

GRADE 6 GARDENING & ANIMALS

First edition

8 units

32 lessons

A video for every lesson

FIRST EDITION

COURSE GUIDE

This course is the sixth step in School Launch's Gardening & Animals sequence. Each year the same eight strands return (seasons and harvest, wildlife, soil, pets, plant science, farm animals and bees, planting, and plant health), and each year the student goes deeper. In Grade 6 the student begins to ask *why* as well as *how*: why the tilt of the earth makes seasons, why soil pH locks up iron, why a cow can live on grass while a pig cannot, why a disease needs three things before it can spread.

The year follows the garden calendar. It begins in late summer with frost dates, growing degree days, harvest and food preservation; moves into fall wildlife ecology and the chemistry and biology of soil; spends early winter on responsible pet keeping; starts seeds and studies plant cells, photosynthesis and Mendel's peas in late winter; visits the dairy, the sheepfold and the beehive in early spring; plants in spring; and ends with plant pathology and integrated pest management as the garden grows.

The approach is the classical one of careful attention. Students observe closely, record honestly in a nature journal, learn the real vocabulary of the sciences, and then put their hands to the work: testing soil, calculating germination rates, grafting, reading pet-food labels, building a bluebird box, and scouting the garden for disease. We treat the garden and the animals as part of God's creation, entrusted to us "to dress it and to keep it" (Genesis 2:15), and we hope the student finishes the year more observant, more diligent and more grateful.

Most videos come from university extension services (Minnesota, Ohio State, Michigan State, Arkansas, Penn State and others), state wildlife agencies, established gardening and homestead educators, veterinarians and beekeeping teachers. Every video was watched in preview and checked against our content standards. A few growers mention their own seed shops, books or courses at the start or end;

simply skip those parts. Where a video needs a word of warning, the lesson's video note says so.

Start with Lesson 1.1 →

WHO IT IS FOR

Students about 11–12 years old who read independently and can handle simple arithmetic with averages and percentages. No yard and no animals are required: every lesson gives a windowsill, balcony, library or farm-visit option. Families with a garden, a flock or a pet will simply find more to do.

HOW TO USE THIS COURSE

1. **The weekly rhythm.** One lesson a week for 32 weeks, in two sessions of about 50 minutes. Session 1 is the warm-up, the core ideas, the video and the picture study. Session 2 is the hands-on project and the nature journal. The last week of each unit adds a third session for the unit review and the portfolio project.
2. **The calendar.** The units follow a school year that starts in late summer: harvest and wildlife in fall, soil and pets in early winter, seeds indoors in late winter, farm animals and bees in early spring, planting in spring, and plant health as the garden grows. Look up your own average last spring frost and first fall frost dates (your county extension office publishes them) and shift Units 5 to 8 earlier or later to match. In a warm climate you may swap Units 7 and 8.
3. **Reading the lesson.** Grade 6 students should read the core ideas themselves, then tell back the main points in their own words before watching the video. Key terms are meant to be learned; copy each one into the back of the nature journal as a running glossary.
4. **Picture study.** Look quietly at the picture for two minutes. Then put it away and tell back everything you remember. Look again, using the “look for” list, and answer the questions. Every picture is tied to the lesson's science, so the questions ask about crops, animals, weather and work as well as about art.
5. **The nature journal.** Keep one bound notebook all year. Date every page and note the weather. Grade 6 entries should include measurements, labeled diagrams, simple data tables and graphs, as well as careful drawings.
6. **Unit review and portfolio project.** Each unit ends with a written review (100 points, with one or two short written answers) and a portfolio project that uses

the unit's skills on something real. Keep finished portfolio work, photos and the best journal pages in a folder for the end-of-year family harvest fair.

7. **4-H, FFA, fairs and contests.** This course prepares students for real youth programs: 4-H (homeschoolers usually join through the county extension office), Junior Master Gardener, county and state fair youth classes, junior beekeeping programs, and, where a school-based agriculture program or a state homeschool chapter exists, FFA, which in some places begins as early as grade 5. Along the way the student keeps project-book records (dates, work done, costs, growth and yields), judges classes and gives oral reasons (Lessons 1.3, 2.4 and 6.2), prepares exhibits (a plate of vegetables, a potted plant, a jar of honey), practices showmanship (Lesson 6.3), gives an illustrated talk (Lesson 7.2) and drills identification for a skillathon (Lesson 8.4). Rules and eligibility differ by county and state, so check your county extension office or fair book before entering.
8. **Safety and adult supervision.** Read each lesson's safety note before Session 2. An adult handles sharp grafting knives, stoves, ovens and canners, power tools and any fertilizer or soil amendment. Wash hands after soil, compost, manure, animals and especially reptiles. Never touch wild animals, check for ticks after time outdoors, and never eat wild mushrooms or berries.
9. **Videos.** Watch each video together the first time. The lesson tells you when to watch it and where to pause. A backup video is given for many lessons in case the first one becomes unavailable.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–4

Seasons and Harvest

Why the tilt of the earth makes seasons, how frost forms and how growing degree days measure heat, how to tell when crops are ripe, and the microbiology behind drying, freezing and safe canning.

- 1.1 Earth's Orbit and the Seasons
- 1.2 Frost Dates and Growing Degree Days
- 1.3 Harvest Timing and Techniques
- 1.4 The Science of Food Preservation

UNIT 3 • WEEKS 9–12

Soil Chemistry and Biology

Soil chemistry and biology: pH and nutrient availability, the nitrogen cycle and nitrogen-fixing bacteria, the soil food web, and reading a soil test to choose amendments.

- 3.1 Soil pH and Nutrient Availability
- 3.2 The Nitrogen Cycle
- 3.3 The Soil Food Web
- 3.4 Soil Testing and Amendments

UNIT 2 • WEEKS 5–8

Wildlife Ecology

Wildlife ecology: deer populations and carrying capacity, predator and prey cycles, rabies and tick-borne disease, and how to improve habitat with nest boxes, brush piles and native plants.

- 2.1 Populations and Carrying Capacity: White-Tailed Deer
- 2.2 Predator and Prey
- 2.3 Wildlife Diseases and Safety: Rabies, Ticks and Lyme
- 2.4 Habitat Stewardship: Nest Boxes, Brush Piles and Native Plants

UNIT 4 • WEEKS 13–16

Pets: Stewardship and Care

- 4.1 Choosing a Pet Wisely
- 4.2 Pet Nutrition and Food Labels
- 4.3 Reptile and Amphibian Husbandry
- 4.4 Pet Health, Hygiene and the Veterinarian

UNIT 5 • WEEKS 17–20

Plant Science

- 5.1 Cells, Tissues and the Vascular System
- 5.2 The Photosynthesis Equation
- 5.3 Flowers, Pollination and Fruit
- 5.4 Gregor Mendel's Peas and Heredity

UNIT 6 • WEEKS 21–24

Farm Animals and Bees

- 6.1 Ruminant and Single-Stomach Digestion
- 6.2 Dairy Cattle and Milk
- 6.3 Sheep and Goats: Shearing, Hoof Care and Showmanship
- 6.4 Honey: From Nectar to Jar

UNIT 7 • WEEKS 25–28

Planting: Seeds, Roots, Grafts and Fields

- 7.1 Seed-Starting Science and Germination Rates
- 7.2 Root Health, Repotting and the Potted-Plant Exhibit
- 7.3 Grafting and Propagation
- 7.4 Field Crops: Corn, Wheat and Soybeans

UNIT 8 • WEEKS 29–32

Plant Pathology and Pest Management

- 8.1 The Disease Triangle
- 8.2 Fungal Diseases
- 8.3 Bacterial and Viral Diseases
- 8.4 Integrated Pest Management and the Skillathon

WEEKLY PACING CALENDAR

WEEK	PLAN
1	• Session 1: Lesson 1.1 Earth's Orbit and the Seasons: warm-up, video, teaching and picture study • Session 2: Lesson 1.1 hands-on project and nature journal <i>Two sessions a week is the usual rhythm. Younger children can split a long session in two; older students can do both sessions in one sitting.</i>
2	• Session 1: Lesson 1.2 Frost Dates and Growing Degree Days: warm-up, video, teaching and picture study • Session 2: Lesson 1.2 hands-on project and nature journal
3	• Session 1: Lesson 1.3 Harvest Timing and Techniques: warm-up, video, teaching and picture study • Session 2: Lesson 1.3 hands-on project and nature journal

WEEK	PLAN
4	• Session 1: Lesson 1.4 The Science of Food Preservation: warm-up, video, teaching and picture study • Session 2: Lesson 1.4 hands-on project and nature journal • Session 3: Unit 1 review and portfolio project
5	• Session 1: Lesson 2.1 Populations and Carrying Capacity: White-Tailed Deer: warm-up, video, teaching and picture study • Session 2: Lesson 2.1 hands-on project and nature journal
6	• Session 1: Lesson 2.2 Predator and Prey: warm-up, video, teaching and picture study • Session 2: Lesson 2.2 hands-on project and nature journal
7	• Session 1: Lesson 2.3 Wildlife Diseases and Safety: Rabies, Ticks and Lyme: warm-up, video, teaching and picture study • Session 2: Lesson 2.3 hands-on project and nature journal
8	• Session 1: Lesson 2.4 Habitat Stewardship: Nest Boxes, Brush Piles and Native Plants: warm-up, video, teaching and picture study • Session 2: Lesson 2.4 hands-on project and nature journal • Session 3: Unit 2 review and portfolio project
9	• Session 1: Lesson 3.1 Soil pH and Nutrient Availability: warm-up, video, teaching and picture study • Session 2: Lesson 3.1 hands-on project and nature journal
10	• Session 1: Lesson 3.2 The Nitrogen Cycle: warm-up, video, teaching and picture study • Session 2: Lesson 3.2 hands-on project and nature journal
11	• Session 1: Lesson 3.3 The Soil Food Web: warm-up, video, teaching and picture study • Session 2: Lesson 3.3 hands-on project and nature journal
12	• Session 1: Lesson 3.4 Soil Testing and Amendments: warm-up, video, teaching and picture study • Session 2: Lesson 3.4 hands-on project and nature journal • Session 3: Unit 3 review and portfolio project
13	• Session 1: Lesson 4.1 Choosing a Pet Wisely: warm-up, video, teaching and picture study • Session 2: Lesson 4.1 hands-on project and nature journal

WEEK	PLAN
14	• Session 1: Lesson 4.2 Pet Nutrition and Food Labels: warm-up, video, teaching and picture study • Session 2: Lesson 4.2 hands-on project and nature journal
15	• Session 1: Lesson 4.3 Reptile and Amphibian Husbandry: warm-up, video, teaching and picture study • Session 2: Lesson 4.3 hands-on project and nature journal
16	• Session 1: Lesson 4.4 Pet Health, Hygiene and the Veterinarian: warm-up, video, teaching and picture study • Session 2: Lesson 4.4 hands-on project and nature journal • Session 3: Unit 4 review and portfolio project
17	• Session 1: Lesson 5.1 Cells, Tissues and the Vascular System: warm-up, video, teaching and picture study • Session 2: Lesson 5.1 hands-on project and nature journal
18	• Session 1: Lesson 5.2 The Photosynthesis Equation: warm-up, video, teaching and picture study • Session 2: Lesson 5.2 hands-on project and nature journal
19	• Session 1: Lesson 5.3 Flowers, Pollination and Fruit: warm-up, video, teaching and picture study • Session 2: Lesson 5.3 hands-on project and nature journal
20	• Session 1: Lesson 5.4 Gregor Mendel's Peas and Heredity: warm-up, video, teaching and picture study • Session 2: Lesson 5.4 hands-on project and nature journal • Session 3: Unit 5 review and portfolio project
21	• Session 1: Lesson 6.1 Ruminant and Single-Stomach Digestion: warm-up, video, teaching and picture study • Session 2: Lesson 6.1 hands-on project and nature journal
22	• Session 1: Lesson 6.2 Dairy Cattle and Milk: warm-up, video, teaching and picture study • Session 2: Lesson 6.2 hands-on project and nature journal

WEEK	PLAN
23	• Session 1: Lesson 6.3 Sheep and Goats: Shearing, Hoof Care and Showmanship: warm-up, video, teaching and picture study • Session 2: Lesson 6.3 hands-on project and nature journal
24	• Session 1: Lesson 6.4 Honey: From Nectar to Jar: warm-up, video, teaching and picture study • Session 2: Lesson 6.4 hands-on project and nature journal • Session 3: Unit 6 review and portfolio project
25	• Session 1: Lesson 7.1 Seed-Starting Science and Germination Rates: warm-up, video, teaching and picture study • Session 2: Lesson 7.1 hands-on project and nature journal
26	• Session 1: Lesson 7.2 Root Health, Repotting and the Potted-Plant Exhibit: warm-up, video, teaching and picture study • Session 2: Lesson 7.2 hands-on project and nature journal
27	• Session 1: Lesson 7.3 Grafting and Propagation: warm-up, video, teaching and picture study • Session 2: Lesson 7.3 hands-on project and nature journal
28	• Session 1: Lesson 7.4 Field Crops: Corn, Wheat and Soybeans: warm-up, video, teaching and picture study • Session 2: Lesson 7.4 hands-on project and nature journal • Session 3: Unit 7 review and portfolio project
29	• Session 1: Lesson 8.1 The Disease Triangle: warm-up, video, teaching and picture study • Session 2: Lesson 8.1 hands-on project and nature journal
30	• Session 1: Lesson 8.2 Fungal Diseases: warm-up, video, teaching and picture study • Session 2: Lesson 8.2 hands-on project and nature journal
31	• Session 1: Lesson 8.3 Bacterial and Viral Diseases: warm-up, video, teaching and picture study • Session 2: Lesson 8.3 hands-on project and nature journal
32	• Session 1: Lesson 8.4 Integrated Pest Management and the Skillathon: warm-up, video, teaching and picture study

WEEK	PLAN
	• Session 2: Lesson 8.4 hands-on project and nature journal • Session 3: Unit 8 review and portfolio project <i>Last week. Hold a family harvest fair: set out the best project from each unit (journal pages, plants, photos of animal care) and let the student show guests one of them.</i>

MATERIALS

Nature journal (bound sketchbook or notebook)

Used every lesson for drawings, data tables, graphs and notes.

Pencils, colored pencils, fine black pen and a ruler

For labeled diagrams and graphs.

Hand lens (10×) and, if possible, a simple student microscope

A microscope is optional but makes Lessons 5.1 and 8.2 far richer.

Indoor/outdoor thermometer (a min/max type is best)

For frost watching, growing degree days and seed-starting warmth.

Seeds: bush beans or peas, radishes, lettuce, corn, sunflowers, marigolds or zinnias, and a few herbs

Cheap packets are fine. Dried peas from the grocery store work for Lesson 5.4.

Potting mix, seed-starting mix, and pots or cups with drainage holes

Several sizes, including one pot about 2 inches wider than a houseplant you will repot.

Paper towels, zip-top bags, clear jars and a spray bottle

For germination tests and soil experiments.

Home soil test kit (pH, nitrogen, phosphorus, potassium)

A capsule-type kit from a garden center. Optional: a laboratory soil test through your county extension office.

Trowel, hand pruners and a watering can

Pruners and grafting knives are used by or with an adult.

Kitchen scale and measuring cups

For drying apples, weighing harvests and figuring yield.

Disposable gloves and garden gloves

For compost, manure, soil amendments and handling diseased leaves.

Wood and screws for a bluebird nest box (optional)

One 1×6 cedar or pine board about 6 feet long makes one box; an adult runs the saw.

A pet, a flock, a hive or a garden (all optional)

Not required. Neighbors, 4-H members, farms, shelters, pet stores and beekeepers are generous teachers.

GRADING

Grade 6 work is graded, but the aim is careful observation, honest records and real skill, not speed.

PART	%
Hands-on projects	35
Nature journal	20
Unit reviews	20
Portfolio projects	25

Scale: A 90–100, B 80–89, C 70–79, D 60–69. Below 60, redo the work.

- Grade a hands-on project by its self-check list: did the student follow the steps, record real data and explain the result?
- Grade the nature journal once a unit for dated entries, honest measurements, labeled drawings and neat tables, not for artistic talent.
- Unit reviews are worth 100 points each. Let the student correct missed questions for half credit.
- Use each portfolio rubric as a conversation: show the student where the work is strong and what one thing would make it better.

A NOTE TO PARENTS

You do not need to be a gardener or a farmer to teach this course. Every lesson explains the science in the student's own reading, gives a video to watch together, and lays out a project step by step. Your job is to supervise the few tasks that need an adult, ask the student to tell back what was learned, and enjoy the growing things that appear on your windowsill.

Some lessons touch on hard things honestly: farm animals are raised for milk, wool, eggs and meat; predators eat prey; some wild animals carry disease. These are handled plainly and gently, and nothing gruesome is described or shown.

Throughout, we hope your student comes to see the garden and the barnyard as the Creator's handiwork, entrusted to our care, and learns the patience, diligence and thankfulness that growing things teach so well.

UNIT 1

SEASONS AND HARVEST

The school year begins at the richest time of the garden year: the harvest. Before we pick and preserve, we ask the big questions behind every farmer's calendar. Why do we have seasons at all? Why does frost come on clear, still nights? How do farmers measure the heat a crop has received? This unit answers those questions with real astronomy, real weather science and a little arithmetic.

Then we turn to the harvest itself: how to know when each crop is truly ripe, how to pick it without harming the plant, and how microbes, acidity and heat decide whether food keeps safely through the winter. "While the earth remaineth, seedtime and harvest ... shall not cease" (Genesis 8:22). Learning the order God built into the year helps us work with it wisely.

PREREQUISITES

- Can read a thermometer in °F
- Can find an average of two numbers
- Has a nature journal ready for the year

MASTERY CHECKLIST

- ☐ I can explain how the tilt of the earth's axis, not its distance from the sun, causes the seasons.
- ☐ I can explain how frost forms and find my area's average frost dates.
- ☐ I can calculate growing degree days from daily high and low temperatures.
- ☐ I can name signs of ripeness for at least six crops and harvest them carefully.
- ☐ I can explain how drying, freezing, canning and acidity keep microbes from spoiling food.

LESSONS IN THIS UNIT

1.1 Earth's Orbit and the Seasons

2 sessions of 50 minutes

1.2 Frost Dates and Growing Degree Days

2 sessions of 50 minutes

1.3 Harvest Timing and Techniques

2 sessions of 50 minutes

UNIT 1 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. Use your journal tables if you need them. 100 points total.

1. (8 pts)

What causes the seasons? Name the two effects of this cause.

2. (6 pts)

When is the earth closest to the sun? What does this prove?

3. (6 pts)

What is the difference between a solstice and an equinox?

4. (8 pts)

Why do clear, calm nights bring frost, and why do low spots freeze first?

5. (8 pts)

Calculate the growing degree days (base 50°F) for a day with a high of 84°F and a low of 62°F, and for a day with a high of 56°F and a low of 40°F.

6. (6 pts)

Name two tender crops and two hardy crops.

7. (8 pts)

Give the sign of ripeness for sweet corn and for winter squash.

8. (8 pts)

What is the difference between a climacteric and a non-climacteric fruit? Give one example of each.

9. (8 pts)

Name four things microbes need to grow, and match one preservation method to each.

10. **8 pts**

What pH number divides high-acid from low-acid foods in canning, and which kind of canner does each need?

11. **13 pts**

Explain why a tested tomato-canning recipe tells you to add bottled lemon juice to every jar.

12. **13 pts**

Your corn needs 2,600 GDD and your frost-free season is short. Explain how a gardener could use frost dates and GDD together to plan.

ANSWER KEY

1. The 23.4° tilt of the earth's axis. It changes the angle of sunlight (steep in summer, low in winter) and the length of the day.
2. In early January. It proves that distance from the sun does not cause the seasons.
3. A solstice is the longest or shortest day of the year (about June 21 and December 21); an equinox is a day of nearly equal day and night (about March 20 and September 22).
4. Without clouds or wind, the ground and plants lose heat into the sky (radiational cooling). Cold air is heavy and drains downhill into low spots.
5. $(84 + 62) \div 2 - 50 = 23$ GDD. $(56 + 40) \div 2 = 48$, which is below 50, so 0 GDD.
6. Tender: any two of tomato, pepper, basil, bean, squash, cucumber. Hardy: any two of kale, cabbage, spinach, carrot, garlic.
7. Sweet corn: silks brown and dry, kernels squirt milky juice. Winter squash: rind cannot be dented with a fingernail, stem dry and corky.
8. A climacteric fruit keeps ripening after picking because of ethylene (tomato, apple, pear, peach, banana). A non-climacteric fruit does not ripen after picking (strawberry, cherry, grape, watermelon, pepper).
9. Moisture (drying, salt, sugar), warmth (freezing, refrigeration), suitable pH (pickling, fermenting), air (vacuum sealing, canning).
10. 4.6. High-acid foods (4.6 or lower) can use a boiling-water canner; low-acid foods (above 4.6) need a pressure canner.
11. Tomatoes have a pH near the 4.6 line, and some are above it. Botulinum spores survive boiling and can grow in low-acid, sealed jars. Lemon juice lowers the pH safely below 4.6, so a boiling-water canner is enough to keep the food safe.
12. Frost dates show the window when corn can be outside without freezing. GDD totals show how much heat the area usually gets in that window. If the season does not supply enough GDD, the gardener should choose an earlier (shorter-season) variety, plant as soon as it is safe after the last frost, or use a warm spot.

PORTFOLIO PIECE: A FAMILY HARVEST CALENDAR

Make a one-year garden calendar for your own location. Mark your average last and first frost dates, the solstices and equinoxes, and the planting and harvest windows for at least eight crops you would like to grow. Add a short ripeness sign for each crop and a note on how you would preserve its harvest. Include your two-week GDD table and a sample of your dried apples or a photo of them.

LOOK FOR	WHAT IT MEANS
Accurate dates	Frost dates, solstices and equinoxes are correct for your location.
Crop windows	Planting and harvest times for eight crops fit the growing season and respect tender and hardy crops.
Ripeness and preservation	Each crop has a true sign of ripeness and a safe, sensible preservation method.
Data	The GDD table and apple-drying measurements are complete and correctly calculated.
Neatness	The calendar is clear, labeled and easy for the family to use.

1.1 EARTH'S ORBIT AND THE SEASONS

OBJECTIVES

- Explain how the 23.4° tilt of the earth's axis causes the seasons.
- Describe the solstices and equinoxes and what happens to day length at each.
- Show with a flashlight model why low-angle sunlight warms the ground less.

Warm-up. Without looking anything up, write two sentences in your journal answering: “Why is summer hot and winter cold?” Then mark your guess with a star. You will come back to it at the end of the lesson to see whether it holds up.

WATCH

Why Do We Have Different Seasons? | California Academy of Sciences

California Academy of Sciences · 3:17

https://www.youtube.com/watch?v=WgHmqv_-UbQ

WHEN TO WATCH

After the core ideas. Watch once straight through, then again and pause at December and June to point out which hemisphere leans toward the sun.

BACKUP VIDEO

Reasons for the seasons - Rebecca Kaplan

TED-Ed · 5:20

https://www.youtube.com/watch?v=DD_8Jm5pTLk

Use if the first video is unavailable, or as a second look at sun angle and day length.

KEY TERMS

axis

The imaginary line through the North and South Poles that the earth spins around once a day. It is tilted about 23.4° from straight up.

orbit

The earth's yearly path around the sun, taking about 365¼ days.

solstice

The day the sun's noon path is highest (about June 21, the longest day in the Northern Hemisphere) or lowest (about December 21, the shortest day).

equinox

One of two days (about March 20 and September 22) when day and night are nearly equal everywhere on earth.

angle of incidence

The angle at which sunlight strikes the ground. Steep, direct light concentrates energy; low, slanting light spreads it out.

CORE IDEAS

Most people guess that summer comes when the earth is closest to the sun. In fact the earth is closest to the sun in early January (about 91 million miles away) and farthest in early July (about 94 million miles). The difference is small, and it is backward for the Northern Hemisphere's seasons. Distance is not the reason for the seasons.

The real reason is the **tilt** of the earth's axis. As the earth travels its **orbit**, the axis keeps pointing the same direction in space, toward the North Star. In June the Northern Hemisphere is leaning toward the sun; in December it leans away. Meanwhile the Southern Hemisphere has the opposite season, which is why Christmas is in summer in Australia.

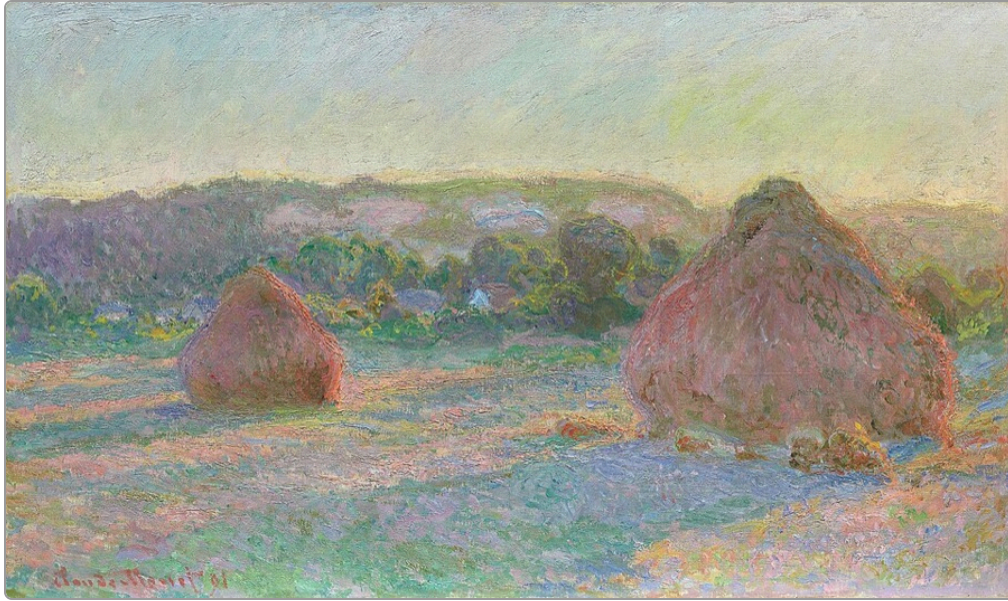
Tilt changes two things at once. First, **sun angle**: when your half of the earth leans toward the sun, the noon sun climbs high in the sky and its rays strike the ground steeply. A beam of steep light falls on a small patch and heats it strongly; the same beam at a low angle is spread over a much larger patch, so each square foot gets less energy. At 40° north latitude (about the latitude of Philadelphia, Columbus or Denver), the noon sun stands about 73° above the horizon on the June solstice but only about 27° on the December solstice.

Second, **day length**: at 40° north, the June solstice gives about 15 hours of daylight and the December solstice about 9 hours and 20 minutes. More hours of stronger light means more heat stored in soil, water and air. Because the ground and oceans

take weeks to warm up and cool down, the hottest weather usually comes in late July and the coldest in late January, a few weeks after the solstices.

For a gardener, the seasons are not just dates on a calendar. Day length tells many plants when to flower (spinach bolts as days lengthen; chrysanthemums bloom as they shorten), and the slanting autumn sun is why a fall garden grows more slowly than a spring one. God promised Noah that “seedtime and harvest, and cold and heat, and summer and winter” would not cease, and the steady tilt of the earth is part of how He keeps that promise.

PICTURE STUDY



Stacks of Wheat (End of Summer), Claude Monet, 1890–91 · Oil on canvas · Art Institute of Chicago

Image: [Wikimedia Commons](#), public domain

Monet painted the same stacks of wheat near his home in Giverny more than twenty-five times, in every season and at every hour, to catch how the changing sun changed what he saw. This one shows the end of summer, just after harvest.

Look closely

- Find the shadows. Which direction is the sunlight coming from? Is the sun high or low?
- Look at the colors of the stacks. Which side is warm and golden, and which is cool and blue?
- Look at the field. Has the wheat already been cut? How can you tell?
- Find the trees and hills in the distance. What season do their colors suggest?

Talk about it

1. If Monet painted these same stacks at noon on the June solstice, how would the shadows be different?
2. Why would a farmer stack wheat in the field instead of leaving it in loose bundles?
3. Monet painted the stacks again in winter snow. What would change about the light?

HANDS-ON PROJECT

Sun Angle and Shadow Experiments

You will prove with your own measurements why low sun gives less heat, and you will start a noon-shadow record that you can continue all year.

You will need

- A flashlight with a round beam
- Graph paper
- A protractor and a pencil
- A stick or dowel about 12 inches long, or a pencil stuck upright in clay
- A tape measure or ruler
- A compass or a phone compass (optional)

Steps

1. Lay graph paper on a table in a dim room. Hold the flashlight 12 inches above the paper, pointing straight down (90°). Have a helper trace the edge of the bright spot.
2. Keep the flashlight the same distance from the paper but tilt it to about 30° from the table. Trace the new, stretched spot.
3. Count the squares inside each traced spot. Divide the larger count by the smaller. This tells you how many times more area the same light is spread over at a low angle.
4. Write a sentence explaining which spot would heat the paper more, and why. Connect it to summer and winter sun.
5. Outdoors on a sunny day, stand your stick straight up on level ground in an open spot.
6. Close to solar noon (about 1:00 p.m. during daylight saving time in many places), measure the length of the stick's shadow every 10 minutes for half an hour. The shortest shadow marks local noon.
7. Record the date, the stick height and the shortest shadow length in your journal.

8. Repeat the noon measurement once a month for the rest of the school year and graph it. Predict now: in which month will the shadow be longest?

Tips

- If it is cloudy, try again the next sunny day; the shadow changes only a little from day to day.
- Mark the stick's spot with a stone so you use the same place every month.

Check your work

- ☐ I measured how much larger the low-angle light spot was than the straight-down spot.
- ☐ I can explain in two sentences why tilt, not distance, causes the seasons.
- ☐ I have a dated noon-shadow measurement and a plan to repeat it monthly.

NATURE JOURNAL

1. Draw a diagram of the earth on both sides of the sun, tilted the same way in space. Label June and December, and shade the half of each earth that is in darkness.
2. Draw your outdoor shadow stick and its noon shadow to scale (for example, 1 inch = 3 inches).
3. Return to your warm-up guess. Write what you now know and what you got right or wrong.

From history. Ancient farmers watched the sunrise move along the horizon to know when to plant. About 1,800 years ago the astronomer Ptolemy recorded the sun's yearly path carefully, and in the 1500s and 1600s Copernicus and Johannes Kepler showed that the earth travels around the sun in a slightly oval orbit. Kepler, a devout Christian, is remembered for describing science as "thinking God's thoughts after Him."

COMMON MISTAKES

- Saying summer happens because the earth is closer to the sun. It is actually closest in January.
- Drawing the earth's tilt flipping to point the other way in winter. The axis always points the same direction in space; it is the earth's position in its orbit that changes.

- Measuring the noon shadow at 12:00 by the clock. Solar noon is often closer to 1:00 p.m. during daylight saving time.

Make it a game • Orbit Walk Seasons. Make a floor orbit with four paper signs: two solstices and two equinoxes. Carry a tilted ball or orange, with a pencil as the axis, around a chair that is the sun. At each sign, announce the season for the northern half and the day length. Your parent slips in one wrong stop. Catch it and explain angle of incidence.

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 set the rhythm of the seasons in motion and promised to keep it. The tilt of the earth and its steady orbit are how that faithful promise plays out every year.

1.2 FROST DATES AND GROWING DEGREE DAYS

OBJECTIVES

- Explain how frost forms on clear, calm nights and why low spots get frost first.
- Find your area's average last spring frost and first fall frost dates and calculate the length of the growing season.
- Calculate growing degree days from daily high and low temperatures.

Warm-up. Look out a window or step outside. List five clues that tell you what kind of night it was last night (dew on the grass, clouds, wind, temperature, frost). Which clues would warn a gardener that frost was possible?

WATCH

Frost Dates Explained - Garden Quickie Episode 20

The Ripe Tomato Farms · 3:48

<https://www.youtube.com/watch?v=EW01jeZGIQE>

WHEN TO WATCH

After the first three core ideas, before you look up your own frost dates.

BACKUP VIDEO

What are Growing Degree Days?

State Climate Office of North Carolina · 6:34

<https://www.youtube.com/watch?v=dLC529eQpCc>

Watch this one too, before the growing degree day part of the project. Pause on the worked example and do the arithmetic yourself.

KEY TERMS

frost

Ice crystals that form on plants and other surfaces when they cool to 32°F (0°C) or below.

radiational cooling

The loss of heat from the ground and plants into the sky at night, strongest when the sky is clear and the air is still.

average last frost date

The spring date after which frost becomes unlikely in an area, based on many years of weather records. Frost can still come after it.

growing season

The number of days between the average last spring frost and the average first fall frost.

growing degree days (GDD)

A measure of heat a crop or insect receives. Daily GDD = $(\text{high} + \text{low}) \div 2 - \text{base temperature}$, never less than zero.

base temperature

The temperature below which a particular plant or insect hardly develops; 50°F for corn and many warm-season crops.

CORE IDEAS

On a clear, calm night, the ground and plant leaves send their heat straight up into the sky. This is **radiational cooling**. Clouds act like a blanket and send some heat back down; wind stirs warmer air down from above. So the frostiest nights are clear and still, often right after a cold front has passed. Because cold air is heavier than warm air, it slides downhill and pools in low spots, called frost pockets. A garden at the bottom of a slope may freeze when one halfway up the hill does not.

When leaves cool to 32°F (0°C), ice crystals can form on and inside them. Inside the plant, ice tears cell walls, and the leaf turns dark and limp when it thaws. **Tender** crops such as tomatoes, peppers, basil, beans, squash and cucumbers are killed by even a light frost. **Hardy** crops such as kale, cabbage, spinach, carrots and garlic handle frost well; kale often survives nights near 20°F, and frost even makes carrots and kale taste sweeter, because the plants store more sugar in the cold.

Weather records from many years give each place an **average last spring frost date** and an **average first fall frost date**. The days between them make the **growing season**. In much of the central United States it is roughly 160 to 200 days. Remember that an average date means frost can still come after it, so careful gardeners wait a week or two past the last frost date before setting out tender plants, and keep an old sheet ready to cover them.

Frost dates tell *when* you can grow; **growing degree days** tell how fast crops will grow. Plants and insects develop according to accumulated heat, not the calendar. For each day, average the high and low and subtract the crop's **base temperature**. For

corn, the base is 50°F. A day with a high of 80°F and a low of 60°F gives $(80 + 60) \div 2 - 50 = 20$ GDD. A day with a high of 54°F and a low of 38°F averages 46°F, which is below the base, so it counts as 0, never as a negative number.

Farmers add up GDD from planting day. A typical field-corn variety needs very roughly 2,500 to 2,800 GDD to reach maturity, so a cool summer delays harvest even if the calendar says it is time. Extension services also use GDD to predict when insect pests will hatch, so farmers can scout at the right time instead of guessing.

PICTURE STUDY



The Magpie, Claude Monet, 1868–69 · Oil on canvas · Musée d'Orsay, Paris

Image: [Wikimedia Commons](#), public domain

Monet painted this outdoors in the cold near the coast of Normandy, France. Few painters had noticed that shadows on snow are not gray but blue and violet. Winter light, low and slanting, is exactly what we studied in Lesson 1.1.

Look closely

- Find the magpie. Where is it sitting?
- Look at the shadows of the fence. Are they short or long? What does that tell you about how high the sun is?
- Look for places where the snow is lit by sun and places where it lies in shade. Which would melt first?
- Find the hedge and trees. Is anything green or growing?

Talk about it

1. What does the length of the shadows tell you about the season and the time of day?
2. Which plants in a garden would survive a snowy scene like this, and which would have died at the first frost?
3. Why is the magpie a good bird to paint in winter? (Think about which birds stay all year.)

My Growing Season Calculator

You will find your own frost dates, calculate your growing season, and keep a two-week growing degree day log, just as farmers and extension agents do.

You will need

- A thermometer, preferably a min/max type that records the day's high and low, or a local weather service's daily report
- A calendar
- Your nature journal and a calculator
- Internet access with an adult, or a call to your county extension office

Steps

1. With an adult, look up your average last spring frost and first fall frost dates. Your county extension office, a state climate office or a frost-date table by zip code will have them.
2. Count the days between the two dates on a calendar. Write: "My growing season is about ___ days."
3. Look up the "days to maturity" on three seed packets or catalog entries (for example, a tomato, a winter squash and a bean). Which fit easily in your season? Which would need an early start indoors?
4. Make a table in your journal with columns: Date, High °F, Low °F, Average, GDD (base 50).
5. Each day for 14 days, record the high and low. Find the average, subtract 50 and write the GDD. If the answer is below zero, write 0.
6. Add a running total column. At the end, how many GDD did your area receive in two weeks?
7. If corn needs about 2,600 GDD to mature, how many weeks like these would it take? Show your work.
8. On a clear, calm evening this fall, check the forecast low. If frost is possible, put a thermometer at ground level and another at chest height and compare them in the morning (with an adult's permission).

Tips

- Fall weeks will give small GDD numbers. That is the point: it shows why gardens slow down in autumn.
- Keep the thermometer in the shade; a thermometer in the sun reads far too high.

Check your work

- ☐ I know my average frost dates and the length of my growing season.
- ☐ I correctly calculated daily GDD and never used a negative number.
- ☐ I can explain why clear, calm nights are the frostiest.

NATURE JOURNAL

1. Draw a cross-section of a hillside garden. Use arrows to show cold air sliding downhill and label the frost pocket.
2. Make a line graph of your 14 days of highs and lows. Shade the area between the line at 50°F and the daily averages that rose above it.
3. After a frosty morning, draw a frosted leaf or blade of grass with a hand lens. Note the shape of the ice crystals.

From history. In the 1730s the French scientist René-Antoine Ferchault de Réaumur noticed that a crop needed about the same total of daily warmth to ripen each year, even when the calendar dates changed. His idea grew into the growing degree day method that farmers and extension services use today.

COMMON MISTAKES

- Treating the average last frost date as a guarantee. It is an average; frost can still come later.
- Counting negative growing degree days on cold days. A day below the base temperature counts as zero.
- Putting the thermometer in direct sun, which gives readings that are far too high.

Make it a game • Frost Detective Duel. Teach your parent why frost forms on clear, calm nights: radiational cooling, and why low spots freeze first. Then play a calculation duel: parent names a last spring frost and first fall frost date, and you race to count the growing season in days. Add a base temperature question about growing degree days. Fastest correct count wins.

1.3 HARVEST TIMING AND TECHNIQUES

OBJECTIVES

- Recognize signs of ripeness in at least six common crops.
- Explain the difference between fruits that keep ripening after picking and those that do not.
- Harvest and handle produce in ways that protect quality and the plant.
- Prepare a plate of vegetables for a fair exhibit and judge a class of four plates with oral reasons.

Warm-up. Your teacher will set out several fruits or vegetables at different stages (for example, a green and a red tomato, a firm and a soft pear, a banana with green tips and one with brown spots). Sort them from least to most ripe and write the clue you used for each.

WATCH

How to Tell When Your Fruits and Vegetables are Ready to Harvest

GrowVeg · 5:29

<https://www.youtube.com/watch?v=8gCt675555o>

WHEN TO WATCH

After the core ideas. Pause after each crop group and add it to your ripeness chart.

Note: The video was filmed in England, so a few varieties have British names (courgettes are zucchini).

BACKUP VIDEO

Preparing Vegetables for Exhibition

University of Illinois Extension · 4:23

<https://www.youtube.com/watch?v=6H5dIS-kgLI>

Before preparing your fair plate in the project. Note what the extension educator says judges look for.

KEY TERMS

maturity

The stage when a crop has finished developing and can be harvested for its intended use.

non-climacteric fruit

A fruit that does not ripen further once picked (strawberries, cherries, grapes, citrus, watermelon), so it must be picked ripe.

curing

Holding certain crops (winter squash, sweet potatoes, onions) in warm or dry conditions after harvest to toughen skins and improve storage.

climacteric fruit

A fruit that keeps ripening after it is picked, using a natural ripening gas called ethylene (tomatoes, apples, pears, peaches, bananas).

field heat

The warmth a crop carries from the sunny field; removing it quickly slows spoiling.

CORE IDEAS

Every crop tells you it is ready, if you know what to look for. **Sweet corn** is ready about three weeks after the silks appear, when the silks are brown and dry and a kernel pressed with a fingernail squirts milky juice. **Winter squash** is ready when the rind is too hard to dent with a fingernail and the stem has turned dry and corky. **Onions** tell you by flopping their tops over. **Potatoes** for storage are dug two or three weeks after the vines die back, so the skins can toughen.

Some crops are picked young on purpose. Green beans, cucumbers, zucchini and okra are best before the seeds inside grow large and tough; a zucchini left a week too long becomes a watery club. Leafy greens are picked by cutting the outer leaves and letting the center keep growing. Herbs are best just before they flower. Picking often also tells the plant to keep producing.

Fruits fall into two groups. **Climacteric** fruits, such as tomatoes, apples, pears, peaches and bananas, give off a gas called **ethylene** that keeps them ripening after picking. A tomato picked at the “breaker” stage, when it first blushes pink, will finish ripening on the kitchen counter with excellent flavor, and it will be safe from birds

and splitting. **Non-climacteric** fruits, such as strawberries, cherries, grapes, peppers and watermelons, will not get sweeter after picking, so they must be harvested fully ripe. A watermelon is ready when the curly tendril nearest it has dried brown and the spot where it rested on the ground has turned creamy yellow.

Technique matters as much as timing. Harvest leafy greens and herbs in the cool of the morning, when they are full of water. Use clean, sharp scissors or pruners instead of yanking, which can break vines and pull up roots. Handle produce gently, because a bruise is a doorway for rot. Get the harvest out of the sun quickly to remove **field heat**; greens can be dunked in cold water. Winter squash, onions and sweet potatoes are **cured** before storage.

Many county fairs have a youth vegetable class, and the judges look for the same things a good cook does. An exhibit is usually a plate of a set number of matched vegetables (for example 5 tomatoes, 3 peppers or 5 carrots). Judges want **uniformity** (all the same size, shape and ripeness), **true to type** (each looks like its variety should), **condition** (fresh, firm, no blemishes, bruises, cracks or insect damage), correct **trimming** (stems or tops cut as the fair book directs), cleanliness (gently wiped or brushed, never polished or oiled), and a neat, correct label. Choose your plate from a large harvest, and pick a spare.

Harvest is the reward of months of patient work, and in the Bible it is a time of joy and thanksgiving. It is also a time of generosity: Old Testament farmers left the corners of their fields for the poor to glean, as Ruth gleaned in the field of Boaz.

PICTURE STUDY



The Harvesters, Pieter Bruegel the Elder, 1565 · Oil on wood · Metropolitan Museum of Art, New York

Image: [Wikimedia Commons](#), public domain

This is one of a series of paintings Bruegel made of the months of the year. It shows the wheat harvest in late summer, done entirely by hand, from cutting to bundling to carrying home.

Look closely

- Find the workers cutting wheat with long curved blades called scythes. How do they hold them?
- Find the bundles of cut wheat, called sheaves, standing upright in the field. Why stand them up?
- Find the workers eating lunch under the tree. What foods can you see?
- Look for other harvests going on: someone picking fruit from a tree, and a cart in the distance.
- Look at how tall the wheat is compared with the people.

Talk about it

1. How can you tell the wheat is ripe and ready to cut?
2. Why might farmers have hurried to finish this harvest before the weather changed?
3. How many different jobs can you find? Which would you want to do?

Safety first. Use pruners and harvest knives only with an adult's permission, cutting away from your body. Wash all produce before eating, and never eat anything from a plant you cannot identify.

HANDS-ON PROJECT

A Ripeness Field Guide and a Fair Plate

You will make a set of ripeness cards and use them for a real harvest, in your garden, at a pick-your-own farm, or at a farmers market.

You will need

- Ten index cards
- Colored pencils
- Clean scissors or garden pruners (with an adult)
- A harvest basket or box
- A kitchen scale
- Access to a garden, a pick-your-own farm, or a farmers market

Steps

1. Choose eight crops that grow in your area in late summer and fall (for example tomatoes, sweet corn, winter squash, potatoes, apples, beans, peppers, carrots).
2. For each crop, make a card: draw the crop when ripe, list two or three signs of ripeness, and write “keeps ripening after picking” or “pick it ripe.”
3. Add one card for harvest technique (time of day, tools, handling) and one for storage (field heat, curing).
4. Take your cards to a garden, farm or market. Find at least four of your crops and check them against your cards.
5. If you are harvesting, pick only what passes your ripeness test. Cut, do not pull, and lay produce gently in the basket.
6. Weigh your harvest and record the crop, date and weight in your journal. If you are at a market instead, ask a farmer how he or she decides when to pick one crop, and write down the answer.
7. Judging class: set out four plates of the same vegetable (3 to 5 each, from your harvest, a market or a grocery store). Number them 1 to 4, place them from best to last using uniformity, true-to-type, condition, trimming and cleanliness, and write the placing on a card (for example 3-1-4-2).

8. Give oral reasons for your placing in under two minutes, comparing each pair (“I placed 3 over 1 because 3 is more uniform in size and free of cracks”). Then prepare your best plate as a fair exhibit with a neat label, and correct your ripeness cards based on what you learned.

Tips

- Pick-your-own apple orchards are open in early fall in many areas and are a perfect place to test your cards.
- Keep your cards in a zip-top bag in the garden so they stay clean.
- Check your county fair book for the exact number of vegetables per plate and how stems and tops should be trimmed.

Check your work

- ☐ I made eight crop cards with true signs of ripeness.
- ☐ I can explain which fruits keep ripening after picking and why.
- ☐ I tested my cards on real produce and recorded what I found.
- ☐ I placed a class of four plates and gave oral reasons, and prepared one exhibit plate.

NATURE JOURNAL

1. Draw an ear of sweet corn with the husk pulled back. Label the silk, the kernels and the husk.
2. Draw one fruit at three stages of ripeness side by side and describe the color, firmness and smell of each.
3. Keep a harvest log: crop, date, weight. Add to it all fall.

From history. Before machines, a whole village worked together at harvest, and children helped by binding sheaves and gleaning. In 1831 Cyrus McCormick of Virginia first showed off his horse-drawn reaper, which could cut as much wheat in a day as several men with scythes.

COMMON MISTAKES

- Letting zucchini and cucumbers grow huge. They become seedy and tough, and the plant slows down.
- Waiting for strawberries or watermelons to ripen on the counter. They will not get sweeter after picking.

- Pulling fruit off the vine instead of cutting it, which can break stems and damage the plant.
- Leaving freshly picked greens in the sun, where they wilt within minutes.

Make it a game · Ripeness Rapid Fire. Set out six pretend crops on cards. Parent calls each one and you give its sign of ripeness in under ten seconds. Then sort the cards into climacteric fruit that keep ripening after picking and non-climacteric fruit that do not. Add field heat and curing questions. Whoever scores more correct answers out of twelve wins.

1.4 THE SCIENCE OF FOOD PRESERVATION

OBJECTIVES

- Name what microbes need to grow and explain how each preservation method takes one of those things away.
- Explain why acidity (pH 4.6 and below) decides whether a food can be water-bath canned or must be pressure canned.
- Preserve a food by drying and measure the water removed.

Warm-up. List every preserved food you can find in your kitchen in three minutes (dried, canned, frozen, pickled, salted, jam). Beside each, guess how it was kept from spoiling.

WATCH

How to Can Tomatoes in a Water Bath Canner

Ohio State University Extension · 9:21

https://www.youtube.com/watch?v=2_6BUwS9iQQ

WHEN TO WATCH

After the core ideas. Listen for the reason lemon juice is added to tomatoes, and pause at the pH screen to connect it to the 4.6 line.

BACKUP VIDEO

Why Food Acidity Level Matters in Home Canning

BallCanning® · 2:40

<https://www.youtube.com/watch?v=z6VAS1d1eS4>

A short explanation of high-acid and low-acid foods; watch after the core ideas.

KEY TERMS

microbe

A living thing too small to see without a microscope, such as a bacterium, yeast or mold.

pH

A scale from 0 to 14 that measures how acidic or basic something is. Lower numbers are more acidic; 7 is neutral.

high-acid food

A food with a pH of 4.6 or lower (most fruits, pickles, and tomatoes with added lemon juice), safe to process in a boiling-water canner.

low-acid food

A food with a pH above 4.6 (green beans, corn, most vegetables), which must be processed in a pressure canner.

spore

A tough, resting form some bacteria make that can survive boiling and later grow again.

botulism

A dangerous illness caused by a poison made by *Clostridium botulinum* bacteria that can grow in sealed, low-acid food that was not processed correctly.

CORE IDEAS

Food spoils because microbes (bacteria, yeasts and molds) eat it before we do. Like all living things, microbes need certain conditions: **moisture**, **warmth**, a suitable **pH**, and for many of them, **air**. Every method of preserving food works by taking away at least one of these, or by killing the microbes and sealing the food so new ones cannot get in.

Drying removes water, so microbes cannot grow; that is why raisins, dried beans and jerky keep for months. **Salt and sugar** work in a similar way: they pull water out of microbes by osmosis, which is why jam and salted fish keep. **Freezing** stops microbes from growing but does not kill most of them; they wake up when the food thaws. **Fermentation** uses friendly lactic-acid bacteria to turn sugars into acid, which keeps harmful microbes away. Sauerkraut and old-fashioned dill pickles are made this way.

Canning uses heat to kill microbes inside a jar, then forms a vacuum seal as the jar cools. The great danger in canning is a soil bacterium called *Clostridium botulinum*. It forms **spores** that survive boiling at 212°F. In a sealed jar with no air, low acid and room temperature, those spores can grow and make a poison that causes **botulism**. The poison has no smell or taste.

Here is the key fact: botulinum spores cannot grow in food with a pH of **4.6 or lower**. So **high-acid foods** (most fruits, jams, pickles in vinegar) can be safely processed in a boiling-water canner. **Low-acid foods** (green beans, corn, carrots, potatoes, meats) must be processed in a **pressure canner**, which reaches 240°F, hot enough to destroy

the spores. Tomatoes sit right on the line (pH about 4.2 to 4.9), so tested recipes add 2 tablespoons of bottled lemon juice per quart to push them safely below 4.6.

Because the danger is invisible, safe home canning always follows a **tested recipe** from a reliable source, such as the USDA guide or a university extension service, with the correct jar size, time and altitude adjustment. Never use a family recipe that guesses, and never taste food from a jar with a bulging or unsealed lid. Preserving the harvest is good stewardship: “Gather up the fragments that remain, that nothing be lost” (John 6:12).

PICTURE STUDY



Still Life with Oranges, Jars, and Boxes of Sweets, Luis Meléndez, about 1760–65 • Oil on canvas •
Museum of Fine Arts, Boston

Image: [Wikimedia Commons](#), public domain

Luis Meléndez of Spain painted ordinary kitchen foods with great care. Long before canning, Spanish households kept fruit through the year as thick fruit pastes, such as quince paste, packed in round wooden boxes, and as preserves stored in glazed jars sealed with paper or cork.

Look closely

- Find the round wooden boxes. What might be packed inside them?
- Find the glazed jars. How are they closed? (Look for paper tied down with string.)
- Find the fresh oranges. Which foods on the table would spoil first, and which would keep for months?
- Look at how Meléndez shows the different textures: shiny glaze, rough wood, dimpled orange peel.

Talk about it

1. Fruit pastes are cooked down with a great deal of sugar. Using what you learned about microbes and water, explain why they keep so long.
2. Why would a glazed jar be better for preserves than an unglazed clay pot?

3. What foods does your family preserve or buy preserved for winter?

Safety first. An adult runs the oven, stove and any canner. Use knives only with an adult nearby. Never taste home-canned food from a jar with a bulging, leaking or unsealed lid; tell an adult so it can be thrown away safely.

HANDS-ON PROJECT

Drying Apples: Measuring the Water

You will preserve apples by drying them and use a kitchen scale to measure how much of an apple is water, the very thing microbes need.

You will need

- 3 or 4 apples
- An apple corer and a sharp knife (with an adult)
- Lemon juice and a bowl of water
- Baking sheets with cooling racks, or a food dehydrator
- A kitchen scale
- Paper towels and a clean glass jar with a lid

Steps

1. Wash and core the apples. With an adult, slice them into rings about $\frac{1}{4}$ inch thick. Peeling is optional.
2. Dip the rings for a minute in a bowl of water with $\frac{1}{4}$ cup lemon juice. This acid slows the browning reaction.
3. Pat the rings dry. Weigh them all together and record the starting weight in grams.
4. Arrange the rings in one layer on racks set on baking sheets (or in a dehydrator).
5. An adult sets the oven to its lowest setting, about 150–170°F, and props the door open an inch to let moisture escape. Dry for 6–10 hours, turning once, until the rings are leathery with no wet spots.
6. Let the rings cool and weigh them again. Record the final weight.
7. Calculate: $\text{water lost} = \text{start} - \text{final}$. $\text{Percent water} = \text{water lost} \div \text{start} \times 100$.
8. Store the rings in a clean, dry jar. Check them after a few days; any moisture on the glass means they need more drying.

Tips

- Most apples are about 85 percent water. How close did your result come?

- Save two fresh rings in a covered dish on the counter as a comparison. Check them after three days and note what happens.

Check your work

- ☐ I measured the weight of my apples before and after drying and calculated the percent of water removed.
- ☐ I can explain why dried food does not spoil easily.
- ☐ I can explain the 4.6 pH rule for canning and why low-acid foods need a pressure canner.

NATURE JOURNAL

1. Make a chart with five columns (drying, salting or sugaring, freezing, fermenting, canning). Under each, write what it takes away from microbes and give two foods preserved that way.
2. Draw a pH number line from 0 to 14. Place lemon juice (about 2), vinegar (about 2.5), tomatoes (about 4.4), green beans (about 5.5), water (7) and baking soda solution (about 8.3). Draw a bold line at 4.6.
3. Draw your fresh and dried apple rings side by side and describe their color, texture and smell.

From history. In 1810 a French confectioner named Nicolas Appert won a prize for discovering that food sealed in glass bottles and boiled would keep for months. He did not know why it worked. About fifty years later Louis Pasteur showed that microbes cause spoiling, and that heat kills them.

COMMON MISTAKES

- Thinking freezing kills microbes. It only puts them to sleep; they grow again when food thaws.
- Water-bath canning low-acid vegetables like green beans. They must be pressure canned to destroy botulinum spores.
- Leaving out the lemon juice in tomato recipes because tomatoes “taste acidic enough.”
- Using an untested recipe or skipping the altitude adjustment.

Make it a game · Spoilage Escape Room. Microbes need four things: water, food, warmth and the right acidity. Parent hides these four cards around the room. Find each one and say which preservation method removes it: drying, freezing, canning or pickling. Then answer the pH 4.6 puzzle: which foods get water-bath canned and which need pressure canning, and why botulism spores matter.

UNIT 1

SEASONS AND HARVEST

The school year begins at the richest time of the garden year: the harvest. Before we pick and preserve, we ask the big questions behind every farmer's calendar. Why do we have seasons at all? Why does frost come on clear, still nights? How do farmers measure the heat a crop has received? This unit answers those questions with real astronomy, real weather science and a little arithmetic.

Then we turn to the harvest itself: how to know when each crop is truly ripe, how to pick it without harming the plant, and how microbes, acidity and heat decide whether food keeps safely through the winter. "While the earth remaineth, seedtime and harvest ... shall not cease" (Genesis 8:22). Learning the order God built into the year helps us work with it wisely.

PREREQUISITES

- Can read a thermometer in °F
- Can find an average of two numbers
- Has a nature journal ready for the year

MASTERY CHECKLIST

- ☐ I can explain how the tilt of the earth's axis, not its distance from the sun, causes the seasons.
- ☐ I can explain how frost forms and find my area's average frost dates.
- ☐ I can calculate growing degree days from daily high and low temperatures.
- ☐ I can name signs of ripeness for at least six crops and harvest them carefully.
- ☐ I can explain how drying, freezing, canning and acidity keep microbes from spoiling food.

LESSONS IN THIS UNIT

1.1 Earth's Orbit and the Seasons

2 sessions of 50 minutes

1.2 Frost Dates and Growing Degree Days

2 sessions of 50 minutes

1.3 Harvest Timing and Techniques

2 sessions of 50 minutes

UNIT 1 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. Use your journal tables if you need them. 100 points total.

1. (8 pts)

What causes the seasons? Name the two effects of this cause.

2. (6 pts)

When is the earth closest to the sun? What does this prove?

3. (6 pts)

What is the difference between a solstice and an equinox?

4. (8 pts)

Why do clear, calm nights bring frost, and why do low spots freeze first?

5. (8 pts)

Calculate the growing degree days (base 50°F) for a day with a high of 84°F and a low of 62°F, and for a day with a high of 56°F and a low of 40°F.

6. (6 pts)

Name two tender crops and two hardy crops.

7. (8 pts)

Give the sign of ripeness for sweet corn and for winter squash.

8. (8 pts)

What is the difference between a climacteric and a non-climacteric fruit? Give one example of each.

9. (8 pts)

Name four things microbes need to grow, and match one preservation method to each.

10. **8 pts**

What pH number divides high-acid from low-acid foods in canning, and which kind of canner does each need?

11. **13 pts**

Explain why a tested tomato-canning recipe tells you to add bottled lemon juice to every jar.

12. **13 pts**

Your corn needs 2,600 GDD and your frost-free season is short. Explain how a gardener could use frost dates and GDD together to plan.

ANSWER KEY

1. The 23.4° tilt of the earth's axis. It changes the angle of sunlight (steep in summer, low in winter) and the length of the day.
2. In early January. It proves that distance from the sun does not cause the seasons.
3. A solstice is the longest or shortest day of the year (about June 21 and December 21); an equinox is a day of nearly equal day and night (about March 20 and September 22).
4. Without clouds or wind, the ground and plants lose heat into the sky (radiational cooling). Cold air is heavy and drains downhill into low spots.
5. $(84 + 62) \div 2 - 50 = 23$ GDD. $(56 + 40) \div 2 = 48$, which is below 50, so 0 GDD.
6. Tender: any two of tomato, pepper, basil, bean, squash, cucumber. Hardy: any two of kale, cabbage, spinach, carrot, garlic.
7. Sweet corn: silks brown and dry, kernels squirt milky juice. Winter squash: rind cannot be dented with a fingernail, stem dry and corky.
8. A climacteric fruit keeps ripening after picking because of ethylene (tomato, apple, pear, peach, banana). A non-climacteric fruit does not ripen after picking (strawberry, cherry, grape, watermelon, pepper).
9. Moisture (drying, salt, sugar), warmth (freezing, refrigeration), suitable pH (pickling, fermenting), air (vacuum sealing, canning).
10. 4.6. High-acid foods (4.6 or lower) can use a boiling-water canner; low-acid foods (above 4.6) need a pressure canner.
11. Tomatoes have a pH near the 4.6 line, and some are above it. Botulinum spores survive boiling and can grow in low-acid, sealed jars. Lemon juice lowers the pH safely below 4.6, so a boiling-water canner is enough to keep the food safe.
12. Frost dates show the window when corn can be outside without freezing. GDD totals show how much heat the area usually gets in that window. If the season does not supply enough GDD, the gardener should choose an earlier (shorter-season) variety, plant as soon as it is safe after the last frost, or use a warm spot.

PORTFOLIO PIECE: A FAMILY HARVEST CALENDAR

Make a one-year garden calendar for your own location. Mark your average last and first frost dates, the solstices and equinoxes, and the planting and harvest windows for at least eight crops you would like to grow. Add a short ripeness sign for each crop and a note on how you would preserve its harvest. Include your two-week GDD table and a sample of your dried apples or a photo of them.

LOOK FOR	WHAT IT MEANS
Accurate dates	Frost dates, solstices and equinoxes are correct for your location.
Crop windows	Planting and harvest times for eight crops fit the growing season and respect tender and hardy crops.
Ripeness and preservation	Each crop has a true sign of ripeness and a safe, sensible preservation method.
Data	The GDD table and apple-drying measurements are complete and correctly calculated.
Neatness	The calendar is clear, labeled and easy for the family to use.

UNIT 2

WILDLIFE ECOLOGY

As the garden winds down in fall, the wild animals around us become busier and easier to see: deer move along field edges at dusk, hawks hunt over mown fields, and raccoons raid unguarded trash cans. In this unit we study wildlife the way an ecologist does, asking how many animals a place can support, how predators and prey keep each other in balance, and how disease moves through wild populations.

We also learn how to live wisely alongside wild creatures: how to stay safe from rabies and ticks, and how to make a yard or farm better habitat for the birds and small animals we want to welcome. Adam was given the work of naming the animals (Genesis 2:19–20); knowing them well is still part of our stewardship.

PREREQUISITES

- Can read and make a simple line graph
- Knows the difference between herbivores, carnivores and omnivores
- Has learned the rule: never touch or feed a wild animal

MASTERY CHECKLIST

- ☐ I can explain carrying capacity and the limiting factors that set it, using deer as an example.
- ☐ I can describe a predator–prey cycle and explain why predator numbers lag behind prey numbers.
- ☐ I can name the warning signs of a rabid animal and the steps to prevent and remove ticks.
- ☐ I can build or plan a bluebird nest box with the correct measurements and placement.
- ☐ I can explain how brush piles and native plants improve habitat for wildlife.

LESSONS IN THIS UNIT

2.1 Populations and Carrying Capacity: White-Tailed Deer	2 sessions of 50 minutes
2.2 Predator and Prey	2 sessions of 50 minutes
2.3 Wildlife Diseases and Safety: Rabies, Ticks and Lyme	2 sessions of 50 minutes

2.4 Habitat Stewardship: Nest Boxes, Brush Piles and Native Plants

2 sessions of 50 minutes

UNIT 2 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

Define carrying capacity.

2. (7 pts)

Name four limiting factors for a deer population.

3. (8 pts)

What is a browse line, and what does it tell you?

4. (7 pts)

How can you tell a deer bite on a twig from a rabbit bite?

5. (8 pts)

In a predator-prey cycle, which population peaks first? Why?

6. (7 pts)

Name two ways an owl is designed for hunting and two ways a rabbit is designed for escaping.

7. (8 pts)

List three warning signs that a wild animal might have rabies.

8. (8 pts)

Which stage of the blacklegged tick causes most human Lyme disease, and why is it easy to miss?

9. (7 pts)

Describe the correct way to remove a tick.

10. **8 pts**

Give three features of a good bluebird nest box and its placement.

11. **12 pts**

Explain why too many deer can lower the carrying capacity of a forest for deer and for other animals.

12. **13 pts**

Explain why planting native plants helps songbirds raise their young.

ANSWER KEY

1. The largest population of a species that an area can support year after year without damaging its habitat.
2. Any four of: food, water, shelter, space, predators, disease, severe winter weather, hunting.
3. A line about 5 to 6 feet high below which deer have eaten nearly all leaves and twigs. It shows there are more deer than the habitat can support.
4. Deer have no upper front teeth, so they tear twigs, leaving a rough edge; rabbits cut cleanly at a slant, close to the ground.
5. The prey peaks first. Predators need time to raise young after food becomes plentiful, so their numbers rise later.
6. Owl: silent flight feathers, forward-facing eyes, ears at different heights, sharp talons. Rabbit: eyes on the sides of the head, swiveling ears, camouflage fur, powerful legs.
7. Any three of: a nocturnal animal out in daylight, staggering or circling, unusual tameness, unusual aggression, drooling, paralysis.
8. The nymph. It is only about the size of a poppy seed.
9. Grasp it close to the skin with fine-tipped tweezers, pull straight up with steady pressure, clean the bite, note the date and watch for a rash or fever.
10. Any three: 1½-inch hole, about 5 × 5-inch floor, hole 6 to 7 inches above the floor, no perch, drainage and air holes, opening side for cleaning, mounted 4 to 6 feet high on a pole with a predator guard, facing open ground.
11. When deer overshoot, they eat the wildflowers, shrubs and young trees faster than they can grow back. The food supply shrinks, so the forest can support fewer deer in the future, and shrub-nesting birds and other animals lose their food and shelter as well.
12. Most caterpillars can eat only the native host plants they are fitted to, and songbirds feed their nestlings mostly caterpillars. Native plants such as oaks host many kinds of caterpillars, so they supply the thousands of insects a bird family needs.

PORTFOLIO PIECE: A BACKYARD HABITAT PLAN

Draw a scaled map of your yard, a schoolyard or a section of a park, and plan improvements for wildlife. Show where you would add food (native plants), water, shelter (a nest box, a brush pile) and safe travel lanes, and where you would reduce risks (tick edges, raccoon attractants). Include a photo or drawing of your bluebird box and a short written explanation of each change.

LOOK FOR	WHAT IT MEANS
Four habitat needs	The plan adds food, water, shelter and space, with at least one specific improvement for each.
Good placement	The nest box, brush pile and plants are placed sensibly (box facing open ground, brush pile away from the garden).
Safety	The plan identifies tick habitat and wildlife attractants and gives a practical fix for each.
Accuracy	Native plants are truly native to the region, and nest-box measurements are correct.
Clear map	The map has a scale, a key and labels and is neat enough to follow.

2.1 POPULATIONS AND CARRYING CAPACITY: WHITE-TAILED DEER

OBJECTIVES

- Define population, limiting factor and carrying capacity.
- Explain how deer populations grow and what happens when they overshoot their habitat.
- Survey deer browse in a yard, park or woodland edge and interpret the results.

Warm-up. List everything a white-tailed deer needs to survive a whole year. Then circle the one thing you think would run out first in your area during a hard winter.

WATCH

What Happens To A Forest After 25 Years Without Deer?

Learn Your Land · 15:00

<https://www.youtube.com/watch?v=jhTQyCQ1l0A>

WHEN TO WATCH

After the core ideas. A naturalist compares woods inside and outside a deer-proof fence. Pause each time he steps from one side of the fence to the other and list the differences.

Note: The last minute advertises the channel's online courses.

BACKUP VIDEO

Ecological Carrying Capacity-Biology

MooMooMath and Science · 3:26

<https://www.youtube.com/watch?v=ozW7y-y6Ymw>

A short review of carrying capacity and the S-shaped growth curve; watch before drawing the graph in the nature journal.

KEY TERMS

population

All the members of one species living in one area at the same time.

limiting factor

Anything that keeps a population from growing larger, such as food, water, shelter, space, predators, disease or harsh weather.

carrying capacity

The largest population of a species that an area can support year after year without damaging its habitat.

browse

The twigs, buds and leaves of woody plants that deer and other animals eat; also the act of eating them.

browse line

A visible line, about 5 to 6 feet off the ground, below which deer have eaten nearly every leaf and twig.

overshoot

When a population grows beyond the carrying capacity and begins damaging its own food supply.

CORE IDEAS

Every living thing has needs, and every habitat has limits. A **population** grows when births and arrivals outnumber deaths and departures. But sooner or later some need runs short: food, water, shelter or space. Whatever runs short first is the **limiting factor**. Predators, disease and severe weather are limiting factors too. The largest population an area can support year after year, without wearing out its habitat, is its **carrying capacity**.

When a population starts small with plenty of food, it grows slowly at first, then faster and faster, because more parents produce more young. As it nears carrying capacity, food gets scarcer and growth slows. Graphed over time, this makes an S-shaped curve that levels off. Deer can grow quickly: healthy does often have twin fawns each spring, so a herd with no checks on it can nearly double in two or three years.

White-tailed deer show this clearly. Around 1900, after years of unregulated market hunting and forest clearing, fewer than half a million whitetails were left in the United States. With regulated hunting seasons, recovering forests and very few wolves or cougars left in the East, deer rebounded, and today there are tens of

millions. Deer thrive along edges, where woods meet fields, gardens and suburbs, which is exactly the landscape people have made.

When deer pass carrying capacity, they **overshoot**. An adult deer eats several pounds of plants every day. Too many deer strip the woods of wildflowers, shrubs and young trees, leaving a **browse line** and bare forest floor. Birds that nest in shrubs disappear, and the forest cannot replace its old trees. Starving deer in a hard winter are weak and sick, and the damaged woods can now support even fewer deer than before.

Ecologists also speak of a *cultural* carrying capacity: how many deer people can live with before car collisions, garden damage and tick problems become too great. State wildlife agencies count deer, study the plants, and set hunting seasons to keep herds healthy and in balance with their habitat. Good stewardship means caring about the whole community of living things, not just one species.

PICTURE STUDY



The Shelter of the Roe Deer at the Stream of Plaisir-Fontaine, Gustave Courbet, 1866 · Oil on canvas ·
Musée d'Orsay, Paris

Image: [Wikimedia Commons](#), public domain

Courbet grew up in the forested hills of eastern France and loved to paint the animals of the woods. Roe deer are smaller European cousins of our white-tailed deer. Here they rest safely in a secluded spot beside a stream.

Look closely

- Count the deer. What is each one doing?
- Find the stream. Which of the deer's needs does it meet?
- Look at the plants around the deer. Is there thick green growth near the ground, or bare earth?
- Find where the light comes into the glade. Is this an open field or deep woods?

Talk about it

1. Which of a deer's needs (food, water, shelter, space) can you see in this painting?
2. What would this glade look like if there were three times as many deer?
3. Why might deer choose a spot like this to rest during the day?

Safety first. Stay on trails and wear long pants during the browse survey, and do a full tick check afterward. Survey only where you have permission.

HANDS-ON PROJECT

A Deer Browse Survey

Wildlife biologists measure deer pressure by looking at the plants, not just by counting deer. You will do a simple browse survey and graph a model deer population.

You will need

- A tape measure
- String and four sticks or tent stakes
- Your nature journal and a clipboard
- A hand lens
- A field guide or app for common shrubs and young trees (optional)

Steps

1. With an adult, choose a spot at a woodland edge, a park or a hedgerow where deer live.
2. Stake out a square plot 10 feet on each side with string.
3. Inside the plot, examine every shrub and young tree shorter than 6 feet. Count the twig tips you can reach.
4. Sort each twig tip as *browsed* or *not browsed*. Deer have no upper front teeth, so a browsed twig ends in a rough, torn edge; a rabbit's bite leaves a clean, slanted cut.
5. Record your counts in a table and calculate the percent of twigs browsed.
6. Step back and look for a browse line on nearby shrubs or evergreens. Measure its height from the ground.
7. Look for other deer signs: tracks, droppings, beds of flattened grass, and rubs where bucks scraped bark with their antlers.
8. At home, model a herd: start with 20 deer and let the herd grow 30 percent each year until it reaches a carrying capacity of 80, then hold it there. Make a table for 10 years and graph it.
9. Write a short report: Is the deer browse at your site light (under 20 percent), moderate (20–50 percent) or heavy (over 50 percent)? What evidence

supports your answer?

Tips

- Late fall and winter are the best times to see browse, because the leaves are gone.
- If you have no woods nearby, survey the shrubs around a park or ask to look along a farm hedgerow.

Check your work

- ☐ I measured a plot, counted browsed and unbrowsed twigs, and calculated a percent.
- ☐ I can tell a deer bite from a rabbit bite.
- ☐ My graph shows a population that grows and then levels off at carrying capacity.

NATURE JOURNAL

1. Draw a browsed twig and an unbrowsed twig side by side with a hand lens. Label the torn edge.
2. Draw the S-shaped population curve and label the slow start, the fast growth, and the carrying capacity line.
3. Sketch a deer track (two pointed halves like an upside-down heart) at life size, about 2 to 3 inches long.

From history. In the early 1900s, the Kaibab Plateau in Arizona became a famous lesson, though scientists still debate the details. Deer numbers grew enormously after their predators were removed, the deer stripped their range of food, and huge numbers then starved. Wildlife scientists such as Aldo Leopold used stories like this to teach that a herd must be kept in balance with its habitat.

COMMON MISTAKES

- Thinking carrying capacity is a fixed number forever. Habitat changes: a damaged forest supports fewer deer, and a recovering one supports more.
- Believing more deer always means a healthier herd. Overcrowded deer are often thin and sick.
- Mixing up deer and rabbit damage. Deer tear twigs; rabbits snip them cleanly at a slant, close to the ground.

Make it a game • Deer Overshoot Simulation. Scatter forty dried beans, or paper bits, as food in a taped yard on the floor. You are the deer herd and your parent adds fawns each round while you pick food. Watch the food run out, the browse line rise and the herd overshoot. Explain limiting factor and carrying capacity, then find a fair balance.

2.2 PREDATOR AND PREY

OBJECTIVES

- Describe the predator–prey cycle and explain why predator numbers lag behind prey numbers.
- Identify local predators and their prey and the special designs that fit each for its life.
- Run and graph a simple predator–prey simulation.

Warm-up. Name five predators that live within 20 miles of your home and the main foods of each. Draw arrows from each food to the animal that eats it. You have started a food web.

WATCH

Predator prey cycle | Ecology | Khan Academy

Khan Academy · 5:08

https://www.youtube.com/watch?v=NYq2078_xqc

WHEN TO WATCH

After the core ideas. Pause when the two curves are drawn and explain to someone why the predator peak comes after the prey peak.

BACKUP VIDEO

Predator Prey Interactions | Basic Ecology |

MooMooMath and Science · 2:28

<https://www.youtube.com/watch?v=wShaj7IUO5g>

A short review of predators, prey and food chains.

KEY TERMS

predator

An animal that catches and eats other animals.

prey

An animal that is caught and eaten by a predator.

food web

A diagram of all the feeding connections among living things in a community.

predator–prey cycle

The repeating rise and fall of predator and prey populations, with the predator’s numbers following a little behind the prey’s.

trophic level

A feeding level in a food chain: producers (plants), herbivores, and the carnivores that eat them.

CORE IDEAS

In every community, some animals eat plants and some eat animals. The **predators** in an American backyard and farm country include red-tailed hawks, great horned owls, barn owls, red foxes, coyotes, snakes and even house cats. Their **prey** are mostly mice, voles, rabbits, squirrels and insects. A barn owl family can eat more than a thousand rodents in a year, which is why farmers have long welcomed owls in their barns.

Predator and prey populations are tied together. When food is plentiful, prey such as rabbits multiply. More rabbits mean more food for foxes and owls, so more young predators survive. Soon there are so many predators that they catch rabbits faster than rabbits can be born, and the rabbit population falls. Then predators go hungry, raise fewer young, and their numbers fall too, allowing the rabbits to rise again. This is the **predator–prey cycle**. The predator peak always comes a little after the prey peak, because it takes time for predators to raise young.

The most famous example comes from the snowshoe hare and the Canada lynx. Fur-trading records kept for nearly a century in northern Canada show both populations rising and falling about every ten years, with the lynx peak following the hare peak. Food supply and disease play a part too, but the pattern clearly links the two animals.

God has fitted predators and prey for their lives in wonderful ways. An owl’s wing feathers have soft, comb-like edges that let it fly in near silence, and its ears are set at slightly different heights so it can locate a mouse under snow by sound alone. A rabbit, in turn, has eyes on the sides of its head that see almost all the way around,

ears that swivel, fur that blends with dead grass, and powerful legs for sudden zigzag escapes.

Energy moves up a food chain from plants to herbivores to carnivores. At each step only about a tenth of the energy is passed on, because most is used for living or lost as heat. That is why there are always far more mice than owls. Predators are not villains; they keep prey populations from overshooting, and they often catch the sick and weak. “The young lions roar after their prey, and seek their meat from God” (Psalm 104:21).

PICTURE STUDY



Great Horned Owl, John James Audubon, 1829 (engraved by Robert Havell) · Hand-colored engraving from *The Birds of America* · National Gallery of Art, Washington

Image: [Wikimedia Commons](#), public domain

Audubon set out to paint every bird in North America at life size. The great horned owl is the fiercest common predator of our woods and farms, able to hunt rabbits, skunks and even other owls.

Look closely

- Find the ear tufts. (They are only feathers; the real ears are hidden on the sides of the head.)
- Look at the eyes. Which way do they face? How is that different from a rabbit's eyes?
- Look closely at the feet and talons. What are they designed to do?
- Look at the color and pattern of the feathers. Where would this owl be hard to see?

Talk about it

1. Why do predators usually have eyes facing forward, while prey animals have eyes on the sides of their heads?
2. How might a great horned owl help a farmer? How might it be a problem for a farmer with chickens?

3. What do you think these two owls are watching?

HANDS-ON PROJECT

The Rabbit and Fox Simulation

You will model a predator–prey cycle with paper “rabbits” and cardboard “foxes,” then graph your results to see whether a cycle appears.

You will need

- 200 paper squares, 1 inch on a side (rabbits)
- Ten cardboard squares, 3 inches on a side (foxes)
- Masking tape to mark a 3-foot by 3-foot field on the floor or a table
- Graph paper and two colored pencils

Steps

1. Mark the field. Scatter 3 rabbit squares in it to start generation 1.
2. Toss one fox square into the field from about 2 feet away. Remove any rabbits it touches; the fox has “eaten” them.
3. Rules: a fox must catch at least 3 rabbits in one generation to survive; if it catches 3 or more, it survives and raises one new fox for the next generation. A fox that catches fewer than 3 is removed. If all foxes are gone, add one new fox the next generation (one wanders in from elsewhere).
4. Toss each fox in turn. Then the surviving rabbits double: add as many rabbits as are left in the field.
5. Record the number of rabbits and foxes at the end of each generation in a table.
6. Repeat for 20 generations. If rabbits ever exceed 200, stop adding and note it.
7. Graph both populations on the same axes, with generations along the bottom. Use one color for rabbits and one for foxes.
8. Write what you see. Do the populations rise and fall? Which one peaks first?

Tips

- Toss the fox the same way each time, so your results are fair.
- Have one person toss and another record.

Check your work

- ☐ I ran at least 20 generations and recorded both populations.
- ☐ My graph shows both populations with a key.
- ☐ I can explain why the fox peak comes after the rabbit peak.

NATURE JOURNAL

1. Draw a food web for your area with at least 10 living things, starting with plants at the bottom.
2. Draw an energy pyramid with plants, mice and owls. Label the levels and write roughly how much energy passes up each step.
3. Watch a bird feeder, field edge or park for 20 minutes at dawn or dusk. Note any hunting behavior you see, from a robin catching worms to a hawk circling.

From history. The Hudson's Bay Company bought furs from trappers in Canada for more than two hundred years and kept careful records. In the 1920s and 1930s the ecologist Charles Elton studied those records and discovered the ten-year rise and fall of the snowshoe hare and the lynx.

COMMON MISTAKES

- Thinking predators wipe out their prey. In a healthy community, predators and prey both persist, rising and falling together.
- Drawing food-chain arrows backward. The arrow points from the food to the eater, showing which way energy flows.
- Forgetting that pets can be predators. Outdoor cats catch great numbers of songbirds and small animals.

Make it a game • Rabbit and Fox Cycle. Use beans as rabbits and a paper cup as the fox. Start with ten rabbits and one fox. Each round, rabbits double and the fox eats some; add or remove beans as the rules say. Graph the numbers on paper and explain why predator numbers lag behind prey. Name two local predators and the design that fits each.

Scripture. “The young lions roar after their prey, and seek their meat from God.” (Psalm 104:21, KJV)

The psalmist sees even the predator's hunt as part of God's care for His creatures. Each animal, hunter and hunted, depends on Him for its food.

2.3 WILDLIFE DISEASES AND SAFETY: RABIES, TICKS AND LYME

OBJECTIVES

- Explain how rabies spreads and name the warning signs of a sick wild animal.
- Describe the life cycle of the blacklegged tick and how it carries Lyme disease.
- Practice tick prevention, a full tick check, and correct tick removal.

Warm-up. Write down what you would do, step by step, if you found a raccoon wandering in your yard at noon, walking in circles. Keep your answer; you will check it at the end of the lesson.

WATCH

5 Tips to Prevent Tick Bites and Getting Lyme Disease | Johns Hopkins Medicine

Johns Hopkins Rheumatology · 6:34

<https://www.youtube.com/watch?v=ENmVXtwsKE8>

WHEN TO WATCH

After the core ideas on ticks. Write each of the five tips in your journal as he gives it.

Note: The doctor mentions repellents and yard treatments; in this course an adult chooses and applies any repellent.

BACKUP VIDEO

How to properly remove a tick

University of Manitoba · 1:59

<https://www.youtube.com/watch?v=27McsguL2Og>

Before practicing tick removal in the project. A tick expert removes a tick from her arm with fine tweezers.

KEY TERMS

rabies

A deadly virus disease of the brain and nerves that spreads through the saliva of an infected mammal, usually by a bite.

nocturnal

Active mainly at night. Raccoons, skunks, opossums and bats are nocturnal.

blacklegged tick

A small tick (also called the deer tick) that can carry the bacteria that cause Lyme disease.

nymph

The young, eight-legged stage of a tick, about the size of a poppy seed; the stage most likely to give people Lyme disease.

Lyme disease

An illness caused by bacteria passed by the bite of an infected blacklegged tick, often beginning with a spreading rash, fever and aches.

CORE IDEAS

Rabies is a virus that attacks the brain and nerves of mammals. It lives in saliva and spreads mainly through bites. In the United States, most rabies cases are found in wild animals, especially raccoons, skunks, bats and foxes. Once symptoms begin, rabies is almost always fatal, but treatment given promptly after an exposure works extremely well. That is why every bite or scratch from a wild animal must be reported to an adult and a doctor right away.

A rabid animal often acts strangely. A **nocturnal** animal such as a raccoon or skunk out in daylight, staggering, circling, unusually tame or unusually aggressive may be sick. (Not every daytime raccoon is rabid; a mother may be foraging for her young. But keep your distance and tell an adult.) Bats deserve special care: a bat bite can be so small it is not noticed, so if a bat is found in a room where someone was sleeping, an adult should call the health department. Keeping dogs, cats and ferrets up to date on their rabies shots protects both pets and people.

Ticks are small relatives of spiders that drink blood. The **blacklegged tick** has a two-year life: the tiny larva feeds on a mouse or bird, molts into a **nymph**, feeds again the

next spring or summer, and becomes an adult that feeds on a deer in fall. White-footed mice often carry the Lyme bacteria, so a tick that feeds on an infected mouse can pass the germs to its next host. Nymphs, no bigger than a poppy seed, are active from late spring through summer and cause most human cases of **Lyme disease**.

A tick usually has to be attached for more than a day (about 36 to 48 hours) to pass Lyme bacteria, so a careful daily tick check is one of the best protections. Ticks wait on grass and brush and climb onto anyone who brushes past; they do not jump or fly. Wear long pants tucked into socks and light-colored clothes so ticks show up, walk in the center of trails, and let an adult apply a registered repellent. After time outdoors, shower and check everywhere: scalp, behind the ears, armpits, waist, behind the knees and between the toes.

To remove a tick, grasp it as close to the skin as possible with fine-tipped tweezers and pull straight up with slow, steady pressure. Do not twist, burn it, or smother it with petroleum jelly. Clean the bite with soap and water or rubbing alcohol, write down the date, and tell an adult. Watch the spot for a month; a spreading red rash, fever or aches means a visit to the doctor.

PICTURE STUDY



Raccoon, John James Audubon, about 1846 · Hand-colored lithograph from *The Viviparous Quadrupeds of North America*, Plate 61 · *The Viviparous Quadrupeds of North America* by John James Audubon and John Bachman

Image: [Wikimedia Commons](#), public domain

After finishing his bird book, John James Audubon worked with his sons and the naturalist John Bachman on a great book of North American mammals. This raccoon, one of the most common and clever animals of our neighborhoods, is drawn at natural size.

Look closely

- Find the raccoon's black mask and ringed tail.
- Look at its front paws. How are they like hands?
- Look at its eyes and ears. What senses help a raccoon find food at night?
- Find what the raccoon is standing on. Where do raccoons like to rest and search for food?

Talk about it

1. Why are raccoons so successful living near people? (Think about trash cans, pet food and gardens.)
2. If you saw this raccoon on your porch at noon acting confused, what should you do?
3. How could a family make its yard less attractive to raccoons?

Safety first. Never touch, feed or try to help a wild animal, even a baby or one that seems tame; tell an adult. Never touch a bat with bare hands. Do not handle raccoon droppings. Practice tick removal on a model, and let an adult remove any real tick if you are unsure.

HANDS-ON PROJECT

A Family Wildlife-Safety Plan

You will map the tick and wildlife risks around your home and make a safety card for your family, then practice tick removal on a model.

You will need

- Paper and colored pencils for a yard map
- An index card and a pen
- Fine-tipped tweezers
- A poppy seed, a sesame seed and a lentil (tick models)
- A piece of modeling clay or a small orange

Steps

1. Draw a map of your yard, or of a park or schoolyard you visit often.
2. Shade in color the places ticks are most likely: tall grass, brushy edges, leaf litter, stone walls and woodpiles.
3. Mark anything that attracts raccoons, skunks or opossums: open trash cans, outdoor pet food, bird seed on the ground, compost with food scraps.
4. On the map, write one fix for each risk (for example, “Keep trash in the garage,” “Feed the cat indoors,” “Keep a 3-foot strip of wood chips between lawn and woods”).
5. On an index card, write a family safety card: the warning signs of a rabid animal, who to call (animal control or the health department), the steps after a bite, and the five places to check for ticks.
6. Compare a poppy seed (nymph), a sesame seed (adult male) and a lentil (fed adult female) to see how small ticks are.
7. Press the poppy or sesame seed slightly into modeling clay. Practice gripping it with fine tweezers right at the surface and lifting straight up with steady pressure.
8. Do a full tick check on yourself after your next time outdoors, using your card.

Tips

- Post your safety card by the back door.
- Ask your county health department or extension office which ticks are common in your area.

Check your work

- ☐ My map shows tick habitat and wildlife attractants, with a fix for each.
- ☐ My safety card lists rabies warning signs, who to call, and the tick-check spots.
- ☐ I can show correct tick removal with fine tweezers.

NATURE JOURNAL

1. Draw the life cycle of the blacklegged tick as a circle: egg, larva on a mouse, nymph, adult on a deer. Label the seasons.
2. Draw a life-size row of dots showing a larva, a nymph and an adult tick.
3. Draw a raccoon track (it looks like a small human handprint with five long toes).

From history. In 1885 the French scientist Louis Pasteur saved the life of a nine-year-old boy named Joseph Meister, who had been badly bitten by a rabid dog, with a treatment no one had tried on a person before. Lyme disease was named in the 1970s after the town of Lyme, Connecticut, where mothers noticed an unusual number of children with swollen joints and pressed doctors to find the cause.

COMMON MISTAKES

- Thinking a friendly wild animal is safe to touch. Unusual tameness can be a sign of rabies.
- Using a hot match, nail polish or petroleum jelly to remove a tick. Use fine tweezers and pull straight up.
- Checking only arms and legs for ticks. Nymphs hide in the scalp, behind the ears, and in warm creases.

Make it a game • Safety Plan Role-Play. Act out wildlife safety scenes. Your parent plays a hiker, a camper or a neighbor, and you coach them: how rabies spreads, the warning signs of a sick wild animal, and what to do about a tick on the skin. Walk through the blacklegged tick life stages and Lyme disease. Parent stumps you with one tricky scenario.

2.4 HABITAT STEWARDSHIP: NEST BOXES, BRUSH PILES AND NATIVE PLANTS

OBJECTIVES

- Name the four parts of habitat and explain how people can improve each.
- Build or plan a bluebird nest box with correct measurements and placement.
- Explain how brush piles and native plants support birds and small animals.

Warm-up. Walk around your yard, street or a park for five minutes. Count the places a bird could nest, hide from a hawk, drink, and find food. Which of the four was hardest to find?

WATCH

Building Bluebird Nest Boxes

Arkansas Division of Agriculture • 4:40

<https://www.youtube.com/watch?v=qS7rXKW5u2k>

WHEN TO WATCH

Before the project. Pause and write down every measurement given: the hole size, floor size and height.

BACKUP VIDEO

Brushpiles with Game Commission biologist Dan Mummert

PA Game Commission • 4:36

<https://www.youtube.com/watch?v=pXTGUBPYwPo>

After the core idea about brush piles.

KEY TERMS

habitat

The place where an animal finds the food, water, shelter and space it needs.

cavity nester

A bird that nests inside a hole in a tree or a nest box, such as a bluebird, chickadee, wren or tree swallow.

predator guard

A cone, tube or baffle on a nest-box pole that keeps snakes, raccoons and cats from climbing to the nest.

native plant

A plant that grew naturally in a region before modern times and that local insects and animals are fitted to use.

host plant

A plant whose leaves a particular caterpillar or insect can eat and grow on.

CORE IDEAS

Every animal needs four things from its **habitat**: food, water, shelter and space. A tidy lawn with a few shrubs supplies almost none of them. A good steward can add each one: native plants and seed heads for food, a shallow birdbath for water, nest boxes and brush piles for shelter, and connected hedgerows that let animals move safely.

Eastern bluebirds are **cavity nesters**. They need an old woodpecker hole or a hollow fence post. As old orchards and wooden posts disappeared and non-native house sparrows and starlings took over the remaining holes, bluebirds became scarce in the 1900s. Then thousands of people put up nest boxes, and bluebirds made a remarkable comeback.

A good bluebird box has a floor about 5 by 5 inches, an entrance hole exactly 1½ inches across (big enough for a bluebird, too small for a starling), set about 6 to 7 inches above the floor. It has no perch, because bluebirds do not need one and house sparrows like one. It has small holes for air and drainage, and a side or front that opens so you can check and clean it. Mount it 4 to 6 feet high on a metal pole with a **predator guard**, facing an open lawn or field, about 100 yards from the next bluebird box. Clean out the old nest after each brood fledges.

A **brush pile** is shelter you can build from fallen branches. Start with a base of large logs laid crisscross to leave tunnels, then pile smaller branches on top until it is waist to head high. Wrens, sparrows, rabbits, chipmunks and toads hide in it from hawks and winter wind. Place it at the edge of the woods, well away from the vegetable garden, or the rabbits it shelters will dine on your lettuce.

Native plants feed wildlife in ways many imported garden plants cannot. Most caterpillars can eat only certain **host plants** they are fitted to digest, and nearly all songbirds feed their nestlings caterpillars. Researchers estimate that a single pair of chickadees needs several thousand caterpillars to raise one brood, and a native oak tree may host hundreds of kinds of caterpillars. Planting oaks, serviceberry, dogwood, milkweed, goldenrod, asters and coneflowers turns a yard into a pantry for birds.

In the 4-H **Wildlife Habitat Evaluation Program** (WHEP), young people compete in judging habitat. Teams look at a site or a photo, score it for food, water, cover and space, and then choose management practices (such as nest boxes, brush piles, planting native shrubs, or leaving dead standing trees) that would help a named species, like the eastern bluebird or the cottontail rabbit. Juniors can compete at county and state levels; ask your county extension office.

PICTURE STUDY



Blue-bird, John James Audubon, 1827–38 (engraved by Robert Havell) · Hand-colored engraving from *The Birds of America*, Plate 113 · *The Birds of America*

Image: [Wikimedia Commons](#), public domain

Audubon painted a whole bluebird family on the tall stalk of a mullein plant, a common weed of old fields. He showed the male, the female and a young bird so a reader could recognize all three.

Look closely

- Find the male, the female and the young bird. How are their colors different?
- Look at the young bird's speckled breast. Why might speckles help a young bird?
- Find the plant they are perched on. Where does a plant like this grow?
- Look at the bluebirds' beaks. Are they built for cracking seeds or catching insects?

Talk about it

1. Bluebirds hunt insects by watching from a perch and dropping to the ground. Why does a bluebird box belong near an open field instead of deep woods?
2. Why might the male be so much brighter than the female, who sits on the nest?

3. What could you plant near a nest box to feed the bluebirds in winter? (Think of berries.)

Safety first. An adult runs the saw and drill. Wear safety glasses when hammering or drilling. Wear gloves when dragging branches for a brush pile, and check for ticks afterward.

HANDS-ON PROJECT

Build a Bluebird Nest Box

You will build (or, without tools, carefully plan) a bluebird box from one board, then choose a good place to mount it.

You will need

- One untreated cedar or pine board, 1 × 6 inches (actual size $\frac{3}{4} \times 5\frac{1}{2}$), about 5 feet long
- Galvanized deck screws or nails, 1 $\frac{5}{8}$ inches
- A saw, a drill with a 1 $\frac{1}{2}$ -inch spade bit or hole saw, and a $\frac{1}{4}$ -inch bit (adult use)
- A tape measure, pencil and square
- Safety glasses
- A metal pole or conduit and a predator guard (optional, for mounting)

Steps

1. With an adult, mark and cut the board into: front 9 inches; back 14 inches; two sides 10 inches; roof 8 $\frac{1}{2}$ inches; floor 4 inches (trim the floor to fit between the sides).
2. On the front piece, mark the center of the hole 6 $\frac{1}{2}$ inches up from the bottom edge. An adult drills the 1 $\frac{1}{2}$ -inch entrance hole.
3. Cut a small notch off each corner of the floor for drainage, and drill two $\frac{1}{4}$ -inch air holes near the top of each side.
4. Screw the back to one side. Attach the floor between the sides, recessed $\frac{1}{4}$ inch up from the bottom so rain cannot soak into it.
5. Attach the front. Attach the second side with only two screws near the top, as a pivot, so it can swing open for cleaning. Add one nail near the bottom as a latch.
6. Attach the roof so it overhangs the front to keep rain out of the hole. Do not add a perch.
7. Choose a site facing an open lawn or field, away from heavy brush and at least 100 yards from another bluebird box, and with an adult mount it 4 to 6

feet high on a pole with a guard.

8. Habitat judging, WHEP style: choose a named species (eastern bluebird, cottontail rabbit or white-tailed deer). Score your yard or a park photo from 1 to 5 for that species' food, water, cover and space. Then pick the three management practices that would help it most, and give a one-minute oral explanation of your choices.
9. Record the date and location in your journal. Check the box once a week in spring (quickly and quietly) and record what you see.

Tips

- If you have no tools, draw a full-size plan with every measurement, or buy a kit and assemble it.
- Do not paint or stain the inside of the box. If you paint the outside, use a light color so it stays cool.

Check your work

- ☐ My box has a 1½-inch hole about 6½ inches above the floor, drainage, air holes and no perch.
- ☐ One side opens for cleaning.
- ☐ I chose a mounting site that faces open ground and can be protected from predators.
- ☐ I scored a habitat for one species and chose management practices with reasons.

NATURE JOURNAL

1. Draw a labeled diagram of your nest box showing every measurement.
2. Draw a cross-section of a brush pile, showing the large crisscrossed logs at the bottom and smaller branches above. Label who might hide where.
3. List and sketch three native plants that grow wild near you. For each, note what birds or insects use it.

From history. In the 1960s, after bluebirds had grown rare, Dr. Lawrence Zeleny of Maryland began urging Americans to build nest boxes and set them out in long lines called bluebird trails. His book and the North American Bluebird Society he helped found in 1978 inspired families and schoolchildren to put up hundreds of thousands of boxes.

COMMON MISTAKES

- Adding a perch below the hole. Bluebirds do not need it, and it helps house sparrows.
- Mounting the box on a tree or fence without a guard, where cats, raccoons and snakes can reach it.
- Building a brush pile right beside the vegetable garden, where it shelters garden-eating rabbits.

Make it a game • Habitat Four Corners. Label four corners of a room: food, water, shelter and space. Parent calls a yard improvement, like a brush pile, native plant, shallow dish or nest box, and you run to the right corner and explain. Then recite the bluebird nest box measurements and placement from memory. Parent keeps score and adds a predator guard challenge.

Scripture. “By them shall the fowls of the heaven have their habitation, which sing among the branches.” (Psalm 104:12, KJV)

God provides homes for the birds beside the streams and in the trees. When we put up a nest box or plant a native shrub, we share a small part in that providing.

UNIT 2

WILDLIFE ECOLOGY

As the garden winds down in fall, the wild animals around us become busier and easier to see: deer move along field edges at dusk, hawks hunt over mown fields, and raccoons raid unguarded trash cans. In this unit we study wildlife the way an ecologist does, asking how many animals a place can support, how predators and prey keep each other in balance, and how disease moves through wild populations.

We also learn how to live wisely alongside wild creatures: how to stay safe from rabies and ticks, and how to make a yard or farm better habitat for the birds and small animals we want to welcome. Adam was given the work of naming the animals (Genesis 2:19–20); knowing them well is still part of our stewardship.

PREREQUISITES

- Can read and make a simple line graph
- Knows the difference between herbivores, carnivores and omnivores
- Has learned the rule: never touch or feed a wild animal

MASTERY CHECKLIST

- ☐ I can explain carrying capacity and the limiting factors that set it, using deer as an example.
- ☐ I can describe a predator–prey cycle and explain why predator numbers lag behind prey numbers.
- ☐ I can name the warning signs of a rabid animal and the steps to prevent and remove ticks.
- ☐ I can build or plan a bluebird nest box with the correct measurements and placement.
- ☐ I can explain how brush piles and native plants improve habitat for wildlife.

LESSONS IN THIS UNIT

2.1 Populations and Carrying Capacity: White-Tailed Deer	2 sessions of 50 minutes
2.2 Predator and Prey	2 sessions of 50 minutes
2.3 Wildlife Diseases and Safety: Rabies, Ticks and Lyme	2 sessions of 50 minutes

2.4 Habitat Stewardship: Nest Boxes, Brush Piles and Native Plants

2 sessions of 50 minutes

UNIT 2 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. **7 pts**
Define carrying capacity.
2. **7 pts**
Name four limiting factors for a deer population.
3. **8 pts**
What is a browse line, and what does it tell you?
4. **7 pts**
How can you tell a deer bite on a twig from a rabbit bite?
5. **8 pts**
In a predator-prey cycle, which population peaks first? Why?
6. **7 pts**
Name two ways an owl is designed for hunting and two ways a rabbit is designed for escaping.
7. **8 pts**
List three warning signs that a wild animal might have rabies.
8. **8 pts**
Which stage of the blacklegged tick causes most human Lyme disease, and why is it easy to miss?
9. **7 pts**
Describe the correct way to remove a tick.

10. **8 pts**

Give three features of a good bluebird nest box and its placement.

11. **12 pts**

Explain why too many deer can lower the carrying capacity of a forest for deer and for other animals.

12. **13 pts**

Explain why planting native plants helps songbirds raise their young.

ANSWER KEY

1. The largest population of a species that an area can support year after year without damaging its habitat.
2. Any four of: food, water, shelter, space, predators, disease, severe winter weather, hunting.
3. A line about 5 to 6 feet high below which deer have eaten nearly all leaves and twigs. It shows there are more deer than the habitat can support.
4. Deer have no upper front teeth, so they tear twigs, leaving a rough edge; rabbits cut cleanly at a slant, close to the ground.
5. The prey peaks first. Predators need time to raise young after food becomes plentiful, so their numbers rise later.
6. Owl: silent flight feathers, forward-facing eyes, ears at different heights, sharp talons. Rabbit: eyes on the sides of the head, swiveling ears, camouflage fur, powerful legs.
7. Any three of: a nocturnal animal out in daylight, staggering or circling, unusual tameness, unusual aggression, drooling, paralysis.
8. The nymph. It is only about the size of a poppy seed.
9. Grasp it close to the skin with fine-tipped tweezers, pull straight up with steady pressure, clean the bite, note the date and watch for a rash or fever.
10. Any three: 1½-inch hole, about 5 × 5-inch floor, hole 6 to 7 inches above the floor, no perch, drainage and air holes, opening side for cleaning, mounted 4 to 6 feet high on a pole with a predator guard, facing open ground.
11. When deer overshoot, they eat the wildflowers, shrubs and young trees faster than they can grow back. The food supply shrinks, so the forest can support fewer deer in the future, and shrub-nesting birds and other animals lose their food and shelter as well.
12. Most caterpillars can eat only the native host plants they are fitted to, and songbirds feed their nestlings mostly caterpillars. Native plants such as oaks host many kinds of caterpillars, so they supply the thousands of insects a bird family needs.

PORTFOLIO PIECE: A BACKYARD HABITAT PLAN

Draw a scaled map of your yard, a schoolyard or a section of a park, and plan improvements for wildlife. Show where you would add food (native plants), water, shelter (a nest box, a brush pile) and safe travel lanes, and where you would reduce risks (tick edges, raccoon attractants). Include a photo or drawing of your bluebird box and a short written explanation of each change.

LOOK FOR	WHAT IT MEANS
Four habitat needs	The plan adds food, water, shelter and space, with at least one specific improvement for each.
Good placement	The nest box, brush pile and plants are placed sensibly (box facing open ground, brush pile away from the garden).
Safety	The plan identifies tick habitat and wildlife attractants and gives a practical fix for each.
Accuracy	Native plants are truly native to the region, and nest-box measurements are correct.
Clear map	The map has a scale, a key and labels and is neat enough to follow.

UNIT 3

SOIL CHEMISTRY AND BIOLOGY

Soil is not dirt. It is a mixture of minerals, water, air, organic matter and an astonishing crowd of living things, and its chemistry decides whether the nutrients in it can actually reach a plant's roots. In earlier years you learned soil types and compost. This year you will look deeper, at the chemistry of pH, at the great nitrogen cycle that links the air to every leaf, and at the food web of bacteria, fungi and tiny animals that keeps soil alive.

The unit ends with a real soil test, the same kind farmers send to a laboratory, and with the arithmetic of choosing amendments and fertilizer wisely. God formed the first man from the dust of the ground and set him in a garden “to dress it and to keep it” (Genesis 2:15). Caring for soil is one of the oldest jobs there is.

PREREQUISITES

- Knows the soil textures sand, silt, clay and loam
- Knows that compost is made of decayed plant material
- Can calculate a percentage

MASTERY CHECKLIST

- ☐ I can explain the pH scale and how soil pH affects which nutrients plants can absorb.
- ☐ I can trace nitrogen through fixation, ammonification, nitrification, plant uptake and denitrification.
- ☐ I can describe the main members of the soil food web and what each one does.
- ☐ I can take a proper soil sample, read a soil test, and calculate how much fertilizer or amendment to apply.

LESSONS IN THIS UNIT

3.1 Soil pH and Nutrient Availability

2 sessions of 50 minutes

3.2 The Nitrogen Cycle

2 sessions of 50 minutes

3.3 The Soil Food Web

2 sessions of 50 minutes

UNIT 3 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. 7 pts

Soil A has a pH of 5 and soil B has a pH of 7. How many times more acidic is soil A?

2. 7 pts

What pH range suits most vegetables? Name one plant that prefers more acidic soil.

3. 8 pts

A plant in alkaline soil has yellow new leaves with green veins. What is the likely problem and why?

4. 7 pts

What would you add to raise soil pH? To lower it?

5. 8 pts

Why can't plants use the nitrogen in the air?

6. 8 pts

Where do Rhizobium bacteria live, and what does each partner give the other?

7. 7 pts

Put these in order: nitrate, ammonium, dead leaves, plant protein.

8. 8 pts

Name four groups of organisms in the soil food web and one job of each.

9. 7 pts

What do mycorrhizal fungi give a plant, and what does the plant give them?

10. **8 pts**

A soil test calls for 2 pounds of nitrogen per 1,000 square feet. How many pounds of 20-5-5 fertilizer is that?

11. **12 pts**

Describe how to take a good soil sample from a vegetable garden.

12. **13 pts**

Explain why adding extra fertilizer “just to be safe” is poor stewardship.

ANSWER KEY

1. 100 times (each whole number on the pH scale is ten times).
2. About 6.0 to 7.0 (6.5 is a good target). Blueberries or azaleas (potatoes also accepted).
3. Iron chlorosis. Iron is in the soil but becomes insoluble (locked up) at high pH, so the roots cannot absorb it.
4. Raise: lime (ground limestone). Lower: elemental sulfur.
5. Air nitrogen is N_2 , held by a very strong triple bond that plants cannot break. They need nitrogen as ammonium or nitrate.
6. In root nodules on legumes. The plant gives the bacteria sugar; the bacteria give the plant fixed nitrogen (ammonia).
7. Dead leaves → ammonium → nitrate → plant protein.
8. Bacteria (decompose simple materials), fungi (decompose tough materials, mycorrhizae), protozoa and nematodes (eat bacteria and fungi, release nitrogen), arthropods (shred litter, eat fungi, hunt), earthworms (mix soil, make castings and tunnels).
9. The fungi give water and nutrients, especially phosphorus; the plant gives sugar.
10. $2 \div 0.20 = 10$ pounds per 1,000 square feet.
11. Use a clean plastic bucket and trowel or probe. Take 10 to 15 cores about 6 inches deep in a zigzag across the whole garden, avoiding unusual spots. Mix them well, remove stones and roots, air-dry about two cups, label it, and test it or send it to a lab.
12. Extra fertilizer wastes money, can burn roots with salts and cause leafy growth with little fruit, and the excess nitrogen and phosphorus wash into streams and lakes, feeding algae blooms that harm fish. Testing and applying only what is needed cares for the plants, the soil and the water.

PORTFOLIO PIECE: A SOIL REPORT CARD

Create a two-page soil report for one garden bed, lawn or large planter. Include a map with sampling points, your pH results from the cabbage indicator and the kit, your nutrient test results, a list of the soil animals you found in the Berlese funnel, a drawing of the nitrogen cycle as it works in this bed, and a calculated amendment plan with amounts. End with a one-paragraph “grade” for the soil and what you would do over the next year to raise it.

LOOK FOR	WHAT IT MEANS
Good data	The sample was taken correctly and the pH and nutrient results are recorded clearly.
Soil life	Soil animals are identified and counted, and the report explains their role.
Science explained	The nitrogen cycle drawing is accurate and tied to this particular bed (legumes, compost, drainage).
Calculations	Amendment amounts are calculated correctly from the N-P-K numbers and the area.
Wise plan	The one-year plan is realistic and uses organic matter, testing and moderate fertilizing.

3.1 SOIL pH AND NUTRIENT AVAILABILITY

OBJECTIVES

- Explain the pH scale and why each step is ten times more acidic or basic than the next.
- Describe how soil pH locks up or releases nutrients such as phosphorus and iron.
- Test the pH of several soils with a homemade indicator and a soil test kit.

Warm-up. Taste is not a good test for soil, but it works for foods. List five foods that taste sour (acidic) and two things that feel slippery or taste bitter (basic), like baking soda water. Where do you think garden soil falls?

WATCH

Understanding Soil pH

OklahomaGardening · 9:46

<https://www.youtube.com/watch?v=7Z15h189LCc>

WHEN TO WATCH

After the first two core ideas. An extension soil specialist walks along a giant pH scale chalked on a garden path; pause and name a food at each number she stops on.

BACKUP VIDEO

DIY Soil pH Test - Garden Quickie Episode 114

The Ripe Tomato Farms · 3:47

<https://www.youtube.com/watch?v=OvWB86nglds>

Before step 1 of the project; it shows the quick vinegar and baking soda test.

KEY TERMS

pH

A number from 0 to 14 that measures how acidic or basic a substance is; 7 is neutral, lower is acidic, higher is basic (alkaline).

acidic soil

Soil with a pH below 7, common in rainy regions such as the eastern United States.

alkaline soil

Soil with a pH above 7, common in dry regions and in soils formed from limestone.

nutrient availability

Whether a nutrient in the soil is in a form plant roots can actually absorb.

chlorosis

Yellowing of leaves from lack of chlorophyll, often caused by too little nitrogen, iron or magnesium.

lime

Ground limestone (calcium carbonate) added to soil to raise its pH.

CORE IDEAS

The **pH** scale runs from 0 to 14. Pure water is 7, neutral. Lemon juice is about 2; baking soda dissolved in water is about 8. The scale is logarithmic: each whole number is ten times stronger than the next. Soil with a pH of 5 is ten times more acidic than soil at 6 and a hundred times more acidic than soil at 7.

Most vegetables and flowers grow best in slightly acidic soil, about pH 6.0 to 7.0, with 6.5 a good target. Some plants prefer more acid: blueberries and azaleas thrive at 4.5 to 5.5, and potatoes are often grown near 5.5 because the bacteria that cause potato scab dislike acid soil. In rainy places, rain slowly washes calcium and magnesium out of the soil and leaves it **acidic**. In dry places, and where soil formed from limestone, it is often **alkaline**.

Why does pH matter so much? Because it controls **nutrient availability**. A nutrient can be present in the soil and still be locked up in a chemical form the roots cannot absorb. In strongly acidic soil, phosphorus binds tightly with iron and aluminum, and too much dissolved aluminum can poison roots; calcium and magnesium run short. In alkaline soil, iron, manganese and zinc become insoluble, and plants show iron **chlorosis**: yellow new leaves with green veins. Most nutrients are easiest to reach between about 6 and 7, which is why that range suits most crops.

A dramatic example grows in many yards. Bigleaf hydrangeas bloom blue in acidic soil, where aluminum is available, and pink in alkaline soil, where it is locked up. The plant is showing you the soil chemistry.

To raise pH, gardeners add **lime**, finely ground limestone (dolomitic lime adds magnesium too). To lower pH, they add elemental sulfur, which soil bacteria slowly turn into acid. Both work over months, not days, and both should be measured

from a soil test, never guessed. Changing pH too far in either direction causes new problems.

PICTURE STUDY



The Large Piece of Turf, Albrecht Dürer, 1503 · Watercolor and gouache on paper · Albertina, Vienna
Image: [Wikimedia Commons](#), public domain

Dürer knelt down and painted a single clod of wild field plants exactly as he saw it, more than five hundred years ago. Botanists can still name nearly every plant. Many of them are common lawn and garden weeds, and weeds can tell a gardener a good deal about the soil.

Look closely

- Find the dandelion leaves and flower stalks. Dandelions thrive in many soils but especially in heavy, compacted ground.
- Find the broad, ribbed leaves of plantain, a weed of trampled, compacted soil.
- Look at the bottom of the picture. Can you see the dark soil and the roots?
- Count how many different kinds of plants you can find.

Talk about it

1. Why might a gardener study the weeds in a plot before testing the soil?
2. What does the dark, damp soil at the bottom suggest about this spot?
3. Why do you think Dürer chose such an ordinary subject to paint so carefully?

Safety first. An adult boils the cabbage for the indicator. Wear goggles when mixing vinegar or baking soda with soil, wash hands after handling soil, and do not taste any test solutions.

Testing Soil pH Three Ways

You will make a natural pH indicator from red cabbage, test several soils with it and with a soil test kit, and compare the results.

You will need

- Soil samples from three places (garden bed, lawn, under a pine or oak tree, or bagged potting mix), about ½ cup each
- Half a red cabbage, a pot and a strainer (adult uses the stove)
- White vinegar and baking soda
- Distilled water
- Clear cups or jars, labeled
- A home soil pH test kit or pH strips
- Safety goggles

Steps

1. Indicator: an adult chops half a red cabbage, simmers it in 4 cups of water for 15 minutes, and strains the purple liquid into a jar. Let it cool.
2. Calibrate: pour a little indicator into three cups. Add a spoonful of vinegar to one, nothing to the second, and a pinch of baking soda to the third. Record the colors for acid (pink-red), neutral (purple) and basic (blue-green).
3. Quick test: put 2 spoonfuls of each soil in two cups. Add vinegar to one cup; fizzing means the soil is alkaline (it contains lime). Add water and a pinch of baking soda to the other; fizzing means the soil is acidic.
4. Indicator test: mix 2 spoonfuls of each soil with ½ cup distilled water, stir, let settle 20 minutes, and pour the clear water into a cup of indicator. Compare to your calibration colors.
5. Kit test: follow the kit directions exactly for each soil and read the pH number.
6. Make a table: Soil source, Vinegar fizz?, Baking-soda fizz?, Cabbage color, Kit pH.

7. Decide which soil would suit tomatoes (6.2–6.8), which would suit blueberries (4.5–5.5), and which would need lime or sulfur.

Tips

- Use distilled water, because tap water may not be neutral.
- Soil from under pines is often more acidic, and soil near concrete foundations is often more alkaline. See whether yours agrees.

Check your work

- ☐ I calibrated my cabbage indicator with an acid, a base and a neutral sample.
- ☐ I tested three soils three ways and recorded the results in a table.
- ☐ I can explain why a plant in alkaline soil might have yellow new leaves even though iron is in the soil.

NATURE JOURNAL

1. Draw a pH scale from 0 to 14 and place lemon juice, vinegar, coffee, rain, pure water, garden soil, baking soda and household ammonia on it. Shade the range most vegetables like.
2. Draw a bar chart showing how available phosphorus and iron are at pH 5, 6.5 and 8, using the core ideas.
3. Sketch one weed from your yard in detail and note the soil where it was growing (dry, wet, compacted, sandy).

From history. The pH scale was invented in 1909 by the Danish chemist Søren Sørensen while he worked at the Carlsberg Laboratory in Copenhagen. Long before that, farmers spread chalk and marl on sour fields; the Romans wrote about it, and English farmers practiced “marling” for centuries without knowing the chemistry behind it.

COMMON MISTAKES

- Thinking pH 5 is only a little more acidic than pH 6. It is ten times more acidic.
- Adding lime “just in case.” Without a test, you may push an already alkaline soil higher and lock up iron.
- Expecting lime or sulfur to work in a week. pH changes slowly over months.

Make it a game • Ten Times Ladder. Make a pH ladder on paper from 0 to 14. Parent names a substance and you place a button on its rung. Then answer the 'ten times' challenge: how much more acidic is pH 4 than pH 6? Finish with nutrient availability: which nutrients lock up at the wrong pH, and what lime does. Beat your own streak.

3.2 THE NITROGEN CYCLE

OBJECTIVES

- Explain why plants cannot use the nitrogen gas that makes up most of the air.
- Trace nitrogen through fixation, ammonification, nitrification, plant uptake and denitrification.
- Find and examine nitrogen-fixing nodules on the roots of a legume.

Warm-up. Air is about 78 percent nitrogen, yet gardeners buy nitrogen fertilizer. Write a one-sentence guess explaining how both can be true.

WATCH

The Nitrogen Cycle!

BioMan Biology · 5:54

<https://www.youtube.com/watch?v=uip4Q6t7yfQ>

WHEN TO WATCH

After the core ideas. Pause each time a new kind of bacteria appears and label it on your cycle diagram.

BACKUP VIDEO

Legumes: Biological Nitrogen Fixation

UMDHGIC · 4:10

<https://www.youtube.com/watch?v=X1W6PbiCeFg>

Before the project. A University of Maryland Extension educator pulls up soybean roots in the field and shows the nodules.

KEY TERMS

nitrogen fixation

Changing nitrogen gas (N₂) from the air into ammonia or ammonium, a form living things can use; done mainly by certain bacteria.

legume

A plant of the pea family (peas, beans, clover, alfalfa, soybeans) that partners with nitrogen-fixing bacteria in its roots.

root nodule

A small swelling on a legume root where *Rhizobium* bacteria live and fix nitrogen.

nitrification

The two-step change of ammonium into nitrite and then nitrate by soil bacteria.

denitrification

The change of nitrate back into nitrogen gas by bacteria in waterlogged, airless soil.

leaching

The washing of dissolved nutrients, especially nitrate, down through the soil and out of reach of roots.

CORE IDEAS

Every protein in your body and every molecule of chlorophyll in a leaf contains nitrogen. The air is full of it: about 78 percent of every breath. But air nitrogen is N_2 , two atoms locked together by a triple bond, one of the strongest bonds in nature. Neither plants nor animals can break it. Plants need nitrogen in the form of ammonium (NH_4^+) or nitrate (NO_3^-), and getting it into those forms is the work of the **nitrogen cycle**.

Fixation. A few kinds of bacteria can break the triple bond. The most important for farmers are *Rhizobium* bacteria, which live in **root nodules** on **legumes**. The plant feeds the bacteria sugar; the bacteria feed the plant ammonia. A healthy nodule is pink or red inside. A good stand of clover or alfalfa can add well over a hundred pounds of nitrogen to an acre in a season. Lightning fixes a little nitrogen too, and since the early 1900s factories have fixed it to make fertilizer.

Ammonification and nitrification. When plants, animals and manure decay, decomposer bacteria and fungi release their nitrogen as ammonium. Then two groups of **nitrifying** bacteria go to work: one turns ammonium into nitrite, and another turns nitrite into nitrate. Plant roots take up both ammonium and nitrate, build them into proteins, and animals get their nitrogen by eating plants.

Losses. Nitrate dissolves easily, so heavy rain can wash it below the roots (**leaching**) and into streams. In soggy, airless soil, **denitrifying** bacteria turn nitrate back into nitrogen gas, which floats away into the air, completing the cycle. That is one reason waterlogged plants turn yellow.

Farmers have used this cycle for thousands of years, long before anyone knew about bacteria. Rotating corn, which needs a lot of nitrogen, with soybeans or clover,

which add it, keeps fields fertile. Spreading well-rotted manure returns nitrogen to the soil. In Jesus' parable the gardener asks for one more year to "dig about it, and dung it" (Luke 13:8): good soil care has always been part of patient faithfulness.

PICTURE STUDY



Red Clover (Trifolium pratense), Jacob Sturm, published 1796–1862 · Hand-colored engraving from *Deutschlands Flora in Abbildungen* · Jacob Sturm, *Deutschlands Flora in Abbildungen*

Image: [Wikimedia Commons](#), public domain

Jacob Sturm engraved hundreds of exact plates of German wild plants. Red clover, a legume, has been sown by farmers for centuries to feed livestock and to enrich tired fields, because of the bacteria in its roots.

Look closely

- Find the leaves. How many leaflets does each have?
- Find the round flower head and the small drawings of single flowers beside it.
- Look for the root, if it is shown. Where would the nodules be?
- Look at the shape of each tiny flower. Does it remind you of a pea flower?

Talk about it

1. Why would a farmer plant clover in a field before planting corn?
2. Clover also feeds bees and cattle. What other gifts does this one plant give a farm?
3. Why do you think botanists drew magnified parts of the flower beside the plant?

Safety first. Wash hands after digging and handling roots and soil. Ask permission before digging in a lawn or garden.

HANDS-ON PROJECT

Hunting for Root Nodules

You will dig up legume roots, find the nodules, and check whether they are actively fixing nitrogen. If the ground is frozen, grow your own pea plants indoors.

You will need

- A trowel
- A bucket of water
- A hand lens and a paper plate
- A clean craft knife or paring knife (with an adult)
- Indoor option: 10 dried peas or bean seeds, a pot of garden soil (not sterile potting mix), and a sunny window

Steps

1. Outdoor option: find white clover in a lawn, or bean, pea or soybean plants at the end of the season. Dig widely around one plant, at least 4 inches out and 6 inches deep, so you lift the whole root ball.
2. Indoor option: soak the peas overnight and plant them 1 inch deep in a pot of real garden soil, which contains wild *Rhizobium*. Water and grow them in a sunny window for 4 to 5 weeks, then tip out one plant.
3. Swish the roots gently in the bucket of water until the soil falls away.
4. Lay the roots on a paper plate. Look for small round or oval bumps attached to the side of the roots. Count them.
5. With an adult, slice one large nodule in half. Pink or red inside means it is actively fixing nitrogen; white means it is young; green or brown means it is old or not working.
6. Compare with the roots of a non-legume dug from the same area, such as a grass plant or dandelion. Are there any nodules?
7. Record the plant, date, nodule count, nodule color and your comparison in your journal.

Tips

- Pulling a plant straight up strips off the nodules. Dig, don't pull.
- Do not confuse nodules with the hard knots made by root-knot nematodes. Nodules rub off the side of the root easily; nematode galls are swellings of the root itself.

Check your work

- ☐ I found and counted nodules on a legume root.
- ☐ I cut a nodule and recorded its color and what that color means.
- ☐ I can explain how the plant and the bacteria help each other.

NATURE JOURNAL

1. Draw a large labeled diagram of the nitrogen cycle with arrows: air N_2 , fixation (bacteria in nodules and lightning), plants, animals, decay to ammonium, nitrifying bacteria, nitrate, leaching and denitrification.
2. Draw a legume root with nodules, life size, and a magnified cross-section of one nodule.
3. Write a paragraph from the point of view of one nitrogen atom traveling from the air to a bean, into a rabbit, and back to the soil.

From history. In 1886 two German scientists, Hermann Hellriegel and Hermann Wilfarth, proved that peas grown in sterile sand could not fix nitrogen, but peas grown with a little field soil could. Something in the soil was doing the work. Two years later the Dutch microbiologist Martinus Beijerinck isolated the root-nodule bacteria.

COMMON MISTAKES

- Thinking plants take nitrogen straight from the air. Only bacteria (and lightning and factories) can fix N_2 .
- Pulling legumes up and leaving the nodules behind in the soil, then concluding there were none.
- Assuming all nitrogen put on a field stays there. Nitrate leaches easily in heavy rain and can pollute streams.

Make it a game • Nitrogen Cycle Dance. Choreograph the nitrogen cycle as a dance with a step for each stage: fixation, ammonification, nitrification, plant uptake and denitrification. Perform it for your parent, who guesses each step by name. Include the legume and root nodule step and one leaching splash. Then add the surprise: explain why plants cannot use nitrogen gas straight from the air.

Scripture. “And he answering said unto him, Lord, let it alone this year also, till I shall dig about it, and dung it:” (Luke 13:8, KJV)

The patient gardener in Jesus’ parable feeds the soil around a struggling tree.
Returning manure and plant matter to the earth feeds the nitrogen cycle
God designed.

3.3 THE SOIL FOOD WEB

OBJECTIVES

- Name the main groups of soil organisms and the job each does.
- Explain how mycorrhizal fungi and plant roots trade with one another.
- Collect and identify small soil animals with a Berlese funnel.

Warm-up. Pick up a handful of moist leaf litter or garden soil and look at it with a hand lens for three minutes. List every living thing you can see, and anything that might once have been alive.

WATCH

Family Activity: Berlese Funnel

United States Botanic Garden · 2:53

<https://www.youtube.com/watch?v=-mKin7b8ymc>

WHEN TO WATCH

After the core ideas, before the project. A Botanic Garden educator builds a Berlese funnel from a bottle and leaf litter; note each step so you can build your own.

BACKUP VIDEO

Bacteria, Fungi, Protozoa and Nematodes from soil

Soil Foodweb Institute · 2:47

<https://www.youtube.com/watch?v=RY-JY-D4v7I>

After the core idea about grazers. Real microscope footage of soil bacteria, fungal threads and protozoa; try to name each as it appears.

KEY TERMS

soil food web

The community of organisms living in soil and the feeding relationships that link them, from bacteria to earthworms.

decomposer

An organism, mainly bacteria and fungi, that breaks down dead plants and animals into simpler substances.

hyphae

The thin, thread-like strands that make up the body of a fungus.

mycorrhizae

Partnerships between fungi and plant roots in which the fungus supplies water and nutrients, especially phosphorus, and the plant supplies sugar.

protozoa and nematodes

Single-celled organisms and tiny roundworms that eat bacteria and fungi and release extra nutrients near plant roots.

arthropods

Small jointed-leg animals of the soil such as mites, springtails, beetles and centipedes.

CORE IDEAS

A single teaspoon of healthy garden soil may contain hundreds of millions of bacteria, many yards of fungal threads, thousands of protozoa, dozens of nematodes, and a few mites and springtails. Together with the earthworms and insects, they make up the **soil food web**. Like a food web above ground, it starts with energy captured by plants.

Plants feed the web in two ways. Dead leaves, roots and stems fall to the soil as food for **decomposers**. Living roots also leak sugars and other substances into the soil around them, feeding a crowd of bacteria and fungi right at the root surface. Bacteria are the great chemists of the soil, digesting simple materials quickly. Fungi, spreading in long **hyphae**, can break down tough materials like wood and straw.

The next level is made of grazers. **Protozoa** and many **nematodes** eat bacteria and fungi. Because bacteria contain more nitrogen than these grazers need, the extra is released as ammonium, right beside the roots where plants can use it. Mites, springtails and other **arthropods** shred dead leaves and eat fungi; centipedes, spiders and ground beetles hunt them. Earthworms swallow soil and organic matter and leave behind rich castings and tunnels for air and water.

One of the most remarkable partnerships is **mycorrhizae**, from Greek words meaning “fungus-root.” Most kinds of land plants, including tomatoes, corn, beans and fruit trees, partner with fungi whose hyphae reach far beyond the roots. The fungus delivers water and hard-to-reach nutrients, especially phosphorus, and the

plant pays it in sugar. (Cabbage-family plants and beets are notable exceptions.) Fungal threads and the sticky substances of microbes also glue soil particles into crumbs, giving good soil its spongy structure.

Gardeners can feed this web or starve it. Compost, mulch, cover crops and living roots feed it. Bare soil, heavy tilling (which shreds fungal threads), compaction and overuse of chemicals harm it. When we care for the unseen creatures of the soil, they care for our plants: one more sign of the wisdom with which God made the world.

PICTURE STUDY



Ascomycetes (from *Art Forms in Nature*), Ernst Haeckel, 1904 · Color lithograph · *Kunstformen der Natur*
(Art Forms in Nature)

Image: [Wikimedia Commons](#), public domain

Ernst Haeckel was a German zoologist and illustrator who drew living things in beautiful, symmetrical arrangements. This plate shows sac fungi magnified many times under a microscope: their threads, their tiny round spore cases, and the sacs that hold their spores. Some of these relatives live as decomposers in soil and leaf litter; others, like the powdery mildews, live on plants. To the unaided eye, all of them would be no more than a fuzz or a speck.

Look closely

- Find the long, tangled threads. These are hyphae, the main body of a fungus.
- Find the round spore cases with branching or hooked arms around them. What might the arms be for?
- Find the large cut-open shape at the bottom center. Look for the long sacs inside; each holds spores.
- Find the strings of tiny beads at the upper left. These are chains of spores ready to blow away.

Talk about it

1. If a teaspoon of soil holds many yards of hyphae, why don't we usually see them?

2. How do you think spores travel from one place to another?
3. Why do you think Haeckel arranged these tiny living things like a decorative design?

Safety first. Never eat any mushroom you find. An adult sets up the lamp and keeps it from touching paper or plastic. Wash hands after handling soil and leaf litter.

HANDS-ON PROJECT

A Berlese Funnel Soil Safari

Scientists use a Berlese funnel to drive tiny animals out of soil and leaf litter with gentle heat and light. You will build one, catch the animals alive, identify them and return them.

You will need

- A 2-liter plastic bottle
- Window screen or hardware cloth, about 4 inches square
- A desk lamp with an LED or incandescent bulb
- A clear jar with a damp paper towel in the bottom
- Two cups of moist leaf litter or the top inch of garden soil
- A hand lens or microscope and a white plate
- Scissors (adult help)

Steps

1. With an adult, cut the bottle about one-third of the way down. Turn the top part upside down to make a funnel.
2. Place the screen inside the funnel, near the neck, to hold the litter.
3. Set the funnel in the jar so the neck sits above the damp paper towel.
4. Fill the funnel loosely with leaf litter or soil.
5. Position the lamp 4 to 6 inches above the litter and leave it on for 3 to 4 hours (an adult checks that nothing gets hot). The animals move down, away from the heat and drying, and drop into the jar.
6. Tip the animals gently onto a white plate. Examine them with a hand lens.
7. Sort them: springtails (tiny, jump), mites (round, eight legs), pill bugs, centipedes (one pair of legs per segment), millipedes (two pairs per segment), beetle larvae, worms.
8. Count each kind and record a table. Then return the animals and the litter to where you found them.

Tips

- Leaf litter from under trees in late fall often has the most animals.
- Compare litter from two places, such as under trees and a bare garden bed. Which has more life?

Check your work

- ☐ I built a working Berlese funnel and collected live soil animals.
- ☐ I sorted and counted at least four kinds of soil animals.
- ☐ I can explain how bacteria, fungi, grazers and mycorrhizae help plants.

NATURE JOURNAL

1. Draw a soil food web diagram with arrows from plants and dead leaves to bacteria and fungi, then to protozoa and nematodes, mites and springtails, and up to centipedes, beetles and birds.
2. Draw three of your soil animals as large as possible from the hand lens view. Count the legs and label body parts.
3. Draw a plant root with mycorrhizal hyphae reaching out into the soil. Use arrows to show sugar going one way and water and phosphorus the other.

From history. In the 1880s Charles Darwin published a book on earthworms after decades of measuring how much soil they move, and he concluded that few animals have played so important a part in the world's history. Antonio Berlese, an Italian entomologist, invented his funnel in 1905; Albert Tullgren of Sweden added the lamp in 1918.

COMMON MISTAKES

- Thinking of soil as lifeless dirt. Healthy soil is full of living things.
- Believing all fungi are harmful. Most soil fungi are decomposers or helpful partners of plants.
- Leaving the lamp on too long or too close, which kills the animals instead of driving them down.

Make it a game • Soil Neighbors Memory Match. Make eight memory cards: four soil organisms, such as bacteria, fungi, protozoa and arthropods, and four jobs. Lay them face down and match pairs by flipping two at a time. Say the full job aloud before keeping a pair. Then explain the mycorrhizal trade between hyphae and roots. Fewest flips wins; beat your own record.

3.4 SOIL TESTING AND AMENDMENTS

OBJECTIVES

- Collect a proper soil sample for laboratory testing.
- Read the main parts of a soil test report: pH, phosphorus, potassium, organic matter and recommendations.
- Read a fertilizer label and calculate how much product supplies a needed amount of nitrogen.

Warm-up. Find a bag of fertilizer, plant food or potting mix in your home or a store and copy the three numbers on the front (such as 10-10-10). Write a guess for what each number means.

WATCH

How to Take a Soil Sample From your Lawn or Garden

UMN Extension - Yard and Garden • 5:30

<https://www.youtube.com/watch?v=BeK4Eg9Dzr8>

WHEN TO WATCH

Before you collect your sample. Write down how deep, how many cores and what kind of bucket to use.

BACKUP VIDEO

How to Interpret Your Soil Test Results

UMN Extension - Yard and Garden • 7:03

<https://www.youtube.com/watch?v=HYrkcfE62Pg>

After the core ideas, before you read the sample report in the project.

KEY TERMS

soil sample

A mixture of many small cores of soil from one area, used to represent the whole area in a test.

N-P-K

The three numbers on a fertilizer label: the percent by weight of nitrogen (N), phosphate (P_2O_5) and potash (K_2O).

organic matter

The decayed remains of plants, animals and microbes in soil; it holds water and nutrients and feeds soil life.

amendment

Anything added to soil to improve it, such as compost, lime, sulfur, gypsum or manure.

cation exchange capacity (CEC)

A measure of how many positively charged nutrients (calcium, magnesium, potassium) a soil can hold; clay and organic matter raise it.

CORE IDEAS

A soil test replaces guessing with knowledge. County extension offices send samples to university laboratories for a small fee, and the report tells you the pH, the levels of phosphorus, potassium, calcium and magnesium, the organic matter, and exactly how much lime and fertilizer to add. Nitrogen is often not tested, because it changes from week to week with rain and temperature; labs base nitrogen advice on the crop you plan to grow.

A test is only as good as the sample. Use a clean plastic bucket (galvanized metal adds zinc) and a trowel or soil probe. Take 10 to 15 small cores from all over one area, about 6 inches deep for a vegetable garden, skipping odd spots like an old burn pile. Mix the cores well, let the soil air-dry, and send about two cups. Sample the vegetable garden, the lawn and the flower beds separately, because each has its own history.

Every fertilizer bag carries three numbers, **N-P-K**: the percent by weight of nitrogen, phosphate and potash. A 50-pound bag of 10-10-10 holds 5 pounds each of N, phosphate and potash; the rest is filler that helps spread it evenly. To figure how much product to use, divide the pounds of nutrient you need by the percent. If a test calls for 1 pound of nitrogen per 1,000 square feet and you have 10-10-10, you need $1 \div 0.10 = 10$ pounds of fertilizer for that area.

Amendments improve soil in other ways. Compost and well-rotted manure add **organic matter**, which helps sandy soil hold water and helps clay soil drain, and they feed the soil food web. Lime raises pH and adds calcium; sulfur lowers pH; gypsum

adds calcium without changing pH. Bone meal is a slow source of phosphorus, and blood meal and feather meal supply nitrogen.

More is not better. Too much fertilizer can burn roots with salts, make plants all leaves and no fruit, and wash into streams, where extra phosphorus and nitrogen feed huge blooms of algae that choke out fish. Testing first and applying only what the soil needs is both good farming and good stewardship of the creation God entrusted to us.

PICTURE STUDY



Man with a Hoe, Jean-François Millet, 1860–62 · Oil on canvas · J. Paul Getty Museum, Los Angeles

Image: [Wikimedia Commons](#), public domain

Millet grew up on a farm in Normandy and painted the hard labor of French peasants. This man has been breaking up stony, thistle-covered ground by hand. His field is the opposite of the rich, crumbly soil a gardener hopes for.

Look closely

- Look at the ground at the man's feet. What do you see: stones, thistles, bare earth?
- Find the thistles. What do weeds like these tell you about how the field has been cared for?
- Look into the distance. Is the land there plowed or rough?
- Look at the man's hands and posture. How long do you think he has been working?

Talk about it

1. If you were given this field, what would you test first, and what amendments might it need?
2. How could compost, cover crops and patient work change this field over several years?

3. Why might Millet have chosen to paint such a tired worker instead of a cheerful one?

Safety first. Wear gloves when handling fertilizers, manure and soil amendments, read every label with an adult, and wash hands afterward. Store fertilizers out of reach of small children and pets.

Test Your Soil and Plan the Amendments

You will take a real soil sample, test it (with a home kit, or by mailing it to a lab), and turn the results into a written plan with calculated amounts.

You will need

- A clean plastic bucket and a trowel or soil probe
- A ruler
- Newspaper for drying soil
- A zip-top bag and a permanent marker
- A home N-P-K and pH test kit, or a soil test kit from your county extension office
- A fertilizer label to read (on a bag or from a website)
- Garden gloves

Steps

1. Choose one area to test: a garden bed, a lawn, or a large planter. Sketch it in your journal.
2. Walk a zigzag across the area. At 10 to 15 spots, push the trowel 6 inches deep, take a thin slice from the side of the hole, and drop it in the bucket.
3. Mix the soil well. Remove stones, roots and worms (return the worms to the garden).
4. Spread about 2 cups on newspaper to air-dry for two days. Label a bag with the date and location.
5. Test the dried soil with your kit, following every direction exactly, or mail it to your extension lab and wait for the report.
6. Record the results: pH, nitrogen, phosphorus and potassium (as low, medium or high, or as numbers).
7. Measure your area in feet and calculate its square footage.
8. Write an amendment plan: what to add (compost, lime, sulfur, a fertilizer), why, and how much. Use the N-P-K rule to calculate pounds of product needed for your area.

9. Show your plan to an adult before anything is applied.

Tips

- Fall is an excellent time to test, because lime and compost have all winter to work.
- If your county offers a free or low-cost lab test, use it; it is far more accurate than a home kit.
- Many states hold 4-H and FFA land and soil judging contests, where students judge soil texture, depth, slope and drainage in a pit. Ask your county extension office or conservation district.

Check your work

- ☐ I took a sample of 10 to 15 cores from one area with a clean plastic bucket.
- ☐ I recorded the pH and nutrient results and what each means.
- ☐ I calculated the amount of fertilizer or amendment for my area correctly.

NATURE JOURNAL

1. Draw a sample fertilizer bag front and label each number of N-P-K with what it stands for and what it does for plants (N: leaves; P: roots, flowers and fruit; K: overall strength and disease resistance).
2. Draw a map of your sampling zigzag with dots for each core.
3. Make a two-column chart: “Amendment” and “What it does,” with at least six amendments.

From history. In the 1840s the German chemist Justus von Liebig showed that plants take up mineral nutrients from the soil and that a crop’s growth is held back by whichever nutrient is scarcest, an idea called the law of the minimum. Soon afterward, Sir John Lawes began the Broadbalk wheat experiment at Rothamsted in England in 1843, testing fertilizers on the same field year after year; it is still running today.

COMMON MISTAKES

- Taking one scoop from one spot. A good sample mixes many cores.
- Using a metal bucket, which can add zinc and spoil the test.
- Reading 10-10-10 as 10 pounds of each nutrient. The numbers are percentages of the bag’s weight.

- Fertilizing heavily “to be safe,” which wastes money and can harm plants and streams.

Make it a game · Soil Report Reader. Write a pretend soil test report on a sheet: pH, phosphorus, potassium, organic matter and recommendations. Parent invents the numbers. You read them aloud, say what is low or high, and prescribe the amendment, like lime or compost. Then describe the proper way to collect the sample. Three correct prescriptions earn a paper prescription pad.

UNIT 3

SOIL CHEMISTRY AND BIOLOGY

Soil is not dirt. It is a mixture of minerals, water, air, organic matter and an astonishing crowd of living things, and its chemistry decides whether the nutrients in it can actually reach a plant's roots. In earlier years you learned soil types and compost. This year you will look deeper, at the chemistry of pH, at the great nitrogen cycle that links the air to every leaf, and at the food web of bacteria, fungi and tiny animals that keeps soil alive.

The unit ends with a real soil test, the same kind farmers send to a laboratory, and with the arithmetic of choosing amendments and fertilizer wisely. God formed the first man from the dust of the ground and set him in a garden “to dress it and to keep it” (Genesis 2:15). Caring for soil is one of the oldest jobs there is.

PREREQUISITES

- Knows the soil textures sand, silt, clay and loam
- Knows that compost is made of decayed plant material
- Can calculate a percentage

MASTERY CHECKLIST

- ☐ I can explain the pH scale and how soil pH affects which nutrients plants can absorb.
- ☐ I can trace nitrogen through fixation, ammonification, nitrification, plant uptake and denitrification.
- ☐ I can describe the main members of the soil food web and what each one does.
- ☐ I can take a proper soil sample, read a soil test, and calculate how much fertilizer or amendment to apply.

LESSONS IN THIS UNIT

3.1 Soil pH and Nutrient Availability

2 sessions of 50 minutes

3.2 The Nitrogen Cycle

2 sessions of 50 minutes

3.3 The Soil Food Web

2 sessions of 50 minutes

UNIT 3 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. 7 pts

Soil A has a pH of 5 and soil B has a pH of 7. How many times more acidic is soil A?

2. 7 pts

What pH range suits most vegetables? Name one plant that prefers more acidic soil.

3. 8 pts

A plant in alkaline soil has yellow new leaves with green veins. What is the likely problem and why?

4. 7 pts

What would you add to raise soil pH? To lower it?

5. 8 pts

Why can't plants use the nitrogen in the air?

6. 8 pts

Where do Rhizobium bacteria live, and what does each partner give the other?

7. 7 pts

Put these in order: nitrate, ammonium, dead leaves, plant protein.

8. 8 pts

Name four groups of organisms in the soil food web and one job of each.

9. 7 pts

What do mycorrhizal fungi give a plant, and what does the plant give them?

10. **8 pts**

A soil test calls for 2 pounds of nitrogen per 1,000 square feet. How many pounds of 20-5-5 fertilizer is that?

11. **12 pts**

Describe how to take a good soil sample from a vegetable garden.

12. **13 pts**

Explain why adding extra fertilizer “just to be safe” is poor stewardship.

ANSWER KEY

1. 100 times (each whole number on the pH scale is ten times).
2. About 6.0 to 7.0 (6.5 is a good target). Blueberries or azaleas (potatoes also accepted).
3. Iron chlorosis. Iron is in the soil but becomes insoluble (locked up) at high pH, so the roots cannot absorb it.
4. Raise: lime (ground limestone). Lower: elemental sulfur.
5. Air nitrogen is N_2 , held by a very strong triple bond that plants cannot break. They need nitrogen as ammonium or nitrate.
6. In root nodules on legumes. The plant gives the bacteria sugar; the bacteria give the plant fixed nitrogen (ammonia).
7. Dead leaves $\rightarrow$ ammonium $\rightarrow$ nitrate $\rightarrow$ plant protein.
8. Bacteria (decompose simple materials), fungi (decompose tough materials, mycorrhizae), protozoa and nematodes (eat bacteria and fungi, release nitrogen), arthropods (shred litter, eat fungi, hunt), earthworms (mix soil, make castings and tunnels).
9. The fungi give water and nutrients, especially phosphorus; the plant gives sugar.
10. $2 \div 0.20 = 10$ pounds per 1,000 square feet.
11. Use a clean plastic bucket and trowel or probe. Take 10 to 15 cores about 6 inches deep in a zigzag across the whole garden, avoiding unusual spots. Mix them well, remove stones and roots, air-dry about two cups, label it, and test it or send it to a lab.
12. Extra fertilizer wastes money, can burn roots with salts and cause leafy growth with little fruit, and the excess nitrogen and phosphorus wash into streams and lakes, feeding algae blooms that harm fish. Testing and applying only what is needed cares for the plants, the soil and the water.

PORTFOLIO PIECE: A SOIL REPORT CARD

Create a two-page soil report for one garden bed, lawn or large planter. Include a map with sampling points, your pH results from the cabbage indicator and the kit, your nutrient test results, a list of the soil animals you found in the Berlese funnel, a drawing of the nitrogen cycle as it works in this bed, and a calculated amendment plan with amounts. End with a one-paragraph “grade” for the soil and what you would do over the next year to raise it.

LOOK FOR	WHAT IT MEANS
Good data	The sample was taken correctly and the pH and nutrient results are recorded clearly.
Soil life	Soil animals are identified and counted, and the report explains their role.
Science explained	The nitrogen cycle drawing is accurate and tied to this particular bed (legumes, compost, drainage).
Calculations	Amendment amounts are calculated correctly from the N-P-K numbers and the area.
Wise plan	The one-year plan is realistic and uses organic matter, testing and moderate fertilizing.

UNIT 4

PETS: STEWARDSHIP AND CARE

In early winter, when the garden rests, we turn to the animals who share our homes. A pet is not a toy or a decoration; it is a living creature that depends on us for every meal, every clean drink and every visit to the doctor. “A righteous man regardeth the life of his beast” (Proverbs 12:10). This unit is about doing that well.

You will learn how to choose an animal that truly fits a family’s time, space and budget; how to read a pet-food label like a veterinarian; how to give reptiles and amphibians the heat, light and humidity they were designed for; and how to keep a pet healthy, recognize illness early, and protect your own family with good hygiene. No pet is needed: every project works with a neighbor’s animal, a shelter visit, or a careful plan.

PREREQUISITES

- Knows the basic needs of all animals: food, water, shelter, space and care
- Can calculate a percentage and a simple budget
- Has learned to wash hands after handling animals

MASTERY CHECKLIST

- ☐ I can match a pet to a family by comparing lifespan, space, time, cost and care needs.
- ☐ I can read a pet-food label: the nutritional adequacy statement, the guaranteed analysis and the ingredient list.
- ☐ I can describe correct heat, light, humidity and diet for a leopard gecko or bearded dragon, and explain why amphibians need special care.
- ☐ I can perform a simple home health check and name signs that a pet needs a veterinarian.
- ☐ I can explain how to prevent diseases that pass from animals to people.

LESSONS IN THIS UNIT

4.1 Choosing a Pet Wisely

2 sessions of 50 minutes

4.2 Pet Nutrition and Food Labels

2 sessions of 50 minutes

4.3 Reptile and Amphibian Husbandry

2 sessions of 50 minutes

4.4 Pet Health, Hygiene and the Veterinarian

2 sessions of 50 minutes

UNIT 4 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

List four questions a family should answer before getting a pet.

2. (7 pts)

Put these pets in order from shortest to longest typical lifespan: rabbit, hamster, cat, guinea pig.

3. (7 pts)

Why do guinea pigs need vitamin C every day?

4. (8 pts)

What is an obligate carnivore? Name one.

5. (8 pts)

A canned food has 10% protein and 75% moisture. What is its protein on a dry-matter basis?

6. (7 pts)

What does a body condition score of 5 out of 9 mean, and how can you check it?

7. (8 pts)

What is a thermal gradient, and why does a reptile need one?

8. (8 pts)

Why does a bearded dragon need UVB light, and what happens without it?

9. **7 pts**

Why must amphibians be handled with clean, wet, soap-free hands?

10. **8 pts**

Name four signs that a pet should see a veterinarian.

11. **12 pts**

Explain how a family with a pet bearded dragon can keep everyone safe from salmonella.

12. **13 pts**

Explain why rabbits, guinea pigs and birds can become very sick before their owners notice, and what an owner should do about it.

ANSWER KEY

1. Any four: Who will care for it daily? Do we have space? Can we afford food, supplies and a veterinarian? Allergies? Will it fit our family for its whole lifespan? Who cares for it during trips?
2. Hamster, guinea pig, rabbit, cat.
3. Their bodies cannot make vitamin C, so it must come from food every day.
4. An animal that must eat animal tissue to get nutrients it cannot make for itself. A cat.
5. $10 \div (100 - 75) \times 100 = 10 \div 25 \times 100 = 40\%$.
6. Ideal weight. You can feel the ribs easily under a thin layer of fat and see a waist from above.
7. A range from warm to cool in the enclosure. Reptiles are ectotherms and must move between warm and cool spots to control their body temperature.
8. UVB lets it make vitamin D₃ to absorb calcium. Without it, it develops metabolic bone disease.
9. Their thin skin absorbs water and anything dissolved in it, so soap, lotion or salt can harm them.
10. Any four: not eating for more than a day (any time for a rabbit), lasting vomiting or diarrhea, trouble breathing, straining to urinate, swollen belly, limping, unusual tiredness, a bird fluffed up on the cage floor.
11. Wash hands with soap and water after touching the dragon or anything in its enclosure; clean dishes and equipment outside the kitchen, never in the kitchen sink; keep the dragon off kitchen counters and away from faces; and do not let children under five handle it.
12. They are prey species, designed to hide signs of weakness so predators will not single them out. Owners should watch daily for small changes in eating, droppings and behavior, keep records, and call a veterinarian promptly when something changes rather than waiting.

PORTFOLIO PIECE: A RESPONSIBLE PET-CARE PLAN

Choose one pet (one you have, or the one your pet-match chart recommended) and write a complete care plan: a habitat drawing with measurements and temperatures, a feeding plan based on label reading, a daily, weekly and monthly chore chart with names, a first-year budget, a health record page, and a list of warning signs for calling the veterinarian. Present it to your family as if they were deciding whether to adopt.

LOOK FOR	WHAT IT MEANS
Correct husbandry	Housing, temperature, light and diet are accurate for the species.
Chore chart	Daily, weekly and monthly jobs are complete, realistic and assigned to people.
Budget	Setup, food, supplies and veterinary care are included with realistic prices.
Health and hygiene	The plan includes a health record, warning signs, preventive care and hand-washing rules.
Presentation	The plan is neat, organized and explained clearly to the family.

4.1 CHOOSING A PET WISELY

OBJECTIVES

- List the questions a family should answer before bringing home any pet.
- Compare common pets by lifespan, space, daily time, yearly cost and special needs.
- Build a pet-match chart and a first-year budget for three possible pets.

Warm-up. Write down the pet you would most like to have. Then list every job you think it would need each day, each week and each year. Put a star by any job you have never done before.

WATCH

Picking the Right Bird for a Pet

American Veterinary Medical Association • 4:35

<https://www.youtube.com/watch?v=QGNqhddDD48>

WHEN TO WATCH

After the core ideas. As you watch, write down every question the veterinarian says a family should ask; most apply to any pet, not just birds.

BACKUP VIDEO

What's the Real Cost of Owning A Pet?

Two Cents • 5:38

<https://www.youtube.com/watch?v=ma3Mt5BPITE>

Before you make your pet budget in the project.

KEY TERMS

stewardship

Faithful care of something that belongs to someone else; for us, care of the creatures God has entrusted to us.

lifespan

How long an animal usually lives with good care.

husbandry

The practical care of animals: housing, feeding, cleaning and keeping them healthy.

first-year cost

The total cost of a pet's first year: adoption or purchase, housing and supplies, food, and veterinary care.

exotic pet

Any pet other than dogs and cats, such as birds, reptiles, small mammals and fish; many need a veterinarian with special training.

CORE IDEAS

The most important day in a pet's life is the day before it comes home, when the family decides whether they are truly ready. Good questions to ask: Who will feed and clean every day, including on busy days and vacations? Do we have the space? Can we afford food, supplies and a veterinarian, including an emergency? Does anyone have allergies? Will this pet fit our family in ten or fifteen years?

Lifespan surprises many families. With good care, a hamster lives about two to three years, a guinea pig five to seven, a rabbit eight to twelve, a parakeet (budgie) often five to ten or more, a dog ten to fifteen, and a cat fifteen years or more. A leopard gecko can live fifteen to twenty years, and some parrots outlive their owners. A pet chosen at age eleven may still need care when its owner is grown and moving away.

Every animal has its own **husbandry** needs. Dogs need daily exercise, training and companionship. Cats need a clean litter box and things to climb and scratch. Rabbits and guinea pigs are social and need a large pen, unlimited hay and gentle handling; guinea pigs also need vitamin C every day, because their bodies cannot make it. Parakeets need company and a cage wide enough to fly from perch to perch. Reptiles need carefully controlled heat and light. Fish need a cycled tank and weekly water changes.

Costs add up. The purchase or adoption fee is usually the smallest part. The habitat, food, bedding, toys and veterinary visits cost far more over the years, and an **exotic pet** may need a specialist veterinarian. A dog's first year often costs well over a thousand dollars. A good steward counts the cost before beginning, as Jesus said a wise builder sits down first and counts the cost of a tower (Luke 14:28).

Where a pet comes from matters too. Animal shelters and rescue groups have many wonderful animals waiting for homes. If you buy from a breeder or a store, look for clean housing, healthy, alert animals, and people who answer questions honestly. Never take an animal from the wild to keep as a pet, and never release a pet into the wild, where it may starve, spread disease, or harm native animals.

PICTURE STUDY



Dignity and Impudence, Sir Edwin Landseer, 1839 · Oil on canvas · Tate Britain, London

Image: [Wikimedia Commons](#), public domain

Landseer was the most famous animal painter of Victorian England, and Queen Victoria herself collected his pictures. Here a huge bloodhound and a little West Highland terrier share a kennel. The title is a joke about their very different personalities.

Look closely

- Compare the size of the two dogs. How much more food might the bloodhound need?
- Look at the bloodhound's long ears and loose skin. This breed was developed for following scents.
- Look at the terrier's expression. What kind of personality does Landseer give it?
- Look at the kennel. Is it a good shelter? What would you add for the dogs' comfort?

Talk about it

1. Which of these two dogs would fit better in a small apartment? Which in a farm family? Why?
2. How might the daily care of these two dogs be different (exercise, grooming, food)?

3. Why do you think Landseer named the painting as he did?

HANDS-ON PROJECT

A Pet-Match Chart and Budget

You will research three possible pets, compare them honestly, and make a first-year budget, so that a family decision can be made with clear eyes.

You will need

- Your nature journal or a large sheet of paper
- A ruler and colored pencils
- Internet access with an adult, library books on pet care, or a pet-store and shelter visit
- A calculator

Steps

1. Choose three pets that might suit your family, such as a guinea pig, a parakeet and a leopard gecko, or a dog, a cat and a rabbit.
2. Make a chart with a row for each pet and columns for: lifespan, adult size, space needed, daily care time, special needs, social needs, and allergy concerns.
3. Fill in the chart from at least two reliable sources (a veterinary or extension website, a library book, or a veterinarian).
4. Make a first-year budget for each pet: adoption or purchase, habitat and setup, food for 12 months, bedding or litter, toys, and one veterinary visit. Visit a store or price items online with an adult.
5. Add a line for an emergency fund. Ask a veterinarian's office what a typical sick visit costs.
6. Interview someone who owns one of your three pets. Ask: What surprised you? What is the hardest part? What do you love most?
7. Score each pet from 1 to 5 on how well it fits your family's time, space and budget.
8. Write a one-page recommendation to your parents: which pet fits best (or that now is not the right time), with reasons from your chart.

Tips

- An honest “not yet” is a good answer. Pet-sitting for a neighbor is a fine way to learn first.
- Remember to include the cost of care while your family is away on trips.

Check your work

- ☐ My chart compares three pets on at least seven features.
- ☐ My budget includes setup, a year of food and supplies, and veterinary care.
- ☐ My recommendation gives reasons based on facts, not just on what I want.

NATURE JOURNAL

1. Draw a timeline of your own life from now to age 30. Mark where each of your three pets' lifespans would end if you got it this year.
2. Visit a shelter, a pet store or a friend's pet and draw one animal from life. Note its behavior for ten minutes.
3. Draw a floor plan of where a pet's habitat would go in your home, considering light, drafts, noise and other pets.

From history. The first society to protect animals from cruelty was founded in London in 1824; Queen Victoria later made it the Royal Society for the Prevention of Cruelty to Animals. In 1866 Henry Bergh founded the ASPCA in New York, after seeing horses mistreated in the streets.

COMMON MISTAKES

- Choosing a pet because it is cute or popular without learning its needs.
- Thinking small pets like hamsters or fish need little care. Every pet needs daily attention and a clean home.
- Counting only the purchase price and forgetting food, supplies and veterinary bills.
- Buying a baby animal without learning how large it will grow.

Make it a game • Match the Pet Family. Make a pet-match chart with three pets across and five clues down: lifespan, space, daily time, yearly cost and special needs. Parent draws a family card, such as 'busy, small apartment, one hour a day.' Pick the pet and defend the choice in thirty seconds, using the word stewardship. Swap roles and judge your parent's pick.

Scripture. “A righteous man regardeth the life of his beast: but the tender mercies of the wicked are cruel.” (Proverbs 12:10, KJV)

To “regard” an animal’s life is to pay attention to what it needs. Choosing a pet wisely is the first act of that care.

4.2 PET NUTRITION AND FOOD LABELS

OBJECTIVES

- Name the six classes of nutrients and explain why different animals need different diets.
- Read a pet-food label: the nutritional adequacy statement, the guaranteed analysis and the ingredient list.
- Compare foods on a dry-matter basis and assess a pet's body condition.

Warm-up. Find a cereal box or any packaged food in your kitchen. Copy the first five ingredients and the grams of protein, fat and fiber per serving. Why do you think the ingredients are listed in that order?

WATCH

Choosing the BEST Food for Your Pets | Vet's Voice (Part 1)

Vet Med Corner • 12:46

<https://www.youtube.com/watch?v=eXiqSKUWp0c>

WHEN TO WATCH

After the core ideas, before the label project. Pause each time the veterinarian names something to look for on a bag.

BACKUP VIDEO

How to Perform a Body Condition Assessment - Dog

Purina Institute • 2:41

<https://www.youtube.com/watch?v=GSmWGq4INEQ>

Before step 7 of the project, which uses body condition scoring.

KEY TERMS

nutrient

A substance in food that an animal needs to live and grow: water, protein, fat, carbohydrate, vitamins and minerals.

obligate carnivore

An animal, such as a cat, that must eat animal tissue to get certain nutrients its body cannot make.

nutritional adequacy statement

The line on a pet-food label stating whether the food is complete and balanced, and for which life stage (growth, adult maintenance, or all life stages).

guaranteed analysis

The part of a label listing the minimum percent of crude protein and fat and the maximum percent of fiber and moisture.

dry-matter basis

A nutrient's percent after the water is mathematically removed, which lets you compare dry and canned foods fairly.

body condition score

A 1-to-9 scale veterinarians use to judge whether an animal is too thin, ideal or overweight, by feeling the ribs and looking at the waist.

CORE IDEAS

Every animal needs the same six classes of **nutrients**: water, protein, fat, carbohydrate, vitamins and minerals. But each kind of animal is designed to get them from different foods. Dogs can thrive on a mix of meat and plant foods. Cats are **obligate carnivores**: they must have animal protein and nutrients such as taurine and preformed vitamin A, and a cat fed dog food or a homemade vegetarian diet can go blind or develop heart disease. Rabbits and guinea pigs are herbivores that need mostly grass hay, about 80 percent of their diet, to keep their digestion moving and their ever-growing teeth worn down.

In the United States, a complete pet food carries a **nutritional adequacy statement**, based on standards from the Association of American Feed Control Officials (AAFCO). Look for words like “complete and balanced for adult maintenance” or “for growth.” A food labeled “for intermittent or supplemental feeding only” is a treat or a topper, not a full diet. A puppy or kitten needs a food for growth.

The **guaranteed analysis** lists minimum crude protein and fat and maximum fiber and moisture. Ingredients are listed by weight before cooking, so fresh meat, which is about 70 percent water, may appear first even if the food contains less meat than it seems. To compare a dry food with a canned food fairly, use the **dry-matter basis**: divide the protein percent by (100 – the moisture percent) and multiply by 100. A canned food with 8 percent protein and 78 percent moisture has $8 \div 22 \times 100 \approx 36$ percent protein on a dry-matter basis, more than a dry food with 26 percent protein and 10 percent moisture (about 29 percent).

More food is not better. Many American pets are overweight, which shortens their lives. Veterinarians use a **body condition score** from 1 (very thin) to 9 (obese), with 4 to 5 ideal: you should feel the ribs easily under a thin layer of fat and see a waist from above. Treats should be no more than about a tenth of the day's calories. Fresh, clean water must always be available.

Some human foods are dangerous for pets. Chocolate, grapes and raisins, onions and garlic, and the sweetener xylitol (found in some gum and peanut butter) can poison dogs. Lilies can cause kidney failure in cats. Avocado is toxic to birds. When in doubt, don't share your plate.

PICTURE STUDY



Cat with Kittens, Henriëtte Ronner-Knip, 1860s · Oil on panel

Image: [Wikimedia Commons](#), public domain

Henriëtte Ronner-Knip, a Dutch painter who lived in Brussels, was famous for her cats. She kept a glass-sided box in her studio so she could watch her cats and kittens closely without disturbing them. Her paintings show real cat behavior, not just pretty poses.

Look closely

- Count the kittens. What is each one doing?
- Look at the mother cat's body. Does she look thin, ideal or heavy?
- Look at the kittens' ears, eyes and fur. Do they look healthy and alert?
- Look at the cushion and the doorway. Is this a warm, dry, safe place for a mother cat and kittens?

Talk about it

1. Kittens need a food labeled "for growth." Why would their needs be different from an adult cat's?
2. Cats are obligate carnivores. What does that mean for how this family should feed them?
3. What signs of good care, or of things that could be improved, can you see in this picture?

HANDS-ON PROJECT

Be a Pet-Food Detective

You will compare two pet foods label by label, calculate their protein on a dry-matter basis, and practice body condition scoring.

You will need

- Two pet-food labels for the same kind of animal, one dry and one canned (from your pantry, a store, or a manufacturer's website)
- A calculator
- Your nature journal
- A dog or cat to score (your own, a neighbor's, or photos from a shelter website)

Steps

1. For each food, copy the nutritional adequacy statement. Is it complete and balanced? For which life stage?
2. Copy the guaranteed analysis: crude protein (min), crude fat (min), crude fiber (max), moisture (max).
3. Copy the first five ingredients. Circle any ingredient that is mostly water (fresh meat, broth).
4. Calculate protein and fat on a dry-matter basis for both foods. Show your work.
5. Find the feeding directions. How much of each food would a 30-pound dog or a 10-pound cat eat per day?
6. Compare the cost per day of the two foods.
7. Body condition: with an owner's permission, gently feel along the animal's ribs and look at its waist from above and from the side. Give it a score from 1 to 9 using the core ideas.
8. Write a short report: Which food would you choose for this animal and why? What does its body condition suggest about how much it should eat?

Tips

- Ask before touching anyone's pet, and let the animal sniff your hand first.

- If you have no pet nearby, practice scoring using clear side and top-view photos of shelter animals.

Check your work

- ☐ I correctly copied and explained the adequacy statement and guaranteed analysis for two foods.
- ☐ I calculated dry-matter protein correctly.
- ☐ I can explain why cats cannot be fed like dogs or rabbits.

NATURE JOURNAL

1. Draw a sample pet-food label and label its parts: product name, adequacy statement, guaranteed analysis, ingredient list, feeding directions.
2. Draw outline sketches of a dog from above at body condition scores 2, 5 and 8. Show the waist and ribs.
3. List ten human foods and mark each safe, unsafe or “ask the vet” for a dog.

From history. The first commercial dog food was sold in London around 1860 by an American electrician named James Spratt, who noticed dogs at the docks eating ships’ biscuits. Canned pet food appeared in the 1920s, and dry, puffed kibble became common in the 1950s.

COMMON MISTAKES

- Comparing canned and dry foods by their label percentages without correcting for water.
- Feeding a cat a vegetarian diet or dog food. Cats must have animal-based nutrients.
- Giving rabbits mostly pellets and treats instead of unlimited grass hay.
- Judging a pet’s weight by eye alone. Feel the ribs.

Make it a game • Label Detective Lineup. Draw three pretend pet-food labels with different guaranteed analysis and ingredient lists. Parent plays a puzzled owner. You find the nutritional adequacy statement, compare protein and moisture, and explain dry-matter basis. Name the six nutrient classes and tell why a cat as an obligate carnivore needs a different diet than a rabbit. Win by explaining each label.

4.3 REPTILE AND AMPHIBIAN HUSBANDRY

OBJECTIVES

- Explain how ectotherms control their body temperature and why they need a thermal gradient.
- Describe correct temperatures, lighting, housing and diet for leopard geckos and bearded dragons.
- Explain why amphibians need special handling and how to prevent salmonella.

Warm-up. Feel three places in your home: a sunny windowsill, a spot near a heat vent, and a floor near an outside door. Rank them from warmest to coolest. If you were a lizard, where would you go after a cold night? After a big meal?

WATCH

Complete Leopard Gecko Care Guide!

TikisGeckos · 6:06

https://www.youtube.com/watch?v=hU681Z_KXvM

WHEN TO WATCH

After the core ideas. Fill in a care card as you watch: enclosure size, warm-side and cool-side temperatures, hides, food and supplements.

BACKUP VIDEO

The Ultimate Bearded Dragon Lighting & Heating Guide

Zen Habitats · 8:54

<https://www.youtube.com/watch?v=XEzEUHQ2WUY>

For bearded dragon keepers; watch before designing a dragon enclosure.

KEY TERMS

ectotherm

An animal, such as a reptile or amphibian, whose body temperature depends mostly on its surroundings.

thermal gradient

A range of temperatures from a warm end to a cool end of an enclosure, letting the animal move to the temperature it needs.

basking spot

The warmest place in an enclosure, under a heat lamp, where a reptile warms up to digest and stay active.

UVB

A kind of ultraviolet light that lets reptiles make vitamin D₃ in their skin so they can absorb calcium.

metabolic bone disease

A painful weakening of the bones caused by too little calcium, vitamin D₃ or UVB.

salmonella

Bacteria that many reptiles and amphibians carry harmlessly but that can make people, especially young children, sick.

CORE IDEAS

Reptiles and amphibians are **ectotherms**. Instead of making their own body heat as mammals and birds do, they move between warm and cool places to control their temperature. A lizard basks in the morning sun, digests its meal in the warmth, then retreats to shade before it overheats. In captivity, we must build that choice into the enclosure with a **thermal gradient**: a warm end, a cool end, and hiding places at both.

Leopard geckos come from the rocky grasslands of south-central Asia and are active at dusk and night. A good setup gives a warm-side surface of about 88 to 92°F (from an overhead heat lamp or a heat mat controlled by a thermostat), a cool side in the low to mid 70s, and a nighttime drop to the upper 60s. They need a warm hide, a cool hide and a humid hide with damp moss to help them shed. They eat live insects (crickets, dubia roaches, mealworms) dusted with calcium. Many keepers now add a low-level UVB light as well. One adult needs at least a 20-gallon long tank, and larger is better.

Bearded dragons come from the deserts and dry woodlands of Australia and are active by day. Adults need a basking spot of about 100 to 110°F, a cool side around 75 to 85°F, and nights in the mid 60s to mid 70s. They must have strong **UVB** light, usually a long fluorescent tube spanning much of the enclosure, replaced on the maker's schedule, because the bulb's UVB fades long before its visible light does. Without UVB and calcium, dragons develop **metabolic bone disease**. Young dragons eat mostly insects; adults eat mostly leafy greens and vegetables with some insects. An adult needs an enclosure about 4 feet long, 2 feet deep and 2 feet tall.

Amphibians (frogs, toads and salamanders) have thin, moist skin that absorbs water and whatever is dissolved in it. Lotion, soap or salt on your hands can harm them, so handle them as little as possible and only with clean, wet hands rinsed of soap. Their water must be free of chlorine (use a water conditioner), and their enclosures need steady humidity. Some, like fire-bellied toads, have skin secretions that sting your eyes, another reason to wash hands well afterward.

Many healthy reptiles and amphibians carry **salmonella** bacteria. Always wash your hands with soap and water after touching the animal or anything in its enclosure. Never wash its dishes in the kitchen sink, never let it roam on kitchen counters, and do not snuggle it near your face. Health officials advise that children under five should not handle reptiles at all. With good hygiene, a reptile can be a safe and fascinating pet.

PICTURE STUDY



The Lyon Lizard, Mark Catesby, published 1731–43 · Hand-colored etching from *The Natural History of Carolina, Florida and the Bahama Islands* · National Gallery of Art, Washington

Image: [Wikimedia Commons](#), public domain

Mark Catesby was an English naturalist who traveled through the American colonies in the early 1700s and drew their plants and animals. His book was the first illustrated natural history of North America. The striped lizard he called the “Lyon Lizard” is probably the six-lined racerunner, a fast, sun-loving lizard of sandy open ground.

Look closely

- Look along the lizard’s back and sides for stripes or markings.
- Look at the lizard’s legs, toes and long tail. What do they tell you about how it moves?
- Look at the plant the lizard is climbing. Why do you think Catesby drew the lizard and the plant together?
- Look at the lizard’s scales. How are they drawn?

Talk about it

1. A racerunner basks on hot, sandy ground. What temperatures would it need in a terrarium?
2. Why should a wild lizard like this one be watched and drawn, not caught and kept?

3. How is Catesby's drawing different from a photograph? What can a careful drawing show better?

Safety first. Wash hands with soap and water after touching any reptile, amphibian, or anything in its enclosure. Children under five should not handle reptiles. An adult sets up and checks heat lamps, which can burn and start fires.

HANDS-ON PROJECT

Measuring a Thermal Gradient

You will build a model enclosure with a heat lamp, measure its thermal gradient, and use your data to design a correct habitat for a leopard gecko or bearded dragon.

You will need

- A large cardboard box or an empty aquarium with a screen lid
- A clamp lamp with an incandescent or halogen bulb (adult sets up)
- Three thermometers, or one digital infrared temperature gun
- A ruler or tape measure
- Two small boxes or overturned flowerpots to act as hides
- Graph paper

Steps

1. With an adult, place the lamp at one end of the box or tank, about 10 inches above the floor. Never let the bulb touch cardboard.
2. Place thermometers at the warm end directly under the lamp, in the middle, and at the cool end, all at floor level.
3. Turn on the lamp and record all three temperatures every 5 minutes for 30 minutes.
4. Graph temperature against distance from the lamp after 30 minutes.
5. Raise or lower the lamp 2 inches and repeat. How does the basking temperature change?
6. Compare your numbers with the needs of a leopard gecko (warm side 88–92°F) and a bearded dragon (basking 100–110°F). Which setup fits which animal?
7. Draw a full plan for a real enclosure for one of the two species: size, heat source and thermostat, UVB light, hides, substrate, water, food, and where each thermometer goes.
8. Add a shopping list with prices, and turn off and unplug the lamp when you are finished.

Tips

- If you have a real reptile, measure its enclosure instead and compare it with the correct ranges.
- Infrared guns read surface temperature, which is what a basking lizard feels.

Check your work

- ☐ I recorded and graphed temperatures from warm end to cool end.
- ☐ I can explain what a thermal gradient is and why reptiles need one.
- ☐ My enclosure plan includes correct temperatures, UVB (where needed), hides and hygiene.

NATURE JOURNAL

1. Draw a side view of your enclosure plan with arrows showing warm and cool zones and labeled temperatures.
2. Draw a leopard gecko and a bearded dragon side by side. Label one feature of each that fits it for its native home.
3. Make a two-column chart comparing the care of a leopard gecko and a bearded dragon.

From history. Mark Catesby spent years in Virginia and Carolina in the 1710s and 1720s, then taught himself etching so that he could make the plates for his book himself. Scientists used his pictures for decades; Linnaeus based several species names on them.

COMMON MISTAKES

- Heating the whole enclosure to one temperature. Reptiles need a gradient to choose from.
- Using a UVB bulb until it burns out. UVB output fades months before the visible light does.
- Handling amphibians with dry or soapy hands.
- Washing reptile dishes in the kitchen sink.

Make it a game • Gradient Temperature Hunt. Hide a paper gecko in a room while your parent stays out. Then your parent hunts using only thermal-gradient clues from you: 'basking spot warmer, cool hide cooler.' When found, quiz each other on temperatures, lighting, housing and diet for leopard geckos and bearded dragons. Name what UVB prevents and how to handle salmonella risk safely.

4.4 PET HEALTH, HYGIENE AND THE VETERINARIAN

OBJECTIVES

- Describe what happens at a preventive veterinary visit and why it matters.
- Perform a simple nose-to-tail home health check and recognize signs that a pet needs a veterinarian.
- Explain how to prevent zoonotic diseases and parasites.

Warm-up. Think of the last time you went to the doctor for a checkup. List everything the doctor checked. Now guess which of those things a veterinarian would check on a dog.

WATCH

In the Exam Room: Preventive Care Visits

American Veterinary Medical Association • 4:43

https://www.youtube.com/watch?v=MnuhJ_it4UY

WHEN TO WATCH

After the core ideas. List each body part the veterinarian checks, in order; you will use the list for your own health check.

BACKUP VIDEO

Choosing a Veterinarian

American Veterinary Medical Association • 4:01

https://www.youtube.com/watch?v=TNCUByli_Dg

After the core idea about finding the right veterinarian.

KEY TERMS

preventive care

Regular checkups, shots, parasite control and dental care that keep an animal healthy and find problems early.

parasite

A living thing that lives on or in another and feeds from it, such as fleas, ticks, heartworms and intestinal worms.

zoonotic disease

A disease that can pass between animals and people, such as rabies, ringworm or salmonella.

vital signs

Basic measures of health: temperature, heart rate and breathing rate.

prey species

Animals such as rabbits, guinea pigs and birds that instinctively hide signs of illness to avoid looking weak.

CORE IDEAS

Most pets should see a veterinarian at least once a year, and older pets often twice. At a **preventive care** visit, the veterinarian weighs the animal, takes its temperature, listens to its heart and lungs, looks in its eyes, ears and mouth, checks its skin and coat, feels its belly and joints, and asks about eating, drinking and behavior. The visit is also the time for core shots (such as rabies shots, which most states require for dogs and cats), parasite prevention, and dental care.

Parasites are a major part of preventive care. Fleas and ticks bite and can spread disease. Heartworms, passed by mosquitoes, live in a dog's heart and lungs and can be fatal, but a monthly preventive stops them. Intestinal worms rob nutrients and some can infect people. A yearly stool test and regular preventives protect both pets and families.

You are the person who sees your pet every day, so you are the first line of defense. Learn what is normal: a dog's temperature is about 101 to 102.5°F, a healthy coat is clean and shiny, eyes are bright and clear, gums are pink. Call a veterinarian for refusing food for more than a day, vomiting or diarrhea that lasts, trouble breathing, straining to urinate, a swollen belly, limping, or unusual tiredness. Small animals and birds are **prey species**: they hide illness until they are very sick, so a rabbit that stops eating or a bird sitting fluffed up on the cage floor is an emergency.

Some diseases are **zoonotic**, able to pass between animals and people. Ringworm (a fungus, not a worm) spreads by touch; salmonella comes from reptiles, chicks and their habitats; some roundworms spread through pet waste in soil. Good hygiene prevents almost all of these: wash hands after handling animals and cleaning cages

or litter, scoop waste daily, keep pets' dishes out of the kitchen sink, and keep pets on parasite prevention.

Pets can also bite or scratch, usually when frightened, hurt or handled roughly. Approach calmly, let an animal sniff you, support small animals' bodies with both hands, and never grab a pet that is eating or sleeping. Wash every bite or scratch with soap and water and tell an adult. A good veterinarian is a partner in your stewardship; choose one early, before an emergency, and keep a written health record for each pet.

PICTURE STUDY



A Distinguished Member of the Humane Society, Sir Edwin Landseer, 1838 · Oil on canvas · Tate Britain, London

Image: [Wikimedia Commons](#), public domain

This Newfoundland dog, named Paul Pry, was famous for rescuing people from the water. The “Humane Society” of the title was a society that gave medals for saving people from drowning, so Landseer is joking that the dog deserves to be a member.

Look closely

- Look at the dog’s coat. Does it look healthy and well kept?
- Look at the dog’s eyes and expression. Does it look alert or tired?
- Look at how the dog is lying. What does its body tell you about its mood?
- Find the water. Why would a Newfoundland be good at rescues? (Look at its size and coat.)

Talk about it

1. If you were doing a home health check on this dog, what would you look at first?
2. What special care might a large, thick-coated dog like this need in hot weather?
3. How does Landseer make the dog look noble and trustworthy?

Safety first. Only examine an animal whose owner is present and agrees. Stop if the animal shows fear (flattened ears, growling, hissing, trying to escape). Wash hands after handling any animal, and report any bite or scratch to an adult.

A Nose-to-Tail Home Health Check

You will create a health-check form and a health record, perform a gentle check on a pet (yours or a neighbor's, with the owner's help), and assemble a pet first-aid kit list.

You will need

- Your nature journal
- A watch with a second hand
- A kitchen or bathroom scale
- A flashlight
- A calm, willing pet and its owner (or a stuffed animal for practice first)

Steps

1. Make a health-check form with sections for: weight, eyes, ears, nose, mouth and gums, skin and coat, breathing rate, heart rate, feet and nails, belly, rear end, behavior, appetite and droppings.
2. Practice the order of the check on a stuffed animal first.
3. With the owner holding the pet, look at the eyes (bright, clear), ears (clean, no bad smell), and nose (no thick discharge).
4. Gently lift the lip to see the gums. Press a finger on the gum and count how many seconds until the pink color returns (normally under 2 seconds).
5. Watch the chest rise and fall for 30 seconds and double it to get breaths per minute while the pet is resting.
6. Run your hands over the body, feeling for lumps, scabs or sore spots, and check the feet and nails.
7. Weigh the pet (for a dog, weigh yourself holding it, then subtract your own weight). Record everything on the form.
8. Start a health record page: the pet's name, birth date or age, weight, veterinarian's phone number, shot dates and preventives.
9. Make a first-aid kit list: gauze, self-sticking bandage, saline eyewash, tweezers, a digital thermometer, a towel, gloves, and emergency phone

numbers.

Tips

- Keep the check short and pleasant, and reward the pet with praise.
- Repeat the check once a month; changes over time matter more than one reading.
- A dated health record like this is part of every 4-H small-animal project book. Keep yours going all year.

Check your work

- ☐ I made a complete health-check form and used it gently on a real or practice animal.
- ☐ I can name five signs that a pet needs a veterinarian.
- ☐ I can explain how hand-washing and parasite prevention protect people from zoonotic diseases.

NATURE JOURNAL

1. Draw an outline of a dog or cat and label each area checked during a health exam.
2. Draw the life cycle of a flea or a heartworm, showing how it passes from host to host.
3. Record one week of a pet's eating, drinking and behavior in a simple log.

From history. The first veterinary school opened in Lyon, France, in 1761, founded by Claude Bourgelat to fight diseases killing cattle and horses. In the United States, the American Veterinary Medical Association was founded in 1863, and today veterinarians care for everything from farm animals to hamsters.

COMMON MISTAKES

- Waiting to see whether a rabbit or bird “gets better.” These animals hide illness until it is serious.
- Skipping heartworm or flea prevention in winter in areas where the parasites remain active.
- Forgetting to wash hands after cleaning cages and litter boxes.
- Choosing a veterinarian only during an emergency, when there is no time to find one who treats your kind of pet.

Make it a game • Nose-to-Tail Checkup Tag. Take turns being the pretend pet and the checker with a stuffed animal. Go through the nose-to-tail health check in order: eyes, ears, nose, mouth, coat, skin, belly, legs, vital signs. Call out signs a pet needs a vet. Remember that prey species hide illness well. Explain preventive care and zoonotic disease. Beat your own checking time.

UNIT 4

PETS: STEWARDSHIP AND CARE

In early winter, when the garden rests, we turn to the animals who share our homes. A pet is not a toy or a decoration; it is a living creature that depends on us for every meal, every clean drink and every visit to the doctor. “A righteous man regardeth the life of his beast” (Proverbs 12:10). This unit is about doing that well.

You will learn how to choose an animal that truly fits a family’s time, space and budget; how to read a pet-food label like a veterinarian; how to give reptiles and amphibians the heat, light and humidity they were designed for; and how to keep a pet healthy, recognize illness early, and protect your own family with good hygiene. No pet is needed: every project works with a neighbor’s animal, a shelter visit, or a careful plan.

PREREQUISITES

- Knows the basic needs of all animals: food, water, shelter, space and care
- Can calculate a percentage and a simple budget
- Has learned to wash hands after handling animals

MASTERY CHECKLIST

- ☐ I can match a pet to a family by comparing lifespan, space, time, cost and care needs.
- ☐ I can read a pet-food label: the nutritional adequacy statement, the guaranteed analysis and the ingredient list.
- ☐ I can describe correct heat, light, humidity and diet for a leopard gecko or bearded dragon, and explain why amphibians need special care.
- ☐ I can perform a simple home health check and name signs that a pet needs a veterinarian.
- ☐ I can explain how to prevent diseases that pass from animals to people.

LESSONS IN THIS UNIT

4.1 Choosing a Pet Wisely

2 sessions of 50 minutes

4.2 Pet Nutrition and Food Labels

2 sessions of 50 minutes

4.3 Reptile and Amphibian Husbandry

2 sessions of 50 minutes

4.4 Pet Health, Hygiene and the Veterinarian

2 sessions of 50 minutes

UNIT 4 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

List four questions a family should answer before getting a pet.

2. (7 pts)

Put these pets in order from shortest to longest typical lifespan: rabbit, hamster, cat, guinea pig.

3. (7 pts)

Why do guinea pigs need vitamin C every day?

4. (8 pts)

What is an obligate carnivore? Name one.

5. (8 pts)

A canned food has 10% protein and 75% moisture. What is its protein on a dry-matter basis?

6. (7 pts)

What does a body condition score of 5 out of 9 mean, and how can you check it?

7. (8 pts)

What is a thermal gradient, and why does a reptile need one?

8. (8 pts)

Why does a bearded dragon need UVB light, and what happens without it?

9. **7 pts**

Why must amphibians be handled with clean, wet, soap-free hands?

10. **8 pts**

Name four signs that a pet should see a veterinarian.

11. **12 pts**

Explain how a family with a pet bearded dragon can keep everyone safe from salmonella.

12. **13 pts**

Explain why rabbits, guinea pigs and birds can become very sick before their owners notice, and what an owner should do about it.

ANSWER KEY

1. Any four: Who will care for it daily? Do we have space? Can we afford food, supplies and a veterinarian? Allergies? Will it fit our family for its whole lifespan? Who cares for it during trips?
2. Hamster, guinea pig, rabbit, cat.
3. Their bodies cannot make vitamin C, so it must come from food every day.
4. An animal that must eat animal tissue to get nutrients it cannot make for itself. A cat.
5. $10 \div (100 - 75) \times 100 = 10 \div 25 \times 100 = 40\%$.
6. Ideal weight. You can feel the ribs easily under a thin layer of fat and see a waist from above.
7. A range from warm to cool in the enclosure. Reptiles are ectotherms and must move between warm and cool spots to control their body temperature.
8. UVB lets it make vitamin D₃ to absorb calcium. Without it, it develops metabolic bone disease.
9. Their thin skin absorbs water and anything dissolved in it, so soap, lotion or salt can harm them.
10. Any four: not eating for more than a day (any time for a rabbit), lasting vomiting or diarrhea, trouble breathing, straining to urinate, swollen belly, limping, unusual tiredness, a bird fluffed up on the cage floor.
11. Wash hands with soap and water after touching the dragon or anything in its enclosure; clean dishes and equipment outside the kitchen, never in the kitchen sink; keep the dragon off kitchen counters and away from faces; and do not let children under five handle it.
12. They are prey species, designed to hide signs of weakness so predators will not single them out. Owners should watch daily for small changes in eating, droppings and behavior, keep records, and call a veterinarian promptly when something changes rather than waiting.

PORTFOLIO PIECE: A RESPONSIBLE PET-CARE PLAN

Choose one pet (one you have, or the one your pet-match chart recommended) and write a complete care plan: a habitat drawing with measurements and temperatures, a feeding plan based on label reading, a daily, weekly and monthly chore chart with names, a first-year budget, a health record page, and a list of warning signs for calling the veterinarian. Present it to your family as if they were deciding whether to adopt.

LOOK FOR	WHAT IT MEANS
Correct husbandry	Housing, temperature, light and diet are accurate for the species.
Chore chart	Daily, weekly and monthly jobs are complete, realistic and assigned to people.
Budget	Setup, food, supplies and veterinary care are included with realistic prices.
Health and hygiene	The plan includes a health record, warning signs, preventive care and hand-washing rules.
Presentation	The plan is neat, organized and explained clearly to the family.

UNIT 5

PLANT SCIENCE

Late winter is seed-catalog season, and the best time to look closely at how a plant actually works. In this unit you will go inside the plant: to its cells and the pipelines that carry water and sugar, to the chemical reaction that turns sunlight, water and air into food, to the flower where seeds and fruit begin, and to the garden of a patient friar who discovered the rules of heredity by counting peas.

Each lesson pairs real science vocabulary with a hands-on experiment you can do at a kitchen table. As you learn, notice how much order and wisdom is built into even the smallest leaf. “And the earth brought forth grass, and herb yielding seed after his kind ... and God saw that it was good” (Genesis 1:12).

PREREQUISITES

- Knows the main parts of a plant: roots, stem, leaves, flowers, fruit and seeds
- Has used a hand lens
- Can read a simple chemical formula such as H_2O or CO_2

MASTERY CHECKLIST

- ☐ I can name the parts of a plant cell and the three tissue systems, and explain what xylem and phloem do.
- ☐ I can write and explain the photosynthesis equation and name the factors that limit it.
- ☐ I can label the parts of a flower and explain how pollination leads to seeds and fruit.
- ☐ I can explain Mendel’s experiments and use a Punnett square to predict the results of a cross.

LESSONS IN THIS UNIT

5.1 Cells, Tissues and the Vascular System

2 sessions of 50 minutes

5.2 The Photosynthesis Equation

2 sessions of 50 minutes

5.3 Flowers, Pollination and Fruit

2 sessions of 50 minutes

5.4 Gregor Mendel’s Peas and Heredity

2 sessions of 50 minutes

UNIT 5 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

Name three parts of a plant cell that animal cells do not have, and the job of each.

2. (8 pts)

What is the difference between xylem and phloem?

3. (7 pts)

Why does a lettuce leaf wilt, and why does it firm up in cold water?

4. (8 pts)

Write the balanced equation for photosynthesis.

5. (7 pts)

Where does the oxygen released in photosynthesis come from?

6. (7 pts)

Name four factors that can limit photosynthesis.

7. (8 pts)

Name the parts of the stamen and the parts of the pistil.

8. (7 pts)

After fertilization, what does the ovule become, and what does the ovary become?

9. (8 pts)

Why should sweet corn be planted in a block instead of a single row?

10. (8 pts)

Use a Punnett square to predict the offspring of $Rr \times rr$ peas (R = round, r = wrinkled).

11. 12 pts

Explain how Mendel's round × wrinkled cross showed that the wrinkled trait had not disappeared.

12. 13 pts

Explain why a sunflower's weight comes mostly from the air rather than the soil.

ANSWER KEY

1. Cell wall (support), chloroplasts (photosynthesis), large central vacuole (stores water, keeps the plant firm).
2. Xylem is dead, hollow cells carrying water and minerals up from the roots; phloem is living cells carrying sugar from the leaves to the rest of the plant.
3. Without water, the vacuoles shrink and turgor pressure falls, so it wilts; in water the cells refill and press against their walls again.
4. $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.
5. From water molecules split by light energy.
6. Light, carbon dioxide, temperature and water.
7. Stamen: anther and filament. Pistil: stigma, style and ovary (with ovules).
8. The ovule becomes a seed; the ovary becomes the fruit.
9. Corn is wind-pollinated and each kernel needs pollen on its own silk; in a block, pollen from the tassels falls on neighboring silks, so ears fill completely.
10. Rr, Rr, rr, rr: half round (Rr) and half wrinkled (rr), a 1:1 ratio.
11. All the first-generation offspring were round, so the wrinkled trait seemed gone. But when those plants (Rr) pollinated themselves, about one in four of the next generation had wrinkled seeds (rr). The recessive allele had been carried, hidden, in the first generation.
12. Through photosynthesis the plant takes carbon dioxide from the air and water from the soil and builds them into sugar, cellulose and starch. Most of its dry weight is carbon from carbon dioxide; the soil supplies only water and small amounts of minerals.

PORTFOLIO PIECE: A PLANT SCIENCE LAB NOTEBOOK

Assemble a lab notebook with a formal write-up of two of this unit's experiments (celery and turgor, floating leaf disks, flower dissection, or the Mendel simulation). Each write-up includes a question, a hypothesis, materials, procedure, a data table, a graph, and a conclusion that uses at least five key terms correctly. Add one labeled diagram from each lesson.

LOOK FOR	WHAT IT MEANS
Scientific method	Each write-up has a clear question, hypothesis, procedure and conclusion.
Data	Data tables are complete and graphs are labeled with titles, axes and units.
Accuracy	Conclusions and diagrams are scientifically correct and use key terms properly.
Diagrams	One clear, labeled diagram is included from each of the four lessons.
Neatness	The notebook is organized, dated and easy to follow.

5.1 CELLS, TISSUES AND THE VASCULAR SYSTEM

OBJECTIVES

- Name the parts of a plant cell and explain what each does.
- Describe the dermal, ground and vascular tissues of a plant.
- Trace water through xylem with a dye experiment and explain turgor pressure.

Warm-up. Take a stalk of celery and snap it in half. Look at the broken end with a hand lens. Draw what you see and guess what the stringy parts are for.

WATCH

Xylem and Phloem - Transport in Plants | Biology | Free Animated Education

Free Animated Education · 3:48

<https://www.youtube.com/watch?v=DhyYtT1K844>

WHEN TO WATCH

After the core ideas. Pause when the xylem and phloem are shown side by side and copy the diagram.

BACKUP VIDEO

The Color-Changing Celery Experiment!

SciShow Kids · 4:13

<https://www.youtube.com/watch?v=Klug9Foou3s>

Before setting up the project. It is aimed at younger students but shows the experiment clearly.

KEY TERMS

cell wall

The stiff outer layer of a plant cell, made mostly of cellulose, that supports and protects it.

central vacuole

A large, water-filled sac in a plant cell; when full, it presses outward and keeps the plant firm.

chloroplast

A green structure in plant cells where photosynthesis takes place.

xylem

Vascular tissue made of hollow, dead cells that carries water and minerals up from the roots.

phloem

Vascular tissue made of living cells that carries sugar from the leaves to the rest of the plant.

turgor pressure

The pressure of water inside plant cells pushing against the cell walls, which keeps leaves and stems stiff.

CORE IDEAS

Every plant is built of **cells**, far too small to see without a microscope. A plant cell has several parts that animal cells lack. The **cell wall**, made of cellulose, gives it a stiff box shape; cellulose is the stuff of wood, cotton and paper. **Chloroplasts**, full of green chlorophyll, capture light to make food. A large **central vacuole** stores water. Like animal cells, plant cells also have a cell membrane, a nucleus that holds the cell's instructions, cytoplasm, and mitochondria that release energy from sugar.

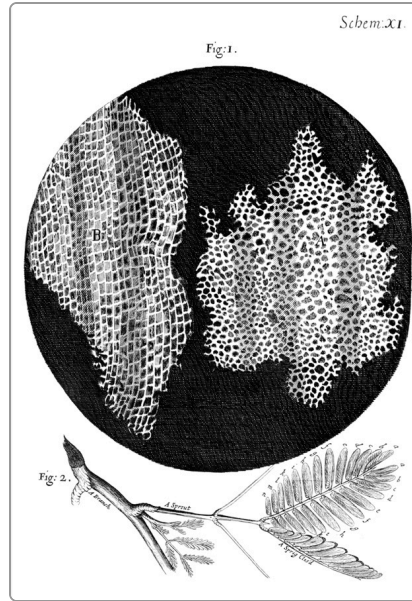
Cells of the same kind working together form tissues, and plants have three tissue systems. **Dermal tissue** is the skin: the epidermis with its waxy cuticle that keeps water in, tiny pores called stomata on the leaves, and root hairs that soak up water. **Ground tissue** fills most of the plant; it makes and stores food, as in the soft white flesh of a potato. **Vascular tissue** is the plumbing.

The vascular system has two kinds of pipes. **Xylem** is made of long cells that die when they mature, leaving hollow tubes with strong walls. Water and dissolved minerals travel up through them from roots to leaves, pulled along as water evaporates from the leaves. **Phloem** is made of living cells that carry sugar from the leaves, where it is made, to roots, fruits, flowers and growing tips, wherever it is needed. Xylem and phloem run side by side in bundles; in a celery stalk, the “strings” are vascular bundles.

In a tree, each year's new xylem forms a growth ring; old xylem is the wood. The phloem lies just under the bark. That is why a tree with a ring of bark chewed off all the way around by mice or deer slowly starves: its roots no longer receive sugar.

When the vacuoles are full, cells press against their walls like inflated balloons in boxes. This **turgor pressure** holds up soft stems and leaves. When a plant runs short of water, the vacuoles shrink and the plant wilts. That is why a wilted lettuce leaf firms up in cold water, and why gardeners water before plants droop.

PICTURE STUDY



Cork Cells, from Micrographia, Robert Hooke, 1665 · Engraving · Micrographia, published by the Royal Society, London

Image: [Wikimedia Commons](#), public domain

In 1665 the English scientist Robert Hooke looked at a thin slice of cork through one of the first good microscopes. He saw rows of tiny empty boxes that reminded him of the small rooms, or “cells,” of monks. He named them cells, and the word has been used ever since.

Look closely

- Find the magnified cork. What do the little boxes look like to you?
- Look at the walls between the boxes. Are they thick or thin?
- Are the boxes all the same size and shape?
- Find the second drawing on the plate. What did Hooke show beside the cork?

Talk about it

1. Cork comes from bark, and its cells are dead and empty. What part of a living plant cell was Hooke actually seeing?
2. Why do you think cork floats and keeps out water so well?
3. How might Hooke’s discovery have changed the way people thought about living things?

Safety first. An adult cuts the celery and any thin slices with a sharp knife. Food coloring stains; wear old clothes and cover the table.

HANDS-ON PROJECT

Following the Water: Celery, Carnations and Turgor

You will watch water climb through xylem, look at vascular bundles in cross-section, and test turgor pressure with fresh and salty water.

You will need

- Four celery stalks with leaves
- A white carnation (optional)
- Food coloring (red and blue work best)
- Four clear glasses or jars
- Table salt
- A ruler, a hand lens, and a sharp knife (adult use)
- A student microscope and an onion (optional)

Steps

1. An adult trims the bottom of each celery stalk with a fresh cut. Fill two glasses with water and 20 drops of food coloring.
2. Put one celery stalk in each colored glass, one in a glass of plain water, and one in a glass of very salty water (3 tablespoons of salt in a cup). Split a carnation stem lengthwise halfway up and put each half in a different color, if you have one.
3. After 1 hour, 4 hours and 24 hours, measure how far the color has climbed in the colored stalks and record it.
4. After 24 hours, have an adult cut a thin crosswise slice from a colored stalk. Look at it with a hand lens. Count the colored dots (the vascular bundles).
5. Bend the plain-water stalk and the salt-water stalk. Which is crisp and which is limp? Record what you find.
6. Put the limp stalk into fresh plain water overnight and test it again.
7. Optional: peel a thin layer from an onion, lay it flat on a slide with a drop of water, and look for cell walls under a microscope.
8. Write a conclusion explaining what xylem does and why the salt water made celery limp.

Tips

- Leaves speed up the climb, because water evaporating from them pulls water upward.
- Warm room temperature also speeds the experiment.

Check your work

- ☐ I measured and graphed how fast the dye climbed.
- ☐ I found and counted vascular bundles in a cross-section.
- ☐ I can explain turgor pressure and why salty water caused wilting.

NATURE JOURNAL

1. Draw and label a large plant cell: cell wall, cell membrane, nucleus, chloroplasts, central vacuole, cytoplasm and mitochondria.
2. Draw your celery cross-section and label the vascular bundles, xylem (where the dye was) and ground tissue.
3. Make a line graph of dye height against time.

From history. Robert Hooke's *Micrographia* of 1665 was one of the first books of microscope drawings, with pictures of fleas, mold and cork. About ten years later Antonie van Leeuwenhoek, a Dutch cloth merchant who ground his own lenses, saw living single-celled creatures in pond water.

COMMON MISTAKES

- Mixing up xylem and phloem. Remember: xylem carries water up; phloem carries food (sugar) wherever it is needed.
- Thinking plant cells have no mitochondria. Plants make sugar in chloroplasts but still burn it in mitochondria.
- Forgetting to make a fresh cut on the celery, which lets air block the xylem.

Make it a game • Celery Race Cell Cards. Make cards for plant cell parts and tissues: cell wall, chloroplast, central vacuole, dermal, ground, vascular. Parent holds up a job and you slap the matching card. Then explain xylem, phloem and turgor pressure with a floppy and a crisp celery stalk. Count correct slaps in sixty seconds, and try to beat your best score.

5.2 THE PHOTOSYNTHESIS EQUATION

OBJECTIVES

- Write and explain the balanced equation for photosynthesis.
- Explain the roles of chlorophyll, stomata and light, and the factors that limit photosynthesis.
- Measure photosynthesis with the floating leaf disk experiment.

Warm-up. A sunflower seed weighs less than a gram, but a sunflower plant can weigh several pounds by August. Write where you think all that weight comes from: the soil, the water, the air, or the sun?

WATCH

Photosynthesis

Science Sauce · 3:56

<https://www.youtube.com/watch?v=7LVzJbHfW1g>

WHEN TO WATCH

After the core ideas. Pause when the equation appears and copy it, then check your copy against the core ideas.

BACKUP VIDEO

Bubbling Plants Experiment to Quantify Photosynthesis

Teach Engineering · 2:50

<https://www.youtube.com/watch?v=B3-16GVWfe0>

Before the project. It shows the floating leaf disk method you will use.

KEY TERMS

photosynthesis

The process by which plants use light energy to turn carbon dioxide and water into sugar, releasing oxygen.

chlorophyll

The green pigment in chloroplasts that absorbs red and blue light to power photosynthesis.

stomata

Tiny pores, mostly on the undersides of leaves, that let carbon dioxide in and oxygen and water vapor out.

glucose

A simple sugar ($C_6H_{12}O_6$) made in photosynthesis and used for energy and building materials.

cellular respiration

The process in all living cells, plants included, that releases energy from sugar using oxygen and gives off carbon dioxide and water.

limiting factor

Whatever is in shortest supply (light, carbon dioxide, water or warmth) and so sets the speed of photosynthesis.

CORE IDEAS

Plants do not eat soil. They make their own food from three simple ingredients: carbon dioxide from the air, water from the soil, and energy from light. The balanced equation is: $6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$. In words: six molecules of carbon dioxide and six of water, powered by light, make one molecule of glucose sugar and six of oxygen. The atoms are not created or destroyed, only rearranged; count them on each side and they match.

Photosynthesis happens in the **chloroplasts**, mostly in the leaves. **Chlorophyll** absorbs red and blue light strongly and reflects green, which is why leaves look green. Carbon dioxide enters through the **stomata**, and water arrives through the xylem. In the first stage, light energy splits water molecules, and the oxygen from the water is released into the air. In the second stage, the plant uses that captured energy to join carbon dioxide into sugar.

The sugar has many uses. Some is burned at once for energy by **cellular respiration**, which runs day and night in every plant cell and is nearly the reverse of photosynthesis. Some is linked into long chains of cellulose to build cell walls, or stored as starch in roots, tubers and seeds; a potato is a storehouse of sugar made in its leaves. So almost all of a plant's dry weight is built from carbon that came from the air.

Photosynthesis speeds up with more light, more carbon dioxide and warmer temperatures, up to a point. Whatever is in shortest supply is the **limiting factor**. A lettuce plant in deep shade is limited by light; a corn plant on a hot, dry afternoon closes its stomata to save water and is limited by carbon dioxide. Gardeners give

vegetables at least six to eight hours of direct sun because, for most crops, light is the factor that limits growth.

Nearly every bite of food you eat, and every breath of oxygen you take, traces back to photosynthesis. “He causeth the grass to grow for the cattle, and herb for the service of man: that he may bring forth food out of the earth” (Psalm 104:14).

PICTURE STUDY



Sunflowers, Vincent van Gogh, 1888 · Oil on canvas · National Gallery, London

Image: [Wikimedia Commons](#), public domain

Van Gogh painted sunflowers again and again in the summer of 1888 in the south of France. He showed them at every stage of life, from fresh blooms to heads heavy with seed. A sunflower can grow taller than a man in one summer, built almost entirely from air, water and sunlight.

Look closely

- Count the sunflowers. How many different stages of life can you find?
- Find a head that has lost its petals. What is left in the center?
- Look at the leaves on the stems. Are they fresh and green or drying?
- How many shades of yellow can you see?

Talk about it

1. Where did the material to build all those seeds come from?
2. The flowers in the vase are cut. How long can they keep making food without roots? Why?
3. Why do you think Van Gogh painted the flowers fading as well as blooming?

Safety first. Use a plastic syringe without a needle. Baking soda and dish soap are safe, but keep the solution away from eyes and wash hands afterward.

The Floating Leaf Disk Experiment

Scientists use this simple method to measure photosynthesis. You will pull the air out of small leaf disks so they sink, then watch them float back up as photosynthesis fills them with oxygen.

You will need

- Fresh spinach leaves
- A single-hole paper punch or a sturdy drinking straw
- A 10 ml or larger plastic syringe (no needle)
- Baking soda (sodium bicarbonate) and a drop of dish soap
- Two clear cups
- A bright lamp, or a sunny window
- A timer and your journal

Steps

1. Make the solution: stir $\frac{1}{8}$ teaspoon of baking soda into 1 cup of water, and add one small drop of dish soap. The baking soda supplies carbon dioxide.
2. Punch 20 disks from spinach leaves, avoiding the big veins.
3. Remove the plunger, drop 10 disks into the syringe, replace the plunger, and draw in about 5 ml of solution. Tap so the disks float.
4. Hold your finger over the tip and pull back on the plunger to make a vacuum for 10 seconds; release. Repeat 2 or 3 times until the disks sink.
5. Pour the sunk disks into a cup of the same solution. Repeat with the other 10 disks for a second cup.
6. Place one cup under a bright lamp or in the sun and the other in a dark cupboard.
7. Every minute for 20 minutes, count how many disks are floating in each cup (check the dark cup quickly and close it again).
8. Graph the number floating against time for both cups. Write a conclusion: what made the disks rise, and why did the cups differ?

9. Extension: test a third cup with plain water and no baking soda. What does it show about carbon dioxide as a limiting factor?

Tips

- If the disks will not sink, add another tiny drop of soap and try the vacuum again.
- Scientists often report the time when half the disks are floating; find that time for your light cup.

Check your work

- ☐ I sank the leaf disks and recorded how many floated each minute.
- ☐ My graph compares light and dark.
- ☐ I can write the photosynthesis equation and explain where the oxygen bubbles came from.

NATURE JOURNAL

1. Write the photosynthesis equation large across a page. Under each part, draw where it comes from or goes: air, roots, sunlight, sugar stored in the plant, oxygen to the air.
2. Draw a leaf cross-section showing the upper epidermis, the chloroplast-packed cells, the veins, and stomata on the underside.
3. Graph your floating-disk results.

From history. In the 1600s the Flemish scientist Jan Baptist van Helmont grew a 5-pound willow in a tub of weighed soil for five years. The willow gained about 164 pounds, but the soil lost only about 2 ounces. He concluded the tree was made from water; later scientists discovered that most of it came from the air. In 1779 Jan Ingenhousz showed that plants make oxygen only in light.

COMMON MISTAKES

- Thinking plants get their food from the soil. Soil supplies water and minerals; the food (sugar) is made from carbon dioxide and water.
- Believing plants photosynthesize but do not respire. All plant cells respire day and night.
- Saying the oxygen comes from carbon dioxide. The oxygen released comes from splitting water.

Make it a game • Balance the Equation. Write the photosynthesis equation using small square paper tiles: six carbon dioxide, six water, light, glucose, six oxygen. Build it from memory, count atoms to prove it balances, then cover the tiles and rebuild it. Parent removes one factor, such as light or carbon dioxide, and you explain what limits photosynthesis and the roles of chlorophyll and stomata.

Scripture. “He causeth the grass to grow for the cattle, and herb for the service of man: that he may bring forth food out of the earth;” (Psalm 104:14, KJV)

Through photosynthesis God turns sunlight, air and water into the food that feeds every animal and person. Every meal begins with a leaf in the sun.

5.3 FLOWERS, POLLINATION AND FRUIT

OBJECTIVES

- Label the parts of a flower and explain the job of each.
- Explain how pollination and fertilization lead to seeds and fruit.
- Dissect a flower and a fruit and connect their parts.

Warm-up. Sort these foods into two groups, “fruit” and “vegetable,” using your own idea of the words: tomato, apple, carrot, cucumber, pea pod, lettuce, pepper, potato, pumpkin. You will sort them again at the end of the lesson using the botanist’s definition.

WATCH

Look Inside a Flower! | Science Project for Kids

SciShow Kids · 4:14

<https://www.youtube.com/watch?v=R9sn7HZM7uY>

WHEN TO WATCH

Before the flower dissection. It is aimed at younger students, so after watching, add the correct terms (anther, filament, stigma, style, ovary) to what you see.

BACKUP VIDEO

Strawberry Flower to Fruit Time-lapse (Aphids Issue)

eLapse · 2:06

<https://www.youtube.com/watch?v=cLj71H3kiZI>

After the core idea on fruit. Watch the flower parts fall away as the fruit swells.

KEY TERMS

stamen

The pollen-making part of a flower, made of an anther on a thin filament.

pistil

The seed-making part of a flower: the sticky stigma, the stalk-like style, and the ovary at the base.

pollination

The transfer of pollen from an anther to a stigma, by wind, insects, birds or a gardener's brush.

fertilization

The joining of a cell from the pollen with an egg cell in the ovule, which begins a seed.

ovary

The swollen base of the pistil that holds the ovules; after fertilization it ripens into the fruit.

fruit (botanical)

The ripened ovary of a flower, containing seeds. Tomatoes, cucumbers, peppers and squash are fruits in this sense.

CORE IDEAS

A flower is a seed factory. On the outside are green **sepals**, which protected the bud, and colorful **petals**, which advertise to pollinators. Inside are the **stamens**, each an anther full of dusty pollen held on a filament. In the center is the **pistil**: a sticky stigma at the top, a slender style, and the swollen ovary at the base, holding tiny ovules that can become seeds.

Pollination carries pollen from an anther to a stigma. Many crops are pollinated by insects: bees, flies, beetles and butterflies visit flowers for nectar and pollen and carry pollen grains from flower to flower on their hairy bodies. Others are pollinated by wind: corn, wheat, oats and grasses have no showy petals, but make clouds of light pollen and feathery stigmas to catch it. Some plants, like peas, beans and tomatoes, usually pollinate themselves inside the flower.

After pollen lands on a compatible stigma, it grows a tiny tube down through the style to an ovule. A cell from the pollen joins the egg cell inside: this is **fertilization**. The ovule becomes a seed, with a baby plant inside, and the ovary around it swells into the **fruit**. In a corn ear, every kernel had its own silk; if some silks were not pollinated, the ear has gaps. That is why corn is planted in blocks of several short rows instead of one long row, so pollen falls on the silks of neighbors.

Squash, cucumbers and melons have separate pollen-bearing and fruit-bearing flowers on the same vine; the fruit-bearing ones have a tiny fruit at their base. If bees are scarce, a gardener can carry pollen with a small paintbrush. A strawberry is unusual: the “seeds” on the outside are actually the true fruits, and the red flesh is a swollen flower base.

To a botanist, any ripened ovary with seeds is a **fruit**, so tomatoes, cucumbers, peppers, pumpkins, pea pods and even corn kernels are fruits. Carrots (roots), lettuce (leaves) and potatoes (stems) are true vegetables. The care God has built into flowers is extravagant: Jesus said that even Solomon in all his glory was not arrayed like one of the lilies of the field.

PICTURE STUDY



Almond Blossom, Vincent van Gogh, 1890 · Oil on canvas · Van Gogh Museum, Amsterdam

Image: [Wikimedia Commons](#), public domain

Van Gogh painted these branches as a gift when his brother's baby son was born. Almond trees are among the first to bloom in early spring, and their blossoms became a symbol of new life. Almond farmers depend on honeybees to pollinate the flowers; without them, few almonds would form.

Look closely

- Find a fully open blossom. How many petals does it have?
- Find the center of a flower. Can you see the stamens?
- Find the buds that have not yet opened.
- Look at the branches. Are there any leaves yet?

Talk about it

1. Almond trees bloom before their leaves come out. Why might this help bees find the flowers?
2. Which part of each blossom will become the almond? (Think about the ovary.)
3. What might happen to an almond orchard after a cold, rainy week in bloom time when bees cannot fly?

HANDS-ON PROJECT

Dissecting a Flower and a Fruit

You will take apart a flower to find every part, then cut open fruits to find the ovary's work: seeds inside a ripened wall.

You will need

- A large, simple flower such as a lily, tulip or alstroemeria (from a grocery bouquet)
- A hand lens, tweezers and a craft knife or paring knife (adult help)
- Clear tape and white paper
- An apple, a tomato, a pea pod or green bean, and a cucumber
- A dark piece of paper

Steps

1. Draw the whole flower first, from the side.
2. Gently remove the sepals and petals, count them, and tape them to the paper in a row with labels.
3. Remove the stamens. Tap one anther on dark paper and look at the pollen with a hand lens. Tape a stamen down and label the anther and filament.
4. Look at the pistil. Touch the stigma lightly. Is it sticky? Label the stigma, style and ovary.
5. With an adult, slice the ovary crosswise and look for the tiny ovules inside. Count them.
6. Cut an apple crosswise (around its middle). Find the five-pointed star of seed chambers: these match the five parts of the apple flower's pistil.
7. Open a pea pod, a tomato and a cucumber. For each, find the seeds and decide what part of the old flower the fruit came from.
8. Re-sort your warm-up list into botanical fruits and vegetables, and explain each choice.

Tips

- Lilies have very large parts but their pollen stains clothes; work on newspaper.
- Look at the blossom end of the cucumber or tomato for the dried remains of the flower.

Check your work

- ☐ I found and labeled sepals, petals, stamens (anther and filament) and pistil (stigma, style, ovary).
- ☐ I found ovules in the flower and seeds in the fruits.
- ☐ I can explain how pollination and fertilization turn an ovary into a fruit.

NATURE JOURNAL

1. Draw a large labeled cross-section of a flower showing every part, with a pollen tube growing down to an ovule.
2. Draw your apple's cross-section with its five seed chambers.
3. Draw an ear of corn with silks, and explain in a sentence why each kernel needs its own grain of pollen.

From history. In 1694 the German botanist Rudolf Camerarius showed by experiment that plants need pollen to make seeds. In the 1700s Joseph Kölreuter carried pollen by hand between tobacco plants, and Christian Sprengel spent years watching insects visit flowers, discovering that many flowers are designed to be visited by particular pollinators.

COMMON MISTAKES

- Confusing pollination with fertilization. Pollination moves pollen to the stigma; fertilization happens later, inside the ovule.
- Planting corn in one long row, which leads to poorly filled ears.
- Calling tomatoes and cucumbers vegetables in a science answer. Botanically they are fruits.

Make it a game • Flower Fruit Story Chain. Tell a story chain with your parent, one sentence each, following a bee on a flower: petals attract it, pollen sticks to the stamen, travels to the pistil, fertilization happens, and the ovary swells into fruit. Each sentence must use a correct term. Parent adds one wrong sentence on purpose; catch it. Finish by labeling a quick flower drawing.

Scripture. “Consider the lilies of the field, how they grow; they toil not, neither do they spin: And yet I say unto you, That even Solomon in all his glory was not arrayed like one of these.” (Matthew 6:28-29, KJV)

Jesus told His followers to “consider” the flowers, to look closely. Dissecting a flower is one way of doing what He said, and it reveals beauty and design down to the smallest grain of pollen.

5.4 GREGOR MENDEL'S PEAS AND HEREDITY

OBJECTIVES

- Describe Mendel's pea experiments and the 3:1 pattern he discovered.
- Use the terms gene, allele, dominant, recessive, genotype and phenotype correctly.
- Predict the results of a cross with a Punnett square and test the prediction with a simulation.

Warm-up. Look at the people in your family, or at a litter of kittens or puppies you have seen. List three traits that children share with a parent and one trait that seemed to “skip” a generation.

WATCH

How Mendel's pea plants helped us understand genetics - Hortensia Jiménez Díaz

TED-Ed · 3:06

<https://www.youtube.com/watch?v=Mehz7tCxjSE>

WHEN TO WATCH

After the first two core ideas. Pause at the second generation and predict the ratio before it is shown.

KEY TERMS

heredity

The passing of traits from parents to offspring.

gene

A unit of inherited information that helps determine a trait; Mendel called them “factors.”

allele

One version of a gene, such as the version for round peas or the version for wrinkled peas.

dominant and recessive

A dominant allele shows its trait whenever it is present; a recessive allele shows only when an organism has two copies of it.

genotype and phenotype

The genotype is the pair of alleles an organism carries (such as Rr); the phenotype is the trait you can see (round).

Punnett square

A grid used to predict the possible allele combinations in the offspring of a cross.

CORE IDEAS

Gregor Mendel (1822–1884) was a friar at the Abbey of St. Thomas in Brno, in what is now the Czech Republic, and a teacher of science. In the monastery garden, from about 1856 to 1863, he grew and studied tens of thousands of pea plants. Peas were a wise choice: they grow quickly, they normally pollinate themselves, and they come in clear, contrasting forms. Mendel studied seven traits, including round or wrinkled seeds, yellow or green seeds, purple or white flowers, and tall or short stems.

First, Mendel grew pure lines that always produced the same trait. Then he crossed them by hand: he removed the stamens from a flower before they shed pollen and dusted its stigma with pollen from a plant of the other type. When he crossed round-seeded peas with wrinkled-seeded peas, *every* offspring had round seeds. The wrinkled trait seemed to vanish. But when he let those offspring pollinate themselves, wrinkled seeds came back in the next generation, about one in every four. In one count he found 5,474 round and 1,850 wrinkled seeds, a ratio of almost exactly 3 to 1.

Mendel explained this with “factors” that we now call **genes**. Each plant carries two copies of each gene, one from each parent, and passes on only one copy in each pollen grain or egg cell. A gene can come in different versions, or **alleles**. Call the round allele R and the wrinkled allele r . R is **dominant**: an Rr plant has round seeds. r is **recessive**: only rr plants have wrinkled seeds. The letters (RR , Rr , rr) are the **genotype**; what you see (round or wrinkled) is the **phenotype**.

A **Punnett square** shows why the 3:1 ratio appears. Write one parent’s two alleles across the top (R , r) and the other’s down the side (R , r). Fill in the four boxes: RR , Rr , Rr , rr . Three of the four have at least one R and are round; one is rr and wrinkled. The square gives probabilities, not guarantees, which is why Mendel needed thousands of seeds to see the pattern clearly.

Mendel published his results in 1866, but almost no one understood them until 1900, when three botanists rediscovered his paper. Today his laws are the foundation of

genetics and of plant and animal improvement: every heirloom tomato kept true to type and every new disease-resistant variety rests on them. Mendel's patient counting shows the orderly way God made living things to reproduce "after his kind."

PICTURE STUDY



Garden Pea (*Pisum sativum*), Otto Wilhelm Thomé, 1885 · Chromolithograph from *Flora von Deutschland, Österreich und der Schweiz* · *Flora von Deutschland, Österreich und der Schweiz*

Image: [Wikimedia Commons](#), public domain

Professor Otto Thomé's great German flora, published while Mendel was still alive, showed thousands of plants in clear colored plates. Here is the very plant Mendel used, the garden pea, with its flowers, pods and seeds.

Look closely

- Find the tendrils. What do they help the pea plant do?
- Find a flower. What color is it? (Mendel studied purple and white flowers.)
- Find the pods and the seeds inside. Are the seeds round or wrinkled?
- Look at the small numbered drawings of flower parts. Can you find the stamens and the pistil?

Talk about it

1. Pea flowers keep their stamens and pistil enclosed inside the petals. Why did that make peas perfect for Mendel's experiments?
2. Which of the traits you can see on this plate did Mendel study?
3. Why do you think a careful drawing was useful to scientists before photographs were common?

HANDS-ON PROJECT

Predicting and Testing a Pea Cross

You will use Punnett squares to predict the results of crosses, test the 3:1 prediction with a coin simulation, and examine real peas for Mendel's seed traits.

You will need

- Two coins and masking tape
- A marker
- Your journal
- A bag of dried whole green peas and a bag of dried whole yellow peas from the grocery store (optional), or a seed packet of a wrinkled-seeded and a round-seeded pea
- A hand lens

Steps

1. Put a piece of tape on each side of both coins. On each coin, write R on one side and r on the other. Each coin is an Rr parent.
2. Predict: draw a Punnett square for $Rr \times Rr$. What fraction of offspring should be round? Wrinkled?
3. Flip both coins together 100 times. Each flip is one offspring. Tally RR , Rr and rr .
4. Count round ($RR + Rr$) and wrinkled (rr) offspring and divide to find your ratio. How close is it to 3:1?
5. Combine your results with a family member's 100 flips. Does the ratio come closer to 3:1 with more flips? Explain why.
6. Draw Punnett squares for $RR \times rr$ and for $Rr \times rr$, and predict the results of each.
7. Look at dried peas or seed-packet peas with a hand lens. Find round and wrinkled seeds and yellow and green seeds. Sweet, wrinkled seeds belong to garden varieties with more sugar and less starch.

8. Plan a real cross to try this spring: which two pea varieties would you cross, and which trait would you watch?

Tips

- Wrinkled-seeded peas include many sweet garden varieties; smooth-seeded peas are often sold as soup peas or early varieties.
- Real pea crosses take two growing seasons to show the 3:1 result, just as Mendel's did.

Check your work

- ☐ I drew correct Punnett squares for three crosses.
- ☐ I flipped at least 100 times and compared my ratio with 3:1.
- ☐ I can explain the difference between genotype and phenotype using pea seeds.

NATURE JOURNAL

1. Draw a family tree for three generations of peas: round × wrinkled parents, all-round children, and grandchildren in a 3:1 ratio. Write each genotype.
2. Draw a pea flower in cross-section and show where Mendel removed the stamens and added pollen.
3. Copy Mendel's seven traits in a chart, with the dominant and recessive form of each.

From history. In 1900 three botanists, Hugo de Vries, Carl Correns and Erich von Tschermak, each rediscovered Mendel's forgotten paper. In 1905 the English geneticist Reginald Punnett invented the square that bears his name, partly to explain Mendel's results to farmers and students.

COMMON MISTAKES

- Thinking a 3:1 ratio means every group of four offspring will have exactly three round and one wrinkled. It is a probability.
- Confusing dominant with "more common" or "better." Dominant only means it shows when present.
- Mixing up genotype (the letters) and phenotype (what you see).

Make it a game • Pea Cross Punnett Duel. Draw a four-box Punnett square on paper and cross two pea plants, tall (T) and short (t). Parent chooses the parents, such as Tt and Tt, and you fill in the boxes, then name each genotype and phenotype and the 3:1 pattern. Explain gene, allele, dominant and recessive. Score a point per correct box. Mendel would be proud.

Scripture. “And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good.” (Genesis 1:12, KJV)

Seed “after his kind” is the steady pattern Mendel measured. Peas give peas, with traits passed on by orderly laws God built into living things.

UNIT 5

PLANT SCIENCE

Late winter is seed-catalog season, and the best time to look closely at how a plant actually works. In this unit you will go inside the plant: to its cells and the pipelines that carry water and sugar, to the chemical reaction that turns sunlight, water and air into food, to the flower where seeds and fruit begin, and to the garden of a patient friar who discovered the rules of heredity by counting peas.

Each lesson pairs real science vocabulary with a hands-on experiment you can do at a kitchen table. As you learn, notice how much order and wisdom is built into even the smallest leaf. “And the earth brought forth grass, and herb yielding seed after his kind ... and God saw that it was good” (Genesis 1:12).

PREREQUISITES

- Knows the main parts of a plant: roots, stem, leaves, flowers, fruit and seeds
- Has used a hand lens
- Can read a simple chemical formula such as H_2O or CO_2

MASTERY CHECKLIST

- ☐ I can name the parts of a plant cell and the three tissue systems, and explain what xylem and phloem do.
- ☐ I can write and explain the photosynthesis equation and name the factors that limit it.
- ☐ I can label the parts of a flower and explain how pollination leads to seeds and fruit.
- ☐ I can explain Mendel’s experiments and use a Punnett square to predict the results of a cross.

LESSONS IN THIS UNIT

5.1 Cells, Tissues and the Vascular System

2 sessions of 50 minutes

5.2 The Photosynthesis Equation

2 sessions of 50 minutes

5.3 Flowers, Pollination and Fruit

2 sessions of 50 minutes

5.4 Gregor Mendel’s Peas and Heredity

2 sessions of 50 minutes

UNIT 5 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

Name three parts of a plant cell that animal cells do not have, and the job of each.

2. (8 pts)

What is the difference between xylem and phloem?

3. (7 pts)

Why does a lettuce leaf wilt, and why does it firm up in cold water?

4. (8 pts)

Write the balanced equation for photosynthesis.

5. (7 pts)

Where does the oxygen released in photosynthesis come from?

6. (7 pts)

Name four factors that can limit photosynthesis.

7. (8 pts)

Name the parts of the stamen and the parts of the pistil.

8. (7 pts)

After fertilization, what does the ovule become, and what does the ovary become?

9. (8 pts)

Why should sweet corn be planted in a block instead of a single row?

10. (8 pts)

Use a Punnett square to predict the offspring of $Rr \times rr$ peas (R = round, r = wrinkled).

11. 12 pts

Explain how Mendel's round × wrinkled cross showed that the wrinkled trait had not disappeared.

12. 13 pts

Explain why a sunflower's weight comes mostly from the air rather than the soil.

ANSWER KEY

1. Cell wall (support), chloroplasts (photosynthesis), large central vacuole (stores water, keeps the plant firm).
2. Xylem is dead, hollow cells carrying water and minerals up from the roots; phloem is living cells carrying sugar from the leaves to the rest of the plant.
3. Without water, the vacuoles shrink and turgor pressure falls, so it wilts; in water the cells refill and press against their walls again.
4. $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.
5. From water molecules split by light energy.
6. Light, carbon dioxide, temperature and water.
7. Stamen: anther and filament. Pistil: stigma, style and ovary (with ovules).
8. The ovule becomes a seed; the ovary becomes the fruit.
9. Corn is wind-pollinated and each kernel needs pollen on its own silk; in a block, pollen from the tassels falls on neighboring silks, so ears fill completely.
10. Rr, Rr, rr, rr: half round (Rr) and half wrinkled (rr), a 1:1 ratio.
11. All the first-generation offspring were round, so the wrinkled trait seemed gone. But when those plants (Rr) pollinated themselves, about one in four of the next generation had wrinkled seeds (rr). The recessive allele had been carried, hidden, in the first generation.
12. Through photosynthesis the plant takes carbon dioxide from the air and water from the soil and builds them into sugar, cellulose and starch. Most of its dry weight is carbon from carbon dioxide; the soil supplies only water and small amounts of minerals.

PORTFOLIO PIECE: A PLANT SCIENCE LAB NOTEBOOK

Assemble a lab notebook with a formal write-up of two of this unit's experiments (celery and turgor, floating leaf disks, flower dissection, or the Mendel simulation). Each write-up includes a question, a hypothesis, materials, procedure, a data table, a graph, and a conclusion that uses at least five key terms correctly. Add one labeled diagram from each lesson.

LOOK FOR	WHAT IT MEANS
Scientific method	Each write-up has a clear question, hypothesis, procedure and conclusion.
Data	Data tables are complete and graphs are labeled with titles, axes and units.
Accuracy	Conclusions and diagrams are scientifically correct and use key terms properly.
Diagrams	One clear, labeled diagram is included from each of the four lessons.
Neatness	The notebook is organized, dated and easy to follow.

UNIT 6

FARM ANIMALS AND BEES

Early spring is the busiest season in the barnyard: lambs and kids arrive, cows freshen and give their richest milk, sheep are shorn, and honeybee colonies wake up and begin to build. In this unit you will study farm animals the way a farmer and a 4-H or FFA member must: how their bodies are designed to turn grass and grain into milk, wool and meat, how to care for their feet and fleece, how judges evaluate them, and how bees turn nectar into honey.

No livestock is needed. A farm visit, a county fair, a 4-H member's barn, a dairy tour or a local beekeeper will teach you a great deal, and every project has a no-farm option. "Be thou diligent to know the state of thy flocks, and look well to thy herds" (Proverbs 27:23).

PREREQUISITES

- Knows what farm animals give us: milk, eggs, wool, meat, work and honey
- Knows the three castes of honeybees: queen, workers and drones
- Has learned the farm safety rules: an adult present, move calmly, never stand behind a horse or cow

MASTERY CHECKLIST

- ☐ I can compare ruminant and single-stomach digestion and explain why a cow can live on grass and a pig cannot.
- ☐ I can name the major dairy breeds, describe how milk is produced and processed, and place a class of four cows with oral reasons.
- ☐ I can explain why sheep are shorn and why hooves are trimmed, and describe good showmanship.
- ☐ I can explain how bees turn nectar into honey and how a beekeeper harvests, extracts and exhibits it.
- ☐ I can keep an expense and income record for a small animal project.

LESSONS IN THIS UNIT

6.1 Ruminant and Single-Stomach Digestion

2 sessions of 50 minutes

6.2 Dairy Cattle and Milk

2 sessions of 50 minutes

UNIT 6 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. **8 pts**
Name the four compartments of a ruminant's stomach in order and give one job of each.
2. **7 pts**
Why can a cow live on grass while a pig cannot?
3. **7 pts**
What is a hindgut fermenter? Name one.
4. **7 pts**
Name four of the six major dairy breeds and one fact about one of them.
5. **8 pts**
Describe a cow's lactation cycle.
6. **7 pts**
What does pasteurization do, and how is it typically done?
7. **8 pts**
In dairy judging, which trait counts most on the scorecard, and why?
8. **7 pts**
Why must wool sheep be shorn, and why must hooves be trimmed?
9. **7 pts**
Name three things a showmanship judge looks for in the exhibitor.

10. **8 pts**

Name two things bees do to turn nectar into honey.

11. **13 pts**

Write a short set of oral reasons for placing Cow 3 over Cow 1, using at least two comparing terms and one grant.

12. **13 pts**

Explain why honey keeps for years without spoiling, connecting it to what you learned about food preservation.

ANSWER KEY

1. Rumen (microbes ferment fiber), reticulum (sorts food, sends up cud), omasum (absorbs water), abomasum (true stomach, acid and enzymes).
2. Microbes in the cow's rumen digest cellulose; the pig has a simple stomach and cannot digest much fiber.
3. A single-stomach animal that digests fiber with microbes in its cecum after the stomach. Horse or rabbit.
4. Any four of Holstein, Jersey, Guernsey, Brown Swiss, Ayrshire, Milking Shorthorn; e.g., Holsteins give the most milk; Jerseys give the richest milk.
5. She has a calf, gives milk for about ten months, then has a dry period of about two months before her next calf.
6. Kills harmful bacteria; milk is heated to about 161°F for 15 seconds, then quickly cooled.
7. The udder (about 40 percent), because a strong, well-attached udder lets a cow stay healthy and productive for many years.
8. Their wool keeps growing; unshorn sheep suffer heat, dirt and flies. Hooves grow continually; overgrown hooves cause lameness and foot rot.
9. Any three: clean, well-groomed animal; neat dress; calm control; correct posing; watching the judge; staying on the correct side; knowledge of the animal's breed, age, feed and care; courtesy.
10. They add enzymes (invertase splits sucrose into glucose and fructose) and they evaporate water by fanning until it is about 17–18 percent water, then cap it.
11. Sample: "I placed 3 over 1 because 3 has a higher, wider rear udder with a stronger attachment and stands on a straighter, stronger rear leg. 3 is also longer and more open in her rib. I grant that 1 is taller at the shoulder and smoother in the neck."
12. Bees evaporate honey to about 17–18 percent water, so there is too little free water for microbes; its high sugar draws water out of any microbes by osmosis; and enzymes make it slightly acidic and add a little hydrogen peroxide. These take away what microbes need, just as drying and sugaring preserve food.

PORTFOLIO PIECE: A 4-H-STYLE ANIMAL PROJECT RECORD

Choose one farm animal or a beehive (one you care for, or one you visit and follow with its owner's help). Keep a record for the rest of the unit and beyond in the style of a 4-H project book: the animal's or hive's description, a feeding or care schedule, a dated log of what you did and observed, an expense and income table, a health or hive-inspection record, a photo or drawing, and a page on what you learned. Include your dairy placing card and reasons, or your honey exhibit, as an extra page.

LOOK FOR	WHAT IT MEANS
Complete records	The log is dated, regular and specific (feed, water, weights, eggs, milk, hive notes).
Money	The expense and income table is complete and correctly totaled.
Husbandry	The care schedule and health record show sound, humane, accurate animal care.
Evaluation	The placing card and reasons (or honey exhibit) use correct terms and clear comparisons.
Reflection	The "what I learned" page is thoughtful and specific.

6.1 RUMINANT AND SINGLE-STOMACH DIGESTION

OBJECTIVES

- Name the four compartments of a ruminant's stomach and the job of each.
- Compare the digestion of ruminants, pigs, chickens, horses and rabbits.
- Read livestock feed tags and explain why different animals need different feeds.

Warm-up. Chew a cracker for 30 seconds without swallowing and notice how it changes. Now imagine eating only grass, which is mostly tough fiber. List three problems your stomach would have.

WATCH

Ruminant Nutrition: A Symbiotic Relationship

Penn State Extension · 5:12

<https://www.youtube.com/watch?v=GedC1WjJEnM>

WHEN TO WATCH

After the core ideas. Pause each time a stomach compartment is named and add it to your diagram.

BACKUP VIDEO

Mobile Dairy Classroom: Learn About Cattle Eating Habits and Cow Digestion, Grades 4-6

Dairy Council of California · 3:04

<https://www.youtube.com/watch?v=meMHJ4Pt8kl>

A shorter review, filmed with a real cow, if the first video is unavailable.

KEY TERMS

ruminant

A hooved animal with a four-compartment stomach that chews cud, such as a cow, sheep, goat or deer.

rumen

The largest stomach compartment of a ruminant, a fermentation vat where microbes digest fiber.

cud

A wad of partly digested food that a ruminant brings back up to chew again.

monogastric

Having a single, simple stomach, as pigs, chickens, dogs and people do.

hindgut fermenter

A single-stomach animal, such as a horse or rabbit, that digests fiber with microbes in a large cecum after the stomach.

forage

Grass, hay, silage and other leafy plant feed for livestock.

candling

Shining a bright light through an egg to check its air cell, yolk and shell for grading.

CORE IDEAS

Grass is everywhere, but it is mostly cellulose, which no mammal can digest on its own. **Ruminants** such as cattle, sheep, goats and deer solve the problem with a partnership. Their huge **rumen**, which in a grown cow holds about 40 to 50 gallons, is home to billions of bacteria, protozoa and fungi that ferment fiber. The microbes break cellulose into fatty acids that supply most of the animal's energy, and the microbes themselves, washed onward and digested, supply much of its protein.

Food passes through four compartments. The **rumen** ferments it. The **reticulum**, lined with a honeycomb pattern, sorts it and sends large pieces back up the throat as **cud**, which the animal chews again; a cow may spend seven or eight hours a day chewing her cud and makes a great deal of saliva, which keeps the rumen from turning too acidic. The **omasum**, full of leaf-like folds, absorbs water. The **abomasum** is the "true stomach," with acid and enzymes much like ours. A newborn calf drinking milk has a groove that sends milk straight to the abomasum, because its rumen is not yet working.

Monogastric animals have one simple stomach. Pigs, like people, are omnivores; they cannot live on grass, and need grain, protein and minerals in balanced amounts. Chickens have no teeth: food goes to a storage pouch called the crop, then

a glandular stomach, then the muscular gizzard, which grinds food with small stones the bird swallows.

Horses and rabbits are single-stomach animals that eat grass. They are **hindgut fermenters**: microbes in a large pouch called the cecum, after the stomach, ferment fiber. Rabbits even re-eat special soft droppings from the cecum to get the vitamins and protein the microbes made. That is why horses and rabbits need plenty of hay and why sudden diet changes can make them very sick.

These designs shape farm life. Cattle, sheep and goats can turn pasture and hay that people cannot eat into milk, meat and wool, so they can graze land too steep or rocky to plow. A ruminant switched suddenly to too much grain can get bloat or acidosis, so feed changes are made slowly. Reading a feed tag, and knowing why a layer hen, a growing pig and a beef calf get different feeds, is basic good husbandry.

A hen's feed becomes eggs, and eggs are graded for quality. In **candling**, an egg is held up to a bright light in a dark room to see inside the shell. Graders check the air cell at the wide end (small in a fresh egg; it grows as the egg ages), the yolk (a faint, centered shadow in a top egg) and the shell (clean, smooth, uncracked). U.S. grades are AA (tiny air cell, firm white, clean shell), A (slightly larger air cell, reasonably firm white), and B (larger air cell, thinner white, or slight shell stains). Many 4-H poultry contests include egg candling and grading.

PICTURE STUDY



Ploughing in the Nivernais, Rosa Bonheur, 1849 · Oil on canvas · Musée d'Orsay, Paris

Image: [Wikimedia Commons](#), public domain

Rosa Bonheur was one of the most famous animal painters of the 1800s. She spent long days at farms, fairs and livestock markets sketching cattle, horses and sheep so she could paint them exactly. Here, teams of oxen plow a field in central France in autumn. Oxen are cattle trained for work: ruminants turning grass and hay into pulling power.

Look closely

- Count the oxen and the teams. How are they joined to the plows?
- Look at the turned soil. Which way is the furrow going?
- Look at the oxen's heads and the wooden yoke. Where does the pulling force go?
- Find the drivers. Where do they stand, and what are they holding?

Talk about it

1. What did these oxen eat to have strength for plowing? Why couldn't a horse or pig live on the same diet as easily?
2. Why were oxen often preferred to horses for slow, heavy work on small farms?
3. What season do you think this is? What clues tell you?

Safety first. On a farm visit, an adult must be present. Move calmly and quietly, never stand directly behind cattle, sheep or goats, stay outside pens unless the farmer invites you in, and wash hands after touching animals, feed or fences.

HANDS-ON PROJECT

Four Stomachs and a Feed Store

You will draw a ruminant digestive system to scale, observe cud chewing, and compare real livestock feed tags.

You will need

- Large paper and colored pencils
- A timer
- Access to a farm, a 4-H member's animals, or a video of a cow or goat chewing cud
- A visit to a farm-supply store, or feed tags found on manufacturers' websites
- Your journal
- Six eggs of different ages, a bright flashlight and a plate

Steps

1. Draw a large outline of a cow from the side. Inside it, draw and color the esophagus, rumen, reticulum, omasum, abomasum, small intestine and large intestine, with the rumen filling most of the left side.
2. Add arrows showing the path of food, including the trip back up as cud. Label each compartment with its job.
3. Watch a cow, sheep or goat chewing cud (at a farm or in a video). Count the chews for one cud and time how long until it swallows and brings up the next. Repeat for three cuds and average.
4. At a farm store or online, copy the feed tags for three feeds: one for laying hens, one for growing pigs, and one for cattle, sheep or goats. Record the crude protein, crude fat and crude fiber.
5. Compare the fiber in each. Which animal's feed has the most? Explain why, using what you know about digestion.
6. Find any warnings on the tags (for example, some cattle feeds must not be fed to sheep because of their copper content). Write them down.

7. Egg grading: in a dark room, hold each of six eggs (some fresh, some two or three weeks old) against a bright flashlight cupped in your hand. Sketch the air cell of each, then crack one fresh and one older egg onto a plate and compare the height of the white and yolk. Grade each egg AA, A or B and explain why.
8. Write a one-paragraph explanation for a younger child: “Why a cow can eat grass and you can’t.”

Tips

- Ruminants usually chew 40 to 60 times per cud. See how close your count comes.
- Farm-store staff and 4-H leaders are usually glad to explain feeds; ask politely.

Check your work

- ☐ My diagram shows all four compartments in the right order with their jobs.
- ☐ I recorded cud-chewing counts and times.
- ☐ I compared three feed tags and explained the differences in fiber and protein.
- ☐ I candled and graded eggs AA, A or B and explained my grades.

NATURE JOURNAL

1. Draw a chicken’s digestive system: beak, crop, glandular stomach, gizzard, intestines. Label the gizzard and explain the grit.
2. Make a chart comparing cow, pig, chicken, horse and rabbit: stomach type, where fiber is digested, main foods.
3. If you visit a farm, sketch an animal chewing cud and note the time of day and what it had been eating.

From history. In the 1940s the American microbiologist Robert Hungate, studying the rumen, invented ways to grow bacteria that can live only without oxygen. His methods let scientists finally identify the many microbes that digest grass inside a cow, and they are still used in laboratories around the world.

COMMON MISTAKES

- Saying a cow has four stomachs. It has one stomach with four compartments.

- Thinking horses and rabbits are ruminants. They eat grass but are single-stomached hindgut fermenters.
- Changing a ruminant's feed suddenly, which can cause bloat or acidosis.

Make it a game • Gut Tour Guide. You are a tour guide inside an animal. Pick ruminant, pig, chicken, horse or rabbit, and lead your parent through the digestive system in order, naming each compartment's job. Your parent guesses the animal from your tour. For ruminants, name rumen, reticulum, omasum and abomasum. Score a bean for a correct guess; first to five wins.

6.2 DAIRY CATTLE AND MILK

OBJECTIVES

- Identify the six major dairy breeds and describe the lactation cycle.
- Explain how milk is kept clean and safe from cow to carton, including pasteurization.
- Place a judging class of four dairy cows and give oral reasons.

Warm-up. Look at a carton or jug of milk. Copy every word and number on the label that tells you how the milk was processed (pasteurized, homogenized, percent fat, vitamins). Guess what each word means.

WATCH

Follow Milk's Journey from Farm to Store

Midwest Dairy • 4:54

<https://www.youtube.com/watch?v=1LEGl6SF4Jc>

WHEN TO WATCH

After the core ideas on milk. List each step from cow to store in order.

BACKUP VIDEO

Holstein Senior 3 Year Old Cow Reasons by Jordan Siemers of Wisconsin 4-H

University of Wisconsin Extension • 2:50

<https://www.youtube.com/watch?v=f8z6aChCJeo>

Watch before giving your own oral reasons in the project. Listen for how she compares each pair of cows.

KEY TERMS

lactation

The period when a cow gives milk, beginning when she has a calf and lasting about ten months.

dry period

About two months before her next calf when a cow is not milked, so her udder can rest and rebuild.

heifer

A young female cow that has not yet had a calf.

pasteurization

Heating milk briefly (for example to 161°F for 15 seconds) to kill harmful bacteria, then cooling it quickly.

mastitis

An infection of the udder, prevented by clean housing and careful, clean milking.

oral reasons

A short spoken explanation, given to a judge, of why you placed a class of animals in the order you did.

CORE IDEAS

Six dairy breeds are common in the United States and in 4-H dairy shows. **Holsteins**, black and white or red and white, are the largest and give the most milk. **Jerseys**, small and fawn-colored, give less milk but the richest, highest in butterfat.

Guernseys give golden-tinted milk; **Brown Swiss** are large, gray-brown and long-lived; **Ayrshires** are red and white and hardy; and **Milking Shorthorns** are red, white or roan. A good dairy cow today often gives more than 20,000 pounds of milk a year, over 2,300 gallons.

Like all mammals, a cow makes milk after she has a young one. A **heifer** usually has her first calf at about two years old and begins her **lactation**, which lasts about ten months; she then has a **dry period** of about two months before her next calf. On dairy farms, calves are raised by hand on milk or milk replacer. Most heifer calves grow up to join the milking herd, and most bull calves are raised for beef. Cows are milked two or three times a day, often by machines or by robots the cows visit on their own.

Clean milk starts in the barn. Clean, dry bedding and careful milking prevent **mastitis**. Before milking, each teat is cleaned and dipped in a disinfectant; milk flows through closed stainless-steel pipes into a refrigerated tank and is cooled to below 40°F within a couple of hours. Every load is tested before it reaches the dairy plant. There it is **pasteurized**, typically heated to 161°F for 15 seconds and quickly cooled, which kills harmful bacteria. Most milk is also homogenized, forced through tiny openings so the cream stays mixed instead of rising to the top.

Milk is about 87 percent water. The rest is butterfat, protein (mostly casein, which makes cheese), lactose (milk sugar), and minerals such as calcium. Shake cold cream

long enough and the fat globules clump into butter; add rennet or acid to milk and the casein curdles into cheese curds.

Dairy judging is one of the oldest 4-H and FFA contests. Judges use a scorecard that values the udder most (about 40 percent), then dairy strength (25 percent), feet and legs (20 percent) and frame (15 percent), because a cow with a strong, well-attached udder and sound feet will stay healthy and productive for many years. Contestants place a class of four cows from best to last and then give **oral reasons**: a two-minute talk comparing each pair with specific terms. Learning to look carefully and explain a judgment clearly is a skill for life.

PICTURE STUDY



Milking Time, Winslow Homer, 1875 · Oil on canvas · Delaware Art Museum, Wilmington

Image: [Wikimedia Commons](#), public domain

Winslow Homer painted many scenes of American farm life after the Civil War. Here the cows wait in the pasture, and the children of the farm are ready with pail and stool for milking.

Look closely

- Count the cows. What colors are they?
- Find the girl and her milk pail. What is she about to do?
- Find the boy on the fence. What might his chore be?
- Find the milking stool. Why would a milker need one?

Talk about it

1. Cows are milked at about the same times every day. Why does a regular schedule matter for the cow?
2. How is milking in this painting different from milking on a modern dairy farm? How is it the same?
3. What chores would children on this farm have done every morning and evening?

Safety first. On a dairy visit, stay behind the farmer, move slowly, and never walk directly behind a cow, which may kick. Do not drink raw (unpasteurized) milk. Wash hands after touching animals.

HANDS-ON PROJECT

Judge a Dairy Class and Make Butter

You will place a class of four cows the way 4-H and FFA dairy judges do, write a placing card, give oral reasons, and then turn cream into butter to see milk's parts with your own eyes.

You will need

- Four side-view photos of cows of the same breed and similar age (from a breed association, a fair results page, or an extension dairy-judging practice site), printed or on a screen
- Index cards for a placing card and notes
- A timer
- 1 cup of cold heavy cream, a clean pint jar with a tight lid, a pinch of salt
- A strainer and a bowl

Steps

1. Label the four cows 1, 2, 3 and 4. Study each from the side for one minute: udder (high, wide, firmly attached, level floor), dairy strength (long neck, open ribs, clean bone), feet and legs (strong, straight, good hoof angle), and frame (long, level topline).
2. Decide your placing from best to last, for example 2-1-4-3. Write it on a placing card with your name.
3. For each pair (top, middle and bottom), write one or two reasons using comparing words: "I placed 2 over 1 because 2 has a higher, wider rear udder and stands on a straighter leg."
4. Add a "grant": something good about the lower-placed cow. ("I grant that 1 is longer in the neck.")
5. Practice your reasons aloud, then give them to a parent from memory in under two minutes. Ask your listener whether each reason was clear.
6. Butter: fill the jar halfway with cold cream, close the lid tightly, and shake hard. Record the time when the cream becomes whipped, then when it suddenly separates into a yellow lump and liquid.

7. Strain off the buttermilk. Rinse the butter in cold water, pressing it until the water runs clear, and stir in a pinch of salt.
8. Write which parts of milk you can now see: butterfat (butter) and the watery buttermilk that still holds protein and lactose.

Tips

- Look for 4-H dairy judging practice classes from your state extension office; many post photos with official placings to check your work.
- In real contests, reasons are given without notes. Short, specific, confident sentences score best.

Check your work

- ☐ I placed four cows and wrote a placing card.
- ☐ I gave oral reasons comparing each pair, with at least one grant, in under two minutes.
- ☐ I made butter and can explain what happened to the butterfat.

NATURE JOURNAL

1. Draw the six dairy breeds side by side as simple outlines, colored correctly, with one fact about each.
2. Draw a flowchart of milk's journey: cow, milking, cooling tank, truck, testing, pasteurizing, homogenizing, packaging, store.
3. Draw a dairy cow from the side and label the parts judges look at: udder, rear leg, hoof, topline, ribs, neck.

From history. In the 1860s Louis Pasteur discovered that gentle heating kills spoilage microbes in liquids, and the method was soon applied to milk. In the early 1900s, pasteurizing city milk greatly reduced illness among children. 4-H dairy clubs grew up in the same years, and many county fairs still hold youth dairy shows and judging contests; check your county fair book for the rules.

COMMON MISTAKES

- Thinking cows give milk all the time without having calves.
- Placing animals on color or size alone instead of on the scorecard traits.
- Giving oral reasons that only describe one cow. Good reasons always compare: "2 over 1 because..."

Make it a game • Dairy Breed Cards. Draw the six major dairy breeds on cards and shuffle them. Pull one and tell a fact about it for your parent to guess the breed. Next, build the lactation cycle on a timeline: calving, milking peak, dry period, heifer growth. Then explain how milk stays clean from cow to carton and what pasteurization does.

Scripture. “Be thou diligent to know the state of thy flocks, and look well to thy herds.” (Proverbs 27:23, KJV)

A good dairyman knows each cow: her udder, her feet, her appetite, her milk. Judging trains exactly that kind of careful looking.

6.3 SHEEP AND GOATS: SHEARING, HOOF CARE AND SHOWMANSHIP

OBJECTIVES

- Explain why sheep are shorn and describe how a fleece is handled.
- Explain why hooves must be trimmed and describe how it is done safely.
- Describe good showmanship for small animals and for sheep and goats.

Warm-up. Look at your own fingernails. How long since you trimmed them? Write what would happen if they never wore down or were never trimmed. Then guess what happens to a goat's hooves in a soft, grassy pen.

WATCH

How to Shear Sheep and Why It's Important

The Livestock Conservancy • 11:32

<https://www.youtube.com/watch?v=mANMw7nFYIQ>

WHEN TO WATCH

After the core ideas on shearing. Note how the shearer positions the sheep so it stays calm.

BACKUP VIDEO

4-H Dairy Goat Showmanship

NDSU Extension 4-H • 6:58

<https://www.youtube.com/watch?v=ahUN3OClyus>

Before the showmanship part of the project. List every rule the exhibitor follows.

KEY TERMS

fleece

The whole coat of wool shorn from one sheep, which comes off in one piece.

skirting

Removing the dirty, matted or short wool from the edges of a fleece before it is sold or spun.

hoof wall

The hard outer rim of the hoof, which grows continually like a fingernail.

foot rot

A painful bacterial infection of the hoof, encouraged by wet, muddy ground and overgrown hooves.

browser

An animal, like a goat, that prefers to eat leaves, twigs and shrubs; sheep are grazers that prefer grass.

showmanship

A class in which the exhibitor, not the animal, is judged on how well he or she prepares, handles and presents the animal.

body condition score

A hands-on score of an animal's fat cover, from 1 (very thin) to 5 (very fat) for sheep and goats, felt along the backbone and loin.

CORE IDEAS

Wild sheep shed their coats, but most modern wool sheep have been kept and improved by shepherds for so long that their wool keeps growing. A wool sheep must be **shorn** at least once a year, usually in spring before hot weather, or it suffers from heat, carries dirt and burrs, and can be attacked by flies. A skilled shearer sets the sheep on its rump, where it relaxes, and removes the **fleece** in one piece in a few minutes, without hurting the animal. A typical fleece weighs roughly 5 to 10 pounds. The fleece is spread out, **skirted**, rolled and bagged for sale, spinning or felting.

Sheep and goats are both small ruminants, but they eat differently. Sheep are grazers that prefer grass. Goats are **browsers** that prefer leaves, twigs and brush. Dairy goat breeds include Nubians, LaMancha, Alpines, Saanens and Nigerian Dwarfs; Boer goats are raised for meat. Wool sheep include Merino and Rambouillet, and Suffolk and Hampshire sheep are raised mainly for meat. Both species are popular 4-H projects because they are a manageable size.

A sheep's or goat's **hoof wall** grows all the time. On rocky ground it wears down; on soft pasture or bedding it grows long, curls under, traps mud and manure, and causes lameness and **foot rot**. Hooves are usually trimmed every 4 to 8 weeks for goats and several times a year for sheep. With the animal held securely, the keeper

cleans the hoof, trims the overgrown wall level with the sole using hoof shears, and stops at the first sign of pink, which means the living tissue is close. Dry footing and regular trimming keep feet healthy. Good keepers also check **body condition** regularly, because wool and long hair hide a thin or fat animal. Feeling along the backbone and loin just behind the ribs, they score sheep and goats from 1 (very thin: sharp spine, no fat) to 5 (very fat: spine cannot be felt); about 3 is ideal for most animals.

Showmanship is judged at fairs and 4-H shows in every species, from rabbits and chickens to goats, sheep and steers. In small-animal showmanship, the exhibitor carries and poses a rabbit or holds a hen calmly with its wings secured, then shows the judge the animal's eyes, ears or comb, teeth or beak, feet, coat or feathers, and explains its breed and care. With goats and sheep, the exhibitor leads the animal by a collar or halter, sets its legs square, keeps it between himself and the judge, watches the judge at all times, and keeps the animal calm and still.

In every class, judges reward the same things: an animal that is clean, healthy, well groomed and well trained, and an exhibitor who is neat, courteous and knows the animal's age, breed, feed and care. Good showmanship is mostly good daily husbandry made visible. It is earned at home, week after week, long before the fair.

PICTURE STUDY



The Sheep-Shearer (after Millet), Vincent van Gogh, 1889 · Oil on canvas · Van Gogh Museum, Amsterdam

Image: [Wikimedia Commons](#), public domain

Van Gogh greatly admired Jean-François Millet's paintings of farm work and painted his own colorful versions of them. Here, a sheep is being shorn by hand with metal shears, as nearly all sheep were before electric clippers.

Look closely

- Find the shears. How are they different from scissors?
- Look at how the sheep is held. Does it seem calm?
- Look at the wool on the sheep. Which parts have already been clipped?
- Look for the second person. What is his job?

Talk about it

1. Why is it important to keep the sheep calm and still during shearing?
2. Why would shearing be done in spring rather than late fall?
3. How does Van Gogh's color and brushwork make ordinary work look important?

Safety first. Only an experienced adult uses shears and hoof trimmers. Hold animals gently but securely, never by the wool, ears or horns alone. Wash hands after handling livestock, and keep fingers away from the mouth of any animal.

Hoof, Fleece and Showmanship Practice

You will observe or assist with hoof care, examine wool, and practice showmanship. Choose the options that fit what is available to you.

You will need

- Access to sheep or goats (a farm, a 4-H member, a fair barn), or a borrowed rabbit or hen, or a calm family dog
- A small sample of raw wool (from a farmer, a yarn shop or a fiber festival), optional
- A hand lens and a ruler
- Your journal

Steps

1. With an adult and the owner, watch a hoof trimming. Draw a hoof before and after, and label the wall, sole and heel.
2. Ask the owner how often the animals' feet are trimmed and what the ground in their pen is like. Record the answers.
3. With the owner's help, feel along the backbone and loin of two or three sheep or goats and give each a body condition score from 1 to 5. Record the scores and compare them with the owner's.
4. If you have a wool sample, measure the staple (lock) length, look at the crimp (waves) with a hand lens, and try twisting a few fibers into yarn with your fingers.
5. Make a showmanship checklist from the core ideas and the video: animal preparation, exhibitor dress, leading or carrying, posing, eye contact with the judge, and answering questions.
6. Practice showmanship with whatever animal you have: carry and pose a rabbit, hold a hen with wings secured, lead a goat, or walk and set up the family dog. If you have no animal, practice with a stuffed animal.
7. Prepare answers to five questions a judge might ask: breed, age, what it eats, how much, and one health practice you follow.

8. Have a family member act as judge using your checklist, and score you. Repeat to improve.
9. Write what you learned and one thing you would practice every day before a real show.

Tips

- Many county fairs offer a beginner or “novice” showmanship class. Check your county fair book or 4-H office.
- Calm, daily handling at home makes an animal easy to show.
- Biosecurity: wear clean shoes and clothes to each farm, do not visit two farms in one day without changing, wash hands before and after, and never bring animals home from a show without asking how long to keep them apart. Diseases travel on boots and hands.

Check your work

- ☐ I can explain why sheep are shorn and why hooves are trimmed.
- ☐ I gave body condition scores and explained what they mean.
- ☐ I made a showmanship checklist and practiced it with a judge scoring me.
- ☐ I can answer five judge’s questions about my animal.

NATURE JOURNAL

1. Draw a goat’s hoof from below, showing the two toes, the wall and the sole, before and after trimming.
2. Draw a sheep and a goat side by side and label three differences (tail, coat, what each eats).
3. Draw an exhibitor posing a goat for a judge, with arrows showing where the exhibitor’s eyes and hands should be.

From history. Electric sheep-shearing machines were developed in Australia in the 1880s and spread around the world, letting a skilled shearer shear well over a hundred sheep a day. The first boys’ and girls’ agricultural clubs, which grew into 4-H, began in the early 1900s, and showing animals at the county fair soon became one of their best-loved traditions.

COMMON MISTAKES

- Trimming too deep into the hoof. Stop when the sole turns pink.

- Thinking showmanship judges the animal. It judges the exhibitor's preparation and handling.
- Turning your back on the judge or losing track of where the judge is.

Make it a game • Fleece and Hoof Walkthrough. Be the shepherd. Walk your parent through shearing, skirting a fleece, trimming hooves and showmanship, each in order. Use a towel as a fleece and a cardboard shape as a hoof. Parent plays the judge and asks why hooves must be trimmed, what foot rot is, and how browsers like goats eat. Rate each other with paper ribbons.

6.4 HONEY: FROM NECTAR TO JAR

OBJECTIVES

- Explain how bees turn nectar into honey with enzymes and evaporation.
- Describe how a beekeeper decides when to harvest and how honey is extracted.
- Prepare a honey exhibit and keep an expense and income record for a small hive.

Warm-up. Taste a tiny drop of two different honeys if you have them (or look closely at their colors in the jar). Write three words for each about color, smell and taste. Why might two honeys differ?

WATCH

Beekeeping. | Simplest Way To Harvest Your Honey.

David Burns · 12:55

https://www.youtube.com/watch?v=Z_Ptm0evTdc

WHEN TO WATCH

After the core ideas. List the steps from hive to jar in order.

Note: The beekeeper teaches beekeeping courses and mentions them briefly.

BACKUP VIDEO

Honey Bees Make Honey ... and Bread? | Deep Look

Deep Look · 4:11

<https://www.youtube.com/watch?v=sAKkjD3nEv0>

Before the core ideas, as an introduction. Close-up footage shows bees packing pollen and fanning nectar.

KEY TERMS

nectar

A sugary liquid made by flowers, mostly water, that bees collect and turn into honey.

invertase

An enzyme bees add to nectar that splits sucrose into the simpler sugars glucose and fructose.

capped honey

Honey that bees have dried to about 18 percent water and sealed in its cell with a wax lid.

extractor

A drum that spins uncapped frames so that honey is flung out of the comb by centrifugal force.

super

A box placed on top of the hive where bees store extra honey for the beekeeper to harvest.

crystallization

The natural process in which glucose in honey forms solid crystals; it does not mean the honey is spoiled.

CORE IDEAS

A forager bee sips **nectar**, often more than half water, from flowers and carries it home in her honey stomach, adding enzymes on the way. In the hive she passes it to younger house bees, who pass it mouth to mouth and add more enzymes. **Invertase** splits the nectar's sucrose into glucose and fructose, and another enzyme makes a small amount of hydrogen peroxide and acid that help protect honey from microbes.

The house bees spread the nectar in thin layers in wax cells and fan their wings to drive off water. When the honey reaches about 17 to 18 percent water, too dry for yeasts and bacteria to grow, the bees seal each cell with a wax cap. That is the same science you learned in Lesson 1.4: honey keeps for years because it has too little free water for microbes. To make one pound of honey, a colony's foragers may visit around two million flowers.

A colony needs its own stores to survive winter; in a cold climate a strong hive may need 60 pounds or more. The beekeeper harvests only the surplus, usually from **supers** placed on top of the hive, and waits until most of the cells (about 80 percent or more) are capped, so the honey is dry enough to keep. Bees are cleared from the supers with a bee escape board or a gentle brush. Indoors, the wax caps are sliced off with a heated knife or scratched open with a fork, the frames are spun in an **extractor**, and the honey is strained and left to settle so air bubbles rise before bottling. The empty comb goes back to the bees to refill.

Honey's color and flavor depend on the flowers: clover and orange blossom honeys are light and mild; buckwheat honey is dark and strong. All pure honey eventually **crystallizes**, some in weeks and some in years; gently warming the jar in warm water makes it liquid again. One important rule: never give honey to a baby under

one year old, because it can carry botulism spores that a baby's digestive system cannot yet handle.

Many county and state fairs have honey classes. Judges look for a jar filled to the right level, clean glass and lid, honey free of foam, wax bits and crystals, uniform color among jars, a moisture content of about 18.6 percent or less, and a clean, correct label. Beekeeping is also a small business: tracking costs (hive, bees, protective gear, jars) against income (honey and wax sold) is the kind of record a 4-H project book asks for. "Sweeter also than honey and the honeycomb" (Psalm 19:10).

PICTURE STUDY



The Beekeepers, Pieter Bruegel the Elder, about 1568 · Pen and ink · Kupferstichkabinett, Berlin

Image: [Wikimedia Commons](#), public domain

Before modern hives with removable frames, beekeepers kept bees in straw baskets called skeps. Bruegel drew these beekeepers about 450 years ago, wearing heavy clothing and woven masks for protection, as they carried their skeps.

Look closely

- Find the straw skeps. How many can you count?
- Look at the beekeepers' masks and smocks. What are they protecting against?
- Find the boy in the tree. What do you think he is doing?
- Look at how the beekeepers carry the skeps. Are they moving quickly or carefully?

Talk about it

1. Skeps had no removable frames. How do you think beekeepers got the honey out? What happened to the comb?
2. How is a modern beekeeper's suit like these smocks and masks?
3. Why did the invention of removable frames make honey harvesting kinder to the bees?

Safety first. Work with bees only alongside an experienced adult beekeeper, in a veil and protective clothing. Anyone allergic to stings must stay away from hives, and an adult should know where the allergy medicine is. Never give honey to a baby under one year old.

HANDS-ON PROJECT

A Honey Exhibit and a Hive Ledger

You will compare honeys like a fair judge, prepare an exhibit jar to fair standards, and keep a one-year expense and income record for a small backyard hive.

You will need

- Two to four different honeys (local and store-bought if possible)
- Clean, clear glass jars with lids (a matching set if you have them)
- A white paper background and a good light
- A small spoon for each honey
- Labels and a fine pen
- A local beekeeper's price list, or supply prices from a catalog or website

Steps

1. Hold each honey jar against white paper in good light. Rank them for color (lightest to darkest) and clarity, and look for foam, wax bits, crystals or bubbles.
2. Taste a small amount of each with a clean spoon (if you have no honey allergy). Record aroma and flavor.
3. Act as judge: place the honeys 1 to 4 for an exhibit class and write one reason for each placing.
4. Prepare an exhibit jar: wash and dry a clear jar and lid, pour honey slowly down the side to avoid bubbles, fill to just below the lid's shoulder, let it settle overnight, and skim any foam. Wipe the glass spotless.
5. Make a neat label with the type of honey, your name and the date, following your county fair book's rules if you have one.
6. Make a hive ledger with two columns: Expenses (hive boxes and frames, a package of bees, veil and gloves, smoker, jars) and Income (pounds of honey sold $\times$ price, beeswax).
7. Use real prices. Estimate a first-year harvest of 0 to 30 pounds and a second-year harvest of 40 pounds. Calculate profit or loss for year one and year two.

8. Write a short paragraph: Is beekeeping mostly a business, a service to the garden, or both? Use your numbers.

Tips

- Many first-year colonies produce no surplus honey at all, because the bees are still building comb. That is normal.
- A local beekeepers' association often welcomes young visitors and may have a junior beekeeping program.

Check your work

- ☐ I placed four honeys and gave reasons for my placing.
- ☐ My exhibit jar is clean, correctly filled, free of foam and neatly labeled.
- ☐ My hive ledger shows expenses, income and profit or loss for two years.

NATURE JOURNAL

1. Draw a flowchart of nectar becoming honey: flower, forager, honey stomach, house bees, cell, fanning, capping.
2. Draw a frame of comb with capped honey, uncapped nectar, and pollen cells. Label each.
3. Draw your exhibit jar at life size and label what a judge would check.

From history. In 1851 the Reverend Lorenzo Langstroth, a Pennsylvania-born pastor, discovered “bee space,” the small gap bees leave open rather than filling with comb. It let him design a hive with removable frames, which beekeepers still use. In 1865 Franz von Hruschka of Austria invented the centrifugal honey extractor, so the comb could be emptied and returned to the bees.

COMMON MISTAKES

- Harvesting frames before they are mostly capped. The honey may be too wet and can ferment.
- Taking all the honey and leaving the bees too little for winter.
- Throwing out crystallized honey. It is still good; warm it gently.
- Giving honey to an infant.

Make it a game • Honey Maker Story. Narrate the honey journey like a nature documentary: foragers collect nectar, invertase turns it into honey, workers fan it to evaporate water, and the cell is capped. Your parent interrupts with 'why' at three points. Then explain when a beekeeper harvests, how an extractor works, and why honey crystallizes. Switch with your parent's version.

Scripture. “More to be desired are they than gold, yea, than much fine gold: sweeter also than honey and the honeycomb.” (Psalm 19:10, KJV)

The psalmist compares God’s words to the sweetest thing he knew: honey fresh from the comb. Honey was precious because it took so much work, by bees and beekeepers, to gather.

UNIT 6

FARM ANIMALS AND BEES

Early spring is the busiest season in the barnyard: lambs and kids arrive, cows freshen and give their richest milk, sheep are shorn, and honeybee colonies wake up and begin to build. In this unit you will study farm animals the way a farmer and a 4-H or FFA member must: how their bodies are designed to turn grass and grain into milk, wool and meat, how to care for their feet and fleece, how judges evaluate them, and how bees turn nectar into honey.

No livestock is needed. A farm visit, a county fair, a 4-H member's barn, a dairy tour or a local beekeeper will teach you a great deal, and every project has a no-farm option. "Be thou diligent to know the state of thy flocks, and look well to thy herds" (Proverbs 27:23).

PREREQUISITES

- Knows what farm animals give us: milk, eggs, wool, meat, work and honey
- Knows the three castes of honeybees: queen, workers and drones
- Has learned the farm safety rules: an adult present, move calmly, never stand behind a horse or cow

MASTERY CHECKLIST

- ☐ I can compare ruminant and single-stomach digestion and explain why a cow can live on grass and a pig cannot.
- ☐ I can name the major dairy breeds, describe how milk is produced and processed, and place a class of four cows with oral reasons.
- ☐ I can explain why sheep are shorn and why hooves are trimmed, and describe good showmanship.
- ☐ I can explain how bees turn nectar into honey and how a beekeeper harvests, extracts and exhibits it.
- ☐ I can keep an expense and income record for a small animal project.

LESSONS IN THIS UNIT

6.1 Ruminant and Single-Stomach Digestion

2 sessions of 50 minutes

6.2 Dairy Cattle and Milk

2 sessions of 50 minutes

UNIT 6 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. **8 pts**
Name the four compartments of a ruminant's stomach in order and give one job of each.
2. **7 pts**
Why can a cow live on grass while a pig cannot?
3. **7 pts**
What is a hindgut fermenter? Name one.
4. **7 pts**
Name four of the six major dairy breeds and one fact about one of them.
5. **8 pts**
Describe a cow's lactation cycle.
6. **7 pts**
What does pasteurization do, and how is it typically done?
7. **8 pts**
In dairy judging, which trait counts most on the scorecard, and why?
8. **7 pts**
Why must wool sheep be shorn, and why must hooves be trimmed?
9. **7 pts**
Name three things a showmanship judge looks for in the exhibitor.

10. **8 pts**

Name two things bees do to turn nectar into honey.

11. **13 pts**

Write a short set of oral reasons for placing Cow 3 over Cow 1, using at least two comparing terms and one grant.

12. **13 pts**

Explain why honey keeps for years without spoiling, connecting it to what you learned about food preservation.

ANSWER KEY

1. Rumen (microbes ferment fiber), reticulum (sorts food, sends up cud), omasum (absorbs water), abomasum (true stomach, acid and enzymes).
2. Microbes in the cow's rumen digest cellulose; the pig has a simple stomach and cannot digest much fiber.
3. A single-stomach animal that digests fiber with microbes in its cecum after the stomach. Horse or rabbit.
4. Any four of Holstein, Jersey, Guernsey, Brown Swiss, Ayrshire, Milking Shorthorn; e.g., Holsteins give the most milk; Jerseys give the richest milk.
5. She has a calf, gives milk for about ten months, then has a dry period of about two months before her next calf.
6. Kills harmful bacteria; milk is heated to about 161°F for 15 seconds, then quickly cooled.
7. The udder (about 40 percent), because a strong, well-attached udder lets a cow stay healthy and productive for many years.
8. Their wool keeps growing; unshorn sheep suffer heat, dirt and flies. Hooves grow continually; overgrown hooves cause lameness and foot rot.
9. Any three: clean, well-groomed animal; neat dress; calm control; correct posing; watching the judge; staying on the correct side; knowledge of the animal's breed, age, feed and care; courtesy.
10. They add enzymes (invertase splits sucrose into glucose and fructose) and they evaporate water by fanning until it is about 17–18 percent water, then cap it.
11. Sample: "I placed 3 over 1 because 3 has a higher, wider rear udder with a stronger attachment and stands on a straighter, stronger rear leg. 3 is also longer and more open in her rib. I grant that 1 is taller at the shoulder and smoother in the neck."
12. Bees evaporate honey to about 17–18 percent water, so there is too little free water for microbes; its high sugar draws water out of any microbes by osmosis; and enzymes make it slightly acidic and add a little hydrogen peroxide. These take away what microbes need, just as drying and sugaring preserve food.

PORTFOLIO PIECE: A 4-H-STYLE ANIMAL PROJECT RECORD

Choose one farm animal or a beehive (one you care for, or one you visit and follow with its owner's help). Keep a record for the rest of the unit and beyond in the style of a 4-H project book: the animal's or hive's description, a feeding or care schedule, a dated log of what you did and observed, an expense and income table, a health or hive-inspection record, a photo or drawing, and a page on what you learned. Include your dairy placing card and reasons, or your honey exhibit, as an extra page.

LOOK FOR	WHAT IT MEANS
Complete records	The log is dated, regular and specific (feed, water, weights, eggs, milk, hive notes).
Money	The expense and income table is complete and correctly totaled.
Husbandry	The care schedule and health record show sound, humane, accurate animal care.
Evaluation	The placing card and reasons (or honey exhibit) use correct terms and clear comparisons.
Reflection	The "what I learned" page is thoughtful and specific.

UNIT 7

PLANTING: SEEDS, ROOTS, GRAFTS AND FIELDS

Spring is planting season, and a good planter works from knowledge, not guesswork. In this unit you will test your seeds before you trust them, learn to read a plant's roots, multiply plants by cuttings and grafting, and step out from the garden to the farm field, where corn, wheat and soybeans are planted by the hundreds of acres and measured by the bushel.

You will also learn to prepare a potted plant for a fair exhibit, give a short illustrated talk the way 4-H members do, and serve your neighbors with what you grow. "I have planted, Apollos watered; but God gave the increase" (1 Corinthians 3:6). We do the planting faithfully, and we trust Him for the growth.

PREREQUISITES

- Knows what a seed needs to germinate: water, air and the right temperature
- Knows the parts of a plant and the job of roots
- Knows your average last frost date (Lesson 1.2)

MASTERY CHECKLIST

- ☐ I can run a germination test, calculate a germination rate, and plan seed starting by counting back from the last frost date.
- ☐ I can tell healthy roots from root-bound or rotting roots and repot a plant correctly.
- ☐ I can explain why fruit trees are grafted and take cuttings that root.
- ☐ I can describe how corn, wheat and soybeans are planted and estimate a corn yield in bushels per acre.
- ☐ I can prepare a potted plant exhibit and give a 3–5 minute illustrated talk.

LESSONS IN THIS UNIT

7.1 Seed-Starting Science and Germination Rates

2 sessions of 50 minutes

7.2 Root Health, Repotting and the Potted-Plant Exhibit

2 sessions of 50 minutes

7.3 Grafting and Propagation

2 sessions of 50 minutes

UNIT 7 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

What three things does a seed need to germinate?

2. (8 pts)

In a germination test, 17 of 25 seeds sprouted. What is the germination rate?

3. (7 pts)

Your last frost is May 10. When should you start tomato seeds indoors?

4. (7 pts)

What is hardening off and why is it needed?

5. (8 pts)

Describe healthy roots, root-bound roots and rotting roots.

6. (7 pts)

Why should you repot into a pot only 1-2 inches wider?

7. (8 pts)

Why are named apple varieties grafted instead of grown from seed?

8. (7 pts)

In a graft, what must line up for the two pieces to grow together?

9. (7 pts)

Name four ways to propagate plants without seed.

10. (8 pts)

Estimate corn yield: 32 ears in 1/1000 acre, 16 rows per ear, 35 kernels per row.

11. 13 pts

Explain why farmers often rotate corn and soybeans.

12. 13 pts

List what a fair judge looks for in a youth potted-plant exhibit, and explain how you would prepare one.

ANSWER KEY

1. Water, oxygen and a suitable temperature (some seeds also need light or darkness).
2. $17 \div 25 \times 100 = 68$ percent.
3. About 6 to 8 weeks before: roughly mid-March to late March.
4. Gradually exposing seedlings to outdoor sun, wind and cool temperatures over 7–10 days, so they are not shocked or sunburned when transplanted.
5. Healthy: white or tan, firm, spread through the soil. Root-bound: circling the pot wall, packed tight. Rotting: brown or black, mushy, sour-smelling.
6. A much larger pot holds too much wet soil around the small root system, which can lead to root rot.
7. Seedlings mix the traits of two parents and do not come true; grafting makes exact clones of the variety.
8. The cambium layers of the scion and rootstock.
9. Any four: cuttings, grafting, budding, division, layering, runners, tubers.
10. $32 \times 16 \times 35 \div 90 = 17,920 \div 90 \approx 199$ bushels per acre.
11. Soybeans are legumes whose root-nodule bacteria fix nitrogen, leaving some for the next crop, while corn needs a lot of nitrogen. Rotating also breaks the life cycles of pests and diseases that build up when the same crop grows year after year.
12. A healthy, vigorous, well-shaped plant free of pests, disease and dead leaves; a clean pot of the right size with no salt crust; neat soil surface; correct label with common and scientific names; meeting the fair book rules (such as time in the pot). I would repot it months ahead, turn it weekly toward the light, remove dead leaves, clean the pot, and label it neatly.

PORTFOLIO PIECE: A FAIR-READY PLANT AND ILLUSTRATED TALK

Grow and prepare one potted plant to fair-exhibit standard (a herb, houseplant or rooted cutting from this unit), with a record sheet showing its source, repotting date, care log and any problems you solved. Give your 3–5 minute illustrated talk on repotting or taking cuttings to an audience outside your family (a co-op class, a 4-H club meeting, grandparents). Include your germination test results and corn yield estimate as supporting pages.

LOOK FOR	WHAT IT MEANS
Exhibit quality	The plant is healthy, clean, well shaped, in a suitable clean pot, and correctly labeled.
Records	The care log is dated and complete, with repotting, watering and problems noted.
Illustrated talk	The talk is 3–5 minutes, organized, shows real steps with hands, and uses a clear poster.
Science	Germination and yield calculations are correct and explained.
Service	The plan for a shared row of food is specific (crop, amount, who receives it).

7.1 SEED-STARTING SCIENCE AND GERMINATION RATES

OBJECTIVES

- Explain what happens inside a seed during germination and what conditions it needs.
- Run a germination test and calculate the germination rate and days to emergence.
- Plan a seed-starting calendar by counting back from the last frost date.

Warm-up. Look at three seed packets. Copy the “days to germination,” the planting depth and any number labeled “germination” or “tested.” Which seed do you think will sprout fastest?

WATCH

Is Your Seed Too OLD? Test It First With Paper Towels And Germinate It BEFORE You Plant!

Garden Well Eat Well • 8:30

https://www.youtube.com/watch?v=4wFCurhel_Q

WHEN TO WATCH

Before setting up the project. Note how the gardener counts and records the seeds.

BACKUP VIDEO

What's the BEST Temperature for Starting Seeds Indoors?

Gardening Experiments with Mind & Soil • 6:39

<https://www.youtube.com/watch?v=z8ktF0ne4F8>

After the core idea on temperature. The gardener tests several crops at different temperatures, the same kind of experiment you will run.

KEY TERMS

germination

The sprouting of a seed: the embryo begins to grow and the root breaks through the seed coat.

imbibition

The first step of germination, when a dry seed soaks up water and swells.

germination rate

The percent of seeds in a test that sprout: $\text{number sprouted} \div \text{number tested} \times 100$.

viability

Whether a seed is alive and able to germinate; it declines as seeds age.

damping off

A disease in which fungi or water molds rot seedlings at the soil line so they topple over.

hardening off

Gradually exposing indoor seedlings to sun, wind and cooler temperatures over 7 to 10 days before transplanting.

CORE IDEAS

A seed is a living plant waiting, with a food supply and a protective coat. Germination begins with **imbibition**: the dry seed soaks up water and swells, sometimes to twice its size. Water wakes up the seed's enzymes, which turn stored starch into sugar for energy. The seed must also have **oxygen** to burn that sugar, which is why seeds in waterlogged soil rot. Soon the root (radicle) breaks through the coat, grows down, and the shoot follows.

Each crop has a temperature range for germination. Peas and spinach germinate in cool soil, even near 40°F, and lettuce does best around 60 to 70°F and may refuse to sprout above 80°F. Tomatoes germinate fastest around 75 to 85°F, peppers like 80 to 85°F, and beans, squash and corn rot in cold soil below about 55 to 60°F. Most seeds germinate in the dark, but some tiny seeds, like lettuce, need light and should barely be covered.

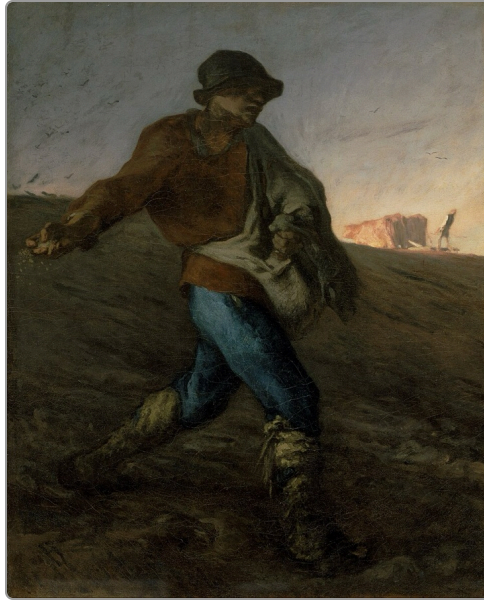
Seeds lose **viability** as they age, faster when warm and damp. Onion and parsnip seeds may last only a year or two; tomato seeds often last four or more years in a cool, dry jar. A seed company tests every lot and prints the germination percent on the packet. You can test your own: place a counted number of seeds (10, 20, or 100) on a damp paper towel, keep it warm, and count the sprouts. **Germination rate** = $\text{sprouted} \div \text{tested} \times 100$. If only 60 percent sprout, you sow more thickly or buy fresh seed.

Starting seeds indoors gives tender crops a head start. Count back from your average last frost date: tomatoes and peppers are usually started 6 to 8 weeks before; broccoli and cabbage 5 to 7 weeks; squash and cucumbers only 3 to 4 weeks, because they dislike transplanting. Use a sterile, fine **seed-starting mix**, containers with drainage,

gentle bottom warmth, and strong light: a shop light or LED grow light 2 to 4 inches above the seedlings for 14 to 16 hours a day. A windowsill alone usually makes pale, stretched seedlings.

Seedlings need air movement and moderate watering to avoid **damping off**. Before transplanting, **harden them off** for a week to ten days, setting them outdoors in shade for an hour or two at first and gradually longer in sun and wind. “Except a corn of wheat fall into the ground and die, it abideth alone: but if it die, it bringeth forth much fruit” (John 12:24).

PICTURE STUDY



The Sower, Jean-François Millet, 1850 · Oil on canvas · Museum of Fine Arts, Boston

Image: [Wikimedia Commons](#), public domain

Millet grew up sowing grain by hand on his family's farm in Normandy. His sower strides across a freshly plowed hillside, scattering wheat seed in a wide arc with each step, as farmers did for thousands of years before seed drills.

Look closely

- Find the seed bag. How does the sower carry it?
- Look at his arm and stride. How does he spread the seed evenly?
- Find the figure working with animals in the distance. What job are they doing, and why must it come before sowing?
- Look at the soil. Has the field been prepared for sowing?

Talk about it

1. Hand sowing scatters seed on the surface. Why might some seed fail to germinate? (Think about birds, dryness and depth.)
2. How does a germination test help a farmer decide how much seed to sow?
3. Jesus told a parable about a sower. What happened to seed that fell in different places?

The Great Germination Test

You will test two kinds of seed at two temperatures, calculate germination rates and days to germination, and use your results to plan your own seed starting.

You will need

- Two kinds of seed, at least 40 of each (for example, lettuce and tomato, or peas and beans; old and new packets make a good comparison)
- Paper towels and four zip-top bags
- A spray bottle and a permanent marker
- A thermometer
- A warm spot (top of a refrigerator, about 75–80°F) and a cool spot (about 60°F)
- Your journal and a calculator

Steps

1. Label four bags: Seed A warm, Seed A cool, Seed B warm, Seed B cool.
2. Dampen a paper towel (wet but not dripping). Lay 20 seeds of one kind in rows on half of it, fold it over, and slide it into the matching bag. Repeat for all four bags.
3. Place two bags in the warm spot and two in the cool spot. Record each spot's temperature daily.
4. Each day for 10 to 14 days, open the bags briefly and count seeds whose root has broken through. Mist if the towel dries.
5. Make a table: Day, and number sprouted in each bag. Note the day the first seed sprouted in each bag.
6. At the end, calculate each germination rate ($\text{sprouted} \div 20 \times 100$) and the average days to germination.
7. Graph cumulative sprouts against days for all four bags on one graph.
8. Write a conclusion: Which seed liked warmth more? Would you buy new seed for either one?

9. Using your last frost date, make a seed-starting calendar for six crops, showing the week to start indoors, the week to harden off, and the week to transplant or sow outdoors.

Tips

- Pot up sprouted seeds carefully with tweezers instead of throwing them away.
- Keeping a dated record like this is exactly what a 4-H plant or garden project book asks for.

Check your work

- ☐ I tested 80 seeds under two conditions and recorded daily counts.
- ☐ I calculated germination rates and days to germination correctly.
- ☐ My seed-starting calendar counts back correctly from my last frost date.

NATURE JOURNAL

1. Draw a bean seed opened in half, labeling the seed coat, embryo (root, shoot, first leaves) and food storage.
2. Draw a sprouting seed at days 1, 3 and 5 from your test.
3. Graph your germination results with a key and title.

From history. In the late 1800s seed fraud was common, and farmers sometimes bought seed that was dead or full of weeds. In 1869 the first official seed-testing station was founded in Tharandt, Germany. The United States passed the Federal Seed Act in 1939, which requires seed packets to state their germination percent truthfully.

COMMON MISTAKES

- Keeping the paper towel soaking wet. Seeds need oxygen as well as water.
- Starting tomatoes too early, so they become tall and leggy before it is warm enough to plant out.
- Using a windowsill as the only light source for seedlings.
- Skipping hardening off, which leads to sunburned, wind-shocked transplants.

Make it a game • Germination Math Duel. Pretend you planted twenty seeds. Parent announces how many sprouted and on which days. You calculate the germination rate and the days to emergence. Do five rounds with different numbers. Between rounds, explain what happens inside a seed: imbibition, then growth. Whoever calculates faster and correctly wins. Add a viability question.

Scripture. “Verily, verily, I say unto you, Except a corn of wheat fall into the ground and die, it abideth alone: but if it die, it bringeth forth much fruit.” (John 12:24, KJV)

A seed gives up its own life as a seed to become a fruitful plant. Jesus used this picture to explain how His death would bring life to many.

7.2 ROOT HEALTH, REPOTTING AND THE POTTED-PLANT EXHIBIT

OBJECTIVES

- Tell healthy roots from root-bound or rotting roots and explain the causes of each.
- Repot a plant correctly into a slightly larger container.
- Prepare a potted plant for a fair exhibit and give a 3–5 minute illustrated talk.

Warm-up. Look at the bottom of three potted plants in your home or a store. Do any roots poke out of the drainage holes? Is the soil dry, damp or soggy? Predict which plant most needs repotting.

WATCH

Understanding Root Health

[LogeesPlants](#) · 6:34

<https://www.youtube.com/watch?v=xksuZvHq9hc>

WHEN TO WATCH

After the core ideas. Pause each time a root ball is shown and decide: healthy, root-bound or rotting?

BACKUP VIDEO

Root bound plants - 2 ways to loosen the roots plus what NEVER to do!

[Backyard Farmer Pat](#) · 7:39

<https://www.youtube.com/watch?v=i811VMaDrls>

Before step 4 of the project, which loosens a root ball.

KEY TERMS

root-bound

A plant whose roots have filled the pot and begun circling the inside wall, leaving little soil.

root rot

Decay of roots, usually caused by water molds and fungi in soggy, airless soil.

root ball

The mass of roots and soil that comes out of a pot together.

drainage hole

An opening in the bottom of a pot that lets extra water escape.

illustrated talk

A short, practiced talk in which the speaker shows and explains how to do a task step by step, as in a 4-H illustrated talk.

CORE IDEAS

Roots do most of their work out of sight, but a gardener can learn a great deal by sliding a plant gently out of its pot. **Healthy roots** are white or light tan, firm, and branch through the whole soil ball, with fine root hairs at the tips. They smell earthy. Roots breathe: they need air spaces in the soil as much as they need water.

Root rot appears as brown or black, mushy roots that pull apart and smell sour. It is almost always caused by soil kept too wet, often in a pot with no **drainage hole**; water molds such as *Pythium* attack roots starved of air. Above ground, a plant with rotting roots wilts even though the soil is wet, which fools many people into watering more. The cure is to trim away the dead roots, repot in fresh mix, and water only when the top inch of soil is dry.

A **root-bound** plant has filled its pot. Its roots circle the inside wall and pack tightly, water runs straight through, and the plant dries out quickly and stops growing. If planted out without help, circling roots may keep circling and even strangle the plant. Before repotting, gently tease the outer roots loose with your fingers; if they are tightly matted, an adult can make three or four shallow vertical cuts down the sides of the root ball to encourage new roots to grow outward.

Repot into a pot only about 1 to 2 inches wider than the old one, because a huge pot holds too much wet soil around a small root system. Use fresh potting mix, not garden soil, which packs down in a pot. Set the plant at the same depth as before, fill around it, firm gently, and water thoroughly until water runs out the bottom. Do not put gravel in the bottom of the pot; it actually makes water collect in the soil above it.

Many county fairs have a potted-plant class for youth. Judges look for a healthy, vigorous plant that is well shaped and free of pests, dead leaves and disease; a clean pot of suitable size with no salt crust; soil neatly topped; and a correct label with the plant's common and scientific names. Fair books often require that the plant has grown in its pot for several months, so plan ahead and check your county fair book for the rules.

PICTURE STUDY



Flowerpot with Garlic Chives, Vincent van Gogh, 1887 · Oil on canvas · Van Gogh Museum, Amsterdam

Image: [Wikimedia Commons](#), public domain

In Paris, Van Gogh painted many small still lifes of everyday things, including this ordinary clay pot of garlic chives, an herb that grows easily on a windowsill. A potted herb like this is a perfect first fair exhibit.

Look closely

- Look at the pot. What is it made of? Can you guess whether it has a drainage hole?
- Look at the chives. Are they growing straight and green, or drooping?
- Compare the size of the plant with the size of the pot. Does it look crowded?
- Look at the background. How does Van Gogh make the plant stand out?

Talk about it

1. If you slid this clump of chives out of its pot, what would healthy roots look like?
2. Would this plant be ready for a fair exhibit? What would a judge want you to fix?
3. Why might clay pots dry out faster than plastic ones?

Safety first. An adult makes any cuts in a root ball. Wear gloves if you have sensitive skin, and wash hands after handling potting mix, which can contain fertilizers and fungal spores; avoid breathing the dust.

HANDS-ON PROJECT

Repot, Exhibit and Present

You will diagnose and repot a plant, prepare a potted plant to fair-exhibit standard, and give an illustrated talk on repotting to your family.

You will need

- A root-bound houseplant or herb (or a nursery plant on sale)
- A clean pot with a drainage hole, about 1–2 inches wider than the old one
- Fresh potting mix
- A trowel, newspaper and a watering can
- Clean scissors or pruners (adult help)
- A label and a fine pen
- Poster board and markers for your illustrated talk

Steps

1. Water the plant an hour before. Spread newspaper. Tip the pot on its side and slide the plant out, supporting the stems.
2. Examine the roots. Record color, smell, how much they circle, and whether you see any rot. Take a photo or draw it.
3. Trim away any dead, mushy roots with clean scissors.
4. Tease the outer roots loose, or have an adult make shallow vertical cuts if they are tightly matted.
5. Put fresh mix in the new pot so the top of the root ball sits about 1 inch below the rim. Set the plant in, fill around it, firm gently, and water until water drains out.
6. Exhibit preparation: clean the pot inside and out, remove dead or yellow leaves, turn the plant weekly toward the light so it grows evenly, and make a neat label with its common and scientific names.
7. Plan a 3–5 minute illustrated talk called “How to Repot a Plant”: an introduction (why repot), 4 to 6 steps shown with real materials, a poster listing the steps, and a summary. End by asking for questions.

8. Practice twice, then give your talk to your family. Ask them to score you on clear speaking, eye contact, neat work, and correct information.

Tips

- In an illustrated talk, show each step with your hands while you explain it. Face your audience, not the plant.
- Many 4-H clubs and county fairs hold illustrated-talk or public-speaking contests. Ask your county extension office.

Check your work

- ☐ I diagnosed the roots and repotted the plant correctly.
- ☐ My exhibit plant is clean, groomed and correctly labeled.
- ☐ I gave a 3–5 minute illustrated talk with a poster and real materials.

NATURE JOURNAL

1. Draw three root balls side by side: healthy, root-bound and rotting. Label the signs of each.
2. Draw your plant before and after repotting, with the date and pot sizes.
3. Write the outline of your illustrated talk on one page: title, introduction, steps, summary.

From history. The 4-H illustrated-talk contest dates back to the early clubs of the 1910s, when boys and girls showed their neighbors how to test seed corn or can tomatoes. Speaking clearly while working with your hands is still one of the most useful skills 4-H teaches.

COMMON MISTAKES

- Moving a small plant into a huge pot, where the extra wet soil can rot the roots.
- Watering a wilted plant in wet soil. Check the roots; it may be root rot.
- Putting gravel or pot shards in the bottom of a pot “for drainage.”
- Using garden soil in containers, where it packs down and drains poorly.

Make it a game • Root Rescue Case Files. Draw three root balls: healthy, root-bound and rotting. Parent describes plant symptoms and you diagnose the root problem and the cause, like poor drainage or too small a pot. Then arrange the repotting steps in order. Ask for a surprise cause: drainage hole blocked. Win by diagnosing and repotting correctly in five rounds.

7.3 GRAFTING AND PROPAGATION

OBJECTIVES

- Explain why most fruit trees are grafted instead of grown from seed.
- Describe the roles of rootstock, scion and cambium in a graft.
- Propagate plants by cuttings and record their rooting.

Warm-up. An apple has five to ten seeds. If you planted every seed from a Honeycrisp apple, would the trees bear Honeycrisp apples? Write your guess and your reason.

WATCH

Whip and Tongue grafting and how to graft an apple tree

Orchard People • 6:03

<https://www.youtube.com/watch?v=gJgblmEkmz8>

WHEN TO WATCH

After the core ideas on grafting. Pause at each cut and sketch it.

BACKUP VIDEO

How to Propagate Plants from Cuttings | This Old House

This Old House • 7:15

<https://www.youtube.com/watch?v=fzwVKZ6UoGM>

Before taking cuttings in the project.

KEY TERMS

vegetative propagation

Growing new plants from a piece of a parent plant (a cutting, graft, division or runner), so the new plant is an exact copy.

rootstock

The lower part of a graft, which supplies the roots and often controls the tree's size.

clone

A plant that is genetically identical to its parent.

scion

A short piece of stem from the desired variety, grafted onto a rootstock.

cambium

A thin layer of dividing cells just under the bark; in a graft, the cambium of scion and rootstock must touch to grow together.

rooting hormone

A powder or gel containing auxin, a natural plant hormone, that encourages cuttings to form roots.

CORE IDEAS

Plants can be grown from seed or from pieces of themselves. Seeds mix the traits of two parents, so each seedling is a little different, as Mendel showed. An apple seed from a Honeycrisp grows into a tree with apples unlike its parent, usually small and sour. To get more trees of a variety, growers use **vegetative propagation**, making **clones** that are exact copies. Every Honeycrisp tree in the world grew from wood cut from the original tree.

Grafting joins two plants into one. The **scion**, a pencil-thick piece of last year's growth from the variety you want, is cut in winter while dormant. The **rootstock** provides the roots. Rootstocks are chosen for hardiness, disease resistance and size: a dwarfing rootstock gives a small tree that bears in a few years, which is ideal for backyards.

In a **whip-and-tongue graft**, done in late winter or early spring, matching long, slanting cuts are made on scion and rootstock, then a second "tongue" cut on each lets them lock together. The key is the **cambium**, the thin green layer of dividing cells just under the bark. Where the cambium layers touch, new cells grow and knit the pieces into one living stem. The union is wrapped tightly with grafting tape to hold it and keep it from drying out. In summer, growers also use budding, grafting a single bud instead of a stick.

Many plants root easily from **cuttings**. Softwood cuttings, 4 to 6 inches of young stem, root quickly from coleus, basil, mint, pothos, geraniums and many shrubs. Strip the lower leaves, dip the cut end in **rooting hormone** if you like, and set it in moist mix or water. Other methods: *division* splits a clump (hostas, daylilies, chives); *layering* roots a stem while it is still attached (raspberries do it themselves); *runners* make new strawberry plants; and potatoes are planted from pieces of tuber.

Grafting is an ancient skill; the apostle Paul used it as a picture of believers being grafted into God's family (Romans 11). It is also patient work: a grafted apple tree may take three or four years to bear, and it can live and bear for decades.

PICTURE STUDY



Orchard in Bloom, Louveciennes, Camille Pissarro, 1872 · Oil on canvas · National Gallery of Art, Washington

Image: [Wikimedia Commons](#), public domain

Pissarro painted the orchards around the village of Louveciennes near Paris in every season. In spring, rows of fruit trees burst into bloom. Every tree in an orchard like this was grafted, so that each one would bear the same kind of fruit.

Look closely

- Look at how the trees are spaced. Why do orchard trees need room between them?
- Look at the size and shape of the trees. Are they tall or low and spreading?
- Find the people. What work might they be doing in spring?
- Look at the ground under the trees. Is it grass or bare soil?

Talk about it

1. Why would a farmer want every tree in a row to be the same variety?
2. How could you tell where a tree had been grafted if you could walk up to its trunk?
3. What will these blossoms need to become fruit? (Think back to Lesson 5.3.)

Safety first. Grafting knives are extremely sharp. Only an adult cuts with one; if you practice, use a dull practice knife or have an adult guide your hands, and always cut away from your body. Wash hands after using rooting hormone.

HANDS-ON PROJECT

A Cutting Garden and a Practice Graft

You will take cuttings from several plants, compare rooting in water and in soil, and (with an adult) practice the whip-and-tongue cuts on willow or fruit-tree prunings.

You will need

- Healthy plants to cut from: coleus, basil, mint, pothos, geranium or a shrub
- Clean scissors or pruners
- Clear cups of water and small pots of moist potting mix
- Rooting hormone (optional)
- Clear plastic bags or a clear plastic tote to keep humidity high
- Pencil-thick willow or fruit-tree prunings, grafting or electrical tape, and a grafting knife (adult only)

Steps

1. Take six 4- to 6-inch cuttings of two or three kinds of plants, cutting just below a leaf node. Strip the lower leaves.
2. Put three in water and three in pots of moist mix (dip in rooting hormone first if you have it). Cover the potted cuttings loosely with a clear bag.
3. Label each with the plant, method and date. Keep them in bright, indirect light.
4. Check every two days. Record the day roots first appear (in water you can see them; in soil, a gentle tug that meets resistance means roots).
5. After three weeks, compare: which plants and which method rooted fastest? Pot up the rooted cuttings.
6. Practice graft: an adult makes a 1-inch slanting cut on two matching willow twigs, then a short tongue cut on each. Fit them together so the cambium lines up on at least one side.
7. Wrap the union snugly with tape. Stand the grafted twig in a jar of water in a bright spot; willow roots easily, and you may see whether the graft holds.

8. Draw and describe the graft union, labeling scion, rootstock and cambium.

Tips

- Willow is perfect for practice because it roots and heals so easily.
- Extension offices and fruit-growing clubs often hold “scion exchange” and grafting workshops in late winter.

Check your work

- ☐ I took cuttings correctly and recorded the day roots appeared.
- ☐ I compared rooting in water and in soil.
- ☐ I can explain why the cambium must line up in a graft.

NATURE JOURNAL

1. Draw the four steps of a whip-and-tongue graft, labeling scion, rootstock, cambium and tape.
2. Draw a cutting on day 1 and the same cutting with roots, with dates.
3. Make a chart of six ways to propagate plants with one example of each.

From history. John Chapman, known as Johnny Appleseed, planted apple nurseries from seed across Ohio and Indiana in the early 1800s; most of his seedling trees bore small, tart apples, not named eating varieties. Grafted varieties later took over. The Honeycrisp apple was developed at the University of Minnesota and released in 1991, and every Honeycrisp tree since has been grafted.

COMMON MISTAKES

- Expecting apple seeds to grow the same variety. Named fruit varieties must be grafted.
- Letting the scion and rootstock cambium miss each other, so the graft never knits.
- Leaving too many leaves on a cutting, which loses water faster than the cutting can drink without roots.
- Keeping cuttings in hot, direct sun before they root.

Make it a game • Graft Parts Quiz-Me. Quiz your parent about grafting using a stick and a paper cut graft. Label the rootstock, scion and cambium on a drawing. Then reverse: your parent quizzes you, sneaking in one false fact, such as 'grafts grow from seed.' Explain why most fruit trees are grafted instead of grown from seed, and what a clone means.

7.4 FIELD CROPS: CORN, WHEAT AND SOYBEANS

OBJECTIVES

- Describe how corn, wheat and soybeans are planted, grown and harvested.
- Explain how farmers measure yield in bushels per acre.
- Estimate a corn yield from ear counts, and plan a service planting.

Warm-up. Find three foods in your kitchen made from corn, three from wheat and three from soybeans. (Check labels for corn syrup, cornstarch, flour, soybean oil and soy lecithin.) Which list was hardest to fill?

WATCH

Corn School: Planting Depth Lessons

RealAgriculture • 4:37

<https://www.youtube.com/watch?v=kyKNrjMjmlU>

WHEN TO WATCH

After the core ideas on corn. An agronomist digs up seedlings planted at different depths; note which depth did best and why.

BACKUP VIDEO

The Journey of Wheat - from Field to Table

Kansas Wheat • 4:58

<https://www.youtube.com/watch?v=3ihTep7zMNI>

After the core ideas on wheat.

KEY TERMS

agronomy

The science of growing field crops and managing soil on a farm scale.

bushel

A unit for grain; by standard weight, a bushel of corn is 56 pounds and a bushel of wheat or soybeans is 60 pounds.

yield

The amount of crop harvested from an area, usually in bushels per acre.

plant population

The number of plants per acre; for corn, often about 30,000 to 35,000.

winter wheat

Wheat sown in fall that sprouts, survives winter as small plants, and is harvested the next summer.

combine

A harvesting machine that cuts the crop, threshes the grain from the plant, and cleans it in one pass.

CORE IDEAS

Corn is planted in spring once the soil reaches about 50°F, usually 1½ to 2 inches deep in rows 30 inches apart, at roughly 30,000 to 35,000 seeds per acre. Even depth matters: seeds planted too shallow may lack moisture and form weak roots, and uneven emergence leaves late plants that yield little. Corn is a hungry crop that needs plenty of nitrogen, and each ear forms from silks pollinated by tassels, as you learned in Lesson 5.3. It is harvested in fall when the kernels are dry.

Soybeans are legumes, so with their root-nodule bacteria they make most of their own nitrogen (Lesson 3.2). They are planted after corn, about 1 to 1½ inches deep, often in narrower rows and at much higher populations, often over 100,000 seeds per acre. The beans form in hairy pods and are harvested in fall when the plants drop their leaves and the pods rattle. Rotating corn and soybeans helps both crops and breaks pest and disease cycles.

Wheat in much of the United States is **winter wheat**, sown in early fall. It sprouts, stays small through winter, and needs the cold to trigger heading in spring. It turns golden and is harvested in early summer. In the far north, where winters are too harsh, farmers grow spring wheat instead. A modern grain drill places the seed in narrow rows at an even depth.

Farmers measure success by **yield** in bushels per acre. Recent U.S. averages are very roughly 175 bushels per acre for corn, about 50 for soybeans and about 50 for wheat, though good farms in good years do far better. Before harvest, a farmer can estimate corn yield: in a length of row equal to 1/1000 of an acre (17 feet 5 inches in 30-inch rows), count the ears, then count kernel rows and kernels per row on several ears. $\text{Ears} \times \text{rows} \times \text{kernels} \div 90$ gives an estimate in bushels per acre.

The **combine**, the seed drill, the tractor and good seed have made it possible for a small number of farmers to feed many people. But the work still depends on soil, rain, sun and the steady rhythm God set: “first the blade, then the ear, after that the full corn in the ear” (Mark 4:28). Gardeners can share in that bounty, too: many families plant an extra row to give fresh food to a local food pantry.

PICTURE STUDY



Wheat Field with Cypresses, Vincent van Gogh, 1889 · Oil on canvas · Metropolitan Museum of Art, New York

Image: [Wikimedia Commons](#), public domain

Van Gogh painted this field near Saint-Rémy in southern France in midsummer, when the wheat was ripe. He said the wheat fields and cypresses were among the most beautiful things he had seen.

Look closely

- Look at the color of the wheat. Is it green and growing, or ripe and ready?
- Find the way the wheat bends. What is the wind doing?
- Find the tall, dark cypress trees. How do they act as a windbreak?
- Look at the sky. Would this be good harvest weather?

Talk about it

1. Is this winter wheat or spring wheat likely to be ripe in midsummer in southern France? Why?
2. Why must ripe wheat be harvested before heavy rain and wind?
3. How would this field be harvested today compared with Bruegel's *The Harvesters* (Lesson 1.3)?

HANDS-ON PROJECT

Estimate a Corn Yield and Plant a Row to Share

You will practice the farmer's yield estimate, grow a small test plot of a field crop, and plan a row of food to give away.

You will need

- Three or four ears of field corn or sweet corn (from a farm, a fall display, or the grocery store)
- A tape measure and a calculator
- Seeds of corn, wheat or soybeans (a farm store or seed company sells small packets)
- A garden bed or several large containers
- Your journal

Steps

1. On each ear, count the number of kernel rows around the ear (always an even number) and the number of kernels in one row from base to tip. Average your results.
2. Pretend you counted 34 ears in 17 feet 5 inches of row. Estimate yield: ears $\times$ average rows $\times$ average kernels per row $\div$ 90 = bushels per acre. Show your work.
3. If you can visit a cornfield before harvest (with the farmer's permission), do a real count.
4. Convert your answer to pounds per acre (corn: 56 pounds per bushel), and then figure how many 1-pound bags of cornmeal that could fill.
5. In spring, plant a small test plot: a 4-by-4-foot block of corn (16 plants), or a row of soybeans, or a patch of wheat. Record planting date, depth and spacing.
6. Keep a growth record: the date of emergence, weekly height, the dates of tasseling or flowering, and harvest date and weight.
7. Service: plan one extra row or container of a vegetable you grow well (beans, tomatoes, squash, greens) to give to a food pantry, a neighbor or your

church. Call ahead to ask what they can accept.

8. Record what you grew and gave in your journal.

Tips

- Plant corn in a block, not a single row, so it pollinates well.
- Many communities take part in “Plant a Row” programs that collect garden produce for food pantries.

Check your work

- ☐ I estimated a corn yield correctly from ear counts.
- ☐ I planted and recorded a small field-crop plot.
- ☐ I planned (and later grew) a row of food to give away.

NATURE JOURNAL

1. Draw a corn plant, a wheat plant and a soybean plant at maturity side by side, labeling where the grain forms on each.
2. Draw an ear of corn and count its rows and kernels. Show your yield calculation.
3. Make a calendar for the three crops: planting month, harvest month, and what the field looks like in winter.

From history. Norman Borlaug, an Iowa farm boy who became a plant scientist, spent decades crossing wheat varieties in Mexico to develop short, sturdy, disease-resistant wheat. His varieties helped Mexico, India and Pakistan grow far more grain in the 1960s, and he received the Nobel Peace Prize in 1970 for helping to feed millions.

COMMON MISTAKES

- Planting corn into cold soil, where seeds rot or emerge unevenly.
- Forgetting that soybeans are legumes and need little nitrogen fertilizer.
- Thinking all wheat is planted in spring. Most U.S. wheat is sown in fall.

Make it a game • Bushel Estimate Duel. Look at an ear of corn or a drawing. Guess a yield in bushels per acre using a simple formula with plant population, ears, kernels per ear and bushel conversion. Parent guesses too. Calculate with pencil and see who is closer. Then match corn, wheat and soybeans to how each is planted, grown and harvested.

Scripture. “For the earth bringeth forth fruit of herself; first the blade, then the ear, after that the full corn in the ear.” (Mark 4:28, KJV)

Jesus described the growth of grain in exact stages, the same stages farmers watch today. The farmer plants and tends, but the growing is God’s work.

UNIT 7

PLANTING: SEEDS, ROOTS, GRAFTS AND FIELDS

Spring is planting season, and a good planter works from knowledge, not guesswork. In this unit you will test your seeds before you trust them, learn to read a plant's roots, multiply plants by cuttings and grafting, and step out from the garden to the farm field, where corn, wheat and soybeans are planted by the hundreds of acres and measured by the bushel.

You will also learn to prepare a potted plant for a fair exhibit, give a short illustrated talk the way 4-H members do, and serve your neighbors with what you grow. "I have planted, Apollos watered; but God gave the increase" (1 Corinthians 3:6). We do the planting faithfully, and we trust Him for the growth.

PREREQUISITES

- Knows what a seed needs to germinate: water, air and the right temperature
- Knows the parts of a plant and the job of roots
- Knows your average last frost date (Lesson 1.2)

MASTERY CHECKLIST

- ☐ I can run a germination test, calculate a germination rate, and plan seed starting by counting back from the last frost date.
- ☐ I can tell healthy roots from root-bound or rotting roots and repot a plant correctly.
- ☐ I can explain why fruit trees are grafted and take cuttings that root.
- ☐ I can describe how corn, wheat and soybeans are planted and estimate a corn yield in bushels per acre.
- ☐ I can prepare a potted plant exhibit and give a 3–5 minute illustrated talk.

LESSONS IN THIS UNIT

7.1 Seed-Starting Science and Germination Rates

2 sessions of 50 minutes

7.2 Root Health, Repotting and the Potted-Plant Exhibit

2 sessions of 50 minutes

7.3 Grafting and Propagation

2 sessions of 50 minutes

UNIT 7 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

What three things does a seed need to germinate?

2. (8 pts)

In a germination test, 17 of 25 seeds sprouted. What is the germination rate?

3. (7 pts)

Your last frost is May 10. When should you start tomato seeds indoors?

4. (7 pts)

What is hardening off and why is it needed?

5. (8 pts)

Describe healthy roots, root-bound roots and rotting roots.

6. (7 pts)

Why should you repot into a pot only 1-2 inches wider?

7. (8 pts)

Why are named apple varieties grafted instead of grown from seed?

8. (7 pts)

In a graft, what must line up for the two pieces to grow together?

9. (7 pts)

Name four ways to propagate plants without seed.

10. (8 pts)

Estimate corn yield: 32 ears in 1/1000 acre, 16 rows per ear, 35 kernels per row.

11. 13 pts

Explain why farmers often rotate corn and soybeans.

12. 13 pts

List what a fair judge looks for in a youth potted-plant exhibit, and explain how you would prepare one.

ANSWER KEY

1. Water, oxygen and a suitable temperature (some seeds also need light or darkness).
2. $17 \div 25 \times 100 = 68$ percent.
3. About 6 to 8 weeks before: roughly mid-March to late March.
4. Gradually exposing seedlings to outdoor sun, wind and cool temperatures over 7–10 days, so they are not shocked or sunburned when transplanted.
5. Healthy: white or tan, firm, spread through the soil. Root-bound: circling the pot wall, packed tight. Rotting: brown or black, mushy, sour-smelling.
6. A much larger pot holds too much wet soil around the small root system, which can lead to root rot.
7. Seedlings mix the traits of two parents and do not come true; grafting makes exact clones of the variety.
8. The cambium layers of the scion and rootstock.
9. Any four: cuttings, grafting, budding, division, layering, runners, tubers.
10. $32 \times 16 \times 35 \div 90 = 17,920 \div 90 \approx 199$ bushels per acre.
11. Soybeans are legumes whose root-nodule bacteria fix nitrogen, leaving some for the next crop, while corn needs a lot of nitrogen. Rotating also breaks the life cycles of pests and diseases that build up when the same crop grows year after year.
12. A healthy, vigorous, well-shaped plant free of pests, disease and dead leaves; a clean pot of the right size with no salt crust; neat soil surface; correct label with common and scientific names; meeting the fair book rules (such as time in the pot). I would repot it months ahead, turn it weekly toward the light, remove dead leaves, clean the pot, and label it neatly.

PORTFOLIO PIECE: A FAIR-READY PLANT AND ILLUSTRATED TALK

Grow and prepare one potted plant to fair-exhibit standard (a herb, houseplant or rooted cutting from this unit), with a record sheet showing its source, repotting date, care log and any problems you solved. Give your 3–5 minute illustrated talk on repotting or taking cuttings to an audience outside your family (a co-op class, a 4-H club meeting, grandparents). Include your germination test results and corn yield estimate as supporting pages.

LOOK FOR	WHAT IT MEANS
Exhibit quality	The plant is healthy, clean, well shaped, in a suitable clean pot, and correctly labeled.
Records	The care log is dated and complete, with repotting, watering and problems noted.
Illustrated talk	The talk is 3–5 minutes, organized, shows real steps with hands, and uses a clear poster.
Science	Germination and yield calculations are correct and explained.
Service	The plan for a shared row of food is specific (crop, amount, who receives it).

UNIT 8

PLANT PATHOLOGY AND PEST MANAGEMENT

As the garden grows in late spring and summer, trouble arrives: spotted leaves, white powder, sudden wilting, chewed holes. A plant doctor does not panic or reach for a spray. Like a physician, he or she observes, asks questions, and diagnoses before treating. In this unit you will learn the science of plant disease, called plant pathology, and the careful method of integrated pest management that farmers and extension agents use.

You will study why disease needs three things at once, how fungi, bacteria and viruses attack plants, and how to scout, identify and act wisely, starting with the gentlest effective control. You will also practice the identification drills used in 4-H and FFA horticulture contests. Faithful, patient care of a garden is a picture of all good work: “let us not be weary in well doing: for in due season we shall reap, if we faint not” (Galatians 6:9).

PREREQUISITES

- Knows that some fungi and bacteria are helpful decomposers and partners (Unit 3)
- Knows the parts of a plant and how water moves through xylem (Unit 5)
- Has a garden bed, containers or houseplants to observe (or access to a community garden)

MASTERY CHECKLIST

- ☐ I can explain the disease triangle and use it to prevent disease.
- ☐ I can tell signs from symptoms and recognize common fungal, bacterial and viral diseases.
- ☐ I can explain how vectors and tools spread disease and how sanitation prevents it.
- ☐ I can follow the steps of integrated pest management, from scouting to action thresholds.
- ☐ I can identify at least 25 common vegetables, seeds, weeds and insects.

LESSONS IN THIS UNIT

8.1 The Disease Triangle	2 sessions of 50 minutes
8.2 Fungal Diseases	2 sessions of 50 minutes

UNIT 8 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. (7 pts)

Name the three parts of the disease triangle.

2. (8 pts)

Give one way a gardener can break each side of the disease triangle.

3. (7 pts)

What is the difference between a sign and a symptom? Give an example of each.

4. (7 pts)

How can you tell an abiotic problem from a disease?

5. (8 pts)

Describe the symptoms of early blight and of powdery mildew.

6. (7 pts)

Why should blighted plants be thrown away, not composted?

7. (8 pts)

How do cucumber beetles and bacteria work together to kill a cucumber vine?

8. (7 pts)

What is a vector? Name two insect vectors of plant viruses.

9. (7 pts)

List the IPM steps in order.

10. **8 pts**

Put these controls in IPM order, first to last: spraying, row covers, crop rotation, releasing lady beetles.

11. **13 pts**

You find a tomato hornworm covered with small white cocoons. Explain what they are and what you should do.

12. **13 pts**

Explain why no spray will cure a plant with a viral disease, and what a gardener should do instead.

ANSWER KEY

1. A susceptible host, a pathogen, and a favorable environment.
2. Host: plant resistant varieties. Pathogen: remove infected leaves, rotate crops, clean tools. Environment: water soil in the morning, space plants, mulch.
3. A sign is the pathogen itself (white powdery mildew, rust pustules, mushrooms); a symptom is the plant's response (wilting, yellowing, spots).
4. Abiotic problems often affect many kinds of plants at once in a pattern; diseases usually affect one kind of plant and spread over time.
5. Early blight: brown spots with target-like rings on the lowest tomato or potato leaves, which yellow and drop. Powdery mildew: white, powdery patches on leaf surfaces that wipe off.
6. Spores can survive in compost and reinfect the garden.
7. The beetles carry the bacteria and infect feeding wounds; the bacteria multiply in the xylem and clog it, so the vine wilts.
8. An organism that carries a pathogen between plants. Any two: aphids, thrips, whiteflies, leafhoppers, cucumber beetles.
9. Prevent, identify, monitor (scout), decide with an action threshold, control (gentlest first), evaluate.
10. Crop rotation (cultural), row covers (mechanical/physical), releasing lady beetles (biological), spraying (chemical).
11. The cocoons belong to tiny parasitic wasps whose larvae fed inside the hornworm. The hornworm will soon die and has mostly stopped feeding. Leave it in the garden so the wasps can emerge and parasitize more hornworms; this is biological control.
12. Viruses multiply inside the plant's own cells, so sprays cannot reach or kill them, and fungicides do not affect viruses at all. The gardener should remove and bag the infected plant, control the insect vectors and weeds, wash hands and tools, and choose resistant varieties and clean seed in the future.

PORTFOLIO PIECE: A PLANT DOCTOR'S CASEBOOK

Create a casebook of at least four real plant problems you found this season (in your garden, a neighbor's, or a community garden). For each case, include a drawing or photo, the plant doctor's questions and answers, signs and symptoms, your diagnosis (abiotic, fungal, bacterial, viral or insect), the disease-triangle or IPM reasoning behind it, the action taken, and the result. Add your scouting sheets and your two skillathon scores.

LOOK FOR	WHAT IT MEANS
Observation	Each case has clear drawings or photos and dated, specific notes.
Diagnosis	Diagnoses are reasonable and supported by signs, symptoms and patterns.
IPM reasoning	Actions follow the IPM order and the disease triangle, using the gentlest effective control.
Records	Scouting sheets and skillathon scores are complete.
Reflection	The casebook ends with what you would do differently next season.

8.1 THE DISEASE TRIANGLE

OBJECTIVES

- Explain the three parts of the disease triangle and how removing any one prevents disease.
- Distinguish signs from symptoms and living from nonliving causes of plant problems.
- Test the disease triangle with a mold experiment.

Warm-up. Think about the last time someone in your family caught a cold. List what had to be true for it to happen: a germ, a person who could catch it, and the conditions that helped it spread. You have just described a disease triangle.

WATCH

Fundamentals of Plant Diseases - Slide 2 - THE DISEASE TRIANGLE

UWPDDC • 5:15

<https://www.youtube.com/watch?v=zdf1viBhw5k>

WHEN TO WATCH

After the first two core ideas. A plant pathologist from the University of Wisconsin Plant Disease Diagnostic Clinic explains the triangle; draw it while you listen.

Note: This is a short lecture with slides from a university clinic; it is calm and clear but not flashy.

BACKUP VIDEO

Guidelines for Diagnosing Plant Problems

UNH Extension • 6:42

<https://www.youtube.com/watch?v=7HnLVYhvars>

After the core idea on diagnosis. List the questions the extension specialist asks.

KEY TERMS

plant pathology

The science of plant diseases: their causes, how they spread, and how to manage them.

disease triangle

The three things needed for disease: a susceptible host, a pathogen, and a favorable environment.

sign

The pathogen itself, seen on the plant: mold, spores, mushrooms, or bacterial ooze.

pathogen

A living organism that causes disease, such as a fungus, water mold, bacterium, virus or nematode.

symptom

The plant's visible response to disease, such as wilting, yellowing, spots or stunting.

abiotic disorder

A plant problem from a nonliving cause, such as frost, drought, sunscald, nutrient shortage or chemical injury.

CORE IDEAS

A plant disease happens only when three things come together. There must be a **susceptible host**, a plant that can catch the disease. There must be a **pathogen**, a fungus, bacterium, virus or other organism able to cause it. And there must be a **favorable environment**: the right temperature, humidity, leaf wetness or soil moisture for the pathogen to grow and spread. Draw these as the three sides of a triangle. Take away any one side, and there is no disease. Plant pathologists sometimes add time as a fourth factor, because a pathogen needs enough hours of good conditions to infect.

This simple idea guides every disease-control choice. To change the **host**, plant resistant varieties; seed catalogs mark them with codes like V, F or N for tomatoes resistant to *Verticillium*, *Fusarium* and nematodes. To remove the **pathogen**, use clean seed, rotate crops, remove infected leaves, and clean tools. To change the **environment**, space plants for air flow, water the soil in the morning instead of wetting leaves at night, mulch to stop soil splashing onto leaves, and improve drainage.

Diagnosis begins with careful looking. A **symptom** is how the plant responds: wilting, yellowing, spots, blights, cankers, stunting. A **sign** is the pathogen itself: white powder, fuzzy gray mold, orange rust pustules, mushrooms at the base, or

bacterial ooze. Signs are especially helpful, because many different problems cause the same symptoms.

Not every sick plant has a disease. Many problems are **abiotic**: frost, drought, too much water, sunscald, nutrient shortages, salt, or herbicide drift. A useful rule: abiotic problems often affect many kinds of plants in one area at the same time, often in a pattern (one side of a bed, all the low spots), while diseases usually strike one kind of plant and spread over time. A good plant doctor asks: Which plants? Which parts? When did it start? Is it spreading? What was the weather?

The history of plant disease shows how serious this is. In the 1840s a water mold called late blight swept through Ireland's potato fields during cool, wet summers. Almost every farmer grew the same susceptible variety, so all three sides of the triangle were present at once, and the crop failed for several years. A great famine followed. Today's rules of variety, sanitation and timing were learned at a great cost.

PICTURE STUDY



The Song of the Lark, Jules Breton, 1884 · Oil on canvas · Art Institute of Chicago

Image: [Wikimedia Commons](#), public domain

Jules Breton grew up among farm families in northern France and painted their work with great respect. Here a young field worker, on her way to the day's labor at sunrise, stops to listen to a lark singing overhead.

Look closely

- Find the sun. Is it rising or setting? How can you tell from the girl's tools and the field?
- Look at the field. Is it a crop or bare soil? How wet do you think it is at dawn?
- Find her sickle. What will she use it for today?
- Look at the distant village and haystacks. What season might this be?

Talk about it

1. Early morning brings dew on leaves. Why does a gardener prefer to water in the morning rather than in the evening?
2. Which side of the disease triangle does morning dew affect?
3. Why do you think Breton painted a single worker so large, against such a wide field?

Safety first. Keep the mold experiment bags sealed and never open them. When finished, throw them away sealed. Anyone with mold allergies or asthma should not handle the bags.

HANDS-ON PROJECT

Testing the Triangle with Bread Mold

You will use bread (the host) and mold spores from the air (the pathogen) to test the third side of the triangle: environment. Then you will use the triangle to diagnose a real plant problem.

You will need

- Four slices of bread from bakery or homemade bread (it molds faster than preservative-treated bread)
- Four zip-top bags and a permanent marker
- A spray bottle of water
- Tape
- A refrigerator and a warm, dark cupboard
- A hand lens

Steps

1. Leave all four slices uncovered on a counter for one hour so mold spores from the air can settle on them.
2. Label the bags: Dry + Warm, Moist + Warm, Dry + Cold, Moist + Cold.
3. Mist the two “moist” slices with 5 sprays of water. Leave the “dry” slices as they are. Seal each slice in its bag and tape it shut.
4. Put the two “warm” bags in a dark cupboard and the two “cold” bags in the refrigerator.
5. Each day for 10 days, look through the sealed bag with a hand lens. Estimate the percent of the slice covered with mold and record it. Do not open the bags.
6. Graph mold coverage over time for all four bags.
7. Write a conclusion: which environment favored disease? Which side of the triangle did you change?
8. Apply it: walk a garden or houseplant collection and find one plant with a problem. Answer the plant doctor’s questions (which plants, which parts,

when, spreading, weather) and decide whether it is more likely abiotic or a disease, and why.

9. Throw the sealed bags away unopened.

Tips

- Molds on bread are the same kinds of fungi that cause gray mold and fruit rots in the garden.
- If your county has a plant disease diagnostic clinic or master gardener help desk, it is a good place to send a real mystery sample.

Check your work

- ☐ I changed only one or two environmental factors and kept the rest the same.
- ☐ My graph shows which environment grew the most mold.
- ☐ I can explain the disease triangle and give one control for each side.

NATURE JOURNAL

1. Draw the disease triangle. On each side, write two ways a gardener can break it.
2. Draw one plant problem you found, labeling any signs and symptoms.
3. Sketch a garden bed showing a pattern that points to an abiotic cause (for example, only the plants nearest the driveway or the low corner affected).

From history. In the 1840s the clergyman-naturalist Miles Berkeley argued that a living organism, not bad weather alone, caused the potato blight, and in 1861 Anton de Bary proved it with careful experiments. Their work helped found the science of plant pathology.

COMMON MISTAKES

- Spraying before diagnosing. Many problems are abiotic, and a spray will not help.
- Confusing signs and symptoms. The sign is the pathogen; the symptom is the plant's response.
- Watering leaves in the evening, which leaves them wet all night, the favorite environment of many pathogens.

Make it a game • Triangle Break. Draw the disease triangle with a host, a pathogen and an environment. Parent describes a sick plant and you name which corner you would remove to stop the disease. Then sort descriptions into signs, like visible fuzz, and symptoms, like spots, and living or nonliving causes. Remove a corner of paper for each right answer.

8.2 FUNGAL DISEASES

OBJECTIVES

- Explain how fungi infect plants and spread by spores.
- Identify powdery mildew, early blight, late blight, rust, gray mold and damping off.
- Make a spore print and scout plants for fungal disease.

Warm-up. Look at the underside of a store-bought mushroom cap with a hand lens. Count how many gills you see in a one-inch section. What do you think the gills are for?

WATCH

How to Detect and Treat Early Blight

Utah State University Extension · 3:17

<https://www.youtube.com/watch?v=UKf5eCNBvBw>

WHEN TO WATCH

After the core idea on early blight. Write down the target-ring symptom and the prevention steps.

Note: Any fungicide mentioned is chosen and applied by an adult who reads and follows the label.

BACKUP VIDEO

Prevent & Treat Powdery Mildew and 4 Home Remedies that Work!!

Next Level Gardening · 6:45

https://www.youtube.com/watch?v=A_xsjZ139g4

After the core idea on powdery mildew.

KEY TERMS

spore

A tiny reproductive cell of a fungus, carried by wind, water, insects or tools, that can start a new infection.

powdery mildew

A fungal disease that forms white, powdery patches on the surface of leaves, common on squash, cucumbers, zinnias and lilacs.

early blight

A fungal disease of tomatoes and potatoes that makes brown spots with target-like rings, starting on the lowest leaves.

late blight

A fast-spreading disease of tomatoes and potatoes caused by a water mold, with greasy gray-green patches and white fuzz in wet weather.

rust

A fungal disease with orange or reddish-brown powdery pustules, usually on the undersides of leaves.

resistant variety

A plant variety that is not easily infected by a particular disease.

CORE IDEAS

Most plant diseases are caused by fungi and their look-alikes, the water molds. A fungal disease starts when a **spore** lands on a leaf, stem or fruit. With moisture and the right temperature, it germinates and sends a thread into the plant through a stoma, a wound, or directly through the skin. The fungus feeds on the plant, then makes thousands of new spores that blow in the wind or splash in rain drops to new leaves. Many fungi survive the winter in fallen leaves and old stems, which is why garden cleanup matters.

Powdery mildew looks like white flour dusted on leaves. Unlike most fungi, it lives on the leaf surface and does not need wet leaves; it thrives with warm days and cool, humid nights, often in late summer on squash, cucumbers, zinnias, phlox and lilacs. **Early blight** makes brown spots with concentric rings like a target on the lowest tomato leaves; the leaves turn yellow and drop as it climbs. It splashes up from the soil, so mulch and removing lower leaves help.

Late blight (the Irish potato famine disease) is caused by a water mold and moves very fast in cool, wet weather, turning leaves and stems into greasy, gray-green patches that can kill a planting in a week. Infected plants should be bagged and thrown away, never composted, and neighbors and the extension office alerted. **Rust** makes orange pustules; **gray mold** (*Botrytis*) makes fuzzy gray rot on strawberries and flowers in damp weather; and **damping off** (Lesson 7.1) rots seedlings at the soil line.

Prevention follows the disease triangle. Choose **resistant varieties**. Space plants and prune so air moves through them. Water the soil, not the leaves, and in the morning.

Mulch to stop splashing. Rotate tomatoes, potatoes and squash to a new bed each year for at least three years. Remove infected leaves promptly (sealed in the trash, not the compost), and clean tools and stakes. When a fungicide is needed, an adult chooses one labeled for the crop and disease and follows the label exactly; the label is the law.

Remember that most fungi are friends. The decomposers and mycorrhizal partners of Unit 3 vastly outnumber the troublemakers. Like a good shepherd who knows the difference between a wolf and a sheepdog, a good gardener learns to tell them apart.

PICTURE STUDY



Blue Mould and Rose-Leaf Rust, from Micrographia, Robert Hooke, 1665 · Engraving · Micrographia, published by the Royal Society, London
Image: [Wikimedia Commons](#), public domain

Robert Hooke looked through his microscope at the blue mold growing on a piece of leather and at the little spots on the leaves of rose bushes. He drew what he saw: a tiny forest of stalks with round heads, and clusters of fungus bursting from a leaf. These are among the first drawings ever made of fungi under a microscope.

Look closely

- Find the stalks of mold in the top picture. What do the round heads hold?
- Look at the lower picture of the rose leaf. Find the clusters of rust bursting out.
- Compare the size of the mold stalks with what you could see with your eyes alone.
- Look at the shading Hooke used. How did he make the tiny stalks look round?

Talk about it

1. If each round head is full of spores, how might the mold spread to new food?
2. Rust on roses spreads best in moist weather. Which side of the disease triangle is that?

3. Hooke did not know that fungi cause disease. What do we know now that he did not?

Safety first. Do not eat any wild mushroom. Wash hands after handling diseased leaves, and bag them for the trash. Only an adult handles fungicides, even “natural” ones.

HANDS-ON PROJECT

Spore Prints and a Disease Scouting Walk

You will capture the spores of a mushroom to see how many a fungus makes, then scout plants for fungal diseases and record what you find.

You will need

- Two fresh store-bought mushrooms with open caps (white button and brown cremini or portobello)
- White and black paper, and a bowl or glass to cover the caps
- A hand lens
- Your journal and colored pencils
- Zip-top bags for any diseased leaf samples

Steps

1. Cut the stem off each mushroom flush with the cap. Set each cap, gills down, half on white paper and half on black.
2. Cover with a bowl to block drafts and leave overnight.
3. Lift the caps carefully. Draw the spore print and note its color. Every speck is made of thousands of spores.
4. Scout: visit a garden, park or your own plants. Check the lowest leaves, undersides of leaves, stems and fruits of at least ten plants.
5. For each plant with a problem, record: plant, part affected, symptom, sign (if any), how much of the plant is affected, and the weather that week.
6. Using the core ideas, make your best identification (powdery mildew, early blight, rust, gray mold, or “unknown”).
7. Collect one example in a sealed bag to examine with a hand lens, then throw it away sealed.
8. Write a prevention plan for the worst problem you found, with one step for each side of the disease triangle.

Tips

- Powdery mildew can be wiped off with a finger; many other leaf coatings cannot.
- Look for early blight on the lowest tomato leaves after rainy weeks.

Check your work

- ☐ I made a spore print and described it.
- ☐ I scouted at least ten plants and recorded signs and symptoms.
- ☐ My prevention plan addresses host, pathogen and environment.

NATURE JOURNAL

1. Draw a tomato leaf with early blight, showing the target rings and the yellow halo.
2. Draw a squash leaf with powdery mildew, and a magnified view of the white threads and spore chains.
3. Draw your spore print and label its color.

From history. In 1882 the French botanist Pierre-Marie-Alexis Millardet noticed that grapevines along a roadside, sprayed with a blue copper-and-lime mixture to discourage passers-by from picking, stayed free of mildew. The “Bordeaux mixture” became the first widely used fungicide.

COMMON MISTAKES

- Composting blighted plants. Many spores survive; bag them for the trash.
- Planting tomatoes in the same bed every year, so spores in the soil wait for them.
- Thinking all white coatings are powdery mildew. Check whether it wipes off, and look closely with a hand lens.

Make it a game • Spore Print Disease Gallery. Make a gallery of six drawn leaves: powdery mildew, early blight, late blight, rust, gray mold and damping off. Parent describes symptoms and you point to the right leaf and name a fix, like resistant variety or spacing. Explain how spores spread. Get all six in under two minutes, then repeat to beat your time.

8.3 BACTERIAL AND VIRAL DISEASES

OBJECTIVES

- Compare how bacteria and viruses infect plants and how they spread.
- Recognize bacterial wilt, bacterial leaf spot, soft rot, and viral mosaic and leaf curl.
- Model how vectors, hands and tools spread disease, and write a sanitation plan.

Warm-up. Look at a picture of a striped red-and-white tulip (see the picture study) and a plain red one. Which would you think is healthier? Write your guess before reading.

WATCH

Early season management of cucumber beetles and bacterial wilt on pumpkin and squash

The Ohio State University IPM Program • 5:24

https://www.youtube.com/watch?v=RSzTT_gbma4

WHEN TO WATCH

After the core idea on bacterial wilt. Note how the beetle and the bacteria work together.

Note: Any insecticide discussed is a decision for an adult, after scouting and reading the label.

BACKUP VIDEO

The Plant Virus That Started It All

Virology Research Services • 3:39

<https://www.youtube.com/watch?v=STg7c-tCq-Q>

After the history note, to learn how tobacco mosaic virus led to the discovery of viruses.

KEY TERMS

bacterium

A single-celled organism; plant-disease bacteria enter through wounds and natural openings and spread in water, on tools and by insects.

vector

An organism, usually an insect, that carries a pathogen from one plant to another.

mosaic

A light-and-dark green mottled pattern on leaves, a common symptom of virus disease.

virus

A tiny particle of genetic material in a protein coat that can multiply only inside living cells.

bacterial wilt

A disease of cucumbers and melons, spread by cucumber beetles, in which bacteria clog the xylem and vines wilt suddenly.

sanitation

Keeping tools, hands, seed and the garden clean to stop pathogens from spreading.

CORE IDEAS

Bacteria that cause plant disease cannot push through healthy skin as fungi can. They enter through wounds, stomata and other natural openings, and they travel in splashing water, on hands and tools, and inside insects. In warm, wet weather they multiply quickly. Common bacterial diseases include **bacterial leaf spot** (small, angular, water-soaked spots, often with yellow edges), **soft rot** (mushy, foul-smelling rot of potatoes, carrots and cabbages), and **bacterial wilt**.

Bacterial wilt shows a partnership of pests. Striped and spotted **cucumber beetles** carry the bacteria in their guts. When they feed on cucumber or melon seedlings, bacteria enter the wounds, multiply in the xylem and clog it, so the vine wilts suddenly even when the soil is wet, and does not recover. A simple field test: cut a wilted stem, touch the cut ends together and slowly pull them apart; sticky, string-like strands suggest bacterial wilt. Control centers on the **vector**: row covers on young plants until flowering, yellow sticky traps for scouting, and resistant or less-favored varieties.

Viruses are far smaller than bacteria and can multiply only inside living cells. Plant viruses are spread mainly by sap-sucking insects such as aphids, thrips and

whiteflies, and some by hands and tools, or in seed. Symptoms include a **mosaic** of light and dark green on leaves, curled or puckered leaves, yellow rings, streaks, and stunting. Tobacco mosaic virus is so tough it can survive on hands, tools and even dried tobacco, which is why gardeners wash hands before handling tomatoes and peppers.

Neither bacterial nor viral diseases can be cured once a plant is infected; no spray will fix them. Gardeners rely on prevention: clean seed and resistant varieties (look for codes such as TMV on tomato packets), **sanitation** (clean tools with soapy water or a disinfectant, wash hands, stay out of wet plants), crop rotation, controlling the insect vectors and weeds that shelter them, and pulling and bagging infected plants promptly before insects spread the disease further.

Some virus symptoms were once prized. In the 1600s, Dutch growers paid astonishing prices for tulips with flamed and feathered stripes, such as the famous *Semper Augustus*. No one knew that the beautiful streaks were caused by a virus spread by aphids, which also weakened the bulbs. Modern striped tulips get their patterns from healthy genes instead.

PICTURE STUDY



Semper Augustus, Unknown Dutch artist, 1600s · Watercolor, from a tulip book

Image: [Wikimedia Commons](#), public domain

During the 1630s, Dutch tulip lovers recorded their most prized varieties in painted catalogs called tulip books. The *Semper Augustus* (“always majestic”) was the most famous and most expensive tulip of all. Its flame-like stripes were, we now know, caused by a virus.

Look closely

- Look at the stripes on the petals. Are they even, or do they look like flames?
- Find the leaves. Can you see any mottling or streaks?
- Look at the stem and the size of the flower. Does the plant look strong?
- Compare the white and red areas. Where is the color “broken”?

Talk about it

1. The virus that caused these stripes was spread by aphids. How would a tulip grower today stop it?
2. Why might a virus-infected tulip produce fewer and weaker bulbs each year?
3. Why do you think people valued a diseased flower so highly?

Safety first. Wash hands before and after handling plants, especially tomatoes, peppers and potatoes. Bag diseased plants for the trash. An adult mixes any disinfectant for tools, and you should never mix cleaning products.

HANDS-ON PROJECT

Spread It, Stop It: A Sanitation Experiment

You will model how a pathogen spreads from plant to plant on hands, tools and “insects,” then design a sanitation plan that would stop it.

You will need

- Ten small potted plants or ten paper “plants” (cups with paper leaves)
- Fine glitter or a little flour (the “pathogen”)
- A pair of garden scissors and a small paintbrush (the “insect”)
- Soap and water, a towel
- A hand lens and your journal

Steps

1. Line up the ten plants and number them. Lightly dust plant 1 with glitter or flour: it is “infected.”
2. Trial 1, hands: touch plant 1, then touch each plant down the line in order, as if pinching off suckers. Count how many plants now have glitter.
3. Clean everything. Re-dust plant 1.
4. Trial 2, tools: snip a leaf of plant 1 with the scissors, then snip a leaf of each other plant. Count the spread.
5. Trial 3, insect vector: brush plant 1, then “fly” the brush to five random plants. Count the spread.
6. Trial 4, sanitation: repeat trial 2, but wash and dry the scissors after each plant. Count the spread.
7. Make a bar graph of plants infected in each trial.
8. Write a garden sanitation plan with at least six rules (for example: wash hands before handling tomatoes, clean pruners between plants, work in the healthy part of the garden first, stay out of wet plants, use row covers against beetles, bag diseased plants).

Tips

- Work from healthy plants toward sick ones, never the other way, both in the experiment and in the garden.
- Look on the undersides of leaves of real plants for aphids and whiteflies, the most common virus vectors.

Check your work

- ☐ I ran four trials and graphed the spread in each.
- ☐ I can explain what a vector is and name three insect vectors.
- ☐ My sanitation plan has at least six specific rules.

NATURE JOURNAL

1. Draw a leaf with a mosaic pattern next to a healthy leaf.
2. Draw the bacterial wilt cycle: beetle feeds, bacteria enter, xylem clogs, vine wilts, beetle moves on.
3. Make a table comparing fungi, bacteria and viruses: size, how they enter, how they spread, signs and symptoms, and controls.

From history. In 1892 the Russian scientist Dmitri Ivanovsky found that the sap of tobacco plants with mosaic disease could infect healthy plants even after passing through a filter fine enough to stop every bacterium. In 1898 Martinus Beijerinck concluded it must be a new kind of agent, which he called a virus. Tobacco mosaic virus was the first virus ever discovered.

COMMON MISTAKES

- Spraying a fungicide on a bacterial or viral disease. It will not help.
- Leaving a virus-infected plant in the garden, where insects carry the virus to healthy plants.
- Working among wet plants, which spreads bacteria in water droplets.

Make it a game • Spread It Stop It. Play a sanitation tag. Dip a finger in flour, 'touch' paper plants to show how bacteria or viruses spread by tools, hands, insects and water. Then clean the tools and repeat to show sanitation breaking the chain. Name a vector in each round, and match bacterial wilt, soft rot and mosaic to their symptoms. Fewest infected plants wins.

8.4 INTEGRATED PEST MANAGEMENT AND THE SKILLATHON

OBJECTIVES

- List and explain the steps of integrated pest management.
- Scout a garden, record pest and beneficial insect counts, and compare them with an action threshold.
- Identify at least 25 vegetables, seeds, weeds and insects in a skillathon-style drill.

Warm-up. Name every insect you have seen in a garden this year. Sort them into three groups: “helps,” “harms,” and “not sure.” Which group is biggest?

WATCH

5 IPM (integrated pest management) strategies to keep your garden pest free!

MU Extension Integrated Pest Management · 8:31

https://www.youtube.com/watch?v=-h4ny_sqY4k

WHEN TO WATCH

After the core ideas. Write each strategy and one example of it in your own garden.

BACKUP VIDEO

How to Scout your Garden for Pests

Utah State University Extension · 7:17

https://www.youtube.com/watch?v=F_MAHfhBf60

Before your first scouting walk in the project.

KEY TERMS

integrated pest management (IPM)

A step-by-step method of controlling pests that combines prevention, monitoring and the least harmful effective controls.

scouting

Regularly inspecting plants to find and count pests, beneficial insects and damage.

action threshold

The level of pests or damage at which action is needed; below it, the pests are tolerated.

beneficial insect

An insect that helps the garden, such as a pollinator or a predator or parasite of pests (lady beetles, lacewings, parasitic wasps).

cultural control

Changing how the garden is grown to prevent pests: rotation, timing, resistant varieties, spacing, clean-up.

skillathon

A 4-H or FFA contest of hands-on stations, such as identifying plants, seeds, insects or tools.

CORE IDEAS

Integrated pest management, or IPM, replaces the old habit of spraying on a schedule with a thoughtful method. Its steps are: **prevent** problems with healthy soil, resistant varieties and good timing; **identify** exactly which insect, disease or weed is present; **monitor** by scouting regularly and counting; decide using an **action threshold**; **control** starting with the gentlest effective method; and **evaluate** whether it worked.

Scouting means walking the garden once or twice a week, turning over leaves, and counting. Look for eggs, young and adult insects, and damage. Yellow sticky cards catch flying pests such as whiteflies and cucumber beetles and show when they arrive. Write everything down. Most insects in a garden are harmless or helpful, and a few holes in leaves rarely reduce a harvest. The **action threshold** is the point where action pays: for example, a home gardener might act when aphids crowd the tips of many shoots, or when hornworms or cabbage worms are found on more than a few plants.

Controls are chosen in order. **Cultural controls** come first: rotate crops, plant at times when pests are fewer, choose resistant varieties, and clean up crop debris. **Mechanical and physical controls** come next: hand-pick hornworms and beetles into soapy water, blast aphids off with a stream of water, cover young squash and cabbage with floating row covers, set board traps for slugs. **Biological controls** work with God's design: lady beetles and lacewing larvae eat aphids, and tiny parasitic wasps lay eggs in hornworms. A hornworm covered in white cocoons is already doomed; leave it, so the wasps hatch and hunt again.

Chemical controls come last, and only when the threshold is passed and other methods fail. Even then an adult chooses the least toxic product labeled for that pest and that crop, reads the whole label, protects bees by not spraying open flowers, and follows the label exactly, because the label is the law. Children never handle pesticides.

IPM depends on knowing what you are looking at. That is why 4-H and FFA horticulture and entomology contests include identification **skillathons**: stations where contestants name vegetables, seeds, weeds, insects and tools. A gardener who can tell a lady beetle larva from a pest, or a seedling squash from a weed, makes far better decisions.

PICTURE STUDY

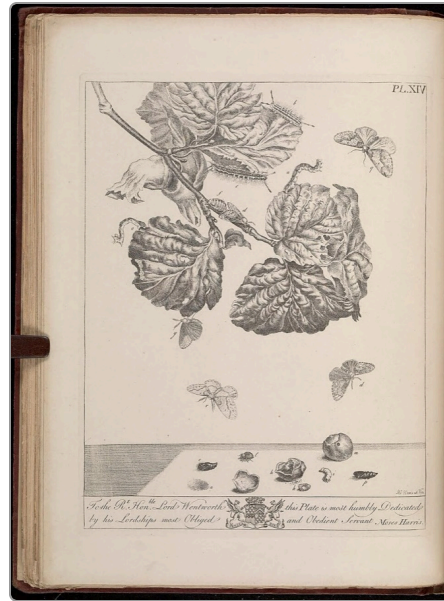


Plate XIV, from *The Aurelian*, Moses Harris, 1766 · Engraving from *The Aurelian, or Natural History of English Insects* · *The Aurelian* by Moses Harris

Image: [Wikimedia Commons](#), public domain

Moses Harris was an English entomologist and engraver who raised caterpillars himself so he could draw every stage of their lives: egg, caterpillar, chrysalis or cocoon, and adult. Knowing every stage of an insect is the first step in IPM, because each stage is found, and controlled, in a different way.

Look closely

- Find the caterpillars. Where are they feeding?
- Find leaves with damage. What do the chewed edges look like?
- Find the eggs, chrysalises or cocoons. Where are they placed?
- Find the adult moths or butterflies. How are they different from the caterpillars?

Talk about it

1. At which stage does this insect damage the plant? At which stage might a gardener find it easiest to remove?
2. If you scouted a plant like this and found three caterpillars, would you act? What would your threshold be?

3. Why is it important to know an insect's whole life cycle before deciding how to control it?

Safety first. Never handle pesticides; only an adult does, following the label. Wear gloves to hand-pick beetles and slugs, and wash hands afterward. Some caterpillars have stinging hairs; if you do not know what it is, don't touch it bare-handed.

Weekly Scouting and a 25-Item Skillathon

You will scout a garden for three weeks like an IPM professional, and then run a timed identification drill like the ones in 4-H and FFA contests.

You will need

- A garden, community garden plot, or several containers of vegetables
- A hand lens, a clipboard and a scouting sheet you design
- Two yellow sticky cards and stakes
- 25 numbered items or photos for the skillathon (see step 6)
- A timer

Steps

1. Design a scouting sheet with columns for: date, plant, pest (name and count), beneficial insects (name and count), damage (percent of leaves), disease signs, and action.
2. Once a week for three weeks, examine 10 plants of each crop, including the undersides of leaves. Record every insect and every sign of damage.
3. Set two yellow sticky cards on stakes at plant height. Count and identify the insects on them each week, then replace them.
4. After three weeks, compare your counts with an action threshold you set in advance for each pest. Decide: no action, a cultural or mechanical control, a biological control, or ask an adult about further steps.
5. Carry out one gentle control if needed (hand-picking, a water spray for aphids, a row cover) and record whether it worked the next week.
6. Skillathon: with a parent, gather 25 numbered items or clear photos: at least 8 vegetable seeds (bean, pea, corn, squash, radish, lettuce, carrot, tomato), 8 vegetables, 5 common weeds (dandelion, crabgrass, purslane, lamb's-quarters, plantain), and 4 insects (lady beetle, aphid, tomato hornworm, cucumber beetle).
7. Set a timer for 15 minutes and write the name of each item. Have your parent check your answers.

8. Study the ones you missed, mix the order, and take the drill again a week later. Record both scores.

Tips

- Look up your state's 4-H horticulture or vegetable identification list; many extension offices post the exact items used in contests.
- A lady beetle larva looks like a tiny, spiny orange-and-black alligator. Learn it well; it is one of your best allies.

Check your work

- ☐ I scouted for three weeks and recorded pests, beneficial insects and damage.
- ☐ I compared counts with action thresholds and chose the gentlest effective control.
- ☐ I took the 25-item identification drill twice and improved my score.

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1. Draw the life cycle of a lady beetle: egg, larva, pupa, adult. Label which stages eat aphids.
2. Draw a tomato hornworm, and one carrying white parasitic wasp cocoons.
3. Draw the IPM steps as a ladder, with cultural controls on the bottom rung and chemical controls on the top.

From history. In the 1950s, entomologists in California found that heavy spraying of alfalfa was killing the beneficial insects that controlled aphids, and pests were coming back worse. Ray Smith, Vernon Stern and their colleagues proposed “integrated control” based on scouting and thresholds, and the idea grew into the IPM programs that university extension services teach today.

COMMON MISTAKES

- Killing every insect you see. Most garden insects are harmless or helpful.
- Mistaking lady beetle larvae for pests.
- Acting without counting first, so you never know whether the control worked.
- Spraying open flowers where bees are working.

Make it a game • Scouting Count Showdown. Scatter paper bugs, pests and beneficial insects around a room. Walk in a scouting pattern, count each kind and record on a chart. Compare your pest total to an action threshold the parent names. Decide: act or wait? Explain each IPM step in order. Pick cultural controls first. Parent hides more bugs next round.

Scripture. “And let us not be weary in well doing: for in due season we shall reap, if we faint not.” (Galatians 6:9, KJV)

Scouting every week, hand-picking pests and keeping records is patient, unglamorous work. Paul’s words remind us that faithful work bears fruit in its season.

UNIT 8

PLANT PATHOLOGY AND PEST MANAGEMENT

As the garden grows in late spring and summer, trouble arrives: spotted leaves, white powder, sudden wilting, chewed holes. A plant doctor does not panic or reach for a spray. Like a physician, he or she observes, asks questions, and diagnoses before treating. In this unit you will learn the science of plant disease, called plant pathology, and the careful method of integrated pest management that farmers and extension agents use.

You will study why disease needs three things at once, how fungi, bacteria and viruses attack plants, and how to scout, identify and act wisely, starting with the gentlest effective control. You will also practice the identification drills used in 4-H and FFA horticulture contests. Faithful, patient care of a garden is a picture of all good work: “let us not be weary in well doing: for in due season we shall reap, if we faint not” (Galatians 6:9).

PREREQUISITES

- Knows that some fungi and bacteria are helpful decomposers and partners (Unit 3)
- Knows the parts of a plant and how water moves through xylem (Unit 5)
- Has a garden bed, containers or houseplants to observe (or access to a community garden)

MASTERY CHECKLIST

- ☐ I can explain the disease triangle and use it to prevent disease.
- ☐ I can tell signs from symptoms and recognize common fungal, bacterial and viral diseases.
- ☐ I can explain how vectors and tools spread disease and how sanitation prevents it.
- ☐ I can follow the steps of integrated pest management, from scouting to action thresholds.
- ☐ I can identify at least 25 common vegetables, seeds, weeds and insects.

LESSONS IN THIS UNIT

8.1 The Disease Triangle

2 sessions of 50 minutes

8.2 Fungal Diseases

2 sessions of 50 minutes

UNIT 8 REVIEW

Answer each question. Short questions may be answered in a phrase; questions 11 and 12 should be written in complete sentences. 100 points total.

1. **7 pts**

Name the three parts of the disease triangle.

2. **8 pts**

Give one way a gardener can break each side of the disease triangle.

3. **7 pts**

What is the difference between a sign and a symptom? Give an example of each.

4. **7 pts**

How can you tell an abiotic problem from a disease?

5. **8 pts**

Describe the symptoms of early blight and of powdery mildew.

6. **7 pts**

Why should blighted plants be thrown away, not composted?

7. **8 pts**

How do cucumber beetles and bacteria work together to kill a cucumber vine?

8. **7 pts**

What is a vector? Name two insect vectors of plant viruses.

9. **7 pts**

List the IPM steps in order.

10. **8 pts**

Put these controls in IPM order, first to last: spraying, row covers, crop rotation, releasing lady beetles.

11. **13 pts**

You find a tomato hornworm covered with small white cocoons. Explain what they are and what you should do.

12. **13 pts**

Explain why no spray will cure a plant with a viral disease, and what a gardener should do instead.

ANSWER KEY

1. A susceptible host, a pathogen, and a favorable environment.
2. Host: plant resistant varieties. Pathogen: remove infected leaves, rotate crops, clean tools. Environment: water soil in the morning, space plants, mulch.
3. A sign is the pathogen itself (white powdery mildew, rust pustules, mushrooms); a symptom is the plant's response (wilting, yellowing, spots).
4. Abiotic problems often affect many kinds of plants at once in a pattern; diseases usually affect one kind of plant and spread over time.
5. Early blight: brown spots with target-like rings on the lowest tomato or potato leaves, which yellow and drop. Powdery mildew: white, powdery patches on leaf surfaces that wipe off.
6. Spores can survive in compost and reinfect the garden.
7. The beetles carry the bacteria and infect feeding wounds; the bacteria multiply in the xylem and clog it, so the vine wilts.
8. An organism that carries a pathogen between plants. Any two: aphids, thrips, whiteflies, leafhoppers, cucumber beetles.
9. Prevent, identify, monitor (scout), decide with an action threshold, control (gentlest first), evaluate.
10. Crop rotation (cultural), row covers (mechanical/physical), releasing lady beetles (biological), spraying (chemical).
11. The cocoons belong to tiny parasitic wasps whose larvae fed inside the hornworm. The hornworm will soon die and has mostly stopped feeding. Leave it in the garden so the wasps can emerge and parasitize more hornworms; this is biological control.
12. Viruses multiply inside the plant's own cells, so sprays cannot reach or kill them, and fungicides do not affect viruses at all. The gardener should remove and bag the infected plant, control the insect vectors and weeds, wash hands and tools, and choose resistant varieties and clean seed in the future.

PORTFOLIO PIECE: A PLANT DOCTOR'S CASEBOOK

Create a casebook of at least four real plant problems you found this season (in your garden, a neighbor's, or a community garden). For each case, include a drawing or photo, the plant doctor's questions and answers, signs and symptoms, your diagnosis (abiotic, fungal, bacterial, viral or insect), the disease-triangle or IPM reasoning behind it, the action taken, and the result. Add your scouting sheets and your two skillathon scores.

LOOK FOR	WHAT IT MEANS
Observation	Each case has clear drawings or photos and dated, specific notes.
Diagnosis	Diagnoses are reasonable and supported by signs, symptoms and patterns.
IPM reasoning	Actions follow the IPM order and the disease triangle, using the gentlest effective control.
Records	Scouting sheets and skillathon scores are complete.
Reflection	The casebook ends with what you would do differently next season.