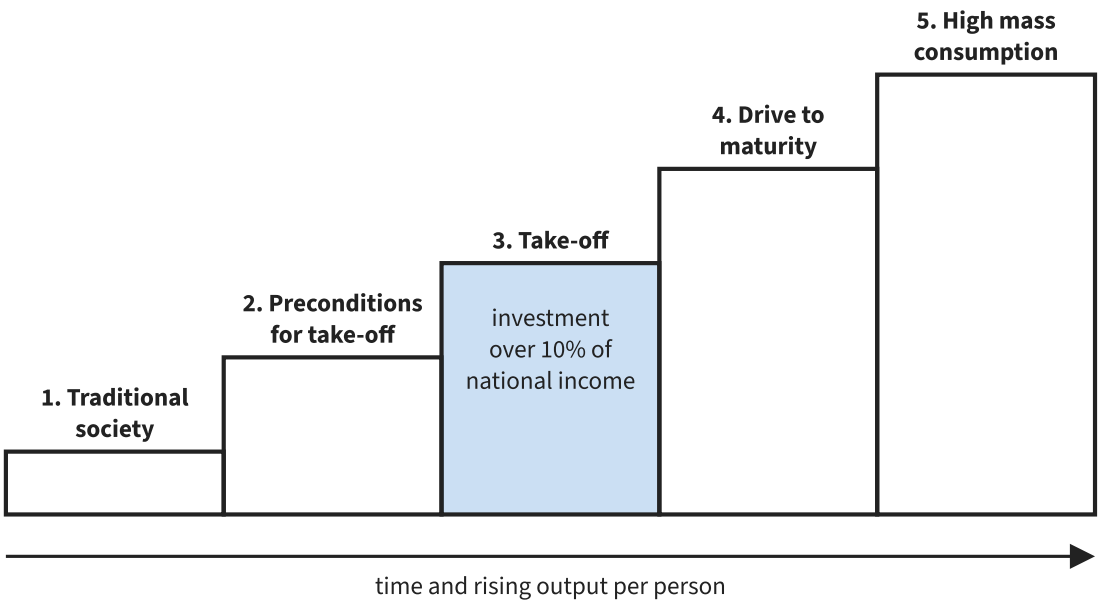
therefore measure development several ways: GDP per capita adjusted for **purchasing power parity**, the **Human Development Index**, and the share of workers in the primary (farming, mining), secondary (manufacturing) and tertiary (services) sectors.

The critics. The economic historian Alexander Gerschenkron argued in 1962 that latecomers do not repeat the leaders' steps: Germany and Russia industrialized with big banks and the state doing what private savers had done in Britain. The **dependency** school, from Raúl Prebisch in the 1950s to Andre Gunder Frank's essay "The Development of Underdevelopment" (1966), argued that poor countries were kept poor by trading raw materials to rich ones; its strength is attention to world trade, its weakness that the East Asian countries that traded most grew fastest, while the import-substitution policies it inspired in Latin America and India often ended in stagnation and debt. Immanuel Wallerstein's **world-systems theory** (1974) pictured one world economy with a **core**, a **semi-periphery** and a **periphery**; it rightly sees countries as connected, not climbing alone, but it is hard to test, and countries keep moving between its zones. From another side, the economist Peter Bauer, and later Douglass North and Hernando de Soto, argued that what matters most is **institutions**: secure property, honest courts, the rule of law and freedom to trade and start businesses. Rostow's stages, they said, describe growth but do not explain what causes it.

Hard lessons of the century. The great alternative to Rostow's road was tried, and its record must be told plainly. Stalin's five-year plans built steel mills and dams quickly, but the forced collectivization of farms brought the famine of 1932–1933 in which millions died, most of all in Ukraine. Mao Zedong's Great Leap Forward (1958–1962) set out to overtake Britain's steel output and instead caused a famine that killed tens of millions of Chinese. By contrast, when China began opening to markets and trade under Deng Xiaoping after 1978, hundreds of millions of its people rose out of extreme poverty. A model must be judged against evidence like this.

The big idea. Rostow's stages are a *model*: a simplified picture drawn mainly from the history of a few Western countries and Japan. Use it to describe and compare, and use its critics to ask what it leaves out: the influence of world trade, geography (landlocked or coastal, tropical or temperate), institutions, culture and the choices of rulers. Scripture also reminds us that growth in goods is not the whole of a good life: "Man shall not live by bread alone" (Matthew 4:4). Yet it pictures a blessed land as one where "they shall sit every man under his vine and under his fig tree; and none shall make them afraid" (Micah 4:4): secure property, peace and the fruit of one's own work, which are the very conditions development needs.

Take-off dates (Rostow): Britain 1783–1802; U.S. 1843–1860; Japan 1878–1900



Rostow's five stages of economic growth (1960), with some of his take-off dates.

PICTURE STUDY

Flywheel Magneto Assembly Line, Ford Highland Park Plant, Unknown photographer (Ford Motor Company), 1913 · Black-and-white photograph · National Archives and Records Administration (NAID 1633486); prints also at The Henry Ford, Dearborn, Michigan

In the spring of 1913, Ford engineers at the Highland Park plant in Michigan tried an experiment. Instead of one worker building a whole flywheel magneto, the part that made the spark for the Model T's engine, they lined up workers along a sliding rack, and each man did one small task before pushing the work along. Assembly time dropped from about 20

minutes to about 13, and soon far less. By the end of that year the method was applied to the whole car.

Rostow saw the moving assembly line and the cheap Model T as the beginning of America's "age of high mass consumption," when ordinary families could buy what only the rich had owned before. In January 1914 Ford also announced its famous five-dollar day for qualifying workers, about double the usual factory wage.

Look closely

- Count the workers you can see. How is the work divided among them?
- Look at the rack in front of the men. Which direction does the work move?
- Look at the ceiling. What drove the machines in this factory before every machine had its own electric motor?
- Look at the men's clothes and faces. What might a day of this work have felt like?

Talk about it

1. Which of Rostow's stages does this photograph represent, and why?
2. What were the gains of the assembly line for buyers and workers, and what were its costs?
3. Why might a factory like this be built in Detroit in 1913, using what you learned about Weber's agglomeration?

PROJECT: A DEVELOPMENT STAIRCASE CHART OF THREE COUNTRIES

You will gather real data on three countries, graph them by hand on one chart, and test whether their histories fit Rostow's staircase or one of his critics better.

You will need

- Graph paper (or a large sheet ruled into a grid), a ruler and three colored pencils
- Access to free data: FRED from the Federal Reserve Bank of St. Louis or the World Bank's open data site (GDP per capita, and share of employment in agriculture)
- Index cards for notes

Steps

1. Choose three countries with different stories, for example South Korea, Argentina and India, or the United States, Japan and Ghana.
2. For each country, look up GDP per capita (in constant dollars if possible) for every tenth year from 1960 to 2020, and the share of workers in agriculture at the start and end.
3. Draw a graph with years across the bottom and GDP per capita up the side. Use a ratio (logarithmic) scale if you can: mark $250, $500, $1,000, $2,000 and so on at equal spacing, so equal growth rates make equal slopes.
4. Plot each country in its own color and connect the points.

5. Shade the decade where each country grew fastest. Did it look like a take-off?
6. On an index card for each country, write which Rostow stage it was in by 1960 and in 2020, and one fact (geography, policy, institutions or trade) that helps explain its path.
7. Write a paragraph: which country fits Rostow best, which fits a critic best, and why.

Tips

- On a ratio scale, a straight line means a steady growth rate; a steeper line means faster growth.
- Different sources give slightly different numbers. Use one source for all three countries so they can be compared fairly, and write its name on the chart.

Check your work

- My chart has a title, labeled axes, a key and a named source.
- I placed each country in a stage at two dates with a reason.
- My paragraph weighs Rostow against at least one critic using my evidence.

MAP NOTEBOOK

1. Draw Rostow's staircase and, beside each step, sketch one picture that represents it (a plow, a road and bank, a cotton mill, a steel mill, a family car).
2. Draw a world-systems sketch map: shade three or four core regions, several semi-periphery countries and several periphery countries, with a key. Note in the margin that countries move between zones over time.
3. Make a comparison table with columns Rostow, Gerschenkron, Dependency, Wallerstein, Institutions, and rows What causes development? Strength, Weakness.

> **From history.** Rostow was a Rhodes Scholar at Oxford in the 1930s and served in the Office of Strategic Services in the Second World War, choosing bombing targets in Germany by studying its economic bottlenecks. That experience, of asking which industries a whole economy depends on, shaped his later idea of "leading sectors" in development. He taught for many years at the Massachusetts Institute of Technology and later at the University of Texas at Austin.

WORKED EXAMPLES

Example 1. Country X has a national income of $40 billion, of which $2 billion is invested in new factories, machines and infrastructure. Fifteen years later its national income is $60 billion and investment is $7.2 billion. Has it met Rostow's numerical test for take-off?

1. First rate: $2 billion ÷ $40 billion = 0.05 = 5 percent.
2. Later rate: $7.2 billion ÷ $60 billion = 0.12 = 12 percent.
3. Rostow's test: investment rises from about 5 percent or less to more than 10 percent of national income over a period of about two decades.

Answer: Yes. Investment rose from 5 percent to 12 percent of national income in fifteen years, which meets Rostow's test. A full judgment would also look for fast-growing leading sectors and institutions that keep the growth going.

Example 2. Country A's GDP per capita grows 2 percent a year; Country B's grows 7 percent a year. Both start at $1,000. Find each country's doubling time and its GDP per capita after 30 years.

1. Rule of 70: A doubles in 70 ÷ 2 = 35 years; B doubles in 70 ÷ 7 = 10 years.
2. After 30 years, A: $1,000 × 1.02^30 = $1,000 × 1.811 ≈ $1,811.
3. After 30 years, B: $1,000 × 1.07^30 = $1,000 × 7.612 ≈ $7,612. (Check: three doublings in 30 years gives $8,000, close to the exact answer.)

Answer: A doubles every 35 years and reaches about $1,811; B doubles every 10 years and reaches about $7,612. A few points of growth, held for a generation, separate a stagnant country from one like South Korea.

Example 3. A country has 12 million workers: 6.0 million in the primary sector, 2.4 million in the secondary sector and 3.6 million in the tertiary sector. Twenty-five years later it has 15 million workers: 3.0 million primary, 4.5 million secondary and 7.5 million tertiary. Find the sector shares at both dates and describe the change in Rostow's terms.

1. First date: primary 6.0 ÷ 12 = 50 percent; secondary 2.4 ÷ 12 = 20 percent; tertiary 3.6 ÷ 12 = 30 percent.
2. Later date: primary 3.0 ÷ 15 = 20 percent; secondary 4.5 ÷ 15 = 30 percent; tertiary 7.5 ÷ 15 = 50 percent.
3. Primary fell by 30 percentage points; secondary rose by 10; tertiary rose by 20.

Answer: 50/20/30 became 20/30/50. Half the workers farming fits a country in the preconditions or early take-off; a shrinking farm sector with growing industry and services fits the drive to maturity, with the growing service sector pointing toward high mass consumption. The United States made the same shift over a longer time: about 40 percent of its workers farmed in 1900, and under 2 percent did by 2000.

PRACTICE

1. EASY List Rostow's five stages in order.
2. EASY Why did Rostow subtitle his book "A Non-Communist Manifesto"?
3. EASY Name the three parts of the Human Development Index.
4. MEDIUM Rostow dated the U.S. take-off to 1843–1860. Which leading sector did he connect with it, and why does that make geographic sense?
5. MEDIUM A country's investment is $3 billion out of a national income of $50 billion. What percentage is that, and which Rostow stage does it suggest?
6. MEDIUM Use the rule of 70 to find the doubling time of GDP per capita growing at 3.5 percent a year. How many doublings occur in 60 years?
7. MEDIUM A country's GDP per capita is $2,000 at market exchange rates, but prices for the same goods there average 40 percent of U.S. prices. Estimate its GDP per capita at purchasing power parity.
8. HARD A country has a health index of 0.9, an education index of 0.8 and an income index of 0.7. The HDI is the geometric mean (cube root of the product) of the three. Calculate it.
9. MEDIUM Classify each in Wallerstein's model as of 2026, and give a reason for one: (a) Germany, (b) Brazil, (c) Chad.
10. HARD State dependency theory's main claim, and give one piece of evidence that supports it and one that challenges it.
11. HARD Explain Gerschenkron's criticism of Rostow with one example.
12. CHALLENGE Compare North and South Korea after 1953 in a paragraph (5–7 sentences). What does the comparison suggest about the causes of development, and which model or critic does it support best?

COMMON MISTAKES

- Treating Rostow's stages as a law every country must follow in order. It is a description drawn mainly from a few countries' histories.
- Using GDP at market exchange rates to compare living standards. PPP adjusts for what money actually buys.
- Presenting the critics as if they were simply right. Each model explains some cases and fails others; test each against evidence.

Make it a game · Which Stage? Which Critic?. Prepare cards, each describing a real country at a real date (for example: Britain 1790, the United States 1850, Japan 1890, the United States 1925, South Korea 1960, South Korea 2020, Argentina 1990, Saudi Arabia 2000). Draw a card; your partner names the Rostow stage and earns one point, then earns a bonus point by naming which critic or rival model would describe the case differently and how. Swap roles after each card.

Scripture. "But they shall sit every man under his vine and under his fig tree; and none shall make them afraid: for the mouth of the LORD of hosts hath spoken it." (Micah 4:4, KJV)

The prophet pictures a peaceful land where each family owns and enjoys the fruit of its own work without fear. Peace, secure property and honest rule are among the deepest roots of real development.

Practice answers

1. Traditional society; preconditions for take-off; take-off; drive to maturity; age of high mass consumption.
2. He was answering Marx's Communist Manifesto (1848) and its theory of fixed historical stages ending in communism. In the Cold War he wanted to show new nations that development could come through private investment, trade and enterprise rather than Soviet-style planning.
3. Life expectancy (health), education (years of schooling) and income per person (gross national income per capita at PPP).
4. Railroads. In a vast country with long distances between farms, mines and cities, railroads opened the interior, created demand for iron, coal and engines, and tied the national market together.
5. 3 ÷ 50 = 6 percent. That is below Rostow's 10 percent take-off level, suggesting a traditional society or the preconditions stage.
6. 70 ÷ 3.5 = 20 years. In 60 years there are 3 doublings, so GDP per capita rises about 8 times.
7. $2,000 ÷ 0.40 = $5,000 at PPP. Money buys two and a half times as much there, so PPP gives a truer picture of living standards.
8. Product = 0.9 × 0.8 × 0.7 = 0.504. Cube root of 0.504 ≈ 0.796 (check: $0.796^3 \approx 0.504$). HDI ≈ 0.80.
9. (a) Core: high-wage, high-technology industry and finance. (b) Semi-periphery: a large industrial economy that also exports many raw materials. (c) Periphery: a landlocked country

exporting mainly oil and farm products with low incomes. (Category boundaries are debated; reasons should match.)

10. Claim: poor countries stay poor because trade with rich countries locks them into exporting cheap raw materials and importing costly manufactures. Support: many economies that rely on a single raw-material export suffer when its price falls. Challenge: South Korea, Taiwan, Singapore and Hong Kong grew rich by trading more with rich countries, while import-substitution policies inspired by the theory often led to stagnation and debt.
11. Latecomers do not repeat the leaders' path; they use substitutes for missing preconditions and can skip steps. Germany relied on large investment banks, and Russia on the state, to supply capital that in Britain came from many private savers and merchants.
12. A strong answer notes that the two share geography, language, culture and history, so the large gap in income and living standards since the 1960s points to institutions and policy: South Korea's private enterprise, export trade, property rights and heavy investment in education versus North Korea's command economy and isolation. It best supports the institutions view (Bauer, North, de Soto) and shows a Rostow-like take-off in the South; it challenges dependency theory, since the South grew by trading with rich countries. A careful answer adds that South Korea's government also directed credit to favored industries, so the case is not simple.

8.4 Trade and Development

OBJECTIVES

- Explain absolute and comparative advantage using David Ricardo’s example of English cloth and Portuguese wine (1817), and calculate opportunity costs and the gains from specialization and trade.
- Show how geography (climate, soils, resources, coasts and landlocked interiors) shapes comparative advantage, and explain the Heckscher–Ohlin idea of factor endowments.
- Compare development through import substitution with development through exports, and weigh fairly the arguments for free trade and for protecting home industry, from Hamilton and List to the debates of 2026.

Warm-up. Find a product label in your kitchen that says where the food was grown or made (coffee, bananas, olive oil, rice, tea, a can of tuna). Make a list of five items and their countries. Find each country on a globe or map. For each, write one geographic reason why that country might be a good place to produce it. Could your own state produce any of them? At what cost?

Watch. *Comparative Advantage* (Marginal Revolution University, 7:15).
https://www.youtube.com/watch?v=4rUfoU04QJM
After the story: watch Bob and Ann work through comparative advantage the same way Ricardo did with England and Portugal, then notice what happened to Tasmania when it was cut off from trade.
Note: Captions were not available to check; preview it first. The Tasmania example may describe the island being cut off by rising seas about 10,000 years ago. Uses a made-up Bob and Ann example instead of Ricardo's England–Portugal cloth and wine numbers.

KEY TERMS

absolute advantage
The ability to produce a good with fewer resources (such as hours of labor) than another producer.

comparative advantage
The ability to produce a good at a lower opportunity cost than another producer. Trade according to comparative advantage lets both sides gain, even if one is better at everything.

opportunity cost
What must be given up to produce or obtain something: the amount of the other good that the same resources could have made.

terms of trade
The rate at which one country’s exports exchange for its imports, for example how many bolts of cloth trade for one cask of wine.

import substitution industrialization (ISI)
A development strategy of using tariffs and quotas to block imports so that home factories will grow up to replace them.

export-oriented industrialization
A development strategy of building industries that sell to world markets, as South Korea, Taiwan, Singapore and Hong Kong did from the 1960s.

CORE IDEAS

The story. In 1817 a London stockbroker who had made a fortune and retired early published *On the Principles of Political Economy and Taxation*. His name was David Ricardo. In the chapter "On Foreign Trade," he set down four numbers that every student of economics still learns. Suppose, he wrote, that England needs the labor of 100 men for a year to make a certain quantity of cloth and 120 men to make a certain quantity of wine. Portugal needs only 90 men for the cloth and 80 for the wine. Portugal is better at *both*. Should Portugal make everything for itself? Ricardo's answer, which surprised many readers then and still surprises people now, was no. Portugal should make wine, England should make cloth, and they should trade, because both will end up with more.

How it worked. The key is **opportunity cost**. In England, making one unit of wine uses 120 men who could have made 1.2 units of cloth, so wine "costs" 1.2 cloth. In Portugal, one unit of wine uses 80 men who could have made 80/90, or about 0.89 units of cloth. Wine is cheaper in Portugal in terms of what is given up, so Portugal has the **comparative advantage** in wine, even though it also has the **absolute advantage** in cloth. England, by the same reasoning, has the comparative advantage in cloth. If Portugal puts all 170 of its men into wine, it makes 2.125 units instead of 1; if England puts all 220 of its men into cloth, it makes 2.2 units instead of 1. Together the two countries now have more of both goods than before, from the same labor, and any trade at a rate between 0.89 and 1.2 cloth per wine leaves both better off. Ricardo's choice of example was not random. The Methuen Treaty of 1703 had already opened Portugal to English woollens and given Portuguese wine lower duties in England than French wine, and the port wine of the Douro valley had become an English habit.

On the map. Where does comparative advantage come from? Much of it is geography, the way God has distributed climate, soils and resources. The hot, dry summers and terraced slopes of the Douro favor grapes; the damp pastures and coal-fed mills of England favored wool and cotton cloth. Coffee grows on the cool highlands of Brazil, Colombia and Ethiopia, not in Ohio. The Swedish economists Eli Heckscher (1919) and Bertil Ohlin (1933) added that countries export goods that use their most plentiful **factors of production**: Australia and Canada, with vast land, export grain and minerals; densely peopled countries with many workers have exported labor-intensive goods such as clothing; countries rich in capital and skills export aircraft, machinery and software. Location matters too. A coastal country can reach the world by cheap sea freight; a landlocked one such as Bolivia, Chad or Mongolia must pay to cross its neighbors first, which raises the cost of every export and import. As Course B showed, the great straits and ports are where these flows concentrate.

Trade and development. After 1945 many newly independent and Latin American countries, persuaded in part by dependency theory, chose **import substitution**: high tariffs to keep out foreign manufactures so that home factories could grow. India followed a version of this policy from independence in 1947 until its reforms of 1991. Some industries did grow, but many stayed small and costly behind the walls, and growth often stalled. Meanwhile South Korea, Taiwan, Singapore and Hong Kong chose **export-oriented** growth, competing in world markets from cheap textiles up to ships, steel and electronics. Their rapid rise convinced many economists. China's opening after 1978, beginning with special economic zones such as Shenzhen in 1980, and its entry into the World Trade Organization (founded 1995) in 2001, followed the export path on a vast scale. Trade has not always been just. The Atlantic trade of the 1600s to 1800s carried enslaved Africans as cargo, and in the Opium War of 1839–1842 Britain went to war after China tried to stamp out the British opium trade, then forced China to open five ports to trade and to cede Hong Kong. Free exchange benefits both sides only when both are free to agree.

Several views. Ricardo's case for free trade won in Britain when Parliament repealed the Corn Laws, its tariffs on imported grain, in 1846. But there has always been a serious second view. Alexander Hamilton's *Report on Manufactures* (1791) argued that a young nation should protect and encourage its new industries until they could stand alone, and the German economist Friedrich List, who had lived in the United States, built on that idea in 1841. Arguments for some protection today include "infant industries," national security (a country at war must be able to make steel, ships, medicines and computer chips), and the hardship of towns whose factories close when production moves abroad. Arguments for open trade include lower prices for families, larger markets for exporters, the pressure of competition that drives improvement, and the record of countries that grew by trading. As of 2026 many governments are revisiting tariffs and trade agreements, and citizens weigh these arguments differently. A geographer's task is to map the flows and measure the effects fairly.

The big idea. Comparative advantage teaches that people and places gain by specializing in what they do at lowest cost and exchanging with others. Paul used the human body to describe the church: "the eye cannot say unto the hand, I have no need of thee" (1 Corinthians 12:21). The world economy is not the church, but the same pattern of different gifts serving one another runs through God's ordering of the nations, whom He "hath made of one blood" and set in their lands (Acts 17:26).

Country	Cloth (men for a year)	Wine (men for a year)	Cost of 1 wine (in cloth)
England	**100**	120	1.2
Portugal	90	**80**	0.89

Bold red: the good each country should specialize in (comparative advantage)

Ricardo's example from 1817: the labor of men for one year needed to make one unit of each good.

The cloth-and-wine trade: English woollens south, Portuguese wine from the Douro valley north through Porto.

PICTURE STUDY

Interior of the Port of Marseille (from the Ports of France series), Claude-Joseph Vernet, 1754 · Oil on canvas · Musée national de la Marine, Paris (owned by the Louvre)

In 1753 King Louis XV of France commissioned the painter Claude-Joseph Vernet to paint the great seaports of his kingdom. Over the next twelve years or so Vernet painted fifteen large views, from Marseille and Toulon on the Mediterranean to Bordeaux and Bayonne on the Atlantic. The king wanted a record of the harbors, fortifications and trade that made France rich.

Vernet worked from careful sketches made on the spot. In this view of Marseille, France's chief Mediterranean port, he filled the quay with people of many nations doing business, as an eighteenth-century trading port really was.

Look closely

- Find the goods on the quay: bales, barrels, sacks. What might be in them?
- Look closely at the people. How many different kinds of dress can you find? What does that suggest about where the traders came from?
- Look at the shape of the harbor. Why is a sheltered basin like this valuable to a trading city?
- Find the people doing the hard work of lifting and carrying. How were goods moved from ship to shore before cranes and containers?

Talk about it

1. What geographic advantages made Marseille a great Mediterranean port?
2. If France exported wine, cloth and soap through Marseille, what might it have imported in return, and from where?

3. How would a painting of a container port today show the same idea of comparative advantage in a different way?

PROJECT: RICARDO'S WORKSHOP: A TWO-COUNTRY TRADE EXPERIMENT

You and a partner will each be a "country." You will time yourselves making two simple products, find your opportunity costs, specialize, trade and compare what you end up with against what you could make alone. It is Ricardo's argument, worked out with your own hands.

You will need

- A stack of scrap paper squares (about 6 × 6 inches, 15 × 15 cm) to fold paper boats (the "cloth")
- Beads or pasta tubes and pieces of string 12 inches (30 cm) long; a string of 10 beads is one "cask of wine"
- A stopwatch or phone timer, pencil and a ruled chart
- A partner (a parent, sibling or classmate)

Steps

1. Each person times how long it takes to make 3 paper boats and then 3 bead strings. Divide by 3 to find your minutes per boat and per string. Record these in a chart like Ricardo's.
2. Compute each person's opportunity cost of one string in boats (minutes per string ÷ minutes per boat) and of one boat in strings.
3. Decide who has the comparative advantage in each product. Note whether one person has the absolute advantage in both.
4. Round 1, self-sufficiency: each person spends 10 minutes making both products, half the time on each. Count the total boats and strings made by both people together.
5. Round 2, specialization: each person spends 10 minutes making only the product of their comparative advantage. Count the totals again.
6. Agree on a trading rate between your two opportunity costs and trade so that each person ends up with some of both. Check whether each person has more than in Round 1.
7. Write a paragraph explaining your results using the terms absolute advantage, comparative advantage, opportunity cost and terms of trade.

Tips

- If your opportunity costs come out exactly the same, there is no gain from specialization. Try making the bead strings longer or the boats fancier so that the two products differ more.
- Practice makes you faster at the product you specialize in. Ricardo's example leaves that out, but it is one more real gain from specialization that Adam Smith described.

Check your work

- My chart shows both people's times and opportunity costs.
- I compared totals in the two rounds and the result of the trade.
- I explained why both partners could gain even if one was faster at both tasks.

MAP NOTEBOOK

1. Copy Ricardo's table and, beside it, draw the sea route from London to Porto, marking the English Channel, the Bay of Biscay and Cape Finisterre.
2. On a world outline map, draw one arrow for each of five real exports you found in the warm-up, from the country of origin to your home, and note the geographic advantage beside each arrow.
3. Make a T-chart titled "Protect or Trade?" with three arguments on each side, and mark which argument you find strongest and why.

> **From history.** David Ricardo was born in London in 1772, the son of a Sephardic Jewish stockbroker from the Netherlands. He became interested in economics after reading Adam Smith's *Wealth of Nations* while on a visit to Bath in 1799. Having made his fortune in the bond market during the Napoleonic Wars, he retired to a country estate, entered Parliament in 1819, and spoke there for lower tariffs on grain. He died in 1823, only fifty-one years old, more than twenty years before the Corn Laws he had criticized were repealed.

WORKED EXAMPLES

Example 1. Using Ricardo's numbers (England: cloth 100 men, wine 120 men; Portugal: cloth 90 men, wine 80 men), find each country's opportunity cost of one unit of wine and of one unit of cloth, and identify absolute and comparative advantages.

(Use the map or drawing "Ricardo's numbers, 1817." shown earlier in this lesson.)

1. England, wine: 120 ÷ 100 = 1.2 units of cloth given up. England, cloth: 100 ÷ 120 ≈ 0.83 units of wine.
2. Portugal, wine: 80 ÷ 90 ≈ 0.89 units of cloth. Portugal, cloth: 90 ÷ 80 = 1.125 units of wine.
3. Absolute advantage: Portugal uses fewer men for both goods (90 < 100 and 80 < 120).
4. Comparative advantage: Portugal has the lower opportunity cost of wine (0.89 < 1.2); England has the lower opportunity cost of cloth (0.83 < 1.125).

Answer: Portugal has the absolute advantage in both goods, but the comparative advantage only in wine. England has the comparative advantage in cloth. Portugal should specialize in wine and England in cloth.

Example 2. Before trade, each country makes 1 unit of cloth and 1 unit of wine. Then each specializes completely: England puts all its 220 men into cloth and Portugal all its 170 men into wine. How much of each good is made in total before and after?

1. Before: England 1 cloth + 1 wine (220 men); Portugal 1 cloth + 1 wine (170 men). Total: 2 cloth and 2 wine.
2. After: England makes 220 ÷ 100 = 2.2 units of cloth.
3. After: Portugal makes 170 ÷ 80 = 2.125 units of wine.
4. Change: cloth rises from 2 to 2.2 (+0.2); wine rises from 2 to 2.125 (+0.125).

Answer: Total output rises to 2.2 cloth and 2.125 wine from the same 390 men. The extra 0.2 cloth and 0.125 wine are the gains from specialization, which trade lets the two countries share.

Example 3. England and Portugal agree to trade 1 unit of wine for 1 unit of cloth. Show that both gain, measured in labor saved.

1. England: making 1 wine at home costs 120 men. Instead it makes 1 cloth (100 men) and trades it for 1 wine. Saving: 120 − 100 = 20 men.
2. Portugal: making 1 cloth at home costs 90 men. Instead it makes 1 wine (80 men) and trades it for 1 cloth. Saving: 90 − 80 = 10 men.
3. The rate of 1 cloth per wine lies between England’s opportunity cost (1.2 cloth per wine) and Portugal’s (0.89 cloth per wine), which is why both gain.

Answer: England saves the labor of 20 men and Portugal the labor of 10 men for each unit traded. Any terms of trade between 0.89 and 1.2 cloth per wine make both better off; outside that range, one side would rather produce at home.

PRACTICE

1. EASY Define absolute advantage and comparative advantage in one sentence each.
2. EASY In what book and year did Ricardo publish his cloth-and-wine example?
3. MEDIUM Illustrative figures: Brazil needs 2 hours of labor for a bag of coffee and 6 hours for a machine part. Germany needs 8 hours for a bag of coffee (grown in greenhouses) and 4 hours for a machine part. Find each country’s opportunity cost of coffee and state who should specialize in what.
4. MEDIUM In problem 3, does either country have the absolute advantage in both goods?
5. MEDIUM In Ricardo’s example, would a trade of 1 wine for 1.5 cloth benefit both countries? Explain.
6. EASY Give two geographic sources of comparative advantage, with a real example of each.
7. MEDIUM State the Heckscher–Ohlin idea and apply it to Australia.

8. MEDIUM Why do landlocked countries such as Bolivia, Chad and Mongolia often face a disadvantage in trade?
9. HARD Compare import substitution and export-oriented industrialization, naming one country or region that tried each and one result.
10. HARD Summarize Alexander Hamilton's argument in the Report on Manufactures (1791) and one argument a free-trade economist would make in reply.
11. HARD A country exports 60 million tons of goods worth $30 billion and imports 20 million tons of goods worth $40 billion. Find the average value per ton of its exports and imports. What does that suggest about its economy?
12. CHALLENGE Write a balanced paragraph (6–8 sentences) on the question: Should a developing country lower its tariffs to grow? Present the strongest argument on each side and the evidence for it, and then give your own reasoned conclusion.

COMMON MISTAKES

- Confusing absolute with comparative advantage. A country can be worse at producing everything and still have a comparative advantage in something.
- Thinking that if one side gains from trade, the other must lose. Voluntary trade within the range of both opportunity costs makes both better off.
- Treating comparative advantage as fixed forever. Education, investment, roads, ports and technology can change it, as South Korea moved from wigs and textiles to ships and electronics.

Make it a game · Who Should Make It?. Write pairs of countries and pairs of goods on cards, with hours of labor for each (for example: Canada wheat 2, cars 10; Mexico wheat 4, cars 12). Draw a card; the first player to call out the correct opportunity costs and say which country should make which good earns two points. A player who correctly names a real geographic reason for the advantage earns a bonus point. Include a few cards where one country is faster at both, to test comparative advantage.

Scripture. "And the eye cannot say unto the hand, I have no need of thee: nor again the head to the feet, I have no need of you." (1 Corinthians 12:21, KJV)

Paul teaches that the members of Christ's body have different gifts and need one another. God has also given different lands different gifts, so that peoples serve one another through honest exchange.

Practice answers

1. Absolute advantage: producing a good with fewer resources than another producer. Comparative advantage: producing a good at a lower opportunity cost than another producer.
2. On the Principles of Political Economy and Taxation, 1817, in the chapter "On Foreign Trade."
3. Brazil: 1 coffee = 2/6 ≈ 0.33 machine part. Germany: 1 coffee = 8/4 = 2 machine parts. Brazil has the comparative advantage in coffee; Germany in machine parts (Germany's cost of a part is 0.5 coffee, Brazil's is 3 coffee).

4. No. Brazil has the absolute advantage in coffee (2 hours < 8 hours) and Germany in machine parts (4 hours < 6 hours). Each also has the comparative advantage in its absolute-advantage good.
5. No. 1.5 cloth per wine lies outside the range 0.89–1.2. England would have to give 1.5 cloth (150 men of labor) for wine it could make at home with 120 men, so England would refuse.
6. Any two: climate (coffee in the Colombian and Ethiopian highlands; grapes in the Douro valley); soils and flat land (wheat on the Canadian prairies); mineral deposits (iron ore in Western Australia; copper in Chile); coasts and harbors (Singapore's position on the Strait of Malacca); rivers and water power.
7. Countries export goods that use intensively the factors of production they have in abundance and import goods that use their scarce factors. Australia, with vast land and mineral deposits and a small population, exports wheat, wool, beef, iron ore and coal and imports many manufactured goods.
8. They have no seaport, so exports and imports must travel overland through neighboring countries to reach the sea, adding transport costs, border delays and dependence on the neighbors' roads, rails and policies.
9. Import substitution blocks imports with tariffs so home industries can replace them; India (1947–1991) and much of Latin America (1950s–1980s) tried it, and many protected industries stayed costly and growth often stalled. Export orientation builds industries that compete in world markets; South Korea, Taiwan, Singapore and Hong Kong tried it from the 1960s and grew rapidly to high incomes.
10. Hamilton argued that a young nation should encourage and, where needed, protect its new manufactures until they could compete, so that it would not depend on foreign powers for essential goods. A free-trade reply: protection raises prices for consumers and can shelter inefficient firms indefinitely, while open competition drives improvement and lets a country use its comparative advantage.
11. Exports: $30 billion ÷ 60 million tons = $500 per ton. Imports: $40 billion ÷ 20 million tons = $2,000 per ton. It exports bulky, low-value goods (raw materials such as ore, grain or coal) and imports compact, high-value manufactures, the pattern of a resource-exporting country that dependency theorists studied.
12. A strong answer presents the open-trade case (comparative advantage, cheaper inputs, access to large markets, the export-led rise of the Asian Tigers and China after 1978) and the protection case (infant industries as argued by Hamilton and List, national security, hardship for workers and towns, the risk of depending on one raw-material export). It notes that even export-oriented countries used some selective support. It reaches a reasoned conclusion supported by evidence and treats the other view fairly.

Unit 8 test

Answer each question. Show your work for every calculation, including units, and write complete sentences for explanations. Where a question asks for several views, present each fairly before giving your own judgment. A calculator is allowed. The test is worth 100 points.

1. (6 pts) What did Abraham Darby achieve at Coalbrookdale in 1709? Name three site advantages that made Coalbrookdale a good place for ironmaking.
2. (6 pts) Explain how the improved steam engine and the canal changed the location of cotton mills between about 1770 and 1830, using Cromford and Manchester as examples.
3. (8 pts) A metropolitan region has 120,000 workers, of whom 18,000 work in automobile manufacturing. The nation has 150,000,000 workers, of whom 900,000 work in automobile manufacturing. Calculate the location quotient and interpret it.
4. (6 pts) A coalfield’s output rose from 20 million tons to 160 million tons in 63 years. Find the doubling time and the approximate average annual growth rate.
5. (6 pts) Define material index. Find it for a sugar refinery that uses 8 tons of sugar beets to make 1 ton of sugar, and for a brewery whose localized inputs weigh 0.2 ton per ton of beer. Predict where each will locate.
6. (10 pts) A factory needs 4 tons of ore and 1 ton of coal to make 1 ton of product. The ore deposit O is 100 miles (160 km) from the coal field C and 150 miles (240 km) from the market M; C is 120 miles (190 km) from M. Freight costs the same per ton-mile everywhere. Compute the ton-miles at each corner and choose the least-cost site. Explain the result in Weber’s terms.
7. (8 pts) A factory’s least-cost site has freight costs of $30 per unit. Town R offers labor $10 per unit cheaper with freight of $37 per unit. Town S offers the same labor saving with freight of $42 per unit. Using the critical isodapane, decide where the factory should go and give the net change in cost.
8. (6 pts) Name three limits of Weber’s least-cost model and give one modern industry it explains poorly.
9. (6 pts) List Rostow’s five stages in order and state his numerical test for the take-off.
10. (8 pts) Country Y has a national income of $80 billion and invests $9.6 billion a year. (a) What percentage is invested, and does it meet Rostow’s take-off level? (b) Its GDP per capita of $3,000 grows 5 percent a year. Use the rule of 70 to find the doubling time and estimate GDP per capita after 28 years.
11. (8 pts) Choose two of these critics or rival models of Rostow: Gerschenkron, dependency theory (Prebisch, Frank), Wallerstein’s world-systems theory, the institutions view (Bauer, North, de Soto). For each, state its main claim, one strength and one weakness.
12. (8 pts) Country A needs 3 hours of labor for a ton of wheat and 6 hours for a bolt of cloth. Country B needs 4 hours for a ton of wheat and 12 hours for a bolt of cloth. (a) Who has the absolute advantage in each good? (b) Find each country’s opportunity cost of wheat and of cloth. (c) Which country should specialize in which good? (d) Give a range of terms of trade (wheat per bolt of cloth) that benefits both.

13. (6 pts) Give two ways geography creates comparative advantage, with a real example of each, and explain why a landlocked country faces a trade disadvantage.
14. (8 pts) Write a paragraph (6–8 sentences) comparing import substitution with export-oriented industrialization, using at least one real example of each, and presenting fairly one argument for protecting home industry and one for open trade.

UNIT PROJECT: AN INDUSTRIAL REGION ATLAS

Choose one real industrial region: Lancashire, the Ruhr, the Pittsburgh–Great Lakes steel belt, Detroit, Upper Silesia, or a modern region such as South Korea's southeast coast (Pohang and Ulsan). Make a three-page hand-drawn atlas. Page 1 is a map of the region showing its raw materials, rivers, canals or ports, rail lines, major cities and markets, with a scale bar in miles and kilometers. Page 2 is a Weber analysis of its leading industry: a locational triangle with real or carefully estimated distances and weights, the material index, and a paragraph on labor, agglomeration and break-of-bulk points. Page 3 places the region's country on Rostow's stages at two dates with a hand-drawn graph of real GDP per capita data and a paragraph weighing Rostow against one critic, and closes with the region's main exports and the comparative advantage behind them.

- **Map accuracy**: Resources, waterways, rail lines, cities and markets are placed correctly, labeled clearly, and shown with a key and a correct scale bar.
- **Models applied**: The Weber triangle, material index, Rostow placement and comparative advantage are calculated correctly from stated data and applied to the region with reasons.
- **Fair judgment**: The writing tests each model against the evidence, presents at least one critic or opposing view fairly, and names real costs and real achievements without slogans.
- **Craft and sources**: The atlas is neat and readable, the graph has a title, labeled axes and a key, and every data source is named.

Answer key

1. He smelted iron ore with coke made from coal instead of charcoal, freeing ironmaking from shrinking forests (2 points). Any three advantages (4 points): local coal for coke, iron ore, limestone for flux, streams for water power to work the bellows, the navigable River Severn for shipping.
2. Early mills such as Arkwright's at Cromford (1771) were water-powered and had to stand at power sites on fast streams (2 points). Watt's engines (from the 1780s) let mills run on coal anywhere coal was cheap (2 points). Canals such as the Bridgewater (1761) cut the price of coal in Manchester by about half, so mills crowded into coalfield and canal-side towns, making Manchester the great cotton city (2 points).
3. Regional share = 18,000 ÷ 120,000 = 0.15 (2 points). National share = 900,000 ÷ 150,000,000 = 0.006 (2 points). LQ = 0.15 ÷ 0.006 = 25 (2 points). The region has 25 times the national share of auto jobs: it is intensely specialized in making cars and exports them to the rest of the country (2 points).
4. 160 ÷ 20 = 8 = 2^3, so three doublings in 63 years: doubling time = 21 years (3 points). Rate ≈ 70 ÷ 21 ≈ 3.3 percent per year (3 points).

5. Material index = weight of localized materials ÷ weight of finished product (2 points). Sugar refinery: 8 ÷ 1 = 8, weight-losing, locate near the beet fields (2 points). Brewery: 0.2 ÷ 1 = 0.2, weight-gaining because water is ubiquitous, locate near the market (2 points).
6. At O: 1 × 100 + 1 × 150 = 250 ton-miles (2 points). At C: 4 × 100 + 1 × 120 = 520 ton-miles (2 points). At M: 4 × 150 + 1 × 120 = 720 ton-miles (2 points). Least cost: the ore deposit O (2 points). The ore weighs more than the coal and the product together (4 ≥ 1 + 1), so the ore corner pulls the factory all the way to itself; this is a strongly weight-losing industry (2 points).
7. The critical isodapane is the $10 ring (equal to the labor saving) (2 points). Town R: added freight $7 < $10, inside the critical isodapane; net saving $3 per unit (3 points). Town S: added freight $12 > $10, outside; net loss $2 per unit (2 points). The factory should move to R (1 point).
8. Three limits (4 points; any three clearly stated): real transport follows networks and costs taper with distance and jump at transfers; markets are spread out, not single points; competitors react to one another (Hotelling); government taxes, tariffs and incentives; agglomeration and skilled labor; just-in-time supply chains; multi-plant firms. Example (2 points): a footloose industry such as software, smartphone design or pharmaceuticals, where freight is a tiny share of cost.
9. Traditional society; preconditions for take-off; take-off; drive to maturity; age of high mass consumption (1 point each, 5 points). Take-off: productive investment rises from about 5 percent or less to over 10 percent of national income, over about two decades (1 point).
10. (a) 9.6 ÷ 80 = 12 percent, above 10 percent, so it meets the take-off level (3 points). (b) Doubling time = 70 ÷ 5 = 14 years (2 points); 28 years = 2 doublings, so about $3,000 × 4 = $12,000 (3 points). (Exact: $3{,}000 \times 1.05^{28} \approx \$11{,}760$.)
11. 4 points each. Gerschenkron: latecomers substitute for missing preconditions (banks in Germany, the state in Russia); strength, fits real German and Russian history; weakness, still describes rather than fully explains. Dependency: poor countries are kept poor by exporting raw materials on poor terms; strength, attention to world trade; weakness, the East Asian exporters grew fastest and import substitution often stalled. Wallerstein: one world economy of core, semi-periphery and periphery; strength, sees countries as connected; weakness, hard to test and countries move between zones. Institutions: secure property, rule of law and free exchange cause growth; strength, explains North versus South Korea; weakness, institutions are hard to build and measure, and some fast growers also used heavy state direction.
12. (a) A has the absolute advantage in both (3 < 4 and 6 < 12) (1 point). (b) A: 1 wheat = 3/6 = 0.5 cloth; 1 cloth = 2 wheat. B: 1 wheat = 4/12 ≈ 0.33 cloth; 1 cloth = 3 wheat (3 points). (c) B has the comparative advantage in wheat, A in cloth (2 points). (d) Any rate between 2 and 3 tons of wheat per bolt of cloth benefits both (2 points).
13. Any two with examples (2 points each): climate (coffee in the Colombian highlands, grapes and port wine in the Douro valley); land and soils (wheat on the Canadian prairies); mineral deposits (iron ore in Western Australia, copper in Chile); coasts and harbors (Singapore). Landlocked (2 points): goods must cross neighboring countries to reach a seaport, adding freight cost, delay and dependence on others' roads, rails and policies (examples: Bolivia, Chad, Mongolia).
14. Import substitution uses tariffs and quotas to replace imports with home production; India (1947–1991) and much of Latin America (1950s–1980s) followed it, often with costly protected industries and stalled growth (2 points). Export orientation builds industries that compete in world markets; South Korea, Taiwan, Singapore, Hong Kong and China after 1978 grew rapidly that way (2 points). A fair argument for protection: infant industries (Hamilton 1791, List 1841) or national security in essential goods (1.5 points). A fair argument for open

trade: comparative advantage, lower prices, larger markets and competition that drives improvement (1.5 points). Clear, balanced writing (1 point).

UNIT 9

Geography and Stewardship

"The earth is the LORD'S, and the fulness thereof" (Psalm 24:1). God made the earth (Genesis 1:1), gave mankind dominion over it (Genesis 1:28), and put the first man in a garden "to dress it and to keep it" (Genesis 2:15). In this unit you will study how people use the earth's resources, water and land, and how they respond to the hazards of a world that is good, fallen and still under God's hand. The theme is **stewardship**: real authority to use creation, exercised by people who will give an account to its Owner.

You will sit in the East Room of the White House in 1908 as Theodore Roosevelt and Gifford Pinchot call the governors to conserve the nation's resources, and you will learn why resources "are not, they become." You will follow the Colorado River from the 1922 Compact to Hoover Dam and walk the green circles of the High Plains above the Ogallala Aquifer. You will hear John Muir and Gifford Pinchot argue over Hetch Hetchy, watch Hugh Hammond Bennett's farmers stop the Dust Bowl soil from blowing, and state four views of land use fairly. Finally you will stand in Galveston after the hurricane of 1900 and watch a city build a seawall and raise itself out of the sea.

The tools of the unit are quantitative: reserves-to-production ratios, doubling times, location quotients, acre-feet, water budgets, land-use percentages, density change, soil-loss rates, recurrence intervals and earthquake magnitudes. As always in this course, models are models. The R/P ratio, the McKelvey box and the 100-year flood are useful ways of thinking, to be tested against what people actually discover, build and choose.

BEFORE YOU BEGIN

- Can compute percents, rates, ratios and the rule of 70 (Units 2 and 3)
- Can read a map scale and convert between miles and kilometers, acres and square miles
- Knows von Thünen's model and the urban models of Burgess and Hoyt (Units 6 and 7)
- Knows the idea of site and situation (Unit 7) and the basic outline of U.S. history from 1865 to 1945

MASTERY CHECKLIST

- I can explain dominion and stewardship from Genesis 1:28 and 2:15 and apply them to real uses of resources, water and land.
- I can distinguish renewable from nonrenewable resources and resources from reserves, and compute an R/P ratio, a doubling time and a location quotient.
- I can explain riparian rights and prior appropriation, tell the story of the Colorado River Compact and Hoover Dam, and work with acre-feet and water budgets.
- I can state the preservation, wise-use, private-stewardship and land-ethic views fairly and use land-use data to evaluate a real question.

- I can explain risk as hazard, exposure and vulnerability, describe the main human responses to hazards with real examples, and compute flood probabilities and magnitude comparisons.

OPTIONAL BOOKS AND RESOURCES

- **Water Science School (U.S. Geological Survey)** (https://www.usgs.gov/special-topics/water-science-school): Free. Clear explanations and diagrams of the water cycle, aquifers, groundwater, water use and watersheds, with data by state (Lessons 9.2 and 9.3).
- **Hoover Dam (U.S. Bureau of Reclamation)** (https://www.usbr.gov/lc/hooverdam/): Free. History, facts and figures, and historic photographs of the dam and Lake Mead, from the agency that built and runs it (Lesson 9.2).
- **National Hurricane Center (NOAA)** (https://www.nhc.noaa.gov/): Free. Official hurricane forecasts, storm-surge maps and educational pages on hurricane hazards; useful for the storm-surge project and for following storms in season (Lesson 9.4).

9.1 Resources and Their Use

OBJECTIVES

- Explain dominion and stewardship from Genesis 1:28 and 2:15 and apply them to the use of natural resources.
- Classify resources as renewable or nonrenewable, distinguish a resource from a reserve, and read a McKelvey diagram.
- Compute a reserves-to-production ratio, a doubling time and a location quotient, and explain why each is a model with limits.

Warm-up. Pick up three things within reach: a pencil, a soda can, a phone charger, a glass jar. For each one, guess what raw materials it is made of and where on earth those materials might have come out of the ground or grown. Write the three guesses down. By the end of this lesson you will be able to check them.

Video. Coming soon. Search for the 1908 White House Conference of Governors on conservation, Theodore Roosevelt and Gifford Pinchot, and how mineral reserves are found and counted: Hillsdale Studios, The History Guy, Library of Congress, NASA Earth Observatory (satellite views of mines and forests); Practical Engineering for mining and resource engineering.

KEY TERMS

natural resource
Any part of God’s creation (soil, water, minerals, forests, fish, sunlight) that people have learned to use to meet a need.

renewable resource
A resource that is replaced by natural processes within a human lifetime, such as timber, fish, crops, sunlight and river water, if it is not used faster than it renews.

nonrenewable resource
A resource that exists in a fixed stock and is not replaced within human time, such as coal, oil, natural gas and metal ores.

reserve
The part of a resource that has been found and can be recovered at a profit with today’s technology and prices.

reserves-to-production ratio (R/P)
Proved reserves divided by the amount produced in one year; how many years current reserves would last at the current rate of production.

stewardship
Caring for and managing what belongs to another. In Scripture, man rules the earth as a steward who answers to God, its owner.

CORE IDEAS

The story. On May 13, 1908, the governors of the American states gathered in the East Room of the White House at the call of President Theodore Roosevelt. The meeting had been planned largely by Gifford Pinchot, the chief of the new U.S. Forest Service. For three days they talked about forests, soil, rivers, coal and iron. Roosevelt warned that the nation had used its forests and minerals as though they could never run out, and he urged the governors to think of the generations to come. Out of the conference came a National Conservation Commission, chaired by Pinchot, which in 1909 produced the first inventory of the natural resources of the United States. Pinchot summed up his own creed in a phrase he repeated for decades: resources should be used for the greatest good of the greatest number for the longest time.

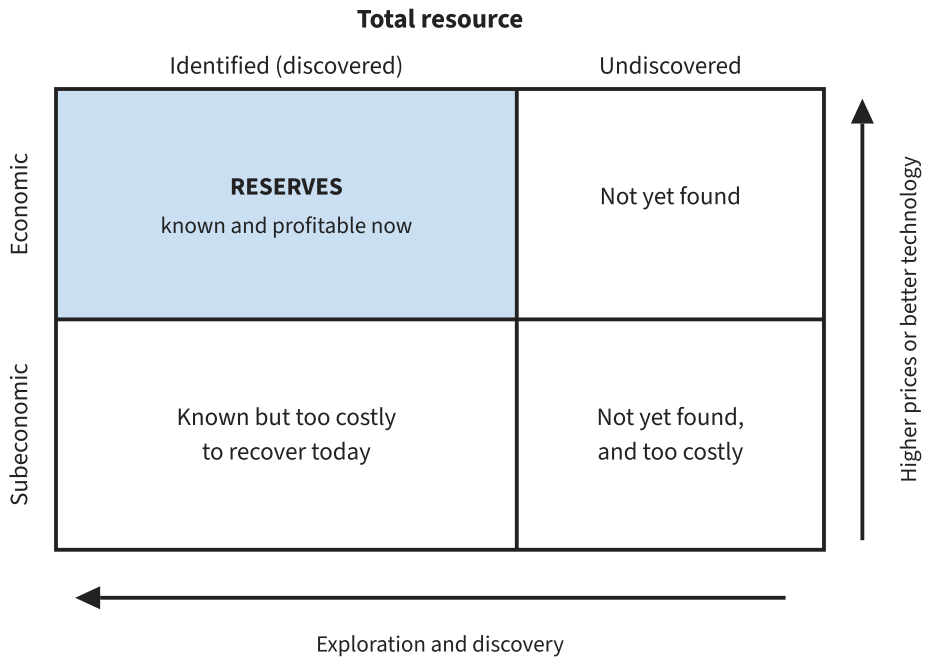
How they figured it out. Roosevelt's worry had a famous British ancestor. In 1865 the economist William Stanley Jevons published *The Coal Question*. Britain's factories, ships and railroads ran on coal, and Jevons argued that cheap coal would not last forever. He also noticed something surprising: when steam engines became more efficient, Britain burned *more* coal, not less, because cheaper power found new uses. Economists still call this the Jevons paradox. Jevons was right that British coal would become harder to get, and British output peaked in 1913. But the industry declined over the next century mostly because oil and natural gas replaced coal and the remaining seams became costly to work, not because the coal was all gone. In 1933 the economist Erich Zimmermann put the lesson in one short sentence: "Resources are not, they become." Petroleum seeped out of the ground in Pennsylvania for centuries before Edwin Drake drilled his well at Titusville in 1859. It became a resource when people learned to refine it and use it.

The big idea. Geographers sort resources in several ways. **Renewable** resources, such as forests, fish, crops, sunlight, wind and river flow, are replaced by natural processes, but they can still be overused: a forest cut faster than it grows, or a fishery fished faster than it breeds, behaves like a nonrenewable stock. **Nonrenewable** resources, such as coal, oil, gas and metal ores, exist in fixed amounts. Yet even a fixed stock is not a fixed *supply*. The U.S. Geological Survey geologist Vincent McKelvey drew a box in 1972 to show why (see the figure). The whole box is the total resource. Its columns divide deposits that have been *identified* from those still *undiscovered*; its rows divide deposits that are *economic* to recover today from those that are *subeconomic*. Only the top-left corner, deposits that are both known and profitable, counts as **reserves**. Exploration moves deposits to the left; higher prices or better technology move them upward. That is why the world's proved oil reserves have generally grown over the last century even as billions of barrels were pumped. The **reserves-to-production ratio** (R/P) divides reserves by yearly production. It is useful, but it is a snapshot, not a countdown: discovery, price, technology, substitution and recycling all change it. A famous test of the two views came in 1980, when the economist Julian Simon bet the biologist Paul Ehrlich that the prices of five metals (chromium, copper, nickel, tin and tungsten) would be lower in 1990. They were, and Ehrlich mailed Simon a check for $576.07. Later studies noted that over some other ten-year periods the bet would have gone the other way, so the wager illustrates a tendency rather than a law.

On the map. Resources are unevenly spread, and that unevenness shapes trade, wealth and politics. As of the mid-2020s, Chile is the world's largest producer of copper, Australia and Guinea lead in bauxite (aluminum ore), Australia and Chile lead in lithium, and much of the world's cobalt comes from the Democratic Republic of the Congo. Geographers measure how concentrated an activity is in a place with a **location quotient**: a region's share of jobs in an industry divided by the nation's share. A quotient well above 1 marks a specialized region, such as the coal counties of Wyoming's Powder River Basin or the iron ranges of northern Minnesota. Resource regions often become boom towns and later bust towns, and some nations that depend on one resource find their whole economies rising and falling with its price.

Dominion and stewardship. The Christian view of resources begins with ownership: "The earth is the LORD'S, and the fulness thereof" (Psalm 24:1). God blessed the man and the woman and said, "Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth" (Genesis 1:28). Dominion is real authority. Mining iron, plowing prairie, damming rivers and refining oil can all be faithful uses of a world made for human life. But dominion is delegated. Genesis 2:15 shows what it looks like in practice: "the LORD God took the man, and put him into the garden of Eden to dress it and to keep it." To *dress* is to work and improve; to *keep* is to guard and preserve. A steward, like the servants in Christ's parables, uses his master's goods boldly and well and then gives an account. This view rejects two errors at once: treating creation as a thing to be stripped for today's profit, and treating it as too sacred for human hands to touch.

Technology overcoming geography. Again and again, invention has made a scarce resource plentiful and a worthless one valuable. The Haber–Bosch process (1913) pulled nitrogen fertilizer out of the air; deep drilling, hydraulic fracturing and horizontal wells opened oil and gas once thought unreachable; recycling now supplies a large share of the aluminum and steel used in the United States. Models of resource use, from Jevons to the R/P ratio, must be tested against what people actually discover and invent.



A simplified McKelvey box (after Vincent McKelvey, 1972). Only the shaded corner counts as reserves; exploration and new technology move deposits into it.

PICTURE STUDY

View from Mount Holyoke, Northampton, Massachusetts, after a Thunderstorm (The Oxbow), Thomas Cole, 1836 · Oil on canvas · Metropolitan Museum of Art, New York

Thomas Cole, born in England in 1801, came to America at seventeen and became the founder of the Hudson River School of landscape painters. He climbed Mount Holyoke in western Massachusetts and painted the great loop of the Connecticut River below it, called

the Oxbow. Cole split the picture down the middle: on one side wilderness and storm, on the other cleared fields, fences and farmhouses in sunlight.

Cole himself put a tiny figure of a painter at his easel in the foreground. Art historians have long noticed that the plowed hills in the distance seem to spell Hebrew letters, which some read as “Noah” and, upside down, as “Shaddai” (the Almighty). Whether or not every viewer sees them, the painting asks the question of this lesson: what should people do with the land God has given them?

Look closely

- Divide the picture with your finger. What is on the left half? What is on the right half?
- Find the river’s great loop. Why would farmers settle on the flat land inside a river bend?
- Find the painter at his easel. Where is he sitting, in the wild part or the farmed part?
- Look at the sky. Which way is the storm moving, toward the farms or away from them?

Talk about it

1. Does Cole seem to celebrate the farms, mourn the lost forest, or both? Give evidence from the painting.
2. How does this painting show both “dress it” and “keep it” from Genesis 2:15?
3. Find the oxbow on a modern map or satellite view of Northampton. What has changed since 1836?

PROJECT: WHERE DOES IT COME FROM? A HOUSEHOLD RESOURCE MAP

Every object in your house began as a resource somewhere on the earth. You will trace ten household objects back to their raw materials and the regions that produce them, then map the result and measure how far your house reaches across the globe.

You will need

- A world outline map (printed, or traced from an atlas)
- Colored pencils and a ruler
- An atlas or reliable reference (the U.S. Geological Survey’s yearly *Mineral Commodity Summaries* lists leading producers of each mineral)
- Ten household objects, such as an aluminum can, copper wire, a glass jar, a steel spoon, a paper bag, a cotton shirt, a wooden spoon, a plastic bottle, a phone battery and a bag of coffee or chocolate

Steps

1. Make a table with columns: Object, Main raw material, Renewable or nonrenewable, Leading producing region(s), Distance from home.
2. For each object, name its main raw material (aluminum from bauxite, glass from silica sand, plastic from oil or natural gas, paper from wood pulp, and so on).

3. Look up one or two leading producing countries or regions for each raw material and write them in your table.
4. Mark each producing region on your world map with a small symbol and draw a line to your home. Use one color for renewable and another for nonrenewable resources.
5. Use the map scale (or a globe and string) to estimate each distance in miles and kilometers.
6. Find the average distance of your ten resources and the farthest one.
7. Write a paragraph: which of these resources could be recycled or replaced, and what does it mean to be a steward of things that came from so far away?

Tips

- Many objects contain several materials; choose the main one by weight.
- Producing a raw material and processing it are often done in different countries. Note both if you can.

Check your work

- My table has ten complete rows with sensible raw materials and regions.
- My map shows renewable and nonrenewable resources in two colors, with distances measured.
- My paragraph applies dominion and stewardship to real objects in my home.

MAP NOTEBOOK

1. Copy the McKelvey box and add one real example to each of its four cells (for example, an oil field being pumped today for Reserves).
2. Sketch the Oxbow loop of the Connecticut River and label the floodplain, the wild slope and the farmed land.
3. Draw a timeline from 1859 (Drake’s well) to 1972 (McKelvey’s box) and mark Jevons (1865), the Governors’ Conference (1908), Haber–Bosch (1913) and Zimmermann (1933).

> **From history.** Gifford Pinchot (1865–1946) studied forestry in France because no American school taught it, and in 1900 his family endowed the Yale Forest School, one of the first in the United States. As first chief of the Forest Service (1905–1910) he managed the national forests for timber, grazing and water under the idea of “wise use.” He later served two terms as governor of Pennsylvania. His approach, and the arguments it provoked, return in Lesson 9.3.

WORKED EXAMPLES

Example 1. A country has proved oil reserves of 48 billion barrels and produces 4.0 billion barrels a year. (a) Find its R/P ratio. (b) Over the next 10 years production stays at 4.0 billion barrels a year, and exploration and new technology add 5.0 billion barrels of reserves a year. Find the reserves and the R/P ratio after 10 years.

1. (a) R/P = reserves ÷ yearly production = 48 ÷ 4.0 = 12 years.
2. (b) Barrels produced in 10 years: 4.0 × 10 = 40 billion.
3. Reserves added in 10 years: 5.0 × 10 = 50 billion.
4. New reserves: 48 − 40 + 50 = 58 billion barrels.
5. New R/P = 58 ÷ 4.0 = 14.5 years.

Answer: (a) 12 years. (b) 58 billion barrels and an R/P of 14.5 years. Ten years later the country has *more* years of reserves than it started with, which is why R/P is a snapshot, not a countdown.

Example 2. A mineral has a static R/P of 70 years at today's production. (a) If yearly use grows 2 percent a year, how long does it take use to double? (b) Using the exponential exhaustion formula T = ln(1 + r × R/P) ÷ r, how long would today's reserves last if use grows 2 percent a year and no reserves are added?

1. (a) Rule of 70: doubling time ≈ 70 ÷ growth rate in percent = 70 ÷ 2 = 35 years.
2. (b) r = 0.02 and R/P = 70, so r × R/P = 1.4.
3. ln(1 + 1.4) = ln(2.4) ≈ 0.875.
4. T = 0.875 ÷ 0.02 ≈ 44 years.

Answer: (a) About 35 years. (b) About 44 years instead of 70. Growth shortens the life of a fixed reserve a great deal. But the model assumes no new discoveries, no recycling, no substitutes and no price change, so in practice it gives a warning, not a date.

Example 3. Using round, illustrative numbers: a western state has 280,000 jobs, of which 24,000 are in mining. The nation has 150,000,000 jobs, of which 600,000 are in mining. Find the location quotient (LQ) for mining in the state and interpret it.

1. State share: 24,000 ÷ 280,000 ≈ 0.0857 (8.57 percent).
2. National share: 600,000 ÷ 150,000,000 = 0.004 (0.40 percent).
3. LQ = state share ÷ national share = 0.0857 ÷ 0.004 ≈ 21.4.

Answer: LQ ≈ 21. Mining is about 21 times more concentrated in the state's job market than in the nation's, marking a strongly specialized resource region whose economy will rise and fall with mineral prices.

PRACTICE

1. EASY Classify each as renewable or nonrenewable: coal, timber, copper ore, wind, natural gas, Atlantic cod.
2. EASY Explain the difference between a resource and a reserve.
3. EASY What did Erich Zimmermann mean by “Resources are not, they become”? Give one example.
4. EASY Quote Genesis 2:15 (KJV) and explain the two verbs that describe Adam’s work.
5. MEDIUM A country has 30 billion barrels of proved reserves and produces 1.5 billion barrels a year. Find its R/P ratio.
6. MEDIUM World use of a metal grows 3.5 percent a year. About how long until use doubles?
7. MEDIUM A county has 40,000 jobs, 2,000 of them in forestry and logging. The nation has 150,000,000 jobs, 450,000 in forestry and logging. Find the location quotient.
8. MEDIUM British coal output peaked in 1913 and then declined. Give two reasons that had little to do with running out of coal.
9. MEDIUM Use the McKelvey box figure. A new mining technology makes a known low-grade copper deposit profitable. Which cell does the deposit move from and to?
   (Use the map or drawing “Exploration moves deposits left; price and technology move them up.” shown earlier in this lesson.)
10. HARD Describe the Simon–Ehrlich wager (who, when, what was bet, the result) and state one fair limit on what it proves.
11. HARD A mineral has a static R/P of 50 years. If use grows 3 percent a year and no reserves are added, how long would reserves last? Use $T = \ln(1 + r \times R/P) \div r$.
12. CHALLENGE In one well-organized paragraph, explain how Genesis 1:28 and Genesis 2:15 together shape a Christian view of mining or logging. Use one real geographic example and avoid both extremes described in the lesson.

COMMON MISTAKES

- Treating the R/P ratio as the number of years until a resource “runs out.” It is a snapshot that changes with discovery, price, technology and substitution.
- Assuming renewable means unlimited. A forest, fishery or aquifer used faster than it renews behaves like a nonrenewable stock.
- Reading “dominion” as permission to waste, or “stewardship” as a ban on use. Genesis holds both together: work the garden and keep it.

Make it a game · Resource or Not Yet?. One player names a material (sand, uranium, whale oil, lithium, peat, helium, guano). The others must say whether it is a resource today, was one in the past, or might become one, and name the invention or need that made the difference. A correct example with a date earns two points. Then name one way to steward it.

> **Scripture.** “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.” (Genesis 2:15, KJV)

Before there was any sin in the world, God gave man work: to cultivate the earth and to guard it. Resource use is part of that calling, and so is accountability to the Owner.

Practice answers

1. Renewable: timber, wind, Atlantic cod. Nonrenewable: coal, copper ore, natural gas. (Timber and cod renew only if they are not harvested faster than they grow and breed.)
2. A resource is the whole amount of a material that exists, found or not, profitable or not. A reserve is only the part that has been found and can be recovered at a profit with today’s technology and prices.
3. A material becomes a resource only when people have the knowledge, technology and need to use it. Example: petroleum was a nuisance seeping from the ground in Pennsylvania until refining and Drake’s 1859 well at Titusville made it valuable (or uranium before the 1940s).
4. “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.” To dress is to work, cultivate and improve; to keep is to guard and preserve. Stewardship includes both.
5. 30 ÷ 1.5 = 20 years.
6. Rule of 70: 70 ÷ 3.5 = 20 years.
7. County share 2,000 ÷ 40,000 = 0.05. National share 450,000 ÷ 150,000,000 = 0.003. LQ = 0.05 ÷ 0.003 ≈ 16.7, a strongly specialized timber county.
8. Oil and natural gas replaced coal for ships, heating and power; the remaining seams were deeper and thinner, so British coal cost more than imported coal or other fuels. (Labor costs and cheaper foreign coal are also acceptable.)
9. From identified–subeconomic (bottom left) to identified–economic (top left, reserves). It moves straight up.
10. In 1980 economist Julian Simon bet biologist Paul Ehrlich that the inflation-adjusted prices of five metals (chromium, copper, nickel, tin, tungsten) would fall by 1990. They fell and Ehrlich paid $576.07. Limit: one decade is a small sample; over some other ten-year periods prices rose, so it shows a tendency for ingenuity and substitution to ease scarcity, not a law that prices always fall.
11. $r \times R/P = 0.03 \times 50 = 1.5$. $\ln(2.5) \approx 0.916$. $T \approx 0.916 \div 0.03 \approx 31$ years.
12. A strong answer explains that Genesis 1:28 gives real authority to subdue and use the earth, so mining and logging can be good work that serves people; that Genesis 2:15 makes that authority a stewardship (dress and keep) under God, the owner (Psalm 24:1); and that the steward neither strips the land for quick profit nor forbids all use. Example: replanting harvested forests in the Pacific Northwest, restoring land after strip mining, or recycling aluminum.

9.2 Water: Rivers, Aquifers and Dams

OBJECTIVES

- Describe how rivers, drainage basins and aquifers supply water, and explain the riparian and prior-appropriation systems of water law.
- Tell the story of the Colorado River Compact (1922) and Hoover Dam (1931–1936) and weigh the gains and costs of large dams, including the Aswan High Dam and the Three Gorges Dam.
- Convert acre-feet to gallons and cubic meters, compute a water budget and the irrigated area of a center-pivot field.

Warm-up. Fill a clear glass with clean, rinsed gravel or small pebbles, then slowly pour in water until it rises halfway. Look at the side of the glass: the water fills the spaces between the stones. Now push a drinking straw down into the gravel and sip. You have just made an aquifer and a well. What happens to the water level if you sip faster than you pour?

Watch. *How Wells & Aquifers Actually Work* (Practical Engineering, 14:13).
https://www.youtube.com/watch?v=bG19b06NG_w
With the big idea: watch how water moves through soil and rock underground and how a well draws from an aquifer, which will help you picture the Ogallala Aquifer under the High Plains.
Note: Captions were not available to check; preview it first. Practical Engineering videos often include a sponsor message (here probably Nebula or Curiosity Stream) that you can skip.

Backup video. *Why Engineers Can't Control Rivers* (Practical Engineering, 15:52).
https://www.youtube.com/watch?v=vLZElIYHmAI
As review: watch river models show how rivers shift and push back when engineers try to straighten or control them, and think about what that means for dams like Hoover. Note: Captions were not available to check; preview it first. It may include a short sponsor message that you can skip.

KEY TERMS

drainage basin (watershed)
All the land drained by a river and its tributaries, bounded by a divide.

aquifer
A layer of porous rock, sand or gravel underground that holds water and lets it flow to wells and springs.

acre-foot

The volume of water that would cover one acre to a depth of one foot: about 325,851 gallons or 1,233.5 cubic meters.

riparian rights
The rule, from English common law and used in the eastern United States, that landowners along a stream may make reasonable use of its water.

prior appropriation
The western U.S. rule of “first in time, first in right”: the first person to put water to beneficial use holds the senior right, whether or not he owns land on the stream.

interbasin transfer
Moving water by canal, aqueduct or pipeline from one drainage basin to another.

CORE IDEAS

The story. On September 30, 1935, President Franklin D. Roosevelt stood on the crest of a new wall of concrete in Black Canyon on the Arizona–Nevada border and dedicated the tallest dam the world had yet seen. Then called Boulder Dam (Congress restored the name Hoover Dam in 1947), it rose 726 feet (221 m) from bedrock and held back the Colorado River to form Lake Mead. Thousands of men had come to the desert in the depth of the Great Depression to build it, working in summer heat above 110°F. The contractors, a group called Six Companies under superintendent Frank Crowe, finished the dam in 1936, about two years ahead of schedule. Ninety-six men died in industrial accidents during construction, a toll that was named and mourned at the time. The dam tamed the floods that had swept the lower river, stored water for farms and cities, and its generators sent electricity to Los Angeles and across the Southwest.

How they figured it out. Before anyone could build the dam, the seven states of the Colorado basin had to agree on who owned the water. In November 1922, commissioners from Colorado, Wyoming, Utah, New Mexico, Arizona, Nevada and California met near Santa Fe with Secretary of Commerce Herbert Hoover as chairman, and on November 24 they signed the **Colorado River Compact**. It drew a line at Lees Ferry, Arizona, just below where Glen Canyon Dam now stands. The Upper Basin (Colorado, Wyoming, Utah, New Mexico) and the Lower Basin (Arizona, Nevada, California) were each apportioned 7.5 million acre-feet a year, and the Upper Basin promised not to cause the flow at Lees Ferry to fall below 75 million acre-feet in any ten consecutive years. Congress then passed the Boulder Canyon Project Act (1928), which divided the Lower Basin’s share: 4.4 million acre-feet for California, 2.8 million for Arizona and 0.3 million for Nevada. A 1944 treaty promised Mexico 1.5 million acre-feet a year. The trouble, discovered later, was the arithmetic. The negotiators worked from stream records of the early 1900s, which turned out to be unusually wet years. Longer gauge records and tree-ring studies point to an average natural flow closer to about 15 million acre-feet, less than the 16.5 million promised on paper. Much of the river’s modern politics comes from that gap.

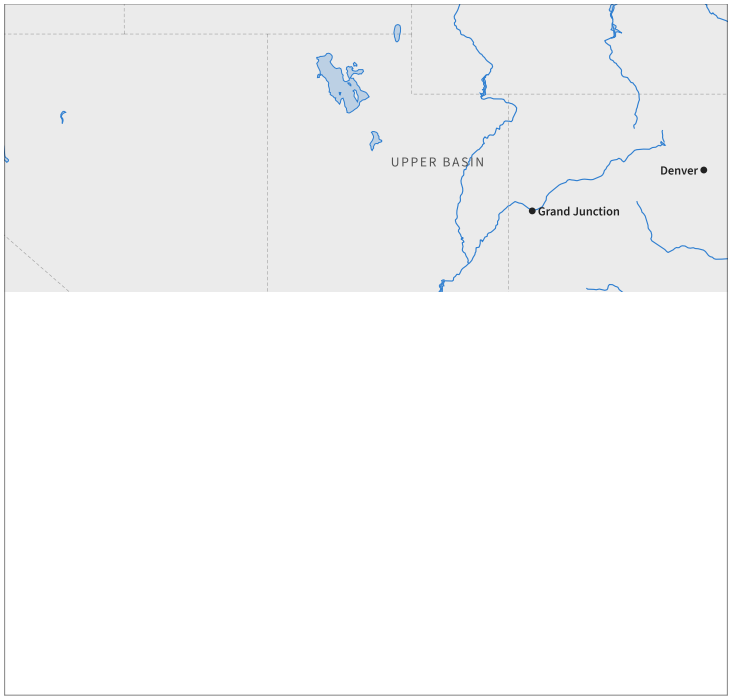
The big idea. Water is the one resource every human settlement must have, and its geography is set by the shape of the land. Rain and snow that fall within a **drainage basin** run toward one river; divides such as the Continental Divide separate one basin from

another. Water also soaks into the ground and fills **aquifers**. The largest in the United States, the Ogallala or High Plains Aquifer, lies beneath about 174,000 square miles (450,000 km²) of eight states from South Dakota to Texas. In 1952 Frank Zybach, a Colorado farmer, patented the center-pivot sprinkler, a long pipe on wheeled towers that walks in a circle around a well. Seen from an airplane, the High Plains became a quilt of green circles, and the region turned into one of the great grain and cattle regions of the world. In parts of western Kansas and the Texas Panhandle, wells have drawn water much faster than rain and snowmelt return it, and the water table has dropped by tens of feet, sometimes more than a hundred; in Nebraska, where recharge is greater, levels have changed far less. Farmers and water districts have answered with more efficient sprinklers, metered wells and local limits on pumping.

On the map. Water law follows climate. In the humid East, American states kept the English common-law **riparian** rule: owners along a stream share its reasonable use. In the arid West, the miners of the California gold rush and the irrigators of Colorado needed to carry water miles away from the stream, so the West adopted **prior appropriation**: first in time, first in right. Colorado wrote it into its constitution in 1876. In a dry year, the holder of an 1880 right takes his full share before the holder of a 1950 right gets a drop. The same logic shapes nations. Great rivers cross borders, and upstream and downstream states must bargain: Egypt, Sudan and Ethiopia over the Nile; Turkey, Syria and Iraq over the Tigris and Euphrates; the United States and Mexico over the Colorado and the Rio Grande.

Technology overcoming geography. Dams and aqueducts move water through time (from wet years to dry) and through space (from one basin to another). They bring large gains and real costs, and honest geography weighs both. Egypt's Aswan High Dam, completed in 1970, ended the Nile's yearly flood and the famines and floods that came with it, doubled as a great power plant and allowed year-round irrigation. It also trapped the silt that once renewed Egypt's fields, so farmers now buy fertilizer, and it flooded Nubian villages; the ancient temples of Abu Simbel were cut apart and lifted to higher ground between 1964 and 1968 in a famous international rescue. China's Three Gorges Dam on the Yangtze, built between 1994 and 2006 and in full operation by 2012, is the largest power station on earth, about 22,500 megawatts, and it eases navigation and floods downstream; the reservoir required the relocation of more than a million people. Dams also age and fill with sediment. A good engineer and a good steward ask the same questions: Who gains? Who pays? Will it last?

Stewardship. Scripture treats water as God's gift and His work: "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again" (Ecclesiastes 1:7). The water cycle God made is generous but not unlimited in any one place. Stewardship of water is mostly local and practical: farmers who measure soil moisture before they irrigate, cities that fix leaking pipes, states that honor their compacts, and neighbors who settle disputes by law rather than force.



The Colorado River basin. Lees Ferry divides the Upper and Lower Basins under the 1922 Compact. The dashed line shows the approximate route of the Central Arizona Project canal.

PICTURE STUDY

Boulder Dam, 1941, Ansel Adams, 1941 · Gelatin silver photograph · National Archives and Records Administration, College Park, Maryland (Ansel Adams Photographs of National Parks and Monuments)

In 1941 the Department of the Interior hired the photographer Ansel Adams, already famous for his pictures of Yosemite, to make large photographic murals of the national parks and of the department’s great works. Among the few pictures he made of human engineering was

this view of Boulder Dam. Because he made it for the federal government, the photograph is in the public domain and is held today by the National Archives.

Adams is usually remembered as a photographer of untouched wilderness, but here he turned his camera on one of the largest things people had ever built in that wilderness. Notice how he uses the same tools, light, shadow and the curve of stone, to show concrete and canyon together.

Look closely

- Find the curve of the dam. Which way does it bow, toward the lake or toward the river below? Why would engineers build it that way?
- Find the power lines and towers. Where is the electricity going?
- Compare the texture of the canyon rock with the smooth concrete. How does Adams use light to make each one visible?
- Is there any person in the picture? How does Adams show the size of the dam?

Talk about it

1. Does this photograph celebrate the dam, warn about it, or simply record it? Give reasons.
2. Adams spent most of his life photographing wild places. Why might he have still found beauty in this dam?
3. What does the dam give to people in Los Angeles or Phoenix who will never see it?

PROJECT: A MODEL AQUIFER AND WELL FIELD

You will build a working aquifer in a clear container, pump it with a well, recharge it with rain and watch a cone of depression form. Then you will compare the speed of pumping with the speed of recharge, the central question of the High Plains.

You will need

- A clear plastic storage box or large glass baking dish
- Aquarium gravel or small pebbles, sand, and a little modeling clay
- A small hand-pump soap dispenser or a turkey baster, with a piece of mesh or nylon stocking over its tip
- A watering can or spray bottle (the “rain”), a ruler and a measuring cup
- A few drops of food coloring and masking tape for marking levels

Steps

1. Lay 1 inch of clay along one end of the bottom as a sloping impermeable layer, then fill the box about 3 inches deep with gravel, with a 1-inch layer of sand on top.
2. Tape a ruler to the outside of the box. Pour in measured water until it stands 2 inches deep in the gravel. Record how many cups it took. This is your saturated thickness.

3. Push your pump or baster down into the gravel at the center as a well. Pump out exactly one cup and record the new water level next to the well and at the far end of the box. Notice the dip near the well: the cone of depression.
4. Sprinkle half a cup of “rain” evenly over the surface. Wait two minutes and record the level again.
5. Repeat: pump one cup, rain half a cup, five times. Make a table of the water level after each round.
6. Add one drop of food coloring on the surface at the far end (a spill) and watch whether pumping draws it toward the well.
7. Graph the water level against the round number. Write a paragraph comparing your box to the Ogallala Aquifer and propose two ways a farmer could keep the level steady.

Tips

- Pump slowly so you do not suck gravel into the well.
- If the level does not change, use a smaller container or measure with a more careful ruler; the difference between pumping and recharge is the whole point.

Check your work

- My table and graph show the water level falling when pumping exceeds recharge.
- I can point to the cone of depression and explain it.
- My paragraph connects the model to the High Plains and suggests realistic stewardship.

MAP NOTEBOOK

1. Sketch the Colorado River basin from the figure, mark Lees Ferry, and write each state’s share in acre-feet beside it.
2. Draw a cross-section of an aquifer: land surface, water table, saturated gravel, clay layer, a well and its cone of depression.
3. Sketch a quarter section (a square half a mile on a side) with a center-pivot circle inside it, and shade the unwatered corners.

> **From history.** John Wesley Powell, the one-armed Civil War veteran who led the first known expedition through the Grand Canyon in 1869, warned Congress in his 1878 *Report on the Lands of the Arid Region of the United States* that the West had too little water for the homestead system designed for the humid East. He proposed organizing the West by drainage basins, so that each community would govern its own watershed. Congress did not adopt his plan, but water managers still quote his insight that in the West, water rather than land is the limiting resource.

WORKED EXAMPLES

Example 1. Under the Colorado River Compact and the 1944 treaty with Mexico, the Upper Basin, the Lower Basin and Mexico are apportioned 7.5, 7.5 and 1.5 million acre-feet a year. (a) Find the total. (b) Convert it to cubic kilometers (1 acre-foot ≈ 1,233.5 m^3). (c) If the long-term average natural flow is about 15 million acre-feet, by what percent does the paper total exceed it?

(Use the map or drawing "Lees Ferry is the dividing point between Upper and Lower Basins." shown earlier in this lesson.)

1. (a) 7.5 + 7.5 + 1.5 = 16.5 million acre-feet.
2. (b) 16,500,000 × 1,233.5 m^3 ≈ 20,350,000,000 m^3. One cubic kilometer is 1,000,000,000 m^3, so this is about 20.4 km^3.
3. (c) Excess: 16.5 − 15 = 1.5 million acre-feet; 1.5 ÷ 15 = 0.10.

Answer: (a) 16.5 million acre-feet a year. (b) About 20.4 km^3. (c) About 10 percent more than the river supplies in an average year, before any water evaporates from the reservoirs.

Example 2. A center-pivot sprinkler sits in the middle of a quarter section, a square field half a mile (2,640 ft) on a side, and its arm reaches 1,320 ft. (a) Find the irrigated area in acres (1 acre = 43,560 ft^2). (b) What fraction of the square is watered? (c) If the farmer applies 18 inches of water in a season, how many acre-feet and how many gallons is that?

1. (a) Area = π × r^2 = 3.1416 × $1{,}320^2$ = 3.1416 × 1,742,400 ≈ 5,474,000 ft^2. Divide by 43,560: about 125.7 acres.
2. (b) The square is $2{,}640^2$ = 6,969,600 ft^2 = 160 acres. 125.7 ÷ 160 ≈ 0.785, which is π ÷ 4.
3. (c) 18 inches = 1.5 ft. 125.7 acres × 1.5 ft ≈ 188.6 acre-feet.
4. 188.6 × 325,851 gallons ≈ 61,400,000 gallons.

Answer: (a) About 126 acres. (b) About 79 percent; the four dry corners are why the High Plains look like green circles in squares. (c) About 189 acre-feet, or roughly 61 million gallons (about 233,000 m^3).

Example 3. Using illustrative numbers for a well in western Kansas: in 1980 the aquifer's saturated thickness at the well was 150 ft; in 2020 it was 90 ft. (a) Find the average yearly decline. (b) If wells become impractical below about 30 ft of saturated thickness, how many more years remain at the same rate? (c) How much would yearly pumping need to fall to cut the decline in half?

1. (a) 150 − 90 = 60 ft lost in 40 years; 60 ÷ 40 = 1.5 ft per year.
2. (b) Usable thickness left: 90 − 30 = 60 ft; 60 ÷ 1.5 = 40 years.
3. (c) The decline is pumping minus recharge. To halve the decline, pumping must fall by an amount equal to half the decline (0.75 ft of water level per year), not by half of all pumping.

Answer: (a) 1.5 ft (about 0.46 m) per year. (b) About 40 more years, to about 2060, if nothing changes. (c) Pumping must drop by enough to save 0.75 ft of level a year. Because recharge also counts, a modest cut in pumping can have a large effect on the life of the well; this is why metering and efficient sprinklers matter.

PRACTICE

1. EASY Define drainage basin and divide, and name the divide that separates rivers flowing to the Pacific from those flowing to the Atlantic and the Gulf of Mexico.
2. EASY Contrast riparian rights and prior appropriation. Where in the United States is each used, and why?
3. EASY Who chaired the 1922 Colorado River Compact negotiations, and where is the dividing point between the Upper and Lower Basins?
4. EASY Name the eight states over the Ogallala (High Plains) Aquifer.
5. MEDIUM Convert 2.8 million acre-feet (Arizona's share) to gallons and to cubic kilometers.
6. MEDIUM A city of 500,000 people uses an average of 150 gallons per person per day for all purposes. How many acre-feet does it use in a year?
7. MEDIUM Hoover Dam is 726 feet high. Convert to meters, and explain why its arch curves upstream toward Lake Mead.
8. MEDIUM In a dry year a river can supply only 1,000 acre-feet. Three farms hold rights: Farm A, 1885, 600 acre-feet; Farm B, 1902, 500 acre-feet; Farm C, 1871, 300 acre-feet. Under prior appropriation, how much does each receive?
9. MEDIUM Give two benefits and two costs of the Aswan High Dam.
10. HARD Use the figure. Why is Lees Ferry a sensible place to divide the basin, and why might the Upper Basin states have wanted a ten-year delivery rule rather than a yearly one?
    (Use the map or drawing "Find Lees Ferry and Glen Canyon Dam." shown earlier in this lesson.)
11. HARD A center pivot with a 1,000-ft arm waters a circle. Find its area in acres, and the water in acre-feet if 20 inches is applied in a season.
12. CHALLENGE Write a paragraph evaluating large dams as "technology overcoming geography." Use at least two of Hoover, Aswan and Three Gorges, with facts, and reach

a reasoned conclusion that acknowledges the other side.

COMMON MISTAKES

- Thinking an aquifer is an underground lake. Nearly all groundwater fills tiny spaces between grains of sand and gravel or cracks in rock.
- Confusing the units: an acre-foot is a volume (about 326,000 gallons), not an area.
- Assuming the river's water can be divided by treaty without regard to how much actually flows. The Colorado Compact shows that the paper and the river can disagree.

Make it a game · First in Time. Each player draws a card with a water-right date (1860 to 1990) and an amount. The leader announces the river's flow for the year (roll two dice and multiply by 100 acre-feet). Fill rights from the oldest date down until the water runs out. Players who get water score their amount; then discuss whether the result seems fair and what a steward would do in a drought.

Scripture. "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again." (Ecclesiastes 1:7, KJV)

Solomon described the water cycle God designed: water is never lost from the earth, but it is not always where people need it. That is why dams, wells, canals and fair laws matter.

Practice answers

1. A drainage basin is all the land drained by one river system; a divide is the high ground between basins. The Continental Divide, along the crest of the Rocky Mountains, separates Pacific drainage from Atlantic and Gulf drainage.
2. Riparian rights give landowners along a stream a share of reasonable use; used in the humid East, from English common law, where water is plentiful. Prior appropriation gives the senior right to the first person to put water to beneficial use ("first in time, first in right"), regardless of land along the stream; used in the arid West, where water had to be carried far from streams to mines and farms.
3. Herbert Hoover, then Secretary of Commerce. The dividing point is Lees Ferry, Arizona.
4. South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico and Texas.
5. 2,800,000 × 325,851 ≈ 912,000,000,000 gallons (about 912 billion). 2,800,000 × 1,233.5 m^3 ≈ 3.45 × 10^9 m^3 = about 3.5 km^3.
6. 500,000 × 150 × 365 = 27,375,000,000 gallons. ÷ 325,851 ≈ 84,000 acre-feet a year.
7. 726 × 0.3048 ≈ 221 m. Curving upstream lets the arch carry the water's push sideways into the canyon walls, like a stone arch, as well as resisting it by the dam's own weight (it is an arch-gravity dam).
8. Seniority runs by date: C (1871) gets its full 300; A (1885) gets its full 600; that leaves 100 for B (1902), which receives 100 of its 500.
9. Benefits: flood control and an end to the yearly flood's destruction; stored water for year-round irrigation; hydroelectric power; protection in drought years. Costs: silt trapped in Lake Nasser so fields need fertilizer and the delta coast erodes; Nubian villages flooded and people relocated; ancient sites such as Abu Simbel had to be moved.

10. Lees Ferry lies near the natural break between the high, snow-fed upper river and the desert lower river, just above the Grand Canyon, where nearly all upper-basin water has gathered into one channel and can be measured. A ten-year total (75 million acre-feet) lets wet years make up for dry ones, so the Upper Basin is not in violation after a single drought year.
11. $\pi \times 1{,}000^2 \approx 3{,}141{,}600$ ft^2 ÷ 43,560 ≈ 72.1 acres. 20 in = 1.667 ft; 72.1 × 1.667 ≈ 120 acre-feet.
12. A strong answer names specific gains (Hoover: flood control, storage for the Southwest, power; Aswan: an end to flood and famine cycles, year-round irrigation; Three Gorges: about 22,500 MW of power, flood control, navigation) and specific costs (displaced people, silt trapped, lost farmland and sites, the Colorado's over-promised supply), and concludes with a judgment that weighs both, such as that dams have served millions but must be planned with honest numbers and maintained over time.

9.3 Land Use and Conservation

OBJECTIVES

- Tell the story of the Hetch Hetchy controversy (1913) and state the preservation, conservation (wise use), private-stewardship and land-ethic views fairly in their own terms.
- Explain the main tools of land-use planning (zoning, greenbelts, public lands, soil conservation districts) and the arguments made for and against each.
- Compute land-use percentages, population density change and soil-loss rates, and use them to evaluate a land-use question.

Warm-up. Look out a window or walk to the end of your street. List every use of land you can see: houses, a road, a lawn, a field, woods, a church, a store, a parking lot. Guess what share of the view each one takes up. Which of these uses could change in the next twenty years, and who would decide?

Watch. *14th April 1935: Black Sunday dust storm sweeps across the Great Plains during the Dust Bowl era* (HistoryPod, 2:36). https://www.youtube.com/watch?v=yyExSjvwkU4
As review: this short history clip retells Black Sunday, April 14, 1935, and how poor farming practices and drought let the topsoil blow away.
Note: Captions were not available to check; preview it first. It describes panic and fear during the storm.

KEY TERMS

land use
The human purpose to which an area of land is put: farming, forestry, housing, industry, transportation, recreation or preservation.

preservation
The view, associated with John Muir, that some wild places should be protected from development and kept as nearly untouched as possible.

conservation (wise use)
The view, associated with Gifford Pinchot, that natural resources should be used and managed efficiently for the long-term good of the people.

zoning
Local laws that divide a town into districts and set what kinds of buildings and uses are allowed in each.

greenbelt
A ring of land around a city where building is restricted, to limit outward growth and keep farms and open country nearby.

suburban sprawl

Low-density growth spreading outward from a city, usually built around the automobile; its critics and defenders disagree about its costs and benefits.

CORE IDEAS

The story. On December 19, 1913, President Woodrow Wilson signed the Raker Act, which allowed the city of San Francisco to dam the Tuolumne River in the Hetch Hetchy Valley, inside Yosemite National Park, and carry its water across California to the city. The fight had lasted more than a decade, and the great earthquake and fire of 1906, when San Francisco's water mains broke and much of the city burned, had strengthened the city's case. On one side stood the naturalist John Muir, founder of the Sierra Club, who had walked these mountains for forty years and believed Hetch Hetchy was a second Yosemite Valley. He wrote in 1912: "Dam Hetch Hetchy! As well dam for water-tanks the people's cathedrals and churches, for no holier temple has ever been consecrated by the heart of man." On the other side stood San Francisco, its engineers, and Gifford Pinchot, who testified to Congress that supplying water to a great city was a higher use of the valley than keeping it for the few who visited. The city won. O'Shaughnessy Dam was finished in 1923, and Hetch Hetchy water reached San Francisco in 1934 through an aqueduct about 167 miles (270 km) long that runs almost entirely by gravity. As of 2026, the system still supplies water to more than two million people around San Francisco Bay, and proposals to drain the reservoir and restore the valley are still debated.

How they figured it out. Hetch Hetchy gave Americans a vocabulary that is still used. **Preservationists**, following Muir, argue that some places should be kept wild, for their beauty, for the renewal of the human spirit and because they cannot be remade once lost. **Conservationists** in Pinchot's sense argue that land and water should be *used*, carefully and efficiently, for the greatest good of the people over the long run. A third view grew from the farm. When drought and windblown soil turned the southern Plains into the Dust Bowl in the 1930s, the soil scientist Hugh Hammond Bennett persuaded Congress to pass the Soil Conservation Act of 1935. Rather than order farmers about from Washington, his Soil Conservation Service worked through local, voluntary soil conservation districts run by farmers themselves; the first, Brown Creek in Anson County, North Carolina, was organized in 1937. Farmers learned contour plowing, terracing, strip cropping and windbreaks, and millions of acres stopped blowing away. This tradition stresses that most land in America is private and is best cared for by owners who have a lasting stake in it. A fourth view came from the forester Aldo Leopold, whose *A Sand County Almanac* (1949) proposed a "land ethic": "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."

The big idea. Every piece of land is put to some use, and land-use questions are really questions about who decides and by what standard. Geographers group the tools into a few families. **Public ownership**: the federal government manages about 640 million acres, roughly 28 percent of the United States, mostly in the West and Alaska; in Nevada the share is about 80 percent, while in Connecticut and Iowa it is under 1 percent. **Regulation**: New York City passed the first comprehensive zoning ordinance in 1916, and the Supreme Court upheld zoning in *Village of Euclid v. Ambler Realty Co.* (1926). Britain went further with

greenbelts; London's, established after 1938 and enlarged after 1947, rings the city with land where building is tightly limited. **Private and voluntary action**: farmers' conservation districts, land trusts that buy conservation easements, and families who keep a farm in the family for generations.

Several views, fairly stated. Thoughtful people disagree about these tools, and a geographer should be able to state each view as its own supporters would. On *federal lands*, some argue that national ownership protects parks, forests and grazing land for all citizens and future generations; others argue that distant management serves western communities poorly and that more land should be run by the states or sold. On *suburban growth*, critics of sprawl point to long commutes, the cost of new roads and pipes, and the loss of farmland at the city's edge; defenders answer that suburbs have given millions of families affordable homes with yards, that the United States has abundant land (urban areas cover only a few percent of it), and that strict limits push housing prices up, as studies of tightly zoned cities and of London's greenbelt suggest. On *wild places*, preservationists, multiple-use managers and private owners each claim to be the better stewards. These debates are not settled by slogans but by evidence, local knowledge and moral principles.

Stewardship. Scripture gives the steward a frame wider than any of the four views. God told Israel, "The land shall not be sold for ever: for the land is mine; for ye are strangers and sojourners with me" (Leviticus 25:23). He commanded a sabbath rest for the fields every seventh year, so that the land itself would not be worked without pause. Biblical stewardship agrees with the preservationist that creation has beauty and worth that point to its Maker (Psalm 19:1); with the conservationist that land is given for human use and fruitfulness (Genesis 1:28); and with the farmer that the one who works the land and will hand it to his children is usually its most careful keeper. It differs from Leopold in grounding right and wrong not in the "biotic community" but in God, who made both the land and the people who dwell on it.

On the map. Land use shows up on every map you read in this course. Von Thünen's rings (Unit 6) and the urban models of Burgess and Hoyt (Unit 7) are models of land use shaped by rent and distance. Satellite images from the Landsat program, launched in 1972, now let geographers measure changes in cropland, forest and built-up area across whole continents, year by year.

The Hetch Hetchy system. The aqueduct line is approximate; it runs about 167 miles (270 km), mostly by gravity, from the Sierra Nevada to San Francisco.

PICTURE STUDY

Looking Down Yosemite Valley, California, Albert Bierstadt, 1865 · Oil on canvas · Birmingham Museum of Art, Birmingham, Alabama

Albert Bierstadt, a German-born American painter, first visited Yosemite in 1863, only a year before Congress and President Abraham Lincoln set the valley aside in the Yosemite Grant of 1864, the first time the federal government protected a piece of wild land for public enjoyment. Bierstadt painted this enormous canvas, about five by eight feet, from sketches made on that trip, and exhibited it in New York in 1865.

Paintings like this one helped convince Americans in the crowded East that the far West held wonders worth protecting. Bierstadt was sometimes criticized for exaggerating the height of the cliffs and the drama of the light, but his pictures shaped how a nation imagined Yosemite and, later, why so many cared about Hetch Hetchy.

Look closely

- Find the river. Follow it from the foreground into the distance. Where does the light fall brightest?
- Look for any sign of people: a road, a house, a fence, a figure. What did Bierstadt choose to show, and what did he leave out?
- Compare the size of the trees with the cliffs. How does the painter make the valley feel vast?
- What time of day does it seem to be? How does the light change the mood?

Talk about it

1. Would John Muir or Gifford Pinchot have liked this painting more? Could they both have loved it for different reasons?
2. Bierstadt's painting helped protect Yosemite. Can art properly influence land-use decisions? Explain.
3. How does this painting illustrate Psalm 19:1, "The heavens declare the glory of God; and the firmament sheweth his handywork"?

PROJECT: A SQUARE-MILE LAND-USE SURVEY

Geographers measure land use before they argue about it. You will map one square mile (or one square kilometer) around your home, classify every part of it, compute the share of each use, and then write a short land-use proposal that presents more than one view.

You will need

- A printed satellite image or county parcel map of the square mile around your home (free online map services and many county websites provide these)
- Tracing paper or a clear sheet protector and fine markers in six colors
- A ruler and a sheet of graph paper with a 20 × 20 grid (400 squares)
- A notebook for field notes

Steps

1. Print or draw your square mile at a scale where it fills most of a page. Mark its four corners and a north arrow.
2. Choose six land-use classes: residential, commercial and industrial, transportation (roads and parking), agriculture, forest and open space, and public or institutional (schools, churches, parks).
3. Lay tracing paper over the image and color each area by its class. Walk or drive part of the area to check at least five places in person.

4. Lay the 20 × 20 grid over your map. For each of the 400 squares, record the class that covers most of it. Count the squares in each class and divide by 400 to get percentages.
5. Convert to acres: one square mile is 640 acres, so each grid square is 1.6 acres (about 0.65 hectares).
6. Find one place in your square mile where the land use could change (a vacant lot, a farm for sale, a closed store). Write a one-page proposal that states at least two views on what should happen there, fairly, then gives your own reasoned recommendation.

Tips

- Roads and parking usually take more space than people expect. Count them carefully.
- If you live in the country, a square mile may be almost all one class. Then compare it with a square mile in the nearest town.

Check your work

- My map is colored in six classes with a key, scale and north arrow.
- My percentages add to 100 and my acres add to 640.
- My proposal states at least two views fairly before giving my own.

MAP NOTEBOOK

1. Copy the Hetch Hetchy map. Mark the dam, Yosemite Valley, the aqueduct and San Francisco, and write the length of the aqueduct in miles and kilometers.
2. Make a four-box chart: Muir, Pinchot, Bennett, Leopold. In each box write the person’s view in one sentence and one place where it was put into practice.
3. Sketch a hillside farm before and after contour plowing and terracing, with arrows showing where rainwater runs in each.

> **From history.** Theodore Roosevelt camped with John Muir in Yosemite in May 1903, sleeping under the stars at Glacier Point and near the Mariposa Grove of giant sequoias. Yet Roosevelt also relied on Gifford Pinchot as his chief adviser on forests, and he tried to hold both men’s views together, adding national monuments and wildlife refuges while managing the national forests for use. During his presidency, from 1901 to 1909, about 230 million acres of land came under federal protection.

WORKED EXAMPLES

Example 1. Nevada has a land area of about 70.3 million acres, and the federal government manages about 80 percent of it. The whole United States has about 2.27 billion acres, of which about 640 million are federal. (a) Find Nevada's federal acreage in acres and in square miles. (b) Find the national federal share. (c) How many times larger is Nevada's share than the national share?

1. (a) 0.80 × 70.3 million ≈ 56.2 million acres. One square mile = 640 acres, so 56,200,000 ÷ 640 ≈ 87,900 square miles (about 228,000 km²).
2. (b) 640 million ÷ 2,270 million ≈ 0.28, or 28 percent.
3. (c) 80 ÷ 28 ≈ 2.9.

Answer: (a) About 56.2 million acres, or 87,900 square miles (228,000 km²), larger than the whole state of Minnesota's land area. (b) About 28 percent. (c) Nearly three times the national share. That difference explains why federal land policy matters far more to Nevadans than to Iowans.

Example 2. An 80-acre sloping field plowed straight up and down the hill loses about 20 tons of soil per acre per year. One inch of topsoil over one acre weighs about 150 tons. (a) How many tons does the field lose in a year? (b) How many years to lose one inch? (c) After contour plowing and terraces, loss falls to 5 tons per acre per year (the common "tolerable" limit). Repeat (b) and find the percent reduction.

1. (a) 20 × 80 = 1,600 tons a year.
2. (b) 150 ÷ 20 = 7.5 years per inch.
3. (c) 150 ÷ 5 = 30 years per inch. Reduction: (20 − 5) ÷ 20 = 0.75.

Answer: (a) 1,600 tons (about 1,450 metric tons) a year. (b) About 7.5 years to lose an inch (2.5 cm) of topsoil. (c) About 30 years per inch, a 75 percent reduction. This is the arithmetic behind Bennett's soil conservation districts.

Example 3. Using illustrative numbers: in 1990 a metropolitan county had 200,000 people living on 100 square miles of urbanized land. In 2020 it had 260,000 people on 160 square miles. (a) Find the density each year in people per square mile and per km² (1 sq mi = 2.59 km²). (b) Compare the percent growth of population and of urbanized land. (c) What does this suggest, and what further facts would you want before judging it?

1. (a) 1990: 200,000 ÷ 100 = 2,000 per sq mi; ÷ 2.59 ≈ 772 per km². 2020: 260,000 ÷ 160 = 1,625 per sq mi; ÷ 2.59 ≈ 627 per km².
2. (b) Population: (260,000 − 200,000) ÷ 200,000 = 30 percent. Land: (160 − 100) ÷ 100 = 60 percent.
3. (c) Urbanized land grew twice as fast as population, so density fell by about 19 percent.

Answer: (a) 2,000 per sq mi (772/km²) in 1990; 1,625 per sq mi (627/km²) in 2020. (b) Population +30 percent, land +60 percent. (c) The county is spreading out (suburban growth). Before judging, a geographer would ask what land was converted (farmland, forest, vacant lots), what happened to housing prices and commute times, and what residents themselves chose and why.

PRACTICE

1. EASY Distinguish preservation from conservation (wise use) and name the person most associated with each.
2. EASY What did the Raker Act of 1913 allow, and what event of 1906 strengthened San Francisco’s case?
3. EASY Name three farming methods promoted by the Soil Conservation Service after 1935 and explain how one of them works.
4. EASY What was decided in *Village of Euclid v. Ambler Realty Co.* (1926), and which city passed the first comprehensive zoning ordinance?
5. MEDIUM In a land-use survey of one square mile, 132 of 400 grid squares are residential and 58 are roads and parking. Find each percentage and the acreage of each.
6. MEDIUM The Hetch Hetchy aqueduct is about 167 miles long, and O’Shaughnessy Dam stands at about 3,800 ft elevation while San Francisco is near sea level. Find the average drop in feet per mile, and the aqueduct length in kilometers.
7. MEDIUM A field loses 12 tons of soil per acre per year. Using 150 tons per acre-inch, how long does it take to lose 6 inches of topsoil?
8. MEDIUM State the strongest argument a critic of suburban sprawl would make and the strongest answer a defender would give.
9. MEDIUM A city grew from 50,000 people on 20 sq mi to 75,000 on 25 sq mi. Did its density rise or fall? By what percent?
10. HARD Use the figure. Why did San Francisco look 150 miles away to the Sierra Nevada for water rather than to nearby rivers, and why could the water travel mostly by gravity?

(Use the map or drawing "Trace the aqueduct from the Sierra Nevada to the coast." shown earlier in this lesson.)

11. HARD State Aldo Leopold's land ethic in your own words, give one strength, and explain how a Christian view of stewardship would agree and differ.
12. CHALLENGE Write a balanced paragraph on whether Hetch Hetchy Reservoir should be drained and the valley restored. Present at least two views fairly, use facts from the lesson, and give your own reasoned conclusion.

COMMON MISTAKES

- Treating Muir and Pinchot as hero and villain. Both loved the land and both were influential conservation leaders; they disagreed about whether use or protection should come first.
- Assuming all land-use questions are decided in Washington. Most U.S. land is private, and most land-use rules are local zoning and county decisions.
- Stating a view one disagrees with in its weakest form. A geographer should be able to state each side so that its supporters would recognize it.

Make it a game · Four Voices. Write a land-use case on a card (a farm at the edge of town is for sale; a forest could be logged; a valley could be dammed). Four players take the parts of Muir, Pinchot, Bennett and Leopold, and each has one minute to argue the case from that view. Then everyone votes on the best argument, not the side they agree with. Rotate roles and play three cases.

Scripture. "The land shall not be sold for ever: for the land is mine; for ye are strangers and sojourners with me." (Leviticus 25:23, KJV)

Israel held its land as tenants of God. Every land-use decision, public or private, is made by people who are temporary keepers of what belongs to the Lord.

Practice answers

1. Preservation (John Muir) seeks to keep some wild places as nearly untouched as possible. Conservation or wise use (Gifford Pinchot) seeks to use and manage resources efficiently for the greatest good over the long run.
2. It allowed San Francisco to dam the Tuolumne River in the Hetch Hetchy Valley inside Yosemite National Park for a water supply. The 1906 earthquake and fire, when broken water mains left the city unable to fight the fires, strengthened its case.
3. Contour plowing, terracing, strip cropping, windbreaks (shelterbelts), cover crops. Example: contour plowing runs furrows along the level lines of a slope, so each furrow catches rainwater instead of channeling it downhill.
4. The Supreme Court upheld local zoning as a constitutional use of government power. New York City passed the first comprehensive zoning ordinance in 1916.
5. Residential: 132 ÷ 400 = 33 percent; 0.33 × 640 = 211.2 acres. Roads and parking: 58 ÷ 400 = 14.5 percent; 0.145 × 640 = 92.8 acres.
6. 3,800 ÷ 167 ≈ 23 ft per mile (about 4.3 m per km). 167 × 1.609 ≈ 269 km.

7. One inch: 150 ÷ 12 = 12.5 years. Six inches: 6 × 12.5 = 75 years.
8. Critic: low-density growth consumes farmland and open space, lengthens commutes and costs more per household for roads, pipes and services. Defender: suburbs give families affordable homes and yards by their own free choice; urban land is only a few percent of the country; and strict growth limits raise housing prices and shut out young families.
9. Before: 2,500 per sq mi. After: 3,000 per sq mi. Density rose by 500 ÷ 2,500 = 20 percent; population grew faster than land.
10. The San Francisco peninsula has small local streams and little storage; the Sierra Nevada catches heavy snow, and the Tuolumne's high, granite canyon offered a clean supply and a dam site. Because the source is about 3,800 ft above sea level and the city is near sea level, the water can flow downhill through tunnels and pipes the whole way, with siphons carrying it across the Central Valley.
11. Leopold said an action is right if it preserves the integrity, stability and beauty of the community of living things on the land, and wrong if it does not. Strength: it asks people to consider the long-term health of the whole land, not just this year's profit. A Christian agrees that creation's beauty and order matter and that land should be handed on in good health, but grounds right and wrong in God, the Owner and Creator, and holds that people bear His image and have a calling to use and rule the land, not merely to be members of a biotic community.
12. A strong answer states the restoration case (Muir's view that the valley was a rare natural wonder inside a national park, which could be recovered for visitors) and the case against (the reservoir supplies clean gravity-fed water and hydropower to more than two million people, replacement storage would be costly and would itself use land elsewhere), cites the 1913 Raker Act, the 1923 dam and 1934 aqueduct, and reaches a reasoned conclusion that acknowledges the strongest point on the other side.

9.4 Natural Hazards and Human Response

OBJECTIVES

- Distinguish a natural hazard from a disaster and explain risk as the meeting of hazard, exposure and vulnerability.
- Describe the main kinds of human response (avoid, protect, adapt, warn, insure, rebuild) using Galveston (1900), Lisbon (1755) and other real cases.
- Compute the chance of a 100-year flood within a span of years, compare earthquake magnitudes, and read a cross-section of a coastal defense.

Warm-up. Think about the place you live. Which natural hazards could reach it: flood, tornado, hurricane, earthquake, wildfire, blizzard, drought? Rank the top two. Then list what your family already does about them (a basement, a weather radio, insurance, a snow shovel, a plan). You already practice hazard geography.

Video. Coming soon. Search for the 1900 Galveston hurricane, the Galveston seawall and grade raising, the 1755 Lisbon earthquake, and how seawalls, levees and earthquake-resistant buildings work: The History Guy, Practical Engineering (seawalls, levees, flood control), Library of Congress (Galveston 1900 photographs), NASA Earth Observatory (hurricanes and floods from space); NOAA SciJinks as a candidate (needs vetting).

KEY TERMS

natural hazard
A natural event, such as a hurricane, flood, earthquake, tornado, wildfire or drought, that can threaten people and property.

disaster
A hazard that actually strikes people and causes great loss of life or property beyond what a community can handle on its own.

exposure and vulnerability
Exposure is how many people and things are in harm’s way; vulnerability is how easily they are harmed, depending on buildings, warning, wealth and preparation.

storm surge
A rise of the sea above its normal level, pushed ashore by a hurricane’s winds and low pressure.

recurrence interval
The average number of years between events of a given size; a “100-year flood” has a 1 percent chance of happening in any one year.

mitigation
Actions taken before a hazard strikes to reduce the harm it can do, such as building codes, seawalls, levees and floodplain zoning.

CORE IDEAS

The story. In 1900 Galveston, Texas, was one of the richest cities in the South, a busy cotton port of about 37,000 people on a low, sandy barrier island. Its highest ground stood less than 9 feet above the Gulf of Mexico. On Saturday, September 8, a hurricane came ashore with winds estimated at about 140 miles per hour (225 km/h) and drove a storm surge of about 15 feet across the entire island. Houses broke apart and their wreckage became battering rams against the houses beyond. By morning between 6,000 and 8,000 people in the city were dead, and perhaps 10,000 or more in the region, the deadliest natural disaster in American history. Clara Barton, at seventy-eight, led the American Red Cross to Galveston on what proved to be her last major relief mission. What happened next made Galveston famous a second time.

How they figured it out. The survivors decided to stay and to change the geography of their island. A board of three engineers, chaired by the retired Army engineer Henry M. Robert (author of *Robert's Rules of Order*), designed a curved concrete seawall about 17 feet high along the Gulf shore. The first section, about 3.3 miles (5.3 km) long, was finished in 1904, and later extensions brought it to about 10 miles. Then the city did something bolder: it raised itself. From 1904 to 1911, dredges pumped sand from the ship channel into the city behind the wall, raising the ground as much as 17 feet at the seawall and sloping down toward the bay. More than 2,000 buildings, including the stone St. Patrick's Church, were jacked up on screws and the new fill packed beneath them. When another strong hurricane struck in 1915, the seawall held and far fewer lives were lost. Yet Galveston never regained its place. Investors had seen its danger, and Houston, fifty miles inland and safe from the surge, opened its deepwater ship channel in 1914 and became the great port and city of Texas. A hazard had changed the urban map of a whole state.

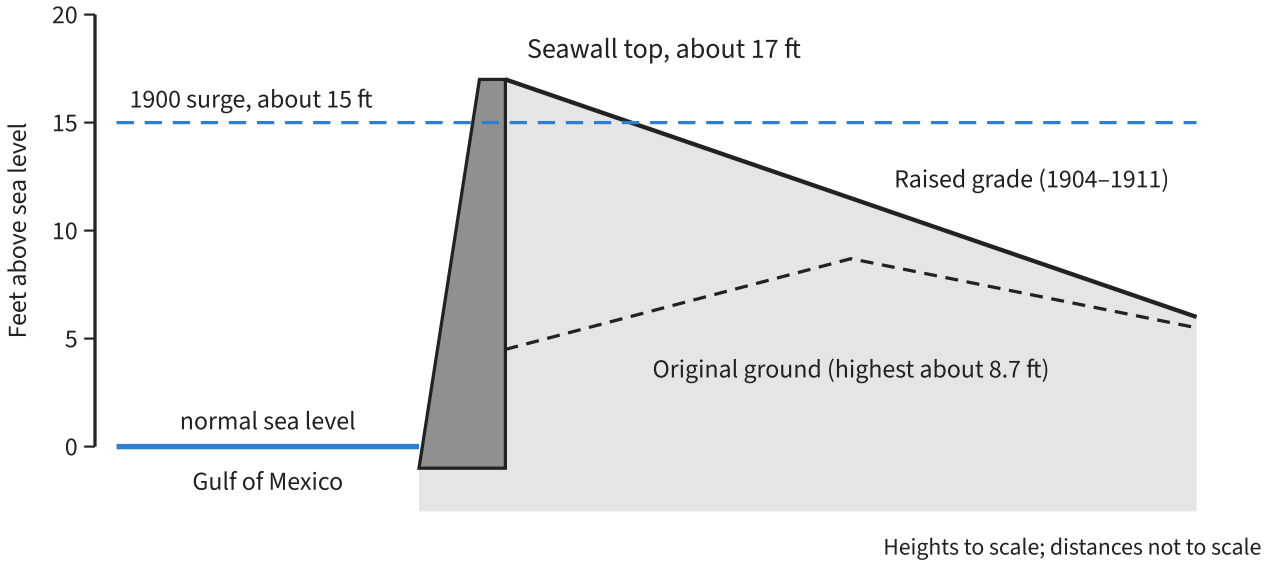
The big idea. Geographers separate the **hazard** (the hurricane) from the **disaster** (the deaths and ruin). A hurricane over open sea harms no one. Risk grows from three things together: the hazard itself, the **exposure** of people and property in its path, and their **vulnerability**, which depends on how they build, whether they are warned and whether they can get out. The American geographer Gilbert F. White, in a 1945 study of flooding along American rivers, put it plainly: floods are acts of God, but flood losses are largely the acts of man. People respond to hazards in a few main ways. They can *avoid* them (floodplain zoning, building on higher ground); *protect* against them (levees, seawalls, dikes, like the Dutch dikes and Mississippi levees of Grade 6, Unit 8); *adapt* (stronger building codes, houses raised on piers); *warn* (forecasting, sirens, evacuation routes); *share the loss* (insurance, savings, neighbors and churches who help); and *rebuild wisely*. White warned that protection can create a false sense of safety: a levee built for a 100-year flood invites building behind it, so the rarer flood that tops it does greater harm.

On the map. Hazards follow physical geography. Earthquakes and volcanoes cluster along plate boundaries, such as the Pacific "Ring of Fire." Hurricanes form over warm tropical seas and strike the Gulf and Atlantic coasts from June to November. Tornadoes are most frequent in the Great Plains and the South, where warm, moist Gulf air meets cool, dry air from the west and north. Human geography decides how much harm they do. On All Saints' Day,

November 1, 1755, an earthquake, followed by a tsunami and fires, destroyed much of Lisbon, then one of the great cities of Europe, and killed tens of thousands of people. The king's chief minister, later the Marquis of Pombal, ordered the dead buried and the city rebuilt quickly. The new Baixa (lower town) was laid out on a grid of wide streets, and its buildings were framed with a flexible wooden lattice, the *gaiola pombalina* ("Pombaline cage"), meant to sway rather than collapse. Pombal also sent a questionnaire to parish priests across Portugal asking how long the shaking lasted and what the sea and wells had done, an early step toward the science of seismology. Modern Japan shows the same pattern of response on a large scale: strict building codes, earthquake drills and warning systems. When a magnitude 9.0 earthquake struck off its northeast coast on March 11, 2011, most buildings withstood the shaking, but the tsunami overtopped seawalls in many towns, and about 18,000 people died or were never found.

Technology overcoming geography. Hazards cannot be abolished, but their toll can be cut sharply. The National Weather Service, satellites (the first weather satellite, TIROS-1, was launched in 1960), Doppler radar and computer forecasts now give coastal cities days of warning before a hurricane, where Galveston in 1900 had little warning of how strong the storm would be. Engineering has raised cities, held back seas and taught buildings to bend. Yet every defense has a design limit. The wise response combines engineering with good land-use choices and honest preparation.

Faith and providence. The Lisbon earthquake stirred a great debate in Europe about how a good God governs the world; Voltaire wrote a bitter poem against easy answers. Christians have long answered with Scripture's honesty: the creation is fallen and "groaneth" (Romans 8:22), yet it remains under the hand of God, who after the Flood of Noah promised that "neither shall there any more be a flood to destroy the earth" (Genesis 9:11). Hazard geography is part of loving our neighbors: building well, warning in time and helping after the storm. Christ's own picture of wisdom is a geographic one: the wise man built his house upon a rock.



The Galveston seawall and grade raising (simplified cross-section; heights in feet above sea level, horizontal distance not to scale).

PICTURE STUDY

Under the Wave off Kanagawa (The Great Wave), from the series Thirty-six Views of Mount Fuji, Katsushika Hokusai, about 1830–1832 · Polychrome woodblock print; ink and color on paper · Metropolitan Museum of Art, New York (one of several surviving impressions; others are in the British Museum and elsewhere)

Katsushika Hokusai was about seventy when he designed this print for his series *Thirty-six Views of Mount Fuji*. It was printed from carved wooden blocks, one for each color, and sold cheaply in Edo (modern Tokyo); thousands of copies were made. It shows not a tsunami but a

great storm wave off the coast of Kanagawa, near modern Yokohama, rising over fast cargo boats rowing fish to market.

Japan is one of the most hazard-prone countries on earth, with earthquakes, tsunamis, typhoons and volcanoes. Hokusai's print captures something every coastal people knows: the sea is beautiful and dangerous, and people still go out on it to make a living.

Look closely

- Find Mount Fuji. How big is it compared with the wave? Why do you think Hokusai made it so small?
- Count the boats and look at the rowers. What are they doing as the wave rises?
- Look at the white tips of the wave. What do they remind you of?
- Find the blue. The deep "Prussian blue" was a new imported pigment in Japan in Hokusai's day. How does it shape the mood?

Talk about it

1. Is this a picture of disaster or of courage? Explain from what you see.
2. The rowers cannot stop the wave. What can they do? How does that match the human responses in this lesson?
3. Why might a picture of danger have been so popular with people who lived beside the sea?

> **Safety first.** Do the storm-surge tray outdoors or on a towel-covered floor. Wipe up spilled water at once so no one slips.

PROJECT: STORM SURGE TRAY: TESTING GALVESTON'S CHOICES

You will build a model barrier island, send a storm surge across it, and test three responses: do nothing, build a seawall, and build a seawall and raise the ground behind it, as Galveston did. You will measure how many houses survive each time.

You will need

- A large plastic storage bin or paint-roller tray, at least 24 inches (60 cm) long
- Damp sand (enough to make a low island along one end)
- Twenty sugar cubes or small wooden blocks for houses
- A strip of stiff plastic or cardboard covered in tape for the seawall
- A pitcher of water, a ruler, and a flat board or plastic lid for making waves

Steps

1. Shape a low, flat island of sand across one end of the tray, about 1 inch (2.5 cm) high. Set ten houses on it in rows. Pour water into the other end to make the Gulf.
2. Trial 1, no defense: raise the water level by pouring slowly until it is just below the island top, then push waves toward the island with the board, ten strokes. Count the

houses knocked over or washed away.
3. Rebuild. Trial 2, seawall only: set the seawall strip along the Gulf edge of the island, pressed into the sand and standing 1 inch above it. Repeat the same water level and ten waves. Count losses.
4. Rebuild. Trial 3, seawall and grade raising: add sand behind the wall so the ground slopes from the top of the wall down toward the far side, and set the houses on the raised ground. Repeat. Count losses.
5. Trial 4: raise the water level a little higher than in the other trials (a storm bigger than the design storm) and test your best defense again.
6. Make a table of houses lost in each trial and a bar graph. Write a paragraph comparing your results with Galveston in 1900 and 1915, and explain what Trial 4 shows about the limits of any defense.

Tips

- Keep the water level and the number of waves the same in Trials 1 to 3 so the test is fair.
- Take a photo before and after each trial for your portfolio.

Check your work

- I ran at least three fair trials and recorded losses in a table and graph.
- I can explain why raising the ground behind the wall helped.
- I can explain what happens when a storm exceeds the design of a defense.

MAP NOTEBOOK

1. Copy the Galveston cross-section and label the seawall, the raised grade, the original ground and the 1900 surge level.
2. Draw a hazard map of your own county: mark floodplains, steep slopes or coasts, and the place your family would go in an emergency.
3. Make a six-box chart of human responses (avoid, protect, adapt, warn, share the loss, rebuild) with one real example in each box.

> **From history.** Isaac Cline, the U.S. Weather Bureau’s chief observer in Galveston, had written in 1891 that a hurricane could not seriously damage the city, because the shallow Gulf would break up any great storm wave. On September 8, 1900, by his own later account, he drove along the beach warning people to move to higher ground, then took shelter with his family in his house, which collapsed in the storm. His wife was among those who died. Cline spent the rest of his long career studying hurricanes and storm tides, and his later work helped forecasters understand how surge builds along the Gulf coast.

WORKED EXAMPLES

Example 1. A family buys a house in a mapped 100-year floodplain with a 30-year mortgage. (a) What is the chance of a 100-year flood in any one year? (b) What is the chance of at least one 100-year flood during the 30 years? (c) Repeat (b) for a 500-year flood, which has a 0.2 percent chance in any one year.

1. (a) A 100-year flood has a 1 in 100 chance each year: 1 percent, or 0.01.
2. (b) Chance of no flood in a year = 0.99. Chance of no flood in 30 independent years = $0.99^{30} \approx 0.740$. Chance of at least one = $1 - 0.740 = 0.260$.
3. (c) For a 500-year flood, the yearly chance is 0.002. $0.998^{30} \approx 0.942$, so $1 - 0.942 = 0.058$.

Answer: (a) 1 percent a year. (b) About 26 percent, roughly 1 chance in 4 over the life of the mortgage. (c) About 6 percent. A “100-year flood” is not one that comes once a century on schedule; it can come two years in a row.

Example 2. Use the figure. In 1900 the highest ground in Galveston was about 8.7 ft above sea level and the storm surge was about 15 ft. (a) How deep was the water over the highest ground at the peak? (b) The seawall top is about 17 ft. How much higher is it than the 1900 surge, in feet and meters? (c) Behind the wall, the ground was raised to about 17 ft. If a house lot there stood at 6 ft before raising, how much fill was added?

(Use the map or drawing “Heights are in feet above sea level.” shown earlier in this lesson.)

1. (a) $15 - 8.7 = 6.3$ ft of water over the highest point; lower parts of the island were deeper.
2. (b) $17 - 15 = 2$ ft. $2 \times 0.3048 \approx 0.61$ m.
3. (c) $17 - 6 = 11$ ft of fill (about 3.4 m).

Answer: (a) About 6 ft (1.9 m) of water even over the highest ground, with breaking waves on top. (b) About 2 ft (0.6 m) above the surge level, although waves still splash over in great storms. (c) About 11 ft (3.4 m) of sand was pumped beneath that lot.

Example 3. On the moment magnitude scale, each step of 1.0 means about 10 times greater ground motion (wave amplitude) and about 32 times more energy released. Compare a magnitude 9.0 earthquake (Japan, 2011) with a magnitude 7.0 earthquake in (a) amplitude and (b) energy.

1. The difference is $9.0 - 7.0 = 2.0$ magnitude units.
2. (a) Amplitude: $10^2 = 100$ times.
3. (b) Energy: $32 \times 32 \approx 1{,}000$ times (more exactly, $10^{(1.5 \times 2)} = 10^3 = 1{,}000$).

Answer: (a) About 100 times the amplitude. (b) About 1,000 times the energy. A magnitude 9 earthquake is not "a little stronger" than a 7; it releases about as much energy as a thousand magnitude 7 earthquakes.

PRACTICE

1. EASY Explain the difference between a hazard and a disaster, with an example.
2. EASY Name the two great engineering responses Galveston made after 1900 and give the years.
3. EASY What does a "100-year flood" mean?
4. EASY Classify each response as avoid, protect, adapt, warn or share the loss: (a) a levee, (b) flood insurance, (c) a tornado siren, (d) a law forbidding houses in a floodway, (e) a house raised on piers.
5. MEDIUM Find the chance of at least one 50-year flood in 20 years.
6. MEDIUM How many times more energy does a magnitude 8.0 earthquake release than a magnitude 6.0? A magnitude 7.5 than a 7.0?
7. MEDIUM The first section of the Galveston seawall was about 3.3 miles long. Convert to kilometers and feet.
8. MEDIUM Explain Gilbert F. White's point about floods and flood losses, and his warning about levees.
9. MEDIUM Why did Houston, rather than Galveston, become the leading city of Texas in the 1900s? Use the idea of site and situation from Unit 7.
10. HARD Use the figure. Explain in two or three sentences why raising the ground behind the seawall mattered as much as the wall itself.
    (Use the map or drawing "Compare the raised grade with the original ground." shown earlier in this lesson.)
11. HARD Describe two features of Lisbon's rebuilding after 1755 and explain how each reduced future risk.
12. CHALLENGE Your town sits on a river floodplain. Write a paragraph recommending a hazard plan that uses at least three kinds of response, and explain how a Christian's duty to love his neighbor shapes the plan.

COMMON MISTAKES

- Thinking a “100-year flood” cannot happen again for a century. It has a 1 percent chance every year, and two can come in a row.
- Treating the magnitude scale as if a 9 were only a little stronger than an 8. Each whole step is about 32 times the energy.
- Believing a seawall or levee makes a place safe from every storm. Every defense has a design limit, and the false sense of safety can draw more people into danger.

Make it a game · Hazard Match. Make two decks of cards. The first names hazards and places (hurricane on a barrier island, earthquake in a city of brick, river flood in a farm town, tornado on the Plains, wildfire in a canyon suburb). The second names responses (seawall, levee, building code, siren, evacuation route, floodplain zoning, insurance, safe room). Draw a hazard; each player has thirty seconds to play the best two response cards and explain why. The group awards a point for each good match and two for naming a real place where it was used.

Scripture. “Therefore whosoever heareth these sayings of mine, and doeth them, I will liken him unto a wise man, which built his house upon a rock: And the rain descended, and the floods came, and the winds blew, and beat upon that house; and it fell not: for it was founded upon a rock.” (Matthew 7:24–25, KJV)

Jesus used a lesson every hazard geographer knows: where and how you build decides what the storm will do. His main point is spiritual, but it rests on a plain truth of the physical world He made.

Practice answers

1. A hazard is a natural event that could cause harm; a disaster is what happens when it strikes exposed, vulnerable people and causes great loss. Example: a hurricane over the open ocean is a hazard; the 1900 Galveston hurricane, which killed thousands in a city, was a disaster.
2. The seawall (first section finished in 1904, about 17 ft high) and the grade raising (1904–1911), which raised the city as much as 17 ft behind the wall.
3. A flood so large that it has a 1 percent chance of being equaled or exceeded in any given year; it is a probability, not a schedule.
4. (a) protect, (b) share the loss, (c) warn, (d) avoid, (e) adapt.
5. Yearly chance 0.02; $0.98^{20} \approx 0.668$; $1 - 0.668 \approx 0.33$, about 33 percent.
6. 8.0 vs 6.0: about $32 \times 32 \approx 1{,}000$ times. 7.5 vs 7.0: 10^(1.5 × 0.5) = 10^0.75 ≈ 5.6 times.
7. $3.3 \times 1.609 \approx 5.3$ km. $3.3 \times 5{,}280 = 17{,}424$ ft.
8. Floods are natural events, but the losses they cause depend largely on human choices about where and how to build. Levees protect against floods up to their design size but encourage building behind them, so when a rarer, larger flood overtops or breaks them, the losses are greater than they would have been.
9. Galveston’s site, a low barrier island, was exposed to hurricanes and storm surge, as 1900 showed. Houston’s site, about fifty miles inland, was safe from the surge, and the Houston

Ship Channel (opened 1914) gave it a seaport situation with rail connections, so investment and shipping moved there.

10. A wall alone leaves low ground behind it, where water that overtops the wall or comes in from the bay side pools and floods houses. Raising the grade puts the city above most surge levels and makes the ground slope away from the Gulf, so water that splashes over drains off toward the bay instead of standing in the streets.
11. Wide, straight grid streets in the Baixa made it easier to escape and to fight fires and kept falling buildings from blocking narrow lanes; the gaiola pombalina, a flexible wooden lattice inside masonry walls, let buildings sway during shaking rather than collapse. (Pombal’s questionnaire to parishes, which gathered evidence about the quake, is also acceptable as a step toward understanding earthquakes.)
12. A strong answer combines several responses, such as floodplain zoning to keep new houses out of the floodway (avoid), a levee or floodwall sized with honest data (protect), raised houses and building codes (adapt), river gauges and sirens (warn), and insurance and a church relief plan (share the loss), and notes the limits of each. It connects love of neighbor to warning others in time, building honestly so others are not endangered, and helping victims after a disaster, as Clara Barton did at Galveston.

Unit 9 test

Answer each question. Show your work for every calculation, give units, and use complete sentences for explanations. Where a question asks for several views, state each one fairly, as its own supporters would. You may use a calculator. Useful values: 1 acre-foot ≈ 325,851 gallons ≈ 1,233.5 m^3; 1 square mile = 640 acres = 2.59 km^2; 1 mile ≈ 1.609 km. The test is worth 100 points.

1. (6 pts) Quote or closely paraphrase Genesis 1:28 and Genesis 2:15, and explain how the two verses together shape a biblical view of using natural resources.
2. (6 pts) Distinguish a resource from a reserve. On a McKelvey box, describe how (a) the discovery of a new deposit and (b) a sharp rise in price would each change the reserves.
3. (8 pts) A country has proved reserves of 60 billion barrels of oil and produces 2.5 billion barrels a year. (a) Find the R/P ratio. (b) If production grows 2.5 percent a year and no reserves are added, how long would the reserves last? Use $T = \ln(1 + r \times R/P) \div r$. (c) Give two reasons the actual life of the reserves may be longer than either answer.
4. (7 pts) A region has 300,000 jobs, 9,000 of them in oil and gas. The nation has 150,000,000 jobs, 450,000 in oil and gas. Find the location quotient and explain one advantage and one risk for a region with such a quotient.
5. (6 pts) State the year of the Colorado River Compact, who chaired the negotiations, the dividing point between the basins, and how much water each basin was apportioned. Why does the river’s water now seem over-promised?
6. (8 pts) Nevada’s share of the Colorado is 0.3 million acre-feet a year. (a) Convert it to gallons and to cubic meters. (b) If each resident of a city uses 150 gallons a day for all purposes, about how many people could this water supply for a year?
7. (7 pts) In a dry year a creek can supply 900 acre-feet. Three users hold rights: Ranch X (1890) 400 acre-feet; Town Y (1875) 300 acre-feet; Farm Z (1912) 400 acre-feet. (a) How much does each receive under prior appropriation? (b) How would a riparian system approach the same shortage differently?
8. (6 pts) At a High Plains well the aquifer’s saturated thickness fell from 120 ft in 1996 to 84 ft in 2020. (a) Find the average yearly decline in feet and meters. (b) If pumping becomes impractical below 30 ft, about when would that happen at the same rate? (c) Name two practical responses.
9. (8 pts) Describe the Hetch Hetchy controversy: what was decided, by what law and in what year, and state John Muir’s and Gifford Pinchot’s positions fairly, each in the way its supporters would.
10. (7 pts) A land-use survey of one square mile, using a 400-square grid, counts: residential 148, commercial and industrial 36, transportation 64, agriculture 92, forest and open space 40, public and institutional 20. Find the percentage and acreage of residential, transportation and agriculture, and check that the counts total 400.
11. (8 pts) (a) A 40-acre field loses 16 tons of soil per acre per year. How many tons a year is that, and how many years to lose one inch of topsoil (about 150 tons per acre)? (b) Who

was Hugh Hammond Bennett, and how did the soil conservation districts work? (c) State one argument for and one against strict growth limits such as a greenbelt.

12. (7 pts) A house lies in a mapped 100-year floodplain. (a) What is the chance of a 100-year flood in any one year? (b) What is the chance of at least one in the next 25 years? (c) Explain why “it flooded last year, so we are safe for a century” is wrong.
13. (8 pts) Describe the Galveston hurricane of 1900 and the city’s two main engineering responses, with numbers. Then explain, using site and situation, why Houston rather than Galveston became the leading city of Texas.
14. (8 pts) (a) Explain risk as the meeting of hazard, exposure and vulnerability. (b) How many times more energy does a magnitude 8.5 earthquake release than a magnitude 6.5? (c) Give one real example each of a “protect” response and an “adapt” response, and state Gilbert F. White’s warning about levees.

UNIT PROJECT: A STEWARDSHIP ATLAS OF MY WATERSHED

Make a four-page atlas of the drainage basin you live in. Page 1: a map of the watershed with its main river, divides, towns and your home, and a paragraph on where your household water comes from (river, reservoir or well and aquifer) and where your wastewater goes. Page 2: a resource and land-use map, with your square-mile survey from Lesson 9.3 inset and one resource-producing place in or near the watershed. Page 3: a hazard map showing floodplains, steep slopes or coasts, with the recurrence interval of the local 100-year flood explained and your family’s emergency plan. Page 4: a two-page essay on one real stewardship question in your watershed (a dam, a well field, a development, a levee), stating at least two views fairly, giving your reasoned recommendation, and grounding it in Genesis 2:15.

Include your data tables, photographs of your aquifer and storm-surge models, and a list of sources (U.S. Geological Survey, county maps, state water agencies, local historical society).

- **Accuracy**: Maps are correctly located with scale, north arrow and key; water sources, land uses and hazard zones are correctly identified from reliable sources.
- **Quantitative work**: Land-use percentages, water quantities in gallons and acre-feet, and flood probabilities are computed correctly with units and shown in tables.
- **Fair reasoning**: The essay states each view as its own supporters would, uses evidence, and reaches a reasoned conclusion grounded in biblical stewardship rather than slogans.
- **Craft**: The atlas is neat, well organized, carefully labeled and readable by a neighbor who has never studied geography.

Answer key

1. Genesis 1:28: God blessed the man and woman and told them to be fruitful, multiply, replenish the earth, subdue it, and have dominion over the fish, the fowl and every living thing. Genesis 2:15: “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.” Together they give real authority to use and develop creation (dominion) while making that authority a stewardship under God, the owner: people are to

work and improve the earth (dress) and guard and preserve it (keep), avoiding both wasteful exploitation and a refusal to use creation at all.

2. A resource is the total amount of a material, found or not, profitable or not; a reserve is the part that is identified and can be recovered at a profit today. (a) Discovery moves a deposit from the undiscovered column to the identified column; if it is profitable, it adds to reserves. (b) A higher price moves identified but subeconomic deposits up into the economic row, adding to reserves without any new discovery.
3. (a) 60 ÷ 2.5 = 24 years. (b) r × R/P = 0.025 × 24 = 0.6; ln(1.6) ≈ 0.470; T ≈ 0.470 ÷ 0.025 ≈ 18.8 years. (c) Any two: new discoveries add reserves; higher prices or new technology turn subeconomic deposits into reserves; recycling or substitutes reduce demand; efficiency reduces use per unit of output.
4. Region share 9,000 ÷ 300,000 = 0.03; national share 450,000 ÷ 150,000,000 = 0.003; LQ = 10. Advantage: the region has skilled workers, suppliers and high wages built around a valuable resource. Risk: its economy rises and falls with oil prices (boom and bust), and it may suffer when the resource declines or is replaced.
5. 1922 (signed November 24); Herbert Hoover, then Secretary of Commerce; Lees Ferry, Arizona; 7.5 million acre-feet a year each to the Upper and Lower Basins (with 1.5 million later promised to Mexico in 1944). The compact relied on stream records from unusually wet early-1900s years; longer gauge and tree-ring records suggest an average natural flow nearer 15 million acre-feet, less than the 16.5 million apportioned.
6. (a) 300,000 × 325,851 ≈ 97,800,000,000 gallons (about 97.8 billion); 300,000 × 1,233.5 ≈ 370,000,000 m^3 (0.37 km^3). (b) One person uses 150 × 365 = 54,750 gallons a year. 97,755,300,000 ÷ 54,750 ≈ 1,790,000 people, about 1.8 million.
7. (a) Oldest first: Town Y (1875) gets 300; Ranch X (1890) gets 400; 200 remain for Farm Z (1912), which receives 200 of its 400. (b) Under riparian rights, landowners along the creek share reasonable use, so in a shortage all would usually cut back together rather than the newest user losing first, and a user without land on the creek would have no right at all.
8. (a) 36 ft in 24 years = 1.5 ft (about 0.46 m) per year. (b) 84 − 30 = 54 ft; 54 ÷ 1.5 = 36 years, about 2056. (c) Any two: more efficient sprinklers or drip irrigation, metering and local pumping limits, switching to crops that need less water, soil-moisture measurement before irrigating, capturing more recharge.
9. Congress passed and President Wilson signed the Raker Act in December 1913, allowing San Francisco to dam the Tuolumne River in the Hetch Hetchy Valley inside Yosemite National Park for a city water supply (dam finished 1923, water delivered 1934). Muir (preservation): Hetch Hetchy was a rare natural wonder, a temple of creation inside a national park, and damming it would destroy something that could never be replaced. Pinchot (wise use): the greatest good for the greatest number meant using the valley to give clean water to a great city, which outweighed keeping it for the relatively few who visited.
10. Total: 148 + 36 + 64 + 92 + 40 + 20 = 400. Residential: 148 ÷ 400 = 37 percent; 0.37 × 640 = 236.8 acres. Transportation: 64 ÷ 400 = 16 percent; 102.4 acres. Agriculture: 92 ÷ 400 = 23 percent; 147.2 acres.
11. (a) 16 × 40 = 640 tons a year; 150 ÷ 16 ≈ 9.4 years per inch. (b) Bennett was the soil scientist who led the Soil Conservation Service after the Soil Conservation Act of 1935; it worked through local, voluntary districts run by farmers (the first, Brown Creek in North Carolina, in 1937), which taught contour plowing, terracing, strip cropping and windbreaks. (c) For: protects farmland and open country near the city and encourages reuse of land already built on. Against: limiting land for building raises housing prices and pushes families farther out, and it overrides owners’ and buyers’ choices.

12. (a) 1 percent. (b) $0.99^{25} \approx 0.778$; $1 - 0.778 \approx 0.22$, about 22 percent. (c) The 1 percent chance applies every year independently; a 100-year flood is a probability, not a schedule, so it can happen in consecutive years.
13. On September 8, 1900, a hurricane with winds of about 140 mph drove a surge of about 15 ft over an island whose highest ground was under 9 ft, killing roughly 6,000 to 8,000 people in the city, the deadliest U.S. natural disaster. Responses: a curved concrete seawall about 17 ft high (first 3.3 miles finished 1904, later about 10 miles) and the grade raising of 1904–1911, which pumped sand to lift the city as much as 17 ft behind the wall and raised more than 2,000 buildings. Galveston's site on a low barrier island remained exposed; Houston's site about 50 miles inland was safe from surge, and the Houston Ship Channel (1914) gave it a port situation with rail links, so investment moved there.
14. (a) A hazard is the natural event; exposure is how many people and how much property lie in its path; vulnerability is how easily they are harmed (building quality, warning, ability to evacuate). Risk is high only where all three combine. (b) Two magnitude units: about $32 \times 32 \approx 1{,}000$ times the energy. (c) Protect: the Galveston seawall, Mississippi levees or Dutch dikes. Adapt: Lisbon's gaiola pombalina buildings, Japan's building codes or houses raised on piers. White warned that levees encourage building behind them, so when a larger flood overtops them, losses are greater.

UNIT 10

Exam Review

A year of human geography has taken you from map projections to megacities, from the demographic transition to the world economy. This last unit gathers it all together for the final examination and, for students who will sit it, the AP Human Geography exam in May. It is not a unit of new content but of practice: writing free-response answers that apply the course's models to real places, reading maps and data under time pressure, reviewing every unit for the multiple-choice section, and sitting a full practice exam under real conditions.

Each lesson still begins with a real moment: Harry Beck redrawing the London Underground as a simplified diagram in 1931, Florence Nightingale persuading the British army with a diagram of deaths in 1858, Frederick Kelly devising one of the first multiple-choice tests in Kansas, and the crew of Apollo 17 photographing the whole sunlit Earth in 1972. Each one teaches a habit the exam rewards: simplifying wisely, reading graphics honestly, choosing carefully among answers, and seeing the whole at once.

As in the rest of the course, the models are reviewed as models: tools to be tested against evidence, with real strengths and real limits. Lesson 10.5 is the course **final examination**, covering Units 1–9, which is published separately. The unit test below may be given in the week before the final as a cumulative review. Exam format details are given as they have stood in recent years; check AP Central for any change before test day.

BEFORE YOU BEGIN

- Has completed Units 1–9 of this course, including their unit tests and the midterm
- Can calculate rates per 1,000, percent change, density, doubling time and location quotients
- Can read thematic maps, population pyramids and data tables
- Can write a clear paragraph that makes a claim and supports it with a specific real example

MASTERY CHECKLIST

- I can name, date and explain the standard models of the course and state one assumption and one limitation of each, with a real example.
- I can answer free-response parts that use each task verb (identify, define, describe, explain, compare, explain the degree to which) with plain, specific answers.
- I can read a map, graph, pyramid or table by its frame, pattern, cause and limits, and calculate the course's key measures from it.
- I can distinguish the confusable pairs of terms in every unit and answer multiple-choice items at a pace of about one per minute.
- I can sit a full timed practice exam, score it, and use an error log to plan my final review.

OPTIONAL BOOKS AND RESOURCES

- **AP Human Geography, College Board (AP Students)** (https://apstudents.collegeboard.org/courses/ap-human-geography): Free. The official course and exam page for students: exam date, format and timing for the current year, plus links to released free-response questions with their scoring guidelines (Lessons 10.1, 10.2 and 10.4). Check it before test day for any change in format.
- **International Database, U.S. Census Bureau** (https://www.census.gov/data-tools/demo/idb/): Free. Population estimates and projections by age and sex for every country, with population pyramids. Use it for the hand-drawn pyramids in Lesson 10.2 and for real birth, death and fertility rates.
- **Maps collection, Library of Congress** (https://www.loc.gov/maps/): Free. Thousands of historic and thematic maps, including census atlases and city maps, for practicing map reading and for the town-model project in Lesson 10.1.

10.1 Free-Response Practice: Models

OBJECTIVES

- Name, date and summarize the standard models of the course (demographic transition, Malthus, gravity, von Thünen, Burgess, Hoyt, multiple nuclei, bid-rent, central place, rank-size, Weber, Rostow, Wallerstein) and state the key assumption and limitation of each.
- Calculate with models: rate of natural increase and doubling time, von Thünen locational rent, and the gravity model, and explain what each result means.
- Write free-response answers to the AP task verbs (identify, define, describe, explain, compare) that apply a model to a real place and explain where it fits and where it fails.

Warm-up. Get a road map (paper or on a screen) of your area and a transit or subway diagram of any large city. Lay them side by side. In five minutes, list three things the road map shows that the subway diagram leaves out, and two things the diagram makes easier to see. Then answer in one sentence: is the diagram “wrong,” or is it useful because it leaves things out?

Watch. *The History of The London Underground* (Real Engineering, 9:01).
https://www.youtube.com/watch?v=lA9g7fDWnok
After the story: watch how the Underground was built and grew, and see whether the video shows why a tangle of lines across London needed a simpler map like Harry Beck's.
Note: Captions were not available to check; preview it first. The description shows a Skillshare sponsor, so there is probably a short sponsor message to skip. This could not be confirmed: the video seems to focus on how the Underground was engineered and built, and it may say little or nothing about Harry Beck's 1931 diagram.

KEY TERMS

model
A simplified picture of reality, built on stated assumptions, that isolates one or a few causes so their effect can be seen and tested.

assumption
A condition a model takes as given (a flat plain, one market, one center, rational choices). Most limitations of a model come from an assumption that real places break.

limitation
A way in which a model fails to describe or predict real places, usually because an assumption does not hold there.

task verb
The command word that tells you what an AP free-response part requires: identify, define, describe, explain, compare, or explain the degree to which.

gravity model

A model predicting that interaction between two places rises with their populations and falls with the square of the distance between them: interaction ∝ $(P_1 \times P_2) \div d^2$.

doubling time

The number of years a population needs to double at a steady growth rate; about 70 ÷ the annual growth rate in percent (the rule of 70).

CORE IDEAS

The story. In 1931 an engineering draftsman named Harry Beck, temporarily out of work from the London Underground, sat down with a sheet of paper and redrew the Underground map in his spare time. The old maps laid the lines over the streets at true scale, so the stations of central London were jammed together while the outer stations straggled across the page. Beck was used to clean technical drawings, and he saw that a rider underground does not care how far apart two stations really are, only which line to take and where to change. So he threw away true distance. He drew every line straight, set every bend at 45 or 90 degrees, spaced the stations evenly and enlarged the crowded center. The Underground's managers doubted that the public would accept a map that was so plainly "wrong," but they printed it in 1933, and riders loved it. Nearly every subway map in the world now follows Beck's plan. His diagram is the perfect picture of a **model**: it is useful precisely because it leaves things out.

How the free-response section works. As the AP Human Geography exam has stood in recent years (check AP Central for any change before you sit it), Section II gives you **three free-response questions in 75 minutes**, worth half your score. Each question has seven parts, A through G, and each part is worth one point. One question has no stimulus, one has one stimulus (a map, graph, table, photo or text), and one has two. Every part begins with a **task verb**. *Identify* means name it, briefly. *Define* means give the meaning. *Describe* means give the relevant characteristics. *Explain* means tell how or why, which almost always needs a "because." *Compare* means give similarities or differences. *Explain the degree to which* means judge how much, and give the reasons. Models appear in nearly every exam: you may be asked to identify a stage, describe what a model predicts, explain why a real place fits or does not fit, or explain a limitation.

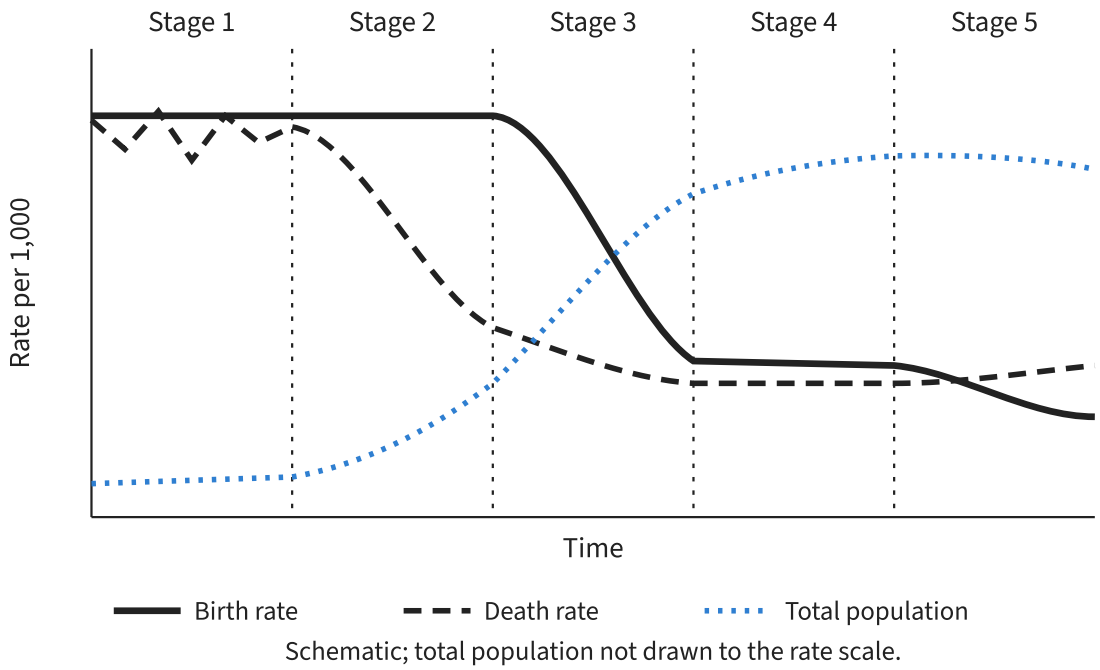
The big idea. The course has given you about a dozen models. In population: the **demographic transition model** (first sketched by Warren Thompson in 1929), whose five stages run from high birth and death rates, through falling death rates and then falling birth rates, to low rates and a debated fifth stage of decline; **Malthus** (1798), who argued that population grows faster than food; and the **gravity model** and Ravenstein's laws of migration (1885), which say that movement falls off with distance. In agriculture: **von Thünen** (1826), whose rings of land use show intensity falling with distance from market. In cities: **Burgess**'s concentric zones (Chicago, 1925), **Hoyt**'s sectors along transport lines (1939), **Harris and Ullman**'s multiple nuclei (1945), **bid-rent** theory (William Alonso, 1964), **Christaller**'s central places with threshold, range and hexagonal market areas (southern Germany, 1933), and the **rank-size rule** and its opposite, the **primate city** (Mark Jefferson, 1939). In industry and development: **Weber**'s least-cost location (1909), **Rostow**'s

five stages of growth (1960) and **Wallerstein**'s world-systems theory of core, semi-periphery and periphery (1974).

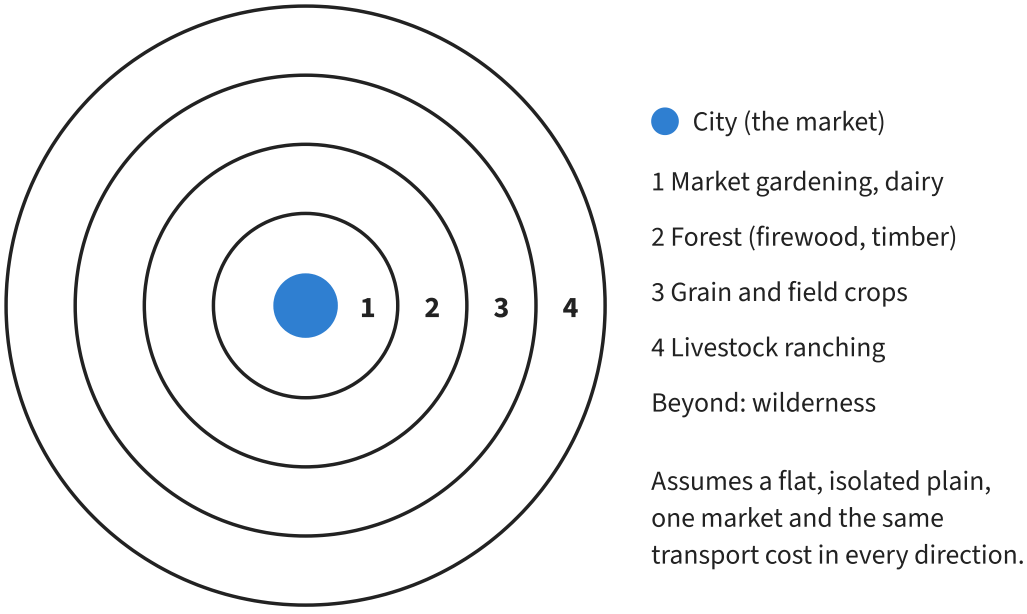
Every model has an assumption that breaks. The surest way to earn the "limitation" point is to name the assumption, name a real place that breaks it, and say what happens. The demographic transition model was drawn from European history; in many poorer countries after 1945, imported vaccines and antibiotics cut death rates in a few decades instead of a century, and the model cannot say when birth rates will fall, because that depends on choices shaped by faith, family and economy. Malthus could not foresee synthetic fertilizer (the Haber process, 1909) or the Green Revolution; world food output has outrun population since his day, and modern famines have mostly come from war and tyranny, such as the Soviet famine of 1932–33 and China's Great Leap Forward (1959–61). Von Thünen assumed a flat, isolated plain and wagon transport; refrigerated trucks and air freight put Chilean grapes in American stores in winter. Burgess assumed one center and walking or streetcar travel; Chicago itself sits on Lake Michigan, so its rings were really half-rings, and the automobile scattered offices and stores to the suburbs. Rostow assumed one path for every nation, modeled on Britain and America, and critics say he ignored a country's place in world trade; yet South Korea and Taiwan did pass through something like his stages in a single lifetime. Wallerstein's critics reply that he underrates what happens inside a country, such as property rights, honest courts and education, since states do climb from periphery toward core.

How to write a model answer. Good free-response writing is plain and specific. For an *explain* part, use a three-step sentence: **claim, model term, real case with a because**. Weak: "The DTM doesn't work everywhere." Strong: "The demographic transition model has trouble predicting Niger's future, *because* the model assumes birth rates fall as death rates fall, but in Niger the death rate has dropped while families still choose to have many children, so the population keeps growing fast." Write each part separately, label it (A), (B), (C), answer only what the verb asks, and do not spend time restating the question. A correct example from the real world nearly always helps; a vague one rarely does.

A Christian reading. Models are a form of the wisdom Proverbs commends: seeing order in a complicated world. But a model is a servant, not a master. People are not billiard balls; they marry, pray, choose, work and move, and nations rise and fall under the providence of God, who "hath determined the times before appointed, and the bounds of their habitation" (Acts 17:26). Use models the way Beck used his diagram: as honest simplifications that help, held loosely enough to notice where the real world is richer.

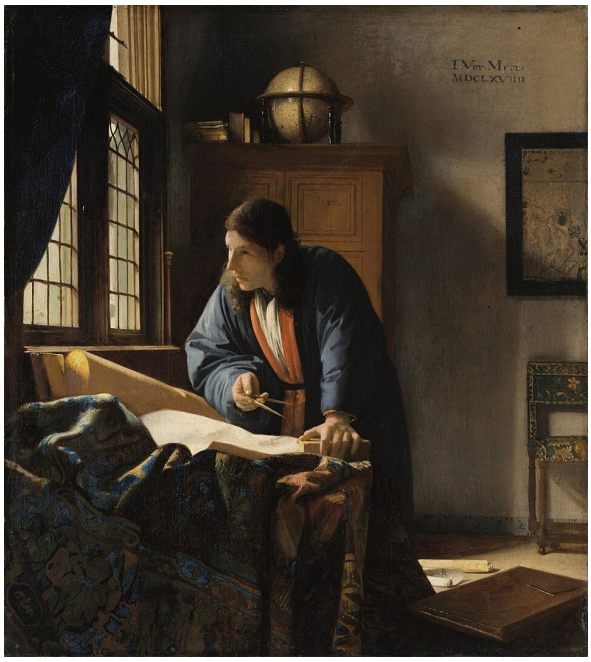


The demographic transition model. It describes Europe's history well; it predicts other countries' futures less reliably.



The von Thünen model in the simplified four-ring form used on the AP exam (Unit 6 showed his original six rings).

PICTURE STUDY



The Geographer, Johannes Vermeer, 1669 · Oil on canvas · Städel Museum, Frankfurt am Main

Johannes Vermeer of Delft painted only a few dozen pictures that survive, and two of them show men of science at work: *The Astronomer* and this one, *The Geographer*, which bears the date 1669. A scholar has paused over his work at a table spread with a chart. He holds a pair of dividers, the tool for measuring distances on a map, and he looks up toward the window as if an idea has just come to him.

The Dutch Republic of Vermeer's day was the map-making center of Europe. Amsterdam publishers such as the Blaeu family sold atlases, globes and sea charts to merchants and captains whose ships reached the East Indies, Africa and the Americas. Vermeer's geographer stands for that whole world of careful measurement: turning a huge, untidy earth into a sheet of paper a person can hold and reason about.

Look closely

- Find the dividers in the geographer's hand. What is he about to measure?
- Find the globe on top of the cabinet and the chart on the back wall. How many different kinds of map are in this room?
- Follow the light from the window. What does it fall on most brightly?
- Look at his face and posture. Is he copying something, or thinking something new?

Talk about it

1. A map, like a model, leaves most of the world out. What would this geographer have had to leave out to make his chart useful to a sea captain?
2. Why might Vermeer have painted the geographer looking away from his chart, toward the window and the real world?

3. Which model from this course would you most like to hand this geographer, and what would he say about its assumptions?

PROJECT: TEST A MODEL ON YOUR OWN TOWN

The best way to understand a model is to test it on a place you know. You will lay the Burgess, Hoyt and central place models over a real map of your own town or the nearest city, record where they fit and where they fail, and turn your findings into a seven-part free-response answer of your own.

You will need

- A printed street map of your town or nearest city (from a free online map, the county GIS website or the chamber of commerce), at least letter size
- Tracing paper or baking parchment
- A drawing compass or a string and pencil, a ruler and colored pencils
- A notebook for field notes; a parent and car for one short drive (optional but helpful)

Steps

1. Find the historic center of your town: the courthouse square, main street or old business district. Mark it with a star.
2. Use the map’s scale bar to draw rings on tracing paper at 1, 2, 3 and 5 kilometers (or ½, 1, 2 and 3 miles) from the star. Lay the tracing paper over the map.
3. Color the land uses you can identify: downtown offices and stores, factories and warehouses, older homes on small lots, newer homes on large lots, shopping centers, farms or open land. Use the map, a satellite view and, if you can, a drive through town.
4. Test Burgess: do the land uses form rings around the center? Circle in green any place that fits and in red any place that does not.
5. Test Hoyt: draw the main highways, rail lines and rivers in black. Do factories or wealthy neighborhoods stretch out along them in wedges?
6. Test Harris and Ullman: mark every second center (a mall, a university, an airport, an industrial park). Is your town really one center or several?
7. Test central place theory: list five services and where the nearest one is (gas station, grocery store, hospital, airport, university). Rank them from lowest threshold to highest and note the distance you must travel to each.
8. Write a seven-part answer (A to G) to this prompt: “Using your town as an example, (A) identify the urban model it fits best, (B) describe one pattern that fits it, (C) explain why, (D) describe one pattern that does not fit, (E) explain why, (F) explain one way transportation changed your town, (G) explain one limitation of the model you chose.”

Tips

- Small towns rarely fit the big-city models neatly. That is a finding, not a failure. Explain why.

- Physical features matter: a river, lake, ridge or railroad often explains more than any ring.

Check your work

- I can draw rings at true scale using a map’s scale bar.
- I can say which urban model fits my town best and give evidence for and against it.
- I can write an explain-answer with a claim, a model term and a real case with a because.

MAP NOTEBOOK

1. Draw a two-column “Model Wall”: in the left column sketch each model in miniature (rings, wedges, stages, hexagons, a core–periphery map); in the right column write its author, date and one key assumption.
2. Redraw a short stretch of your town’s main road as a Harry Beck diagram: straight lines, 45° bends, evenly spaced stops. Note what your diagram leaves out.
3. Copy the six task verbs (identify, define, describe, explain, compare, explain the degree to which). Beside each, write one sample question about the demographic transition model that uses that verb.

> **From history.** Harry Beck was paid only a small fee for the diagram that made his name, and he went on revising it for more than twenty-five years. The map London riders use today is still recognizably his, and transit systems around the world follow the same plan of straight lines, fixed angles and evenly spaced stops. It is one of the most copied designs ever made, and a good reminder that a model which leaves out the right things can outlast the “realistic” maps it replaced.

WORKED EXAMPLES

Example 1. Country P has a crude birth rate (CBR) of 44 per 1,000 and a crude death rate (CDR) of 11 per 1,000. Country Q has a CBR of 6 and a CDR of 13, figures close to Japan's in the early 2020s. For each, find the rate of natural increase (RNI) in percent, the doubling time where it applies, and the stage of the demographic transition model.

(Use the map or drawing "Place each country on the graph: P in stage 2, Q in stage 5." shown earlier in this lesson.)

1. RNI (%) = (CBR − CDR) ÷ 10.
2. Country P: (44 − 11) ÷ 10 = 3.3% per year. Doubling time ≈ 70 ÷ 3.3 ≈ 21 years.
3. Country Q: (6 − 13) ÷ 10 = −0.7% per year. The population is shrinking by natural change, so there is no doubling time.
4. Stages: P has a high birth rate and a death rate that has already fallen, which is stage 2. Q has a very low birth rate below its death rate, which fits the proposed stage 5.

Answer: P: RNI 3.3%, doubling in about 21 years, stage 2. Q: RNI −0.7%, no doubling (natural decrease), stage 5. A full answer adds a limitation: the model cannot tell us when P's birth rate will fall, since that depends on families' choices, not only on falling death rates.

Example 2. On a von Thünen plain, vegetables yield 20 tons per hectare, sell for $100 a ton and cost $60 a ton to grow, with freight of $2 per ton per kilometer. Grain yields 4 tons per hectare, sells for $150 a ton and costs $50 a ton to grow, with freight of $1 per ton per kilometer. Using locational rent $R = Y(p - c) - Yfd$, find where each crop stops paying, and where grain replaces vegetables.

(Use the map or drawing "The vegetable ring (1) lies inside the grain ring (3); in this example there is " shown earlier in this lesson.)

1. Vegetables: $R = 20(100 - 60) - 20 \times 2 \times d = 800 - 40d$ dollars per hectare. $R = 0$ when $d = 800 \div 40 = 20$ km (about 12 mi).
2. Grain: $R = 4(150 - 50) - 4 \times 1 \times d = 400 - 4d$. $R = 0$ when $d = 400 \div 4 = 100$ km (about 62 mi).
3. The crossover is where the two rents are equal: $800 - 40d = 400 - 4d$, so $400 = 36d$ and $d \approx 11.1$ km (about 6.9 mi).
4. Inside 11.1 km vegetables pay the higher rent; from 11.1 km to 100 km grain pays more; beyond 100 km neither pays.

Answer: Vegetables would stop paying at 20 km and grain at 100 km, but grain outbids vegetables from about 11.1 km (6.9 mi) outward. So the vegetable ring runs from the market to 11.1 km and the grain ring from 11.1 km to 100 km (62 mi). The steep rent line of the perishable, heavy crop is what pins it close to market.

Example 3. Use the gravity model, interaction $\propto (P_1 \times P_2) \div d^2$, with populations in millions and distance in kilometers. City A (2 million) is 100 km (62 mi) from City B (1 million) and 200 km (124 mi) from City C (4 million). Which pair should have more interaction: A–B or A–C?

1. A–B: $(2 \times 1) \div 100^2 = 2 \div 10{,}000 = 0.0002$.
2. A–C: $(2 \times 4) \div 200^2 = 8 \div 40{,}000 = 0.0002$.
3. The two indexes are equal. Doubling the distance cuts interaction to one quarter (because distance is squared), and City C, being four times as large as B, exactly makes up for it.

Answer: The model predicts equal interaction for A–B and A–C. The example shows the two forces of the model in balance: population pulls interaction up and distance squared pulls it down. Real interaction would also depend on things the model leaves out, such as a shared language, a highway or a border crossing.

PRACTICE

1. EASY List Rostow's five stages of economic growth in order and give the year of his book.

2. EASY Match each model to its author and date: concentric zones, sectors, multiple nuclei, central place theory, least-cost industrial location, world-systems theory.
3. EASY Use the graph (he-u10-dtm). In which stage is the birth rate still high while the death rate falls steeply, so that the population grows fastest?
   (Use the map or drawing "Find the stage where the two rate lines are farthest apart." shown earlier in this lesson.)
4. MEDIUM A country has a CBR of 38 per 1,000 and a CDR of 9 per 1,000. Find its RNI and doubling time, and name its stage in the demographic transition model.
5. MEDIUM Using the gravity model with populations in millions: City X (6 million) is 300 km from City Y (2 million) and 100 km from City Z (1 million). Which pair should interact more, and by what factor?
6. MEDIUM A country's largest city has 12 million people and its second-largest has 2 million. What does the rank-size rule predict for the second city? What pattern does the country show instead? Name one country often given as an example.
7. MEDIUM Define threshold and range in central place theory, and explain why a small town has a gas station but not a heart surgeon.
8. MEDIUM According to Weber, where should (a) a soft-drink bottling plant and (b) a copper smelter locate? Explain each.
9. HARD Explain one limitation of the Burgess concentric-zone model, using a real example.
10. HARD Classify each in Wallerstein's world-systems theory as it is commonly applied today: Germany, Brazil, Chad, Japan, India. Then state one criticism of the model.
11. HARD State Malthus's argument (1798) and give two pieces of evidence against his prediction from the two centuries since.
12. CHALLENGE Write answers to this three-part free-response item. (A) Identify the stage of the demographic transition model in which most of Western Europe lay around 1850. (B) Describe the change in the death rate during that stage. (C) Explain one reason the model may not accurately predict the population change of a country in sub-Saharan Africa today.

COMMON MISTAKES

- Describing a model when the question asks for a limitation. A limitation names an assumption, a real place that breaks it, and the result.
- Writing "the model doesn't fit everywhere" with no example. Vague answers almost never earn the point; a specific real place almost always helps.
- Mixing up the urban models: Burgess is rings, Hoyt is wedges along transport lines, Harris and Ullman is several centers. Remember the dates in order: 1925, 1939, 1945.

> **Make it a game · Model Match-Up.** Make three sets of index cards: thirteen model names, thirteen authors and dates, and thirteen "broken assumptions" (for example, "a city on a lake," "refrigerated trucks," "imported vaccines"). Deal them face down in a grid. Players turn over three cards per turn and keep any matching name, author and assumption, explaining aloud why the assumption breaks that model. A correct trio with a real example scores 3 points; without an example, 2. Play until the grid is empty.

> **Scripture.** “Wisdom is the principal thing; therefore get wisdom: and with all thy getting get understanding.” (Proverbs 4:7, KJV)

Memorizing a model is knowledge; knowing when it fits and when it fails is understanding. The exam rewards both, and so does life.

Practice answers

1. (1) Traditional society, (2) preconditions for take-off, (3) take-off, (4) drive to maturity, (5) age of high mass consumption. *The Stages of Economic Growth*, 1960.
2. Concentric zones: Ernest Burgess, 1925. Sectors: Homer Hoyt, 1939. Multiple nuclei: Chauncy Harris and Edward Ullman, 1945. Central place theory: Walter Christaller, 1933. Least-cost location: Alfred Weber, 1909. World-systems: Immanuel Wallerstein, 1974.
3. Stage 2.
4. RNI = (38 − 9) ÷ 10 = 2.9% per year. Doubling time ≈ 70 ÷ 2.9 ≈ 24 years. Stage 2 (high birth rate, death rate already low).
5. X–Y: (6 × 2) ÷ 300^2 = 12 ÷ 90,000 ≈ 0.000133. X–Z: (6 × 1) ÷ 100^2 = 6 ÷ 10,000 = 0.0006. X–Z interacts more, by 0.0006 ÷ 0.000133 = 4.5 times. Distance outweighs Y’s larger size.
6. Rank-size predicts 12 ÷ 2 = 6 million. The actual second city is only a third of that, so the country has a primate city: one city far larger than the rest and dominant in its economy and politics. Thailand (Bangkok) is a classic example; Peru (Lima) is another.
7. Threshold is the minimum number of customers needed to support a good or service; range is the maximum distance people will travel to get it. A gas station has a low threshold and a short range, so many small towns can support one. A heart surgeon needs a very large population to stay busy (high threshold), and patients will travel far for one (long range), so such surgeons cluster in large central places.
8. (a) Near the market: bottling is a weight-gaining (bulk-gaining) process, since water is added, so the finished product costs more to ship than the inputs. (b) Near the mine: smelting is weight-losing (bulk-reducing), since most of the ore is waste rock, so it is cheaper to remove the waste before shipping.
9. Sample: Burgess assumed a city grows evenly in all directions from one center over flat land, but Chicago, the city he studied, lies on Lake Michigan, so its zones were half-rings, and later automobile suburbs, highways and outlying office parks created many centers. Other acceptable limits: it was based on one American industrial city of the 1920s; it does not fit Latin American or European cities, where the wealthy often live near the center.
10. Germany: core. Brazil: semi-periphery. Chad: periphery. Japan: core. India: semi-periphery (classifications vary by author). Criticism: it explains a country’s wealth mainly by its place in world trade and underrates internal factors such as property rights, honest courts, education and stable government; countries such as South Korea have moved from periphery toward core.
11. Malthus argued that population tends to grow geometrically while food grows only arithmetically, so population would outrun food until checked by famine, disease, war or restraint. Evidence against: world population rose from about 1 billion around 1800 to about 8 billion by 2022, yet food output per person rose; synthetic fertilizer (the Haber process, 1909) and the Green Revolution (Norman Borlaug’s wheat, 1950s–1960s) multiplied yields; most modern famines came from war and tyranny (Soviet famine of 1932–33, China’s Great Leap Forward of 1959–61), not from population outrunning the earth’s capacity.

12. (A) Stage 2. (B) The death rate fell steadily while the birth rate stayed high, so the population grew quickly. (C) Sample: the model assumes that birth rates will fall after death rates, as they did in Europe with industry and city life, but in many sub-Saharan countries death rates fell rapidly after 1950 because of imported vaccines and medicines, while most people still live in farming villages where large families are valued, so birth rates have stayed high longer than the model predicts. (One point per part; each must answer its own task verb.)

10.2 Free-Response Practice: Maps and Data

OBJECTIVES

- Read any map or data stimulus systematically (title, key, scale, date, source, units) and choose the right map type and projection for a purpose.
- Calculate and interpret the key measures of the course: rates per 1,000, rate of natural increase, total fertility, infant mortality, dependency ratio, arithmetic and physiological density, and location quotient.
- Write free-response answers that identify a pattern in a stimulus, explain its cause, and explain a limitation of the data or the map.

Warm-up. Take any chart or map from a newspaper, magazine or website. Set a timer for five minutes and write down, in order: its title, what the colors or symbols mean, the units, the date of the data, the source, and the one pattern your eye sees first. Then ask: what does this graphic leave out, and could it mislead someone in a hurry?

Video. Coming soon. Reading thematic maps, population pyramids and census data; Florence Nightingale's statistical diagrams and William Playfair's first charts: search Library of Congress (Geography and Map Division), NASA Earth Observatory (data maps), Hillsdale Studios, The History Guy; U.S. Census Bureau and AP Human Geography teacher review channels are candidates that need vetting (never CrashCourse).

KEY TERMS

choropleth map
A thematic map that shades areas (counties, states, countries) by the value of a rate or ratio, such as density or percent. It should map rates, not raw totals.

dependency ratio
The number of people of dependent age (under 15 and 65 and over) for every 100 people of working age (15 to 64).

physiological density
The number of people per unit of arable (farmable) land; it shows the pressure of population on the land that feeds it.

location quotient
A ratio comparing a place's share of some activity to the nation's share: LQ = (local share) ÷ (national share). Above 1 means the place specializes in it.

total fertility rate (TFR)
The average number of children a woman would bear over her lifetime at current birth rates. About 2.1 is replacement level in countries with low death rates.

scale of analysis
The level at which data are gathered or mapped (local, regional, national, global). A pattern visible at one scale can vanish or reverse at another.

CORE IDEAS

The story. In November 1854 Florence Nightingale arrived at the British army hospital at Scutari, across the Bosporus from Constantinople, with a party of thirty-eight nurses. The Crimean War was in its first winter. She found wards without proper drains, water or ventilation, and soldiers dying in great numbers, most of them not from wounds but from cholera, typhus and dysentery. After a sanitary commission cleaned the drains and improved ventilation in the spring of 1855, the death rate fell sharply. When Nightingale came home she was determined that the army should never forget the lesson, and she knew that tables of figures would not move busy officials. So in 1858 she published a diagram. Two roses of colored wedges, one for each year of the war, showed deaths month by month: blue-gray wedges for preventable disease, red for wounds, black for other causes. The blue-gray swamped everything else. Anyone could see at a glance that far more soldiers had died of dirt than of Russian guns. The diagram helped win reforms in army hospitals and barracks, and it is still studied as one of the great data graphics.

How the stimulus questions work. At least two of the three free-response questions on the AP exam, and many multiple-choice sets, give you a **stimulus**: a map, graph, table, photograph or passage. Read it the way Nightingale wanted hers read. First the **frame**: title, key, units, scale, date and source. Then the **pattern**: what is high, what is low, where are the clusters, what changes over time. Then the **cause**: which concept from the course explains the pattern. Finally the **limits**: what the stimulus cannot show. Free-response parts often ask for exactly these four steps in order: identify the pattern, describe it, explain it, and explain a limitation of the data.

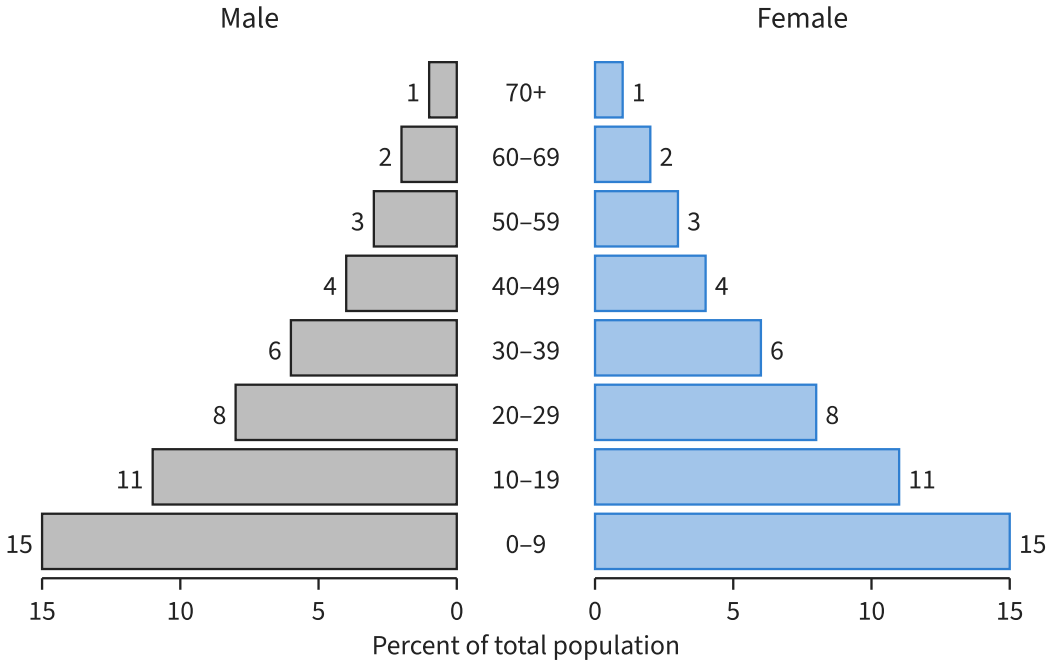
Maps. Know the map types and when each fits. A **choropleth** map shades areas by a rate (people per square mile, percent over 65); it misleads when it maps raw totals, because big areas look important whatever their density. A **dot density** map shows distribution, one dot for so many people. A **graduated** or **proportional symbol** map sizes circles by quantity, good for city populations. An **isoline** map connects points of equal value, such as elevation or travel time. A **flow** map draws arrows whose width shows the volume of migration or trade. A **cartogram** resizes countries by a value such as population, so India and China swell and Canada and Russia shrink. Every flat map uses a **projection** and distorts shape, area, distance or direction. Mercator’s projection (1569) keeps angles true for navigation but enlarges high latitudes, so Greenland looks as large as Africa, which is about fourteen times bigger. Equal-area projections such as the Gall–Peters keep area true but stretch shapes; compromise projections such as the Robinson (1963) distort everything a little. Remember that a **large-scale** map (1:24,000) shows a small area in great detail and a **small-scale** map (1:10,000,000) shows a large area with little detail.

Data. Most population measures are rates, so places of different size can be compared. Crude birth and death rates are per 1,000 people; the rate of natural increase is their difference divided by 10, in percent; doubling time is about 70 divided by that percent. The **infant mortality rate** is infant deaths per 1,000 live births, and it is one of the best single measures of a society’s health. The **total fertility rate** tells you whether each generation will replace the one before; many countries in Europe and East Asia were below 1.5 as of the

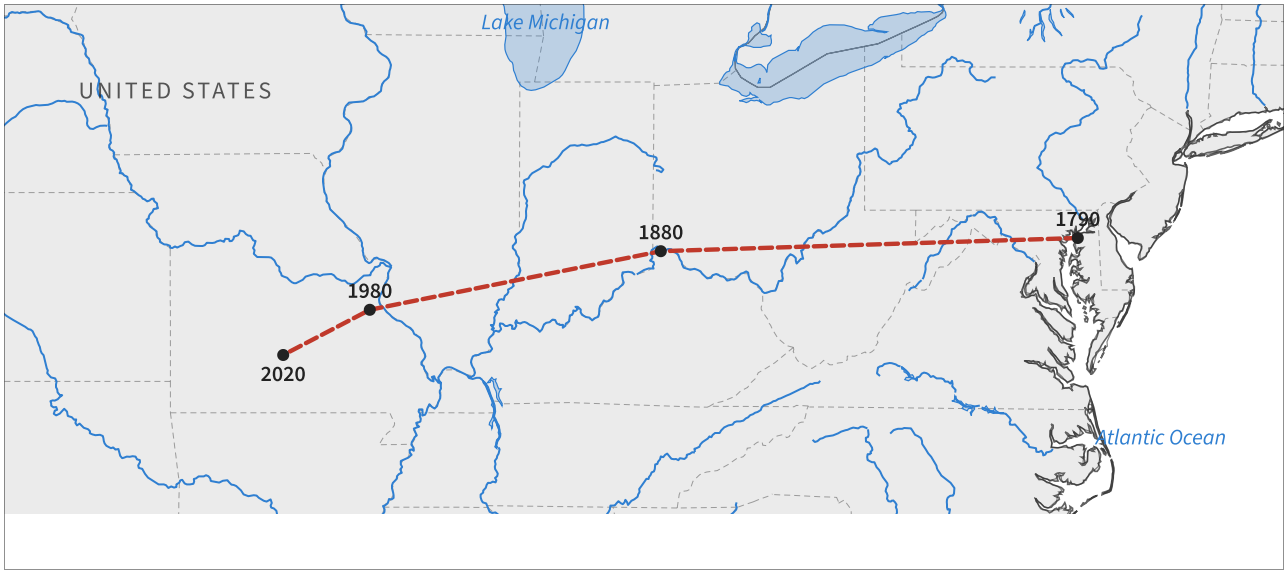
mid-2020s, while several in sub-Saharan Africa were above 5. A **population pyramid** shows the age and sex structure: a wide base means many children and fast growth; straight sides mean slow growth; a narrow base means decline. Density comes in three kinds: **arithmetic** (people per total land), **physiological** (people per arable land) and **agricultural** (farmers per arable land). Development is measured by GDP or GNI per person, often adjusted for purchasing power, and by the **Human Development Index** (introduced by the United Nations in 1990), which combines life expectancy, schooling and income. The **location quotient** shows what a place specializes in.

The limits of data. The surest "limitation" answers for data are these. **Scale**: a state average hides differences between its counties, and a national average hides its regions. **Totals versus rates**: a large population produces large totals even where the rate is low. **Date**: data age quickly, especially for fast-growing places. **Collection**: censuses miss some people, poorer countries may count less often, and definitions (of "urban," of "literate") differ from country to country. **Averages**: GDP per person says nothing about how income is spread. And a pattern across areas does not prove that every person in the area fits it; geographers call that mistake the ecological fallacy.

A Christian reading. "A false balance is abomination to the LORD: but a just weight is his delight" (Proverbs 11:1). Honest maps and honest numbers are a form of just weights. Nightingale, a devout Christian who believed her work was a calling from God, used figures to protect the lives of common soldiers. A geographer who chooses a projection, a scale or a color scheme to make a point should make it truthfully, and a careful reader should always ask what a graphic leaves out.



Country X, a hypothetical expansive pyramid. Each bar is the percent of the whole population in that age band and sex.



The mean center of U.S. population, 1790–2020 (U.S. Census Bureau locations, rounded).

PICTURE STUDY

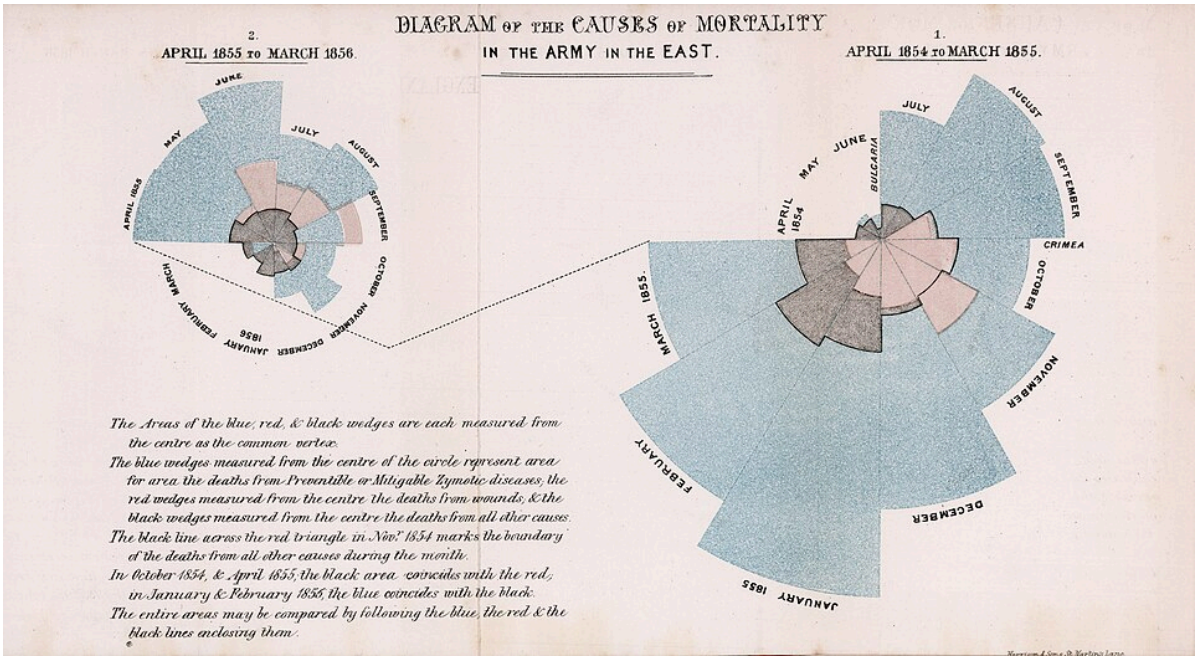


Diagram of the Causes of Mortality in the Army in the East, Florence Nightingale, 1858 · Color-printed diagram (lithograph) published in her report on the health of the British Army · Printed copies survive in many libraries; a widely used scan is on Wikimedia Commons

Florence Nightingale is remembered as the founder of modern nursing, but she was also one of the best statisticians of her century. This diagram compares deaths in the British army in the East month by month: the right-hand rose covers April 1854 to March 1855, and the left-hand rose April 1855 to March 1856. Each wedge's area, measured from the center, stands for the number of deaths that month.

The blue-gray areas are deaths from preventable or "zymotic" diseases such as cholera and typhus; the red are deaths from wounds; the black are all other causes. The second rose is

much smaller than the first, because sanitary reforms in the spring of 1855 cut the deaths from disease dramatically. Nightingale wanted the diagram to speak to people who would never read a table.

Look closely

- Find the largest wedge in the whole diagram. Which month and which cause does it show?
- Compare the red wedges to the blue-gray ones. About how many times larger is the blue-gray area in the worst months?
- Compare the two roses. What changed between the first year and the second?
- Find the dates and the key. How does Nightingale tell you how to read her picture?

Talk about it

1. Why might a picture persuade a government official more than a table of the same numbers?
2. What is one limitation of this diagram? (Think about how hard it is to compare areas of wedges exactly.)
3. How is this diagram like a choropleth or proportional symbol map, and how is it different?

PROJECT: HAND-DRAWN PYRAMIDS AND TWO MAPS OF THE SAME DATA

On the exam you must read graphics quickly. The fastest way to learn to read them is to draw them yourself. You will build two population pyramids by hand from real census data, then map one set of county data two different ways and see how the choice of map changes the story.

You will need

- Graph paper, a ruler, two colored pencils
- Internet access to the U.S. Census Bureau International Database (for pyramids) and the Census QuickFacts pages for your state’s counties
- An outline map of your state with county boundaries (printed twice)

Steps

1. From the International Database, look up the population by five-year age groups and sex for two countries in different stages of the demographic transition: for example Niger and Japan. Write the percents in a table.
2. On graph paper, draw a vertical age axis in the center and a horizontal percent axis to each side, with the same scale for both pyramids (for example, 1 square = 1 percent). Draw both pyramids, males on the left, females on the right.
3. Under each pyramid, calculate the dependency ratio: (under 15 + 65 and over) ÷ (15 to 64) × 100.

4. From QuickFacts, choose ten or more counties of your state. Record each county's total population and its land area, and calculate density.
5. On your first outline map, draw a proportional circle on each county for its total population. On the second, shade each county by density in four classes (choropleth).
6. Compare the maps. Which county looks most important on each? Write a paragraph explaining why the choropleth must use density rather than totals.

Tips

- Use the same horizontal scale on both pyramids, or the comparison is meaningless.
- Choose class breaks for the choropleth that separate the data sensibly; write the breaks in your key.

Check your work

- I can draw a population pyramid from a table and read its stage.
- I can calculate a dependency ratio and a density.
- I can explain why choropleth maps should show rates, not totals.

MAP NOTEBOOK

1. Draw three tiny pyramid outlines (expansive, stationary, contracting) and label each with its demographic transition stage and one real country that fits it.
2. Make a one-page "Map Type Gallery": a thumbnail of a choropleth, dot density, proportional symbol, isoline, flow map and cartogram, each with one sentence on when to use it.
3. Copy the frame–pattern–cause–limits checklist into your notebook and use it on Nightingale's diagram.

> **From history.** Nightingale was not the first to draw data. In 1786 the Scottish engineer William Playfair published *The Commercial and Political Atlas*, with the first line graphs and bar charts of trade, and in 1801 his *Statistical Breviary* introduced the pie chart. Playfair argued that a picture lets the eye take in at once what columns of numbers make the mind labor over, which is exactly what the AP exam asks you to do with every stimulus.

WORKED EXAMPLES

Example 1. A county has 50,000 jobs, of which 9,000 are in manufacturing. In the United States as a whole, about 8 percent of jobs are in manufacturing. Find the county's location quotient (LQ) for manufacturing and interpret it.

1. County share = 9,000 ÷ 50,000 = 0.18, or 18%.
2. National share = 8%.
3. LQ = 18 ÷ 8 = 2.25.

Answer: LQ ≈ 2.25. The county has about 2¼ times the national share of manufacturing jobs, so it specializes in manufacturing and probably exports manufactured goods to other places. An LQ of 1 would mean an average share; below 1 would mean less than average.

Example 2. Country M has 12 million people aged 0–14, 40 million aged 15–64 and 8 million aged 65 and over. Find its total, youth and old-age dependency ratios, and explain what they mean.

1. Total dependency ratio = (12 + 8) ÷ 40 × 100 = 20 ÷ 40 × 100 = 50.
2. Youth dependency ratio = 12 ÷ 40 × 100 = 30.
3. Old-age dependency ratio = 8 ÷ 40 × 100 = 20.

Answer: Total 50, youth 30, old age 20: there are 50 dependents (30 children and 20 elderly) for every 100 people of working age. A country with a rising old-age ratio must plan for pensions and health care with relatively fewer workers; a country with a high youth ratio must plan for schools and jobs.

Example 3. Use the map (he-u10-uscenter). The mean center of U.S. population was near 39.3° N, 76.2° W in 1790 and near 37.4° N, 92.3° W in 2020. At about 38° N, one degree of longitude spans about 87.4 km, and one degree of latitude about 111 km. Estimate how far the center moved and its average speed.

(Use the map or drawing "From Kent County, Maryland (1790) to near Hartville, Missouri (2020)." shown earlier in this lesson.)

1. East–west change: 92.3 − 76.2 = 16.1° of longitude; 16.1 × 87.4 ≈ 1,407 km.
2. North–south change: 39.3 − 37.4 = 1.9° of latitude; 1.9 × 111 ≈ 211 km.
3. Straight-line distance ≈ √(1,407² + 211²) ≈ √2,024,000 ≈ 1,423 km, about 1,420 km or 880 miles.
4. Years: 2020 − 1790 = 230. Average speed ≈ 1,420 ÷ 230 ≈ 6.2 km (3.8 mi) per year.

Answer: About 1,420 km (880 mi) toward the west-southwest, averaging about 6 km (4 mi) a year. The westward movement reflects settlement of the interior and West; the southward drift since the mid-1900s reflects growth in the South and Southwest (the Sun Belt).

PRACTICE

1. EASY Which map type would you use to show (a) the percent of each county's people over age 65, (b) the population of the 25 largest U.S. cities, (c) the number of immigrants moving between countries?
2. EASY Which map has the larger scale and shows more detail: 1:24,000 or 1:1,000,000? On the 1:24,000 map, how many feet does 1 inch represent?
3. EASY Africa covers about 30.4 million km² and Greenland about 2.2 million km². About how many times larger is Africa? Why do they look similar in size on a Mercator map?
4. MEDIUM Use the pyramid (he-u10-pyramid). What percent of Country X's population is under 20? What stage of the demographic transition does its shape suggest?
   (Use the map or drawing "Add both sides of each band you need." shown earlier in this lesson.)
5. MEDIUM Use the pyramid (he-u10-pyramid). What percent of the population is 60 or older? How many times larger is the 0–9 group than the 60–69 group? Name one service the government of Country X must plan for most.
   (Use the map or drawing "Compare the top bars with the bottom bars." shown earlier in this lesson.)
6. MEDIUM A country has a total fertility rate of 1.3. What does this mean, and what will happen to its population over time if nothing changes and there is no immigration?
7. MEDIUM A region recorded 30,000 live births and 450 deaths of infants under one year old in a year. Find its infant mortality rate.
8. MEDIUM Use the map (he-u10-uscenter). Describe the direction the mean center of population moved between 1790 and 1880 and between 1980 and 2020, and give one reason for each.
   (Use the map or drawing "Compare the direction of each segment." shown earlier in this lesson.)

9. HARD The first U.S. census (1790) counted about 3.9 million people; the 2020 census counted about 331 million. By what factor did the population grow? Why is it more useful to compare density or growth rates than totals when mapping these years?
10. HARD In a farm state, 4.0% of jobs are in agriculture; nationally the figure is 1.3%. Find the location quotient and interpret it.
11. HARD A choropleth map shows median household income by state. Explain two ways the map could mislead a reader.
12. CHALLENGE Country A has 50 million people, 500,000 km² of land, and 10% of it arable. Country B has 50 million people, 200,000 km² of land, and 50% of it arable. Compute arithmetic and physiological density for each, and explain which country faces greater pressure on its farmland.

COMMON MISTAKES

- Describing a graph without explaining it. “Births are high” identifies; an explain-answer gives the cause with a because.
- Mixing up large and small scale. Large scale means a small area shown large, with much detail (1:24,000).
- Forgetting to add both sides of a population pyramid, or reading a pyramid’s percents as counts of people.

> **Make it a game · Sixty-Second Stimulus.** One player shows a map, graph or pyramid (from this lesson, an atlas or the census) for sixty seconds. The other must state its frame (title, units, date), one pattern, one cause and one limitation before time runs out. Each correct element scores 1 point, with a bonus point for using a course term correctly (choropleth, dependency ratio, scale of analysis). Switch roles and play five rounds each.

> **Scripture.** “It is the glory of God to conceal a thing: but the honour of kings is to search out a matter.” (Proverbs 25:2, KJV)

The patterns in a map or a column of figures are not obvious at first glance; they must be searched out. That patient searching is part of the honor God gives to people made in His image.

Practice answers

1. (a) Choropleth (a rate by area). (b) Proportional (graduated) symbol map. (c) Flow map, with arrow widths showing the number of migrants.
2. 1:24,000 is the larger scale and shows more detail of a smaller area. 1 inch = 24,000 inches = 2,000 feet.
3. 30.4 ÷ 2.2 ≈ 14 times larger. Mercator’s projection keeps angles true for navigation by stretching the map more and more toward the poles, so high-latitude lands such as Greenland are greatly enlarged.
4. Ages 0–9: 15 + 15 = 30%; ages 10–19: 11 + 11 = 22%; total 52% under 20. The wide base and steep narrowing suggest stage 2 (high births, falling deaths, rapid growth).

5. 60–69: 2 + 2 = 4%; 70+: 1 + 1 = 2%; total 6%. The 0–9 group (30%) is 30 ÷ 4 = 7.5 times the 60–69 group (4%). Schools (also child health care, and jobs for the large cohorts entering adulthood).
6. On average a woman would have 1.3 children in her lifetime, well below the replacement level of about 2.1. Each generation will be smaller than the one before; the population will age and, after a lag, shrink.
7. 450 ÷ 30,000 × 1,000 = 15 infant deaths per 1,000 live births.
8. 1790–1880: almost due west, as settlers moved across the Appalachians into the Ohio Valley, the Midwest and beyond, helped by canals and railroads. 1980–2020: west-southwest, as population grew faster in the South and West (the Sun Belt), drawn by jobs, lower costs, a warm climate and air conditioning.
9. 331 ÷ 3.9 ≈ 85 times. Totals mostly reflect the size of an area and the number of years of growth; rates such as density (people per square mile) or annual growth let places of different size and different periods be compared fairly, and choropleth maps should always show rates.
10. LQ = 4.0 ÷ 1.3 ≈ 3.1. The state has about three times the national share of agricultural jobs, so agriculture is a specialty and likely a basic (export) sector of its economy.
11. Any two: (1) Scale: a state value hides large differences between rich and poor counties or neighborhoods. (2) Ecological fallacy: a reader may wrongly assume every household in a high-income state is well-off. (3) Class breaks and colors chosen by the mapmaker can exaggerate or hide differences. (4) Large, thinly peopled states dominate the map visually even though few people live there. (5) Income is not adjusted for differences in living costs.
12. A: arithmetic 50,000,000 ÷ 500,000 = 100 per km²; arable land 50,000 km²; physiological 50,000,000 ÷ 50,000 = 1,000 per km². B: arithmetic 50,000,000 ÷ 200,000 = 250 per km²; arable land 100,000 km²; physiological 500 per km². A looks less crowded by arithmetic density but has twice B’s physiological density, so its farmland is under greater pressure; it may need to farm more intensively or import food. (Egypt, with nearly all its people on the narrow Nile farmland, is a real case like A.)

10.3 Multiple-Choice Review

OBJECTIVES

- Review the key concepts, terms and models of all nine content units, grouped into the seven units of the AP Human Geography framework, with special care for pairs of terms that are easily confused.
- Use a reliable method for multiple-choice items: read the stem, predict, eliminate, check qualifiers (NOT, EXCEPT, BEST) and read stimulus sets carefully.
- Build and use a spaced-review system (a Leitner box) and practice under timed conditions at the exam's pace of about one minute per question.

Warm-up. Take ten index cards. In five minutes, without looking at your notes, write one course term on the front of each card and its definition on the back, from memory. Then check your notes. Put the cards you got exactly right in one pile and the rest in another. The second pile is your first study list, and you have just practiced the most effective study method there is: trying to recall.

Video. Coming soon. AP Human Geography unit-by-unit review (diffusion, language families, boundaries, agriculture, urban models, development); Holbein's "The Ambassadors" and its instruments: search Hillsdale Studios, The History Guy, Library of Congress, NASA Earth Observatory; AP review channels by individual teachers are candidates that need careful vetting for ideological framing (never CrashCourse).

KEY TERMS

stem
The question part of a multiple-choice item, before the answer choices. Read it fully and predict an answer before looking at the choices.

distractor
A wrong answer choice written to look plausible, often a true statement that does not answer the question asked.

stimulus set
A group of multiple-choice questions that share one map, graph, table, image or passage.

retrieval practice
Studying by trying to recall information from memory (flash cards, practice questions) rather than rereading it; one of the best-tested ways to remember.

spaced repetition
Reviewing material at growing intervals (a day, a few days, a week) rather than all at once, so that it moves into long-term memory.

rank-size rule
The pattern in which a country's nth-largest city has about 1/n the population of the largest city.

CORE IDEAS

The story. In 1914 and 1915 Frederick J. Kelly, a school administrator in Kansas, faced a practical problem: how to test the reading of thousands of children quickly and grade the tests fairly, without each teacher's judgment tilting the scores. His answer was the Kansas Silent Reading Test, usually named as the first multiple-choice test: short passages followed by questions answered by marking one of several printed choices. Within a few years the U.S. Army was testing nearly two million recruits in World War I with multiple-choice examinations, and in 1926 the first SAT was given. AP Human Geography was first examined in 2001. You are the heir of Kelly's idea: a single best answer, marked quickly, among choices built to catch half-learned ideas.

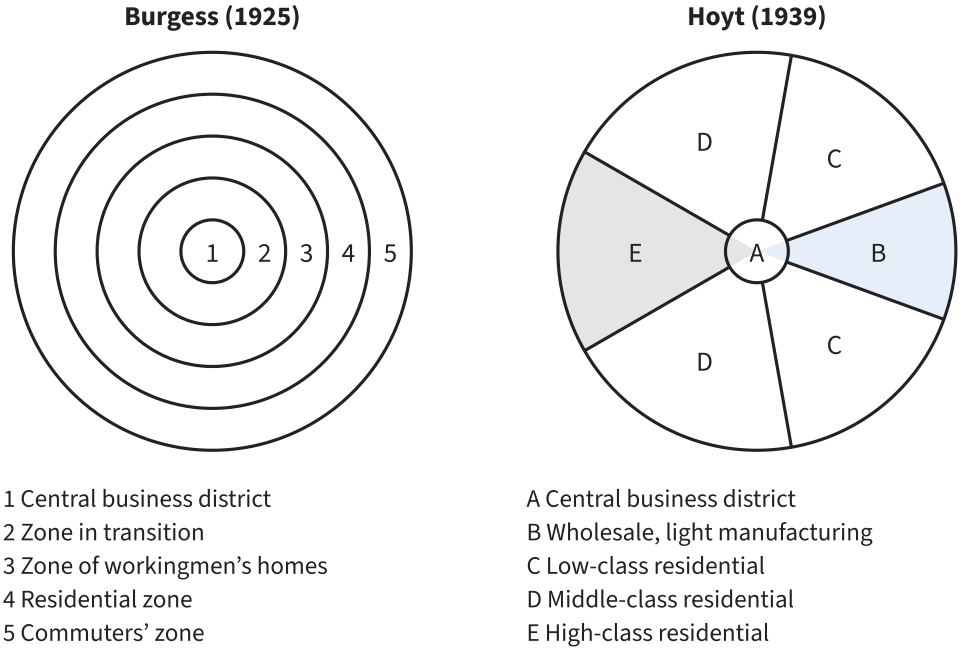
How the multiple-choice section works. As the exam has stood in recent years (confirm the details on AP Central before test day), Section I has **60 questions in 60 minutes**, worth half your score. Some questions stand alone; others come in sets that share a map, graph, table, image or short text. There is no penalty for wrong answers, so never leave a question blank. The framework divides the course into seven units: Thinking Geographically (about a tenth of the exam) and six others weighted about equally: Population and Migration; Cultural Patterns; Political Patterns; Agriculture and Rural Land Use; Cities and Urban Land Use; and Industrial and Economic Development. This course's nine units map onto those seven, with Unit 9 (stewardship, water, hazards) feeding into several of them.

The big idea: know the confusable pairs. Most wrong answers come from mixing up two related ideas, so review them in pairs. In *Thinking Geographically*: absolute vs relative location; site (the physical ground) vs situation (the place's connections); formal vs functional vs perceptual (vernacular) regions; large vs small scale. In *Population and Migration*: CBR vs CDR vs RNI; arithmetic vs physiological density; push vs pull factors; internal vs international and voluntary vs forced migration; refugees (who cross a border) vs internally displaced persons (who do not). In *Culture*: relocation diffusion (people carry the idea as they move) vs expansion diffusion, which is hierarchical (from big places or important people down), contagious (spreading to neighbors, like an epidemic) or stimulus (the idea spreads but is changed); folk vs popular culture; universalizing religions (Christianity, Islam, Buddhism, Sikhism) vs ethnic religions (Hinduism, Judaism, Shinto); language family, branch, group and dialect; lingua franca and pidgin. In *Political Patterns*: state vs nation; antecedent, subsequent, superimposed and relic boundaries; unitary vs federal; centripetal vs centrifugal forces; devolution; supranational organizations. In *Agriculture*: the First (farming's beginnings), Second (the British agricultural revolution and mechanization) and Third (Green Revolution) agricultural revolutions; intensive vs extensive farming; subsistence vs commercial; von Thünen's rings. In *Cities*: site and situation of cities; Burgess, Hoyt and multiple nuclei; bid-rent; central place threshold and range; rank-size vs primate city; suburbanization, edge cities, gentrification. In *Development*: primary, secondary, tertiary, quaternary and quinary sectors; Weber's weight-gaining vs weight-losing industries; Rostow vs Wallerstein; GDP vs GNI vs HDI; comparative advantage; outsourcing and deindustrialization.

How to take a multiple-choice item. Read the whole stem, and underline qualifiers such as *NOT*, *EXCEPT*, *BEST* and *MOST likely*. Cover the choices and predict the answer in your own words. Then read every choice and eliminate the ones that are false, the ones that are true but answer a different question (the favorite distractor), and the ones at the wrong scale. Choose the best of what remains. For stimulus sets, read the title, key and units before the questions; many items can be answered only from the stimulus, and none should be answered against it. Keep your pace near one question per minute: mark a hard item, make your best guess, move on, and return if time allows.

How to study in the last weeks. Rereading notes feels productive but does little. Research on memory over the past century points to three habits that work. **Retrieval practice**: test yourself with cards and questions. **Spacing**: review each card again after a day, then after several days, then a week, instead of cramming. **Interleaving**: mix topics in one session, so you learn to recognize which idea a question needs. A simple tool combines all three: the Leitner box, described by the German writer Sebastian Leitner in the 1970s, in which cards you answer correctly move to a compartment you review less often and cards you miss go back to the front.

A Christian reading. “And whatsoever ye do, do it heartily, as to the Lord, and not unto men” (Colossians 3:23). A test is a small thing, but diligent preparation is a way of honoring God with the mind He gave you. So is rest. God set a rhythm of six days and a Sabbath from the first week of creation, and a rested mind recalls far better than an exhausted one. Study steadily, stop in time, sleep well, and walk into the exam in peace.



Burgess’s concentric zones (Chicago, 1925) and Hoyt’s sectors (1939). Harris and Ullman’s multiple-nuclei model (1945) adds several separate centers.

PICTURE STUDY

The Ambassadors (Jean de Dinteville and Georges de Selve), Hans Holbein the Younger, 1533 · Oil on oak · National Gallery, London

In 1533 Hans Holbein, a German painter working in London, painted two Frenchmen: Jean de Dinteville, the French ambassador to the court of Henry VIII, and his friend Georges de Selve, bishop of Lavaur. Between them stands a shelf crowded with the learning of their age. On the top shelf are a celestial globe and instruments for telling time and measuring the heavens; on the lower shelf are a terrestrial globe, a merchant's arithmetic book, a lute with a broken string and an open hymnbook.

The painting rewards slow, careful reading. The gray shape slanting across the floor is a skull drawn in distorted perspective (anamorphosis): it snaps into shape only when you view the painting from the side. In the top left corner, almost hidden by the curtain, hangs a crucifix. Like a good multiple-choice stimulus, the picture contains everything you need, but only for the person who looks closely.

Look closely

- Find the terrestrial globe on the lower shelf. What does its presence say about the world of 1533, forty years after Columbus?
- Find the lute. One string is broken. What might that mean in a year when Europe was divided by quarrels over religion?
- Find the skull. From where would you have to stand to see it properly?
- Find the crucifix in the top left corner. Why might Holbein have placed it almost out of sight?

Talk about it

1. The ambassadors are surrounded by the best science and geography of their day, yet the skull and the crucifix are there too. What is Holbein saying about the limits of human knowledge?
2. How is reading this painting like reading a stimulus on the exam? What happens if you look too quickly?
3. Which of the objects on the shelf belongs to geography, and which to the heavens?

PROJECT: A LEITNER BOX AND A 200-CARD REVIEW DECK

You will build a simple box that does the scheduling of your review for you, and fill it with about 200 cards covering every unit of the course. Twenty minutes a day with this box in the last weeks before the exam will do more than hours of rereading.

You will need

- A shoebox (or a long box that holds index cards)
- Four pieces of stiff cardboard as dividers, cut to fit the box
- About 200 index cards in four or five colors (one color per group of units)
- Markers, your notes, and the key terms, mastery checklists and unit tests from Units 1–9

Steps

1. Cut and insert the dividers so the box has five compartments. Label them 1 (every day), 2 (every 2 days), 3 (every 4 days), 4 (every 8 days) and 5 (mastered).
2. Write about 20 cards per unit: key terms on the front with the definition and one real example on the back; models with author, date, assumption and limitation; one quick calculation card per unit (doubling time, density, LQ, rank-size).
3. Include at least 15 “confusable pair” cards, such as “hierarchical vs contagious diffusion” or “antecedent vs subsequent boundary,” with an example of each on the back.
4. Put all the cards in compartment 1. Each day, review compartment 1 and any other compartment whose day has come.
5. When you answer a card correctly, move it up one compartment. When you miss it, move it back to compartment 1, no matter where it was.
6. Twice a week, shuffle twenty cards from different units together and answer them as fast as you can, aiming at one per minute or faster.
7. Keep a tally on the box lid: how many cards are in compartment 5 each Saturday. Aim to have most of the deck there before the practice exam in Lesson 10.4.

Tips

- Say the answer aloud or write it before you flip the card. Recognizing an answer is not the same as recalling it.
- Put a real place on every card you can. Examples are what earn free-response points.

Check your work

- I have at least 200 cards covering all nine units.
- I review on schedule and move cards honestly.
- I can answer twenty mixed cards in under twenty minutes.

MAP NOTEBOOK

1. Make a one-page “Confusable Pairs” chart with three columns: term 1, term 2, and the one-sentence difference with an example of each. Fill at least twelve rows.
2. Sketch the Burgess, Hoyt and multiple-nuclei models from memory, then check them against the figure and correct them in a second color.
3. Draw a diffusion map for one idea or product you know (for example, a fast-food chain or a sport) and label whether it spread by hierarchical, contagious, stimulus or relocation diffusion.

> **From history.** The first SAT was given on June 23, 1926, to about eight thousand students, and it was made up mostly of multiple-choice items. Long before that, the College Entrance Examination Board, founded in 1900, had given essay examinations in subjects such as Latin, Greek, history and mathematics. The AP exam you will take combines both traditions: a section of quick, objective items and a section of written answers.

WORKED EXAMPLES

Example 1. In a country that follows the rank-size rule, the largest city has 8 million people. Predict the populations of its 2nd, 3rd, 4th and 5th cities. If the 2nd city actually has 1 million people, what does that suggest?

1. Rank-size rule: population of the nth city ≈ (largest city) ÷ n.
2. 2nd: 8 ÷ 2 = 4 million. 3rd: 8 ÷ 3 ≈ 2.7 million. 4th: 8 ÷ 4 = 2 million. 5th: 8 ÷ 5 = 1.6 million.
3. An actual 2nd city of 1 million is only a quarter of the predicted 4 million, and the largest city is 8 times its size instead of 2 times.

Answer: Predicted: 4, 2.7, 2 and 1.6 million. A 2nd city of 1 million suggests a primate city pattern: the largest city dominates the urban hierarchy, as Bangkok does in Thailand.

Example 2. A road atlas map has a scale of 1:250,000. Two towns are 4.2 cm apart on the map. How far apart are they on the ground, in kilometers and miles? Is this a large-scale or small-scale map compared with a 1:24,000 topographic map?

1. 1 cm on the map = 250,000 cm on the ground = 2,500 m = 2.5 km.
2. 4.2 cm × 2.5 km per cm = 10.5 km.
3. 10.5 km ÷ 1.609 ≈ 6.5 miles.
4. 1/250,000 is a smaller fraction than 1/24,000, so the atlas map is smaller scale.

Answer: About 10.5 km (6.5 mi). The 1:250,000 map is smaller scale than the 1:24,000 map: it covers more area with less detail.

Example 3. Sample item. Between 1970 and 2020, Country K's rate of natural increase fell from 2.8% to 1.2%, while its crude death rate stayed nearly the same. Which of the following BEST explains the change? (A) A rise in the infant mortality rate (B) A falling birth rate as more people moved to cities and children stayed in school longer (C) An increase in emigration (D) The spread of an epidemic disease (E) A rise in life expectancy.

1. Predict first: RNI = birth rate − death rate. If the death rate stayed the same and RNI fell, the birth rate must have fallen. Look for a choice about falling births.
2. Eliminate (A) and (D): both would raise the death rate, which the stem says did not change.
3. Eliminate (C): emigration changes total population growth, but it is not part of natural increase.
4. Eliminate (E): a longer life expectancy lowers or holds the death rate; it does not lower RNI.
5. (B) explains a falling birth rate with two classic causes of stage 3 of the demographic transition: urbanization and longer schooling.

Answer: (B). The key was the qualifier in the stem: the death rate stayed the same, so only a falling birth rate can explain the drop in natural increase.

PRACTICE

1. EASY A clothing style appears first in New York and Paris, then in Chicago and Atlanta, and only later in small towns. This is an example of (A) contagious diffusion (B) relocation diffusion (C) hierarchical diffusion (D) stimulus diffusion (E) distance decay.
2. EASY "The South" or "the Midwest" as people imagine them, with no agreed borders, is an example of a (A) formal region (B) functional region (C) perceptual (vernacular) region (D) nodal region (E) political region.
3. EASY A country's population grows at 1.4% a year. About how long will it take to double? (A) 14 years (B) 35 years (C) 50 years (D) 70 years (E) 140 years.

4. EASY All of the following languages belong to the Indo-European family EXCEPT (A) Hindi (B) Persian (C) Russian (D) Arabic (E) Spanish.
5. MEDIUM Which of the following is an ethnic religion rather than a universalizing religion? (A) Christianity (B) Islam (C) Buddhism (D) Hinduism (E) Sikhism.
6. MEDIUM The remaining sections of the Berlin Wall, which no longer divide anything, are an example of a (A) superimposed boundary (B) relic boundary (C) antecedent boundary (D) subsequent boundary (E) geometric boundary.
7. MEDIUM Cattle ranching on huge stations in the dry interior of Australia is best described as (A) intensive subsistence agriculture (B) extensive commercial agriculture (C) shifting cultivation (D) market gardening (E) plantation agriculture.
8. MEDIUM In von Thünen's model, dairy and market gardening are located closest to the city mainly because (A) the soil is best there (B) the products are perishable and costly to transport, so they can pay the highest rent near market (C) the government requires it (D) forests cannot grow near cities (E) ranchers prefer distant land.
9. MEDIUM Use the diagram (he-u10-urbanmodels). Which model shows high-class residential areas stretching outward in a wedge from the center, and what letter or number marks the zone of workingmen's homes in the other model?
   (Use the map or drawing "Use the keys below each model." shown earlier in this lesson.)
10. MEDIUM According to Weber's least-cost theory, which industry is MOST likely to locate near its market? (A) copper smelting (B) lumber milling (C) soft-drink bottling (D) iron-ore processing (E) sugar-cane milling.
11. HARD In Wallerstein's world-systems theory, a country with a growing manufacturing base, a mix of high-wage and low-wage work, and both core-like and peripheral regions inside it is most likely classified as (A) core (B) semi-periphery (C) periphery (D) Rostow's traditional society (E) a primate state.
12. CHALLENGE Stimulus set. Country R: CBR 12, CDR 10, TFR 1.6. Country S: CBR 35, CDR 8, TFR 4.7. Country T: CBR 9, CDR 12, TFR 1.3. (a) Which country has negative natural increase? (b) Which has a population pyramid with the widest base? (c) Which statement is BEST supported by the data? (A) R is in stage 2. (B) S will double in about 26 years if its rates hold. (C) T's population is growing by natural increase. (D) All three are above replacement fertility.

COMMON MISTAKES

- Choosing a choice that is true but does not answer the question. Ask of every choice, "Does this answer *this* stem?"
- Missing a NOT or EXCEPT in the stem. Underline it, and remember you are looking for the one false or unrelated choice.
- Studying by rereading. Recall is what the exam tests, so practice recalling: cards, questions, and drawing models from memory.

> **Make it a game · Distractor Duel.** Each player writes five multiple-choice questions on any course topic, each with one right answer and four plausible distractors. Trade questions. For each question you answer correctly you score 1 point; for each of your own

questions that fools your opponent, you score 1 point, but only if you can explain afterward why every distractor is wrong. Writing good distractors is one of the fastest ways to learn exactly where the confusable pairs lie.

Scripture. “And whatsoever ye do, do it heartily, as to the Lord, and not unto men;” (Colossians 3:23, KJV)

Paul wrote these words to ordinary workers. Studying well is work, and it can be done for the Lord, not only for a score.

Practice answers

1. (C) Hierarchical diffusion: the style spreads from the largest, most connected places down the urban hierarchy, skipping the countryside in between.
2. (C) Perceptual or vernacular region: it exists in people’s minds and culture, and its edges differ from person to person.
3. (C) 70 ÷ 1.4 = 50 years.
4. (D) Arabic, a Semitic language of the Afro-Asiatic family. Hindi (Indo-Aryan), Persian (Iranian), Russian (Slavic) and Spanish (Romance) are all Indo-European.
5. (D) Hinduism. Ethnic religions are tied mainly to one people and homeland and do not seek converts widely; the others are universalizing religions that seek to spread to all peoples.
6. (B) Relic boundary: a former boundary that no longer functions but still leaves a mark on the landscape.
7. (B) Extensive commercial agriculture: little labor and capital per unit of land, over very large areas, for sale.
8. (B). The model assumes uniform soil, so (A) is wrong; the rings come from transport cost and perishability.
9. Hoyt’s sector model (the high-class residential wedge is E). In Burgess’s model, the zone of workingmen’s homes is ring 3.
10. (C) Soft-drink bottling is weight-gaining (water is added near the end), so it locates near consumers. The others are weight-losing and tend to locate near their raw materials.
11. (B) Semi-periphery, as Brazil, Mexico, China and India are usually classed. (D) is from a different model, and (E) is not a term of the theory.
12. (a) T: RNI = (9 − 12) ÷ 10 = −0.3%. (b) S, with the highest birth rate and TFR. (c) (B): S’s RNI = (35 − 8) ÷ 10 = 2.7%, and 70 ÷ 2.7 ≈ 26 years. (A) is wrong (R is stage 4), (C) is wrong (T is declining), and (D) is wrong (only S is above 2.1).

10.4 A Full Practice Exam

OBJECTIVES

- Sit a full-length, timed practice exam (60 multiple-choice questions in 60 minutes and three free-response questions in 75 minutes) under real conditions, with a pacing plan.
- Score the practice exam, compute a composite percentage, and keep an error log that sorts every miss by cause (content, misreading, careless, time).
- Draw the whole course together around its big ideas (place, scale, region, diffusion, human–environment interaction) and plan the final days of review and rest.

Warm-up. Set a kitchen timer for five minutes. On a blank sheet, draw a rough world map from memory and, without notes, write on it one fact from each of the nine units of this course in the right place (for example, a stage 2 country, a language family's homeland, a primate city, a von Thünen-like ring around a market, a core country). When time is up, count your facts. That map is the whole course in one view, and the practice exam will test all of it.

Watch. *7th December 1972: The Blue Marble photograph taken of the whole Earth* (HistoryPod, 2:36). https://www.youtube.com/watch?v=g7t36737CzI
After the story: watch this short history of the Apollo 17 Blue Marble photo, and look for Africa, the Arabian Peninsula, Madagascar and the Antarctic ice cap.
Note: Captions were not available to check; preview it first. The video says the original frame was taken upside down, with Antarctica at the top. The lesson describes the image as it is usually shown, with Antarctica at the bottom. The video also says Harrison Schmitt probably took the photo, while NASA credits the whole crew.

KEY TERMS

composite score
The combined weighted score of both exam sections, which College Board converts to an AP score from 1 to 5; the cutoffs vary from year to year and are set after each exam.

pacing plan
A set of time checkpoints for an exam (for example, question 20 by minute 20) that keeps you from running out of time.

error log
A record of every missed question with its topic and the cause of the miss, used to target the last weeks of review.

human–environment interaction
The two-way relationship between people and the physical world: how land, water and climate shape human life, and how people change the land.

synthesis

Joining ideas from different units to explain one place or problem, as the hardest free-response parts require.

CORE IDEAS

The story. On December 7, 1972, a few hours after launch, the crew of Apollo 17 looked back from about 29,000 km (18,000 miles) out and photographed the whole Earth, fully lit by the sun behind them. In one frame lay the Mediterranean Sea, the Arabian Peninsula, nearly all of Africa, the island of Madagascar and, at the bottom, the white ice cap of Antarctica. NASA catalogued it as AS17-148-22727; the world calls it **The Blue Marble**, and it has been reproduced as often as almost any photograph ever taken. Look closely and you can trace the course you have just finished: the desert belt of the Sahara and Arabia, where few people live; the thin green thread of the Nile, where a hundred million do; the lands where Christianity first spread from Jerusalem; the old caravan and sea routes. A practice exam is your own Blue Marble: the whole course seen at once.

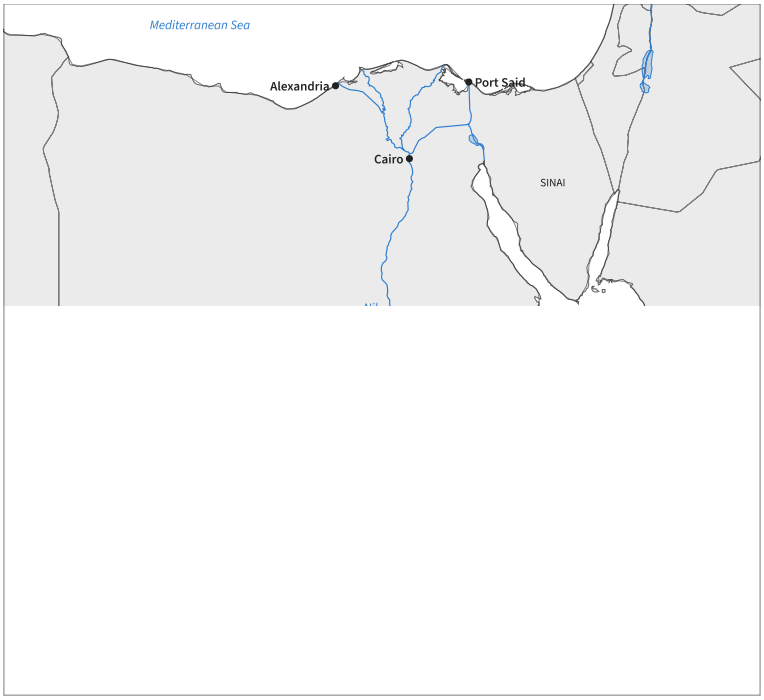
How exam day works. As the AP Human Geography exam has stood in recent years (confirm on AP Central), it is given in May, lasts 2 hours and 15 minutes, and has two sections of equal weight: **Section I, 60 multiple-choice questions in 60 minutes**, and **Section II, three free-response questions in 75 minutes**, each with seven one-point parts. It is given on a computer in the College Board's testing application, so practice reading maps and graphs on a screen. Use a **pacing plan**. In Section I, aim to finish question 20 by minute 20 and question 40 by minute 40, leaving a few minutes to return to marked items; never leave a blank, since wrong answers cost nothing. In Section II, spend the first two or three minutes reading all three questions, then give each about 24 minutes. Answer every part, even with a short, plain sentence; seven separate points are on the table in every question.

How the score works. The multiple-choice raw score and the free-response raw score are each converted to half of a composite. A simple way to estimate your own composite is: (multiple-choice correct ÷ 60 × 50) + (free-response points ÷ 21 × 50), giving a percentage out of 100. College Board does not publish fixed cutoffs; each year's scale is set after the exam to keep scores comparable from year to year. AP scores run from 1 to 5, and colleges decide for themselves which scores earn credit or placement, often a 3 or a 4 and above, so look up the policy of each college you are considering.

After the practice exam. The most valuable hour of the whole review comes after the practice exam, not during it. Score both sections honestly, then build an **error log**: for each miss, write the topic (with its unit number) and the cause. A *content* miss means you did not know the idea; return to the lesson and the cards. A *misreading* miss means you knew it but missed a NOT, a scale or a task verb; slow down on stems. A *careless* miss means arithmetic or bubbling; check calculations once. A *time* miss means you never reached it; work the pacing plan. Most students find that one or two units and one or two causes account for most of their misses. That tells you exactly what to study in the days that remain.

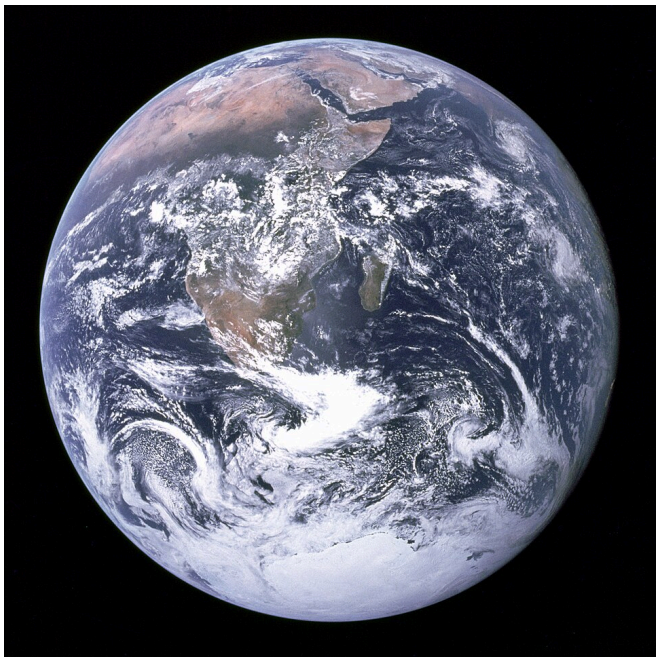
The big idea: the whole course in five words. Nearly every question on the exam is a variation on five ideas you have met in every unit. **Place**: what makes each location unique, in its site and situation. **Scale**: a pattern seen at one scale may vanish at another. **Region**: we group places to understand them, and every grouping simplifies. **Diffusion**: people, languages, faiths, crops and ideas spread, and distance slows them. **Human–environment interaction**: people live within the limits and gifts of the land, and change it in turn. Christians add a sixth idea that holds the others together: providence. God “hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation” (Acts 17:26). The variety of peoples and places you have studied all year is not an accident to be explained away but a world to be understood, served and cared for, as Adam was set in the garden “to dress it and to keep it” (Genesis 2:15).

A Christian reading of exam week. Anxiety before a test is natural, and Scripture speaks to it directly: “Be careful for nothing; but in every thing by prayer and supplication with thanksgiving let your requests be made known unto God” (Philippians 4:6). Prepare faithfully, then put the result in God’s hands. In the final week, review lightly, do not cram the night before, sleep well, eat breakfast, and arrive early with what you need. You have done the work. Walk in with a quiet mind.



Egypt and the Nile: one of the clearest examples on earth of a population pattern shaped by water.

PICTURE STUDY



The Blue Marble (The Earth Seen from Apollo 17), The crew of Apollo 17 (NASA), December 7, 1972 · Color photograph on 70 mm film (NASA image AS17-148-22727) · NASA (public domain; NASA image AS17-148-22727)

Apollo 17 was the last of the Apollo missions to the Moon. Because the spacecraft left Earth with the sun almost directly behind it, the crew saw the whole globe fully lit, something earlier crews had rarely been able to photograph. The picture was taken about five hours after launch.

The photograph is a map no human hand drew. It shows physical geography plainly: the desert belt at about 20 to 30 degrees north, the green of the tropical rain forest, the cloud bands of the oceans. But a student of human geography can read people in it too, in the deserts that are nearly empty and the river valleys and coasts where cities crowd.

Look closely

- Find Africa, the Arabian Peninsula and Madagascar. Which way is north in this photograph?
- Find the desert belt across North Africa and Arabia. What does its color tell you about rainfall?
- Find Antarctica at the bottom. Why could earlier crews rarely photograph the south polar ice cap this way?
- Look for the Nile valley in northeastern Africa. Can you see why almost all Egyptians live in so small a part of their country?

Talk about it

1. The photograph shows no borders, yet the course has studied borders all year. What does that tell you about the difference between physical and political geography?
2. Which unit of this course could you teach from this one picture? Choose one and name three things you would point out.
3. How might seeing the whole earth at once change the way a person thinks about Genesis 1:1, “In the beginning God created the heaven and the earth”?

PROJECT: SIT THE FULL PRACTICE EXAM AND KEEP AN ERROR LOG

This is the dress rehearsal. You will take a complete practice exam under real conditions, score it, and turn every mistake into a study plan for the final weeks. Plan for one long sitting (about 2 hours 30 minutes with a short break) and one scoring session.

You will need

- A full practice exam: a College Board practice exam from AP Classroom if your teacher or test coordinator can provide one; or the released free-response questions on AP Central plus 60 multiple-choice questions assembled from the practice and unit tests of Units 1–9 of this course
- A computer or tablet if possible (the real exam is taken on a screen), a timer, scratch paper and two pencils
- A quiet room, a parent or friend to act as proctor, and a notebook for the error log

Steps

1. Choose a morning at the same time of day as the real exam. Put away phones and notes. Ask your proctor to read the start and stop times aloud.
2. Section I: 60 minutes for 60 multiple-choice questions. Write the pacing checkpoints (20 by minute 20, 40 by minute 40) at the top of your scratch paper. Mark hard items and return to them.
3. Take a ten-minute break: stand, stretch, drink water. Do not look at notes.
4. Section II: 75 minutes for three free-response questions. Read all three first, then answer each part separately, labeled (A) through (G).
5. Scoring session: mark the multiple-choice answers. For each free-response part, ask your proctor (or check the scoring guidelines) whether your answer did exactly what the task verb asked, with a correct, specific example. Award 1 point or 0.
6. Compute your composite estimate: (MC correct ÷ 60 × 50) + (FRQ points ÷ 21 × 50).
7. Make the error log: a table with columns for question number, unit, topic, cause (content, misreading, careless, time) and the fix. Then count the misses in each unit and each cause.
8. Write a two-week study plan that gives the most time to the two weakest units and the most common cause. Plan a second short timed set a week before the exam.

Tips

- Do not stop the clock to look things up. A practice exam tells the truth only if it is timed.
- Read the free-response scoring guidelines that College Board publishes for each released question; they show exactly what earned each point.

Check your work

- I completed both sections within the time limits.
- I scored my exam honestly and computed a composite estimate.
- My error log shows my two weakest units and my most common cause of error, and my study plan targets them.

MAP NOTEBOOK

1. Draw a large circle for the Earth and divide it into five wedges labeled place, scale, region, diffusion and human–environment interaction. In each wedge write three examples from different units.
2. Copy the Egypt map (he-u10-nile) from memory, shading the Nile valley and delta where most Egyptians live, and label Cairo, Alexandria, Aswan and Lake Nasser.
3. Write a one-page letter to yourself to be opened the morning of the exam: your pacing plan, three reminders from your error log, and Philippians 4:6.

> **From history.** Four years before the Blue Marble, on Christmas Eve 1968, the crew of Apollo 8, Frank Borman, Jim Lovell and Bill Anders, became the first people to orbit the Moon. In a television broadcast from lunar orbit, watched by one of the largest audiences of its time, the three men took turns reading the first ten verses of Genesis, beginning, “In the beginning God created the heaven and the earth.” Earlier that day Anders had taken the photograph now called *Earthrise*, showing the Earth rising over the Moon’s horizon.

WORKED EXAMPLES

Example 1. Pacing. In Section I you have 60 minutes for 60 questions; in Section II, 75 minutes for 3 questions of 7 parts each. Make a pacing plan that leaves 6 minutes at the end of Section I for marked questions, and 3 minutes at the start of Section II to read all three questions.

1. Section I: 60 − 6 = 54 minutes for 60 questions = 0.9 minute, or 54 seconds, per question.
2. Checkpoints: question 20 by about minute 18, question 40 by about minute 36, question 60 by minute 54.
3. Section II: 75 − 3 = 72 minutes for 3 questions = 24 minutes per question.
4. Per part: 24 ÷ 7 ≈ 3.4 minutes per part, so a typical part should take a few sentences, not a page.

Answer: Section I: about 54 seconds per question, with checkpoints at 20 (minute 18), 40 (minute 36) and 60 (minute 54), then 6 minutes of review. Section II: read all three questions for 3 minutes, then about 24 minutes per question, or about 3½ minutes per part.

Example 2. On a practice exam a student answers 44 of 60 multiple-choice questions correctly and earns 5, 4 and 6 points on the three free-response questions. Estimate the composite percentage. What would one more correct free-response point be worth compared with one more correct multiple-choice answer?

1. Multiple choice: 44 ÷ 60 × 50 = 36.7.
2. Free response: 5 + 4 + 6 = 15 points; 15 ÷ 21 × 50 = 35.7.
3. Composite ≈ 36.7 + 35.7 = 72.4 out of 100.
4. Value of one MC answer = 50 ÷ 60 ≈ 0.83; value of one FRQ point = 50 ÷ 21 ≈ 2.38.

Answer: About 72 out of 100. Each free-response point is worth about 2.4 composite points, almost three times a multiple-choice answer (about 0.83), which is why answering every free-response part, even briefly, matters so much. (Actual AP score cutoffs are set each year and not published in advance.)

Example 3. Model free-response question, using the map (he-u10-nile). Egypt had more than 105 million people as of the mid-2020s, and about 95 percent of them live on roughly 5 percent of its land. (A) Identify the physical feature along which most Egyptians live. (B) Describe the pattern of population distribution shown by the map. (C) Explain one physical reason for this pattern. (D) Explain why physiological density describes Egypt better than arithmetic density. (E) Explain one effect of the Aswan High Dam (completed 1970) on Egyptian agriculture. (F) Identify Egypt's primate city. (G) Explain the degree to which Egypt's new desert cities are likely to change this pattern.

(Use the map or drawing "Read the map before answering: where are the cities, and where is there nothing?" shown earlier in this lesson.)

1. (A) Identify = name it: the Nile River valley and delta.
2. (B) Describe = give characteristics: the population forms a narrow linear band along the Nile, widening into a dense cluster in the delta between Cairo and the Mediterranean, with almost empty deserts on both sides.
3. (C) Explain = how or why, with a because: Egypt has a hot desert climate with almost no rain, so farming and settlement are possible only where the Nile supplies water and fertile soil.
4. (D) Arithmetic density divides people by all of Egypt's land, most of it empty desert, so it understates crowding; physiological density divides by arable land, nearly all in the valley and delta, and so shows the true pressure on the farmland.
5. (E) The dam ended the yearly flood and stored water in Lake Nasser, allowing year-round irrigation and two or three crops a year; but it also traps the silt that once renewed the fields, so farmers now depend on chemical fertilizer, and the delta coast receives less sediment.
6. (F) Cairo.
7. (G) Degree: only to a limited degree, because the new cities, such as 10th of Ramadan City (founded 1977) and others built since, depend on water piped from the Nile and on jobs, so they extend the pattern outward from the valley rather than replacing it; most Egyptians are still likely to live within reach of the river.

Answer: One point for each part when it does exactly what its verb asks with accurate, specific content: (A) Nile valley and delta; (B) linear and clustered along the river and in the delta, empty desert elsewhere; (C) desert climate, water only from the Nile; (D) physiological density measures people per arable land; (E) year-round irrigation and more harvests, but loss of silt; (F) Cairo; (G) a judgment of degree with a reason.

PRACTICE

1. EASY Mini practice exam, multiple choice. A geographer describes New Orleans as lying on low ground beside the Mississippi River near its mouth. This describes the city's (A) situation (B) site (C) relative location (D) hinterland (E) range.

2. EASY Use the map (he-u10-nile). In which direction does the Nile flow from Aswan to Cairo, and about how far is it in a straight line (Aswan 24.1° N, Cairo 30.0° N; count only the change in latitude and ignore the smaller change in longitude; 1° of latitude ≈ 111 km)?
   (Use the map or drawing "Aswan in the south, Cairo at the head of the delta." shown earlier in this lesson.)
3. EASY Multiple choice. Which of the following is a push factor for migration? (A) higher wages in another country (B) religious freedom abroad (C) war in one's home region (D) family already living in the destination (E) a good climate in the destination.
4. MEDIUM Multiple choice. The spread of Christianity from Jerusalem through the Roman world by the journeys of Paul and other missionaries, who carried the faith to new cities, is the best example of (A) relocation diffusion followed by expansion in each new place (B) stimulus diffusion (C) a centrifugal force (D) a superimposed boundary (E) distance decay alone.
5. MEDIUM Multiple choice. Which of these states is federal? (A) France (B) Japan (C) Germany (D) the United Kingdom (E) China.
6. MEDIUM Multiple choice. The Green Revolution of the 1950s–1970s is best described as (A) the beginning of plant domestication (B) the spread of high-yield seeds, fertilizer and irrigation that greatly raised grain yields in Mexico and Asia (C) the enclosure of fields in eighteenth-century England (D) organic farming (E) the shift from farming to manufacturing.
7. MEDIUM Multiple choice. A large shopping, office and hotel center that grows up at a highway interchange far from the old downtown is called (A) a central business district (B) an edge city (C) a zone in transition (D) a primate city (E) a greenbelt.
8. MEDIUM Multiple choice. A call center answering customers in the United States is located in the Philippines. This is an example of (A) outsourcing of tertiary-sector work to a lower-wage country with a skilled English-speaking labor force (B) a primary-sector activity (C) Weber's weight-losing industry (D) agglomeration in the core (E) deglomeration caused by tariffs.
9. HARD Free-response part. Explain one reason why Japan's population is shrinking, and one challenge this creates for its economy.
10. HARD Free-response part. Using the map (he-u10-nile), explain why Egypt is a good example of the influence of site on city location.
    (Use the map or drawing "Notice where every city lies." shown earlier in this lesson.)
11. HARD A student scores 38 of 60 on multiple choice and 12 of 21 on free response. Estimate the composite, and say which section offers the faster gain if the student can add either 6 multiple-choice answers or 3 free-response points.
12. CHALLENGE Free-response synthesis. Choose one model from the course and one real place. In 6–8 sentences: identify the model; describe what it predicts for that place; explain one way the place fits; explain one way it does not; and explain the degree to which the model is still useful there.

COMMON MISTAKES

- Spending too long on one hard multiple-choice question. Each is worth the same; mark it, guess, and move on.
- Leaving a free-response part blank. A short, plain, specific answer can earn the point; a blank never can.
- Treating the practice score as a verdict. It is information. The error log, not the score, is the most important result of the practice exam.

Make it a game · Blue Marble Tour. Spin a globe (or close your eyes and point at a world map). Wherever your finger lands, you have sixty seconds to say one true thing about that place from as many units as you can: its population stage, language family, main religion, type of government or boundary, farming type, a major city and its site, and its level of development. Score 1 point per accurate unit covered. If you land in the ocean, name the nearest coast and the trade or migration routes across that water for 2 points.

Scripture. “Be careful for nothing; but in every thing by prayer and supplication with thanksgiving let your requests be made known unto God.” (Philippians 4:6, KJV)

“Careful” here means anxious. Prepare well, then bring the exam to God in prayer with thanksgiving for a year of learning, and let Him hold the outcome.

Practice answers

1. (B) Site: the physical character of the place itself. Its situation would be its position relative to other places, such as at the gateway between the Mississippi basin and the Gulf of Mexico.
2. North. Distance ≈ (30.0 − 24.1) × 111 ≈ 5.9 × 111 ≈ 655 km, about 410 miles north–south. The true straight-line distance is about 680 km (420 mi), because Cairo also lies about 1.7° west of Aswan. The river itself is longer still because it bends.
3. (C) War at home pushes people out. The others are pull factors of the destination.
4. (A). Missionaries carried the faith as they moved (relocation), and in each city it then spread to neighbors and through households (expansion, contagious and often hierarchical).
5. (C) Germany, whose constitution divides power between the federal government and the sixteen Länder. The others are unitary states (the UK has devolved some powers, but Parliament remains supreme).
6. (B). It began with Norman Borlaug’s wheat work in Mexico and spread to India, Pakistan and other Asian countries, with high-yield rice developed in the Philippines.
7. (B) Edge city, a term popularized by Joel Garreau in 1991. It illustrates the multiple-nuclei model.
8. (A). The Philippines has many English speakers and lower wages, and modern telecommunications make distance nearly irrelevant for this service work.
9. Sample: Japan’s birth rate has stayed far below replacement (a TFR around 1.2–1.3 in the early 2020s) because many young people marry later or not at all and families have fewer children, while immigration has been small; so deaths exceed births. Challenge: a shrinking labor force must support a growing number of retirees, raising pension and health costs and causing labor shortages.

10. Nearly every major Egyptian city sits on the Nile or its delta (Aswan, Luxor, Cairo) or on the coast where the delta meets the sea (Alexandria, Port Said), because only these sites offer fresh water, fertile land and transport. Cairo grew where the narrow valley opens into the delta, a natural point to control both.
11. MC: 38 ÷ 60 × 50 ≈ 31.7. FRQ: 12 ÷ 21 × 50 ≈ 28.6. Composite ≈ 60.3. Six more MC answers add 6 × 0.83 = 5.0; three more FRQ points add 3 × 2.38 ≈ 7.1. The three free-response points are worth more, and are often easier to gain by answering every part.
12. Scoring guide (7 points): correct identification of the model with author and date (1); accurate description of its prediction (1); one accurate fit with specific evidence (1); one accurate misfit (1); explanation of the misfit tied to a broken assumption (1); a judgment of degree (1); a supported conclusion (1). Example: Rostow and South Korea, which passed from a poor farming society in the 1950s to a high-consumption industrial economy within two generations (fits), but did so with heavy government direction and export-led trade that Rostow’s stages describe only loosely (misfit); the model is useful as a description of the sequence, less as an explanation of why.

Unit 10 test

This cumulative review covers the whole course. Answer each question. Show your work for every calculation and use complete sentences for explanations and the free-response question. Use the rule of 70 for doubling time and 1 mile = 1.609 km where needed. The test is worth 100 points.

1. (6 pts) A country has a crude birth rate of 30 per 1,000 and a crude death rate of 7 per 1,000. Find its rate of natural increase and doubling time, and name its most likely stage in the demographic transition model.
2. (6 pts) State two assumptions of von Thünen's model (1826) and explain how one modern technology has weakened the model's rings.
3. (6 pts) Compare the Burgess concentric-zone model and the Hoyt sector model: give one similarity and one difference, with the date of each.
4. (6 pts) List Rostow's five stages of growth (1960) and give one criticism of the model and one case that partly supports it.
5. (6 pts) Define threshold and range in central place theory (Christaller, 1933) and explain why large central places are fewer and farther apart than small ones.
6. (6 pts) Explain what the Mercator projection preserves and what it distorts, and why an equal-area projection is better for a world map of population density.
7. (6 pts) A country has 60 million people, 600,000 km² of land, and 8% of the land is arable. Find its arithmetic and physiological densities, and explain which is more useful for judging pressure on farmland.
8. (6 pts) In a city, 6,000 of 80,000 jobs are in finance; nationally, about 5% of jobs are in finance. Find the location quotient and interpret it.
9. (6 pts) Country N has 9 million people aged 0–14, 36 million aged 15–64 and 9 million aged 65 and over. Find the total dependency ratio and describe the shape of its population pyramid compared with a stage 2 country.
10. (6 pts) Name the type of diffusion in each case: (a) Irish immigrants bring Catholic parishes to Boston in the 1840s; (b) a new smartphone appears first in the largest world cities; (c) a rumor spreads from house to house through a village; (d) Indian restaurants in Britain create new dishes adapted to British tastes.
11. (6 pts) Classify each religion as universalizing or ethnic and name its hearth: Christianity, Hinduism, Islam, Judaism.
12. (6 pts) Classify each boundary by origin and give a one-line reason: (a) the 49th parallel across the western prairie; (b) the boundary between India and Pakistan drawn in 1947; (c) the remains of the Berlin Wall.
13. (6 pts) Explain why a sugar-cane mill locates near the cane fields while a brewery or bottling plant tends to locate near its customers, using Weber's terms.
14. (8 pts) A country of 40 million people grows at a steady 1.75% a year. Find its doubling time and estimate its population after two doubling times. Then estimate a practice-exam composite for a student with 48 of 60 multiple-choice answers and 14 of 21 free-response points.

15. (14 pts) Free response (seven parts, 2 points each). (A) Identify the stage of the demographic transition model that best describes Japan in the 2020s. (B) Describe one feature of Japan's population pyramid. (C) Explain one cause of Japan's low birth rate. (D) Explain one economic effect of an aging population. (E) Describe one policy a government might use to respond. (F) Compare Japan's situation with that of a stage 2 country such as Niger. (G) Explain the degree to which the demographic transition model helps predict Japan's future population.

UNIT PROJECT: MY HUMAN GEOGRAPHY REVIEW PORTFOLIO

Assemble a review portfolio that shows the whole course at once and prepares you for the final exam. It has five parts: (1) a **Model Wall** poster with every model of the course drawn by hand, each with its author, date, one assumption, one limitation and one real place; (2) your **town-model test** from Lesson 10.1, with the map overlay and your seven-part answer; (3) your **hand-drawn population pyramids** and two maps of the same data from Lesson 10.2; (4) your **Leitner box** deck of at least 200 cards from Lesson 10.3, with the weekly mastery tallies; and (5) your **scored practice exam and error log** from Lesson 10.4, with the two-week study plan.

Finish with a one-page essay titled "The Whole Earth in One View," explaining how the five big ideas of geography (place, scale, region, diffusion and human–environment interaction) appeared in at least four different units of the course, and what Acts 17:26 adds to the way a Christian studies the peoples and places of the world.

- **Accuracy**: Models, authors, dates, calculations, maps and pyramids are correct and clearly labeled; every limitation is tied to a real place.
- **Completeness**: All five parts are present; the card deck covers all nine units; the practice exam is fully scored and the error log is complete.
- **Reasoning**: The essay and the free-response answers make clear claims, use course terms correctly, treat models as models, and support each point with specific examples.
- **Care**: Work is neat, organized and easy to follow; maps have titles, keys and scales; the portfolio shows steady effort over the whole unit.

Answer key

1. RNI = (30 − 7) ÷ 10 = 2.3% per year. Doubling time ≈ 70 ÷ 2.3 ≈ 30 years. Late stage 2 or early stage 3 (the death rate is already low and the birth rate is still high but below stage 1 levels); accept either with that reasoning.
2. Assumptions (any two): one market city; a flat, uniform plain of equal fertility; an isolated state with no outside trade; one mode of transport (wagon) with cost rising evenly with distance; farmers seeking the most profit. Technology: refrigerated trucks, rail cars and air freight lower the cost of moving perishable goods, so milk, fruit and vegetables can come from far away (for example, Chilean grapes sold in the United States in winter), breaking the inner ring.
3. Burgess, 1925; Hoyt, 1939. Similarity: both place the central business district at the center and arrange residential areas outward by income. Difference: Burgess arranges land uses in rings at equal distances from the center, while Hoyt arranges them in wedges along transport

routes such as rail lines and roads, so factories and high-income housing stretch outward in sectors.

4. Traditional society; preconditions for take-off; take-off; drive to maturity; age of high mass consumption. Criticism: it assumes every country follows one path modeled on Britain and the United States and ignores a country's position in world trade and its internal institutions. Partial support: South Korea moved from a poor farming society to a high-consumption industrial economy within about two generations after the 1950s.
5. Threshold: the minimum number of customers needed to support a good or service. Range: the maximum distance people will travel for it. High-order goods (specialized hospitals, major airports) have high thresholds and long ranges, so only a few large places, widely spaced, can support them; low-order goods (groceries, gas) have low thresholds, so many small places close together can support them.
6. Mercator preserves angles and shapes over small areas, so lines of constant compass bearing are straight, which suits navigation; it greatly enlarges areas toward the poles (Greenland looks as large as Africa, which is about 14 times larger). A density map compares people per unit of area, so an equal-area projection is needed for areas to be compared fairly.
7. Arithmetic: 60,000,000 ÷ 600,000 = 100 per km². Arable land: 0.08 × 600,000 = 48,000 km². Physiological: 60,000,000 ÷ 48,000 = 1,250 per km². Physiological density is more useful because it measures people per unit of land that can actually grow food.
8. Local share = 6,000 ÷ 80,000 = 7.5%. LQ = 7.5 ÷ 5 = 1.5. The city has one and a half times the national share of finance jobs, so finance is a specialty and probably serves customers beyond the city.
9. (9 + 9) ÷ 36 × 100 = 50. Its pyramid would have fairly straight sides (or a narrowing base) with a wide top, unlike the broad-based triangle of a stage 2 country; it is an older population in stage 4.
10. (a) Relocation diffusion. (b) Hierarchical (expansion) diffusion. (c) Contagious (expansion) diffusion. (d) Stimulus diffusion.
11. Christianity: universalizing; hearth in the land of Israel (Galilee, and Jerusalem in Judea) in the first century AD. Hinduism: ethnic; hearth in the Indus–Ganges region of South Asia. Islam: universalizing; hearth at Mecca and Medina in Arabia in the 600s AD. Judaism: ethnic; hearth in the land of Israel (Canaan) in the eastern Mediterranean.
12. (a) Antecedent: drawn before the region was heavily settled. (b) Subsequent: drawn after settlement, along lines intended to separate religious communities. (c) Relic: no longer functions but still marks the landscape. (A geometric form for (a) is also correct if the student notes form rather than origin.)
13. Milling cane into raw sugar is weight-losing (bulk-reducing): the raw cane is heavy and spoils, and the finished sugar weighs far less, so the mill sits near the fields to avoid shipping waste. Brewing and bottling are weight-gaining (bulk-gaining): water is added, so the product is heavier than its inputs and cheaper to make near the market.
14. Doubling time ≈ 70 ÷ 1.75 = 40 years. After two doublings (80 years): 40 → 80 → 160 million. Composite: 48 ÷ 60 × 50 = 40.0; 14 ÷ 21 × 50 ≈ 33.3; total ≈ 73.3 out of 100.
15. Scoring guide, 2 points per part when it does exactly what its task verb asks: (A) Stage 5 (or late stage 4), since deaths exceed births. (B) A narrow base and wide upper bars, showing few children and many elderly. (C) Any one, explained: later marriage and fewer marriages; high costs of housing and education; long working hours; a TFR far below 2.1. (D) Fewer workers per retiree raise the cost of pensions and health care and cause labor shortages. (E) Any one: family allowances or child-care support, encouraging marriage and larger families, raising the retirement age, automation and robotics, or admitting more foreign workers (presented

neutrally). (F) Niger has a very wide-based pyramid, a high birth rate and rapid growth with a young population and high youth dependency, the opposite of Japan’s old, shrinking population. (G) A reasoned judgment: the model describes Japan’s past path well and recognizes low fertility, but it was built from European history and cannot predict whether birth rates will recover, fall further or how migration policy will change, so it helps only partly.

Midterm Exam

Units 1–5 · 100 minutes

You have 100 minutes. A calculator is allowed; no notes, books or phones. Useful figures: 1 mile = 1.609 km; 1 sq mi = 2.59 km²; 1 nautical mile = 1.852 km = 1.151 statute miles; 1° of latitude ≈ 111 km (69 mi). **How points are earned:** the points for each problem are shown beside it. On calculations, write the formula, substitute the numbers with units, and give the answer with its unit (in both km and miles when asked); correct method earns partial credit even if the arithmetic slips. Short-answer items earn one point (or the share stated) for each correct part. The two essays are graded on accurate facts, use of evidence, a fair statement of more than one view, and a reasoned conclusion. The exam has 25 problems worth a total of **100 points**.

1. (4 pts) (a) On a map at 1:50,000, two road junctions are 6.4 cm apart. How far apart are they on the ground, in km and miles? (b) Is this map larger or smaller in scale than a 1:24,000 topographic map? (c) On the Mercator projection, lengths at latitude φ are stretched by 1 ÷ cos φ and areas by (1 ÷ cos φ)². By what factor are lengths and areas enlarged at 60° N? (d) An island of 50,000 km² (about 19,300 sq mi) lies at 60° N. About how large does it appear on a Mercator map, and what kind of projection would show its true size?
2. (3 pts) Choose the best thematic map type for each data set and give a one-line reason: (a) the number of cattle in each county of Kansas; (b) the percent of each county’s residents aged 65 or older; (c) the movement of emigrants from Liverpool, Hamburg and Naples to New York, with the number in each stream. Then explain why a choropleth map of raw counts can mislead.
3. (4 pts) City A has 4.0 million people and City B has 1.0 million; they are 120 miles (193 km) apart. City C has 2.0 million people and lies 240 miles (386 km) from A. (a) Use Reilly’s law, breaking point from A = d ÷ (1 + √(P$_B$ ÷ P$_A$)), to find the breaking point between A and B, measured from each city, in miles and km. (b) Use the gravity model (P₁ × P₂ ÷ d²) to decide whether A should interact more with B or with C, and by what factor.
4. (4 pts) Classify each case as relocation, hierarchical, contagious or stimulus diffusion: (a) Konrad Sweynheym and Arnold Pannartz carry printing from Germany to Subiaco and Rome in 1465–1467. (b) After about 1465 presses appear first in Cologne, Rome, Venice and Paris, skipping many small towns. (c) Sequoyah, who could not read English, sees that English speakers write down speech and by 1821 creates a syllabary with his own symbols for Cherokee. (d) Hägerstrand finds that Swedish farmers adopt a new practice mainly after hearing of it from neighbors.
5. (4 pts) A county has 60,000 people on 1,200 square miles of land and 25,000 jobs, of which 2,500 are in agriculture. Nationally about 2 percent of jobs are in agriculture. (a) Find the county’s population density per square mile and per km². (b) Find its location quotient for agriculture and interpret it. (c) In one sentence, why must a geographer normalize counts like these before comparing counties?

6. (3 pts) Two census tracts are combined into one district. Tract A has 2,000 people, 10 percent of them aged 65 or older; Tract B has 6,000 people, 30 percent aged 65 or older. (a) What percent of the district is 65 or older? Why is the simple average of 10 and 30 wrong? (b) A reporter writes that since the district is “25 percent elderly,” the Garcia family on a street in Tract A must have elderly members. Name this error. (c) Define the modifiable areal unit problem.
7. (3 pts) Country K has 60 million people on 500,000 km² (193,000 sq mi) of land; 12 percent of the land is arable. (a) Find its arithmetic density in both units. (b) Find its physiological density in both units. (c) Which measure better shows the pressure of people on the land that feeds them, and why?
8. (4 pts) Country P has a crude birth rate of 38 and a crude death rate of 9 per 1,000. Country Q has a CBR of 8 and a CDR of 11. (a) Find each rate of natural increase. (b) Find P’s doubling time by the rule of 70. (c) Place each on the demographic transition model. (d) Give one real example the lesson uses to show that the model’s timing or causes do not fit every country.
9. (3 pts) (a) On Malthus’s assumptions (population doubles every 25 years; food rises by one original unit every 25 years, starting from 1 and 1), what is the ratio of population to food after 150 years? (b) Distinguish a positive check from a preventive check, with one example of each. (c) Name one invention or development after 1798 that broke Malthus’s “arithmetic” limit on food.
10. (4 pts) Country R has 9.0 million people aged 0–14, 30.0 million aged 15–64 and 6.0 million aged 65 and over. (a) Find the total population and the dependency ratio. (b) Find the youth and old-age dependency ratios. (c) What percent of the population is 65 or older? (d) The 55–59 cohort now holds 2.5 million people. If 6 percent of them die in the next ten years and there is no migration, how many will be in the 65–69 band in ten years?
11. (4 pts) In one year a country of 25,000,000 people records 300,000 births, 200,000 deaths, 180,000 immigrants and 105,000 emigrants. (a) Find the net migration. (b) Find the net migration rate per 1,000. (c) Use the demographic balancing equation to find the total population change and the percent growth. (d) State one of Ravenstein’s laws that this kind of data could be used to test.
12. (4 pts) (a) The Liverpool–New York route is about 5,600 km (3,500 miles). A westbound sailing ship takes 42 days; a steamship around 1900 takes 8 days. Find each average speed in km per day and km per hour (with mph), and how many times faster the steamer is. (b) About 12.5 million Africans were carried onto slave ships and about 10.7 million survived the Middle Passage. What percent died at sea? About 400,000 were landed in mainland North America; what percent of the survivors is that?
13. (4 pts) (a) A Midwestern city grew from 50,000 to 800,000 people in 40 years. How many times did it double, and what was its doubling time? (b) Use the rule of 70 to estimate its average annual growth rate. (c) The original Erie Canal (1825) ran about 363 miles (584 km) from the Hudson to Lake Erie and used 83 locks to lift boats about 568 feet (173 m). Find the average lift per lock in feet and meters. (d) Give one push factor and one pull factor of the Great Migration of Black Southerners (about 1910–1970).

14. (3 pts) A teaching example: the 1890 census counted 240,000 people born in Country Z living in the United States, and 120,000 immigrants from Z had arrived in 1907. (a) Under the 1924 rule of 2 percent of the 1890 foreign-born, what is Z's yearly quota? (b) What percent of the 1907 inflow is that, and by what percent does the law cut immigration from Z? (c) What did the Hart–Celler Act of 1965 put in place of national-origins quotas?

15. (4 pts) Grimm's law: Latin *p, t, k, d* usually answer to Germanic *f, th, h, t*. (a) Give the native English cognates of Latin *tu* (you), *canis* (dog), *piscis* and *duo*, and name the sound shift in each. (b) English *beef* and *cow* mean related things but look nothing alike. Explain why.

16. (3 pts) Name the language family of each: Swahili, Tagalog, Hungarian, Tamil, Hindi, Basque.

17. (4 pts) (a) Use Rodney Stark's model (about 1,000 Christians in AD 40, growing 40 percent per decade) to estimate the number of Christians in AD 200. (b) Find the doubling time. (c) Identify the type of diffusion in Acts 8:4 ("they that were scattered abroad went every where preaching the word") and in Paul's deliberate travel from city to city (Ephesus, Philippi, Corinth, Rome). (d) Name one barrier that later reversed Christianity's spread in a former heartland.

18. (4 pts) India has about 1.4 billion people; about 80 percent are Hindu and about 200 million are Muslim. The world has about 1.2 billion Hindus, and Muslims are about 26 percent of humanity. (a) What share of the world's Hindus live in India? (b) Find the location quotient of Muslims in India, using the world as the base, and interpret it. (c) Why can a map coloring India as "Hindu majority" mislead? (d) Classify as universalizing or ethnic: Sikhism, Shinto, Buddhism, Judaism.

19. (4 pts) (a) The Islamic year is about 354 days. The Hajj began about 14 June 2024. Estimate when it begins in 2027. (b) About how many years does the Hajj take to move through all the seasons? (c) City A (3 million people) is 300 km (186 mi) from a shrine; City B (12 million) is 900 km (559 mi) away. By the gravity model, which sends more pilgrims, and by what factor? (d) Muslims in North America pray toward Mecca. Why does the shortest direction point northeast, not southeast as a flat Mercator map suggests?

20. (3 pts) (a) Classify each: Japan; the Kurds; the Koreans; the United Kingdom (nation-state, stateless nation, multistate nation or multinational state). (b) Give the four criteria of a state in the Montevideo Convention (1933). (c) Name the shape: Chile; South Africa (which surrounds Lesotho); Indonesia.

21. (4 pts) Two countries face each other across a strait 150 statute miles wide. (a) Convert the width to nautical miles. (b) Do their territorial seas overlap? Do their exclusive economic zones? (c) Where would a median line lie, in nautical miles, km and statute miles from each coast? (d) Classify by origin: the Tordesillas line of 1494; the 49th parallel west of Lake of the Woods (1818, 1846); the stretches of the Berlin Wall left standing after 1989.

22. (4 pts) After the 2020 census the apportionment population was 331,108,434 and the average House district held about 761,169 people. A state has 7.6 million people. (a) About how many House seats does it receive, and how many electoral votes? (b)

Compare its share of the national population with its share of the House, the Senate and the Electoral College. (c) Classify France, Japan, Germany and Canada as unitary or federal. (d) Quote or paraphrase the Tenth Amendment's principle.

23. (3 pts) (a) A Security Council draft receives 8 yes, 5 no and 2 abstentions; no permanent member votes no. Does it pass? (b) Another draft receives 10 yes and 5 no, and one of the no votes is from France. Does it pass? (c) Under the 2014 NATO pledge of 2 percent of GDP, a member with a GDP of $250 billion spends $4 billion on defense. What percent is that, and how much more would it need to spend?
24. (8 pts) **Essay.** "Malthus was wrong in his forecast but useful in his question." In a well-organized essay, explain Malthus's argument of 1798, then weigh the evidence of the two centuries since, including at least one case his supporters cite and at least two developments or critics that tell against him (for example Boserup, Simon, Sen, the Irish famine, the Haber–Bosch process, the Simon–Ehrlich bet). End with your own reasoned judgment.
25. (8 pts) **Essay.** Explain the degree to which the United Nations, NATO and the European Union each ask member states to pool or limit their sovereignty. Use correct founding dates and at least one specific rule or event for each (such as the Security Council veto, Article 5, EU law or the euro). Then state fairly the strongest argument for and the strongest argument against pooling sovereignty, using the 2016 British referendum as an example. You may reach any conclusion that you support with evidence.

Answer key

1. (a) 6.4 × 50,000 = 320,000 cm = 3.2 km ≈ 1.99 mi (about 2 miles). (b) Smaller scale: 1/50,000 is a smaller fraction than 1/24,000, so it shows more area with less detail. (c) cos 60° = 0.5, so lengths × 2 and areas × 4. (d) It appears about 4 × 50,000 = 200,000 km² (about 77,200 sq mi). An **equal-area** projection (such as Gall–Peters or Goode's homolosine) shows its true size. (1 point each part.)
2. (a) Dot density map (one dot per so many cattle) or proportional symbol map: the data are counts. (b) Choropleth map: the data are a rate (percent), which a choropleth shades fairly. (c) Flow map, with arrow width showing the number of migrants, as Minard drew his army. A choropleth of raw counts misleads because a large county looks important (and big counties tend to have big totals) even where few people or cattle are spread over much land; counts belong in dots or symbols, rates in choropleths. (1 point for (a)–(b) together, 1 for (c), 1 for the explanation.)
3. (a) √(1.0 ÷ 4.0) = 0.5; 120 ÷ 1.5 = **80 miles (129 km) from A**, so 40 miles (64 km) from B. The larger city's pull reaches twice as far. (2 points.) (b) A–B: 4 × 1 ÷ 120² = 4 ÷ 14,400 ≈ 0.000278. A–C: 4 × 2 ÷ 240² = 8 ÷ 57,600 ≈ 0.000139. A should interact with B about **twice** as much: C is twice as large but twice as far, and distance counts squared. (2 points.)
4. (a) Relocation (the printers moved and carried the skill). (b) Hierarchical (from large and important places first). (c) Stimulus (the idea of writing spread, but the form changed). (d) Contagious (person to person among neighbors). (1 point each.)
5. (a) 60,000 ÷ 1,200 = **50 people per sq mi**; 1,200 sq mi × 2.59 = 3,108 km², and 60,000 ÷ 3,108 ≈ **19.3 per km²**. (1.5 points.) (b) County share = 2,500 ÷ 25,000 = 10 percent; LQ = 10 ÷ 2 = **5.0**: the county has five times the national concentration of farm jobs, so agriculture is a basic (export) activity there. (1.5 points.) (c) Counties differ in size and population, so raw

counts mostly reflect size; dividing by area or population (as Snow did with deaths per 10,000 houses) allows a fair comparison. (1 point.)

6. (a) Elderly: 200 + 1,800 = 2,000 of 8,000 = **25 percent**. The simple average (20 percent) is wrong because the tracts have different populations; the larger tract must count more (a weighted average). (b) The **ecological fallacy**: assuming what is true of an area as a whole is true of each household in it (Booth knew a purple street held both comfortable and poor families). (c) The modifiable areal unit problem is that results change when the same data are grouped into different-sized or differently drawn areas. (1 point each.)
7. (a) 60,000,000 ÷ 500,000 = **120 per km²**; 60,000,000 ÷ 193,000 ≈ **311 per sq mi**. (b) Arable land = 0.12 × 500,000 = 60,000 km² (≈ 23,170 sq mi). Physiological density = 60,000,000 ÷ 60,000 = **1,000 per km² ≈ 2,590 per sq mi**, about 8.3 times the arithmetic density. (c) Physiological density, because it divides people only by farmable land, while arithmetic density counts mountains and desert as if they could feed people (as in Egypt). (1 point each.)
8. (a) P: (38 − 9) ÷ 10 = **2.9 percent**; Q: (8 − 11) ÷ 10 = **−0.3 percent**. (b) 70 ÷ 2.9 ≈ **24 years**. (c) P: stage 2 (births high, deaths already low). Q: stage 5 (deaths exceed births; some texts say late stage 4). (d) Any one: France's birth rate fell in the late 1700s before industrializing; Bangladesh's fertility fell from about six to about two while still poor; death rates in Asia, Africa and Latin America fell within a generation after 1945 (Kenya near 4 percent growth around 1980), not over a century as in Sweden; Israel, a wealthy country, has fertility near 3; the model ignores migration. (1 point each.)
9. (a) 150 years = 6 periods: population $2^6 = 64$; food 1 + 6 = 7; ratio **64 : 7**. (b) Positive checks raise the death rate (famine, disease, war); preventive checks lower the birth rate (chiefly later marriage, Malthus's "moral restraint"). (c) Any one: the Haber–Bosch process for nitrogen fertilizer (1909–1913); railroads and steamships bringing prairie and steppe grain; refrigeration; new rotations and drainage; hybrid corn; the Green Revolution wheat and rice. (1 point each.)
10. (a) Total 45.0 million; dependency ratio = (9.0 + 6.0) ÷ 30.0 × 100 = **50**. (b) Youth 9.0 ÷ 30.0 × 100 = **30**; old-age 6.0 ÷ 30.0 × 100 = **20**. (c) 6.0 ÷ 45.0 ≈ **13.3 percent**. (d) 2.5 × 0.94 = **2.35 million**. A cohort moves up the pyramid predictably, so planners can foresee pension and health needs. (1 point each.)
11. (a) 180,000 − 105,000 = **+75,000**. (b) 75,000 ÷ 25,000,000 × 1,000 = **+3.0 per 1,000**. (c) Change = births − deaths + net migration = 100,000 + 75,000 = **175,000**; 175,000 ÷ 25,000,000 = **0.7 percent**. (d) Any one, e.g.: most migrants move only a short distance; migration proceeds step by step; each current produces a smaller countercurrent; large towns grow more by migration than by natural increase; the chief causes are economic. (1 point each.)
12. (a) Sail: 5,600 ÷ 42 ≈ **133 km/day** (83 mi/day) ≈ 5.6 km/h (3.5 mph). Steam: 5,600 ÷ 8 = **700 km/day** (about 438 mi/day) ≈ 29.2 km/h (18.1 mph). Ratio 42 ÷ 8 = **5.25**. (2 points.) (b) Died: 1.8 ÷ 12.5 = **14.4 percent**. Mainland North America: 0.4 ÷ 10.7 ≈ **3.7 percent**; most went to Brazil and the Caribbean. (2 points.)
13. (a) 800,000 ÷ 50,000 = 16 = 2^4: four doublings in 40 years, a doubling time of **10 years**. (b) 70 ÷ 10 ≈ **7 percent per year** (exactly about 7.2 percent). (c) 568 ÷ 83 ≈ **6.8 ft per lock**; 173 ÷ 83 ≈ **2.1 m**. (d) Push: poverty of sharecropping, the boll weevil's ruin of cotton, segregation laws or lynching. Pull: factory jobs in Northern and Western cities, especially when World War I nearly stopped European immigration; news in the *Chicago Defender* and letters home. (1 point each.)
14. (a) 0.02 × 240,000 = **4,800** per year. (b) 4,800 ÷ 120,000 = **4 percent** of the 1907 inflow, a cut of **96 percent**. (c) A system of preferences for relatives of citizens and residents and for

workers with needed skills. (1 point each.)

15. (a) *tu* → **thou** (t → th); *canis* → **hound** (k → h); *piscis* → **fish** (p → f); *duo* → **two** (d → t). (3 points; ¾ point each.) (b) *Cow* is native Germanic, inherited from the common ancestor; *beef* was borrowed from French after the Norman Conquest of 1066, long after the Germanic sound shift, so it does not follow the old rules. Regular correspondences prove inheritance; borrowings do not. (1 point.)
16. Swahili: Niger-Congo (Bantu). Tagalog: Austronesian. Hungarian: Uralic. Tamil: Dravidian. Hindi: Indo-European (Indo-Iranian branch). Basque: a language isolate with no proven relatives. (½ point each.)
17. (a) AD 40 to 200 = 16 decades: $1{,}000 \times 1.4^{16} \approx 1{,}000 \times 218 \approx$ **218,000**. (b) $\ln 2 \div \ln 1.4 = 0.693 \div 0.336 \approx 2.06$ decades, about **21 years**. (c) Acts 8:4: **relocation** diffusion; Paul's city-to-city route: **hierarchical** diffusion (followed by contagious spread to the countryside). (d) The Arab conquests of the 600s, which over centuries made Syria, Egypt and North Africa mostly Muslim (the 1054 and 1517 divisions split the Church but did not reverse its spread). (1 point each.)
18. (a) 0.80×1.4 billion = 1.12 billion; $1.12 \div 1.2 \approx$ **93 percent** (the lesson cites about 94 percent). (b) Muslim share in India = $200 \div 1{,}400 \approx 14.3$ percent; LQ = $14.3 \div 26 \approx$ **0.55**, below the world share, yet India still holds one of the largest Muslim populations on earth. (c) A majority-religion map hides large minorities (here about 200 million Muslims). (d) Sikhism universalizing; Shinto ethnic; Buddhism universalizing; Judaism ethnic. (1 point each.)
19. (a) $365 - 354 = 11$ days earlier each year; $3 \times 11 = 33$ days earlier: **about 12 May 2027** (accept 11–15 May; months begin with the sighting of the new moon). (b) $365 \div 11 \approx$ **33 years**. (c) A: $3{,}000{,}000 \div 300^2 \approx 33.3$; B: $12{,}000{,}000 \div 900^2 \approx 14.8$; City A sends about **2.25 times** as many. Distance decay outweighs size. (d) The shortest path on a sphere is a great circle, which from North America arcs north across the Atlantic toward Europe and then southeast to Arabia; the straight line on a Mercator map is a rhumb line of constant bearing, which is longer. (1 point each.)
20. (a) Japan: nation-state. Kurds: stateless nation. Koreans: multistate nation. United Kingdom: multinational state. (b) A permanent population, a defined territory, a government, and the capacity to enter into relations with other states. (c) Chile: elongated. South Africa: perforated. Indonesia: fragmented. (1 point each.)
21. (a) $150 \div 1.151 \approx$ **130 nm**. (b) Territorial seas need 12 + 12 = 24 nm, so they do **not** overlap; EEZs would need 400 nm, so they **do** overlap. (c) $130.3 \div 2 \approx$ **65 nm** = $65.2 \times 1.852 \approx$ **121 km** ≈ **75 statute miles** from each coast. (d) Tordesillas: superimposed (and geometric). 49th parallel: antecedent. Berlin Wall remains: relic. (1 point each.)
22. (a) $7{,}600{,}000 \div 761{,}169 \approx 9.98$, so **10 seats**; electoral votes = 10 + 2 = **12**. (b) Population $7.6 \div 331.1 \approx 2.3$ percent; House $10 \div 435 \approx 2.3$ percent; Senate $2 \div 100 = 2.0$ percent; Electoral College $12 \div 538 \approx 2.2$ percent. The House follows population, the Senate gives each state equal weight, and the Electoral College blends the two (the Connecticut Compromise). (c) France and Japan unitary; Germany and Canada federal. (d) Powers not delegated to the United States by the Constitution, nor prohibited by it to the states, are reserved to the states or to the people. (1 point each.)
23. (a) No: it needs at least 9 yes votes. (b) No: France is a permanent member, so its no vote is a veto, even though $10 \geq 9$. (c) $4 \div 250 =$ **1.6 percent**; 2 percent is $5 billion, so it needs **$1 billion** more per year. (1 point each.)
24. **Grading points (8):** (2) Accurate statement of the argument: population unchecked grows geometrically (1, 2, 4, 8, doubling about every 25 years), food arithmetically (1, 2, 3, 4); positive checks (famine, disease, war) and preventive checks (later marriage, "moral restraint" from 1803). (2) Evidence against the forecast: England and Wales grew from about

9 million (1801) to 32.5 million (1901) and ate better; new rotations, railroads, steamships and refrigeration; Haber–Bosch fertilizer (about half the world eats food grown with it); U.S. corn yields up about sevenfold since the 1930s; Ehrlich's 1968 famine forecast failed and he lost the 1980 metals bet. (2) Fair statement of the other side and of the critics: stage 1 societies did follow Malthusian swings; Ireland (8.2 million in 1841, famine from 1845) looks Malthusian to some, though critics note grain exports, land tenure and rigid relief policy; Sen argued famines come from collapse of access to food (Soviet 1932–33 and China 1959–61 famines caused chiefly by Communist policy); Boserup argued population pressure drives intensification; Simon called the human mind the ultimate resource; neo-Malthusians rightly warn about worn soils, pumped aquifers and emptied fisheries as local questions. (2) A reasoned conclusion supported by the evidence.

Model answer (summary): Malthus described the pre-modern world well: harvests, plagues and wars set the jagged line of stage 1. But his ratios assumed food could grow only by fixed steps, and two centuries of invention, trade and harder work on the land proved otherwise; the worst modern famines came from war and tyranny more than from too many mouths. His question remains useful because limits are real at the local scale, but the evidence shows those limits can be raised by human work and invention on a fruitful earth, so they deserve careful study rather than panic.

25. **Grading points (8):** (2) Accurate description with dates: UN Charter signed 26 June 1945 in San Francisco, in force 24 October 1945, 193 members; NATO founded 4 April 1949 by 12 states, 32 members as of 2026; EU grown from the Coal and Steel Community (1951) and the Treaty of Rome (1957), created by Maastricht (signed 1992, in force 1993), 27 members. (2) Correct ranking of degree: the UN asks least (a meeting place of sovereign states; one vote each in the General Assembly; the Security Council can act only with 9 votes and no permanent-member veto); NATO asks a promise of mutual defense (Article 5, invoked once, after 11 September 2001) but members keep command of their own forces and decide by consensus; the EU asks most (EU law applies directly, its Court of Justice can overrule national courts on EU matters, 21 of 27 share the euro, Schengen removed most internal border checks). (2) Both arguments stated fairly: for pooling, peace in Western Europe since 1945 (Schuman's 1950 aim of making war "materially impossible"), wider markets, small states stronger together; against, decisions move from voters to distant officials, common rules fit some regions poorly, and a nation should govern itself. (1) Brexit: 51.9 to 48.1 percent in 2016; the UK left on 31 January 2020, showing citizens weighing these arguments differently. (1) A clear conclusion supported by reasons; any position is acceptable if argued from evidence.

    Model answer (summary): The three bodies sit on a ladder. The UN constrains sovereignty little because the veto protects the great powers; NATO binds members in one specific matter, defense; the EU shares lawmaking and, for most members, money itself. Supporters credit pooled sovereignty with peace and prosperity, critics with weakening self-government, and the British vote shows that free peoples can judge the balance differently.

Final Exam

Units 1–10 · 120 minutes

You have 120 minutes. A calculator is allowed; no notes, books or phones. Useful figures: 1 mile = 1.609 km; 1 sq mi = 2.59 km² = 640 acres; 1 hectare = 2.471 acres; 1 km² = 100 ha; 1 acre-foot = 1,233.5 m³ = 325,851 gallons; 1° of latitude ≈ 111 km (69 mi); 1° of longitude ≈ 111.32 × cos(latitude) km. The exam is cumulative, with most weight on Units 6–10. **How points are earned:** the points for each problem are shown beside it. On calculations, write the formula, substitute the numbers with units, and give the answer with its unit (in both km and miles when asked); correct method earns partial credit even if the arithmetic slips. Short-answer items earn one point (or the share stated) for each correct part. The two essays are graded on accurate facts, use of evidence, a fair statement of more than one view, and a reasoned conclusion. The exam has 27 problems worth a total of **100 points**.

1. (3 pts) (a) Two cities lie on the same meridian, one at 48° N and the other at 12° S. Find the great-circle distance between them in km and miles. (b) New York and Madrid both lie near 40° N. Is the shortest route between them along the 40th parallel? Describe how it runs. (c) How does that shortest route look on a Mercator map, and what does the straight line on a Mercator map represent?
2. (3 pts) (a) A country has a crude birth rate of 41 and a crude death rate of 12 per 1,000. Find its rate of natural increase and its doubling time. (b) Place it on the demographic transition model. (c) Another country has a total fertility rate of 1.3. Is it above or below replacement, and what does that suggest for its future pyramid?
3. (3 pts) Two towns send migrants to a growing city. Town A has 300,000 people and is 60 km (37 mi) away; Town B has 1,200,000 people and is 180 km (112 mi) away. (a) Using the gravity model ($P \div d^2$, the city's own size being the same for both), which town should send more migrants, and by what factor? (b) Name two things the model leaves out that could change the real result.
4. (3 pts) Part of the Egypt–Sudan boundary follows the 22nd parallel north. Assume it runs from 25.0° E to 36.9° E. (a) Estimate its length in km and miles. (b) Classify it by form. (c) Name one advantage and one weakness of such a boundary.
5. (3 pts) (a) By textbook dates, farming reached a site about 6000 BC and a second site 1,500 km (932 mi) away about 4300 BC. Find the average rate of spread in km and miles per year and compare it with Ammerman and Cavalli-Sforza's "wave of advance." (b) Name three founder crops of the Fertile Crescent. (c) Name two other agricultural hearths with one crop from each.
6. (5 pts) On a von Thünen plain, fresh milk yields Y = 10 tonnes per hectare, sells for p = \$250 a tonne, costs c = \$150 a tonne to produce, and has freight f = \$5 per tonne per km. Wheat has Y = 4, p = \$200, c = \$100 and f = \$1. Use $R = Y(p - c) - Yfd$. (a) Find the locational rent of milk at 5 km. (b) Find the margin of cultivation of each product in km and miles. (c) Find the distance where wheat replaces milk, and state the rings. (d) Explain what happens to the rings if a navigable river runs through the plain.

7. (3 pts) A country’s rice yield rose from 1.2 to 3.0 tonnes per hectare between 1965 and 2005. (a) Find the average annual growth rate and the doubling time. (b) The country needs 36 million tonnes a year. How much land does it need at each yield, and how much land is spared, in hectares, km² and square miles? (c) Name one real cost of the Green Revolution that a careful student should weigh against this gain.
8. (3 pts) A weather station reports: coldest month 8°C with 70 mm of rain; hottest month 24°C with 5 mm; wettest winter month 110 mm; annual precipitation 600 mm; mean annual temperature 16°C. Using the Köppen rules of Lesson 6.4 (arid if annual mm < 20 × mean temperature for a winter-rain climate; C if the coldest month is 0–18°C; “s” if the driest summer month has under 30 mm and less than one-third of the wettest winter month; “a” if the hottest month is 22°C or warmer), (a) classify the climate, showing each test; (b) name the farming region it suits and three typical crops; (c) name two places in the world with this climate.
9. (3 pts) (a) A country’s largest city has 12 million people. By the rank-size rule, predict the populations of its 2nd, 3rd and 4th cities. (b) Its actual second city has 2.5 million. What does that suggest? (c) Classify each fact about Pittsburgh as site or situation: (i) a narrow point of land guarded by rivers on two sides; (ii) the Ohio flows 981 miles (1,579 km) from the Forks to the Mississippi; (iii) iron ore from Lake Superior arrived by river and rail.
10. (4 pts) A pharmacy needs a threshold of 6,000 customers, and its range is 10 km. (a) In a farming region with 25 people per km², what market radius does it need, in km and miles? (b) Can it survive? (c) Rural population falls to 15 people per km². Find the new radius needed. (d) Can it survive now? Explain what this shows about small towns.
11. (4 pts) In a model city, bid rents in dollars per square meter per year are: commercial R = 1,200 − 400d; industrial R = 600 − 100d; residential R = 360 − 40d, with d in km from the center. (a) Which use wins at the center? (b) Where does industry replace commerce? (c) Where do homes replace industry? (d) Where does residential land give way to farmland? Give each distance in km and miles, and name the model the pattern matches.
12. (3 pts) (a) Name the model and author: (i) high-rent housing grows outward in wedges along fast transport lines and lakefronts (Chicago’s North Shore, Philadelphia’s Main Line); (ii) a city grows around several separate centers, such as a port, a heavy-industry district and an outlying business district. (b) A city’s density follows Clark’s model $D = D_0 e^{-bx}$ with D_0 = 15,000 people per km² and b = 0.25 per km. Find the density 4 km from the center. (c) At what distance does density fall to half its central value (km and miles)?
13. (4 pts) Assume people will commute 40 minutes each way. Find the radius (miles and km) and the area within reach of downtown (square miles and km²) for (a) walking at 3 mph and (b) an electric streetcar averaging 12 mph; (c) a freeway at 45 mph. (d) How many times larger is the freeway area than the walking area, and what does this explain about the shape of the American city after 1956?
14. (3 pts) (a) A county has 120,000 workers, 18,000 of them in iron and steel. Nationally 1 percent of workers are in iron and steel. Find the location quotient and interpret it. (b) Explain why Britain’s first great industrial regions grew on or beside coalfields. (c)

Name the person and place: the first iron smelted with coke (1709); a water-powered cotton mill in Derbyshire (1771); America’s first such mill, on the Blackstone River (1793).

15. (4 pts) A smelter needs 4 tons of ore and 1 ton of fuel for each ton of metal. In Weber’s triangle, the ore field O is 200 miles (322 km) from the fuel field F and 300 miles (483 km) from the market M; F is 250 miles (402 km) from M. Freight costs the same per ton-mile everywhere. (a) Find the ton-miles per ton of metal at each corner and the least-cost site. (b) Find the material index and say whether the result fits it. (c) A town with cheaper labor saves $12 per ton in wages but adds $9 per ton in freight. Another saves $12 but adds $15. Which, if either, should get the smelter?

16. (3 pts) (a) Country X invested $2 billion of a $50 billion national income; eighteen years later it invests $9.6 billion of $80 billion. Has it met Rostow’s numerical test for take-off? (b) Country A grows 6 percent a year per person, Country B 1.5 percent. Find each doubling time. (c) Both start at $2,000 per person. Find each after 35 years.

17. (4 pts) Hours of labor per unit: Country X makes a computer in 30 hours and a ton of wheat in 10 hours; Country Y makes a computer in 60 hours and a ton of wheat in 15 hours. (a) Which country has the absolute advantage in each good? (b) Find each country’s opportunity cost of a computer and of a ton of wheat. (c) Which should specialize in which, and within what range of terms of trade do both gain? (d) At 3.5 tons of wheat per computer, how many hours does each country save per computer traded?

18. (4 pts) (a) A country has proved oil reserves of 30 billion barrels and produces 2.5 billion barrels a year. Find its R/P ratio. (b) For 8 years production stays at 2.5 billion a year while exploration and technology add 3.0 billion barrels of reserves a year. Find the reserves and R/P after 8 years. (c) A mineral has a static R/P of 50 years, but use grows 3 percent a year. Using T = ln(1 + r × R/P) ÷ r, how long would today’s reserves last, and what is the doubling time of use? (d) Explain Zimmermann’s phrase “Resources are not, they become.”

19. (4 pts) In a dry year a western stream supplies 9,000 acre-feet. Three users hold rights: Ranch A (dated 1880) to 5,000 acre-feet, Town B (1910) to 3,000, and Farm C (1950) to 2,500. (a) Under prior appropriation, how much does each receive? (b) How would a riparian system in the humid East approach the shortage differently? (c) Convert 9,000 acre-feet to cubic meters and gallons. (d) The Boulder Canyon Project Act (1928) gave California 4.4 of the Lower Basin’s 7.5 million acre-feet. What percent is that?

20. (3 pts) A 120-acre sloping field plowed up and down the hill loses 15 tons of soil per acre per year; one inch of topsoil over an acre weighs about 150 tons. (a) How many tons does the field lose each year? (b) How many years to lose one inch (2.5 cm)? (c) After contour plowing and terraces the loss falls to 5 tons per acre per year. How many years per inch now, and what is the percent reduction? Name the man whose Soil Conservation Service promoted these methods.

21. (4 pts) (a) What is the chance of at least one 50-year flood during a 25-year mortgage? (b) Of at least one 100-year flood in 10 years? (c) Compare a magnitude 8.0 earthquake with a 6.0 in ground-motion amplitude and in energy. (d) Explain risk as the meeting of

hazard, exposure and vulnerability, and name the two main responses Galveston made after 1900.

22. (3 pts) For each model, state one key assumption and one limitation with a real example: (a) von Thünen's model (1826); (b) Weber's least-cost model (1909); (c) the demographic transition model.
23. (3 pts) County A covers 4,000 square miles and has 40,000 people; County B covers 400 square miles and has 120,000 people. (a) Find each density per square mile and per km². (b) A student shades a choropleth map by total population. Explain the problem and name a better map for totals. (c) Country M has 10 million people aged 0–14, 40 million aged 15–64 and 6 million aged 65 and over. Find its dependency ratio.
24. (3 pts) (a) On a 1:100,000 map two towns are 7.5 cm apart. How far apart are they in km and miles? (b) Sample item: Which religion is universalizing and nearly vanished from its own hearth region? (A) Hinduism (B) Judaism (C) Buddhism (D) Shinto (E) Sikhism. Give the answer and why each other choice is wrong. (c) Distinguish a refugee from an internally displaced person.
25. (3 pts) (a) A student answers 48 of 60 multiple-choice questions correctly and earns 4, 6 and 5 points on the three free-response questions. Estimate the composite percentage using (MC ÷ 60 × 50) + (FRQ ÷ 21 × 50). (b) Compare the composite value of one free-response point with one multiple-choice answer. (c) Name the five big ideas of the course from Lesson 10.4.
26. (8 pts) **Essay.** Explain the degree to which W. W. Rostow's five stages of economic growth (1960) explain the real paths of nations. Describe the model, test it against at least two real cases (for example South Korea, North Korea, Argentina, the Persian Gulf oil states, Soviet or Chinese planning, China after 1978), and present fairly at least two critics or rival views (Gerschenkron, dependency theory, Wallerstein, the institutions view of Bauer, North and de Soto), with a strength and a weakness of each. End with your own reasoned judgment.
27. (7 pts) **Essay.** In 1913 Congress and President Wilson allowed San Francisco to dam the Hetch Hetchy Valley in Yosemite National Park. State the case John Muir made against the dam and the case San Francisco and Gifford Pinchot made for it, each as its own supporters would. Use specific facts about the decision and its results. Then explain how the biblical idea of stewardship (Genesis 2:15: "to dress it and to keep it") speaks to both sides, and give your own reasoned view of whether the valley should be restored today.

Answer key

1. (a) 48 + 12 = 60° of latitude (add, since they are on opposite sides of the equator); 60 × 111 = **6,660 km**; 60 × 69 = **4,140 miles**. (b) No. The shortest route is a great circle, which bows poleward (north) of the parallel and crosses the Atlantic farther north than 40° N. (c) On a Mercator map it appears as a curve bending north; the straight line on a Mercator map is a rhumb line of constant compass bearing, which is longer. (1 point each.)
2. (a) RNI = (41 − 12) ÷ 10 = **2.9 percent**; doubling time ≈ 70 ÷ 2.9 ≈ **24 years**. (b) Stage 2: births high, deaths already fallen. (c) Below replacement (about 2.1); without immigration its

pyramid will become constrictive, narrow at the base, with an aging population. (1 point each.)

3. (a) A: 300,000 ÷ 60^2 = 300,000 ÷ 3,600 ≈ 83.3. B: 1,200,000 ÷ 180^2 = 1,200,000 ÷ 32,400 ≈ 37.0. Town A should send about **2.25 times** as many migrants, because B is four times larger but three times as far, and distance counts squared (9 times). (2 points.) (b) Any two: cost and ease of travel (a railroad or highway), family ties and chain migration, language, borders and laws, intervening opportunities, the job market in each town. (1 point.)
4. (a) Δ = 11.9°; 1° at 22° N = 111.32 × cos 22° = 111.32 × 0.927 ≈ 103.2 km; 11.9 × 103.2 ≈ **1,228 km ≈ 763 miles**. (b) A **geometric** boundary (a straight line of latitude). (c) Advantage: easy to define and delimit in a treaty. Weakness: it ignores the land and the peoples beneath it, so it can cut across grazing lands, routes or communities; such lines are often superimposed by outside powers. (1 point each.)
5. (a) 6000 − 4300 = 1,700 years; 1,500 ÷ 1,700 ≈ **0.88 km per year** (932 ÷ 1,700 ≈ 0.55 mi per year), close to their figure of about 1 km per year. (b) Any three: emmer wheat, einkorn wheat, barley, lentils, peas, chickpeas, bitter vetch, flax. (c) Any two, e.g.: southern Mexico (maize, beans, squash); the Andes (potatoes, quinoa); China's Yellow and Yangtze valleys (millet, rice); New Guinea highlands (taro, bananas); West African Sahel and savanna (sorghum, pearl millet, African rice, yams); Ethiopian highlands (teff, coffee); eastern North America (sunflower, squash). (1 point each.)
6. (a) Milk: R = 10(100) − 50d = 1,000 − 50d; at 5 km, R = 1,000 − 250 = **$750 per hectare**. (1 point.) (b) Milk: 1,000 = 50d, **d = 20 km (12.4 mi)**. Wheat: R = 400 − 4d, margin **100 km (62.1 mi)**. (1 point.) (c) 1,000 − 50d = 400 − 4d → 600 = 46d → **d ≈ 13.0 km (8.1 mi)**; check: both ≈ $348. Milk ring 0–13 km; wheat ring 13–100 km; beyond 100 km no market farming of these crops. The perishable product with the steep rent line takes the inner ring. (2 points.) (d) Water freight is cheaper than wagon freight, so the rings stretch into long bands along the river, as von Thünen himself showed. (1 point.)
7. (a) Factor 3.0 ÷ 1.2 = 2.5 in 40 years; ln 2.5 ÷ 40 = 0.916 ÷ 40 ≈ 0.023, so about **2.3 percent per year**; doubling ≈ 70 ÷ 2.3 ≈ **30 years**. (b) 36,000,000 ÷ 1.2 = 30 million ha; 36,000,000 ÷ 3.0 = 12 million ha; spared **18 million ha = 180,000 km^2 ≈ 69,500 sq mi**. (c) Any one: lowered water tables from heavy pumping (Punjab, parts of the Ogallala); fertilizer runoff; fewer local varieties planted; farmers without irrigation, credit or roads (much of rain-fed Africa) gained less at first. (1 point each.)
8. (a) Arid test: 20 × 16 = 320 mm < 600 mm, so not B. Coldest 8°C → C. Driest summer 5 mm < 30 and < 110 ÷ 3 ≈ 36.7 → s. Hottest 24°C ≥ 22°C → a. **Csa**, hot-summer Mediterranean. (b) Mediterranean agriculture: olives, grapes, citrus and winter wheat (irrigation for summer crops). (c) Any two: the Mediterranean basin (southern Spain, Italy, Greece), central California, central Chile, the Cape of South Africa, southern Australia. (1 point each.)
9. (a) 12 ÷ 2 = **6 million**; 12 ÷ 3 = **4 million**; 12 ÷ 4 = **3 million**. (b) The largest city is 12 ÷ 2.5 = 4.8 times the second, far more than twice: a **primate city** (Mark Jefferson's term), as Paris is in France. (c) (i) site; (ii) situation; (iii) situation. (1 point each.)
10. (a) Area = 6,000 ÷ 25 = 240 km^2; r = √(240 ÷ π) = √76.4 ≈ **8.7 km (5.4 mi)**. (b) Yes: 8.7 km is within its 10 km range. (c) Area = 6,000 ÷ 15 = 400 km^2; r = √(400 ÷ π) = √127.3 ≈ **11.3 km (7.0 mi)**. (d) No: the needed radius exceeds the range, so customers will not travel far enough to supply the threshold. When farm population thins, small-town businesses fall below their thresholds and close, as central place theory predicts. (1 point each.)
11. (a) Commercial ($1,200 versus $600 and $360). (b) 1,200 − 400d = 600 − 100d → 600 = 300d → **2 km (1.2 mi)**; check: residential at 2 km is $280, below $400. (c) 600 − 100d = 360 − 40d → 240 = 60d → **4 km (2.5 mi)**. (d) 360 − 40d = 0 → **9 km (5.6 mi)**. Rings of CBD,

industry/transition and homes: Burgess's concentric zone model, explained by bid rent. (1 point each.)

12. (a) (i) Homer Hoyt's sector model (1939); (ii) Harris and Ullman's multiple-nuclei model (1945). (b) $15{,}000 \times e^{-1} = 15{,}000 \times 0.368 \approx$ **5,520 per km²** (about 14,300 per sq mi). (c) $x = \ln 2 \div 0.25 = 0.693 \div 0.25 \approx$ **2.77 km (1.72 mi)**. (1 point each.)
13. 40 minutes = ⅔ hour. (a) Walking: r = 2 mi (3.2 km); area = $\pi \times 2^2 \approx$ **12.6 sq mi (32.6 km²)**. (b) Streetcar: r = 8 mi (12.9 km); area = $\pi \times 64 \approx$ **201 sq mi (521 km²)**. (c) Freeway: r = 30 mi (48.3 km); area = $\pi \times 900 \approx$ **2,827 sq mi (7,323 km²)**. (d) $(45 \div 3)^2 =$ **225 times**. The travel-time budget stayed about the same, so faster travel was spent on distance: the compact walking city became the star-shaped streetcar city and then, after the Interstate Highway Act of 1956, a broad, low-density metropolis with beltways, suburbs and edge cities. (1 point each.)
14. (a) County share 18,000 ÷ 120,000 = 15 percent; LQ = 15 ÷ 1 = **15**: the county is very strongly specialized in iron and steel and exports it. (b) Coal was heavy and costly to haul over bad roads; once Watt's engine let mills run on steam and coke replaced charcoal for iron, the cheapest place to make goods was where coal lay, or where a canal brought it (the Bridgewater Canal halved Manchester's coal price). (c) Abraham Darby at Coalbrookdale; Richard Arkwright at Cromford; Samuel Slater at Pawtucket, Rhode Island. (1 point each.)
15. (a) At O: fuel 1 × 200 + metal 1 × 300 = **500**. At F: ore 4 × 200 + metal 1 × 250 = **1,050**. At M: ore 4 × 300 + fuel 1 × 250 = **1,450**. Least cost at the **ore field**. (2 points.) (b) Material index = (4 + 1) ÷ 1 = **5**: strongly weight-losing, so it should locate at the material source, as copper smelters stand beside the mines. (1 point.) (c) The first town lies inside the critical isodapane ($9 < $12) and saves a net $3 per ton, so it should get the smelter; the second ($15 > $12) would lose $3 per ton. (1 point.)
16. (a) 2 ÷ 50 = 4 percent; 9.6 ÷ 80 = 12 percent. Yes: investment rose from about 5 percent or less to more than 10 percent within about two decades (a full judgment would also look for leading sectors and sound institutions). (b) A: 70 ÷ 6 ≈ **11.7 years**; B: 70 ÷ 1.5 ≈ **47 years**. (c) A: $2{,}000 \times 1.06^{35} \approx 2{,}000 \times 7.69 \approx$ **$15,370**; B: $2{,}000 \times 1.015^{35} \approx 2{,}000 \times 1.68 \approx$ **$3,370**. (1 point each.)
17. (a) X in both (30 < 60 and 10 < 15). (b) X: a computer costs 30 ÷ 10 = 3 tons of wheat; a ton of wheat costs ⅓ computer. Y: a computer costs 60 ÷ 15 = 4 tons; a ton of wheat costs ¼ computer. (c) X has the comparative advantage in computers (3 < 4), Y in wheat (¼ < ⅓). X should make computers and Y wheat; both gain at any rate between **3 and 4 tons of wheat per computer**. (d) X makes a computer (30 h) and gets 3.5 t of wheat that would cost it 35 h: saves **5 hours**. Y makes 3.5 t (52.5 h) and gets a computer that would cost it 60 h: saves **7.5 hours**. As in Ricardo's cloth and wine, the country better at both still gains. (1 point each.)
18. (a) 30 ÷ 2.5 = **12 years**. (b) 30 − 20 + 24 = **34 billion barrels**; R/P = 34 ÷ 2.5 = **13.6 years**, longer than at the start: R/P is a snapshot, not a countdown. (c) $\ln(1 + 1.5) \div 0.03 = \ln 2.5 \div 0.03 \approx 0.916 \div 0.03 \approx$ **31 years**; use doubles in about 70 ÷ 3 ≈ **23 years** (the model ignores new discoveries, recycling, substitutes and price). (d) A material becomes a resource only when people learn to use it; petroleum seeped out in Pennsylvania for centuries before Drake's 1859 well and refining made it valuable. (1 point each.)
19. (a) "First in time, first in right": A **5,000**, B **3,000**, C only the remaining **1,000** (1,500 short). (b) Riparian rights let landowners along the stream share its reasonable use, so the shortage would be spread among those owners rather than falling on the junior right, and only land on the stream would hold a right. (c) 9,000 × 1,233.5 ≈ **11.1 million m³**; 9,000 × 325,851 ≈ **2.93 billion gallons**. (d) 4.4 ÷ 7.5 ≈ **58.7 percent**. (1 point each.)
20. (a) 15 × 120 = **1,800 tons** a year. (b) 150 ÷ 15 = **10 years** per inch. (c) 150 ÷ 5 = **30 years** per inch; reduction (15 − 5) ÷ 15 ≈ **67 percent**. Hugh Hammond Bennett (Soil Conservation

Act of 1935; local, voluntary districts). (1 point each.)

21. (a) $1 - 0.98^{25} \approx 1 - 0.603 =$ **about 40 percent**. (b) $1 - 0.99^{10} \approx 1 - 0.904 =$ **about 9.6 percent**. (c) Two magnitude units: **100 times** the amplitude and about **1,000 times** the energy (32×32). (d) The hazard is the natural event; exposure is how many people and things are in its path; vulnerability is how easily they are harmed (buildings, warning, preparation). A hurricane at sea harms no one; Galveston in 1900 was a low island with little warning. It responded by *protecting* (a concrete seawall about 17 ft high, first section finished 1904) and *adapting* (raising the grade of the city by pumped sand, 1904–1911). (1 point each.)
22. One point per model for a correct assumption plus a limitation tied to a real case. Examples: (a) Assumes a flat, isolated plain with one market and wagon transport; refrigeration, trucks and air freight put Chilean grapes in American stores in winter, and rivers and rail stretch rings into bands (U.S. milksheds along rail lines). (b) Assumes freight cost rises with weight and distance and that firms seek least cost; footloose industries such as software or phones, where transport is a tiny share of cost, and government incentives, agglomeration or just-in-time suppliers (Toyota) break the model. (c) Assumes birth rates fall after death rates as countries urbanize and industrialize, based on European history; Bangladesh's fertility fell while still poor, France's fell before industrializing, Niger's births stay high, Israel is wealthy with fertility near 3, and migration is ignored.
23. (a) A: $40{,}000 \div 4{,}000 =$ **10 per sq mi** (≈ 3.9 per km²). B: $120{,}000 \div 400 =$ **300 per sq mi** (≈ 116 per km²). (b) Choropleths should map rates, not totals; shading totals hides that B is 30 times as dense as A, and big areas look important whatever their density. Use a proportional (graduated) symbol or dot density map for totals, and a choropleth of density. (c) $(10 + 6) \div 40 \times 100 =$ **40** dependents per 100 working-age people. (1 point each.)
24. (a) $7.5 \times 100{,}000 = 750{,}000$ cm = **7.5 km ≈ 4.7 miles**. (b) **(C) Buddhism**: universalizing, and it later nearly vanished from India. Hinduism, Judaism and Shinto are ethnic religions; Sikhism is universalizing but remains centered on its Punjab hearth (the Golden Temple at Amritsar). (c) A refugee has crossed an international border fleeing a well-founded fear of persecution (1951 Convention); an internally displaced person has fled but remains inside his own country. (1 point each.)
25. (a) $48 \div 60 \times 50 = 40.0$; $15 \div 21 \times 50 \approx 35.7$; composite ≈ **75.7** out of 100. (b) One FRQ point ≈ $50 \div 21 \approx 2.38$; one MC answer ≈ $50 \div 60 \approx 0.83$, so an FRQ point is worth almost three MC answers; answer every part. (c) Place, scale, region, diffusion, and human–environment interaction. (1 point each.)
26. **Grading points (8):** (2) Accurate model: traditional society; preconditions for take-off; take-off (about 20 years, investment rising from about 5 to over 10 percent of national income, leading sectors; Britain 1783–1802, U.S. 1843–1860); drive to maturity; high mass consumption (Ford's assembly line, 1913); "A Non-Communist Manifesto" answering Marx. (2) Evidence from cases: South Korea rose from under $200 per person (1960) to over $30,000 through investment, schooling and exports in sequence (textiles, ships, Pohang steel 1973, cars, electronics), fitting the staircase; North Korea, with the same peninsula and language but a command economy, remains among Asia's poorest; Argentina's 1935 take-off was followed by cycles of crisis; Gulf oil states grew rich without the stages; Soviet collectivization (famine of 1932–33) and the Great Leap Forward (1958–62, with famine 1959–61) show the failure of the planned alternative; China's opening after 1978 lifted hundreds of millions from extreme poverty. (2) Critics fairly stated: Gerschenkron (latecomers use banks and the state; strength: Germany and Russia; weakness: still a stage view); dependency theory (strength: attention to trade terms; weakness: the East Asian traders grew fastest while import substitution often stalled); Wallerstein (strength: countries are connected; weakness: hard to test, countries move between zones); institutions view (secure property, honest courts, rule of

law explain causes that Rostow only describes). (2) Reasoned conclusion on degree.
Model answer (summary): Rostow's stages describe the sequence many growing countries passed through, and South Korea's rise fits remarkably well, but the model describes more than it explains. Argentina and the Gulf states show that there is no single staircase, and the contrast of the two Koreas points to institutions and the choices of rulers as the deeper causes. The best judgment uses Rostow as a description and his critics, especially the institutions view, to ask why some nations climb and others stall.

27. **Grading points (7):** (2) Accurate facts: Raker Act signed 19 December 1913 after more than a decade of debate; the 1906 earthquake and fire, when broken water mains let much of the city burn, strengthened the city's case; O'Shaughnessy Dam finished 1923; water reached San Francisco in 1934 through an aqueduct about 167 miles (270 km) long running almost entirely by gravity; as of 2026 it serves more than two million people around the Bay, and restoration proposals are still debated. (2) Preservation fairly stated: Muir, Sierra Club founder, saw Hetch Hetchy as a second Yosemite; wild beauty renews the human spirit and cannot be remade once lost ("Dam Hetch Hetchy! As well dam for water-tanks the people's cathedrals and churches"). (2) Wise use fairly stated: Pinchot's "greatest good to the greatest number for the longest time"; water for a great city is a higher use than a valley seen by few; the system has supplied clean water for about ninety years. (1) Stewardship and a reasoned judgment: "dress" (work and improve) supports wise use, "keep" (guard and preserve) supports care for creation's beauty (Psalm 19:1); a good answer weighs costs and benefits of restoration (replacement water and storage, cost, recovery of the valley) and reaches either conclusion with reasons.
Model answer (summary): Muir argued that some places are worth more kept than used; Pinchot and the city argued that a safe water supply for a great city was the greatest good. Both claimed to be stewards, and Genesis 2:15 honors both dressing and keeping. Whether to restore the valley turns on evidence: whether the water and storage can be replaced at reasonable cost and whether the restored valley would recover its beauty. A sound answer decides on that evidence rather than on slogans.