

GRADE 5 GARDENING & ANIMALS

First edition

8 units

32 lessons

A video for every lesson

FIRST EDITION

COURSE GUIDE

In Grade 5, students move from simply noticing nature to explaining it. They learn why Earth has seasons, how a leaf makes sugar from light, how water climbs a stem, how microbes heat a compost pile, how bacteria clean an aquarium, and how insects grow through their life cycles. Each idea is tested with a real experiment at a kitchen table, in a few pots, or in the yard: floating leaf disks, jar tests of soil texture, erosion trays, a fertilizer trial, a broadcast-or-drill field trial and more.

The year follows the eight strands of the School Launch gardening and animals spiral: harvest and the seasons, wildlife, soil, pets, plant science, farm animals and bees, planting, and plant health. Along the way students practice the skills of 4-H, FFA and county fair exhibitors: keeping project records and budgets, judging plants and animals and giving reasons, preparing a potted plant or a jar of honey for exhibit, practicing poultry showmanship, and giving a short illustrated talk.

Every lesson includes a picture study of a great painting or natural-history plate, from Dürer and Bruegel to Audubon and Merian, chosen to train the eye on the science of the lesson. The course is written from a classical Christian view: God is the Creator, and we are stewards of His creation, called to tend the garden and care for the animals with knowledge, diligence and gratitude.

Most videos come from university extension services (Penn State, NC State, Missouri, Cornell, Oregon State), state conservation agencies, reputable science channels such as SciShow Kids and TED-Ed, and experienced gardening, homestead, pet and beekeeping educators. Each one was checked for accuracy and wholesome content. Some gardening and pet channels mention their own shops or products at the end; you may skip those parts. A few lessons note specific moments for parents in the video's note.

WHO IT IS FOR

Students about 10 to 11 years old who read independently and can measure, graph and work with simple percentages. No yard, garden or animals are required: every project offers a windowsill, balcony, park, farm-visit, pet-store or planning option.

HOW TO USE THIS COURSE

1. The weekly rhythm: one lesson a week in two sessions of about 45 minutes, 32 weeks in all. Session 1 is the warm-up, core ideas, video and picture study. Session 2 is the hands-on project and the nature journal. Many projects continue with short daily or weekly observations.
2. The calendar: units follow a school year that starts in late summer, with harvest and wildlife in fall, soil and pets in early winter, plant science and seed starting in late winter, farm animals and bees in early spring, planting in spring, and plant health as the garden grows. Shift the units to match your own frost dates; your county extension office lists them.
3. Picture study: look quietly at the picture for two minutes, then put it away and tell back everything you remember. Then look again and work through the questions, which tie the picture to the lesson's science.
4. The nature journal: keep one bound sketchbook for the year. It holds drawings from life, measurements, data tables, graphs, weather notes and records. From this year on, include the kind of record a 4-H project book asks for: dates, what was done, costs, feed or water used, growth measurements and what was learned.
5. Unit review and portfolio project: each unit ends with a written review worth 50 points and a portfolio project that gathers the unit's work into something real, such as a soil report, a pet keeper's handbook or a planting record.
6. Fairs and contests: lessons 5.3, 6.1, 6.4 and 7.1 include judging classes in the 4-H style; 6.4 and 7.1 teach how to prepare a fair exhibit; 6.1 teaches poultry showmanship; and 7.2 ends with a illustrated talk. Homeschoolers can join 4-H through their county extension office. Check your county extension office or fair book for ages, classes and rules.
7. Safety and adult supervision: an adult supervises any use of knives, the stove, sharp garden tools, heat lamps and fertilizers, and every visit with large animals

or beehives. Wash hands with soap after handling soil, compost, animals, reptiles and poultry. Never touch or feed wild animals, and never eat wild plants or mushrooms. Children do not handle pesticides.

8. Scripture: about half the lessons include a verse from the King James Bible with a short note connecting it to the lesson. Read it together and talk about it briefly.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–4

Harvest and the Seasons

Earth's tilt, solstices and equinoxes; keeping a phenology journal; the farmer's year and old almanacs; and the science of canning, drying and freezing the harvest.

- 1.1 Solstices, Equinoxes and Earth's Tilt
- 1.2 Keeping a Phenology Journal
- 1.3 The Farmer's Year and the Old Almanacs
- 1.4 Preserving the Harvest: Canning, Drying and Freezing

UNIT 3 • WEEKS 9–12

Soil Science

The soil texture triangle and jar test; organic matter and humus; the microbiology of hot composting; and erosion, the Dust Bowl and soil conservation.

- 3.1 The Soil Texture Triangle
- 3.2 Organic Matter and Humus
- 3.3 The Science of Composting
- 3.4 Erosion and Conservation: The Dust Bowl

UNIT 2 • WEEKS 5–8

Wildlife

Classifying local mammals with a dichotomous key; identifying birds by field marks and song; living safely alongside raccoons, skunks and coyotes; and telling moles, voles and mice apart.

- 2.1 Classifying Local Mammals
- 2.2 Birds by Song and Field Marks
- 2.3 Living Alongside Raccoons, Skunks and Coyotes
- 2.4 Moles, Voles and Mice

UNIT 4 • WEEKS 13–16

Pets

Basic needs of animals and a pet budget; the aquarium nitrogen cycle; heat gradients and UVB for reptiles; and dog body language and positive-reinforcement training.

- 4.1 Good Stewardship: The Basic Needs of Animals
- 4.2 The Aquarium Nitrogen Cycle
- 4.3 Reptile Heat, UVB and Habitat
- 4.4 Dog Behavior and Training

UNIT 5 • WEEKS 17–20

Plant Science

Photosynthesis and respiration; transpiration and water movement; macro- and micronutrients with a fertilizer trial and judging class; and light intensity and day length.

- 5.1 Photosynthesis and Respiration
- 5.2 Transpiration and Water Movement
- 5.3 Macronutrients and Micronutrients
- 5.4 Light Intensity and Day Length

UNIT 7 • WEEKS 25–28

Planting

Potting mixes, repotting and a fair plant exhibit; propagation from cuttings with a illustrated talk; garden design and crop rotation; and the history of the plow and the seed drill.

- 7.1 Potting Mixes and Repotting
- 7.2 Propagation from Cuttings
- 7.3 Garden Design and Crop Rotation
- 7.4 Field Planting Through History: The Plow and the Seed Drill

UNIT 6 • WEEKS 21–24

Farm Animals and Bees

Raising chicks, biosecurity and poultry showmanship; dairy goats, butter and fresh cheese; horse grooming, hooves, tack and colors; and beekeeping tools, hive inspection and a fair honey jar.

- 6.1 Raising Chicks and Showing Poultry
- 6.2 Goats and Milk: Butter and Simple Cheese
- 6.3 Horse Care: Hooves, Grooming and Tack
- 6.4 Beekeeping Tools and a Hive Inspection

UNIT 8 • WEEKS 29–32

Plant Health

Fungal, bacterial and viral plant diseases; insect pests and their life cycles; beneficial insects and integrated pest management; and weeds and competition.

- 8.1 Plant Diseases: Fungi, Bacteria and Viruses
- 8.2 Insect Pests and Their Life Cycles
- 8.3 Beneficial Insects and Integrated Pest Management
- 8.4 Weeds and Competition

WEEKLY PACING CALENDAR

WEEK	PLAN
1	• Session 1: Lesson 1.1 Solstices, Equinoxes and Earth's Tilt: 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>

WEEK	PLAN
2	• Session 1: Lesson 1.2 Keeping a Phenology Journal: warm-up, video, teaching and picture study • Session 2: Lesson 1.2 hands-on project and nature journal
3	• Session 1: Lesson 1.3 The Farmer's Year and the Old Almanacs: warm-up, video, teaching and picture study • Session 2: Lesson 1.3 hands-on project and nature journal
4	• Session 1: Lesson 1.4 Preserving the Harvest: Canning, Drying and Freezing: 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 Classifying Local Mammals: warm-up, video, teaching and picture study • Session 2: Lesson 2.1 hands-on project and nature journal
6	• Session 1: Lesson 2.2 Birds by Song and Field Marks: warm-up, video, teaching and picture study • Session 2: Lesson 2.2 hands-on project and nature journal
7	• Session 1: Lesson 2.3 Living Alongside Raccoons, Skunks and Coyotes: warm-up, video, teaching and picture study • Session 2: Lesson 2.3 hands-on project and nature journal
8	• Session 1: Lesson 2.4 Moles, Voles and Mice: 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 The Soil Texture Triangle: warm-up, video, teaching and picture study • Session 2: Lesson 3.1 hands-on project and nature journal
10	• Session 1: Lesson 3.2 Organic Matter and Humus: warm-up, video, teaching and picture study • Session 2: Lesson 3.2 hands-on project and nature journal

WEEK	PLAN
11	• Session 1: Lesson 3.3 The Science of Composting: warm-up, video, teaching and picture study • Session 2: Lesson 3.3 hands-on project and nature journal
12	• Session 1: Lesson 3.4 Erosion and Conservation: The Dust Bowl: 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 Good Stewardship: The Basic Needs of Animals: warm-up, video, teaching and picture study • Session 2: Lesson 4.1 hands-on project and nature journal
14	• Session 1: Lesson 4.2 The Aquarium Nitrogen Cycle: 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 Heat, UVB and Habitat: warm-up, video, teaching and picture study • Session 2: Lesson 4.3 hands-on project and nature journal
16	• Session 1: Lesson 4.4 Dog Behavior and Training: 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 Photosynthesis and Respiration: warm-up, video, teaching and picture study • Session 2: Lesson 5.1 hands-on project and nature journal
18	• Session 1: Lesson 5.2 Transpiration and Water Movement: warm-up, video, teaching and picture study • Session 2: Lesson 5.2 hands-on project and nature journal
19	• Session 1: Lesson 5.3 Macronutrients and Micronutrients: warm-up, video, teaching and picture study • Session 2: Lesson 5.3 hands-on project and nature journal

WEEK	PLAN
20	• Session 1: Lesson 5.4 Light Intensity and Day Length: 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 Raising Chicks and Showing Poultry: warm-up, video, teaching and picture study • Session 2: Lesson 6.1 hands-on project and nature journal
22	• Session 1: Lesson 6.2 Goats and Milk: Butter and Simple Cheese: warm-up, video, teaching and picture study • Session 2: Lesson 6.2 hands-on project and nature journal
23	• Session 1: Lesson 6.3 Horse Care: Hooves, Grooming and Tack: warm-up, video, teaching and picture study • Session 2: Lesson 6.3 hands-on project and nature journal
24	• Session 1: Lesson 6.4 Beekeeping Tools and a Hive Inspection: 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 Potting Mixes and Repotting: warm-up, video, teaching and picture study • Session 2: Lesson 7.1 hands-on project and nature journal
26	• Session 1: Lesson 7.2 Propagation from Cuttings: warm-up, video, teaching and picture study • Session 2: Lesson 7.2 hands-on project and nature journal
27	• Session 1: Lesson 7.3 Garden Design and Crop Rotation: 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 Planting Through History: The Plow and the Seed Drill: 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

WEEK	PLAN
29	• Session 1: Lesson 8.1 Plant Diseases: Fungi, Bacteria and Viruses: warm-up, video, teaching and picture study • Session 2: Lesson 8.1 hands-on project and nature journal
30	• Session 1: Lesson 8.2 Insect Pests and Their Life Cycles: warm-up, video, teaching and picture study • Session 2: Lesson 8.2 hands-on project and nature journal
31	• Session 1: Lesson 8.3 Beneficial Insects and Integrated Pest Management: warm-up, video, teaching and picture study • Session 2: Lesson 8.3 hands-on project and nature journal
32	• Session 1: Lesson 8.4 Weeds and Competition: warm-up, video, teaching and picture study • 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 (sketchbook or bound notebook)

For drawings, measurements, data tables, graphs and project records all year.

Colored pencils, a ruler, a tape measure and a calculator

Used in nearly every lesson for drawings, measuring and data.

Magnifying glass

For soil, insects, leaf surfaces, mold and seeds.

Thermometers (one outdoor and one kitchen or compost thermometer)

For weather logs, compost, cheese-making and reptile heat gradients.

Clear jars with lids, zip bags and clear cups

For the soil jar test, mold test, celery dye test and leaf-disk experiment.

Pots with drainage holes, potting mix, seed-starting mix and perlite

For plant experiments, cuttings and repotting.

Seeds: bush beans, radishes, lettuce, sunflowers, herbs and a small amount of wheat or oats

For experiments, the field trial and the garden.

Garden gloves, a trowel and a watering can

For soil, compost, weeding and planting.

A balanced liquid fertilizer and aquarium test strips

Optional; for the fertilizer trial and the aquarium lesson (adult handles fertilizer).

A grow light or LED shop light

Optional but very helpful for seed starting and the light trial.

Field guides to birds, mammals, insects and weeds of your region

From the library, or your state extension and wildlife agency websites.

Binoculars

Optional; for bird counts.

Access to animals: a family pet, a neighbor's animals, a farm, a stable, a beekeeper or a county fair

Optional; every animal project also has a planning or observation option.

GRADING

Grades combine hands-on projects, the nature journal, unit reviews and portfolio projects. Effort, accuracy and careful records matter more than artistic skill.

PART	%
Hands-on projects	40
Nature journal	20
Unit reviews	15
Portfolio projects	25

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

- Hands-on projects are graded on following the steps, accurate measurements, complete records and the self-check statements.
- The nature journal is checked every few weeks for dated entries, careful drawings from life, and data tables and graphs.

- Unit reviews are worth 50 points; a student who scores below 40 should review the lesson and retake the missed questions orally.
- Portfolio projects are scored with the rubric in each unit; share the rubric with the student before starting.

A NOTE TO PARENTS

This course asks your child to do real science and real work: growing, measuring, recording and caring for living things. Some projects run for several weeks, so read each unit's lessons a week ahead and gather materials. You do not need a farm, a large yard or any animals. A windowsill, a few pots, a library card and occasional visits to a park, a farm store, a stable, a beekeeper or the county fair will carry you through the year.

Grade 5 is a wonderful age to connect with 4-H, a Junior Master Gardener group, a local bee club or a county fair. The course teaches the record keeping, judging, exhibiting, showmanship and presentation skills these programs use, so your child will be ready to take part if your family chooses. Above all, help your child see the garden and the animals as gifts from a generous Creator, to be tended faithfully and received with thanks.

UNIT 1

HARVEST AND THE SEASONS

Every gardener and farmer lives by the calendar of the sky. In this unit you will learn why Earth has seasons at all: not because Earth swings closer to the sun, but because it spins on a tilted axis. You will find the solstices and equinoxes, measure shadows, and see how the angle of sunlight and the length of the day decide when plants grow and rest.

Then you will become a careful watcher of the seasons by starting a phenology journal, learn how farmers planned their year with almanacs and calendars, and finish with the science of keeping the harvest: why canning, drying and freezing stop food from spoiling. God promised Noah that “seedtime and harvest” would not cease, and this unit teaches you to read that steady rhythm.

PREREQUISITES

- Knows the four seasons and the twelve months in order
- Can read a ruler and a thermometer
- Has a nature journal (a sketchbook or bound notebook) and colored pencils
- Can measure with a ruler to the nearest quarter inch or half centimeter

MASTERY CHECKLIST

- ☐ I can explain that Earth’s tilted axis, not its distance from the sun, causes the seasons.
- ☐ I can name the dates of the solstices and equinoxes and tell what happens to day length on each.
- ☐ I can keep a phenology log with dates, weather and first-of-the-season observations.
- ☐ I can describe the farmer’s year and tell what an almanac contained.
- ☐ I can explain how canning, drying and freezing each stop the microbes that spoil food.

LESSONS IN THIS UNIT

1.1 Solstices, Equinoxes and Earth’s Tilt

2 sessions of 45 minutes

1.2 Keeping a Phenology Journal

2 sessions of 45 minutes

UNIT 1 REVIEW

Answer each question in complete sentences unless it asks for a list. You may use your shadow log and almanac but not the lesson pages. The review is worth 50 points.

1. 5 pts

What causes the seasons on Earth? Explain in two or three sentences.

2. 5 pts

True or false: Earth is closest to the sun in July. Explain.

3. 5 pts

Name the solstices and equinoxes with their approximate dates.

4. 5 pts

Your 12-inch shadow stick casts a 6-inch shadow at noon one day and a 24-inch shadow at noon another day. Which day was nearer the winter solstice? Why?

5. 5 pts

What is phenology? Give two examples of phenology observations.

6. 5 pts

List three things a good phenology log entry should include.

7. 5 pts

What is a growing season, and how do you find it?

8. 5 pts

Name four things a farmer could find in an old almanac.

9. 5 pts

Explain how drying and freezing each keep food from spoiling.

10. **5 pts**

Why must green beans be canned in a pressure canner instead of a boiling-water canner?

ANSWER KEY

1. Earth's axis is tilted about $23\frac{1}{2}^{\circ}$ and stays pointed the same way as Earth orbits the sun. When our hemisphere leans toward the sun, sunlight strikes steeply and days are long (summer); when it leans away, sunlight slants and days are short (winter).
2. False. Earth is closest to the sun in early January, during northern winter, which shows distance is not the cause of the seasons.
3. Spring equinox about March 20; summer solstice about June 21; fall equinox about September 22; winter solstice about December 21.
4. The 24-inch day. In winter the sun is lower in the sky at noon, so shadows are longer.
5. The study of the timing of seasonal events in living things. Examples: the date of first bloom of a lilac; the date the first robin returns; the date maple leaves turn red.
6. Any three: date, time, temperature, weather, the plant's stage (phenophase), a measurement, a drawing.
7. The number of days between the average last spring frost and the average first fall frost. Count the days between the two dates.
8. Any four: monthly calendars, sunrise and sunset times, moon phases, tide tables, weather forecasts, farming advice, recipes, proverbs.
9. Drying removes the water microbes need to grow. Freezing makes food so cold that microbes stop growing and enzymes slow down.
10. Green beans are low-acid. A pressure canner reaches about 240°F , hot enough to destroy the spores of the bacteria that cause botulism; boiling water at 212°F is not.

PORTFOLIO PIECE: A SEASON KEEPER'S NOTEBOOK

Assemble your work from this unit into one notebook: your shadow-stick log and day-length graph, the first pages of your adopted-plant phenology log, your family garden almanac, and the results of your apple-drying test. Add a cover and a one-page introduction explaining, in your own words, why we have seasons and how a family can prepare for each one.

LOOK FOR	WHAT IT MEANS
Science of the seasons	The introduction correctly explains axial tilt, sun angle and day length, with a labeled diagram.
Accurate records	Shadow and phenology logs have dates, measurements and weather for every entry.
Garden almanac	All 12 months are included, with correct local frost dates and at least two jobs per month.
Preserving experiment	Weights, calculation of percent water and the 3-day comparison are recorded clearly.
Care and neatness	Pages are labeled, drawings are careful and the notebook is complete.

1.1 SOLSTICES, EQUINOXES AND EARTH'S TILT

OBJECTIVES

- Explain how Earth's $23\frac{1}{2}^{\circ}$ tilt causes the seasons.
- Name the solstices and equinoxes and tell what happens to day length on each.
- Measure how the sun's angle changes the length of a noon shadow.

Warm-up. Shine a flashlight straight down onto a sheet of paper and trace the bright spot. Now tilt the flashlight at a low slant from the same height and trace the spot again. Which spot is bigger? Which looks brighter? Write one sentence guessing what this has to do with summer and winter.

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 second core idea. Watch once straight through, then again and pause at June and December to see which half of Earth leans toward the sun.

BACKUP VIDEO

Reasons for the seasons - Rebecca Kaplan

TED-Ed · 5:20

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

A second explanation, useful for the part about Earth being closest to the sun in January.

KEY TERMS

axis

The imaginary line through the North and South Poles that Earth spins around once a day.

axial tilt

The lean of Earth's axis, about $23\frac{1}{2}$ degrees, which always points the same way in space as Earth circles the sun.

solstice

The two days of the year when the sun's noon path is highest (about June 21) or lowest (about December 21) in our sky; the longest and shortest days.

equinox

The two days (about March 20 and September 22) when day and night are nearly equal everywhere on Earth.

angle of sunlight

How steeply the sun's rays strike the ground; steep rays heat the ground more than slanting rays.

CORE IDEAS

Earth makes one trip around the sun each year. Many people think summer comes when Earth is closest to the sun, but that is not true: Earth is actually closest to the sun in early **January**, in the middle of our northern winter. The real cause of the seasons is the **tilt** of Earth's axis. The axis leans about **23½ degrees**, and it keeps leaning the same direction, toward the North Star, all year long.

Because the tilt stays fixed while Earth travels, the Northern Hemisphere leans *toward* the sun for part of the year and *away* from it for the other part. When we lean toward the sun (June), the sun climbs high at noon and its rays hit the ground steeply. Steep rays pack their energy into a small area, like your flashlight shining straight down, so the ground warms. When we lean away (December), the sun stays low and its slanting rays spread the same energy over a much larger area, so the ground stays cool. That is why the Southern Hemisphere has summer when we have winter.

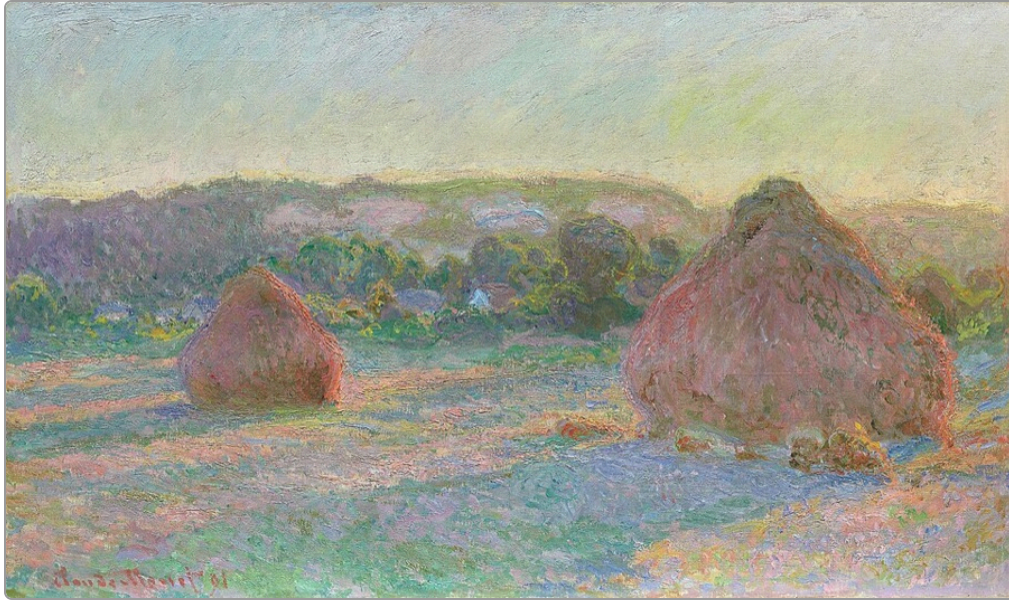
The tilt also changes the **length of the day**. On the **summer solstice**, about June 21, the sun rises far to the northeast, travels a long, high path and sets far to the northwest. At 40° north latitude (near Philadelphia, Columbus or Denver) that gives about 15 hours of daylight. On the **winter solstice**, about December 21, the sun rises in the southeast and sets in the southwest after only about 9 hours and 15 minutes. Long days and steep sunlight together make summer warm; short days and slanting light make winter cold.

Halfway between the solstices come the **equinoxes**, about March 20 and September 22. "Equinox" means "equal night": the sun rises due east, sets due west, and day and

night are each about 12 hours long all over the world. After the spring equinox our days are longer than our nights; after the fall equinox our nights are longer.

Plants and animals respond to these changes. Lengthening spring days and warming soil wake seeds and buds. Shortening fall days tell trees to drop their leaves and tell many birds to migrate, even before the first frost. A gardener who understands the tilt knows why lettuce bolts in June, why tomatoes need summer's long days, and why a fall garden grows slowly after the equinox. God set the lights in the heavens "for signs, and for seasons," and they keep perfect time.

PICTURE STUDY



Haystacks, Claude Monet, 1890–1891 · Oil on canvas (a series of about 25 paintings) · Museums around the world

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

Claude Monet painted the same grain stacks in the field beside his house over and over, from late summer of 1890 into the next winter. He wanted to catch how the light changed with the hour and the season. Each canvas is a record of the sun's angle on one particular day.

Look closely

- Find the shadow of the stack. Is it long or short? What does that tell you about how high the sun was?
- Look at the colors of the light on the stack. Is this the white light of noon or the warm light of a low sun?
- Find clues to the season in the field and the sky: snow, frost, green grass, or bare ground.
- Where is the sun? Trace a line from the bright side of the stack to its shadow to find the direction of the light.

Talk about it

1. If Monet painted the same stack at noon on the summer solstice, how would the shadow be different?

2. Why do you think farmers stacked grain in tall, rounded stacks instead of flat piles?
3. Monet painted the same subject in many seasons. What could a gardener learn by drawing the same place all year?

HANDS-ON PROJECT

A Noon Shadow Stick and Day-Length Chart

You will build a simple shadow stick, called a gnomon, and measure its noon shadow. You will also chart the sunrise and sunset times for your town across the year. Together they show the tilt of Earth working in your own yard.

You will need

- A straight stick or dowel exactly 12 inches tall (or a pencil standing in clay)
- A flat board or piece of cardboard and a lump of modeling clay
- A ruler, a pencil and a compass or phone compass app
- A sunny spot or a sunny windowsill
- Sunrise and sunset times for your town (an almanac, newspaper or weather website, with a parent)
- Graph paper

Steps

1. Stand the stick upright in clay in the middle of the board. Check with a ruler that it is exactly 12 inches tall and straight up and down.
2. Find solar noon for your town (it is usually between noon and 1:30 p.m. during daylight saving time; a parent can look it up). Set the board level in a sunny spot a few minutes before.
3. At solar noon, mark the tip of the shadow with a dot. Measure the shadow from the base of the stick to the dot and record it with the date.
4. Use the compass to check: at solar noon the shadow points due north. Draw an arrow labeled N.
5. Repeat the noon measurement once a week through this unit, and if you can, once a month all year. Record each one in your journal.
6. On graph paper, list the first day of each month down the side. With a parent, look up sunrise and sunset times for your town on each of those days and write them in.

7. Work out the hours of daylight for each date (sunset minus sunrise) and make a bar graph. Color the bars nearest the two solstices and the two equinoxes.
8. Compare your graph with your shadow measurements: when are the days longest, and when is the noon shadow shortest?

Tips

- If your measurements are hard to compare, keep the board in exactly the same place each time; mark the spot with a stone.
- A cloudy day just means waiting for the next sunny noon. Note the clouds in your log anyway.
- In the fall your shadow will grow longer each week. By the winter solstice a 12-inch stick near 40° north casts a shadow about 24 inches long at noon.

Check your work

- ☐ I can explain why the noon shadow is shortest in June and longest in December.
- ☐ I can read my day-length graph and name the longest and shortest days.
- ☐ I can tell a friend why summer is not caused by Earth being closer to the sun.

NATURE JOURNAL

1. Draw a labeled diagram of Earth at the June and December solstices, with the sun in the middle, the tilted axis, and arrows showing which hemisphere leans toward the sun.
2. Start a “Sun Log” page with columns for date, time, noon shadow length, weather and one plant or animal you noticed.
3. Sketch your shadow stick from the side with its shadow, and write the angle of the light in words (high, middle or low).

From history. Long before telescopes, farmers marked the solstices with stones, posts and windows that caught the sunrise on special days. In the 1500s Nicolaus Copernicus showed that Earth travels around the sun, and Johannes Kepler soon worked out that its path is a slightly stretched circle. The seasons still come from the tilt, just as careful observers had noticed all along.

COMMON MISTAKES

- Thinking summer happens because Earth is closer to the sun. Earth is closest in January.
- Measuring the shadow at different times of day and comparing them as if they were the same. Always measure at solar noon.
- Forgetting that the Southern Hemisphere has opposite seasons: Christmas in Australia comes in summer.

Make it a game · Tilt and Spin Show. Hold an orange or ball with a pencil through it, tilted about 23 degrees, and walk it around a chair that is the sun. Stop at four spots and announce solstice or equinox, then say what happens to day length. Parent sneaks in one wrong tilt fact. Catch it before the next stop.

Scripture. “And God said, Let there be lights in the firmament of the heaven to divide the day from the night; and let them be for signs, and for seasons, and for days, and years:” (Genesis 1:14, KJV)

The sun keeps time for the whole world. Every solstice and equinox happens right on schedule because the Creator set the lights “for seasons.”

1.2 KEEPING A PHENOLOGY JOURNAL

OBJECTIVES

- Define phenology and give examples of seasonal events in plants and animals.
- Choose one plant to observe through the year and record it accurately.
- Keep a phenology log with dates, temperatures and first-of-season events.

Warm-up. From memory, list five things that happen in your neighborhood every fall, such as leaves turning or geese flying over. Next to each, guess the date it usually happens. You will check your guesses with real observations this year.

WATCH

The Nature Journal Connection, Episode 3: My Secret Plant

John Muir Laws • 14:06

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

WHEN TO WATCH

Before the hands-on project. Try the “secret plant” game with a family member as he explains it, then use the same close looking on the plant you adopt.

BACKUP VIDEO

The Stories Plants Tell: The Science of Phenology

ProjectBudBurst • 3:16

https://www.youtube.com/watch?v=OHY-c_RDMkM

After the core ideas, as a short summary of what phenology is.

KEY TERMS

phenology

The study of when seasonal events happen in living things, such as budding, flowering, fruiting, leaf fall, migration and hatching.

phenophase

One stage in a plant’s or animal’s yearly cycle, such as “first leaf,” “full bloom” or “ripe fruit.”

first bloom

The date the first flower on a plant opens fully.

citizen science

Real scientific work done by ordinary people who send careful observations to researchers.

CORE IDEAS

Phenology (fee-NOL-uh-jee) is the study of the timing of nature: when the maple buds swell, when the first robin sings, when the apples ripen, when the geese fly south. The word comes from a Greek word meaning “to appear.” A phenologist writes down the date each event appears, year after year, and looks for patterns.

These events are not random. Plants and animals respond to **day length** and **temperature**. Day length changes the same way every year, but temperature does not: a warm March can bring blossoms early, and a cold spring can hold them back. That is why the forsythia might bloom on March 25 one year and April 10 the next. Phenology helps gardeners plant at the right moment by watching the living calendar instead of only the paper one.

Farmers and gardeners have used phenology for centuries. An old farmer’s rule says to plant corn “when oak leaves are the size of a squirrel’s ear,” because by then the soil is usually warm enough for corn seed. Another says to plant peas when the forsythia blooms. These sayings work because the oak, the forsythia and the soil are all being warmed by the same spring weather.

A good phenology journal is **accurate** and **repeatable**. Choose one or two plants you can visit every week, such as a tree in your yard, a lilac at church or a houseplant on the windowsill. Each visit, write the date, the time, the temperature, the weather, and the phenophase you see: buds closed, buds breaking, first leaf, full leaf, first flower, full bloom, fruit, leaves changing color, leaves dropped. Draw what you see, and measure something, such as a leaf’s length.

Over months, your journal becomes real data. Many people send their observations to citizen-science projects that collect dates from across the country. Henry Thoreau kept careful flower dates near Concord, Massachusetts in the 1850s, and scientists still use his notebooks. Faithful, patient watching like this is a way of honoring the One who made the seasons and of learning to garden wisely.

PICTURE STUDY



Almond Blossoms, Vincent van Gogh, 1890 · Oil on canvas · Van Gogh Museum, Amsterdam

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

Almond trees are among the first fruit trees to bloom each year, often while the weather is still cold. Van Gogh painted these branches in early spring in southern France as a gift to celebrate the birth of his baby nephew. To a phenologist, this painting is a picture of one date: first bloom.

Look closely

- Find flowers at different stages: tight buds, half-open flowers and fully open blossoms. Count each kind.
- Look for leaves. Are there any yet? What does that tell you about how early in spring this is?
- Trace one branch from its thick end to its tip. Where are the flowers growing: on old wood or new shoots?
- Notice the sky color. What kind of day does it suggest?

Talk about it

1. Why might a fruit tree that blooms very early be in danger from a late frost?
2. If you watched this tree for a whole year, what phenophases would you write down?
3. What plant near your home would you choose to watch, and why?

Adopt a Plant: A Year-Long Phenology Log

You will choose one plant to watch all year and set up the journal pages you will fill every week. By next summer you will have a record of your plant's whole year that no one else in the world has.

You will need

- Your nature journal and colored pencils
- An outdoor thermometer
- A ruler or measuring tape
- A plant you can visit weekly: a tree, shrub or perennial in your yard or a park (no-yard option: a houseplant, a windowsill herb, or a tree you see from a window)
- A tag or ribbon to mark one branch (optional)

Steps

1. Walk your yard or a nearby park and choose a plant you can reach every week. Deciduous trees and flowering shrubs, such as maple, oak, lilac, dogwood or apple, show the most changes.
2. Find out its name with a field guide or a plant app used with a parent. Write the common and scientific name at the top of your first page.
3. Mark one branch with a loose ribbon so you observe the same twig each time.
4. Make a full-page drawing of the whole plant, then a close-up of your marked twig. Label buds, leaves, flowers, fruits or seeds you see.
5. Make a log table with columns: date, time, air temperature, weather, phenophase, and notes. Fill in today's row.
6. Measure one thing you can measure every week, such as the length of the largest leaf on your twig or the number of leaves left on it.
7. Add one animal observation each visit: insects on the plant, birds nearby, or squirrel signs.

8. Set a day of the week for your visit and write it on the cover. Visit every week this year.

Tips

- Write what you see, not what you expect. If the leaves are half green and half red, write that.
- Use the same thermometer in the same shady spot each time so your temperatures can be compared.
- Photograph your twig from the same spot each week to make a time-lapse at the end of the year.
- Keep your log the way a 4-H project record book asks: dates, what you did, measurements and what you learned. Clear, dated records are what judges and leaders look for.

Check your work

- ☐ I can define phenology and give three examples.
- ☐ My log has a date, temperature, weather and phenophase for each visit.
- ☐ I can name my plant and describe its stage today.

NATURE JOURNAL

1. Draw your marked twig at actual size, using a ruler to check lengths.
2. Make a circular “phenology wheel” page divided into 12 months; add a small drawing each month of what your plant is doing.
3. Write your warm-up guesses for fall events, then add the real date beside each one when it happens.

From history. Henry Thoreau kept lists of the dates flowers bloomed around Walden Pond in the 1850s. In England, the Marsham family recorded the first signs of spring on their estate for more than 200 years, starting in 1736. Their patient notebooks are some of the longest nature records in the world.

COMMON MISTAKES

- Observing a different branch or plant each time, so the record is not comparable.
- Leaving out the date or year; without them the observation is not data.
- Skipping weeks when “nothing is happening.” A winter page that says “buds closed, 28 °F” is valuable.

Make it a game • Phenology Spotter. Parent names a season event, like first bloom, geese flying south or leaf drop, and you shout the matching phenophase and a plant or animal that shows it. Beat the clock: ninety seconds, as many as possible. Then describe from memory how you would record your adopted plant accurately each week. Score one bean per solid answer.

1.3 THE FARMER'S YEAR AND THE OLD ALMANACS

OBJECTIVES

- Describe the main jobs of each season on a crop and livestock farm.
- Explain what an almanac is and what information farmers found in it.
- Plan a garden calendar for one year using local frost dates.

Warm-up. Draw a circle and divide it into four parts for the seasons. In each part, write one farm job you think happens then. Keep the circle; you will correct and add to it after the lesson.

WATCH

Farming Through the Seasons: A Year on an Arable Farm

Food - a fact of life · 3:58

https://www.youtube.com/watch?v=LTq_86S5-nU

WHEN TO WATCH

After the first core idea. Pause at each season title and add to your warm-up circle before going on.

Note: A small channel from Britain's Food – a fact of life education program; chosen because it clearly follows one grain farm through a whole year. The farm sows winter wheat in autumn, as many American farms also do.

KEY TERMS

almanac

A yearly book with calendars, sunrise and sunset times, tides, weather notes and farming advice.

frost date

The average date of the last spring frost or the first fall frost in a place; gardeners plan planting around them.

winter wheat

Wheat sown in the fall that sprouts, rests through winter and is harvested early the next summer.

growing season

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

CORE IDEAS

A farm runs on a yearly cycle. In **spring** the farmer prepares the soil, plants oats, corn and vegetables, and welcomes calves, lambs and chicks. In **summer** he cultivates weeds, cuts and bales hay, and harvests winter wheat. In **fall** come the big harvests of corn, soybeans, apples and squash, the sowing of winter wheat, and the moving of animals to winter pasture. In **winter** the farmer feeds and waters animals every day, mends fences and tools, orders seed and plans next year. There is no season without work.

Every farm calendar is built around **frost dates**. Your average **last spring frost** tells you when it is safe to plant tender crops like tomatoes, beans and squash. Your average **first fall frost** tells you when the season is ending. The days in between are the **growing season**. In much of Ohio, for example, the last frost comes around late April or early May and the first frost around mid-October, giving about 165 frost-free days. Your local extension service publishes your dates.

Before radios and weather websites, farmers kept an **almanac** on a nail by the door. A typical almanac had a calendar for each month, the times of sunrise and sunset, the phases of the moon (useful for night work and travel before electric lights), tide tables for coastal towns, recipes, home remedies, proverbs and advice for each month's chores. Benjamin Franklin's *Poor Richard's Almanack* (1732–1758) was famous for wise sayings like “Early to bed and early to rise.” *The Old Farmer's Almanac*, begun by Robert B. Thomas in 1792, is still printed today.

Almanacs also printed long-range weather forecasts. These were guesses, and careful farmers learned to trust their own records more: the sky, the thermometer, the dates of past frosts written in a farm diary, and the signs of the plants themselves. Today we combine the best of both: average frost dates from many years of measurements, plus the daily forecast and our own phenology notes.

Planning ahead is part of good stewardship. Proverbs praises the ant that “provideth her meat in the summer, and gathereth her food in the harvest.” A wise gardener writes a calendar in winter so that seeds are started, beds are ready and harvests are gathered at the right time, instead of rushing to catch up.

PICTURE STUDY



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

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

Bruegel painted *The Harvesters* as one of a series of six paintings showing the times of the farmer's year, made for a merchant's home in Antwerp. This one shows the wheat harvest in high summer. It is like one page of a painted almanac.

Look closely

- Find the workers cutting wheat. What tool are they using? Find the workers tying sheaves.
- Find the stacks of tied sheaves standing in the field. Why would farmers stand the sheaves up to dry?
- Look at the group resting under the tree. What foods can you see them eating?
- Look far into the distance. What other farm work or village life can you find?

Talk about it

1. What month do you think this is? Give two clues from the painting.
2. Why must the wheat be harvested quickly once it is ripe and dry?
3. If Bruegel painted a winter picture in this series, what jobs might he show?

HANDS-ON PROJECT

Our Family Garden Almanac

You will make a one-year garden and farm almanac for your own home, based on your real frost dates and day lengths. It will guide you through the rest of this course.

You will need

- Your town's average last spring frost and first fall frost dates (from your state extension service website, with a parent)
- Sunrise and sunset times from Lesson 1.1
- 12 sheets of paper, or 12 pages of your journal
- Ruler, colored pencils, a stapler or ribbon
- A seed catalog or seed packets (optional)

Steps

1. Make one page for each month, September through August, to match the school year. Draw a simple calendar grid on each.
2. Write your last spring frost date and first fall frost date in red on the right pages. Count the days between them and write your growing season on the cover.
3. Mark the solstices and equinoxes on their pages, with the day length from your Lesson 1.1 chart.
4. On each month, list two or three garden or farm jobs. For example: September, harvest and save seed; February, start onion seeds indoors; May, plant beans after the last frost.
5. Use seed packets to find “weeks before last frost” for indoor seed starting, such as tomatoes 6 to 8 weeks before. Count back from your frost date and write the start dates in.
6. Add a short wise saying or Bible verse about work or seasons at the bottom of a few pages, as old almanacs did.
7. Draw a small picture for each month, like the pictures in an old calendar.

8. Bind the pages and keep your almanac with your nature journal. Check off jobs as you do them this year.

Tips

- Frost dates are averages. There is still a chance of frost for a week or two after the last frost date, so tender plants wait a little.
- If you live in an apartment, plan a windowsill or balcony almanac instead: herbs, lettuce in pots and a tomato in a large container.

Check your work

- ☐ I can name my last spring frost date and first fall frost date.
- ☐ I can list farm jobs for each season.
- ☐ I can explain what old almanacs contained and why farmers used them.

NATURE JOURNAL

1. Redraw your warm-up seasons circle, correcting it and adding at least three jobs to each season.
2. Copy one proverb about work or seasons in your best handwriting and illustrate it.
3. Sketch one figure from *The Harvesters* and label the tool and the job.

From history. Benjamin Banneker, a self-taught mathematician and surveyor from Maryland, calculated the sunrise times, eclipses and moon phases for his own almanacs from 1792 to 1797. He worked the numbers by hand at night with a borrowed telescope and books.

COMMON MISTAKES

- Treating the last frost date as a guarantee instead of an average.
- Planning only the planting and forgetting the harvesting, saving and storing jobs.
- Trusting a long-range forecast over your own local records and the plants' signs.

Make it a game • Almanac Reader's Duel. Make a mini almanac page with four columns: winter, spring, summer, fall. Race your parent to fill each column with farm jobs for crops and livestock in sixty seconds. Compare lists and count unique jobs only. Then each of you adds one thing an old almanac told farmers, like frost dates or weather guesses. Most unique jobs wins.

Scripture. “Go to the ant, thou sluggard; consider her ways, and be wise: Which having no guide, overseer, or ruler, Provideth her meat in the summer, and gathereth her food in the harvest.” (Proverbs 6:6-8, KJV)

The ant works by the calendar of the seasons without being told. A wise farmer plans ahead the same way.

1.4 PRESERVING THE HARVEST: CANNING, DRYING AND FREEZING

OBJECTIVES

- Explain that food spoils because of microbes and enzymes.
- Describe how canning, drying and freezing each stop spoilage.
- Dry apple slices and calculate how much of an apple is water.

Warm-up. Cut an apple in half (with an adult). Leave one half on a plate and squeeze lemon juice on the other half. Check both at the end of the lesson. Write a prediction now: what will happen to each half, and why?

WATCH

The Science of Canning. | Year-Round Gardening

wpsu · 3:15

<https://www.youtube.com/watch?v=9MN9X-pnjaY>

WHEN TO WATCH

After the second core idea. Listen for the two kinds of foods (high-acid and low-acid) and the two kinds of canners.

BACKUP VIDEO

Program 9 -- The Science Behind Home Canning

K-State Extension · 5:02

<https://www.youtube.com/watch?v=e346h8wKtzo>

For more on pH: watch how she tests the acid level of different foods.

KEY TERMS

microbe

A living thing too small to see without a microscope, such as bacteria, yeasts and molds.

enzyme

A substance inside food that speeds up changes like browning and softening, even after picking.

canning

Sealing food in jars and heating it to kill microbes, which also forms a vacuum seal that keeps new ones out.

pH

A scale for how acidic a food is; foods at pH 4.6 or below, like most fruits and pickles, count as high-acid.

blanching

Briefly boiling or steaming vegetables before freezing to stop their enzymes.

CORE IDEAS

Fresh food does not stay fresh. Two things spoil it. First, **microbes**, such as bacteria, yeasts and molds, land on the food and feed on it. Second, the food's own **enzymes** keep working after harvest, turning cut apples brown and making vegetables soft. Every preserving method works by taking away something microbes need to grow: warmth, water, air, or a mild (not acidic) home.

Canning uses heat. Food is packed in jars with special lids and heated long enough to kill the microbes inside and stop the enzymes. As the jar cools, the air that was pushed out leaves a **vacuum**, and the lid seals down tight so no new microbes can get in. High-acid foods, such as most fruits, jams and pickles, can be safely processed in a boiling-water canner at 212 °F. Low-acid foods, such as green beans, corn and meat, must go in a **pressure canner**, which reaches about 240 °F. That higher heat is needed to destroy the tough spores of the bacteria that cause botulism, a dangerous food poisoning. Home canners always follow a tested recipe from a source like an extension service, never a guess.

Drying takes away water. Microbes need water to grow, and a well-dried apple ring or bean has too little left for them. An apple is about 85 percent water by weight, so 100 grams of apple slices will dry down to roughly 15 to 20 grams. Dried foods are light, keep for months in a sealed jar, and were how families stored beans, corn, fruit and herbs for centuries. Salting and sugaring work in a similar way, by drawing water out of food and out of microbes.

Freezing takes away warmth. At 0 °F, microbes stop growing (most are not killed; they wait), and enzymes slow almost to a stop. Vegetables are usually **blanched** first, dipped in boiling water for a minute or two and then cooled in ice water, to stop their enzymes so the color and flavor last. **Pickling** adds acid, such as vinegar, and

the root cellar uses cool, dark, damp storage to keep potatoes, carrots and apples alive and resting for months.

Preserving the harvest is a work of gratitude and wisdom. The food God provides in late summer can feed a family all winter if it is gathered and kept well. Joseph stored grain in Egypt during the good years so that many were fed in the years of famine.

PICTURE STUDY



Quince, Cabbage, Melon and Cucumber, Juan Sánchez Cotán, about 1602 · Oil on canvas · San Diego Museum of Art, San Diego

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

Juan Sánchez Cotán was a Spanish painter who later became a lay brother in a monastery. In Spain, fruits and vegetables were often stored in a *cantarero*, a cool, dark, airy window or pantry opening, and some were hung on strings so air could move around them and they would not rot where they touched a surface. This painting shows that old way of keeping the harvest.

Look closely

- Find the quince and the cabbage hanging on strings. Why would hanging them help them keep longer?
- Look at the window opening. Is it light or dark, warm or cool? Why would a cool, dark place slow spoiling?
- Find the cut melon. Will it keep as long as the whole quince? Why not?
- Look at the cucumber. Which of today's preserving methods could save it for winter?

Talk about it

1. Which of the four foods would spoil first, and why?
2. How is this cool window like a root cellar or a refrigerator?

3. Which preserving method from this lesson would you choose for each of these foods?

Safety first. Use knives, the stove and the oven only with an adult. Home canning involves boiling water, steam and pressure and must be done by an adult with a tested recipe; you may help by washing produce and labeling jars. Never taste food from a jar whose lid has popped up, leaks or smells wrong.

Dried Apple Rings and the Water Test

You will dry apple rings in the oven and weigh them before and after to discover how much of an apple is water. You will also compare a dried slice with a fresh slice and a frozen slice after a few days.

You will need

- 3 or 4 apples
- An apple corer and a sharp knife (adult only) or an apple slicer
- Lemon juice and a bowl of water
- A kitchen scale that reads in grams
- Baking sheets with parchment paper or cooling racks
- An oven (adult only), or a food dehydrator
- 3 small zip bags and a marker

Steps

1. With an adult, wash, core and slice the apples into rings about $\frac{1}{4}$ inch thick. Keeping the slices the same thickness helps them dry evenly.
2. Dip the rings in a bowl of water with 2 tablespoons of lemon juice. The acid slows the browning enzymes.
3. Pat the rings dry. Set aside 2 fresh rings for comparison. Weigh the rest in grams and record the weight.
4. Lay the rings in one layer on the baking sheets. An adult sets the oven to its lowest setting, about 170 to 200 °F, and props the door open a little with a wooden spoon so moisture can escape.
5. Dry for 2 to 4 hours, flipping halfway. The rings are done when they feel leathery and no wet spots show when you tear one.
6. Let them cool completely, then weigh them again. Record the dry weight.
7. Calculate: $\text{water lost} = \text{fresh weight} - \text{dry weight}$. $\text{Percent water} = \text{water lost} \div \text{fresh weight} \times 100$.
8. Put one fresh ring in a bag on the counter, one fresh ring in a bag in the freezer, and one dried ring in a bag on the counter. Check all three after 3

days and record what you see and smell.

Tips

- Thin, even slices dry fastest. Thick slices may stay moist inside and spoil.
- Store finished rings in a clean, dry glass jar. If droplets appear inside the jar after a day, dry them longer.
- No oven available? Thread rings on a string and hang them in a warm, dry, airy room for about a week, as pioneers did.
- Many county fairs have youth classes for canned, dried and preserved foods. Entries must follow tested recipes and the fair book's rules for jars and labels; check your county extension office or fair book.

Check your work

- ☐ I can explain why dried apples do not spoil.
- ☐ I calculated the percent of water in my apples.
- ☐ I can explain why low-acid foods need a pressure canner.

NATURE JOURNAL

1. Draw your three test bags after 3 days and describe each one in words.
2. Make a chart with four columns (canning, drying, freezing, pickling) and write what each one takes away from microbes.
3. Check your warm-up apple halves and draw them. Was your prediction right?

From history. In 1809 a French cook named Nicolas Appert won a prize offered by his government for a way to keep food for soldiers and sailors: he sealed food in glass bottles and boiled them. He did not know why it worked. About fifty years later Louis Pasteur showed that microbes cause spoiling, and in 1858 John Landis Mason patented the screw-top jar still used today.

COMMON MISTAKES

- Thinking freezing kills microbes. It only stops them; they can grow again when food thaws.
- Using a boiling-water canner for green beans or other low-acid foods. They need a pressure canner.
- Storing dried food before it is fully dry, which lets mold grow in the jar.

Make it a game • Stop the Spoilers. Pretend the kitchen is a food lab. Three bowls represent canning, drying and freezing. Parent names a spoiler, such as microbes or enzymes; you toss a paper food chip into the bowl whose method stops it, and explain why. Mention blanching and pH when they fit. Win by getting ten chips in the right bowls.

UNIT 1

HARVEST AND THE SEASONS

Every gardener and farmer lives by the calendar of the sky. In this unit you will learn why Earth has seasons at all: not because Earth swings closer to the sun, but because it spins on a tilted axis. You will find the solstices and equinoxes, measure shadows, and see how the angle of sunlight and the length of the day decide when plants grow and rest.

Then you will become a careful watcher of the seasons by starting a phenology journal, learn how farmers planned their year with almanacs and calendars, and finish with the science of keeping the harvest: why canning, drying and freezing stop food from spoiling. God promised Noah that “seedtime and harvest” would not cease, and this unit teaches you to read that steady rhythm.

PREREQUISITES

- Knows the four seasons and the twelve months in order
- Can read a ruler and a thermometer
- Has a nature journal (a sketchbook or bound notebook) and colored pencils
- Can measure with a ruler to the nearest quarter inch or half centimeter

MASTERY CHECKLIST

- ☐ I can explain that Earth’s tilted axis, not its distance from the sun, causes the seasons.
- ☐ I can name the dates of the solstices and equinoxes and tell what happens to day length on each.
- ☐ I can keep a phenology log with dates, weather and first-of-the-season observations.
- ☐ I can describe the farmer’s year and tell what an almanac contained.
- ☐ I can explain how canning, drying and freezing each stop the microbes that spoil food.

LESSONS IN THIS UNIT

1.1 Solstices, Equinoxes and Earth’s Tilt

2 sessions of 45 minutes

1.2 Keeping a Phenology Journal

2 sessions of 45 minutes

UNIT 1 REVIEW

Answer each question in complete sentences unless it asks for a list. You may use your shadow log and almanac but not the lesson pages. The review is worth 50 points.

1. 5 pts

What causes the seasons on Earth? Explain in two or three sentences.

2. 5 pts

True or false: Earth is closest to the sun in July. Explain.

3. 5 pts

Name the solstices and equinoxes with their approximate dates.

4. 5 pts

Your 12-inch shadow stick casts a 6-inch shadow at noon one day and a 24-inch shadow at noon another day. Which day was nearer the winter solstice? Why?

5. 5 pts

What is phenology? Give two examples of phenology observations.

6. 5 pts

List three things a good phenology log entry should include.

7. 5 pts

What is a growing season, and how do you find it?

8. 5 pts

Name four things a farmer could find in an old almanac.

9. 5 pts

Explain how drying and freezing each keep food from spoiling.

10. **5 pts**

Why must green beans be canned in a pressure canner instead of a boiling-water canner?

ANSWER KEY

1. Earth's axis is tilted about $23\frac{1}{2}^{\circ}$ and stays pointed the same way as Earth orbits the sun. When our hemisphere leans toward the sun, sunlight strikes steeply and days are long (summer); when it leans away, sunlight slants and days are short (winter).
2. False. Earth is closest to the sun in early January, during northern winter, which shows distance is not the cause of the seasons.
3. Spring equinox about March 20; summer solstice about June 21; fall equinox about September 22; winter solstice about December 21.
4. The 24-inch day. In winter the sun is lower in the sky at noon, so shadows are longer.
5. The study of the timing of seasonal events in living things. Examples: the date of first bloom of a lilac; the date the first robin returns; the date maple leaves turn red.
6. Any three: date, time, temperature, weather, the plant's stage (phenophase), a measurement, a drawing.
7. The number of days between the average last spring frost and the average first fall frost. Count the days between the two dates.
8. Any four: monthly calendars, sunrise and sunset times, moon phases, tide tables, weather forecasts, farming advice, recipes, proverbs.
9. Drying removes the water microbes need to grow. Freezing makes food so cold that microbes stop growing and enzymes slow down.
10. Green beans are low-acid. A pressure canner reaches about 240°F , hot enough to destroy the spores of the bacteria that cause botulism; boiling water at 212°F is not.

PORTFOLIO PIECE: A SEASON KEEPER'S NOTEBOOK

Assemble your work from this unit into one notebook: your shadow-stick log and day-length graph, the first pages of your adopted-plant phenology log, your family garden almanac, and the results of your apple-drying test. Add a cover and a one-page introduction explaining, in your own words, why we have seasons and how a family can prepare for each one.

LOOK FOR	WHAT IT MEANS
Science of the seasons	The introduction correctly explains axial tilt, sun angle and day length, with a labeled diagram.
Accurate records	Shadow and phenology logs have dates, measurements and weather for every entry.
Garden almanac	All 12 months are included, with correct local frost dates and at least two jobs per month.
Preserving experiment	Weights, calculation of percent water and the 3-day comparison are recorded clearly.
Care and neatness	Pages are labeled, drawings are careful and the notebook is complete.

UNIT 2

WILDLIFE

Fall is the busiest season for wild animals near our homes. Squirrels bury nuts, birds pass through on migration, and raccoons, skunks and coyotes fatten up for winter. In this unit you will learn to sort the wild mammals of your area into their true groups by looking at teeth, feet and habits, and to identify birds by their field marks and songs the way real birders do.

You will also learn how to live wisely alongside the larger animals that visit yards and farms: why we never feed them, how to keep trash, pets and chickens safe, and what to do if an animal acts strangely. Finally you will become a lawn detective, telling apart the tunnels of moles, voles and mice. Adam's first job in the garden was to look carefully at the animals and name them; you will practice that same careful looking.

PREREQUISITES

- Knows the difference between a mammal, a bird, a reptile, an amphibian and a fish
- Can use a ruler and keep a dated log
- Has a nature journal and colored pencils; binoculars are helpful but optional

MASTERY CHECKLIST

- ☐ I can sort local mammals into their orders using teeth, feet and diet.
- ☐ I can identify at least ten local birds by sight and five by sound.
- ☐ I can explain why we never feed or touch wild animals and what to do if one acts sick.
- ☐ I can tell mole, vole and mouse signs apart in a yard or garden.
- ☐ I can build and use a simple dichotomous key.

LESSONS IN THIS UNIT

2.1 Classifying Local Mammals

2 sessions of 45 minutes

2.2 Birds by Song and Field Marks

2 sessions of 45 minutes

2.3 Living Alongside Raccoons, Skunks and Coyotes

2 sessions of 45 minutes

2.4 Moles, Voles and Mice

2 sessions of 45 minutes

UNIT 2 REVIEW

Answer each question. Use complete sentences for questions that ask you to explain.
The review is worth 50 points.

1. 5 pts

Name four traits that all mammals share.

2. 5 pts

A rabbit and a squirrel both have front teeth that never stop growing. Why are they placed in different orders?

3. 5 pts

What is the only marsupial in the United States, and what makes it a marsupial?

4. 5 pts

List the four keys birders use to identify birds, in order.

5. 5 pts

What is the difference between a bird's song and its call?

6. 5 pts

Why should we never feed raccoons or coyotes?

7. 5 pts

Name three wild animals that most often carry rabies in the U.S. and two signs that an animal may be sick.

8. 5 pts

What should you do if a coyote walks toward you in a park?

9. 5 pts

You find raised, squishy ridges and mounds with no holes in your lawn. Which animal made them, and what does it eat?

10. 5 pts

Young apple trees in an orchard have bark chewed off all the way around near the ground after winter. What animal probably did it, and how can it be prevented next year?

ANSWER KEY

1. A backbone; hair or fur; warm-blooded; mothers feed their young with milk.
2. Rabbits are lagomorphs: they have a second, tiny pair of upper incisors behind the front pair and eat only plants. Squirrels are rodents with only one pair of upper incisors.
3. The opossum. The mother carries her young in a pouch.
4. Size and shape; color pattern; behavior; habitat.
5. A song is a longer, musical pattern sung mostly by males in spring to claim territory; a call is a short sound used all year to keep in touch or warn.
6. Feeding makes them lose their fear of people (habituated) and draws them close to homes, pets and children, which is dangerous for people and animals.
7. Raccoons, skunks, bats (or foxes). Signs: unusually tame, staggering, circling, drooling, attacking for no reason.
8. Do not run. Stand tall, wave your arms, shout and make noise until it leaves, then tell an adult.
9. A mole. It eats earthworms, grubs and insect larvae, not plants.
10. Voles. Wrap the trunks with wire-mesh guards and pull mulch and tall grass away from the trunks.

PORTFOLIO PIECE: A WILDLIFE FIELD NOTEBOOK FOR MY NEIGHBORHOOD

Make a field notebook about the wild animals of your neighborhood. Include your mammal identification key, your bird-count results and field-mark pages, your home wildlife audit with the fixes you made, and your tunnel-detective map. Finish with a one-page “Neighbor’s Guide” explaining how families can live safely and kindly alongside the wildlife you studied.

LOOK FOR	WHAT IT MEANS
Identification skills	The dichotomous key works for all ten mammals, and at least five birds are identified with correct field marks.
Careful observation	Counts, maps and logs include dates, times, weather and measurements.
Safety and stewardship	The audit and Neighbor’s Guide correctly explain not feeding wildlife, exclusion and rabies warning signs.
Accuracy	Facts about each animal’s order, diet and signs are correct.
Presentation	Drawings are careful and labeled; pages are neat and complete.

2.1 CLASSIFYING LOCAL MAMMALS

OBJECTIVES

- List the traits that all mammals share.
- Sort local mammals into orders such as rodents, rabbits, carnivores, marsupials, insect-eaters, bats and hoofed mammals.
- Build a dichotomous key for ten mammals of your area.

Warm-up. Write the names of every wild mammal you have seen near your home, even just once: squirrels, rabbits, deer, and so on. Then sort your list into groups that seem to belong together. Explain your groups in one sentence. Scientists sort animals too; today you will see how they do it.

WATCH

Animal Classification for Children: Classifying Vertebrates and Invertebrates for Kids - FreeSchool

Free School · 6:52

<https://www.youtube.com/watch?v=mRidGna-V4E>

WHEN TO WATCH

At the start of the lesson, as a review of the big animal groups. Then the core ideas take you inside the mammal group.

KEY TERMS

mammal

An animal with a backbone that has hair or fur, is warm-blooded, and whose mother feeds her young with milk.

order

A large group within a class; for example, the rodent order and the carnivore order are both in the mammal class.

classification

Sorting living things into groups by the features they share.

incisor

A front cutting tooth; rodents and rabbits have incisors that keep growing all their lives.

dichotomous key

A tool for identifying living things by answering a series of two-choice questions.

CORE IDEAS

Every **mammal** has a backbone, has hair or fur at some point in its life, is warm-blooded (keeps its body at a steady warm temperature), and feeds its young with milk. Within the mammal class, scientists sort animals into **orders** by looking closely at their **teeth**, **feet** and way of life. Teeth are especially helpful, because they show what an animal is built to eat.

Rodents are the largest order: squirrels, chipmunks, woodchucks, beavers, mice, voles and muskrats. All have two big orange-tinted **incisors** on top and two on the bottom that never stop growing, so rodents must gnaw to keep them worn down.

Rabbits and hares look similar and also have ever-growing incisors, but they belong to a different order, the lagomorphs: they have a second, tiny pair of upper incisors hidden behind the front pair, and they eat only plants.

Carnivores (the order Carnivora) have long, pointed canine teeth and sharp cheek teeth for slicing: foxes, coyotes, raccoons, skunks, weasels, mink and black bears. The name means “meat eaters,” but many of them, like raccoons and bears, eat fruit, nuts and insects too. The **opossum** is the only **marsupial** in the United States and Canada; the mother carries her tiny young in a pouch, and she has 50 teeth, more than any other North American land mammal.

Moles and shrews are small insect-eaters with tiny eyes and many sharp, pointed teeth for catching earthworms, grubs and insects. **Bats** are the only mammals that truly fly; most of ours eat thousands of insects a night. **White-tailed deer** are hoofed mammals with an even number of toes; they have no upper front teeth at all, only a hard pad, and they chew their cud like cows.

A **dichotomous key** (dye-KOT-uh-mus) turns these clues into a path of two-choice questions: “Does it have a pouch? Yes: opossum. No: go to step 2.” “Does it have hooves? Yes: deer. No: go to step 3.” Scientists use keys to identify unknown animals and plants. God brought the animals to Adam “to see what he would call them”; naming and sorting creatures carefully is one of the oldest jobs people have.

PICTURE STUDY



Young Hare, Albrecht Dürer, 1502 · Watercolor and gouache on paper · Albertina, Vienna

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

Albrecht Dürer painted this hare in his studio in Germany more than 500 years ago, probably from a live animal. He painted nearly every hair. It is one of the most famous animal pictures ever made, and it is also excellent science: a true record of what a hare looks like.

Look closely

- Find the hare's whiskers and its long ears. How do these help an animal that is hunted by foxes and hawks?
- Look at the eye. Is it on the front or the side of the head? What does that let the hare see?
- Look at the back feet tucked under the body. Are they long or short? What are they built for?
- Look closely at the fur. How many colors can you find in it?

Talk about it

1. A hare looks a little like a big rodent. What clue in its mouth shows that it belongs to a different order?
2. Why might a brown, speckled coat help a hare survive in a field?

3. Dürer looked at this hare for many hours. What could you learn by drawing one animal for an hour?

A Dichotomous Key to Our Neighborhood Mammals

You will build a working identification key for ten mammals that live in your area. A family member will test it by secretly choosing an animal and following your questions to see if they reach the right answer.

You will need

- Your nature journal, ruler and colored pencils
- A field guide to mammals of your state or region (library), or your state wildlife agency's website with a parent
- 10 index cards
- Tape or glue

Steps

1. Use a field guide to choose ten wild mammals that live in your county. Try to include at least one rodent, one rabbit, one carnivore, the opossum, one mole or shrew, one bat and the deer.
2. Make one index card per animal. Draw it, and write its name, order, length, what it eats, and one special feature of its teeth or feet.
3. Lay all ten cards on a table. Think of one yes-or-no question that splits them into two groups, for example: "Does it fly?"
4. Write the question as Step 1 in your journal. Write where each answer leads: a name, or "go to Step 2."
5. Keep splitting each group with a new question until every animal stands alone. Ten animals will need nine questions.
6. Use questions about things you can see or know for sure: hooves, a pouch, a striped tail, front teeth that never stop growing, wings, size. Avoid questions like "Is it cute?"
7. Test your key by having a family member secretly pick a card and follow your steps. If they end at the wrong animal, fix the question that led them astray.

8. Copy the finished key neatly on a journal page and tape a small drawing next to each answer.

Tips

- Make your first questions the biggest splits, such as “Does it have hooves?” or “Does it fly?”
- Measurements make good questions: “Is it longer than 2 feet including the tail?”
- No field guide? Your state’s department of natural resources website lists the mammals of your state.

Check your work

- ☐ I can name four traits of mammals.
- ☐ I can explain how a rabbit is different from a rodent.
- ☐ My key correctly identifies all ten animals.

NATURE JOURNAL

1. Draw the front teeth of a rodent, a rabbit and a carnivore side by side from a field guide or museum picture, and label the incisors and canines.
2. Copy the outline of your state and write the names of five mammals that live there in the margin, with their orders.
3. Write down any mammal you see this week with the date, time, place and what it was doing.

From history. The Swedish botanist Carl Linnaeus published a system for naming and sorting all known plants and animals in the 1700s. He gave each creature a two-part Latin name, like *Procyon lotor* for the raccoon. Scientists all over the world still use his method, so that a raccoon has the same scientific name in every language.

COMMON MISTAKES

- Calling rabbits rodents. They are lagomorphs, with a second pair of tiny upper incisors.
- Writing key questions that have more than two answers, or that depend on opinion.
- Thinking every carnivore eats only meat. Raccoons, foxes and bears eat a great deal of fruit and insects.

Make it a game • Mammal Sorting Mystery. Write ten local mammals on cards, such as mouse, rabbit, fox, bat, opossum and deer. Parent hides one card in a pocket and answers only yes or no to your dichotomous key questions. Narrow the order down using traits like incisors and flying wings, then name the mystery mammal. Fewest questions wins; swap roles.

Scripture. “And out of the ground the LORD God formed every beast of the field, and every fowl of the air; and brought them unto Adam to see what he would call them: and whatsoever Adam called every living creature, that was the name thereof.” (Genesis 2:19, KJV)

Naming the animals required Adam to look closely and notice differences. When we classify animals, we take up the same work.

2.2 BIRDS BY SONG AND FIELD MARKS

OBJECTIVES

- Identify birds using the four keys: size and shape, color pattern, behavior and habitat.
- Recognize at least five local birds by their songs or calls.
- Conduct and record a timed backyard bird count.

Warm-up. Sit quietly at a window or outdoors for three minutes with your eyes closed. Count how many different bird sounds you hear. Then describe one of them in words, like “a sharp chip” or “a whistle going down.”

WATCH

Inside Birding: Size and Shape

Cornell Lab of Ornithology • 9:46

<https://www.youtube.com/watch?v=ridajl8uic0>

WHEN TO WATCH

After the first core idea. Pause when the robin silhouette appears and compare it with the sparrow and crow.

BACKUP VIDEO

Learn 25 Common Backyard Bird Calls (Central and Eastern United States)

Badgerland Birding • 7:50

<https://www.youtube.com/watch?v=Egd73TfeiMA>

In the second session, before your bird count. Pause after each bird and say its memory phrase aloud.

KEY TERMS

field mark

A feature that helps identify a bird, such as a wing bar, an eye ring, a crest or a colored patch.

silhouette

The dark outline of a bird's shape, which often identifies it even when colors cannot be seen.

song

A longer, musical sound, usually made by males in spring to claim territory.

call

A short sound, such as a chip or a scold, that birds use all year to keep in touch or warn of danger.

mnemonic

A memory phrase, such as “who cooks for you?” for the barred owl.

CORE IDEAS

Expert birders use four keys, in this order: **size and shape**, **color pattern**, **behavior** and **habitat**. Start with size by comparing to birds you know: is it sparrow-sized, robin-sized or crow-sized? Then look at shape: the bill (thick and cone-shaped for cracking seeds, thin for catching insects, hooked for tearing), the tail (long or short, notched or rounded), and whether the bird has a crest.

Next look for **field marks**, the color patterns that clinch an identification: the black cap and bib of the chickadee, the white wing bars of a goldfinch in winter, the red cap on a downy woodpecker’s head, the white outer tail feathers that flash when a junco flies. Many birds change color through the year. The bright yellow male goldfinch of summer turns olive-brown in winter, so field marks such as wing bars matter more than color alone.

Behavior and **habitat** narrow the choices. Nuthatches creep headfirst *down* tree trunks; woodpeckers hop up. Mourning doves feed on the ground under feeders; chickadees grab one seed and fly off to eat it. Red-winged blackbirds live in marshes and wet fields, while wood thrushes live in shady forests. A bird’s habits are part of how God designed it for its place.

Birds are often heard before they are seen. A **song** is a longer, musical pattern, mostly sung by males in spring. A **call** is short and used all year. Memory phrases help: the northern cardinal whistles “cheer, cheer, cheer” or “birdie, birdie, birdie”; the American robin sings “cheerily, cheer up, cheerio”; the black-capped chickadee says its name, “chick-a-dee-dee-dee,” and whistles “fee-bee”; the barred owl asks, “Who cooks for you? Who cooks for you-all?” and the mourning dove coos a soft, sad “oo-AH-oo, oo, oo.”

Bird counts are real science. Every February, families across the world count the birds in their yards for 15 minutes or more during the Great Backyard Bird Count, and scientists use the results to learn where birds are and how many there are. You can count any day: record the date, time, weather, and the *largest number* of each kind of bird you see at one time, so you do not count the same bird twice.

PICTURE STUDY



The Goldfinch, Carel Fabritius, 1654 · Oil on panel · Mauritshuis, The Hague

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

Carel Fabritius was a Dutch painter and a student of Rembrandt. In the 1600s, goldfinches were popular pets in Holland because they could be trained to draw up tiny buckets of water. Fabritius painted this one life-size, with quick, sure strokes, in the same year he died.

Look closely

- Find the bird's field marks: the red face, the yellow wing patch and the black and white on the head and wings.
- Look at the shape of the bill. Is it thick and cone-shaped or thin and pointed? What food does that suggest?
- Find the perch and the feeder box. How is the bird holding on?
- Look at the shadow on the wall. Where is the light coming from?

Talk about it

1. Which field marks would you write in your journal to identify this bird?
2. The European goldfinch is a different bird from our American goldfinch. How could you use field marks to tell them apart?
3. Why is it better to watch wild birds at a feeder than to keep them chained, as people did in Fabritius's day?

HANDS-ON PROJECT

A Backyard Bird Count and Field-Mark Pages

You will set up a bird-watching station, do three timed bird counts, and make field-mark sketch pages for the birds you identify, by sight and by sound.

You will need

- A bird feeder with black-oil sunflower seed, or a spot where birds already visit (no-yard option: a park bench, a window that faces trees, or a library window)
- A field guide to birds of your region, or a bird-ID app used with a parent
- Binoculars (optional)
- A watch or timer
- Your nature journal and colored pencils

Steps

1. Choose a watching spot where you can see birds without frightening them, such as a window 10 to 15 feet from a feeder or a quiet bench at a park.
2. Make a count sheet with columns for bird name, number, and how you identified it (sight, song or call). Write the date, time, temperature and weather at the top.
3. Watch for exactly 15 minutes. For each kind of bird, record the largest number you see at one time.
4. When you see a bird you do not know, sketch its shape quickly first, then add field marks: bill shape, wing bars, eye ring, cap, tail pattern and colors.
5. Use the four keys and your field guide to identify it. Write which field marks clinched it.
6. Close your eyes for the last 2 minutes and list every bird you can hear. Try to name each sound with its memory phrase.
7. Repeat the count at the same time of day on two other days this week.
8. Make a bar graph of your results: which bird was most common? Did the count change with the weather?

Tips

- Birds are most active in the early morning.
- Move slowly and quietly, and wear plain colors outdoors.
- Keep feeders clean: wash them every two weeks with hot, soapy water so birds do not spread sickness to each other.
- Put your field-mark skills to work in a real bird count: the Christmas Bird Count runs December 14, 2026 to January 5, 2027, and the Great Backyard Bird Count runs February 12 to 15, 2027. Families can count from their own yard or join a local count.

Check your work

- ☐ I can name the four keys to identifying a bird.
- ☐ I identified at least five birds and recorded their field marks.
- ☐ I can say the memory phrases for at least three bird songs.

NATURE JOURNAL

1. Draw silhouettes of a sparrow, a robin, a woodpecker and a crow side by side, at the right sizes compared to each other.
2. Make a full page for one bird, labeling its field marks with arrows like a field guide.
3. Write your three counts in a table and add one sentence about what changed from day to day.

From history. In 1900 an ornithologist named Frank Chapman suggested that people count birds on Christmas Day instead of holding a hunting contest, as some had done before. Twenty-seven people took part that first year. The Christmas Bird Count is now held every winter, and tens of thousands of volunteers join in.

COMMON MISTAKES

- Looking first at color and ignoring size and shape.
- Counting the same bird each time it returns to the feeder. Record the largest number seen at once.
- Flipping to the field guide before the bird flies away. Watch first, sketch, and look it up afterward.

Make it a game • Bird Call Mimic. Pick five local birds. Without naming them, imitate each bird's song or call, or describe its field marks: size, shape, color pattern, behavior and habitat. Your parent guesses the bird, then you swap. Make a silly mnemonic for each song to help it stick. Score a bean per correct guess and try to beat your last count.

Scripture. “Behold the fowls of the air: for they sow not, neither do they reap, nor gather into barns; yet your heavenly Father feedeth them. Are ye not much better than they?” (Matthew 6:26, KJV)

Jesus told His listeners to “behold,” to look closely at the birds. Bird-watching teaches us to see God’s daily care for His creatures and for us.

2.3 LIVING ALONGSIDE RACCOONS, SKUNKS AND COYOTES

OBJECTIVES

- Describe the habits and diets of raccoons, skunks, opossums and coyotes.
- Explain why wild animals must never be fed or handled, and how rabies spreads.
- Audit a home or farm for things that attract wildlife and make a family safety plan.

Warm-up. List everything outside your home that a hungry raccoon might eat: trash, pet food, bird seed, garden vegetables, compost. Circle the ones that would be easy to protect.

WATCH

Living with Wildlife: Urban Coyotes

MOconservation · 3:00

<https://www.youtube.com/watch?v=okULNIOg1Nk>

WHEN TO WATCH

After the third core idea. Notice each thing the families do to make their yards less attractive to coyotes.

Note: From the Missouri Department of Conservation. A small channel, but the advice comes from state wildlife damage biologists.

BACKUP VIDEO

Living with Wildlife - Exclusion #2 (Bats, raccoons and squirrels)

MOconservation · 3:28

<https://www.youtube.com/watch?v=cWpDKccxS3Y>

Before the home audit, to see how gaps in a house are sealed so raccoons and squirrels cannot move in.

KEY TERMS

nocturnal

Active mainly at night; raccoons, skunks and opossums are nocturnal.

omnivore

An animal that eats both plants and animals.

rabies

A deadly disease of mammals caused by a virus that spreads through bites or saliva; raccoons, skunks, bats and foxes are the most common carriers in the U.S.

habituated

Describes a wild animal that has lost its natural fear of people, usually because it was fed.

exclusion

Keeping animals out with fences, lids, screens and sealed gaps instead of harming them.

CORE IDEAS

Raccoons are clever, nimble omnivores with hand-like front paws that can open latches, lids and even doors. They eat fruit, nuts, corn, insects, frogs, eggs, garbage and pet food, and they will raid sweet corn the night before you planned to pick it.

Striped skunks dig for grubs and insects in lawns, leaving small cone-shaped holes. Before spraying, a skunk warns you by stamping its front feet, raising its tail and hissing; its spray can reach about 10 feet. **Opossums** eat almost anything, including many ticks they groom off themselves, and when badly frightened some “play dead.”

Coyotes now live in every state but Hawaii, including cities. A coyote weighs about 20 to 45 pounds, much less than most people expect. They eat mostly mice, voles and rabbits, plus fruit, insects and carrion, but they will also take outdoor cats, small dogs and chickens. They are most active at dawn, dusk and night. A coyote that has been fed by people loses its fear and may become bold, which is dangerous for everyone, including the coyote.

The most important rule is simple: **never feed or touch wild animals**. Feeding makes them **habituated** and brings them close to houses, pets and children. Instead, take away what attracts them: keep trash in cans with tight lids, feed pets indoors, clean up spilled bird seed, pick ripe fruit and vegetables promptly, and close the chicken coop every evening behind hardware cloth (welded wire), since raccoons can reach through chicken wire. Seal gaps under decks and sheds after making sure no animal is inside. This is called **exclusion**.

Rabies is a deadly virus spread by bites or saliva. In the U.S., wild raccoons, skunks, bats and foxes carry it most often. Watch for an animal that is unusually tame, staggering, circling, drooling, or attacking things for no reason. A mother raccoon may forage in daylight in spring, so daytime alone is not proof of sickness, but any strange behavior means: stay far away, bring pets inside, and tell an adult, who can call animal control. Anyone bitten or scratched by a wild animal, or who finds a bat in a bedroom, must see a doctor right away. Pets should get their rabies shots from the vet.

If a coyote comes close, do not run. Stand tall, wave your arms, shout and make noise until it leaves; this is called **hazing**, and it teaches coyotes to keep their distance. Walk dogs on a leash and keep small pets indoors at night. A wise steward does not hate wild animals; he respects them, keeps them wild, and protects the animals in his own care.

PICTURE STUDY



Raccoon, John James Audubon and John Woodhouse Audubon, 1845 · Hand-colored lithograph from *The Viviparous Quadrupeds of North America* · *The Viviparous Quadrupeds of North America*, by John James Audubon and John Bachman
Image: [Wikimedia Commons](#), public domain

After painting the birds of America, John James Audubon set out with his sons and the minister-naturalist John Bachman to paint every mammal of North America. Audubon and his son John Woodhouse Audubon painted the plates, including this raccoon. These pictures were made to help people identify animals correctly.

Look closely

- Find the raccoon's field marks: the black mask, the ringed tail. How many rings can you count?
- Look closely at the front paws. How are they like hands? What can a raccoon do with them?
- Where is the raccoon? What does that tell you about where raccoons rest and hide?
- Look at the fur. Is it thick or thin? What season might this be?

Talk about it

1. Why would a garbage can with a simple loose lid be easy for a raccoon to open?

2. If you saw a raccoon walking in circles in daylight, what should you do?
3. Why did naturalists like Audubon make pictures so carefully, instead of just drawing a general animal?

Safety first. Never touch, feed, chase or corner a wild animal, even a baby that seems alone; its mother is usually nearby. Do not touch raccoon droppings, which can carry a dangerous roundworm. If a wild animal bites or scratches you, wash the wound with soap and water and tell an adult at once.

HANDS-ON PROJECT

A Wildlife-Wise Home Audit and Safety Card

With an adult, you will walk around your home (or a farm, church or school grounds) and look for anything that invites raccoons, skunks, opossums or coyotes too close. Then you will make a family safety card.

You will need

- A clipboard and your nature journal
- A flashlight (for looking under decks from a distance, never crawling under)
- Colored pencils and an index card
- An adult partner

Steps

1. Make a checklist with these headings: Food, Water, Shelter, Pets and Poultry.
2. Under Food, check trash cans (tight lids?), pet food outside, bird seed on the ground, fallen fruit, the compost pile and the garden.
3. Under Water, look for bowls, buckets or ponds that animals could use.
4. Under Shelter, look from a distance for gaps under decks, porches and sheds, holes in the foundation, and brush piles near the house. Do not reach into any hole.
5. Under Pets and Poultry, note where pets stay at night and how chickens or rabbits are housed. Is the coop closed with hardware cloth?
6. Mark each item Safe or Needs a Fix, and write a fix for each problem, such as “bungee cord on trash lid” or “feed the cat indoors.”
7. With your family, choose two fixes to do this week, and do them.
8. Make a safety card listing: never feed or touch wild animals; signs of a sick animal; what to do if a coyote comes close; who to call (an adult, then animal control). Post it by the back door.

Tips

- Look for signs: tipped trash, small holes in the lawn (skunks digging for grubs), tracks in mud, and droppings.

- Apartment families can audit the building's trash area and a balcony, or a grandparent's yard or farm.

Check your work

- ☐ I can name three things that attract raccoons and how to fix each one.
- ☐ I can list the warning signs of a sick wild animal.
- ☐ I can show what to do if a coyote comes close.

NATURE JOURNAL

1. Draw the tracks of a raccoon, an opossum, a skunk and a coyote from a field guide, at actual size, and label which have hand-like prints.
2. Make a two-column page: "Wild animal" and "What it needs from my yard," for four animals.
3. Draw a map of your home and mark the places on your audit, using a green dot for Safe and a red dot for Needs a Fix.

From history. In the 1800s coyotes lived mostly on the western prairies. As forests were cleared and wolves disappeared from the East, coyotes spread across the continent and reached New England, Florida and big cities like Chicago and New York. They are one of the most adaptable animals in North America.

COMMON MISTAKES

- Leaving pet food outdoors overnight, which feeds raccoons, opossums and skunks.
- Thinking a baby wild animal is an orphan and picking it up. Leave it, watch from far away, and ask an adult.
- Using chicken wire to protect hens at night. Raccoons can tear it or reach through; use hardware cloth.

Make it a game · Wildlife Wise Judge. You are the wildlife-wise judge and your parent presents home situations: pet food left outside, a trash lid left off, an animal acting oddly. Ruling on each, say which animal it attracts, what the animal eats, and the fix. Explain why wild animals are never fed or handled and how rabies spreads. Parent gets a point for hard cases.

2.4 MOLES, VOLES AND MICE

OBJECTIVES

- Tell moles, voles and mice apart by their bodies, food and signs.
- Identify mole hills, mole ridges and vole runways in a lawn or garden.
- Explain how each animal helps or harms a garden and how gardeners protect plants.

Warm-up. Look at this list: earthworms, grass roots, tulip bulbs, seeds, beetle grubs, tree bark. Guess which ones a mole eats and which ones a vole eats. Check your answers at the end of the lesson.

WATCH

Moles, Voles and Gophers

Garden Time TV · 5:10

<https://www.youtube.com/watch?v=ny6-wqjH8jw>

WHEN TO WATCH

After the second core idea. Make a three-column chart and write one fact about each animal as you watch.

Note: The expert is a wildlife specialist from Oregon State University Extension. Pocket gophers live mostly in the western and central states.

BACKUP VIDEO

Identifying Moles vs Voles

CurrituckCES · 2:07

<https://www.youtube.com/watch?v=lmL23m-btzg>

A short review from a county extension agent, good just before the lawn survey.

KEY TERMS

mole

A small insect-eating mammal that lives underground, with huge digging front feet, tiny hidden eyes and no outer ears.

vole

A small, chunky rodent with a short tail, small eyes and ears, that eats grass, roots, bulbs and bark.

runway

A narrow path about 1 to 2 inches wide worn through grass by voles traveling on the surface.

girdling

Chewing the bark all the way around a tree trunk, which cuts off the flow of food and can kill the tree.

CORE IDEAS

Three small mammals cause most underground garden mysteries, and they are very different animals. The **mole** is not a rodent at all. It is an insect-eater, related to shrews, about 6 to 8 inches long, with velvety fur that lies flat in any direction so it can back up in its tunnel, tiny eyes hidden in fur, no outer ears, a pointed pink nose, and enormous shovel-like front feet. God fitted the mole perfectly for life underground: it can dig about 18 feet of tunnel an hour.

Moles eat **earthworms**, beetle grubs and insect larvae, not plants. Their tunnels loosen and air the soil and their appetite reduces grubs. The trouble is that their digging lifts lawns and uproots seedlings. Signs of moles are **raised ridges** that squish under your foot, and **volcano-shaped mounds** of loose soil with no open hole, pushed up from deep tunnels.

The **vole**, sometimes called a field mouse, is a rodent, about 4 to 6 inches long, chunky, with a short tail, small eyes and small ears half hidden in fur. Voles eat **plants**: grass, roots, bulbs, seeds, and in winter the bark of young trees, sometimes **girdling** them. Their signs are surface **runways** about 1 to 2 inches wide in the grass, often seen when snow melts in spring, small round holes about the size of a quarter with no mound, and gnawed bark near the ground.

Mice, such as the deer mouse and the house mouse, have large ears, large dark eyes and long tails. They eat seeds, grain and insects and come into sheds, barns and houses in fall looking for warm places to nest. Their droppings look like dark grains of rice. Deer mice can carry a rare but serious disease called hantavirus in their droppings, so an adult should clean up mouse nests and droppings by wetting them with disinfectant first, never by sweeping them dry.

Gardeners protect plants with barriers instead of poisons: wire-mesh cylinders around young tree trunks, bulbs planted in hardware-cloth baskets, keeping grass mowed and mulch pulled back a few inches from tree trunks so voles have no cover, and snap traps set by adults inside sheds. Natural helpers matter too: one barn owl

family can eat over a thousand rodents in a year, and hawks, foxes, snakes and cats hunt them as well.

PICTURE STUDY



American Shrew Mole, John James Audubon and John Woodhouse Audubon, 1845 · Hand-colored lithograph from *The Viviparous Quadrupeds of North America* · *The Viviparous Quadrupeds of North America*, by John James Audubon and John Bachman

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

The “American shrew mole” is the animal we now call the eastern mole, the mole that pushes up ridges in lawns from Massachusetts to Texas. Audubon’s team painted it from real specimens to show its strange and wonderful body.

Look closely

- Find the front feet. How are they shaped, and which way do the palms face?
- Look for the eyes and ears. Can you find them at all?
- Look at the nose. Why might a mole need a sensitive nose more than sharp eyes?
- Compare the front feet with the back feet. Why are they so different?

Talk about it

1. A mole is shown in a garden picture and someone says, “It is eating my tulip bulbs!” What would you tell them?
2. What signs in a lawn would tell you a mole lives there?
3. How is a mole’s body designed for its life underground?

Safety first. Do not touch live or dead mice, voles or moles, or their droppings and nests. Wear gloves for any digging, and wash your hands with soap and water after working in the yard. Traps are set and checked only by adults.

HANDS-ON PROJECT

Lawn and Garden Tunnel Detective

You will survey a lawn, garden or field edge for signs of moles, voles and mice, map them, and use a simple test to find out which mole tunnels are still in use.

You will need

- A yard, garden, park edge or field (no-yard option: a school field or a relative's yard; or study photos of mole and vole signs from an extension website)
- Garden gloves
- 6 to 10 craft sticks or small flags and a marker
- A ruler or measuring tape
- Graph paper and your nature journal

Steps

1. Put on gloves. Walk slowly across the area in straight lines, about 3 feet apart, looking down.
2. Look for raised, spongy ridges and volcano-shaped mounds with no hole (moles); narrow trails through the grass and small round holes with no mound (voles); and gnawed bark near the bottom of young trees (voles).
3. Mark each sign with a numbered stick. Measure the width of any runway or hole and the height and width of any mound.
4. Draw a map on graph paper showing your marked signs, with a key: M for mole, V for vole, ? for unsure.
5. Choose 3 or 4 mole ridges. With your foot, gently press down a short section of each ridge until it is flat, and mark it.
6. Check the flattened sections the next day. A ridge pushed back up is an active tunnel the mole still uses; a ridge that stays flat is an old one.
7. Record your results, and write a short report: Which animals live here? Are they helping, harming, or both?
8. Suggest one barrier or habit (for example, wire guards on young trees) that would protect plants without harming the soil.

Tips

- Early spring, just after snow melts, is the best time to see vole runways.
- Mole ridges are often along edges: sidewalks, fences and garden beds.

Check your work

- ☐ I can name two differences between a mole and a vole.
- ☐ My map shows each sign with a measurement and a label.
- ☐ I can explain how to tell an active mole tunnel from an old one.

NATURE JOURNAL

1. Draw a mole, a vole and a mouse side by side at life size from a field guide, and label the feet, eyes, ears and tail.
2. Draw a cross-section of soil showing a mole's shallow ridge tunnel, a deep tunnel and a mound pushed up from it.
3. Record your mole-tunnel test results in a table with date and weather.

From history. In England, mole catching was a real country trade for hundreds of years. Mole catchers walked from farm to farm, setting traps in pastures and selling the soft moleskins, which were sewn into vests and caps. The heavy, smooth cotton cloth called "moleskin" is named after that fur.

COMMON MISTAKES

- Blaming moles for eaten bulbs and roots. Moles eat worms and grubs; voles eat plants.
- Piling mulch right against tree trunks, which hides voles while they chew the bark.
- Sweeping up mouse droppings dry, which can raise harmful dust.

Make it a game • Tunnel Detective Clues. Draw clue cards: a raised ridge of earth, a volcano-shaped mound, a runway through grass and a girdled stem. Shuffle and flip one. Name the animal, mole, vole or mouse, its food and how the body fits its way of life. Then hide a drawn clue somewhere in the room and let your parent hunt and solve it.

UNIT 2

WILDLIFE

Fall is the busiest season for wild animals near our homes. Squirrels bury nuts, birds pass through on migration, and raccoons, skunks and coyotes fatten up for winter. In this unit you will learn to sort the wild mammals of your area into their true groups by looking at teeth, feet and habits, and to identify birds by their field marks and songs the way real birders do.

You will also learn how to live wisely alongside the larger animals that visit yards and farms: why we never feed them, how to keep trash, pets and chickens safe, and what to do if an animal acts strangely. Finally you will become a lawn detective, telling apart the tunnels of moles, voles and mice. Adam's first job in the garden was to look carefully at the animals and name them; you will practice that same careful looking.

PREREQUISITES

- Knows the difference between a mammal, a bird, a reptile, an amphibian and a fish
- Can use a ruler and keep a dated log
- Has a nature journal and colored pencils; binoculars are helpful but optional

MASTERY CHECKLIST

- ☐ I can sort local mammals into their orders using teeth, feet and diet.
- ☐ I can identify at least ten local birds by sight and five by sound.
- ☐ I can explain why we never feed or touch wild animals and what to do if one acts sick.
- ☐ I can tell mole, vole and mouse signs apart in a yard or garden.
- ☐ I can build and use a simple dichotomous key.

LESSONS IN THIS UNIT

2.1 Classifying Local Mammals

2 sessions of 45 minutes

2.2 Birds by Song and Field Marks

2 sessions of 45 minutes

2.3 Living Alongside Raccoons, Skunks and Coyotes

2 sessions of 45 minutes

2.4 Moles, Voles and Mice

2 sessions of 45 minutes

UNIT 2 REVIEW

Answer each question. Use complete sentences for questions that ask you to explain.
The review is worth 50 points.

1. (5 pts)

Name four traits that all mammals share.

2. (5 pts)

A rabbit and a squirrel both have front teeth that never stop growing. Why are they placed in different orders?

3. (5 pts)

What is the only marsupial in the United States, and what makes it a marsupial?

4. (5 pts)

List the four keys birders use to identify birds, in order.

5. (5 pts)

What is the difference between a bird's song and its call?

6. (5 pts)

Why should we never feed raccoons or coyotes?

7. (5 pts)

Name three wild animals that most often carry rabies in the U.S. and two signs that an animal may be sick.

8. (5 pts)

What should you do if a coyote walks toward you in a park?

9. (5 pts)

You find raised, squishy ridges and mounds with no holes in your lawn. Which animal made them, and what does it eat?

10. **5 pts**

Young apple trees in an orchard have bark chewed off all the way around near the ground after winter. What animal probably did it, and how can it be prevented next year?

ANSWER KEY

1. A backbone; hair or fur; warm-blooded; mothers feed their young with milk.
2. Rabbits are lagomorphs: they have a second, tiny pair of upper incisors behind the front pair and eat only plants. Squirrels are rodents with only one pair of upper incisors.
3. The opossum. The mother carries her young in a pouch.
4. Size and shape; color pattern; behavior; habitat.
5. A song is a longer, musical pattern sung mostly by males in spring to claim territory; a call is a short sound used all year to keep in touch or warn.
6. Feeding makes them lose their fear of people (habituated) and draws them close to homes, pets and children, which is dangerous for people and animals.
7. Raccoons, skunks, bats (or foxes). Signs: unusually tame, staggering, circling, drooling, attacking for no reason.
8. Do not run. Stand tall, wave your arms, shout and make noise until it leaves, then tell an adult.
9. A mole. It eats earthworms, grubs and insect larvae, not plants.
10. Voles. Wrap the trunks with wire-mesh guards and pull mulch and tall grass away from the trunks.

PORTFOLIO PIECE: A WILDLIFE FIELD NOTEBOOK FOR MY NEIGHBORHOOD

Make a field notebook about the wild animals of your neighborhood. Include your mammal identification key, your bird-count results and field-mark pages, your home wildlife audit with the fixes you made, and your tunnel-detective map. Finish with a one-page “Neighbor’s Guide” explaining how families can live safely and kindly alongside the wildlife you studied.

LOOK FOR	WHAT IT MEANS
Identification skills	The dichotomous key works for all ten mammals, and at least five birds are identified with correct field marks.
Careful observation	Counts, maps and logs include dates, times, weather and measurements.
Safety and stewardship	The audit and Neighbor’s Guide correctly explain not feeding wildlife, exclusion and rabies warning signs.
Accuracy	Facts about each animal’s order, diet and signs are correct.
Presentation	Drawings are careful and labeled; pages are neat and complete.

UNIT 3

SOIL SCIENCE

Soil is not just dirt. It is a living mixture of tiny rock particles, decayed plants and animals, water, air and billions of living things. In this unit you will measure your own soil's texture with a jar test and the texture triangle, discover why dark humus is a gardener's treasure, and build a compost pile while learning the science of the microbes that heat it.

You will finish with the story of the Dust Bowl, when wind carried away the topsoil of the Great Plains, and with the ways farmers now protect the soil: contour plowing, terraces, windbreaks and cover crops. God placed the first man in a garden "to dress it and to keep it." Keeping the soil is one of the most important ways we obey that charge.

PREREQUISITES

- Can measure in inches or centimeters and read percentages
- Knows that plants need water, air and nutrients from the soil
- Has gloves, a trowel and a clear quart jar with a lid

MASTERY CHECKLIST

- ☐ I can measure sand, silt and clay with a jar test and find my soil's texture on the texture triangle.
- ☐ I can explain what humus is and how organic matter helps soil hold water and nutrients.
- ☐ I can build a compost pile with the right balance of browns and greens and explain why it heats up.
- ☐ I can explain the causes of the Dust Bowl and four ways farmers prevent erosion.
- ☐ I can test and compare two soils and record the results like a scientist.

LESSONS IN THIS UNIT

3.1 The Soil Texture Triangle

2 sessions of 45 minutes

3.2 Organic Matter and Humus

2 sessions of 45 minutes

3.3 The Science of Composting

2 sessions of 45 minutes

UNIT 3 REVIEW

Answer each question. Show your work for the calculation. The review is worth 50 points.

1. **5 pts**

List sand, silt and clay from largest to smallest, and tell how each feels.

2. **5 pts**

A jar test shows 3 cm of sand, 2 cm of silt and 1 cm of clay. What percent of the soil is each?

3. **5 pts**

Give one advantage and one problem of a sandy soil and of a clay soil.

4. **5 pts**

What is humus, and name two ways it improves soil.

5. **5 pts**

Sort into browns and greens: dry leaves, grass clippings, straw, carrot peels, shredded newspaper, coffee grounds.

6. **5 pts**

Why does a compost pile heat up?

7. **5 pts**

A compost pile smells like ammonia and is slimy. What is wrong and how would you fix it?

8. **5 pts**

Explain two causes of the Dust Bowl.

9. **5 pts**

Name four ways farmers protect soil from erosion.

10. **5 pts**

In your erosion-tray test, which tray lost the most soil and why?

ANSWER KEY

1. Sand (gritty), silt (smooth, like flour), clay (sticky when wet).
2. Total 6 cm. Sand 50%, silt about 33%, clay about 17%.
3. Sand: drains and warms quickly, but dries out and loses nutrients. Clay: holds water and nutrients, but drains slowly, stays cold and gets hard.
4. The dark, stable material left after organic matter decomposes. Any two: holds water, holds nutrients, glues soil into crumbs, feeds soil life.
5. Browns: dry leaves, straw, shredded newspaper. Greens: grass clippings, carrot peels, coffee grounds.
6. Billions of microbes feeding on the organic matter give off heat, and a pile at least 3 feet on each side holds that heat in.
7. It has too many greens and is too wet, with too little air. Add browns and turn the pile.
8. Farmers plowed up the deep-rooted prairie grasses that held the soil, and then years of severe drought killed the crops, leaving bare, dry soil for the wind to blow away.
9. Any four: contour plowing, terraces, strip cropping, windbreaks, cover crops, no-till, mulch.
10. The bare tray, because nothing protected the soil from the falling and running water; mulch and roots held soil in place.

PORTFOLIO PIECE: MY SOIL REPORT AND COMPOST RECORD

Write and illustrate a soil report for your own garden or yard, like the reports a soil scientist gives to a farmer. Include your jar-test results and texture class, your crumb and sponge tests, your compost-pile log and graph, and your erosion-tray results. Include your conservation poster. End with three specific recommendations for improving and protecting your soil next year.

LOOK FOR	WHAT IT MEANS
Texture measured	Jar-test measurements, correct percentages and the correct texture class from the triangle.
Organic matter tested	Crumb and sponge tests are recorded in tables with a clear conclusion.
Compost record	Daily temperature log and graph, with turning days marked and browns and greens listed.
Conservation	Erosion-tray results and recommendations use the methods learned (mulch, cover crops, contours).
Scientific presentation	Report is neat, labeled and written clearly enough for a family member to follow.

3.1 THE SOIL TEXTURE TRIANGLE

OBJECTIVES

- Name the three mineral particles in soil and compare their sizes.
- Measure the percent of sand, silt and clay in a soil sample with a jar test.
- Use the soil texture triangle to name a soil's texture class.

Warm-up. Rub a pinch of dry sand, a pinch of flour and a pinch of moist modeling clay or wet mud between your fingers. Describe each one in a single word. These three feelings are the clues soil scientists use: gritty, silky and sticky.

WATCH

Soil texture by feel

UCDavisGEO • 4:04

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

WHEN TO WATCH

In the second session, while the jar test settles. Follow along with a moist ball of your own soil and pause at each step.

KEY TERMS

soil texture

The proportions of sand, silt and clay particles in a soil.

silt

Medium soil particles, 0.002 to 0.05 millimeters across; they feel smooth and floury.

loam

A soil with a good balance of sand, silt and clay, about 40 percent sand, 40 percent silt and 20 percent clay; most garden plants grow best in loam.

sand

The largest soil particles, 0.05 to 2 millimeters across; they feel gritty.

clay

The smallest soil particles, less than 0.002 millimeters across; they feel sticky when wet.

CORE IDEAS

The mineral part of soil is made of rock broken down into particles of three sizes. If a grain of **sand** were the size of a basketball, a grain of **silt** would be about the size of a marble, and a particle of **clay** would be about the size of a grain of sugar or smaller. The mix of these three sizes is called the **soil texture**, and it changes how a soil behaves more than almost anything else.

Sandy soils have large spaces between grains, so water drains quickly and air moves freely. They warm up fast in spring and are easy to dig, but they dry out quickly and lose nutrients as water washes through. **Clay soils** have tiny spaces, so they hold water and nutrients well, but they drain slowly, stay cold and wet in spring, and bake hard when dry. **Silt** is in between: smooth, fertile and easily washed away. **Loam**, a balanced mix, holds enough water and drains enough to suit most crops.

A **jar test** measures texture at home. Fill a straight-sided jar one-third full of soil, add water almost to the top and a teaspoon of dish soap to help the particles separate, and shake hard for several minutes. Set it down and do not move it. Sand settles in about one minute, silt in about two to six hours, and the tiny clay particles may take a day or more, keeping the water cloudy. Mark each layer on the jar with a pen.

Measure each layer and divide by the total height to get percentages. For example, if the settled soil is 4 inches deep with 2 inches of sand, $1\frac{1}{2}$ of silt and $\frac{1}{2}$ of clay, that is 50 percent sand, 37.5 percent silt and 12.5 percent clay. Then use the **soil texture triangle**, a chart made by the U.S. Department of Agriculture. Each side is a scale from 0 to 100 percent for one particle. Follow the lines for your percentages until they meet, and read the name of the region where they cross: in our example, “loam,” close to “sandy loam.”

Texture cannot be changed easily; a garden would need tons of sand to change clay. But every texture can be improved by adding **organic matter**, which helps sand hold water and helps clay drain. Knowing your texture tells you how often to water, when to dig, and which crops will be happiest. Carrots and radishes love sandy loam; cabbage and beans grow well in heavier loams.

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 greatest animal painters of the 1800s. She studied oxen on farms in central France until she knew every muscle. In this painting, the plows are breaking the heavy soil of a field in autumn to prepare it for sowing.

Look closely

- Look closely at the turned soil in the front. Is it fine and crumbly or in big, shiny clods? What does that suggest about its texture?
- Find the color of the soil. Is it pale, reddish or dark? What might the color tell a farmer?
- Count the oxen pulling each plow. Why would a heavy soil need so many?
- Look at the unplowed part of the field. What is growing there?

Talk about it

1. Would it be easier to plow a sandy soil or a clay soil? Why?
2. Why do you think farmers plow in autumn in some places, so the soil can sit through winter?
3. What would you need to do to test the texture of this field?

The Jar Test and the Texture Triangle

You will measure the texture of soil from your own garden or yard with a jar test and a feel test, then plot it on the soil texture triangle. If you can, test two different soils and compare them.

You will need

- Garden soil from 2 to 6 inches deep (no-yard option: soil from a relative's yard, a park with permission, or a bag of topsoil, not potting mix)
- A clear, straight-sided quart jar with a lid
- Water and 1 teaspoon of liquid dish soap
- A ruler, a permanent marker and a calculator
- A printed soil texture triangle (from a soil science or extension website, with a parent)
- A sieve or colander, and gloves

Steps

1. Put on gloves. Dig down past the grass roots and collect about 2 cups of soil. Pick out stones, roots and leaves, or push the soil through a sieve.
2. Fill the jar about one-third full of soil. Add water to about 1 inch below the rim and add the dish soap.
3. Screw the lid on tight and shake hard for 3 to 5 minutes. Take turns if your arms get tired.
4. Set the jar on a level shelf where it will not be bumped. After 1 minute, mark the top of the settled layer: this is sand.
5. After 2 hours, mark the top of the next layer: this is silt. Leave the jar for 24 to 48 hours, until the water is nearly clear, and mark the top of the last layer: clay.
6. Measure each layer and the total depth in millimeters or sixteenths of an inch. Calculate the percent of sand, silt and clay. Check that they add up to 100.

7. On the texture triangle, find your percent clay on its scale and your percent sand on its scale. Follow the guide lines until they meet and write down your texture class.
8. Do a texture-by-feel test with a moist ball of the same soil, as in the video, and see whether it agrees with your jar.

Tips

- Use a jar with straight sides; a curved jar makes the layers hard to measure.
- Some organic bits will float on top. Skim them off; they are not part of texture.
- If you test two soils, label the jars and shake them the same amount.

Check your work

- ☐ I can name the three soil particles from largest to smallest.
- ☐ I calculated my soil's percentages and they add to 100.
- ☐ I can name my soil's texture class from the triangle.

NATURE JOURNAL

1. Draw your jar actual size with each layer colored and labeled with its height and percent.
2. Draw three circles to show the relative sizes of sand, silt and clay, using the basketball, marble and sugar-grain comparison.
3. Copy the texture triangle and mark your soil with a star.

From history. In the early 1900s scientists at the U.S. Department of Agriculture began mapping the soils of every county in America, and they agreed on the sizes of sand, silt and clay. Their soil surveys, now online, still tell farmers what kind of soil lies under each field.

COMMON MISTAKES

- Moving the jar while the layers settle, which mixes them again.
- Using potting mix, which is mostly organic matter, not mineral soil.
- Forgetting that the percentages must add up to 100.

Make it a game • Jar Test Prediction. Before you shake any jar, play estimation duels. Scoop soil, guess the percent of sand, silt and clay, and write your guess. Your parent guesses too. Shake, wait, and measure the layers. Closest guess wins a point. Also name the size order of the three particles from largest to smallest and say what loam means.

3.2 ORGANIC MATTER AND HUMUS

OBJECTIVES

- Explain what organic matter and humus are and where they come from.
- Describe four ways humus improves soil.
- Test and compare how two soils hold water and stay together.

Warm-up. Scoop up a handful of dark soil from under a tree or from a garden bed, and a handful of pale soil from a bare spot or a path. Compare their color, smell and feel. Write three differences.

WATCH

I Define Humus And Why It's Important For Gardeners

Smiling Gardener · 4:04

<https://www.youtube.com/watch?v=od4ciF9r3Ls>

WHEN TO WATCH

After the second core idea. List each thing he writes on his whiteboard around the word “humus.”

Note: A gardening educator; he says humus helps “detoxify” soil, which means it binds and holds some harmful substances.

BACKUP VIDEO

Soil Health Assessment - Water Stable Aggregates

NRCS Oregon · 3:04

https://www.youtube.com/watch?v=7OYq6-_GW5Q

Before the hands-on project. This is the same test you will do; watch which soil holds together.

KEY TERMS

organic matter

Everything in soil that is or once was alive: roots, leaves, manure, microbes and their remains.

humus

The dark, stable, spongy material left after organic matter has been broken down as far as it will easily go.

decomposer

A living thing, such as a bacterium, fungus or earthworm, that breaks down dead material.

soil aggregate

A small crumb of soil in which particles are glued together by humus, roots and microbes.

CORE IDEAS

Organic matter is the part of soil that is or once was alive: fallen leaves, dead roots, manure, insects, fungi and bacteria. Even though a good garden soil may have only about 3 to 6 percent organic matter by weight, that small part does a huge share of the work. Fresh organic matter is eaten by **decomposers**: earthworms, mites, beetles, fungi and, most of all, bacteria. As they feed, they release nutrients plants can use.

What is left after decomposers have done most of their work is **humus** (HYOO-mus): a dark brown or black, spongy material that can last in the soil for many years. Humus is what makes rich soil dark and gives it that sweet, earthy smell (which actually comes from soil microbes called actinomycetes). Do not confuse humus with the chickpea dip called hummus.

Humus improves soil in four big ways. First, it **holds water** like a sponge, so sandy soils dry out less quickly. Second, it **holds nutrients**: its surfaces carry tiny negative charges that cling to positive nutrients such as calcium, magnesium and potassium, so rain cannot wash them away, and roots can trade for them later. Third, it **glues soil particles into crumbs** called aggregates, which leave spaces for air and water so clay soils drain and roots can push through. Fourth, it **feeds soil life**, which in turn keeps building more.

You can see aggregates for yourself. Drop a dry clod of healthy garden soil into water and it stays mostly together, letting bubbles of air escape. A clod from a worn, bare path may fall apart into mud almost at once. Soil that falls apart in rain forms a hard crust when it dries and washes away easily. That is why farmers watch their organic matter carefully.

Gardeners build humus by adding compost, shredded leaves and aged manure, by keeping the soil covered with mulch or plants, and by digging and tilling no more than they must, since tilling lets air rush in and microbes burn up organic matter faster. In the forest, God's own system builds humus every year as leaves fall and decay. A wise gardener copies it.

PICTURE STUDY



Tree Roots, Vincent van Gogh, 1890 · Oil on canvas · Van Gogh Museum, Amsterdam

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

This may be the last painting Van Gogh worked on. He painted the roots of trees growing out of a crumbling bank of soil, very close up, so the picture is full of shapes and colors. It shows the hidden world where plants meet the earth.

Look closely

- Find the roots. How do they grip the soil? Where do they disappear into it?
- Look at the colors Van Gogh used for the earth. Which parts look like dark, rich soil, and which look like bare, pale soil?
- Look for any fallen leaves, moss or green plants growing on the soil.
- Find a place where the soil bank seems to be crumbling or washing away.

Talk about it

1. How do roots help hold soil in place?
2. When these roots and the leaves above them die, what will happen to them in the soil?
3. Why might the soil under trees be darker than the soil on a bare path?

HANDS-ON PROJECT

Crumb Test and Sponge Test

You will compare two soils, one rich in organic matter and one poor in it, with two simple tests: one to see which holds together in water (the crumb, or slake, test) and one to see which holds more water (the sponge test).

You will need

- Two soil samples: one dark and rich (garden bed, under a tree, or mixed half and half with compost) and one pale and poor (a bare path, subsoil from deeper down, or plain sand)
- Two clear cups or jars of water and two small pieces of window screen or hardware cloth to rest clods on
- Two funnels or two plastic bottles cut in half and turned upside down, each lined with a coffee filter
- A measuring cup and two clear jars to catch water
- A timer, gloves and your journal

Steps

1. Let a clod of each soil, about the size of a walnut, dry on a sunny windowsill for a day or two.
2. Crumb test: set each dry clod on a piece of screen and lower it gently into its own cup of water so it sits just under the surface.
3. Watch for 5 minutes. Record what happens to each clod at 10 seconds, 1 minute and 5 minutes. Give each a score: 0 = fell apart completely, 1 = mostly fell apart, 2 = half held, 3 = mostly held, 4 = held together.
4. Sponge test: put 1 cup of each soil (loose and dry) into its own lined funnel set over a jar.
5. Pour exactly 1 cup of water slowly over each soil. Start the timer.
6. After 10 minutes, measure how much water came through into each jar. Subtract from 1 cup to find how much each soil held.
7. Make a table of both tests. Which soil held together better? Which held more water?

8. Write a conclusion: what does organic matter do for soil? Mix compost into a little of the poor soil and test again if you have time.

Tips

- Lower the clods slowly; dropping them can break them.
- Use the same amount of soil and water every time so the test is fair.

Check your work

- ☐ I can explain the difference between organic matter and humus.
- ☐ I can name four ways humus helps soil.
- ☐ My table shows results for both soils in both tests.

NATURE JOURNAL

1. Draw both clods in water at 1 minute and 5 minutes, side by side.
2. Draw a magnified soil crumb with sand, silt and clay particles glued by humus, with air and water spaces between crumbs.
3. Draw a cut-away of a forest floor: fresh leaves on top, half-rotted leaves beneath, dark humus below that, and mineral soil at the bottom.

From history. George Washington Carver, a scientist at Tuskegee Institute in Alabama, saw that years of cotton had worn out Southern soils. In the early 1900s he wrote simple bulletins teaching poor farmers to rake up leaves, swamp muck and barnyard manure, compost them, and plow them back in, and to grow soil-building crops such as peanuts and cowpeas.

COMMON MISTAKES

- Thinking humus and compost are exactly the same. Compost becomes humus as it finishes breaking down in the soil.
- Tilling the soil over and over, which burns up organic matter.
- Using different amounts of soil or water in the two sides of a test.

Make it a game • Sponge and Crumb Teach-Back. Hold up a kitchen sponge and teach your parent why humus acts like it: holds water, feeds plants, builds crumbs and keeps soil loose. Your parent asks what organic matter is and where humus comes from. Name four ways humus improves soil without peeking. Parent secretly slips in a false fact; ring a spoon on a cup to catch it.

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)

In Jesus’ parable, the patient gardener feeds the soil around a struggling fig tree before giving up on it. Good gardeners still build the soil first.

3.3 THE SCIENCE OF COMPOSTING

OBJECTIVES

- Explain how microbes break down organic matter and why a compost pile heats up.
- Balance browns (carbon) and greens (nitrogen) to make a good compost mix.
- Build a compost pile or bin and track its temperature.

Warm-up. Sort a pile of picture cards or real items into two groups: dry leaves, grass clippings, straw, apple cores, shredded newspaper, coffee grounds, sawdust, lettuce scraps. Which feel dry and brown? Which feel wet and green? Hold your sorting until the lesson explains it.

WATCH

The Carbon To Nitrogen Ratio Explained - Garden Quickie Episode 105

The Ripe Tomato Farms · 3:01

<https://www.youtube.com/watch?v=k0mJ79DhxWE>

WHEN TO WATCH

After the second core idea. Copy his lists of carbon sources and nitrogen sources into your journal.

BACKUP VIDEO

How to Make Hot Compost (Start to Finish)

Epic Gardening · 12:21

<https://www.youtube.com/watch?v=XOu60D6VGqc>

Before you build your pile. Watch how they layer, water and size the pile.

KEY TERMS

compost

Organic matter that microbes have broken down into a dark, crumbly soil-builder.

browns

Dry, carbon-rich materials such as dead leaves, straw, shredded paper and wood chips.

greens

Moist, nitrogen-rich materials such as grass clippings, vegetable scraps, coffee grounds and fresh manure.

C:N ratio

The ratio of carbon to nitrogen in a material; a compost pile works best at about 30 parts carbon to 1 part nitrogen.

thermophilic

Heat-loving; describes the microbes that work in the hot middle stage of composting, about 113 to 160 °F.

CORE IDEAS

A compost pile is a feeding place for **microbes**. Bacteria do most of the work at first, with fungi, actinomycetes, and later earthworms, mites, millipedes and sow bugs joining in. Like every living thing, they need four things: **food** (carbon for energy and nitrogen for building their bodies), **water**, **air** (oxygen) and the right **temperature**. Give them all four and they will turn a heap of scraps into rich compost.

Microbes need about 30 times as much carbon as nitrogen, a **C:N ratio** of about 30:1. **Browns** are high in carbon: dry leaves are about 60:1, straw about 80:1, and sawdust 400:1 or more. **Greens** are high in nitrogen: grass clippings about 20:1, vegetable scraps about 15:1, and coffee grounds about 20:1. A simple rule is two to three buckets of browns for every bucket of greens. Too much green and the pile turns slimy and smells like ammonia; too much brown and it just sits there.

When the mix is right, the microbes multiply by the trillions and their busy feeding gives off heat. A pile at least 3 feet wide, 3 feet long and 3 feet tall holds that heat in. In a few days the center can climb to 130 to 160 °F, hot enough to steam on a cold morning. This is the **thermophilic**, or heat-loving, stage. The heat kills most weed seeds and disease germs. When the microbes use up the easy food, the pile cools; turning it with a fork brings in fresh air and new food, and it heats up again.

Moisture matters too. The pile should feel like a wrung-out sponge: damp all through, but no water drips when you squeeze a handful. A soggy pile fills its spaces with water instead of air, and different microbes that live without oxygen take over

and make bad smells. Turning, adding browns, and covering the pile from heavy rain fix that.

After the hot stage comes a long **curing** stage, when fungi and small creatures finish the work. Finished compost is dark, crumbly and smells like a forest floor; you can no longer tell what went in. A well-tended hot pile may be ready in two to four months; a cold, untended pile takes a year or more. Leave out meat, bones, dairy, oily foods, pet and human waste, and diseased plants, which attract pests or carry germs.

PICTURE STUDY



The Hay Harvest, Pieter Bruegel the Elder, 1565 · Oil on wood · Lobkowitz Palace, Prague

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

This painting belongs to the same series of the farmer's year as *The Harvesters*. It shows haymaking in early summer. Hay was the farm's most important winter food for animals, and its leftover stems, along with manure from the barn, went back to the fields to feed the soil.

Look closely

- Find the haymakers raking hay into rows. Is the hay green, golden, or in between?
- Find the people carrying baskets on their heads. What foods are they bringing to market?
- Look for a wagon piled with hay. How do they keep it from falling off?
- Find any animals in the picture. What would they eat in winter?

Talk about it

1. Is fresh-cut green grass a “brown” or a “green” for composting? What about the dry hay after it has sat for weeks?
2. How did manure and old straw from the barn help a farm like this one keep its soil rich?
3. What scraps from these people's food could go into a compost pile?

Safety first. Wear gloves when handling compost and manure, and wash your hands with soap and water afterward. Use a garden fork with an adult nearby and keep the tines pointed down. Do not put meat, dairy, pet waste or diseased plants in the pile.

HANDS-ON PROJECT

Build a Hot Compost Pile and Keep a Temperature Log

You will build a compost pile or bin with the right mix of browns and greens, then measure its temperature every day for two weeks to watch the microbes at work.

You will need

- Browns: dead leaves, straw, shredded newspaper or cardboard (enough to fill about 6 to 9 buckets)
- Greens: grass clippings, vegetable and fruit scraps, coffee grounds, garden trimmings (about 3 buckets)
- A spot of bare ground about 3 feet by 3 feet, or a compost bin (no-yard option: a large plastic tote with holes drilled in the sides and bottom, kept on a balcony or garage, or help at a community garden)
- A garden fork, a hose or watering can, and gloves
- A compost thermometer or a long-stem kitchen thermometer

Steps

1. Choose a level, well-drained spot, partly shaded, that you can reach with a hose.
2. Lay down about 4 inches of coarse browns, such as twigs or straw, to let air in at the bottom.
3. Add layers: 2 to 3 inches of browns, then 1 inch of greens. Sprinkle water on each layer until it is as damp as a wrung-out sponge.
4. Keep layering until the pile is about 3 feet tall, ending with browns on top to cover the greens.
5. Every day at the same time, push the thermometer into the center and record the temperature, along with the air temperature and the weather.
6. When the center temperature peaks and starts to drop (often after 5 to 10 days), turn the pile with the fork, moving the outside to the inside. Add water if it is dry. Keep recording.

7. After 2 weeks, make a line graph of pile temperature and air temperature by day. Mark the days you turned the pile.
8. Keep turning the pile every week or two. In 2 to 4 months, check for dark, crumbly finished compost at the bottom and center.

Tips

- Chop or shred large materials; smaller pieces give microbes more surface to eat.
- A small tote will not heat up like a big pile, but it will still make compost if you balance browns and greens and stir it.
- If the pile smells bad, add browns and turn it. If it stays cold, add greens and water.

Check your work

- ☐ I can sort materials into browns and greens.
- ☐ I can explain why a compost pile heats up.
- ☐ My temperature log shows daily readings and a graph.

NATURE JOURNAL

1. Draw a cut-away of your compost pile, labeling each layer and the hot center.
2. Make a line graph of your daily temperatures and mark when you turned the pile.
3. Use a magnifying glass to observe the creatures in a handful of older compost, and draw three of them.

From history. Sir Albert Howard, an English farm scientist working in India in the 1920s and 1930s, developed a method of making compost from layers of plant waste and manure in large heaps. His method, called the Indore method after the city where he worked, spread around the world and taught many farmers to return wastes to the soil.

COMMON MISTAKES

- Making the pile too small to heat up; aim for about 3 feet on each side.
- Adding only kitchen scraps and grass, which makes a smelly, slimy pile. Add browns.
- Letting the pile dry out completely, which stops the microbes.

Make it a game • Compost Recipe Race. Write twelve items on scraps: leaves, grass clippings, kitchen peels, shredded paper, coffee grounds and so on. Race to sort them into browns for carbon and greens for nitrogen, then build a pretend layered pile on a plate. Explain why a good pile heats up and what thermophilic microbes are doing. Beat your sorting time.

3.4 EROSION AND CONSERVATION: THE DUST BOWL

OBJECTIVES

- Explain how wind and water erode soil.
- Describe the causes of the Dust Bowl of the 1930s.
- Explain how contour plowing, terraces, windbreaks and cover crops protect soil, and test them with a model.

Warm-up. Pour a cup of water slowly onto a bare patch of soil, then onto a patch of grass or mulch. Watch where the water goes and what it carries. Write what you notice.

WATCH

Preventing Erosion with Cover Crops - Practical Cover Croppers

Practical Farmers of Iowa · 6:27

<https://www.youtube.com/watch?v=abjnRhJ9uR4>

WHEN TO WATCH

After the core ideas. Farmers in Iowa show how cover crops hold soil in place today; list two ways they keep their fields from washing or blowing away, as the Dust Bowl fields did.

KEY TERMS

erosion

The wearing away and carrying off of soil by wind or water.

topsoil

The dark upper layer of soil, richest in humus and nutrients, where most roots grow.

contour plowing

Plowing across a slope, following its level lines, so each furrow catches water instead of sending it downhill.

windbreak

A row of trees or shrubs planted to slow the wind across a field; also called a shelterbelt.

cover crop

A crop such as rye, oats or clover grown to cover and protect the soil between main crops.

CORE IDEAS

Erosion happens when wind or water carries soil away. Each raindrop hitting bare soil splashes particles loose. Water running across a field carries them off, first in thin sheets, then in small channels called rills, and finally in deep gullies. On dry, bare land, strong wind lifts the finest particles, including silt, clay and humus, and blows them away. The richest part of the soil, the **topsoil**, is always the first to go, and it forms back only very slowly.

The worst erosion disaster in American history was the **Dust Bowl**. For thousands of years the southern Great Plains, in parts of Oklahoma, Texas, Kansas, Colorado and New Mexico, had been covered with deep-rooted prairie grasses that held the soil even in dry years. In the 1910s and 1920s, when wheat prices were high and rains were good, farmers with new tractors plowed up millions of acres of grass to plant wheat. Then, in the 1930s, came years of severe drought. The wheat died, the bare, plowed soil dried to powder, and the wind did the rest.

Huge dust storms called “black blizzards” rolled across the plains. On “Black Sunday,” April 14, 1935, a storm turned day into night. Dust drifted against fences like snow, buried farm machinery and blew as far as the East Coast. Many families lost their farms and moved away. A soil scientist named **Hugh Hammond Bennett** convinced the government that soil had to be protected, and in 1935 the Soil Conservation Service was formed to help farmers. Agents taught farmers new methods, and families planted more than 200 million trees in long windbreaks across the plains.

Those methods still protect fields today. **Contour plowing** follows the level lines across a slope so every furrow is a little dam. **Terraces** are wide steps or ridges built across hillsides. **Strip cropping** alternates strips of a row crop with strips of hay or grass. **Windbreaks** of trees slow the wind. **Cover crops**, such as cereal rye or clover sown after harvest, keep living roots and leaves on the soil through winter, and **no-till** farming leaves last year’s stalks on the surface as a blanket.

In your own garden, the same rules apply: never leave soil bare. Mulch beds with straw, shredded leaves or wood chips, plant cover crops in fall, run rows across a slope instead of up and down it, and add organic matter so the soil holds together. Proverbs describes the field of the lazy man, overgrown with thorns and its stone wall broken down. A faithful steward guards the soil so that it can feed his children and grandchildren.

PICTURE STUDY



Spring, Jean-François Millet, 1868–1873 • Oil on canvas • Musée d’Orsay, Paris

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

Jean-François Millet lived among farmers in the village of Barbizon, France, and painted their land through the seasons. In *Spring*, a storm has just passed over a farm garden. The ground is wet, the trees are blooming and a rainbow shines across the sky.

Look closely

- Find the rainbow and the storm clouds. Which way do you think the storm is moving?
- Look at the ground. Where is it covered by grass or plants, and where is it bare?
- Find the paths and garden beds. How are they arranged on the slope?
- Look for the trees in bloom. What kind of trees might they be?

Talk about it

1. After a heavy spring rain, where in this garden would erosion be most likely? Why?
2. How does the grass beside the path protect the soil?
3. God promised Noah the rainbow as a sign. What else did He promise about seedtime and harvest in Genesis 8:22?

The Erosion Trays

You will build three model hillsides and pour “rain” on them to measure how much soil each one loses. You will see with your own eyes why farmers keep the soil covered.

You will need

- Three identical shallow trays or aluminum baking pans, or three plastic bottles cut in half lengthwise
- Garden soil to fill all three
- Mulch (straw, shredded leaves or grass clippings) and a piece of sod or quick-sprouted grass or cereal rye
- A watering can or a cup with holes poked in the bottom
- Three clear jars to catch runoff, books to prop the trays
- A measuring cup and your journal

Steps

1. Fill each tray with the same amount of soil and press it down gently. Cut or bend a spout at one end of each tray.
2. Tray 1: leave bare. Tray 2: cover with 1 inch of mulch. Tray 3: plant grass seed or rye a week ahead, or lay a piece of sod on it.
3. In Tray 1, after the first test, draw shallow furrows with a pencil across the slope (contour rows) for a fourth test if you have time.
4. Prop each tray on books at the same angle with the spout over a jar.
5. Pour 4 cups of water slowly and evenly over each tray from the same height.
6. Compare the jars: how much water ran off, and how muddy is it? Let the jars sit overnight and measure the layer of soil that settles in each.
7. Record your results in a table and rank the trays from most to least erosion.
8. Write a short report recommending how a farmer on a hillside should protect his field.

9. Design a soil conservation poster, like those entered in the National Association of Conservation Districts poster contest (the 2026 theme is “Soil. Where It All Begins”). Use one clear message, big lettering that can be read from across a room, and one simple picture, such as roots holding soil or a cover crop protecting a field.

Tips

- Keep everything the same except the soil cover, so it is a fair test.
- Do this outside or on a towel; it will be muddy.
- Many local conservation districts hold the poster contest for students from kindergarten through grade 12; ask your county conservation district or extension office for the rules and deadline.

Check your work

- ☐ I can explain how bare soil, drought and wind caused the Dust Bowl.
- ☐ I can name four ways farmers prevent erosion.
- ☐ My table compares the runoff from each tray.

NATURE JOURNAL

1. Draw a hillside farm from above showing contour rows, a terrace, a strip of hay and a windbreak, with labels.
2. Draw your three runoff jars after settling, with the soil layer in each measured.
3. Write and illustrate a one-paragraph diary entry as a farm child on Black Sunday, April 14, 1935.

From history. Hugh Hammond Bennett grew up on a cotton farm in North Carolina and spent his life warning about soil erosion. To persuade lawmakers in 1935, he timed his talk in Washington so that a great dust storm from the plains darkened the sky outside their windows while he was speaking.

COMMON MISTAKES

- Running garden rows straight up and down a slope.
- Leaving garden beds bare all winter instead of mulching or planting a cover crop.
- Thinking that soil lost to erosion will quickly come back. Topsoil forms very slowly.

Make it a game • Erosion Newscast. Record or perform a 'radio newscast' from the 1930s. Report what wind and water do to bare soil, the causes of the Dust Bowl, and the cures: contour plowing, windbreaks and cover crops. Your parent interrupts as a farmer asking questions. Use at least five key terms and keep a serious, steady voice. Swap and let your parent report.

Scripture. “Thou waterest the ridges thereof abundantly: thou settlest the furrows thereof: thou makest it soft with showers: thou blessest the springing thereof.” (Psalms 65:10, KJV)

God sends rain to soften the furrows and bless the growing crops. Our part is to care for the soil so that rain blesses it instead of washing it away.

UNIT 3

SOIL SCIENCE

Soil is not just dirt. It is a living mixture of tiny rock particles, decayed plants and animals, water, air and billions of living things. In this unit you will measure your own soil's texture with a jar test and the texture triangle, discover why dark humus is a gardener's treasure, and build a compost pile while learning the science of the microbes that heat it.

You will finish with the story of the Dust Bowl, when wind carried away the topsoil of the Great Plains, and with the ways farmers now protect the soil: contour plowing, terraces, windbreaks and cover crops. God placed the first man in a garden "to dress it and to keep it." Keeping the soil is one of the most important ways we obey that charge.

PREREQUISITES

- Can measure in inches or centimeters and read percentages
- Knows that plants need water, air and nutrients from the soil
- Has gloves, a trowel and a clear quart jar with a lid

MASTERY CHECKLIST

- ☐ I can measure sand, silt and clay with a jar test and find my soil's texture on the texture triangle.
- ☐ I can explain what humus is and how organic matter helps soil hold water and nutrients.
- ☐ I can build a compost pile with the right balance of browns and greens and explain why it heats up.
- ☐ I can explain the causes of the Dust Bowl and four ways farmers prevent erosion.
- ☐ I can test and compare two soils and record the results like a scientist.

LESSONS IN THIS UNIT

3.1 The Soil Texture Triangle

2 sessions of 45 minutes

3.2 Organic Matter and Humus

2 sessions of 45 minutes

3.3 The Science of Composting

2 sessions of 45 minutes

UNIT 3 REVIEW

Answer each question. Show your work for the calculation. The review is worth 50 points.

1. **5 pts**

List sand, silt and clay from largest to smallest, and tell how each feels.

2. **5 pts**

A jar test shows 3 cm of sand, 2 cm of silt and 1 cm of clay. What percent of the soil is each?

3. **5 pts**

Give one advantage and one problem of a sandy soil and of a clay soil.

4. **5 pts**

What is humus, and name two ways it improves soil.

5. **5 pts**

Sort into browns and greens: dry leaves, grass clippings, straw, carrot peels, shredded newspaper, coffee grounds.

6. **5 pts**

Why does a compost pile heat up?

7. **5 pts**

A compost pile smells like ammonia and is slimy. What is wrong and how would you fix it?

8. **5 pts**

Explain two causes of the Dust Bowl.

9. **5 pts**

Name four ways farmers protect soil from erosion.

10. **5 pts**

In your erosion-tray test, which tray lost the most soil and why?

ANSWER KEY

1. Sand (gritty), silt (smooth, like flour), clay (sticky when wet).
2. Total 6 cm. Sand 50%, silt about 33%, clay about 17%.
3. Sand: drains and warms quickly, but dries out and loses nutrients. Clay: holds water and nutrients, but drains slowly, stays cold and gets hard.
4. The dark, stable material left after organic matter decomposes. Any two: holds water, holds nutrients, glues soil into crumbs, feeds soil life.
5. Browns: dry leaves, straw, shredded newspaper. Greens: grass clippings, carrot peels, coffee grounds.
6. Billions of microbes feeding on the organic matter give off heat, and a pile at least 3 feet on each side holds that heat in.
7. It has too many greens and is too wet, with too little air. Add browns and turn the pile.
8. Farmers plowed up the deep-rooted prairie grasses that held the soil, and then years of severe drought killed the crops, leaving bare, dry soil for the wind to blow away.
9. Any four: contour plowing, terraces, strip cropping, windbreaks, cover crops, no-till, mulch.
10. The bare tray, because nothing protected the soil from the falling and running water; mulch and roots held soil in place.

PORTFOLIO PIECE: MY SOIL REPORT AND COMPOST RECORD

Write and illustrate a soil report for your own garden or yard, like the reports a soil scientist gives to a farmer. Include your jar-test results and texture class, your crumb and sponge tests, your compost-pile log and graph, and your erosion-tray results. Include your conservation poster. End with three specific recommendations for improving and protecting your soil next year.

LOOK FOR	WHAT IT MEANS
Texture measured	Jar-test measurements, correct percentages and the correct texture class from the triangle.
Organic matter tested	Crumb and sponge tests are recorded in tables with a clear conclusion.
Compost record	Daily temperature log and graph, with turning days marked and browns and greens listed.
Conservation	Erosion-tray results and recommendations use the methods learned (mulch, cover crops, contours).
Scientific presentation	Report is neat, labeled and written clearly enough for a family member to follow.

UNIT 4

PETS

A pet is a living creature placed in our care, and good care takes knowledge, not just love. In this unit you will learn the basic needs every animal has and how to plan and budget for a pet before bringing one home. Then you will go deeper into three kinds of pets where science matters most: fish, which depend on invisible bacteria to keep their water safe; reptiles, which depend on us for the right heat and light; and dogs, which communicate with their bodies and learn by reward.

You do not need to own a pet for this unit. Every project has an option to plan, visit, observe or help with a neighbor's or a relative's animal. "A righteous man regardeth the life of his beast" (Proverbs 12:10): you will learn what it means to regard an animal's life wisely and faithfully.

PREREQUISITES

- Can add, subtract and multiply money amounts
- Can read a thermometer in °F
- Knows how to wash hands well with soap for 20 seconds

MASTERY CHECKLIST

- ☐ I can list the basic needs of any pet and plan a first-year budget for one.
- ☐ I can explain the aquarium nitrogen cycle and why a new tank must be cycled.
- ☐ I can describe the heat gradient and UVB light a bearded dragon or leopard gecko needs.
- ☐ I can read a dog's body language and use positive reinforcement to teach a behavior.
- ☐ I keep animal-care records with dates, food, costs and observations, like a 4-H project book.

LESSONS IN THIS UNIT

4.1 Good Stewardship: The Basic Needs of Animals

2 sessions of 45 minutes

4.2 The Aquarium Nitrogen Cycle

2 sessions of 45 minutes

4.3 Reptile Heat, UVB and Habitat

2 sessions of 45 minutes

UNIT 4 REVIEW

Answer each question. Use complete sentences for explanations and show your work for the calculation. The review is worth 50 points.

1. (5 pts)

List five basic needs every pet has.

2. (5 pts)

A guinea pig cage costs \$120, a water bottle \$10, and the first vet visit \$70. Hay and pellets cost \$30 a month. What is the first-year cost of these items?

3. (5 pts)

Why is it important to keep a written care record for a pet?

4. (5 pts)

Put these in order in the aquarium nitrogen cycle: nitrate, fish waste, nitrite, ammonia.

5. (5 pts)

Why should you never put a whole tank of fish into a brand-new aquarium?

6. (5 pts)

A tank is 30 inches long, 12 inches wide and 16 inches high. About how many gallons does it hold?

7. (5 pts)

What is a heat gradient and why does a reptile need one?

8. (5 pts)

What happens to a bearded dragon without enough UVB light, and why?

9. (5 pts)

Name three signs that a dog is stressed and what you should do.

10. 5 pts

Explain how to use positive reinforcement to teach a dog to sit.

ANSWER KEY

1. Any five: food, water, shelter, health care, safety, exercise, companionship, enrichment.
2. One-time: $\$120 + \$10 + \$70 = \$200$. Recurring: $\$30 \times 12 = \$360$. Total: $\$560$.
3. Records show changes such as eating less or losing weight, which can be early signs of illness, and they help a vet, an owner or a 4-H leader see what care was given.
4. Fish waste → ammonia → nitrite → nitrate.
5. The tank does not yet have enough beneficial bacteria, so ammonia and nitrite build up and poison the fish. The tank must be cycled first.
6. $30 \times 12 \times 16 = 5,760$ cubic inches; $5,760 \div 231 \approx 25$ gallons.
7. A range of temperatures from a hot basking spot to a cool side. Reptiles are ectotherms and move between warm and cool areas to control their body temperature for digestion and health.
8. It can get metabolic bone disease, because without UVB it cannot make vitamin D3 and cannot use calcium, so its bones become soft and weak.
9. Any three: lip licking, yawning, looking away, tucked tail, ears back, whites of eyes showing, freezing. Stop, calmly give the dog space, and tell an adult.
10. Lure the dog into a sit with a treat raised over its nose, mark “yes!” the moment it sits, and give the treat right away; repeat in short sessions and then add the word “sit.”

PORTFOLIO PIECE: A PET KEEPER'S HANDBOOK

Make a handbook for one pet that a new owner could follow, like a 4-H project book. Include the care sheet, habitat drawing, chore chart and first-year expense table from Lesson 4.1, plus the special science for that kind of pet: the nitrogen cycle for fish, the heat gradient and UVB for reptiles, or body language and training for dogs. Add at least two weeks of care or observation records with dates.

LOOK FOR	WHAT IT MEANS
Complete care	Food, water, housing, temperature, health, exercise and companionship are all covered correctly for the chosen animal.
Budget and records	The expense table is accurate, and care or observation records cover at least two weeks with dates.
Science explained	The handbook clearly explains the key science for that animal in the student's own words with a diagram.
Safety	Hand-washing, safe handling and when to call a vet are included.
Presentation	Neat, organized and illustrated, so a new owner could follow it.

4.1 GOOD STEWARDSHIP: THE BASIC NEEDS OF ANIMALS

OBJECTIVES

- List the basic needs of any pet: food, water, shelter, health care, safety, exercise and companionship.
- Compare pets by lifespan, space, time and cost.
- Make a care plan and a first-year budget with an expense table for one pet.

Warm-up. Name a pet you would like to have someday. Guess three things: how long it lives, how much time it needs each day, and how much money it costs in its first year. Write your guesses and keep them; you will check them by the end of the lesson.

WATCH

What do pets need?

[RSPCAEducation](https://www.youtube.com/watch?v=FOLP8p0jSoA) · 3:38

<https://www.youtube.com/watch?v=FOLP8p0jSoA>

WHEN TO WATCH

After the first core idea. Pause each time a new need is shown and add it to your list.

Note: A short film from a British animal-care charity's education program, made for younger students; we use it as a quick review before the deeper teaching.

BACKUP VIDEO

Choosing a Veterinarian

[American Veterinary Medical Association](https://www.youtube.com/watch?v=TNCUByli_Dg) · 4:01

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

With the fourth core idea, about health care and the vet.

KEY TERMS

stewardship

Caring faithfully for something that has been entrusted to you by its true owner.

husbandry

The skilled, everyday care and management of animals.

lifespan

How long an animal normally lives with good care.

enrichment

Toys, hiding places, foraging and activities that let an animal use its natural behaviors.

expense

Money spent; a one-time expense happens once, and a recurring expense happens again and again.

CORE IDEAS

Every animal in our care depends on us for the same basic needs. It needs the right **food** for its kind and clean, fresh **water** every day. It needs **shelter**: a home of the right size and temperature with a place to hide and rest. It needs **health care**: a checkup with a veterinarian, clean living space, and quick help when it is sick or hurt. And it needs **safety**, **exercise** and **companionship** suited to its kind: guinea pigs and parakeets are happiest with a friend of their own species, while many hamsters must live alone.

Animal-care experts sum these up as freedom from hunger and thirst, from discomfort, from pain and disease, and from fear and distress, plus the freedom to behave as that animal naturally does. A rabbit needs room to hop and dig; a dog needs walks and play; a parakeet needs to fly. That last need is why **enrichment**, such as hiding places, chew toys and foraging for food, is part of good care and not an extra.

Before getting a pet, a wise family thinks about **lifespan**, **time**, **space** and **cost**. A hamster lives about 2 to 3 years; a guinea pig 5 to 7; a rabbit 8 to 12; a dog 10 to 15; a cat 12 to 18 or more; a leopard gecko 15 to 20. Some pets need an hour or more of care every day. Pet costs include **one-time expenses** such as the cage or tank, bowls and the first vet visit, and **recurring expenses** such as food, bedding, litter and yearly checkups, plus savings for an emergency. Many families are surprised to find that the cage or tank costs more than the animal itself.

Good keepers also keep **records**. 4-H members who raise an animal keep a project record book listing each day's feeding, any health problems, weight, costs, and what they learned. Records help you notice when something changes, such as a pet eating

less, which is often the first sign of illness. A veterinarian will ask questions that your records can answer.

Caring for an animal is a small picture of God's care for His creatures. Psalm 104 says the animals "wait all upon thee; that thou mayest give them their meat in due season." When you feed and clean faithfully, even on busy or rainy days, you practice the steady kindness that Proverbs calls righteous.

PICTURE STUDY



Sympathy, Briton Rivière, about 1877 · Oil on canvas · Tate Britain, London

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

Briton Rivière was an English painter who loved dogs and painted them often. In this picture a girl has been sent to sit on the stairs, perhaps after doing something wrong, and her small terrier has come to sit faithfully with her. The painting shows the bond between a child and an animal that is well loved and well cared for.

Look closely

- Look at the dog's body. Is it relaxed or tense? Where is it leaning?
- Look at the dog's coat, eyes and weight. Does it look healthy and well cared for? What clues tell you?
- Look at the girl's face and hands. How is she feeling?
- Notice how close the dog sits. What does this tell you about their friendship?

Talk about it

1. What needs does a dog like this one have every day?
2. How might the girl have earned her dog's trust?
3. What does this painting show about the companionship animals can give us, and the care we owe them?

Safety first. Wash your hands with soap and water after touching any animal, its food, bedding or cage. Never squeeze or chase a small pet. Ask the owner before touching someone else's animal.

HANDS-ON PROJECT

A Pet Care Plan and First-Year Budget

You will choose one pet that could suit your family and write a complete care plan, a daily and weekly chore chart, and a first-year budget in an expense table. This is the same kind of planning a 4-H member does before starting an animal project.

You will need

- Your journal, a ruler and a calculator
- Care information from a veterinarian's website, a pet-care book from the library, or a 4-H project guide
- Prices from a pet store visit, catalog or website, with a parent
- Graph paper for a habitat drawing

Steps

1. Choose one pet: for example, a pair of guinea pigs, a rabbit, a betta fish, a leopard gecko, a parakeet or a cat.
2. Research and write its care sheet: adult size, lifespan, food (what and how much), water, housing size, temperature, bedding, exercise, companionship and common health problems.
3. Draw its habitat to scale on graph paper, labeling food, water, hiding place, toys and bedding.
4. Make a chore chart with daily tasks (food, water, spot-cleaning, handling) and weekly tasks (full cage cleaning, weighing, nail and coat checks).
5. Make an expense table with columns: Item, One-time or Recurring, Cost each, How many per year, Yearly cost.
6. Fill it in with real prices: the cage or tank, bowls, first vet visit, food, bedding, treats and toys. Add a line for emergency savings.
7. Total the one-time costs, the recurring costs, and the whole first year. Divide the recurring costs by 52 to find the cost per week.
8. Compare with your warm-up guesses. Write a short paragraph: is this pet a good fit for your family now? Why or why not?

Tips

- Look for care sheets from veterinarians, university extension services or 4-H; some pet-store care cards suggest cages that are too small.
- If your family already has a pet, make a care plan and budget for it and keep a one-month care record.
- Many county 4-H clubs have pet, rabbit, cavy (guinea pig), poultry and dog projects; check with your county extension office.

Check your work

- ☐ I can list the basic needs of any pet.
- ☐ My budget separates one-time and recurring expenses and has correct totals.
- ☐ I can explain whether my chosen pet fits my family and why.

NATURE JOURNAL

1. Draw your chosen pet from life or from a good photograph, with labels for the features that show it is healthy (bright eyes, clean nose, smooth coat).
2. Start a pet record page with columns for date, food given, water changed, cleaning done, cost, and notes. Fill it for a week if you have or are helping with a pet.
3. Make a bar graph comparing the lifespans of six pets.

From history. 4-H began in rural America in the early 1900s as clubs where boys and girls learned better farming and homemaking by doing real projects, such as raising a calf or a garden plot, and keeping careful records. The four H's stand for Head, Heart, Hands and Health. Today 4-H also offers projects in pets, rabbits, dogs and small animals.

COMMON MISTAKES

- Choosing a pet for how cute it is without checking lifespan, space, time and cost.
- Buying a cage that is too small; for example, guinea pigs need about 7.5 square feet or more for a pair.
- Forgetting to budget for a vet visit and emergencies.

Make it a game • Needs Charades Count. Act out each of the seven basic needs of a pet without speaking: food, water, shelter, health care, safety, exercise and companionship. Your parent guesses and must also tell one cost for it. Then quickly rank three pets by lifespan, space, time and cost. Whoever gets all seven needs and fair rankings first wins. Time it.

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 means to pay attention to what it needs. Good stewardship begins before the pet comes home, with careful planning.

4.2 THE AQUARIUM NITROGEN CYCLE

OBJECTIVES

- Explain how fish waste becomes ammonia, nitrite and nitrate in an aquarium.
- Describe why a new tank must be “cycled” before adding many fish.
- Calculate an aquarium’s volume and plan safe care and water changes.

Warm-up. Look at a glass of tap water and a glass of water from a pond or an old fish tank (or a picture of each). Both may look clear. Write down two things that could be in water that you cannot see.

WATCH

Best Nitrogen Cycle Guide for Beginners (Different Methods Explained)

Aquarium Co-Op · 8:00

<https://www.youtube.com/watch?v=vur3JlfoEtk>

WHEN TO WATCH

After the second core idea. Draw the cycle in your journal as she explains each step.

Note: From an aquarium shop’s educational channel; it mentions their own products a few times.

BACKUP VIDEO

The Aquarium Nitrogen Cycle Video You've Been Looking For! (SIMPLE)

KaveMan Aquatics · 8:07

<https://www.youtube.com/watch?v=bgXRdbMjTc4>

A second, simple explanation of the cycle if anything is unclear.

KEY TERMS

ammonia

A poisonous chemical made from fish waste, uneaten food and decaying plants.

nitrite

A chemical, also poisonous to fish, that helpful bacteria make from ammonia.

nitrate

A much less harmful chemical that other bacteria make from nitrite; it is removed by water changes and used by plants.

beneficial bacteria

Helpful bacteria that live on the filter, gravel and decorations and change ammonia into nitrate.

cycling

Growing a large enough colony of beneficial bacteria in a new tank before adding many fish, which usually takes several weeks.

CORE IDEAS

An aquarium is a small, closed world. In a pond or river, waste is carried away and broken down, but in a tank, everything the fish give off stays in the water. Fish give off **ammonia** through their gills and in their waste, and uneaten food and dead leaves rot into more ammonia. Even a small amount of ammonia burns fish gills and can kill them.

God provided a cleanup crew too small to see. One group of **beneficial bacteria** eats ammonia and changes it into **nitrite**. Nitrite is also poisonous, but a second group of bacteria changes it into **nitrate**, which is much less harmful. This chain is called the **nitrogen cycle**. The bacteria do not swim in the water; they live as a thin film on the filter sponge, the gravel and the decorations, where water flows past them.

A brand-new tank has almost none of these bacteria. If it is filled with fish right away, ammonia builds up faster than the few bacteria can handle, and fish sicken. This is called “new tank syndrome.” So a new tank must be **cycled**: the keeper adds a small source of ammonia (a pinch of fish food, a measured dose of ammonia, or just one or two hardy fish) and waits while the bacteria multiply. With a water test kit, you can watch ammonia rise, then fall as nitrite rises, then nitrite fall as nitrate rises. When ammonia and nitrite both test at zero, usually after 4 to 8 weeks, the tank is cycled.

Nitrate keeps slowly building, so keepers do **partial water changes**, usually 10 to 25 percent of the water every week or two, using new water treated with a **dechlorinator**. Tap water contains chlorine or chloramine, which protects people

but kills fish and the good bacteria. Live plants help by using nitrate as fertilizer. Never wash the filter sponge under the tap; swish it in a bucket of old tank water so the bacteria survive.

Space matters. Goldfish grow large and make a lot of waste; even one fancy goldfish needs about 20 gallons. A betta needs at least 5 gallons, a heater at 76 to 82 °F, and a gentle filter. To find a tank's volume in gallons, multiply length × width × height in inches and divide by 231. Overfeeding is the most common way beginners poison a tank: feed only what the fish eat in about two minutes.

PICTURE STUDY



Fish in a Lotus Pond, Itō Jakuchū, 1760s · Ink and color on silk, from the series *Colorful Realm of Living Beings* · Museum of the Imperial Collections, Tokyo

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

Itō Jakuchū was a Japanese painter who kept birds and studied plants and animals so closely that his pictures are full of exact detail. In this scroll, a school of small fish swims among the stems of lotus plants. A healthy pond, like a healthy aquarium, is full of plants, fish and hidden bacteria working together.

Look closely

- Count the fish. Are they all swimming the same way?
- Find the lotus stems, leaves and flowers. How might the plants help the fish?
- Look at how the fish are spaced. Is the pond crowded?
- Find where the water surface is. How can you tell?

Talk about it

1. In a pond, what happens to the fish's waste? Why is it different in a glass tank?
2. How do plants in a pond or aquarium use the nitrate the bacteria make?
3. What would happen to this pond if someone dumped in far too much fish food?

Safety first. Wash your hands before and after putting them in an aquarium, since fish water can carry germs. Unplug heaters and filters (with an adult) before doing water changes, and never handle electrical cords with wet hands. Keep water-treatment chemicals and test-kit liquids away from younger children.

HANDS-ON PROJECT

Aquarium Plan and Water-Test Log

You will calculate the volume of a real or planned aquarium, draw the nitrogen cycle as it works in that tank, and test real aquarium water. If you have a tank, you will keep a two-week water-test and care log.

You will need

- An aquarium at home, a friend's or relative's, or a classroom or store tank you are allowed to test (no-tank option: plan a 10-gallon or 20-gallon tank on paper)
- Aquarium test strips or a liquid test kit for ammonia, nitrite, nitrate and pH
- A tape measure and calculator
- Your journal and colored pencils

Steps

1. Measure the inside length, width and water height of the tank in inches. Multiply them and divide by 231 to find the gallons. (No tank: use $24 \times 12 \times 16$ inches, a common 20-gallon size.)
2. Draw the tank and label where the beneficial bacteria live: filter, gravel, decorations and plant leaves.
3. Draw the nitrogen cycle as a circle of arrows: fish and food → ammonia → nitrite → nitrate → water changes and plants.
4. With permission, dip a test strip in the tank water (or follow the liquid kit directions with an adult). Compare to the color chart and record ammonia, nitrite, nitrate and pH.
5. Decide: is the tank cycled? Is the nitrate low enough (under about 40 parts per million), or is a water change due?
6. Plan a stocking list for your tank size using a reliable fish guide. Check each fish's adult size, temperature and whether it needs friends of its own kind.
7. If you keep the tank, record the test results, feeding, water changes and fish behavior every few days for two weeks.

8. Write a weekly maintenance schedule and post it near the tank.

Tips

- Test strips must be dry until used; close the bottle tightly.
- Adding fish slowly, a few at a time over weeks, lets the bacteria keep up.

Check your work

- ☐ I can draw and explain the aquarium nitrogen cycle.
- ☐ I calculated my tank's volume in gallons.
- ☐ I can explain why tap water needs a dechlorinator.

NATURE JOURNAL

1. Draw a magnified view of the filter sponge with the bacteria colony on its surfaces, labeled “ammonia in, nitrate out.”
2. Make a line graph of a cycling tank: ammonia rising and falling, then nitrite, then nitrate, over six weeks (use your own data or the pattern from the lesson).
3. Sketch one aquarium fish from life and note its behavior: where it swims, how it eats, how it reacts to light.

From history. In the 1850s an English naturalist named Philip Henry Gosse showed that a glass tank with water plants could keep animals alive for a long time, and he made the word “aquarium” popular. Victorian families soon kept parlor aquariums, though they did not yet understand the bacteria that made them work.

COMMON MISTAKES

- Adding a whole tank of fish on the first day.
- Washing the filter sponge in tap water, which kills the good bacteria.
- Overfeeding, which rots and makes ammonia.

Make it a game • Tank Cycle Chain Gang. Make a human chain of cards: fish waste, ammonia, nitrite, nitrate, beneficial bacteria. Shuffle them, then lay the cycle out in the right order as fast as you can. Say which stage is dangerous to fish and which bacteria change it. Explain why the tank must be cycled before adding many fish. Beat your best time.

4.3 REPTILE HEAT, UVB AND HABITAT

OBJECTIVES

- Explain why reptiles need a heat gradient and how they regulate their temperature.
- Describe the UVB light and calcium a bearded dragon needs and what happens without them.
- Design and test a model heat gradient, and plan safe hygiene around reptiles.

Warm-up. Put one hand in a sunny window and the other in the shade for one minute. Describe the difference. Where would you go if you were cold? If you were too hot? A lizard has to make that choice all day long.

WATCH

The Ultimate Bearded Dragon Lighting & Heating Guide

Zen Habitats · 8:54

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

WHEN TO WATCH

After the third core idea. Write down each temperature and distance she gives and compare them with the lesson.

Note: From an enclosure company's channel; the care information is sound, and you do not need their brand of enclosure.

BACKUP VIDEO

Whats The Best UVB Lights for Bearded Dragons?

Reptiles and Research · 5:36

<https://www.youtube.com/watch?v=1unKZUu8rls>

For more on UVB tubes, distance and the UV index.

KEY TERMS

ectotherm

An animal, such as a reptile, that gets its body heat mainly from its surroundings instead of making it.

heat gradient

A range of temperatures from a hot basking spot at one end of an enclosure to a cool side at the other.

UVB

A kind of invisible ultraviolet light from the sun that lets reptiles make vitamin D3 in their skin.

metabolic bone disease

A disease that leaves bones soft and weak, caused by too little UVB, vitamin D3 or calcium.

Salmonella

Bacteria that many healthy reptiles carry and that can make people sick; hand-washing prevents it.

CORE IDEAS

Reptiles are **ectotherms**: their bodies do not make enough heat to stay warm, so they warm up by basking and cool down by moving into shade. Their digestion, movement and immune system all depend on body temperature. A cold lizard cannot digest its food. So a reptile enclosure must have a **heat gradient**: a hot basking spot at one end and a cooler area at the other, with hiding places in both, so the animal can choose its own temperature, just as wild lizards do on rocks and in burrows.

The **bearded dragon** comes from the dry woodlands and deserts of Australia. An adult needs a basking surface of about 100 to 110 °F, a warm side air temperature in the 80s, a cool side of about 75 to 80 °F, and nighttime temperatures that may drop to the mid-60s. Every heat source should be controlled by a **thermostat**, and temperatures checked with a digital thermometer or a temperature gun, not guessed. An adult dragon needs an enclosure about 4 feet long, 2 feet deep and 2 feet tall.

Bearded dragons also need **UVB** light, which comes from the sun but not through window glass. UVB lets their skin make vitamin D3, and without vitamin D3 they cannot use the calcium in their food. The result is **metabolic bone disease**: soft jaws, bent legs, twitching and weakness. Keepers use a long fluorescent UVB tube (often a T5 high-output 10 or 12 percent tube) stretching across half to two-thirds of the enclosure, at the distance the maker recommends, and replace it about every 12 months, because UVB output fades long before the visible light does. Dragons eat insects dusted with calcium and, as adults, mostly leafy greens.

The **leopard gecko** comes from dry, rocky grasslands of south-central Asia and is most active at dusk and dawn. It likes a warm hide with a floor temperature around 88 to 92 °F, a cool side in the low to mid-70s, a humid hide to help it shed, and a 12-hour day and night cycle. Many keepers now add low-level UVB as well. Leopard geckos eat live insects such as crickets and mealworms, dusted with calcium, and can live 15 to 20 years.

Most healthy reptiles carry **Salmonella** bacteria, which do not hurt the reptile but can make people sick. Always wash hands with soap and water after touching a reptile or anything in its enclosure; never hold a reptile against your face or let it roam the kitchen; clean its supplies outside the kitchen sink. The CDC advises that children under 5 should not handle reptiles. Good keepers use knowledge, measuring and cleanliness to give these remarkable creatures what their design requires.

PICTURE STUDY



The Lyon Lizard, Mark Catesby, 1731–1743 · 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 in the American colonies of Carolina and Florida in the early 1700s. He drew, engraved and colored the plants and animals he found, often showing an animal with a plant from the same place. This lizard is the six-lined racerunner, a fast, sun-loving lizard of sandy fields in the eastern and central United States.

Look closely

- Count the stripes along the lizard's back. How might stripes help it hide in grass and sand?
- Look at its legs and long tail. What kind of movement is this lizard built for?
- Look at its eye and the scales on its head. Draw what you see.
- What plant did Catesby place with the lizard? Why might he show them together?

Talk about it

1. Racerunners are active on the hottest, sunniest days. What does that tell you about the temperatures they need?
2. How would a pet lizard get the warmth and UVB that this wild lizard gets from the sun?

3. Why is it useful to know where a reptile lives in the wild before keeping one as a pet?

Safety first. Wash your hands with soap and water every time you touch a reptile, its food or anything in its enclosure. Do not hold reptiles against your face or let them near food areas. Heat lamps and bulbs get very hot; an adult sets them up and you never touch them while on.

Model Heat Gradient and Habitat Plan

You will build a model enclosure with a lamp to measure a real heat gradient, then design a full bearded dragon or leopard gecko habitat with a shopping list and costs.

You will need

- A cardboard box or plastic storage tote about 2 feet long
- A desk lamp with an ordinary incandescent or halogen bulb (adult sets up; or a sunny window ledge)
- Three thermometers, or one thermometer moved to three spots
- A flat stone or tile for a basking spot
- A small box or cup to make a hide
- Ruler, graph paper and your journal

Steps

1. Set the box on its side or open-top on a table. Put the flat stone at one end and the hide at the other end.
2. With an adult, clamp the lamp above the stone, about 8 to 10 inches away. Never leave it on unattended.
3. Place thermometers on the stone (basking spot), in the middle, and at the far cool end. Turn on the lamp.
4. Record all three temperatures every 5 minutes for 30 minutes. Make a line graph.
5. Move the lamp higher or lower and record again. How does distance change the basking temperature?
6. Using your data, explain where a lizard in this box would go to warm up and to cool down.
7. Design a real habitat for a bearded dragon or leopard gecko on graph paper, drawn to scale. Label the basking spot, UVB tube, thermostat, warm hide, cool hide, humid hide (for a gecko), water and food dishes.

8. Make a shopping list with prices for the enclosure, heat lamp, UVB tube, thermostat, thermometers, hides, substrate and first month of food. Total the cost.

Tips

- Turn the lamp off and let it cool before moving it.
- A pet store or a reptile-keeping neighbor may let you look at a real setup and measure its temperatures.

Check your work

- ☐ I can explain why a reptile needs a heat gradient.
- ☐ My graph shows temperatures at three places in my model.
- ☐ I can explain why bearded dragons need UVB and calcium.

NATURE JOURNAL

1. Draw a bearded dragon basking, and label its spiny “beard,” its eyes, ear openings and claws.
2. Draw a cross-section of your habitat plan with a colored temperature band from red (hot) to blue (cool).
3. Make a care-record page for a reptile: date, temperatures, food, calcium dusting, shedding, weight, cleaning.

From history. Before UVB lighting was understood in the 1980s and 1990s, many pet lizards suffered from soft, bent bones. Veterinarians and zoo keepers discovered that UVB light and calcium prevented the disease, and today’s care sheets are built on what they learned.

COMMON MISTAKES

- Using a heat lamp without a thermostat or thermometer.
- Thinking a bright light means UVB; UVB is invisible and fades in about a year.
- Skipping hand-washing because the reptile “looks clean.”

Make it a game • Gradient Hot and Cold. Hide a toy lizard in the house while your parent steps out. Return and give 'hot' or 'cold' clues only about temperature, like a basking spot and a cool hide, as the hunter finds it. Then each of you explains why a heat gradient matters, what UVB does for a bearded dragon, and what metabolic bone disease is.

4.4 DOG BEHAVIOR AND TRAINING

OBJECTIVES

- Read a dog's body language: relaxed, alert, stressed and warning signals.
- Explain positive reinforcement and use it to teach a simple behavior.
- Practice safe greetings and bite-prevention rules.

Warm-up. Make a quick sketch of a dog that is happy and a dog that is scared. Which parts of the body did you change: ears, tail, mouth, posture? Keep your sketches to compare with what you learn.

WATCH

The easiest, most reliable SIT STAY - sit stay training! sit stay fun!

Kikopup · 7:49

<https://www.youtube.com/watch?v=ksBLKi6lj1s>

WHEN TO WATCH

Before the hands-on project. Watch how she rewards right away and keeps sessions short.

BACKUP VIDEO

How to Teach your Puppy to Sit and Stay

Zak George · 7:22

<https://www.youtube.com/watch?v=DPNz6reMVXY>

A second trainer's method for the same skill.

KEY TERMS

body language

The way an animal uses its ears, eyes, mouth, tail and posture to show how it feels.

marker

A word like “yes!” or a click that tells the dog the exact moment it did the right thing.

positive reinforcement

Adding something the dog likes, such as a treat or praise, right after a behavior so it happens more often.

calming signals

Small signs of stress, such as lip licking, yawning, looking away or showing the whites of the eyes.

lure

A treat held in the hand to guide a dog into a position, such as sit.

CORE IDEAS

Dogs talk with their bodies. A **relaxed** dog has a loose, wiggly body, soft eyes, a slightly open mouth and a tail at its natural height wagging loosely. An **alert** dog stands taller, with ears forward and mouth closed, watching something. A **stressed or worried** dog may lick its lips, yawn when not tired, turn its head away, tuck its tail, flatten its ears, or show the whites of its eyes (sometimes called “whale eye”). These **calming signals** mean, “I am uncomfortable; please give me space.”

If those signals are ignored, a dog may give stronger **warnings**: freezing stiff, staring hard, raising the hair on its back, lifting its lip, or growling. A growl is a gift; it is the dog politely asking you to stop before it feels it must bite. Never punish a growl. Instead, calmly move away and tell an adult. A wagging tail does not always mean a happy dog: a stiff, high, fast-twitching tail can mean tension.

Safe greetings prevent most bites. Always ask the owner, “May I pet your dog?” Then stand sideways, let the dog come to you and sniff your hand, and pet its chest or shoulder, not the top of its head. Never hug a dog or put your face close to its face, never bother a dog that is eating, sleeping, chewing a toy or tied up, and never run or scream around a strange dog. If a loose dog approaches, “be a tree”: stand still, fold your hands, look at your feet and stay calm until it leaves.

Dogs learn by what happens right after they do something. **Positive reinforcement** means rewarding the behavior you want so it happens more often. Timing is everything: say your **marker** word (“yes!”) at the exact moment the dog’s bottom touches the floor, then give a small treat within a second or two. To teach sit, hold a treat at the dog’s nose (a **lure**) and slowly raise it up and back; as the head goes up, the bottom goes down. Mark and reward. After several tries, add the word “sit” just before you move your hand.

Good training sessions are **short** (3 to 5 minutes), happy and end on a success. Use tiny, soft treats, practice in a quiet place first, and add distance, time and distractions slowly. Punishment such as yelling or hitting makes dogs fearful and can make them more likely to bite. A well-trained dog is safer and freer, because it can go more

places with its family. Many 4-H dog clubs teach youth to train and show their own dogs in obedience and showmanship.

PICTURE STUDY



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

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

Edwin Landseer was the most famous animal painter in Victorian England, and Queen Victoria asked him to paint her own dogs. Here he painted two dogs belonging to a friend: a huge, solemn bloodhound and a lively little terrier. The title is a joke about their two very different personalities.

Look closely

- Read the bloodhound's body language: its ears, eyes, mouth and head. Is it relaxed, alert or worried?
- Read the terrier's body language. How is it different?
- Look at the size difference. How might training and handling differ for a big dog and a small one?
- Find the kennel. What does it tell you about how these dogs were cared for?

Talk about it

1. If you met these two dogs, which signals would tell you each one was comfortable being approached?
2. Bloodhounds were bred to follow scents. How might that affect what a bloodhound wants to do on a walk?
3. Why do you think Landseer gave each dog such a strong personality?

Safety first. Only train or touch a dog with its owner's permission and an adult nearby. Never approach a dog that is eating, sleeping, tied up or behind a fence. If a dog bites or scratches you, wash the wound and tell an adult right away.

Teach a Sit-Stay and Keep a Training Log

With a family dog, a neighbor's or relative's dog (with permission), you will teach or polish a sit and a short stay using positive reinforcement and keep a training log. If no dog is available, you will observe dogs and write a training plan instead.

You will need

- A friendly dog and its owner's permission, with an adult present
- Tiny soft treats (pea-sized pieces) in a pouch or pocket
- A leash and a quiet room or yard
- Your journal and a timer
- No-dog option: a park or dog-training class to observe, or a library book on dog training

Steps

1. Watch the dog for two minutes before you start. Write down its body language: is it relaxed and ready to work?
2. Choose your marker word, such as "yes!" Practice saying it and immediately giving a treat, ten times, until the dog perks up when it hears the word.
3. Teach sit with a lure: hold a treat at its nose, raise it slowly up and back, mark "yes!" the instant its bottom touches the floor, and give the treat. Repeat 5 to 8 times.
4. Add the word: say "sit" once, then lure. After several successes, try saying "sit" and using only your empty hand.
5. Start a stay: ask for sit, wait 2 seconds, mark and reward while the dog is still sitting. Then 3 seconds, then 5. Then take one step back and return to reward.
6. Use a release word, such as "free!" to tell the dog the stay is over.
7. Keep each session to 3 to 5 minutes and end on a success. Do two sessions a day for a week.

8. Record each session in your log: date, time, number of tries, number of successes, longest stay in seconds, and the dog's body language. Graph the longest stay each day.

Tips

- If the dog gets up, simply ask for sit again and make the next stay shorter. Do not scold.
- Watch for stress signals such as yawning and lip licking; if you see them, take a break.
- No dog? Observe three dogs at a park for 10 minutes each and record their body language, then write a training plan for teaching sit-stay.

Check your work

- ☐ I can name three stress signals and three relaxed signals in dogs.
- ☐ I can explain positive reinforcement and why timing matters.
- ☐ My training log shows at least five sessions with results.

NATURE JOURNAL

1. Redraw your warm-up dogs with correct body language, and add a third dog showing stress signals. Label each feature.
2. Make a graph of your dog's longest stay each day.
3. Draw a "Safe Greeting" comic strip in four panels for a younger child.

From history. Dogs have worked beside people since ancient times: herding sheep, guarding homes, pulling sleds and finding lost travelers. In the Swiss Alps, monks at the Great St. Bernard Pass kept large dogs that helped rescue travelers caught in snow for more than two hundred years.

COMMON MISTAKES

- Giving the treat too late, so the dog does not know what it was rewarded for.
- Training for too long, until the dog is bored or tired.
- Reaching over a strange dog's head to pet it.

Make it a game • Dog Signals Pantomime. Take turns acting like a dog in each mood: relaxed, alert, stressed and warning. Use ears, tail, mouth and body posture. Your parent guesses the mood and names the right response. Then practice positive reinforcement by teaching your parent a silly cue with a marker word and a treat chip. Score a bean for each correct signal.

Scripture. “Be thou diligent to know the state of thy flocks, and look well to thy herds.” (Proverbs 27:23, KJV)

A good shepherd watches his animals closely enough to know how they feel.
Learning a dog’s body language is a way of looking well to the animals in your care.

UNIT 4

PETS

A pet is a living creature placed in our care, and good care takes knowledge, not just love. In this unit you will learn the basic needs every animal has and how to plan and budget for a pet before bringing one home. Then you will go deeper into three kinds of pets where science matters most: fish, which depend on invisible bacteria to keep their water safe; reptiles, which depend on us for the right heat and light; and dogs, which communicate with their bodies and learn by reward.

You do not need to own a pet for this unit. Every project has an option to plan, visit, observe or help with a neighbor's or a relative's animal. "A righteous man regardeth the life of his beast" (Proverbs 12:10): you will learn what it means to regard an animal's life wisely and faithfully.

PREREQUISITES

- Can add, subtract and multiply money amounts
- Can read a thermometer in °F
- Knows how to wash hands well with soap for 20 seconds

MASTERY CHECKLIST

- ☐ I can list the basic needs of any pet and plan a first-year budget for one.
- ☐ I can explain the aquarium nitrogen cycle and why a new tank must be cycled.
- ☐ I can describe the heat gradient and UVB light a bearded dragon or leopard gecko needs.
- ☐ I can read a dog's body language and use positive reinforcement to teach a behavior.
- ☐ I keep animal-care records with dates, food, costs and observations, like a 4-H project book.

LESSONS IN THIS UNIT

4.1 Good Stewardship: The Basic Needs of Animals

2 sessions of 45 minutes

4.2 The Aquarium Nitrogen Cycle

2 sessions of 45 minutes

4.3 Reptile Heat, UVB and Habitat

2 sessions of 45 minutes

UNIT 4 REVIEW

Answer each question. Use complete sentences for explanations and show your work for the calculation. The review is worth 50 points.

1. (5 pts)

List five basic needs every pet has.

2. (5 pts)

A guinea pig cage costs \$120, a water bottle \$10, and the first vet visit \$70. Hay and pellets cost \$30 a month. What is the first-year cost of these items?

3. (5 pts)

Why is it important to keep a written care record for a pet?

4. (5 pts)

Put these in order in the aquarium nitrogen cycle: nitrate, fish waste, nitrite, ammonia.

5. (5 pts)

Why should you never put a whole tank of fish into a brand-new aquarium?

6. (5 pts)

A tank is 30 inches long, 12 inches wide and 16 inches high. About how many gallons does it hold?

7. (5 pts)

What is a heat gradient and why does a reptile need one?

8. (5 pts)

What happens to a bearded dragon without enough UVB light, and why?

9. (5 pts)

Name three signs that a dog is stressed and what you should do.

10. 5 pts

Explain how to use positive reinforcement to teach a dog to sit.

ANSWER KEY

1. Any five: food, water, shelter, health care, safety, exercise, companionship, enrichment.
2. One-time: $\$120 + \$10 + \$70 = \$200$. Recurring: $\$30 \times 12 = \$360$. Total: $\$560$.
3. Records show changes such as eating less or losing weight, which can be early signs of illness, and they help a vet, an owner or a 4-H leader see what care was given.
4. Fish waste → ammonia → nitrite → nitrate.
5. The tank does not yet have enough beneficial bacteria, so ammonia and nitrite build up and poison the fish. The tank must be cycled first.
6. $30 \times 12 \times 16 = 5,760$ cubic inches; $5,760 \div 231 \approx 25$ gallons.
7. A range of temperatures from a hot basking spot to a cool side. Reptiles are ectotherms and move between warm and cool areas to control their body temperature for digestion and health.
8. It can get metabolic bone disease, because without UVB it cannot make vitamin D3 and cannot use calcium, so its bones become soft and weak.
9. Any three: lip licking, yawning, looking away, tucked tail, ears back, whites of eyes showing, freezing. Stop, calmly give the dog space, and tell an adult.
10. Lure the dog into a sit with a treat raised over its nose, mark “yes!” the moment it sits, and give the treat right away; repeat in short sessions and then add the word “sit.”

PORTFOLIO PIECE: A PET KEEPER'S HANDBOOK

Make a handbook for one pet that a new owner could follow, like a 4-H project book. Include the care sheet, habitat drawing, chore chart and first-year expense table from Lesson 4.1, plus the special science for that kind of pet: the nitrogen cycle for fish, the heat gradient and UVB for reptiles, or body language and training for dogs. Add at least two weeks of care or observation records with dates.

LOOK FOR	WHAT IT MEANS
Complete care	Food, water, housing, temperature, health, exercise and companionship are all covered correctly for the chosen animal.
Budget and records	The expense table is accurate, and care or observation records cover at least two weeks with dates.
Science explained	The handbook clearly explains the key science for that animal in the student's own words with a diagram.
Safety	Hand-washing, safe handling and when to call a vet are included.
Presentation	Neat, organized and illustrated, so a new owner could follow it.

UNIT 5

PLANT SCIENCE

Late winter is the time to start thinking like a plant. Before seeds go into pots, a good gardener understands what happens inside a leaf, a stem and a root. In this unit you will learn how plants make sugar from light, air and water in photosynthesis and burn it in respiration; how water climbs from the roots to the highest leaf; which mineral nutrients plants need and how to recognize when one is missing; and how the brightness of light and the length of the day control growth and flowering.

Every lesson has a real experiment you can do on a kitchen table: floating leaf disks, bagged leaves that “sweat,” a fertilizer trial, and seedlings grown under different light. You will also judge plants the way a 4-H or fair judge does, ranking them and giving reasons. “Consider the lilies of the field, how they grow,” Jesus said. This unit is a close consideration of exactly that.

PREREQUISITES

- Knows the parts of a plant: roots, stem, leaves, flowers, fruit and seeds
- Can measure in millimeters and make a line graph
- Can set up a fair test that changes only one variable

MASTERY CHECKLIST

- ☐ I can write the word equation for photosynthesis and explain how respiration is different.
- ☐ I can trace water from the soil, up the xylem and out of the stomata, and name what speeds up transpiration.
- ☐ I can name the major nutrients (N, P, K) and recognize three deficiency signs.
- ☐ I can explain how light intensity and day length affect seedlings and flowering.
- ☐ I can judge four plants, place them 1 to 4, and give reasons.

LESSONS IN THIS UNIT

5.1 Photosynthesis and Respiration

2 sessions of 45 minutes

5.2 Transpiration and Water Movement

2 sessions of 45 minutes

UNIT 5 REVIEW

Answer each question. Use complete sentences for explanations. The review is worth 50 points.

1. (5 pts)

Write the word equation for photosynthesis.

2. (5 pts)

Do plants carry out respiration? When and why?

3. (5 pts)

In the leaf-disk experiment, why did the disks in the light float?

4. (5 pts)

Trace the path of water through a plant, using the words root hairs, xylem, leaves and stomata.

5. (5 pts)

Name three conditions that speed up transpiration.

6. (5 pts)

What does each of the three numbers on a fertilizer label stand for? How many pounds of nitrogen are in a 10-pound bag of 10-5-5?

7. (5 pts)

A bean plant's oldest, lowest leaves are turning pale yellow all over while new leaves are green. What nutrient is probably short, and why do the old leaves show it first?

8. (5 pts)

Why do seedlings on a dim windowsill grow tall and thin?

9. **5 pts**

Explain short-day and long-day plants and give one example of each.

10. **5 pts**

You are judging four potted bean plants. Write one reason a judge might give for placing one plant over another.

ANSWER KEY

1. Carbon dioxide + water + light energy → sugar (glucose) + oxygen.
2. Yes. Every living plant cell respires all the time, day and night, breaking down sugar with oxygen to release energy for living and growing.
3. Photosynthesis in the light made oxygen gas, which filled the spaces in the leaf and made the disks float.
4. Water enters through root hairs, moves up the xylem through the stem to the leaves, and evaporates out through the stomata.
5. Any three: heat, wind, bright light, dry air.
6. Nitrogen, phosphate and potash, as percent by weight. 10% of 10 pounds = 1 pound of nitrogen.
7. Nitrogen. It is mobile, so the plant moves it from old leaves to new growth, and the old leaves yellow first.
8. In weak light they stretch toward the light (hormones lengthen stem cells), making leggy, weak stems with pale leaves.
9. Short-day plants flower when nights are long (poinsettia, chrysanthemum). Long-day plants flower when nights are short in early summer (spinach, lettuce, radish).
10. Example: "I placed A over B because A had darker green leaves, a thicker stem and no yellow or spotted leaves."

PORTFOLIO PIECE: A PLANT SCIENTIST'S LAB BOOK

Collect your four experiments into one lab book, written the way scientists record their work. For each experiment, include the question, your prediction, materials, procedure, data table, graph and a conclusion. Add the placing card and written reasons from your plant judging class, and finish with a one-page explanation of what a plant needs to grow well, using the words photosynthesis, transpiration, nutrients and light.

LOOK FOR	WHAT IT MEANS
Complete experiments	All four experiments have a question, prediction, procedure, data, graph and conclusion.
Accurate science	Explanations of photosynthesis, respiration, transpiration, nutrients and light are correct.
Data and graphs	Measurements are dated and labeled with units; graphs have titles and labeled axes.
Judging	Four plants are placed with clear, specific reasons comparing each pair.
Presentation	Neat, organized and illustrated with careful drawings.

5.1 PHOTOSYNTHESIS AND RESPIRATION

OBJECTIVES

- Write and explain the word equation for photosynthesis.
- Explain that plants also carry out respiration, day and night.
- Measure photosynthesis with a floating leaf-disk experiment.

Warm-up. A small willow tree planted in a tub of soil grows into a big tree in five years, but the soil in the tub hardly loses any weight. Where do you think the tree's wood came from? Write your best guess.

WATCH

The simple story of photosynthesis and food - Amanda Ooten

TED-Ed · 4:01

<https://www.youtube.com/watch?v=eo5XndJaz-Y>

WHEN TO WATCH

After the first core idea. Pause when the equation appears and copy it.

BACKUP VIDEO

Photosynthesis and Cellular Respiration - Energy Cycle of Life

Point Source Science · 4:10

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

After the third core idea, to see how photosynthesis and respiration fit together.

KEY TERMS

photosynthesis

The process by which green plants use light energy to make sugar from carbon dioxide and water, giving off oxygen.

chlorophyll

The green pigment in leaves that captures light energy.

chloroplast

A tiny green structure inside leaf cells where photosynthesis happens.

cellular respiration

The process by which living cells, in plants and animals, break down sugar with oxygen to release energy, giving off carbon dioxide and water.

stomata

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

CORE IDEAS

In the 1600s a scientist named Jan van Helmont planted a 5-pound willow in 200 pounds of dry soil and gave it only rainwater. Five years later the willow weighed about 169 pounds, but the soil had lost only about 2 ounces. Where did the tree come from? Most of a plant's body is built from **air and water**, by a process called **photosynthesis**, meaning “putting together with light.”

Inside leaf cells are tiny green **chloroplasts** filled with **chlorophyll**, which captures the energy of light. The leaf takes in **carbon dioxide** from the air through tiny pores called **stomata**, and **water** comes up from the roots. Using light energy, the chloroplasts join them into **sugar** (glucose), and release **oxygen** as a by-product. In words: carbon dioxide + water + light energy → sugar + oxygen. In symbols: $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.

The plant uses that sugar in two ways. It builds its body from it, turning sugar into starch for storage (in potatoes and seeds) and cellulose for strong cell walls (wood and stems). And it burns sugar for energy in **cellular respiration**: sugar + oxygen → carbon dioxide + water + energy. Plants respire all the time, day and night, in every living cell, including roots. That is why roots need air in the soil, and why waterlogged soil can drown a plant.

Photosynthesis and respiration fit together like a lock and key. Plants make sugar and oxygen; animals and people eat the plants (or eat animals that ate plants) and breathe the oxygen; we breathe out carbon dioxide, which plants take back in. Every bite of bread, apple or cheese you eat holds energy that began as sunlight caught by a leaf. In daylight, a healthy plant makes much more sugar than it burns, so it grows.

Photosynthesis speeds up with more **light** (up to a point), enough **water**, enough **carbon dioxide**, and a comfortable **temperature**, usually about 65 to 85 °F for garden vegetables. It slows when any one of these runs short. God designed the green leaf as the first link in nearly every food chain on earth: “Let the earth bring forth grass, the herb yielding seed... and it was so.”

PICTURE STUDY



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

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

Van Gogh painted a series of sunflower pictures in the south of France to decorate a room for a friend. He painted the flowers at every stage, from fresh blooms to dried seed heads. Sunflowers are among the most powerful sun-catchers in the garden; a single plant can grow 8 feet or more in one summer, built from air, water and light.

Look closely

- Find a fresh, open flower and a flower that is drying and going to seed. How are they different?
- Look at the center of a seed head. What pattern do the seeds make?
- Find any leaves left on the stems. What color are they? What happens to a leaf when it stops making food?
- Count the flowers. How many different stages can you find?

Talk about it

1. Where did all the material in these big flower heads and seeds come from?
2. Why do you think young sunflower heads turn to follow the sun across the sky?
3. What energy is stored in sunflower seeds, and who uses it?

The Floating Leaf-Disk Experiment

You will watch photosynthesis happen in a few minutes. Small disks of spinach leaf are made to sink in a weak baking-soda solution. In bright light, they make oxygen bubbles and float up one by one. In the dark, they stay down.

You will need

- Fresh spinach leaves
- A hole punch or a sturdy drinking straw to cut disks
- A plastic syringe without a needle (10 mL or larger, from a pharmacy)
- Baking soda, a drop of dish soap, and water
- Two clear cups
- A bright lamp or a sunny window, and a dark cupboard
- A timer and your journal

Steps

1. Make the solution: stir $\frac{1}{8}$ teaspoon of baking soda (the carbon dioxide source) into 1 cup of water, then add one small drop of dish soap.
2. Punch 20 disks from spinach leaves, avoiding the big veins.
3. Pull the plunger out of the syringe, drop 10 disks into the barrel, and push the plunger back in. Draw in some solution, cap the tip with your finger, and pull back the plunger to make a vacuum for 10 seconds. Repeat 2 or 3 times until the disks sink. This pulls the air out of the leaf.
4. Pour the sunken disks into a cup of solution. Do the same with the other 10 disks for a second cup.
5. Put Cup 1 under a bright lamp or in sun. Put Cup 2 in a dark cupboard.
6. Every minute for 20 minutes, count how many disks are floating in Cup 1. Check Cup 2 at the end.
7. Make a line graph of floating disks over time. Compare the light and dark cups.
8. Explain in writing: what gas filled the disks, and why did the light make the difference?

Tips

- If the disks will not sink, add the vacuum step one or two more times.
- A brighter light makes disks float faster. Try a dim light as a third cup to see how light intensity matters.
- In the dark, disks may even sink further, because respiration uses up oxygen.

Check your work

- ☐ I can write the word equation for photosynthesis.
- ☐ I can explain that plants respire all the time.
- ☐ My graph shows how many disks floated over time in light and in dark.

NATURE JOURNAL

1. Draw a large leaf cross-section showing upper skin, the green food-making cells with chloroplasts, the vein, and stomata on the underside, with arrows for carbon dioxide in and oxygen out.
2. Draw the photosynthesis and respiration cycle between a plant and a person, with arrows labeled oxygen, carbon dioxide, sugar and energy.
3. Draw your floating-disk cups at 0, 10 and 20 minutes.

From history. Jan van Helmont's willow experiment in the 1600s proved plants did not simply eat soil. In the 1770s Joseph Priestley found that a sprig of mint could "restore" air in which a candle had burned out, and Jan Ingenhousz soon showed that leaves do this only in light. Step by step, careful experiments revealed photosynthesis.

COMMON MISTAKES

- Thinking plants get their food from the soil. They make it from air and water using light; soil gives water and minerals.
- Thinking only animals breathe. Plants respire too, day and night.
- Shining the lamp too close, so the water heats up and changes the test.

Make it a game • Equation Scramble. Write the word equation for photosynthesis on six small scraps: carbon dioxide, water, light, glucose, oxygen, and the arrow. Mix them up and race to rebuild it. Then add a second scramble for respiration, the reverse. Explain why plants do both day and night. Beat your own rebuild time and keep a score card.

Scripture. “And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so. 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 1:11-12, KJV)

Green plants were made to feed the world. Each leaf quietly turns light into food, just as God designed it to.

5.2 TRANSPIRATION AND WATER MOVEMENT

OBJECTIVES

- Trace the path of water from soil to air through a plant.
- Explain how transpiration pulls water up the xylem.
- Measure transpiration and compare it in different conditions.

Warm-up. On a warm day, tie a clear plastic bag around a few leaves of a houseplant or a tree branch and leave it for one hour. While you wait, guess what you will find inside the bag. (If it is cold outside, use a houseplant in a sunny window.)

WATCH

The Color-Changing Celery Experiment!

[SciShow Kids](#) · 4:13

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

WHEN TO WATCH

In the first session, so you can set up your own celery and leave it overnight.

BACKUP VIDEO

LEAF TRANSPIRATION Experiment (what is transpiration?)

[Kids Fun Science \(Kids Fun Science\)](#) · 3:57

<https://www.youtube.com/watch?v=YeOw-wJR9fc>

Before the bagged-leaf part of the project.

KEY TERMS

transpiration

The loss of water vapor from a plant, mostly through the stomata of its leaves.

phloem

Living tubes that carry sugar from the leaves to other parts of the plant.

xylem

Tubes of tiny dead cells that carry water and minerals up from the roots to the leaves.

root hairs

Tiny hair-like growths near root tips that take in most of a plant's water.

guard cells

A pair of bean-shaped cells around each stoma that open and close it.

CORE IDEAS

A plant needs a steady stream of water. Water enters through millions of tiny **root hairs** near the root tips, moves into the root, and climbs up through the **xylem**, bundles of very thin tubes that run like pipes through the root, stem and leaf veins. In a celery stalk, the “strings” are bundles of xylem and phloem; colored water makes them easy to see.

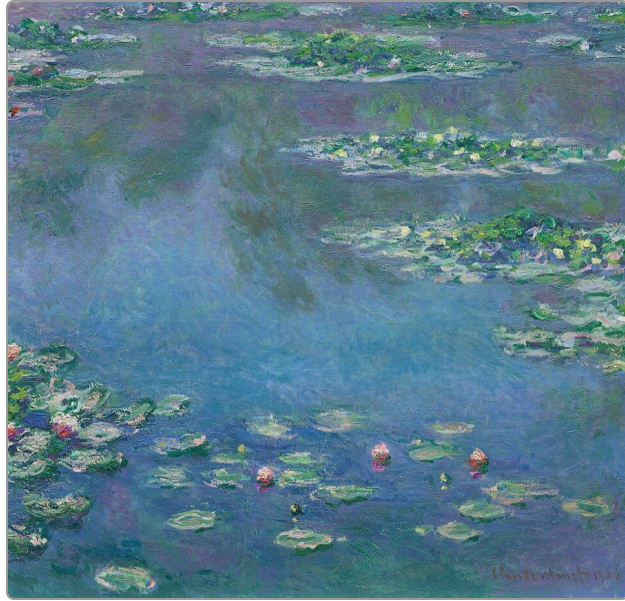
What pulls the water up, even to the top of a 300-foot redwood, with no pump? The answer is **transpiration**. As water evaporates from inside the leaf and escapes through the open stomata, it pulls on the water behind it. Water molecules cling to each other like links in a chain, so the whole column of water in the xylem is drawn upward, from the soil, through the stem, to the leaf. The sun is the engine that drives the plant’s plumbing.

Plants give off an amazing amount of water. Of all the water a plant takes up, about 95 percent or more escapes as vapor; only a little is used in photosynthesis and growth. A large oak tree can give off around 100 gallons on a hot summer day, and a field of corn gives off thousands of gallons per acre each day, which is one reason a cornfield feels humid on a July afternoon.

Each **stoma** is guarded by two **guard cells** that swell open when the plant has plenty of water and light, and close when the plant is thirsty or in the dark. Most stomata are on the shady underside of leaves, which saves water. Floating leaves, like water lilies, have their stomata on top, since the underside touches water. Transpiration speeds up with **heat, wind, bright light and dry air**, and slows in cool, still, humid conditions.

This is why gardeners water deeply in the morning, mulch to keep soil cool and moist, and give new transplants shade and shelter from wind for a few days. A wilting plant has lost water faster than its roots can replace it; its cells go limp like a balloon losing air. The sugar the leaves make travels the other way, down and around through the **phloem**, to feed roots, fruits and growing tips.

PICTURE STUDY



Water Lilies, Claude Monet, 1906 · Oil on canvas · Art Institute of Chicago

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

In his garden at Giverny, Monet dug a pond, planted water lilies and painted them for the last thirty years of his life. Water lilies are a perfect plant for this lesson: they live with their roots in mud and their leaves lying flat on the water.

Look closely

- Find the round lily pads. Which side of the leaf touches the air?
- Look for flowers. Are they open or closed? Water lily flowers open in the morning and close in the afternoon.
- Find reflections of the sky or trees in the water.
- Find the darker and lighter patches of water. What are they reflecting?

Talk about it

1. Most plants have stomata on the undersides of their leaves. Why does a water lily have them on top?
2. Does a water lily ever need to save water the way a cactus does? Why or why not?
3. What would happen to the water level of a small pond full of transpiring plants on a hot, windy day?

HANDS-ON PROJECT

Colored Celery and the Leaf-Bag Contest

You will see water climb the xylem with colored celery, then measure how much water leaves give off in different conditions using plastic bags.

You will need

- 3 stalks of celery with leaves, freshly cut at the bottom
- Clear cups, water and food coloring (blue or red works best)
- A potted plant or a shrub or tree branch outside
- 4 clear zip bags or sandwich bags and twist ties
- A sunny spot, a shady spot, and a fan if you have one
- A teaspoon measure, ruler and journal

Steps

1. Fill three cups with water and 15 drops of food coloring each. Cut 1 inch off the bottom of each celery stalk and stand one in each cup.
2. Put one cup in a sunny window, one in a dark closet, and one in front of a gently blowing fan.
3. After 1 hour, 4 hours and the next morning, check how far the color has climbed in each stalk. Cut a thin slice from the bottom of one stalk to see the colored dots of xylem.
4. Leaf-bag contest: on a sunny day, slip a bag over a leafy branch tip with about the same number of leaves in each bag. Seal each bag with a twist tie. Put two bags on plants in the sun and two in the shade.
5. After 2 to 3 hours, carefully remove the bags, keeping the water inside. Measure the water by pouring it into a teaspoon or a marked straw, or compare the drops.
6. Record all results in a table. Which conditions made the most transpiration?
7. Write a conclusion explaining your results using the words xylem, stomata and transpiration.

Tips

- Use the same number and size of leaves in each bag to make it fair.

- If it is winter, bag the leaves of houseplants instead, one in a sunny window and one in a dim room.

Check your work

- ☐ I can trace water from the soil to the air through a plant.
- ☐ I can explain how transpiration pulls water up.
- ☐ My table compares transpiration in at least two conditions.

NATURE JOURNAL

1. Draw a cross-section of your colored celery, showing the colored xylem dots, actual size and then magnified.
2. Draw a whole plant with blue arrows for water moving up and orange arrows for sugar moving around, labeling root hairs, xylem, phloem and stomata.
3. Draw one stoma, open and closed, with its two guard cells.

From history. In 1727 an English clergyman and scientist, Stephen Hales, measured how much water plants gave off by weighing potted sunflowers morning and evening. His careful book, *Vegetable Staticks*, was among the first to measure the flow of water through plants.

COMMON MISTAKES

- Watering lightly every day so only the top inch is damp, which keeps roots shallow.
- Thinking a plant drinks water to keep it; nearly all of it passes through and out the leaves.
- Comparing bags with very different numbers of leaves.

Make it a game • Water Path Relay. Mark stations across the room: root hairs, xylem, leaf, guard cells, air. Walk a bean-sized water drop from soil to air, saying what pulls it up at each stop through transpiration. Mention phloem when asked. Your parent calls 'hot windy day' and you explain what changes. Race from soil to sky, then do it backwards.

5.3 MACRONUTRIENTS AND MICRONUTRIENTS

OBJECTIVES

- Name the major plant nutrients and tell what nitrogen, phosphorus and potassium each do.
- Recognize common deficiency signs, especially on older and newer leaves.
- Read a fertilizer label and judge four plants in a 4-H style judging class.

Warm-up. Look at three leaves from different plants, or pictures from a garden book: one dark green, one pale yellow-green, one with brown edges. Write what you think each plant might be telling the gardener.

WATCH

[Plant Nutrition](#) | [Plants](#) | [Biology](#) | [FuseSchool](#)

[FuseSchool - Global Education](#) · 4:00

https://www.youtube.com/watch?v=w_x-WDdQdxi

WHEN TO WATCH

After the second core idea. Pause at each nutrient deficiency the video shows and write what the leaves look like when that nutrient is missing.

KEY TERMS

macronutrient

A nutrient plants need in large amounts: nitrogen, phosphorus, potassium, calcium, magnesium and sulfur.

N-P-K

The three numbers on a fertilizer label: the percent by weight of nitrogen, phosphate and potash.

deficiency

A shortage of a nutrient that causes poor growth and visible symptoms.

micronutrient

A nutrient plants need in tiny amounts, such as iron, manganese, zinc, copper, boron and molybdenum.

chlorosis

Yellowing of leaves because they cannot make enough chlorophyll.

CORE IDEAS

Plants make sugar from air and water, but to build proteins, chlorophyll and cells they also need about 14 **mineral nutrients** from the soil, dissolved in water and taken in by the roots. The **macronutrients** are needed in large amounts: **nitrogen (N)**, **phosphorus (P)** and **potassium (K)**, called the primary nutrients, plus calcium, magnesium and sulfur. The **micronutrients**, such as iron, manganese, zinc, copper, boron and molybdenum, are needed only in tiny amounts, but a plant cannot live without them.

Nitrogen builds leaves and stems and is part of chlorophyll; it makes plants green and leafy. **Phosphorus** helps roots, flowers, seeds and fruit and moves energy inside cells. **Potassium** strengthens stems, controls the stomata and helps plants resist drought and disease. A simple way to remember: N for “up” (leaves), P for “down and all around” (roots and flowers), K for “all-around health.”

Deficiency signs follow a pattern. Some nutrients are **mobile**: when they run short, the plant moves them from old leaves to new ones, so symptoms show on **older, lower leaves** first. Nitrogen shortage turns the oldest leaves pale yellow all over. Potassium shortage browns and scorches the edges of older leaves. Magnesium shortage yellows the spaces between the veins of older leaves while the veins stay green. Phosphorus shortage often makes leaves dark green with a purple tinge and roots weak. Other nutrients are **immobile**, so symptoms show on **new leaves** and growing tips: iron shortage yellows the young leaves between green veins, and calcium shortage causes blossom-end rot, a dark, sunken spot on the bottom of tomatoes (often brought on by uneven watering).

A fertilizer bag lists three numbers, such as 10-10-10 or 5-10-5. They are the percent by weight of nitrogen, phosphate and potash. A 20-pound bag of 10-10-10 holds 2 pounds of nitrogen. Compost and aged manure supply many nutrients slowly; bone meal adds phosphorus, and wood ash adds potassium. More is not better: too much nitrogen makes huge leafy plants with few tomatoes, and too much fertilizer can burn roots. A soil test, which you will learn more about in later grades, tells you what your soil really needs.

Judges at county fairs and in 4-H judging contests look at plants the same way: healthy color, sturdy stems, even growth, and no yellowing or spots. They **place** plants first to last and give **reasons**: “I placed A over B because A had darker green

leaves and a thicker stem.” Judging trains your eye to notice what is right and what is wrong, which is the first step in fixing a problem.

PICTURE STUDY



Flowers in a Vase, Rachel Ruysch, about 1685 · Oil on canvas · National Gallery, London

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

Rachel Ruysch was a Dutch painter whose father was a famous professor of anatomy and botany, and she learned to look at plants like a scientist. Her flower paintings were so exact that botanists can name the species. She painted for more than sixty years and became one of the most admired painters of her day.

Look closely

- Find the healthiest-looking leaves. What color are they? Can you find any leaves that are yellow, curled or spotted?
- Look for insects hidden in the bouquet. How many can you find?
- Find flowers at different stages: buds, full blooms and fading flowers.
- Choose two flowers and compare their stems. Which looks strongest?

Talk about it

1. If one of these plants had yellow lower leaves, which nutrient might it be missing?
2. These flowers bloom at different times of year in a real garden. Why might a painter combine them in one picture?

3. If you were judging these flowers at a fair, which would you place first, and what is your reason?

Safety first. Fertilizers are chemicals. Read the label with an adult, wear gloves, measure carefully, keep fertilizer away from your mouth and eyes, store it where little children and pets cannot reach it, and wash your hands afterward.

HANDS-ON PROJECT

The Fertilizer Trial and a Judging Class

You will grow the same plant with no fertilizer, half-strength and full-strength fertilizer and measure the difference for three weeks. At the end you will judge four plants in the style of a 4-H plant judging class and write your reasons.

You will need

- 4 small pots with drainage holes, labeled A, B, C and D
- Plain seed-starting mix or washed sand (low in nutrients)
- Fast-growing seeds such as bush beans, radishes or lettuce, or 4 matching small seedlings
- A balanced liquid fertilizer, such as one labeled 10-10-10 or 20-20-20 (adult measures)
- A sunny window or grow light
- Ruler and journal

Steps

1. Fill the four pots with the same mix and plant the same number of seeds in each. When they sprout, thin to one strong seedling per pot.
2. Pot A gets plain water only. Pot B gets half-strength fertilizer. Pot C gets full label-strength fertilizer. Pot D gets double strength. An adult mixes each solution.
3. Feed once a week with the same amount of solution; on other days, water all pots with the same amount of plain water.
4. Twice a week, record each plant's height, number of leaves, leaf color (dark green, green, pale or yellow) and any spots or brown edges.
5. After three weeks, make a line graph of height for all four plants.
6. Judging class: set the four plants in a row. Study them for three minutes like a fair judge: color, stem strength, leaf health, evenness and overall vigor.
7. Place them 1st to 4th on a card. Then write reasons for each pair, for example: "I placed C over B because C had darker green leaves and a thicker stem."

8. Compare your placing with your data. Did the most fertilizer give the best plant? Explain why or why not.

Tips

- Keep everything the same except the fertilizer: light, water, pot size and seed variety.
- Look closely at the oldest leaves in Pot A for pale yellow, and at the leaf edges in Pot D for brown burn.
- Many county fairs and 4-H clubs hold judging contests for vegetables, plants and animals; check your county extension office for youth events.

Check your work

- ☐ I can name N, P and K and tell what each does.
- ☐ I can describe what nitrogen deficiency looks like.
- ☐ I placed four plants and wrote a reason for each placing.

NATURE JOURNAL

1. Draw a leaf showing each deficiency sign: overall yellow (N), purple tinge (P), brown edges (K), yellow between green veins (Mg or Fe). Label which leaves, old or new, show each one.
2. Copy the label from a fertilizer bag or box and explain each of its numbers.
3. Draw your four judged plants in a row with your placing and one reason under each.

From history. In the 1840s the German chemist Justus von Liebig showed that plants take mineral nutrients from the soil and taught the “law of the minimum”: a plant can grow only as well as its scarcest nutrient allows, like a barrel that can hold water only up to its shortest board.

COMMON MISTAKES

- Thinking more fertilizer is always better; too much burns roots and makes leafy plants with little fruit.
- Blaming every yellow leaf on nitrogen; overwatering, cold and old age can also yellow leaves.
- Judging plants by height alone instead of looking at color, stem and health.

Make it a game • Hungry Plant Doctor. Parent plays a plant and describes a leaf problem: pale yellow old leaves, purple lower leaves, brown edges. You are the doctor and name the nutrient, N, P or K, and what that nutrient does for plants. Say whether the deficiency shows on old or new leaves. Three right diagnoses earn the doctor's badge. Swap and diagnose again.

5.4 LIGHT INTENSITY AND DAY LENGTH

OBJECTIVES

- Explain how light intensity affects seedlings and why weak light makes them leggy.
- Describe short-day, long-day and day-neutral plants with examples.
- Grow seedlings under different light and measure the results.

Warm-up. Look for a houseplant or a seedling near a window. Which way are its leaves and stems leaning? Turn the pot halfway around and write a prediction about what it will do in three days.

WATCH

What Distance Should My Grow Lights be Above My Seeds Starts? & How Long Do I Leave the Lights On?

Gary Pilarchik (The Rusted Garden) · 3:54

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

WHEN TO WATCH

Before the hands-on project. Notice the difference between stocky seedlings and leggy ones.

BACKUP VIDEO

Grow the Right Onions for Your Day Length

Gardenerd · 3:26

<https://www.youtube.com/watch?v=yLvd7hRRhTM>

With the fourth core idea, about onions and day length.

KEY TERMS

light intensity

How bright light is; outdoor sun is many times brighter than a sunny window or a room light.

leggy

Describes a seedling with a long, thin, weak stem and pale leaves from stretching toward too little light.

phototropism

A plant's growth toward light.

photoperiod

The length of daylight (and darkness) in a 24-hour day, which tells many plants when to flower.

bolting

When a leafy crop like lettuce or spinach suddenly sends up a flower stalk, often in long, hot days, and its leaves turn bitter.

CORE IDEAS

Plants need light not only to be on, but to be **bright** enough. Light intensity can be measured in units called foot-candles or lux. Full summer sun gives about 10,000 foot-candles; a bright, sunny windowsill may give a few hundred to a thousand; an ordinary room light, less than 100. Our eyes adjust so well that a room seems bright, but a seedling knows better.

In weak light, seedlings grow **leggy**. A plant hormone called auxin makes the cells on the shady side of the stem grow longer, so the stem bends toward the light. This is **phototropism**. With too little light everywhere, the whole stem stretches long and thin, searching for brightness, and the leaves are small and pale. Leggy seedlings flop over and transplant poorly. Gardeners starting seeds indoors use fluorescent or LED grow lights hung just 2 to 4 inches above the seedlings and left on 14 to 16 hours a day, raising the lights as plants grow.

Plants also measure the **length of the day**, called the **photoperiod**. Scientists discovered that plants are really measuring the length of the uninterrupted **night**. **Short-day plants**, such as chrysanthemums and poinsettias, flower when nights grow long in fall and winter. Florists keep poinsettias in total darkness 14 hours each night for about eight weeks to make them color for Christmas. **Long-day plants**, such as spinach, lettuce, radishes and many grains, flower when nights are short in early summer; that is why spinach and lettuce bolt in June. **Day-neutral plants**, such as tomatoes, peppers, cucumbers and beans, flower when they are old enough, whatever the day length.

Onions show day length clearly. Onions form bulbs when the days reach a certain length. **Long-day onions** start bulbing at about 14 to 16 hours of daylight and suit northern states with long summer days. **Short-day onions** bulb at about 10 to 12 hours and suit the South, where they are planted in fall and grow through the mild winter. Plant the wrong kind and you get all tops and no bulb, or tiny bulbs.

Knowing light helps you plan. Lettuce and spinach do best in spring and fall; tomatoes and squash need full sun, at least 6 to 8 hours of direct light a day; and seedlings need strong light from the moment they sprout. The same sun God set “for seasons” in Lesson 1.1 is quietly telling every plant in your garden what time of year it is.

PICTURE STUDY



Carnation, Lily, Lily, Rose, John Singer Sargent, 1885–1886 · Oil on canvas · Tate Britain, London

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

John Singer Sargent painted this picture outdoors in an English garden over two summers. He could only paint for a few minutes each evening, during the short time when the light at dusk was exactly right, so the picture took months. He was a careful watcher of light and day length, just as a gardener must be.

Look closely

- What time of day is it? Find three clues in the light, colors and lanterns.
- Find the tall white lilies. Are they in full bloom? Lilies bloom in the long days of summer.
- Find the roses and carnations. Where are they growing?
- Look at the glow of the lanterns on the girls' faces and dresses. How is lantern light different from daylight?

Talk about it

1. Sargent painted only a few minutes each evening for weeks. What does that tell you about how quickly evening light changes?
2. In midsummer in England, the sun sets very late. How would those long days affect plants in this garden?

3. Would lantern light be bright enough for a plant to make food? Why or why not?

HANDS-ON PROJECT

The Seedling Light Trial

You will grow seedlings in three different light conditions and measure how light intensity changes their height, stem thickness and color. This will prepare you for starting your garden seeds indoors.

You will need

- 3 cups or small pots with drainage holes and seed-starting mix
- Fast seeds: radish, beans, sunflowers or lettuce (same kind in all three)
- A grow light or LED shop light (if available), a sunny window, and a dim room
- A ruler, a pencil to measure stem width, and a free light-meter phone app (optional, with a parent)
- Your journal

Steps

1. Plant 3 to 4 seeds in each cup at the same depth. Water all the same amount and keep them together in a warm place until they sprout.
2. As soon as they sprout, move Cup 1 under a grow light set 3 inches above the seedlings, on for 16 hours a day. Put Cup 2 on a sunny windowsill. Put Cup 3 in a dim corner of a room.
3. If you have a light meter app, measure the light at each spot at the same time of day and record it.
4. Every two days for two weeks, measure the height of the tallest seedling in each cup, and estimate stem thickness (thin as a thread, as a toothpick, or as a pencil lead).
5. Record the leaf color and any leaning toward light.
6. Turn the windowsill cup halfway around once and record what happens over the next two days.
7. Make a line graph of height for all three cups. Write a conclusion: which light grew the sturdiest seedlings, and why is taller not always better?

Tips

- Keep the grow light close; most beginners hang lights too high.
- A cheap kitchen timer for the light keeps the day length the same each day.

Check your work

- ☐ I can explain why seedlings in weak light grow leggy.
- ☐ I can name one short-day, one long-day and one day-neutral plant.
- ☐ My graph and notes compare three light conditions.

NATURE JOURNAL

1. Draw your three seedlings side by side at actual size at the end of the trial.
2. Draw a 24-hour clock for June and one for December at your latitude, shading the night hours.
3. Make a chart of six garden plants, sorted as short-day, long-day or day-neutral.

From history. In 1920 two U.S. Department of Agriculture scientists, Wightman Garner and Harry Allard, discovered photoperiodism while studying a tobacco variety that would not flower in summer. When they moved it into a dark shed for part of each day, it bloomed. They had found that plants measure day length.

COMMON MISTAKES

- Thinking a bright-looking room has enough light for seedlings.
- Hanging grow lights a foot or more above seedlings.
- Planting long-day onions in the deep South or short-day onions in the North.

Make it a game • Leggy or Stocky?. Draw two seedlings on paper: one tall and floppy, one short and sturdy. Describe from memory what light each had and why weak light makes seedlings leggy. Then play short-day, long-day, day-neutral sorting with plant names written on cards. Parent calls out a plant and you slap the right category pile. Aim for ten in a row.

Scripture. “And why take ye thought for raiment? Consider the lilies of the field, how they grow; they toil not, neither do they spin:” (Matthew 6:28, KJV)

Jesus told us to consider how the lilies grow. When we study light and growth, we are doing what He asked, and learning to trust the One who clothes the flowers.

UNIT 5

PLANT SCIENCE

Late winter is the time to start thinking like a plant. Before seeds go into pots, a good gardener understands what happens inside a leaf, a stem and a root. In this unit you will learn how plants make sugar from light, air and water in photosynthesis and burn it in respiration; how water climbs from the roots to the highest leaf; which mineral nutrients plants need and how to recognize when one is missing; and how the brightness of light and the length of the day control growth and flowering.

Every lesson has a real experiment you can do on a kitchen table: floating leaf disks, bagged leaves that “sweat,” a fertilizer trial, and seedlings grown under different light. You will also judge plants the way a 4-H or fair judge does, ranking them and giving reasons. “Consider the lilies of the field, how they grow,” Jesus said. This unit is a close consideration of exactly that.

PREREQUISITES

- Knows the parts of a plant: roots, stem, leaves, flowers, fruit and seeds
- Can measure in millimeters and make a line graph
- Can set up a fair test that changes only one variable

MASTERY CHECKLIST

- ☐ I can write the word equation for photosynthesis and explain how respiration is different.
- ☐ I can trace water from the soil, up the xylem and out of the stomata, and name what speeds up transpiration.
- ☐ I can name the major nutrients (N, P, K) and recognize three deficiency signs.
- ☐ I can explain how light intensity and day length affect seedlings and flowering.
- ☐ I can judge four plants, place them 1 to 4, and give reasons.

LESSONS IN THIS UNIT

5.1 Photosynthesis and Respiration

2 sessions of 45 minutes

5.2 Transpiration and Water Movement

2 sessions of 45 minutes

UNIT 5 REVIEW

Answer each question. Use complete sentences for explanations. The review is worth 50 points.

1. **5 pts**

Write the word equation for photosynthesis.

2. **5 pts**

Do plants carry out respiration? When and why?

3. **5 pts**

In the leaf-disk experiment, why did the disks in the light float?

4. **5 pts**

Trace the path of water through a plant, using the words root hairs, xylem, leaves and stomata.

5. **5 pts**

Name three conditions that speed up transpiration.

6. **5 pts**

What does each of the three numbers on a fertilizer label stand for? How many pounds of nitrogen are in a 10-pound bag of 10-5-5?

7. **5 pts**

A bean plant's oldest, lowest leaves are turning pale yellow all over while new leaves are green. What nutrient is probably short, and why do the old leaves show it first?

8. **5 pts**

Why do seedlings on a dim windowsill grow tall and thin?

9. **5 pts**

Explain short-day and long-day plants and give one example of each.

10. **5 pts**

You are judging four potted bean plants. Write one reason a judge might give for placing one plant over another.

ANSWER KEY

1. Carbon dioxide + water + light energy → sugar (glucose) + oxygen.
2. Yes. Every living plant cell respires all the time, day and night, breaking down sugar with oxygen to release energy for living and growing.
3. Photosynthesis in the light made oxygen gas, which filled the spaces in the leaf and made the disks float.
4. Water enters through root hairs, moves up the xylem through the stem to the leaves, and evaporates out through the stomata.
5. Any three: heat, wind, bright light, dry air.
6. Nitrogen, phosphate and potash, as percent by weight. 10% of 10 pounds = 1 pound of nitrogen.
7. Nitrogen. It is mobile, so the plant moves it from old leaves to new growth, and the old leaves yellow first.
8. In weak light they stretch toward the light (hormones lengthen stem cells), making leggy, weak stems with pale leaves.
9. Short-day plants flower when nights are long (poinsettia, chrysanthemum). Long-day plants flower when nights are short in early summer (spinach, lettuce, radish).
10. Example: "I placed A over B because A had darker green leaves, a thicker stem and no yellow or spotted leaves."

PORTFOLIO PIECE: A PLANT SCIENTIST'S LAB BOOK

Collect your four experiments into one lab book, written the way scientists record their work. For each experiment, include the question, your prediction, materials, procedure, data table, graph and a conclusion. Add the placing card and written reasons from your plant judging class, and finish with a one-page explanation of what a plant needs to grow well, using the words photosynthesis, transpiration, nutrients and light.

LOOK FOR	WHAT IT MEANS
Complete experiments	All four experiments have a question, prediction, procedure, data, graph and conclusion.
Accurate science	Explanations of photosynthesis, respiration, transpiration, nutrients and light are correct.
Data and graphs	Measurements are dated and labeled with units; graphs have titles and labeled axes.
Judging	Four plants are placed with clear, specific reasons comparing each pair.
Presentation	Neat, organized and illustrated with careful drawings.

FARM ANIMALS AND BEES

Early spring is the season of new life on the farm: chicks arrive from the hatchery, does are milked again, horses shed their winter coats, and honeybee colonies wake and build. In this unit you will learn the daily care these animals need and the products and work they give us. You will plan a brooder and a budget for a flock of chicks, make butter and a simple fresh cheese, learn to groom a horse and pick out its hooves, and go through a beehive inspection step by step.

You will also learn how young people show animals at 4-H and county fairs: how a judge compares an animal to its breed standard, how an exhibitor handles a bird for showmanship, and how a jar of honey is prepared for exhibit. No family is expected to own livestock. Every project can be done by planning, by visiting a farm, a fair or a beekeeper, or by helping a neighbor. “Be thou diligent to know the state of thy flocks” is still the first rule of animal husbandry.

PREREQUISITES

- Knows the basic needs of animals from Unit 4
- Can make a budget table with totals
- Knows to wash hands after handling animals

MASTERY CHECKLIST

- ☐ I can set up and manage a brooder for chicks and plan a first-year chicken budget with expenses and income.
- ☐ I can describe how a dairy goat is cared for and milked, and explain how butter and fresh cheese are made.
- ☐ I can name the grooming tools, parts of the hoof, basic tack, and common horse colors and markings.
- ☐ I can name beekeeping tools and describe what a beekeeper looks for in a hive inspection.
- ☐ I can explain how animals are judged against a breed standard and how a young exhibitor shows a bird.

LESSONS IN THIS UNIT

6.1	Raising Chicks and Showing Poultry	2 sessions of 45 minutes
6.2	Goats and Milk: Butter and Simple Cheese	2 sessions of 45 minutes
6.3	Horse Care: Hooves, Grooming and Tack	2 sessions of 45 minutes
6.4	Beekeeping Tools and a Hive Inspection	2 sessions of 45 minutes

UNIT 6 REVIEW

Answer each question. Use complete sentences for explanations and show your work for calculations. The review is worth 50 points.

1. **5 pts**
What temperature should a brooder be the first week, and how do you lower it after that?
2. **5 pts**
Chicks are huddled together under the lamp and peeping loudly. What is wrong, and what do you do?
3. **5 pts**
Name three biosecurity habits for a backyard flock.
4. **5 pts**
What does a poultry judge compare a bird to, and what is a showmanship class?
5. **5 pts**
Six chicks cost \$4 each, feed to laying age costs \$90, and supplies cost \$60. Once laying, they give 4 dozen eggs a month worth \$4 a dozen. What is the total cost, and how many months of eggs will repay it?
6. **5 pts**
Explain why shaking cream turns it into butter.

7. (5 pts)

Why is milk chilled quickly or pasteurized?

8. (5 pts)

List the grooming tools in order and give one horse safety rule.

9. (5 pts)

A horse has a reddish-brown body with black mane, tail and lower legs and a white stripe down its face. What color and marking is that? How tall is a horse measuring 60 inches at the withers, in hands?

10. (5 pts)

Name three things a beekeeper checks in an inspection and three things a honey judge looks for in a fair jar.

ANSWER KEY

1. About 95 °F at chick level, lowered about 5 °F each week until the chicks are feathered at about 6 weeks.
2. They are cold. Lower the heat source or add heat, and check for drafts.
3. Any three: buy from an NPIP hatchery; keep new birds apart about 30 days; use separate coop shoes; wash hands before and after; keep wild birds and rodents from feed; don't visit other flocks and then your own.
4. The breed standard (the APA Standard of Perfection). In showmanship, the young exhibitor is judged on how well they handle, examine and present the bird and answer questions.
5. Cost: $\$24 + \$90 + \$60 = \$174$. Income: $4 \times \$4 = \$16$ a month. $\$174 \div \$16 \approx 11$ months.
6. Shaking breaks the thin skins around the tiny fat globules, so the fat sticks together into clumps of butter, leaving buttermilk behind.
7. To stop or kill harmful bacteria that can grow in warm milk and make people sick, and to keep it fresh.
8. Curry comb, stiff (dandy) brush, soft (body) brush, mane and tail comb, hoof pick (and face cloth). Rule: never stand directly behind a horse (or approach at the shoulder speaking calmly).
9. Bay with a blaze (or strip, if narrow). $60 \div 4 = 15$ hands.
10. Inspection: eggs or queen, brood pattern, pollen and honey stores, queen cells, room, pests such as varroa. Honey jar: correct fill line, no foam, no bubbles or crystals, no specks, clean jar, correct label.

PORTFOLIO PIECE: A YOUNG STOCKMAN'S NOTEBOOK

Make a notebook a 4-H member could be proud of, covering the four animals of this unit. Include your brooder plan with the flock expense and income table, your butter and cheese records, your horse grooming and identification pages, and your frame reading and honey jar judging card. Finish with a page on one fair class you would like to enter someday, listing what you would need to learn and do to prepare.

LOOK FOR	WHAT IT MEANS
Animal care knowledge	Daily care, housing and health needs are correct for chickens, goats, horses and bees.
Records and budget	The flock budget has correct expense, income and payback figures; butter and cheese records include measurements.
Judging and showing	At least one judging card with placings and reasons, and a correct description of showmanship or exhibit preparation.
Safety	Hand-washing, biosecurity, horse safety and bee safety rules are included.
Presentation	Neat, complete and carefully illustrated with labeled drawings.

6.1 RAISING CHICKS AND SHOWING POULTRY

OBJECTIVES

- Set up a brooder with the right heat, space, feed and water for chicks.
- Read chick behavior to tell if they are too cold, too hot or comfortable.
- Explain biosecurity, breed standards and the basics of poultry showmanship, and plan a flock budget with expenses and income.

Warm-up. Chicks arrive from the hatchery only a day or two old, without a mother hen to keep them warm. Make a list of everything a mother hen does for her chicks. Then, next to each item, write how a person could provide it instead.

WATCH

Chicken Brooders 101: Everything You Need To Know

The Happy Chicken Coop • 6:52

<https://www.youtube.com/watch?v=UPuqV7VvXA0>

WHEN TO WATCH

After the second core idea. List each piece of brooder equipment as it appears.

BACKUP VIDEO

4-H Poultry Showmanship

Penn State Extension • 7:01

<https://www.youtube.com/watch?v=XsQ8Bb2yw8Y>

In the second session, before you practice the showmanship steps with a stuffed toy or a real bird.

KEY TERMS

brooder

A warm, safe pen where young chicks live until they grow feathers, usually about 6 weeks.

chick starter

A feed made for baby chicks, with about 18 to 20 percent protein, ground small enough for them to eat.

biosecurity

Habits that keep diseases from coming into or spreading through a flock.

breed standard

A written description of the ideal bird or rabbit of a breed; for poultry it is the American Poultry Association's *Standard of Perfection*.

showmanship

A contest in which young exhibitors are judged on how well they handle, present and know about their animal.

CORE IDEAS

A hen keeps her chicks warm under her wings, and in a **brooder** a heat lamp or a heat plate takes her place. Chicks need about 95 °F at chick level the first week, then about 5 degrees less each week until they are fully feathered at about 6 weeks. The heat should be at one end so chicks can move closer or farther away. Watch them: chicks **huddled** under the heat and peeping loudly are cold; chicks **crowded** at the far edges, panting with wings held out, are too hot; chicks **spread out**, eating, drinking and napping, with soft cheeping, are just right.

Each chick needs about half a square foot of space at first and 1 to 2 square feet by a month old, more as they grow, so plan a big enough box. Use pine shavings, not slippery newspaper (which can injure legs) or cedar (whose oils can harm lungs). Give **chick starter** feed and fresh water in a chick waterer; put clean marbles or pebbles in the water dish for the first days so tiny chicks cannot fall in. Check every chick daily for “pasty butt,” droppings stuck under the tail, and gently clean it with warm water. Hens usually begin laying eggs at 18 to 22 weeks old.

Biosecurity protects your flock and your neighbors'. Buy chicks from a hatchery that takes part in the National Poultry Improvement Plan, which tests for certain diseases. Keep new birds apart from your flock for about 30 days. Have “chicken shoes” or boots used only in the coop, wash hands before and after chores, keep wild birds and rodents away from feed, and do not visit other flocks and then come straight home to your own. Poultry often carry **Salmonella** on feathers and feet even when healthy, so wash your hands every time, and never hold chicks against your face.

At a county fair, birds are judged against their **breed standard**. The American Poultry Association's *Standard of Perfection*, first printed in 1874, describes the ideal shape, size, weight, color, comb and leg color for each breed, such as a Plymouth Rock or a Rhode Island Red. The American Rabbit Breeders Association publishes a *Standard of Perfection* for rabbits too. A judge does not ask, "Which is the prettiest?" but "Which comes closest to the ideal for its breed, and which is healthiest?"

In **showmanship**, the young exhibitor is judged as well as the bird. The exhibitor takes the bird out of its cage head first, carries it on the forearm with its head tucked under the elbow facing behind and its legs held gently between the fingers, and then shows the judge each part in order: head, eyes, comb and wattles, beak, wings (spread one at a time), feathers, breast and keel bone, legs and toes, checking for health and for lice or mites. The exhibitor answers questions about the breed, feed and care. Rabbit showmanship follows the same idea: a calm, careful exam of a well-cared-for animal by a well-prepared young keeper.

PICTURE STUDY



A Cock, Hens and Chicks, Melchior d'Hondecoeter, about 1660–1670 · Oil on canvas · National Gallery, London

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

Melchior d'Hondecoeter was a Dutch painter who specialized in birds, especially barnyard poultry. Rich families hung his paintings in their country houses. He painted each breed so carefully that people today can see what Dutch chickens looked like more than 350 years ago.

Look closely

- Find the mother hen and her chicks. How are the chicks staying close to her?
- Compare the rooster with the hens. What differences can you see in the comb, tail and size?
- Look at the feathers of each bird. Can you see different breeds or colors?
- Look for food or water in the picture. What do the chickens seem to be doing?

Talk about it

1. What does a mother hen give her chicks that a brooder must replace?
2. If you were a judge, which bird looks healthiest to you? Give a reason.
3. Jesus compared His care for His people to a hen gathering her chicks. What does a hen's care teach us?

Safety first. Wash hands with soap and water after touching chicks, chickens, eggs, feed or bedding; never hold poultry against your face. An adult sets up heat lamps, which can cause burns or fires; secure the lamp with two fasteners and keep it away from bedding. Handle birds gently and never squeeze them.

HANDS-ON PROJECT

A Brooder Plan, a Flock Budget and Showmanship Practice

You will design a brooder for six chicks, make an expense and income table for raising them to laying age, and practice poultry showmanship. If your family raises chicks, you will keep a real chick record; if not, the plan and practice are your project.

You will need

- Graph paper, ruler, calculator and journal
- Prices for chicks, feed, shavings, feeder, waterer and heat source from a farm store or catalog, with a parent
- A stuffed toy bird, or a real calm hen with an experienced owner's help
- Optional: a visit to a farm store in spring "chick days," a 4-H poultry club or a county fair poultry barn

Steps

1. Draw a brooder for six chicks on graph paper to scale. Label the heat source, feeder, waterer, bedding and a draft-free side. Check that it gives at least 1½ square feet per chick for the later weeks.
2. Write a temperature schedule: week 1 95 °F, then 5 degrees less each week to week 6.
3. Make an expense table with columns: Item, One-time or Recurring, Cost, Quantity, Total. Include chicks, brooder supplies, heat lamp or plate, starter feed (about 10 pounds per chick to 8 weeks), grower and layer feed, shavings, and a share of a coop.
4. Add an income section: six hens may lay about 4 to 5 dozen eggs a month at their peak. Multiply by a fair local price per dozen to estimate monthly income once they lay.
5. Find the total cost to raise the flock to laying age (about 20 weeks) and how many months of eggs it would take to repay it. Write one sentence about what you learned.

6. Make a daily chore chart: check heat and behavior, food, water, cleaning, pasty-butt check, and record keeping.
7. Practice showmanship with a stuffed bird: take it out of a box head first, carry it correctly, set it on a table and show each body part in order, saying what you are checking.
8. If your family keeps chicks, keep a daily record for two weeks: date, temperature, feed added, behavior and any problems.

Tips

- Many county fairs and 4-H clubs have poultry and rabbit projects and showmanship classes; check your county extension office or fair book for ages and rules.
- Practice talking to the judge: make eye contact, speak clearly and keep the bird calm.
- Read about your breed in the *Standard of Perfection* or a breed guide from the library, so you can answer questions.

Check your work

- ☐ I can tell from chick behavior whether the brooder is too cold, too hot or just right.
- ☐ My budget table shows expenses, income and a total.
- ☐ I can name three biosecurity habits and show the order of a poultry showmanship exam.

NATURE JOURNAL

1. Draw three brooder views from above showing chicks that are cold, hot and comfortable.
2. Draw a chicken and label comb, wattles, beak, eye, ear lobe, wing, breast, keel, shank, toes and tail.
3. Judging class: draw or print pictures of four hens of the same breed. Place them 1 to 4 and write a reason for each placing, using the breed standard words: body shape, comb, color, legs and health.

From history. In the 1800s Americans and Britons went through a “hen fever,” importing new breeds and holding the first big poultry shows. To make judging fair, breeders formed the American Poultry Association in 1873 and published the first *Standard of Excellence* in 1874, later called the *Standard of Perfection*, which judges still use today.

COMMON MISTAKES

- Setting the heat lamp in the middle so chicks cannot move away from it.
- Using slippery newspaper as bedding.
- Visiting another flock and coming home without changing shoes and washing hands.

Make it a game • Chick Mood Check. Draw three brooder circles with chicks: huddled under the lamp, spread to the edges, and comfortably scattered. Parent points to one at random and you read the chicks' behavior, too cold, too hot or comfortable, and say what to adjust. Then recite the brooder basics: heat, space, feed, water. Five right in a row wins a paper ribbon.

Scripture. “how often would I have gathered thy children together, even as a hen gathereth her chickens under her wings” (Matthew 23:37, KJV)

Jesus compared His love to a mother hen sheltering her chicks. A brooder is our small copy of that warm, protective care.

6.2 GOATS AND MILK: BUTTER AND SIMPLE CHEESE

OBJECTIVES

- Describe dairy goat breeds and the daily care and milking routine.
- Explain how milk is kept clean and safe, including pasteurization.
- Make butter from cream and a simple fresh cheese, and explain the science of each.

Warm-up. Look at a carton of milk, a stick of butter and a package of cheese. Read the labels and write down any words you do not know. Which foods do you think came from the same pail of milk?

WATCH

How To Milk A Goat!

Blue Cactus Dairy Goats · 7:58

<https://www.youtube.com/watch?v=1upYWlbtgZs>

WHEN TO WATCH

After the second core idea. Watch for each step of the clean-milking routine.

BACKUP VIDEO

Let's Make Butter! - #sciencegoals

SciShow Kids · 2:56

<https://www.youtube.com/watch?v=e1LYWF8T8g0>

Before you shake your cream in the hands-on project.

KEY TERMS

doe

A female goat; a male is a buck, and a young goat is a kid.

ruminant

An animal, like a goat, sheep or cow, with a four-part stomach that chews its cud.

butterfat

The fat in milk, which rises as cream and is churned into butter.

pasteurization

Heating milk to a set temperature for a set time to kill harmful germs, then cooling it quickly.

curd and whey

When milk is soured or set, it separates into solid curds (which become cheese) and watery whey.

CORE IDEAS

Goats were among the first animals people kept for milk, and in many parts of the world more people drink goat milk than cow milk. Popular dairy breeds include the **Nubian**, with long floppy ears and rich milk; the **LaMancha**, with tiny ears; the white **Saanen**, which gives a lot of milk; the **Alpine**; and the small **Nigerian Dwarf**, whose milk is very high in butterfat. A doe gives milk after she has had kids in the spring; a full-size dairy doe may give around a gallon a day at her peak.

Goats are **ruminants** with a four-part stomach and are **browsers**: they prefer leaves, twigs and weeds to grass. They need good hay, fresh water, loose goat minerals, a dry, draft-free shelter, strong fences (goats are famous escape artists), and hoof trimming every month or two. Goats are herd animals and should never be kept alone; a single goat is lonely and loud. Milking happens **twice a day**, about 12 hours apart, every day, which is a serious commitment.

Clean milking keeps milk safe and sweet. The milker washes hands, brushes loose hair from the doe, washes and dries the udder, squirts the first few streams into a separate cup to check for lumps or problems, then milks into a clean stainless pail. The milk is strained through a filter and **chilled quickly** to below 40 °F. Raw milk can carry harmful bacteria, so for safety many families **pasteurize** it: heat to 161 °F for 15 seconds, or 145 °F for 30 minutes, then chill fast. Louis Pasteur's discovery saved many children's lives.

Butter comes from cream, the fat-rich part of milk. Milk fat floats in tiny globules, each wrapped in a thin skin. When cream is shaken or churned, the skins break and the fat globules stick together into clumps, until suddenly a lump of butter separates from a thin liquid called buttermilk. Goat milk's fat globules are smaller and rise slowly, so goat butter usually needs a cream separator; cow's cream from the store works well for practice.

Cheese is made by making milk proteins clump into **curds**. In the simplest fresh cheeses, like ricotta-style cheese, queso blanco or paneer, hot milk is mixed with an acid such as vinegar or lemon juice, and white curds form at once and separate from

the yellow-green **whey**. Aged cheeses like cheddar use an enzyme called rennet and helpful bacteria instead, and take weeks or months. Proverbs speaks of a household with “goats’ milk enough for thy food”: a well-kept dairy feeds a family with milk, butter and cheese.

PICTURE STUDY



The Milkmaid, Johannes Vermeer, about 1658 • Oil on canvas • Rijksmuseum, Amsterdam

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

Johannes Vermeer painted quiet scenes of Dutch homes, filled with gentle window light. Here a kitchen maid carefully pours milk, probably to make a bread pudding from the stale bread on the table. Milk was precious, and nothing went to waste.

Look closely

- Follow the thin stream of milk from the pitcher to the bowl. How carefully is she pouring?
- Find the bread on the table. How might milk and bread be used together?
- Look at the light coming from the window. How does it make the kitchen look clean?
- Find the containers in the kitchen. What are they made of?

Talk about it

1. Before refrigerators, how could a household keep milk from spoiling quickly?
2. Why would a dairy kitchen need to be kept very clean?
3. What could be made from this milk if the family wanted it to last longer?

Safety first. Use the stove only with an adult, and be careful with hot milk, which can boil over and scald. Wash hands before handling food. If you visit a goat farm, ask before touching the goats, never stand behind a goat that is being milked, and wash hands afterward.

Shake-Jar Butter and Lemon Fresh Cheese

You will make butter by shaking cream in a jar and make a simple fresh cheese with milk and lemon juice. You will measure what goes in and what comes out to see how much of the milk becomes butter or cheese.

You will need

- 1 cup heavy whipping cream, at cool room temperature
- A clean pint jar with a tight lid, and a clean marble (optional)
- 4 cups (1 quart) whole milk (goat or cow) and 3 tablespoons lemon juice or white vinegar
- A heavy pot, a cooking thermometer, a slotted spoon
- A colander lined with cheesecloth or a clean thin dish towel, a bowl
- Measuring cups, a pinch of salt, and an adult at the stove

Steps

1. Butter: pour the cream into the jar (add the marble if you like), close it tightly and shake. Record the time.
2. Keep shaking. Notice the stages: liquid, then thick whipped cream (the sound stops), then a sudden slosh when a lump of butter separates from thin buttermilk. Record how many minutes each stage took.
3. Pour off the buttermilk into a measuring cup and record the amount. Rinse the butter with cold water, pressing it with a spoon, until the water runs clear. Add a pinch of salt.
4. Measure your butter. What fraction of the cream became butter?
5. Cheese: with an adult, heat the milk in a pot, stirring, until it reaches about 185 °F (steaming with tiny bubbles at the edge, but not boiling).
6. Turn off the heat and stir in the lemon juice gently. Wait 5 minutes and watch the curds form and the whey turn clear yellow-green.
7. Ladle the curds into the lined colander over a bowl. Let it drain 10 to 30 minutes. Add a pinch of salt.

8. Measure the cheese and the whey. Record everything in a table, then taste your butter and cheese on bread with your family.

Tips

- Cream that is very cold takes longer to become butter; cool room temperature works faster.
- Save the whey for baking bread or pancakes, or water the garden with it diluted, so nothing is wasted.
- Many 4-H clubs have dairy goat projects; a 4-H member may let you watch milking at a fair or farm.

Check your work

- ☐ I can explain why shaking cream makes butter.
- ☐ I can explain how acid makes curds and whey.
- ☐ I can describe a clean milking routine and why milk is chilled or pasteurized.

NATURE JOURNAL

1. Draw the stages of butter in five jars: cream, foamy, whipped, breaking, butter and buttermilk, with the minutes for each.
2. Draw a dairy goat and label the ears, muzzle, withers, back, udder, hocks and hooves. Note which breed it is.
3. Make a milk products chart: milk → cream → butter and buttermilk; milk → curds and whey → cheese.

From history. Before refrigerators, farm families kept milk cool in a springhouse, a small stone building over a cold spring or stream. Crops of milk and butter sat in the flowing water. Cream was churned into butter by hand in a wooden dasher churn, a job often given to children.

COMMON MISTAKES

- Keeping one goat alone; goats need a herd companion.
- Letting fresh milk sit warm instead of chilling it quickly.
- Boiling the milk hard for cheese, which can scorch it.

Make it a game • Milk Journey Map. Draw a path from doe to cheese on paper. Walk your finger along it and narrate each step: milking routine, keeping milk clean, pasteurization, then butter from butterfat and curd and whey for cheese. Your parent stops you and asks 'why?' at three spots. Answer each. Then swap and let your parent narrate while you act as the inspector.

Scripture. “And thou shalt have goats’ milk enough for thy food, for the food of thy household,” (Proverbs 27:27, KJV)

In Proverbs, the reward of knowing and caring for your flock is a household well fed with milk. Diligent daily care brings real blessings.

6.3 HORSE CARE: HOOVES, GROOMING AND TACK

OBJECTIVES

- Name the grooming tools and the order in which they are used.
- Identify the parts of the hoof and describe how hooves are cleaned and cared for.
- Identify basic tack and common horse colors and markings, and follow safety rules around horses.

Warm-up. Draw a horse from memory in two minutes. Then label as many parts as you can. After the lesson, add or correct the labels in a different color.

WATCH

How to Groom a Horse (Step-By-Step Guide)

[Carmella Abel - Equine Helper](#) · 12:10

<https://www.youtube.com/watch?v=Plb64MqF0Ks>

WHEN TO WATCH

After the second core idea. Write down each tool and the direction she uses it.

BACKUP VIDEO

How to Properly Pick Out a Horse's Hoof

[greenhawking](#) · 2:28

<https://www.youtube.com/watch?v=2z2bb1syxjU>

Before the hoof diagram in the project. Notice how the hoof pick moves from heel to toe, away from the frog.

KEY TERMS

curry comb

A rubber comb used in small circles to loosen dirt, hair and dandruff.

farrier

A skilled tradesman who trims hooves and fits horseshoes.

frog

The soft, V-shaped pad on the bottom of the hoof that absorbs shock and helps blood flow.

tack

The equipment used on a horse, such as the halter, bridle, bit, saddle and saddle pad.

hand

The unit for measuring a horse's height, equal to 4 inches, measured from the ground to the withers.

CORE IDEAS

A horse is large, strong and easily startled, so safety comes first. Approach at the shoulder from the side where the horse can see you, speaking calmly. **Never stand directly behind a horse**, where it cannot see you and could kick. Wear sturdy closed-toe boots, keep a hand on the horse as you move around it, tie it with a quick-release knot, and never wrap a lead rope around your hand. An experienced adult should always be present.

Grooming cleans the coat, spreads natural oils, lets you check for cuts, lumps and ticks, and builds trust. The usual order: the **curry comb** in firm small circles on the muscled parts of the body (not the face or bony legs) to loosen dirt; the **stiff dandy brush** in short flicks in the direction the hair grows to sweep it away; the **soft body brush** for the face, legs and a final shine; a **mane and tail comb** (working tangles out gently from the bottom up); and a damp cloth or sponge for eyes and nose.

“No hoof, no horse,” horsemen say. Each day, lift each foot and use a **hoof pick** to clean out dirt and stones, working from heel toward toe and not digging into the soft **frog**. Look for stones, nails, a loose shoe, cracks, or **thrush**, a black, bad-smelling infection of the frog that comes from standing in wet, dirty bedding. A **farrier** trims the hooves, which grow like fingernails, every 6 to 8 weeks. A horse eats about 15 to 25 pounds of hay or pasture a day and drinks 5 to 10 gallons of water or more, so feeding and watering are daily chores too.

Tack includes the **halter** and lead rope (for leading and tying), the **bridle** (headstall, bit and reins, for riding), the **saddle** (English or Western), the saddle pad, and the girth (English) or cinch (Western). Tack must fit well and be kept clean; dirty or poorly fitted tack causes sores.

Horse people describe horses exactly, a skill tested in 4-H Horse Bowl and hippology contests. Height is measured in **hands**: a 15-hand horse is 60 inches at the withers; a pony is under 14.2 hands (14 hands 2 inches). Common **colors**: **bay** (reddish-brown body with black mane, tail and lower legs, called black points), **chestnut** or sorrel (red-brown with no black points), **black**, **gray** (born dark and lightening with age),

palomino (golden with a white or flaxen mane and tail), and **buckskin** (tan with black points). Face **markings** include the star, strip, snip and blaze; leg markings include the coronet, sock and stocking. God asks Job, “Hast thou given the horse strength?” The horse is a magnificent creature that deserves skilled, careful care.

PICTURE STUDY



The Horse Fair, Rosa Bonheur, 1852–1855 · Oil on canvas · The Metropolitan Museum of Art, New York

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

Rosa Bonheur spent a year and a half sketching at the horse market in Paris, twice a week, to paint this huge picture, which is more than 16 feet wide. She studied the horses so carefully that every one has its own build, color and character. Horse buyers came to such fairs to judge animals for farm and coach work.

Look closely

- Name the colors of as many horses as you can: gray, bay, black, chestnut.
- Find a horse with a face marking. What kind is it?
- Look at how the grooms are leading and controlling the horses. Where are they standing?
- Look at the horses' legs and hooves. What kind of work were these big horses bred for?

Talk about it

1. If you were a buyer at this fair, what would you check on a horse before choosing it?
2. Which handler looks safest? Which looks like he is in danger? Why?

3. Why do you think Bonheur sketched at the market so many times before painting?

Safety first. Work around horses only with an experienced adult. Approach from the side at the shoulder, speak first, and never stand directly behind a horse. Wear boots, keep fingers flat when offering a treat, and never wrap a rope around your hand.

HANDS-ON PROJECT

Grooming Kit, Hoof Diagram and Horse ID Quiz

You will assemble or draw a grooming kit, make a labeled diagram of the bottom of a hoof, and make and play a Horse Bowl–style identification quiz on colors, markings and tack. If you can visit a stable or a 4-H horse barn at a fair, you will watch or help with grooming under supervision.

You will need

- Your journal, colored pencils and index cards
- Pictures of horses from library books, a breed guide, or a visit to a stable or fair (with permission)
- Optional: a real grooming kit to examine, or a visit to a farm store's horse aisle
- Optional: a supervised visit to a stable, riding lesson barn or 4-H horse show

Steps

1. Draw each grooming tool, label it, and write what it is for and where on the horse it is used, in order.
2. Draw the bottom of a hoof large on one page and label the wall, sole, frog, white line, heel and toe. Add an arrow showing the direction a hoof pick moves.
3. Make 12 quiz cards: on the front, a drawing or picture of a horse color, a face or leg marking, or a piece of tack; on the back, the correct name.
4. Include at least: bay, chestnut, gray, palomino, buckskin, black; star, blaze, sock, stocking; halter, bridle.
5. Quiz a family member, then have them quiz you. Keep score.
6. Measure a family member's height in hands (divide inches by 4) for practice.
7. If you visit a stable, watch a horse being groomed and its hooves picked. Write down what you observed and one question you asked the owner.
8. Write the horse safety rules on a card in your own words.

Tips

- 4-H horse projects include horseless options such as Horse Bowl, hippology and horse judging; check your county extension office.
- When you visit a barn, walk, speak softly and follow the owner's rules about where to stand and whether to touch.
- Biosecurity tip: if you visit more than one barn or farm, clean your boots and wash your hands between visits, so you do not carry germs from one herd or flock to another.

Check your work

- ☐ I can name the grooming tools in order.
- ☐ I can label the parts of the hoof and explain how to pick it out safely.
- ☐ I can identify at least five horse colors and three markings.

NATURE JOURNAL

1. Correct and complete your warm-up horse drawing with these labels: poll, forelock, withers, back, croup, hock, fetlock, pastern, hoof, muzzle.
2. Draw a horse's face five times, each with a different marking: star, strip, snip, blaze, bald face.
3. Draw a bridle and a halter side by side and label the parts.

From history. Before tractors and cars, horses did most of the heavy work on American farms; around 1915 there were about 21 million horses and mules in the United States. Blacksmiths and farriers had shops in nearly every town, and children learned to harness and care for horses as daily chores.

COMMON MISTAKES

- Walking behind a horse without speaking or keeping a hand on it.
- Digging the hoof pick into the frog.
- Using the stiff brush on the face or the bony lower legs.

Make it a game • Groomer's Order Challenge. Write the grooming tools on separate cards, including the curry comb, hard brush, soft brush and hoof pick. Shuffle and race to put them in the right order, saying what each does. Then draw a hoof and label the frog from memory. Your parent calls a horse term, like hand or farrier, and you define it. Beat your time.

Scripture. “Hath thou given the horse strength? hast thou clothed his neck with thunder?” (Job 39:19, KJV)

God reminds Job that the horse’s power comes from its Creator, not from man. Caring for such a strong animal calls for humility and skill.

6.4 BEEKEEPING TOOLS AND A HIVE INSPECTION

OBJECTIVES

- Name the parts of a Langstroth hive and the beekeeper's tools.
- Describe what a beekeeper looks for during a hive inspection.
- Explain how honey is judged at a fair and prepare a practice exhibit jar.

Warm-up. Look at a jar of honey closely in good light. Describe its color, clearness, and anything you see floating or settling in it. Then taste a tiny spoonful and describe the flavor in three words.

WATCH

Beginner Beekeeping: Dave's Hive Inspection

[cornellsmallfarms](https://www.youtube.com/watch?v=jAx9PfuMcWI) · 4:51

<https://www.youtube.com/watch?v=jAx9PfuMcWI>

WHEN TO WATCH

After the third core idea. Watch for each thing he checks on a frame.

BACKUP VIDEO

Proper Hive Inspection Techniques | Beekeeping Academy | Ep. 35

[UFhoneybeelab](https://www.youtube.com/watch?v=cJZ1wc6Zwh0) · 12:26

<https://www.youtube.com/watch?v=cJZ1wc6Zwh0>

For a fuller lesson on how to open the hive and hold frames, from the University of Florida Honey Bee Lab.

KEY TERMS

Langstroth hive

The common box hive with movable wooden frames, designed by Lorenzo Langstroth in 1851.

smoker

A can with a bellows that puffs cool smoke to calm bees by masking their alarm scent.

bee space

A gap of about $\frac{3}{8}$ inch that bees leave open as a walkway instead of filling it with comb or glue.

hive tool

A flat metal bar used to pry apart boxes and frames that bees have glued together.

brood

The eggs, larvae and pupae of bees,
developing in the cells of the comb.

CORE IDEAS

A honeybee colony has one **queen**, who can lay over 1,500 eggs a day in summer; thousands of female **workers**, who clean, nurse, build comb, guard and gather nectar and pollen; and, in spring and summer, a few hundred male **drones**. Most American beekeepers use the **Langstroth hive**, a stack of wooden boxes. From the bottom: a bottom board with an entrance; one or two deep boxes called the **brood chamber**, where the queen lays; sometimes a queen excluder; shallower **honey supers** on top; then an inner cover and an outer cover.

Inside each box hang 8 or 10 removable **frames**. In 1851 Lorenzo Langstroth, a minister and teacher, noticed that bees always leave a gap of about $\frac{3}{8}$ inch, the **bee space**, as a walkway. He built his frames with exactly that space around them, so the bees would not glue them in place and a beekeeper could lift each one out to look. This invention made modern beekeeping possible.

The beekeeper's tools: a **veil** or suit and gloves; a **smoker** fueled with pine needles, burlap or wood shavings, which puffs cool, white smoke at the entrance and under the cover, masking the bees' alarm scent so they stay calm; a **hive tool** to pry apart boxes and frames stuck with propolis (bee glue); and a soft bee brush. Beekeepers move slowly and smoothly, open hives on warm, calm, sunny days when many bees are out foraging, and never stand in front of the entrance.

During an **inspection**, about every one to two weeks in the busy season, the beekeeper lifts each frame and asks: Is the queen laying? **Eggs**, which look like tiny grains of rice standing in the cells, prove a queen was there within the last three days. Is the **brood pattern** solid, with few empty cells? Are there enough **pollen** and **honey** stores? Are there **queen cells**, peanut-shaped cells that may mean the colony plans to swarm? Is there enough room? Are there pests, such as **varroa mites** or small hive beetles? The beekeeper writes everything in a hive record.

Honey from the hive can be entered at many county and state fairs, and judges are strict. A fair jar of extracted honey should be filled to the proper line (usually the shoulder of the jar), with no foam on top, no air bubbles, no crystals, no specks of

wax or bee parts, and no fingerprints or stickiness on a clean jar and lid; it is labeled exactly as the fair book requires. Judges also check that honey is ripe (not too watery, usually no more than about 18.6 percent moisture) and judge its flavor and clarity. “Sweeter also than honey and the honeycomb,” says Psalm 19 of God’s Word: honey has always been a picture of the best of good things.

PICTURE STUDY



The Beekeepers, Pieter Bruegel the Elder, about 1568 · Pen and brown ink on paper ·
Kupferstichkabinett, Berlin

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

Bruegel made this drawing more than 450 years ago, long before the Langstroth hive. The beekeepers use **skeps**, dome-shaped hives woven from straw. With skeps, a beekeeper could not lift out the combs to look inside, and the honey harvest often destroyed the colony.

Look closely

- Find the straw skeps. How many can you count?
- Look at the beekeepers' protective clothing. What did they use instead of a modern veil?
- Find the boy in the tree. What do you think he is doing?
- Look at how the beekeepers carry the skeps. Why might they be moving them?

Talk about it

1. Why could a beekeeper with a skep not do an inspection like the one in this lesson?
2. Why do you think the beekeepers cover their faces completely?
3. How did Langstroth's movable frames make beekeeping kinder to the bees?

Safety first. Only open a beehive with an experienced adult beekeeper, wearing a veil and protective clothing. Anyone allergic to bee stings must stay well away and tell an adult; if someone stung has trouble breathing or swelling of the face, call 911. Scrape a stinger out sideways with a fingernail or card rather than squeezing it.

Frame Reading and a Fair Honey Jar

You will learn to “read” a frame from a photograph or a real hive visit, and you will prepare and judge honey jars the way a fair honey judge does. No hive of your own is needed.

You will need

- Photographs of brood frames from a beekeeping book or extension website, or a visit to a local beekeeper or bee club with an adult
- Two or three small jars of local honey, and a clean, clear glass jar with a new lid
- A clean spoon, a paper towel, and a flashlight
- Labels or paper and tape
- Your journal

Steps

1. Study a photograph of a brood frame (or a real frame held by a beekeeper). Find and label: eggs, young larvae, capped brood, pollen, nectar, capped honey, and any queen cells or drone cells.
2. Write a pretend hive record for that frame: date, weather, queen seen or eggs seen, brood pattern (solid or spotty), stores, pests, and what to do next.
3. Draw and label the parts of a Langstroth hive from bottom board to outer cover.
4. Honey jar: wash and fully dry the clear jar and lid. Slowly pour local honey down the inside of the tilted jar to avoid bubbles, filling to the shoulder line.
5. Let it sit overnight with the lid on. The next day, skim off any foam or specks from the top with a clean spoon.
6. Wipe the jar until there are no drips or fingerprints. Make a neat label with the honey type and your name, the way a fair book asks.
7. Judging class: set your jar beside the other honey jars. Shine a flashlight through each. Place them 1st to last for fill level, clearness, cleanliness, no foam or specks, and label, and write a reason for each placing.

8. Write down three things a junior beekeeper must do before entering honey at a fair.

Tips

- Many county fairs have youth honey classes, and many state beekeeping associations run junior beekeeper or youth scholarship programs; check your fair book and local bee club.
- Bee clubs often hold field days where families can watch a hive inspection in borrowed veils.

Check your work

- ☐ I can name four beekeeping tools and what each is for.
- ☐ I can name five things a beekeeper checks in an inspection.
- ☐ I can list what honey judges look for in a jar.

NATURE JOURNAL

1. Draw a large section of comb showing an egg, a larva, a capped brood cell, a pollen cell and a capped honey cell, labeled.
2. Draw the three kinds of bees, queen, worker and drone, side by side at the same scale.
3. Write a hive-inspection checklist on a card that a beekeeper could carry to the hive.

From history. Lorenzo Langstroth, a Congregational minister in Pennsylvania and Ohio, published *The Hive and the Honey-Bee* in 1853. His movable-frame hive let beekeepers inspect and help their colonies without harming them, and it is still the most common hive in America.

COMMON MISTAKES

- Opening a hive on a cold, rainy or windy day, when bees are all at home and defensive.
- Using hot, puffing flame instead of cool smoke.
- Pouring honey quickly into a jar, which traps air bubbles and foam.

Make it a game • Hive Parts Build-Off. Build a Langstroth hive from stacked boxes, books or paper cut-outs. Add each part as you name it from memory. Parent calls out a tool, smoker or hive tool, and you tell its job. Then answer what a beekeeper looks for during inspection: brood pattern, queen, stores. Parent hides one part; tell what is missing.

Scripture. “More to be desired are they than gold, yea, than much fine gold: sweeter also than honey and the honeycomb.” (Psalms 19:10, KJV)

The psalmist says God’s Word is sweeter than honey. Every jar of honey, made by bees from countless flowers, is a reminder of that sweetness.

FARM ANIMALS AND BEES

Early spring is the season of new life on the farm: chicks arrive from the hatchery, does are milked again, horses shed their winter coats, and honeybee colonies wake and build. In this unit you will learn the daily care these animals need and the products and work they give us. You will plan a brooder and a budget for a flock of chicks, make butter and a simple fresh cheese, learn to groom a horse and pick out its hooves, and go through a beehive inspection step by step.

You will also learn how young people show animals at 4-H and county fairs: how a judge compares an animal to its breed standard, how an exhibitor handles a bird for showmanship, and how a jar of honey is prepared for exhibit. No family is expected to own livestock. Every project can be done by planning, by visiting a farm, a fair or a beekeeper, or by helping a neighbor. “Be thou diligent to know the state of thy flocks” is still the first rule of animal husbandry.

PREREQUISITES

- Knows the basic needs of animals from Unit 4
- Can make a budget table with totals
- Knows to wash hands after handling animals

MASTERY CHECKLIST

- ☐ I can set up and manage a brooder for chicks and plan a first-year chicken budget with expenses and income.
- ☐ I can describe how a dairy goat is cared for and milked, and explain how butter and fresh cheese are made.
- ☐ I can name the grooming tools, parts of the hoof, basic tack, and common horse colors and markings.
- ☐ I can name beekeeping tools and describe what a beekeeper looks for in a hive inspection.
- ☐ I can explain how animals are judged against a breed standard and how a young exhibitor shows a bird.

LESSONS IN THIS UNIT

6.1	Raising Chicks and Showing Poultry	2 sessions of 45 minutes
6.2	Goats and Milk: Butter and Simple Cheese	2 sessions of 45 minutes
6.3	Horse Care: Hooves, Grooming and Tack	2 sessions of 45 minutes
6.4	Beekeeping Tools and a Hive Inspection	2 sessions of 45 minutes

UNIT 6 REVIEW

Answer each question. Use complete sentences for explanations and show your work for calculations. The review is worth 50 points.

1. **5 pts**
What temperature should a brooder be the first week, and how do you lower it after that?
2. **5 pts**
Chicks are huddled together under the lamp and peeping loudly. What is wrong, and what do you do?
3. **5 pts**
Name three biosecurity habits for a backyard flock.
4. **5 pts**
What does a poultry judge compare a bird to, and what is a showmanship class?
5. **5 pts**
Six chicks cost \$4 each, feed to laying age costs \$90, and supplies cost \$60. Once laying, they give 4 dozen eggs a month worth \$4 a dozen. What is the total cost, and how many months of eggs will repay it?
6. **5 pts**
Explain why shaking cream turns it into butter.

7. (5 pts)

Why is milk chilled quickly or pasteurized?

8. (5 pts)

List the grooming tools in order and give one horse safety rule.

9. (5 pts)

A horse has a reddish-brown body with black mane, tail and lower legs and a white stripe down its face. What color and marking is that? How tall is a horse measuring 60 inches at the withers, in hands?

10. (5 pts)

Name three things a beekeeper checks in an inspection and three things a honey judge looks for in a fair jar.

ANSWER KEY

1. About 95 °F at chick level, lowered about 5 °F each week until the chicks are feathered at about 6 weeks.
2. They are cold. Lower the heat source or add heat, and check for drafts.
3. Any three: buy from an NPIP hatchery; keep new birds apart about 30 days; use separate coop shoes; wash hands before and after; keep wild birds and rodents from feed; don't visit other flocks and then your own.
4. The breed standard (the APA Standard of Perfection). In showmanship, the young exhibitor is judged on how well they handle, examine and present the bird and answer questions.
5. Cost: $\$24 + \$90 + \$60 = \$174$. Income: $4 \times \$4 = \$16$ a month. $\$174 \div \$16 \approx 11$ months.
6. Shaking breaks the thin skins around the tiny fat globules, so the fat sticks together into clumps of butter, leaving buttermilk behind.
7. To stop or kill harmful bacteria that can grow in warm milk and make people sick, and to keep it fresh.
8. Curry comb, stiff (dandy) brush, soft (body) brush, mane and tail comb, hoof pick (and face cloth). Rule: never stand directly behind a horse (or approach at the shoulder speaking calmly).
9. Bay with a blaze (or strip, if narrow). $60 \div 4 = 15$ hands.
10. Inspection: eggs or queen, brood pattern, pollen and honey stores, queen cells, room, pests such as varroa. Honey jar: correct fill line, no foam, no bubbles or crystals, no specks, clean jar, correct label.

PORTFOLIO PIECE: A YOUNG STOCKMAN'S NOTEBOOK

Make a notebook a 4-H member could be proud of, covering the four animals of this unit. Include your brooder plan with the flock expense and income table, your butter and cheese records, your horse grooming and identification pages, and your frame reading and honey jar judging card. Finish with a page on one fair class you would like to enter someday, listing what you would need to learn and do to prepare.

LOOK FOR	WHAT IT MEANS
Animal care knowledge	Daily care, housing and health needs are correct for chickens, goats, horses and bees.
Records and budget	The flock budget has correct expense, income and payback figures; butter and cheese records include measurements.
Judging and showing	At least one judging card with placings and reasons, and a correct description of showmanship or exhibit preparation.
Safety	Hand-washing, biosecurity, horse safety and bee safety rules are included.
Presentation	Neat, complete and carefully illustrated with labeled drawings.

UNIT 7

PLANTING

Spring is planting time, and good planting starts with good planning. In this unit you will learn what goes into a potting mix and how to repot a crowded plant, then make new plants for free from cuttings. You will design a garden on paper with a sun map and a crop-rotation plan, and finally go out to the field to learn how farmers have planted grain through history, from the hand-sower of the Bible to Jethro Tull's seed drill and the steel plow.

You will also prepare a potted plant the way a fair exhibitor would, judge four plants and give reasons, and give a short illustrated talk teaching someone else a planting skill, just as 4-H members do. Whether you have a big yard, a balcony or a single sunny window, there is planting to do this spring.

PREREQUISITES

- Knows soil texture and organic matter from Unit 3
- Knows what plants need (light, water, nutrients) from Unit 5
- Can draw to scale on graph paper

MASTERY CHECKLIST

- ☐ I can name the ingredients of a potting mix and explain what each one does.
- ☐ I can recognize a root-bound plant and repot it correctly.
- ☐ I can take and root a stem cutting and explain why the new plant is identical to its parent.
- ☐ I can draw a garden plan to scale with a sun map and a four-year crop rotation.
- ☐ I can explain how the moldboard plow and the seed drill changed farming, and compare broadcast and drilled planting.

LESSONS IN THIS UNIT

7.1 Potting Mixes and Repotting

2 sessions of 45 minutes

7.2 Propagation from Cuttings

2 sessions of 45 minutes

7.3 Garden Design and Crop Rotation

2 sessions of 45 minutes

7.4 Field Planting Through History: The Plow and the Seed Drill

2 sessions of 45 minutes

UNIT 7 REVIEW

Answer each question. Use complete sentences for explanations and show your work for calculations. The review is worth 50 points.

1. (5 pts)

Name three potting-mix ingredients and the job of each.

2. (5 pts)

Why should you not use garden soil in a pot, or put gravel in the bottom?

3. (5 pts)

List three signs that a plant is root-bound.

4. (5 pts)

Name three things a fair judge looks for in a potted plant exhibit.

5. (5 pts)

Where on a stem should you cut a softwood cutting, and why?

6. (5 pts)

Why is a plant grown from a cutting called a clone? Give one reason growers use clones.

7. (5 pts)

Sort into plant families: tomato, broccoli, bean, squash, potato, radish, pea, cucumber.

8. (5 pts)

Give two reasons for crop rotation.

9. (5 pts)

How did Jethro Tull's seed drill improve on broadcast sowing?

10. 5 pts

In a trial, 72 of 100 drilled seeds sprouted and 51 of 100 broadcast seeds sprouted. What are the germination percents, and what is the difference?

ANSWER KEY

1. Any three: peat or coir hold water; perlite adds air and drainage; vermiculite holds water and nutrients; compost or bark adds nutrients.
2. Garden soil packs down and drains poorly in a pot; gravel raises the soggy zone instead of improving drainage. Use potting mix and a pot with drainage holes.
3. Roots coming out of drainage holes; water runs straight through; the plant dries out very quickly; roots circling the pot; slow growth.
4. Any three: healthy color, no pests or disease, no dead or yellow leaves, balanced shape, suitable size for the pot, clean pot, correct label.
5. Just below a node, because roots form most easily at nodes.
6. It has exactly the same traits as its parent. Growers use them to keep a variety true, such as 'Honeycrisp' apples, whose seeds would not grow the same.
7. Nightshade: tomato, potato. Cabbage: broccoli, radish. Legume: bean, pea. Squash: squash, cucumber.
8. It leaves behind soil-borne diseases and pests of a plant family, and it balances nutrients (for example, legumes add nitrogen for the next crop).
9. It placed seeds at an even depth in straight rows, so more sprouted, less seed was wasted or eaten by birds, and rows could be hoed for weeds.
10. Drilled 72%, broadcast 51%; a difference of 21 percentage points.

PORTFOLIO PIECE: MY SPRING PLANTING RECORD

Assemble a planting record like a 4-H or Junior Master Gardener project book. Include your potting-mix recipe and repotting notes, your fair-exhibit plant and judging card, your cuttings trial results and presentation-talk notes, your sun map and four-year garden plan, and your broadcast-or-drill field trial. Add a page listing what you actually planted this spring with dates, and the row or container you planned to share.

LOOK FOR	WHAT IT MEANS
Plans and maps	The garden plan is to scale with north, sun hours, beds, spacing and a four-year rotation.
Experiments	The cuttings and field trials have dated records, tables and conclusions.
Exhibit and judging	The exhibit plant is described with what was done to prepare it, and four plants are placed with reasons.
Communication	Presentation-talk notes or poster are included, with listener feedback.
Records and presentation	Planting dates, costs if any, and results are recorded neatly and completely.

7.1 POTTING MIXES AND REPOTTING

OBJECTIVES

- Name the common ingredients of potting mix and what each one does.
- Recognize the signs of a root-bound plant and repot it step by step.
- Prepare a potted plant for a fair exhibit and judge four plants with reasons.

Warm-up. Fill one cup with garden soil and one with bagged potting mix. Pour the same amount of water into each and watch. Which drains faster? Which feels lighter when dry? Write what you notice.

WATCH

Coconut Coir Potting Mix Recipe - Coco Coir, Compost, Perlite or Vermiculite

California Gardening • 7:07

<https://www.youtube.com/watch?v=crFjC1Z8IUU>

WHEN TO WATCH

After the second core idea. Write down each ingredient and the amount he uses.

BACKUP VIDEO

How to Fix Rootbound Plants

Revolutionary Gardens Landscape & Design • 5:10

<https://www.youtube.com/watch?v=0rxbn86whcc>

Before you repot your own plant. Watch how the roots are loosened.

KEY TERMS

potting mix

A light, soilless growing mix for containers, usually made of peat or coir, perlite or vermiculite, and compost or bark.

perlite

Volcanic glass heated until it pops like popcorn into light white grains that add air to a mix.

coir

Fiber from coconut husks that holds water well and is a renewable substitute for peat moss.

root-bound

Describes a plant whose roots have filled its pot and are circling around the inside.

drainage hole

A hole in the bottom of a pot that lets extra water run out so roots can breathe.

CORE IDEAS

Garden soil works well in the ground, where worms and roots keep it open, but in a pot it packs down, drains poorly and starves roots of air. Containers need a **potting mix**: a light, fluffy blend that holds water and air at the same time. Most mixes contain no real soil at all.

Each ingredient has a job. **Sphagnum peat moss**, dug from bogs, holds a great deal of water and is slightly acidic. **Coir**, made from coconut husks, does the same job and is renewable. **Perlite**, white popped volcanic glass, makes air spaces and improves drainage. **Vermiculite**, heated mica that opens like an accordion, holds water and nutrients. **Compost** or aged bark adds nutrients and life. A simple home recipe is one part coir or peat, one part compost, and one part perlite, by volume. Seed-starting mixes are finer and lower in nutrients.

Every pot needs a **drainage hole**. Without one, water collects at the bottom and the roots suffocate and rot. Putting gravel in the bottom of a pot does not help; it actually raises the soggy zone higher. Instead, use a good mix, a pot with holes, and water until a little runs out the bottom.

As a plant grows, its roots fill the pot. Signs of a **root-bound** plant: roots poking out of the drainage holes, water running straight through without soaking in, the plant drying out within a day, and slow growth. Slide it out of the pot and you may see a solid mat of roots circling the outside. To **repot**: choose a pot only 1 to 2 inches wider; water the plant an hour before; tip it out; gently tease the circling roots loose with your fingers (or make a few shallow cuts down the sides of a very tight root ball); set it in the new pot at the same depth it grew before, on a layer of fresh mix; fill around it, firm gently, and water well.

Many county fairs have youth classes for potted plants. Judges look for a **healthy, well-grown plant**: good color, no pests or disease, no dead or yellow leaves, a balanced shape, a size suited to the pot, a **clean pot** with no soil on the rim, and a correct **label**. Fair books usually require that the exhibitor has grown the plant for a set time; always read the rules first.

PICTURE STUDY



The Orange Trees, Gustave Caillebotte, 1878 · Oil on canvas · Museum of Fine Arts, Houston

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

Gustave Caillebotte was a French painter and a keen gardener who grew orchids and vegetables at his country home. Here, orange trees grow in big planter boxes set out in the garden for the summer. In cold climates, gardeners have grown citrus in containers for centuries and moved them indoors for the winter.

Look closely

- Find the large square planters holding the orange trees. How big are they compared with the people?
- Look at the shapes of the trees. Have they been pruned? How can you tell?
- Find the strong sunlight and the shade. Where would a potted plant dry out fastest?
- Look for the flower beds and paths behind. How is this garden planned?

Talk about it

1. Why would a gardener in northern France grow orange trees in tubs instead of in the ground?
2. What would happen to these trees if their planters had no drainage holes?
3. How would you repot a tree this big? What problems would you face?

Safety first. Wear gloves and a dust mask, or work outdoors, when mixing dry peat, perlite or potting mix, and dampen the mix first to keep dust down. Wash your hands afterward. Some bagged mixes contain fertilizer; read the label with an adult.

HANDS-ON PROJECT

Mix, Repot, Exhibit and Judge

You will make your own potting mix, repot a root-bound plant, prepare a potted plant as if for a fair, and judge four potted plants with written reasons.

You will need

- Coir or peat moss, perlite, and compost (or one bag of good potting mix)
- A bucket, a scoop, water and gloves
- A root-bound houseplant or nursery plant (a garden-center herb or a crowded spider plant works well)
- A clean pot 1 to 2 inches wider, with a drainage hole, and a saucer
- Scissors, a damp cloth and a small label
- Four potted plants of the same kind to judge (at home, at a garden center with permission, or in clear photos)

Steps

1. Mix one scoop each of coir or peat, compost and perlite in a bucket. Add water a little at a time and mix until it is evenly damp, like a wrung-out sponge.
2. Water your root-bound plant an hour before. Turn it upside down, support the base of the stems between your fingers, and tap the pot to slide it out. Draw the root ball in your journal.
3. Gently loosen circling roots with your fingers. Put mix in the new pot so the top of the root ball sits about $\frac{1}{2}$ to 1 inch below the rim. Set the plant in, fill around it, firm lightly, and water until it drains.
4. Exhibit prep: choose your healthiest potted plant. Remove any dead or yellow leaves with clean scissors, turn the pot so the best side faces forward, wipe the pot clean, top-dress with fresh mix, and add a neat label with the plant's name and yours.
5. Judging class: line up four potted plants of the same kind and number them 1 to 4. Study them for three minutes: color, health, pests, shape, size for the pot, cleanliness.

6. Place them 1st through 4th on a card, then write reasons for each pair: “I placed 2 over 4 because 2 had no yellow leaves and a fuller shape.”
7. Record the date you repotted and check your plant weekly for a month. Write how quickly it recovers and starts new growth.

Tips

- Many county fairs list potted plant, herb and houseplant classes in the youth or open divisions; read your fair book for rules and entry dates.
- Do not jump to a much larger pot; extra wet mix around a small root ball can rot the roots.
- Turn potted plants a quarter turn each week so they grow evenly toward the light.

Check your work

- ☐ I can name four potting-mix ingredients and their jobs.
- ☐ I can list three signs of a root-bound plant.
- ☐ I placed four plants and wrote a reason for each placing.

NATURE JOURNAL

1. Draw the root ball of your plant before and after loosening the roots.
2. Make a magnified drawing of potting mix showing coir or peat fibers, perlite grains, compost bits, water films and air spaces.
3. Draw your exhibit plant from the front with its label, and list what a judge would look for.

From history. In the 1600s and 1700s, wealthy European families built orangeries, glass-fronted buildings where potted orange and lemon trees spent the winter. Every spring, gardeners rolled the heavy tubs outside on carts, and repotting them was a major job for a whole team.

COMMON MISTAKES

- Using a pot without drainage holes, or adding gravel at the bottom.
- Using heavy garden soil in pots.
- Planting deeper in the new pot than the plant grew before.

Make it a game • Potting Mix Builder. Set out little cups labeled perlite, coir, compost and bark, using pretend stand-ins such as rice, oats and crumpled paper. Parent calls a job, like drainage, water holding or nutrients; you scoop the right ingredient and explain why. Then list the signs of a root-bound plant. Win by making a mix that passes your parent's review.

7.2 PROPAGATION FROM CUTTINGS

OBJECTIVES

- Explain how a stem cutting grows roots and why the new plant is a clone of its parent.
- Take, prepare and root softwood cuttings.
- Give a 3 to 5 minute illustrated talk teaching someone how to take a cutting.

Warm-up. Look at a stem of a houseplant or an herb. Find the places where leaves join the stem. Draw the stem and mark these spots with dots. Why do you think gardeners call them “nodes”?

WATCH

How to Grow New Herbs from Cuttings

GrowVeg · 3:42

<https://www.youtube.com/watch?v=L06J4cFro6E>

WHEN TO WATCH

Before the hands-on project. Note where she cuts and how many leaves she leaves on each cutting.

BACKUP VIDEO

Grow New Plants from Cuttings – Easy Softwood Propagation Guide

Gardening With Alan Titchmarsh · 8:06

<https://www.youtube.com/watch?v=y-sii94wcmU>

For more on softwood cuttings of shrubs and flowers.

KEY TERMS

propagation

Making new plants, either from seeds or from parts of a plant.

node

The place on a stem where a leaf or bud grows; roots form most easily at nodes.

clone

A plant grown from a piece of another plant, with exactly the same traits as its parent.

rooting hormone

A powder or gel containing auxin, a natural plant hormone that encourages roots to form.

softwood cutting

A cutting taken from new, green, flexible spring or early-summer growth; it roots quickly.

CORE IDEAS

Seeds are not the only way to make new plants. Many plants can grow a complete new root system from a piece of stem. This is **vegetative propagation**. A cutting taken from a mint, basil, rosemary, coleus, geranium, pothos or rose can become a full new plant in a few weeks, and it costs nothing.

Roots form most easily at **nodes**, the places where leaves join the stem, because those spots have cells ready to become new roots or shoots. A natural plant hormone called **auxin** collects at the base of a cutting and tells those cells to grow roots. Gardeners sometimes dip the cut end in **rooting hormone**, which contains a form of auxin, to speed things up, though many easy plants root without it.

To take a **softwood cutting**: choose a healthy, non-flowering shoot of new growth. Cut a piece 3 to 6 inches long just below a node with clean, sharp scissors. Strip the leaves off the bottom half, leaving 2 to 4 leaves at the top (fewer leaves mean less water lost while there are no roots yet). Push the bare stem into moist perlite or seed-starting mix so at least one node is buried. Cover with a clear bag or dome to keep the air humid, and set it in bright light but out of hot direct sun. In 2 to 4 weeks, a gentle tug that meets resistance means roots have formed.

Some cuttings root in a glass of water, too: pothos, coleus, mint and basil are easy. Woody plants are often taken as **semi-hardwood** cuttings in late summer or **hardwood** cuttings in winter, which root more slowly. Other ways to propagate include **division** (splitting a clump of hostas or chives), **layering** (pinning a low branch to the soil until it roots), and **grafting** (joining a branch of one apple tree onto the roots of another).

A plant grown from a cutting is a **clone**: it has exactly the same traits as its parent. This is how growers keep a favorite variety true. Every ‘Honeycrisp’ apple tree and every ‘Russet Burbank’ potato comes from cuttings, grafts or pieces of an original plant, because their seeds would grow into different plants. Fair exhibitors who show a plant they propagated themselves can explain this proudly.

PICTURE STUDY



Rosa centifolia anglica rubra (The Cumberland Rose), Pierre-Joseph Redouté, 1817–1824 · Stipple engraving, hand-colored, from *Les Roses* · *Les Roses*, Paris

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

Pierre-Joseph Redouté was a Belgian painter who worked in Paris and painted roses and lilies for the Empress Josephine's famous garden. His book *Les Roses* recorded the rose varieties of his time so exactly that gardeners still use it to identify old roses. Old garden roses like this one were kept alive for centuries by cuttings and grafts.

Look closely

- Find a node on one of the stems, where a leaf joins. Where would you cut to take a cutting?
- Count the leaflets on one leaf. Roses usually have an odd number.
- Find the buds at different stages. Which would you avoid when choosing a cutting?
- Look at the thorns. How would you handle this stem safely?

Talk about it

1. If you took a cutting from this rose, would the new plant have the same pink flowers? Why?
2. Why might a gardener in 1820 have wanted a picture this exact?

3. Why is it better to take a cutting from a stem without a flower?

Safety first. Use scissors or pruners carefully and with an adult nearby, cutting away from your body. Wear gloves for thorny plants like roses. If you use rooting hormone, wear gloves, do not get it in your eyes or mouth, and wash your hands afterward.

HANDS-ON PROJECT

A Cuttings Trial and a Illustrated Talk

You will take cuttings from two or three easy plants, root them in different ways, and record which roots first. Then you will give a 3 to 5 minute illustrated talk, the kind 4-H members give at a county presentation day, teaching your family how to take a cutting.

You will need

- Healthy plants to take cuttings from: mint, basil, rosemary, coleus, pothos, geranium or a spider plant's babies (from home, a neighbor or grocery-store herbs)
- Clean scissors or pruners
- Small pots or cups with drainage holes, moist perlite or seed-starting mix, and a clear glass of water
- Clear plastic bags or a clear container to make a mini greenhouse
- Optional: rooting hormone powder
- Poster board and markers for your talk

Steps

1. Take 6 cuttings, 3 to 6 inches long, from one or two plants, each cut just below a node. Strip the lower leaves.
2. Put 2 cuttings in a glass of water. Put 2 in moist perlite or mix. Put 2 in mix after dipping the ends in rooting hormone (or, if you have none, give these 2 a bag over the top and the others none).
3. Label every cutting with the plant name, date and method. Set them in bright, indirect light.
4. Every three days, record: leaves still firm or wilting, new growth, and roots (visible in the water; for the pots, a gentle tug).
5. When roots are about 1 inch long, pot the cuttings into potting mix and record the date. Make a table of days to root for each method.
6. Plan your illustrated talk: a title, a short introduction (why propagate?), the steps shown with real materials, a poster with the main steps, and a

summary.

7. Practice once or twice with a timer. Then give your talk to your family. Speak clearly, show each step with your hands, and end by asking, “Are there any questions?”
8. Ask your listeners to tell you one thing you did well and one thing to improve. Write them down.

Tips

- Many 4-H clubs and county extension offices hold presentation or “illustrated talk” contests; check your county extension office for ages and dates.
- In a illustrated talk, let your hands do the work: show, don’t just tell. Keep the poster simple with big words.
- Spider plants and strawberries make “babies” on runners that root easily; pin one onto a pot of mix beside the mother plant.

Check your work

- ☐ I can explain what a node is and why cuttings are cut just below one.
- ☐ I can explain why a cutting is a clone.
- ☐ I gave a 3 to 5 minute illustrated talk with real materials and a poster.

NATURE JOURNAL

1. Draw a cutting step by step in four panels: the shoot, the cut below the node, the stripped stem, and the potted cutting under a bag.
2. Draw a rooted cutting at actual size, showing the new roots growing from the node.
3. Make a table and bar graph of days-to-root for each method in your trial.

From history. The famous ‘Bartlett’ pear and the ‘McIntosh’ apple were each found as a single tree on a farm. The McIntosh tree was discovered by John McIntosh in Ontario in 1811. Every McIntosh apple tree in the world today was grown from grafts or buds taken, generation after generation, from that one tree.

COMMON MISTAKES

- Leaving too many leaves on a cutting, so it wilts before it can grow roots.
- Cutting between nodes and leaving a long bare stub that rots.

- Letting the rooting mix dry out.

Make it a game · Cutting Clone Detective. Be a detective explaining why a stem cutting grows into a clone. Parent plays a doubter and asks how roots form from a node, what rooting hormone does and why softwood works best. Answer with confidence. Then arrange paper steps of taking, preparing and rooting a cutting in order. Fewest hints wins. Tell your Illustrated Talk idea to end.

7.3 GARDEN DESIGN AND CROP ROTATION

OBJECTIVES

- Make a sun map and choose the best site for a vegetable garden.
- Draw a garden plan to scale with beds, paths and plant spacing.
- Sort vegetables into plant families and plan a four-year crop rotation.

Warm-up. List ten vegetables your family likes to eat. Next to each, guess which vegetables are its “relatives.” For example, are potatoes related to sweet potatoes? (They are not!) Keep your list for the plant-family sort.

WATCH

Crop Rotation Made Simple - Rotate Your Vegetable Beds for Healthier Produce

GrowVeg • 7:48

<https://www.youtube.com/watch?v=XeNA6XdMoF8>

WHEN TO WATCH

After the third core idea. Sketch the four beds and how the crops move each year.

BACKUP VIDEO

Crop Rotation Basics

MU Extension Integrated Pest Management • 3:08

<https://www.youtube.com/watch?v=YhyPlrQN64A>

A short extension summary of why rotation reduces pests and diseases.

KEY TERMS

sun map

A map of a yard showing how many hours of direct sunlight each spot gets.

full sun

At least 6 to 8 hours of direct sunlight a day, which most vegetables need.

plant family

A group of related plants that share features, pests and diseases, such as the cabbage family or the nightshade family.

crop rotation

Growing a different plant family in each bed every year so the same family does not return to a spot for three or four years.

succession planting

Planting a new crop as soon as one is harvested, or sowing small batches every few weeks.

CORE IDEAS

A good garden starts with the right place. Most vegetables need **full sun**, at least 6 to 8 hours of direct light a day. Leafy greens can manage with 4 to 6. The garden should be near a water source, on ground that drains well after rain, away from tree roots, and close enough to the house that you will visit it every day. To find the sunniest spot, make a **sun map**: on a sunny day, look at the yard every two hours from morning to evening and shade what is in shadow.

Good design saves work. Make beds no wider than about 4 feet so you can reach the middle from both sides without stepping on and packing the soil. Leave paths 18 to 24 inches wide. Put tall crops, such as corn, pole beans and trellised tomatoes, on the **north side** so they do not shade shorter plants. Check seed packets for spacing; crowding plants invites disease. Plan for **succession planting**: after spring peas and lettuce finish, plant beans or fall carrots in the same space.

Vegetables belong to **plant families**, and family members share the same pests and diseases. The **nightshade family**: tomatoes, peppers, eggplants and potatoes. The **cabbage family**: cabbage, broccoli, kale, radishes and turnips. The **legume family**: beans and peas. The **squash family**: squash, pumpkins, cucumbers and melons. The **onion family**: onions, garlic and leeks. The **carrot family**: carrots, parsley, dill and celery. The **beet family**: beets, spinach and chard. Lettuce belongs to the aster (sunflower) family.

Crop rotation means moving each family to a different bed every year, so that a family returns to the same bed only after three or four years. Soil-borne diseases like early blight of tomatoes, and pests that overwinter in the soil like some beetles, are

left behind without their favorite food. Rotation also balances nutrients: legumes host bacteria that add nitrogen to the soil, so a hungry crop like cabbage or corn grows well after beans. A simple four-bed rotation moves each year: legumes → cabbage family and leafy greens → tomatoes and squash (fruiting crops) → roots and onions → back to legumes.

A garden can also bless others. Many gardeners plant an extra row or bed to share with neighbors, an elderly friend or a local food pantry, and youth groups often help tend gardens at churches, schools and senior homes. Proverbs says, “He that hath a bountiful eye shall be blessed; for he giveth of his bread to the poor.” Planning for generosity is part of good garden design.

PICTURE STUDY



The Gardeners, Gustave Caillebotte, 1875–1877 • Oil on canvas • Private collection

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

Caillebotte painted the vegetable garden at his family's country estate at Yerres, near Paris. Long, straight beds stretch toward a wall, with glass bell jars called *cloches* protecting young plants. This was a carefully planned kitchen garden that fed a large household.

Look closely

- Count the rows. How wide is each bed compared with the gardeners?
- Find the glass *cloches*. What are they protecting the young plants from?
- Look at the wall and its shadow. Which side of the garden gets the most sun?
- Find the watering cans. How do the gardeners water without stepping on the beds?

Talk about it

1. Why might a gardener build a vegetable garden against a south-facing wall?
2. How would you rotate crops in a garden of long rows like this?
3. What is one thing about this garden's design you would copy in your own plan?

A Sun Map and a Four-Year Garden Plan

You will map the sunlight in your yard or balcony, draw a garden plan to scale, and plan a four-year crop rotation. The plan will guide your planting this spring.

You will need

- Graph paper, ruler, pencil and colored pencils
- A tape measure and a compass or phone compass
- Seed packets or a seed catalog for spacing information
- Your list of vegetables from the warm-up
- No-yard option: a balcony, a patio, a sunny window, or a community or church garden plot

Steps

1. Measure your garden area and draw its outline on graph paper at a scale such as 1 square = 1 foot. Mark north with an arrow, and draw buildings, trees and fences.
2. Make a sun map: on a sunny day, at 8, 10, 12, 2, 4 and 6 o'clock, shade the parts of your drawing that are in shadow (use a lighter color each time, or a separate tracing for each time).
3. Count the hours of sun for each part. Mark full sun (6 or more hours), part sun (4 to 6) and shade.
4. Draw four beds about 4 feet wide in the sunniest area, with paths between. (For a balcony, draw four large containers.)
5. Sort your vegetables into families. Assign one group to each bed: Bed A legumes, Bed B cabbage family and greens, Bed C tomatoes and squash, Bed D roots and onions.
6. Draw the plants in each bed using correct spacing from seed packets. Put tall crops on the north side.
7. Make a rotation chart for four years, showing each group moving to the next bed each year.

8. Mark one row or container to share with a neighbor, a friend or a food pantry, and write who you plan to share it with.

Tips

- Shadows are longest in early spring and fall; a spot that is sunny in June may be shaded in April.
- Keep your plan in your journal and write what you actually planted each year. Next year's rotation depends on this record.
- Junior Master Gardener and 4-H gardening projects ask for a garden plan like this one; it can become part of a project record.

Check your work

- ☐ I can name at least five plant families with two members each.
- ☐ My plan is drawn to scale with north marked, beds, paths and spacing.
- ☐ I can explain two reasons for crop rotation.

NATURE JOURNAL

1. Draw your sun map with a color key for full sun, part sun and shade.
2. Draw one member of each of four plant families and note what they share (flowers, leaves or seeds).
3. Draw your four-year rotation as a circle with arrows.

From history. In the 1700s English farmers developed the Norfolk four-course rotation: wheat, then turnips, then barley, then clover. The turnips fed livestock in winter and the clover restored nitrogen. Lord Charles Townshend promoted turnips so eagerly that people nicknamed him "Turnip Townshend."

COMMON MISTAKES

- Choosing a garden spot by convenience instead of sun.
- Making beds so wide that you must step on them.
- Planting tomatoes and potatoes in the same bed in following years; they are in the same family.

Make it a game • Sun Map Garden Plan. Draw a yard or porch on paper and use yellow crayons to mark full sun, part sun and shade through the day. Parent hides a card with a crop and plant family; you place it on the best spot and explain crop rotation. Then plan four years on a grid so no plant family sits in the same bed twice.

7.4 FIELD PLANTING THROUGH HISTORY: THE PLOW AND THE SEED DRILL

OBJECTIVES

- Describe how plows prepare a field and how the steel plow changed American farming.
- Explain how Jethro Tull's seed drill improved on broadcast sowing.
- Compare broadcast and drilled planting in a small field trial.

Warm-up. Toss a handful of dried beans or rice across a sheet of paper on the floor, the way a sower scatters seed. Then place the same number in neat rows. Which way put every seed where you wanted it? Which was faster?

WATCH

Horse Plowing With Farmer Bob

Farmer Bob • 7:06

https://www.youtube.com/watch?v=Ctn-01Z_NOY

WHEN TO WATCH

After the second core idea. Watch how the moldboard turns the soil over and how the horses and plowman work together.

BACKUP VIDEO

Comparing Broadcast and Drill Planting Methods in Wheat

SFNToday • 5:19

<https://www.youtube.com/watch?v=bwz7hh-JZPg>

Before the field trial, to hear how modern wheat farmers compare broadcast and drilled seed.

KEY TERMS

moldboard plow

A plow with a curved blade that cuts a strip of soil and turns it upside down, burying weeds and stubble.

furrow

The trench left behind as the plow turns over a strip of soil.

broadcast sowing

Scattering seed by hand or machine over the surface of a field.

seed drill

A machine that cuts small grooves, drops seeds into them at an even depth and spacing, and covers them.

seeding rate

How much seed is planted per area, such as pounds per acre.

CORE IDEAS

For thousands of years, farmers prepared fields with a **plow**. The earliest plows, called ards, were simple pointed sticks pulled by oxen that only scratched a groove. In the Middle Ages, northern European farmers used a heavy **moldboard plow** with a curved blade that sliced under a strip of soil and turned it upside down, burying weeds and the stubble of last year's crop and leaving a **furrow**. Teams of oxen, and later horses, pulled it. Plowing is still a skill: a good plowman keeps every furrow straight and even.

When American settlers reached the prairies of Illinois and Iowa, their cast-iron plows could not handle the thick, sticky prairie soil, which clung to the blade so farmers had to stop and scrape it every few steps. In 1837 a blacksmith named **John Deere** in Grand Detour, Illinois, made a plow from a polished steel saw blade. The soil slid right off it. His "self-scouring" steel plow helped open the Midwest to farming. Today many farmers plow less or not at all, because, as you learned in Unit 3, bare, plowed soil erodes.

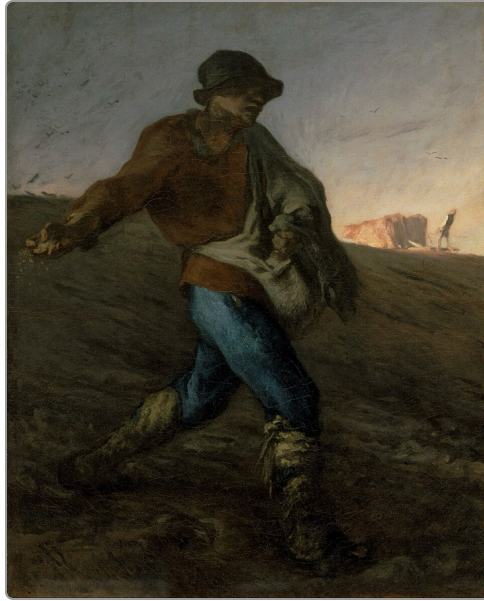
Sowing was just as important. For most of history, farmers **broadcast** seed by hand, walking the field and flinging it in wide arcs, as in Jesus' parable of the sower. Broadcasting is fast, but seed lands unevenly; some lies on top for birds to eat, some is buried too deep, and some falls in clumps. Farmers had to use a lot of extra seed.

Around 1701, an English farmer named **Jethro Tull** built a horse-drawn **seed drill**. A rotating cylinder with grooves dropped seeds one by one into small channels cut by blades, and a harrow behind covered them. Seeds went in at an even depth in straight rows, so more of them sprouted and less seed was wasted. Rows also let a horse-drawn hoe pass between them to kill weeds. Tull explained his methods in his

book *Horse-Hoeing Husbandry* (1731). Modern grain drills and planters follow the same idea, now with steel discs, precise seed meters and satellite guidance.

Field crops depend on the right **seeding rate** and depth. Wheat is usually drilled about 1 to 1½ inches deep in rows 6 to 8 inches apart, at roughly 60 to 120 pounds of seed per acre, depending on the region. Corn is planted 1½ to 2 inches deep with each seed spaced several inches apart in rows 30 inches wide. Whether by hand or by machine, the farmer's goal is the same as the sower's hope in the parable: seed in good ground that brings forth fruit.

PICTURE STUDY



The Sower, Jean-François Millet, 1850 · Oil on canvas · Museum of Fine Arts, Boston

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

Millet grew up on a farm in Normandy, France, and painted the hard work of farmers with great respect. His sower strides downhill, scattering seed with a powerful swing of his arm. This was how most grain was sown for thousands of years, before seed drills became common.

Look closely

- Follow the sower's arm and hand. Where is the seed going?
- Find the seed bag. How does he carry it?
- Find the birds behind him. What are they doing?
- Look in the distance for another farmer at work. What job is he doing?

Talk about it

1. What problems of broadcast sowing can you see in this painting?
2. How would Jethro Tull's seed drill have changed this man's work?
3. Why do you think Millet made the sower look so strong and important?

HANDS-ON PROJECT

Broadcast or Drill? A Mini-Field Trial

You will plant two small “fields” with the same number of seeds, one broadcast and one drilled in rows at an even depth, and compare how many seeds sprout and how even the stand is.

You will need

- Two garden plots about 2 feet by 2 feet, or two large trays or window boxes with drainage and potting mix
- Seeds of wheat, oats, cereal rye or grass (feed-store or garden-center wheat or oats work well), about 200 seeds
- A ruler, a pencil or stick to make grooves, and a rake or your fingers
- Craft sticks for labels and a watering can
- Your journal and a calculator

Steps

1. Prepare both plots or trays the same way: loosen, level and moisten the soil.
2. Count out two piles of 100 seeds each.
3. Plot A (broadcast): stand above the plot and scatter 100 seeds evenly by hand. Lightly rake or brush the surface once, as a farmer would harrow.
4. Plot B (drilled): use a pencil to make 4 straight grooves 1 inch deep and 6 inches apart. Drop 25 seeds evenly into each groove and cover them.
5. Label both plots and water them the same way. If birds visit, note it, but do not cover either plot unless you cover both.
6. Count the seedlings in each plot after 7, 10 and 14 days. Calculate the germination percent: $\text{seedlings} \div 100 \times 100$.
7. Look at how even each stand is. Measure the heights of 5 seedlings in each plot on day 14.
8. Write a conclusion comparing the two methods. Then calculate: if a farmer drills 100 pounds of wheat per acre, how many pounds does a 40-acre field need?

Tips

- Grow your trial in fall or early spring for wheat or rye; oats grow well in spring.
- If you visit a farm show, a county fair or an agricultural museum, look for an old horse-drawn seed drill or walking plow and draw it.

Check your work

- ☐ I can explain how a moldboard plow turns the soil.
- ☐ I can explain two advantages of the seed drill over broadcasting.
- ☐ I calculated the germination percent for both plots.

NATURE JOURNAL

1. Draw a moldboard plow from the side, labeling the coulter (cutting blade), share, moldboard and handles, and show the furrow it leaves.
2. Draw a simple diagram of how a seed drill drops seeds into a groove and covers them.
3. Draw your two plots from above on day 14, showing where the seedlings came up.

From history. Jethro Tull studied law and music before illness sent him home to farm in Berkshire, England. Frustrated that his workers sowed seed wastefully, he borrowed ideas from the grooved sound board of an organ to design his seed drill. Another invention, Cyrus McCormick's horse-drawn reaper of 1831, did for the harvest what the drill did for planting.

COMMON MISTAKES

- Thinking the seed drill and the plow do the same job; the plow prepares the soil, and the drill plants the seed.
- Planting grain seed too deep, so it runs out of food before reaching the light.
- Comparing two plots that were watered or lit differently.

Make it a game • Plow and Drill Debate. Hold a friendly debate between an old farmer with a moldboard plow and Jethro Tull with his seed drill. Take turns arguing your side: furrows, steel plows on tough prairie soil, broadcast sowing waste and seeding rate. Your parent is the judge. Switch sides halfway, then name one way each tool shaped farming. Judge awards a ribbon.

Scripture. “Behold, a sower went forth to sow; And when he sowed, some seeds fell by the way side, and the fowls came and devoured them up:” (Matthew 13:3-4, KJV)

Jesus’ listeners knew exactly how broadcast seed was lost to birds and hard paths. His parable teaches us to receive God’s Word like good, prepared soil.

UNIT 7

PLANTING

Spring is planting time, and good planting starts with good planning. In this unit you will learn what goes into a potting mix and how to repot a crowded plant, then make new plants for free from cuttings. You will design a garden on paper with a sun map and a crop-rotation plan, and finally go out to the field to learn how farmers have planted grain through history, from the hand-sower of the Bible to Jethro Tull's seed drill and the steel plow.

You will also prepare a potted plant the way a fair exhibitor would, judge four plants and give reasons, and give a short illustrated talk teaching someone else a planting skill, just as 4-H members do. Whether you have a big yard, a balcony or a single sunny window, there is planting to do this spring.

PREREQUISITES

- Knows soil texture and organic matter from Unit 3
- Knows what plants need (light, water, nutrients) from Unit 5
- Can draw to scale on graph paper

MASTERY CHECKLIST

- ☐ I can name the ingredients of a potting mix and explain what each one does.
- ☐ I can recognize a root-bound plant and repot it correctly.
- ☐ I can take and root a stem cutting and explain why the new plant is identical to its parent.
- ☐ I can draw a garden plan to scale with a sun map and a four-year crop rotation.
- ☐ I can explain how the moldboard plow and the seed drill changed farming, and compare broadcast and drilled planting.

LESSONS IN THIS UNIT

7.1 Potting Mixes and Repotting

2 sessions of 45 minutes

7.2 Propagation from Cuttings

2 sessions of 45 minutes

7.3 Garden Design and Crop Rotation

2 sessions of 45 minutes

7.4 Field Planting Through History: The Plow and the Seed Drill

2 sessions of 45 minutes

UNIT 7 REVIEW

Answer each question. Use complete sentences for explanations and show your work for calculations. The review is worth 50 points.

1. (5 pts)

Name three potting-mix ingredients and the job of each.

2. (5 pts)

Why should you not use garden soil in a pot, or put gravel in the bottom?

3. (5 pts)

List three signs that a plant is root-bound.

4. (5 pts)

Name three things a fair judge looks for in a potted plant exhibit.

5. (5 pts)

Where on a stem should you cut a softwood cutting, and why?

6. (5 pts)

Why is a plant grown from a cutting called a clone? Give one reason growers use clones.

7. (5 pts)

Sort into plant families: tomato, broccoli, bean, squash, potato, radish, pea, cucumber.

8. (5 pts)

Give two reasons for crop rotation.

9. (5 pts)

How did Jethro Tull's seed drill improve on broadcast sowing?

10. **5 pts**

In a trial, 72 of 100 drilled seeds sprouted and 51 of 100 broadcast seeds sprouted. What are the germination percents, and what is the difference?

ANSWER KEY

1. Any three: peat or coir hold water; perlite adds air and drainage; vermiculite holds water and nutrients; compost or bark adds nutrients.
2. Garden soil packs down and drains poorly in a pot; gravel raises the soggy zone instead of improving drainage. Use potting mix and a pot with drainage holes.
3. Roots coming out of drainage holes; water runs straight through; the plant dries out very quickly; roots circling the pot; slow growth.
4. Any three: healthy color, no pests or disease, no dead or yellow leaves, balanced shape, suitable size for the pot, clean pot, correct label.
5. Just below a node, because roots form most easily at nodes.
6. It has exactly the same traits as its parent. Growers use them to keep a variety true, such as 'Honeycrisp' apples, whose seeds would not grow the same.
7. Nightshade: tomato, potato. Cabbage: broccoli, radish. Legume: bean, pea. Squash: squash, cucumber.
8. It leaves behind soil-borne diseases and pests of a plant family, and it balances nutrients (for example, legumes add nitrogen for the next crop).
9. It placed seeds at an even depth in straight rows, so more sprouted, less seed was wasted or eaten by birds, and rows could be hoed for weeds.
10. Drilled 72%, broadcast 51%; a difference of 21 percentage points.

PORTFOLIO PIECE: MY SPRING PLANTING RECORD

Assemble a planting record like a 4-H or Junior Master Gardener project book. Include your potting-mix recipe and repotting notes, your fair-exhibit plant and judging card, your cuttings trial results and presentation-talk notes, your sun map and four-year garden plan, and your broadcast-or-drill field trial. Add a page listing what you actually planted this spring with dates, and the row or container you planned to share.

LOOK FOR	WHAT IT MEANS
Plans and maps	The garden plan is to scale with north, sun hours, beds, spacing and a four-year rotation.
Experiments	The cuttings and field trials have dated records, tables and conclusions.
Exhibit and judging	The exhibit plant is described with what was done to prepare it, and four plants are placed with reasons.
Communication	Presentation-talk notes or poster are included, with listener feedback.
Records and presentation	Planting dates, costs if any, and results are recorded neatly and completely.

UNIT 8

PLANT HEALTH

By early summer the garden is growing fast, and so are the creatures and germs that feed on it. In this unit you will become a garden doctor. You will learn how fungi, bacteria and viruses cause plant diseases and how the disease triangle explains when they strike; how insect pests grow through their life cycles and where they are easiest to stop; how beneficial insects and integrated pest management (IPM) keep pests in check without harsh chemicals; and how weeds compete with crops for light, water and nutrients.

Every lesson trains your eye with real scouting in a garden, a park or a few pots, careful records, and simple experiments. Good stewards of a garden are watchful, patient and diligent. The sluggard's field in Proverbs was "all grown over with thorns"; yours will be tended.

PREREQUISITES

- Knows plant nutrients and deficiency signs from Unit 5
- Knows crop rotation and plant families from Unit 7
- Can use a magnifying glass and keep a dated log

MASTERY CHECKLIST

- ☐ I can explain the disease triangle and tell fungal, bacterial and viral diseases apart by their signs.
- ☐ I can describe complete and incomplete metamorphosis and name the best stage to control a pest.
- ☐ I can identify at least four beneficial insects and list the steps of integrated pest management.
- ☐ I can explain how weeds compete with crops and choose the right way to control annual and perennial weeds.
- ☐ I can scout a garden and record what I find like a garden doctor.

LESSONS IN THIS UNIT

8.1 Plant Diseases: Fungi, Bacteria and Viruses

2 sessions of 45 minutes

8.2 Insect Pests and Their Life Cycles

2 sessions of 45 minutes

8.3 Beneficial Insects and Integrated Pest Management

2 sessions of 45 minutes

8.4 Weeds and Competition

2 sessions of 45 minutes

UNIT 8 REVIEW

Answer each question. Use complete sentences for explanations. The review is worth 50 points.

1. **5 pts**

Draw or describe the disease triangle and explain how removing one side prevents disease.

2. **5 pts**

Match each to fungus, bacterium or virus: powdery mildew; mosaic pattern spread by aphids; wilt spread by cucumber beetles.

3. **5 pts**

Name three ways to prevent fungal diseases on tomatoes.

4. **5 pts**

What are the stages of complete and incomplete metamorphosis? Give one garden pest for each.

5. **5 pts**

You find a cluster of shiny bronze eggs under a squash leaf. What are they and what should you do?

6. **5 pts**

Why should you leave a hornworm that is covered with small white cocoons?

7. **5 pts**

Name four beneficial insects and what each does.

8. **5 pts**

List the five steps of IPM in order.

9. **5 pts**

Name four things weeds compete with crops for.

10. **5 pts**

Why is tilling a bad way to control bindweed, and what does “one year’s seeding, seven years’ weeding” mean?

ANSWER KEY

1. Host, pathogen and favorable environment. Removing any one (for example, keeping leaves dry, planting a resistant variety, or removing the infected plant) stops the disease.
2. Powdery mildew: fungus. Mosaic spread by aphids: virus. Wilt spread by cucumber beetles: bacterium (bacterial wilt).
3. Any three: resistant varieties, crop rotation, spacing and pruning for air, watering the soil in the morning, mulching, not working among wet plants, removing diseased leaves.
4. Complete: egg, larva, pupa, adult (tomato hornworm, cabbageworm, Japanese beetle). Incomplete: egg, nymph, adult (squash bug, aphid).
5. Squash bug eggs. Scrape them off or press them with tape and destroy them before they hatch.
6. It has been parasitized by tiny wasps; it will die, and the new wasps that hatch will attack more hornworms.
7. Any four: ladybugs and larvae eat aphids; lacewing larvae eat aphids and mites; hover fly larvae eat aphids; parasitoid wasps lay eggs in pests; ground beetles eat slugs and cutworms; bees pollinate.
8. Prevent; scout and identify; set a threshold; control with the least harmful methods first; evaluate.
9. Light, water, nutrients and space.
10. Bindweed spreads by creeping roots, and tilling chops them into pieces that each grow a new plant. The saying means that weeds allowed to set seed fill the soil’s seed bank with seeds that keep sprouting for years.

PORTFOLIO PIECE: A GARDEN DOCTOR'S CASEBOOK

Make a casebook of the plant problems you found and studied this unit, like a plant clinic's records. Include your mold test, your disease scouting notes, your pest scouting log and life-cycle drawings, your helper flower pot observations and IPM plan, your weed competition graph and pressed-weed page. For at least three "cases," write the symptom, your diagnosis (disease, pest, weed or nutrient problem), the evidence, and your recommended treatment, choosing the least harmful method first.

LOOK FOR	WHAT IT MEANS
Careful scouting	Logs have dates, plant numbers, counts and clear drawings.
Correct diagnosis	Each case names the likely cause with evidence and tells disease, pest, weed and nutrient problems apart.
IPM thinking	Treatments follow IPM order, beginning with prevention and the least harmful controls.
Experiments	The mold test and weed competition experiment have data, graphs and conclusions.
Presentation	The casebook is neat, organized and well illustrated.

8.1 PLANT DISEASES: FUNGI, BACTERIA AND VIRUSES

OBJECTIVES

- Explain the disease triangle: host, pathogen and environment.
- Describe common fungal, bacterial and viral plant diseases and how each spreads.
- Test how moisture and temperature affect mold growth, and scout plants for disease.

Warm-up. Look closely at a leaf with spots, a moldy strawberry, or a picture of a sick plant. Draw what you see. Write three guesses about what could have caused it.

WATCH

Scouting and Identifying Tomato Diseases

Penn State Extension • 8:20

<https://www.youtube.com/watch?v=eQjmP9Jr6hA>

WHEN TO WATCH

After the third core idea. Make a list of each disease and the clue that identifies it.

BACKUP VIDEO

Identification of Early Blight of Tomato

NC State Extension • 2:37

<https://www.youtube.com/watch?v=rG7YdE3JJwg>

A short close-up of early blight's target-shaped spots, before you scout.

KEY TERMS

pathogen

A living thing that causes disease, such as a fungus, a bacterium or a virus.

disease triangle

The idea that disease happens only when a susceptible host, a pathogen and a favorable environment come together.

spore

A tiny reproductive cell of a fungus, carried by wind, water, insects or tools.

symptom

A change in the plant caused by disease, such as spots, wilting or yellowing.

resistant variety

A plant variety bred to fight off a particular disease.

CORE IDEAS

A plant disease needs three things at once, and plant doctors draw them as the **disease triangle**: a **host** plant that can catch the disease, a **pathogen** (the germ), and an **environment** that helps it, usually warm, wet or humid weather. Take away any side of the triangle and the disease cannot happen. Every prevention method works by removing one side.

Fungi cause most plant diseases. They spread by microscopic **spores** carried by wind, splashing rain, tools and hands, and most need moisture on leaves to infect. **Powdery mildew** looks like white flour dusted on squash and cucumber leaves. **Early blight** of tomatoes makes brown spots with rings like a target, ringed with yellow, starting on the lowest leaves. **Rust** makes orange, powdery bumps. **Damping off** makes seedlings suddenly collapse at the soil line, usually in wet, cool, crowded trays. Late blight, which destroyed the potato crop in the Irish famine of the 1840s, is caused by a fungus-like water mold.

Bacteria are single-celled germs that enter plants through wounds and natural openings like stomata, and spread by splashing water, tools, hands and insects. **Bacterial leaf spot** makes small, dark, water-soaked spots. **Bacterial wilt** of cucumbers and melons makes whole vines wilt and die, and it is carried from plant to plant by cucumber beetles. **Viruses** are even smaller and can only multiply inside living cells. They are spread mostly by sap-sucking insects such as aphids, thrips and whiteflies, and by hands and tools. Viral diseases often make yellow and green **mosaic** patterns and twisted, stunted leaves. There is no cure for a virus-infected plant; it must be removed.

Most garden disease control is **prevention**. Choose **resistant varieties** (tomato tags list codes such as V, F and N for resistance to certain wilts and nematodes). Rotate

crops. Space plants and prune lower leaves so air can dry them. Water the soil, not the leaves, and water in the morning so leaves dry quickly. Mulch to stop soil from splashing spores onto leaves. Do not work among wet plants. Clean tools, and put diseased plants in the trash, not the compost.

Diseases are a reminder that we live in a world that groans under the curse and needs careful tending. Not every microbe is an enemy, though: as you learned in Unit 3, most soil fungi and bacteria are helpers, breaking down dead matter and feeding plants. A good gardener learns to tell friend from foe.

PICTURE STUDY



Blue Mould (Micrographia, Scheme XII), Robert Hooke, 1665 · Engraving from *Micrographia* ·
Micrographia, London

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

Robert Hooke was an English scientist who built one of the best early microscopes. In 1665 he published *Micrographia*, a book of drawings of tiny things seen under magnification. Here he shows the “blue mould” that grows on old leather and bread, revealing for the first time that mold is made of tiny plant-like threads and stalks bearing spores.

Look closely

- Find the long threads. These are hyphae, the feeding threads of the fungus.
- Find the round heads at the tops of the stalks. What do you think is inside them?
- Compare the sizes. How much bigger than real life do you think these drawings are?
- Look at the careful shading. How did Hooke show which parts are round?

Talk about it

1. If one round head bursts and releases spores into the air, how might the mold spread to a garden plant?
2. Why do you think people in 1665 were amazed by this picture?

3. How does knowing that fungi spread by spores help a gardener prevent disease?

Safety first. Keep mold-experiment bags sealed the whole time and throw them away unopened; some people are allergic to mold spores. Wash your hands after handling diseased plants, and do not touch healthy plants until you have.

HANDS-ON PROJECT

The Disease Triangle Mold Test and a Scouting Walk

You will grow bread mold in sealed bags to test how moisture and temperature, the environment side of the triangle, affect a fungus. Then you will scout real plants for signs of disease.

You will need

- 4 slices of the same bread (homemade or bakery bread molds faster than bread with preservatives)
- 4 zip bags, a marker and tape
- A spray bottle of water
- A warm dark cupboard and a refrigerator
- A magnifying glass, a ruler, your journal and colored pencils
- Garden plants, houseplants, or plants at a park or garden center to scout (with permission)

Steps

1. Wipe each slice across a kitchen counter or a windowsill to pick up spores. Label bags: Dry-Warm, Wet-Warm, Dry-Cold, Wet-Cold.
2. Spray two slices with 5 squirts of water. Leave two dry. Seal each slice in its bag and tape the bags shut.
3. Put the Warm bags in a dark cupboard and the Cold bags in the refrigerator.
4. Every two days for 10 days, look through the bag with a magnifier. Estimate what percent of each slice is covered with mold and record the colors you see. Never open the bags.
5. Make a bar graph of mold coverage on day 10. Which side of the disease triangle did you change? Write a conclusion.
6. Scouting walk: examine 10 plants. For each, check the top and underside of leaves, stems and fruit with a magnifier.
7. Record any spots, powder, mosaic patterns, wilting or rot. Draw each and write your best guess: fungus, bacteria, virus, or not a disease (such as a nutrient problem or insect damage).

8. Throw the sealed mold bags away unopened.

Tips

- Squash and zucchini leaves in midsummer are a good place to find powdery mildew.
- Compare your scouting finds with pictures on your state extension service's plant diagnostic website.

Check your work

- ☐ I can draw and explain the disease triangle.
- ☐ I can name one fungal, one bacterial and one viral disease and how each spreads.
- ☐ My mold test shows which environment grew the most fungus.

NATURE JOURNAL

1. Draw the disease triangle with an example for each side: tomato (host), early blight fungus (pathogen), warm rainy weather (environment).
2. Draw a tomato leaf with early blight and a squash leaf with powdery mildew side by side, labeled.
3. Draw your four bread slices on day 10 with their mold coverage.

From history. In the 1840s a fungus-like disease called late blight swept through the potato fields of Ireland, where most families depended on potatoes for food. Over a million people died in the famine, and many more left for America. Scientists studying the disease afterward helped found the science of plant pathology.

COMMON MISTAKES

- Watering leaves in the evening so they stay wet all night.
- Putting diseased plants in the compost pile, where spores can survive.
- Assuming every yellow or spotted leaf is a disease; check for nutrients and insects too.

Make it a game • Triangle Rescue. Draw a disease triangle with host, pathogen and environment on its corners. Parent names a plant disease; you say whether it is fungal, bacterial or viral, how it spreads and which corner you would break to stop it, such as a resistant variety. Remove a corner of paper for each fix. Get all three corners removed in five rounds.

8.2 INSECT PESTS AND THEIR LIFE CYCLES

OBJECTIVES

- Describe complete and incomplete metamorphosis with garden examples.
- Identify common garden pests by their damage and life stages.
- Choose the best life stage and method to control a pest, and keep a scouting record.

Warm-up. Look at a plant with chewed leaves, or at a picture of one. Are the holes in the middle of the leaf or on the edges? Is there a slimy trail, sticky leaves, or tiny specks underneath? Write what kind of creature you think did it and why.

WATCH

Insect Life Cycles

Ag PhD · 5:03

<https://www.youtube.com/watch?v=C7tIACCPv8w>

WHEN TO WATCH

After the first core idea. Pause at each stage and write whether it is complete or incomplete metamorphosis.

BACKUP VIDEO

How to Prevent and Kill SQUASH BUGS

Next Level Gardening · 7:18

https://www.youtube.com/watch?v=3MZ_4R5GDC4

With the third core idea, to see squash bug eggs, nymphs and adults on real plants.

KEY TERMS

complete metamorphosis

A life cycle with four very different stages: egg, larva, pupa and adult.

incomplete metamorphosis

A life cycle with three stages: egg, nymph and adult; nymphs look like small adults without full wings.

larva

The feeding, growing stage of an insect with complete metamorphosis, such as a caterpillar or grub.

nymph

The young stage of an insect with incomplete metamorphosis, such as a young squash bug or aphid.

scouting

Regularly inspecting plants to find and count pests, beneficial insects and damage.

CORE IDEAS

Insects grow up in one of two ways. In **complete metamorphosis** there are four stages: **egg**, **larva** (a caterpillar, grub or maggot that eats and grows), **pupa** (a resting stage in which the body is rebuilt), and **adult**. Butterflies, moths, beetles, flies and wasps grow this way. In **incomplete metamorphosis** there are three stages: **egg**, **nymph** and **adult**. The nymph looks like a small, wingless adult and molts several times as it grows. True bugs (such as squash bugs and stink bugs), aphids and grasshoppers grow this way.

The **tomato hornworm** shows complete metamorphosis. A large sphinx moth lays single round green eggs under tomato leaves. The green caterpillar, with white stripes and a horn on its tail, eats for about a month and can grow longer than your finger, stripping leaves overnight. It then burrows into the soil to pupate, often through the winter, and emerges as a moth. The **imported cabbageworm**, the velvety green caterpillar of the white cabbage butterfly, chews holes in cabbage, broccoli and kale. Japanese beetles and Colorado potato beetles spend their larval stage as grubs or larvae and chew leaves as adults.

The **squash bug** shows incomplete metamorphosis. Adults lay clusters of shiny bronze eggs on the undersides of squash and pumpkin leaves; gray nymphs hatch and suck sap with needle-like mouths, and the leaves wilt and turn brown. **Aphids** are tiny soft insects that cluster under leaves and on new shoots, sucking sap and leaving sticky “honeydew.” In summer an aphid colony can multiply astonishingly fast, which is why they must be caught early.

Knowing the life cycle tells you **when and where to act**. Squash bug eggs can be scraped off or pressed with tape before they hatch; nymphs and adults can be hand-

picked into soapy water in the morning. Hornworms are easy to hand-pick once you spot their dark droppings on the leaves below. Floating row covers keep cabbage butterflies from laying eggs on young plants. Turning the soil in fall exposes hornworm pupae to birds. A hornworm covered in small white cocoons has been parasitized by a tiny wasp; leave it, because new helper wasps will hatch.

Good gardeners **scout** weekly: walk the garden, turn over leaves, count pests and helpers on a set number of plants, and write it down. Finding ten eggs on Monday is far easier than fighting a hundred nymphs two weeks later. Diligence in small things prevents big losses.

PICTURE STUDY



Butterflies on a Banana Plant, Maria Sibylla Merian, 1705 · Hand-colored engraving from *Metamorphosis insectorum Surinamensium* · *Metamorphosis insectorum Surinamensium*, Amsterdam

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

Maria Sibylla Merian was a German-born naturalist and artist who raised caterpillars from childhood to watch them change. At 52, she sailed to Surinam in South America to study tropical insects. Her plates were among the first to show an insect's whole life cycle together with the plant it eats, and they helped prove that caterpillars come from eggs, not from mud as some people then believed.

Look closely

- Find each stage of the butterfly's life: the caterpillar, the pupa and the adults. Which stage is missing?
- Look at the caterpillar. What is it eating, and what does the damage look like?
- Find the lizard and the wasp. Are they part of the butterfly's life cycle, or other creatures that share the plant?
- Compare the caterpillar and the adult butterfly. How different are they?

Talk about it

1. Is this complete or incomplete metamorphosis? How do you know?
2. At which stage does this insect do the most damage to the plant?

3. Merian raised caterpillars patiently for years to make her pictures. What can a gardener learn by watching a pest's whole life cycle?

Safety first. Wear gloves when hand-picking pests, and wash your hands afterward. Some caterpillars have stinging hairs; never touch fuzzy or spiny caterpillars you do not know. Pesticides are handled only by adults.

HANDS-ON PROJECT

A Pest Scouting Log and a Life-Cycle Jar

You will scout a garden (or a park, or houseplants) every few days for two weeks and keep a pest and helper log. If you find a caterpillar or a group of aphids, you may raise it in a jar to watch its life cycle.

You will need

- A garden, a few vegetable pots, a park flower bed or houseplants
- A magnifying glass, gloves and a small cup of soapy water
- Your journal, a ruler and colored pencils
- Optional: a large clear jar with a cloth lid held by a rubber band, a stick, and fresh leaves of the plant the insect was eating

Steps

1. Choose 10 plants to scout. Number them on a map in your journal.
2. Every 2 to 3 days, check each plant: the top and underside of five leaves, the stem and any flowers or fruit.
3. Record in a table: date, plant number, pest found (and its life stage: egg, larva, pupa, nymph or adult), number seen, helpers seen, and damage (holes, wilting, sticky leaves, droppings).
4. Use a field guide or your extension service's website to identify each insect. Draw it.
5. For each pest you find, write which control fits its stage: scrape off eggs, hand-pick into soapy water, cover with row cover, or leave alone if parasitized.
6. Life-cycle jar (optional): place a caterpillar with fresh leaves of its food plant and a stick in the jar. Add fresh leaves daily and clean out droppings. Record each change and the date until the adult emerges, then release it far from your garden or, if it is a pest, decide with an adult what to do.
7. At the end of two weeks, graph the number of each pest over time and write a short report.

Tips

- Look for hornworms by finding their large dark droppings on lower leaves, then looking straight up.
- Early morning is best for hand-picking squash bugs and beetles; they move slowly when cool.

Check your work

- ☐ I can name the stages of complete and incomplete metamorphosis.
- ☐ I can name two pests and the best stage to control each one.
- ☐ My scouting log has at least five dates with counts.

NATURE JOURNAL

1. Draw the four stages of the tomato hornworm's life cycle in a circle with arrows.
2. Draw the three stages of the squash bug's life cycle in a circle with arrows, and the egg cluster actual size.
3. Draw three kinds of leaf damage: chewed holes, edge-notching and stippling from sap-suckers, and label likely causes.

From history. In the 1870s Rocky Mountain locusts swept across the Great Plains in clouds so vast they darkened the sky, eating crops, fence posts and even clothing on washlines. Farm families recorded the damage in letters and diaries. Strangely, by about 1900 this locust had disappeared entirely, and scientists still study why.

COMMON MISTAKES

- Waiting until plants are badly damaged to look for pests.
- Killing a hornworm covered with white cocoons, which would release helpful wasps.
- Looking only at the tops of leaves; most eggs and aphids are underneath.

Make it a game • Bug Life Cycle Cards. Make cards for egg, larva, pupa, adult and egg, nymph, adult. Parent names a garden pest, like a cabbage worm or aphid, and you build its life cycle in order, calling it complete or incomplete metamorphosis. Then match one damage clue to each pest. Beat your best time for building all the cycles correctly.

8.3 BENEFICIAL INSECTS AND INTEGRATED PEST MANAGEMENT

OBJECTIVES

- Identify beneficial insects and explain how they help the garden.
- List the steps of integrated pest management (IPM) in order.
- Plant a pot or bed to attract beneficial insects and make an IPM plan for one pest.

Warm-up. Look for any insect outdoors or in pictures. Decide whether you think it is a helper, a pest, or neither, and write your reason. Then look at it again: what is it eating, or what is eating it?

WATCH

5 IPM strategies to keep your garden pest free!

MU Extension - Bug n' Garden • 8:31

<https://www.youtube.com/watch?v=gmYz3Py7yUE>

WHEN TO WATCH

After the core ideas. Pause at each IPM step and write it in your journal.

Note: From the University of Missouri Extension; a Master Gardener explains each step of IPM in a demonstration garden.

KEY TERMS

beneficial insect

An insect that helps the garden by eating pests, parasitizing them, pollinating flowers or breaking down dead matter.

predator

An animal that catches and eats other animals, such as a ladybug eating aphids.

parasitoid

An insect, usually a tiny wasp or fly, that lays its eggs in or on a pest, whose body then feeds its young.

integrated pest management (IPM)

A step-by-step way of controlling pests that combines prevention, scouting and the least harmful controls first.

threshold

The amount of pest damage a gardener can accept before taking action.

CORE IDEAS

Most insects in a garden are not pests at all. Many are **beneficial**: pollinators such as bees, decomposers such as beetles that break down dead matter, and the pest-eaters. **Ladybugs** (lady beetles) and especially their alligator-shaped larvae eat aphids by the hundreds. **Green lacewing** larvae, nicknamed “aphid lions,” grab aphids, mites and small caterpillars. **Hover fly** larvae eat aphids too, while the adults, which look like small bees, sip nectar. **Ground beetles** hunt slugs and cutworms at night, and **spiders** catch all kinds of insects.

Tiny **parasitoid wasps**, many smaller than a grain of rice and harmless to people, lay their eggs inside aphids, caterpillars and hornworms; the wasp larvae feed inside the pest and kill it. A swollen, tan, papery aphid is called an aphid “mummy” and is a sign the wasps are at work. Learning to recognize helpers in every life stage, including the strange-looking ladybug larva, keeps you from destroying your own allies.

You can invite helpers to stay. Most adult beneficial insects need **nectar and pollen** from small flowers: dill, fennel, cilantro and parsley allowed to bloom, sweet alyssum, yarrow, zinnias, marigolds and buckwheat. They also need water, shelter in mulch and perennial plants, and freedom from broad-spectrum sprays, which kill helpers along with pests. Buying boxes of ladybugs often fails, because most fly away; growing a welcoming garden works better.

Integrated pest management, or IPM, is the method extension services teach farmers and gardeners. Its steps, in order: 1) **Prevent** problems with healthy soil, resistant varieties, rotation and good spacing. 2) **Scout** regularly and **identify** what you find, helper or pest. 3) Decide on a **threshold**: a few holes in a leaf may be fine; a plant being stripped is not. 4) **Control**, choosing the least harmful methods first: cultural (changing planting time, removing infested plants), physical (hand-picking, row covers, traps, a strong spray of water), and biological (helpers). Pesticides come last, are handled only by adults, and must follow the label. 5) **Evaluate**: did it work? Write it down for next year.

IPM is good stewardship in action. God placed Adam in the garden “to dress it and to keep it.” Keeping a garden means working with the creatures He made, encouraging the helpers, and using wisdom and restraint in dealing with the pests.

PICTURE STUDY



Insects, Jan van Kessel the Elder, 1650s–1660s · Oil on copper · Fitzwilliam Museum, Cambridge

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

Jan van Kessel was a Flemish painter from Antwerp, from a family of famous painters. He painted insects so carefully, from real specimens, that many can be identified today. In the 1600s naturalists were just beginning to study insects closely, and paintings like this were a way of collecting and admiring them.

Look closely

- Count how many different kinds of insects you can find.
- Find any beetles. Could any be ladybugs or ground beetles?
- Find a caterpillar and a butterfly or moth. Might they be the same species at different stages?
- Choose one insect and look at its legs, antennae and wings. Draw it.

Talk about it

1. Which of these insects might be helpers in a garden, and which might be pests? Give reasons.
2. Why is it important to identify an insect before deciding to remove it?
3. What can a gardener learn by looking at insects as closely as this painter did?

Safety first. Do not touch bees or wasps. Handle insects gently, if at all, and wash your hands afterward. Never use or mix pesticides; any spraying is done by an adult following the label.

A Helper Flower Pot and an IPM Plan

You will plant a pot or small bed of flowers that feed beneficial insects, observe which insects visit, and write an IPM plan for one garden pest from Lesson 8.2.

You will need

- A 12-inch pot with drainage holes and potting mix, or a small sunny garden corner
- Seeds or small plants of sweet alyssum, dill, cilantro, zinnia, marigold or yarrow
- A shallow dish with pebbles and water (an insect drinking station)
- A magnifying glass, a field guide to insects or an insect-ID website (with a parent), and your journal

Steps

1. Plant a mix of at least three kinds of small-flowered plants in your pot or corner, and water well. Place it near your vegetables.
2. Set the pebble dish nearby and keep it filled so insects can drink without drowning.
3. Once flowers bloom, watch the pot for 10 minutes at the same time on three different days. Record each visitor: what it is, what it is doing, and whether it is a helper, pest or neither.
4. Look for ladybug larvae, lacewing eggs on thin stalks, hover flies and aphid mummies on nearby plants, and draw any you find.
5. Choose one pest from your Lesson 8.2 scouting. Write an IPM plan with five headings: Prevent, Scout, Threshold, Control (least harmful first), Evaluate.
6. Under each heading, write specific actions for that pest. For example, for squash bugs: Prevent with row covers until flowering; Scout leaf undersides twice a week; Threshold of more than one egg cluster per plant; Control by scraping eggs and hand-picking; Evaluate by counting nymphs each week.
7. Share your plan with your family and post it in the garden shed or by the door.

Tips

- Leave a few herbs like dill and cilantro to flower; their flat clusters of tiny flowers are favorites of helper insects.
- Junior Master Gardener and 4-H entomology projects include insect collections and identification; check your county extension office.

Check your work

- ☐ I can name four beneficial insects and what each eats or does.
- ☐ I can list the five steps of IPM in order.
- ☐ My IPM plan gives specific actions for one pest.

NATURE JOURNAL

1. Draw a ladybug in all four life stages: egg cluster, larva, pupa and adult. Many people do not recognize the larva.
2. Draw an aphid colony with a ladybug larva, a lacewing larva and an aphid mummy among them.
3. Make a two-column chart of “Garden Helpers” and “Garden Pests” with drawings.

From history. In 1888 California’s young orange groves were being destroyed by an insect called the cottony cushion scale. A government entomologist, Charles Valentine Riley, sent a scientist to Australia, who brought back a small ladybug called the vedalia beetle. Within about two years the beetles had brought the scale under control and saved the citrus industry, one of the first great successes of biological control.

COMMON MISTAKES

- Squashing ladybug larvae because they look like pests.
- Spraying at the first sign of a pest instead of scouting and waiting to see if helpers arrive.
- Buying ladybugs instead of planting flowers that keep helpers nearby.

Make it a game • Helper or Pest? Cut out paper bugs or draw them: ladybug, lacewing, parasitoid wasp, aphid, beetle. Parent flashes one; you sort it into helper or pest and say what it does for the garden. Then arrange the steps of integrated pest management in order, ending with the threshold. Race for ten correct, then add a surprise bug that fits neither.

Scripture. “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.” (Genesis 2:15, KJV)

To “keep” a garden is to guard and care for it. IPM is a careful, thoughtful way of keeping the garden God gives us.

8.4 WEEDS AND COMPETITION

OBJECTIVES

- Explain how weeds compete with crops for light, water, nutrients and space.
- Identify common annual and perennial weeds and how each spreads.
- Measure the effect of weed competition on a crop plant in a pot experiment.

Warm-up. Pull one weed from a sidewalk crack, lawn or garden (with permission and gloves). Look at its roots. Are they a single deep root, a mat of fine roots, or runners? Draw it, roots and all.

WATCH

Know your weeds: how to identify and manage them | The RHS

RHS - Royal Horticultural Society · 4:07

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

WHEN TO WATCH

After the second core idea. Sort each weed shown into annual or perennial.

KEY TERMS

weed

A plant growing where it is not wanted, especially one that competes with crops.

competition

When plants struggle for the same limited light, water, nutrients and space.

annual weed

A weed that sprouts, flowers, sets seed and dies in one year, such as lamb's-quarters, pigweed or crabgrass.

perennial weed

A weed that lives for years and spreads by roots, rhizomes or runners as well as seed, such as dandelion, bindweed or quackgrass.

seed bank

The supply of weed seeds lying in the soil, waiting for the right conditions to sprout.

CORE IDEAS

A **weed** is simply a plant in the wrong place: a tomato seedling in the lawn is a weed, and so is a dandelion in the carrot bed. Weeds harm crops through **competition**. They shade crops, drink the water, take up nutrients, and crowd roots, and many grow faster than garden vegetables. Weeds also shelter pests and diseases. Studies at many universities show that crops left weedy during their first several weeks can lose a large part of their harvest.

Annual weeds live one season and spread by seed, and they produce enormous numbers: a single large pigweed or lamb's-quarters plant can make tens of thousands of seeds, and many stay alive in the soil for years. This store of seeds is called the **seed bank**. That is why gardeners say, "One year's seeding means seven years' weeding." Common annual weeds include lamb's-quarters, pigweed, crabgrass, purslane and chickweed.

Perennial weeds live for years and spread underground as well as by seed. Dandelions grow a long taproot that resprouts if broken off. Bindweed, quackgrass and Canada thistle send out creeping roots or **rhizomes**; every small piece left in the soil can grow a new plant, so tilling them can actually spread them. Perennials must be dug out completely, again and again, or smothered.

Gardeners fight weeds with timing and covering. Pull or hoe annual weeds **when they are small**, long before they flower. A sharp hoe slicing just under the surface on a sunny, dry day kills small weeds quickly. Pull weeds by hand after a rain, when the soil is soft and roots come out whole. **Mulch** 2 to 3 inches deep with straw, shredded leaves or wood chips blocks the light weed seeds need to sprout. Plant crops close enough to shade the soil, and keep beds covered with crops or cover crops so weeds have no room.

Weeds also teach. Plantain and dandelions often grow where soil is packed hard; many weeds are early colonizers of bare ground, covering it quickly and holding soil. Some are even edible, though you must never eat a wild plant without an expert adult's identification. The sluggard in Proverbs let his field grow over with thorns and nettles; the diligent gardener pulls a few weeds every day and keeps his ground clean and fruitful.

PICTURE STUDY



Great Piece of Turf, Albrecht Dürer, 1503 · Watercolor and gouache on paper · Albertina, Vienna

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

Albrecht Dürer dug up, or lay down beside, an ordinary clump of field plants and painted it at eye level, as a beetle might see it. More than 500 years later, botanists can still identify the plants, including dandelion, greater plantain, field grasses and yarrow. It is one of the first paintings ever made of common weeds for their own sake.

Look closely

- Find the dandelion. Where are its leaves, its flower stalks and its seed heads?
- Find the broad, ribbed leaves of plantain. How do they lie close to the ground?
- Look at the grasses. How do their thin leaves crowd together?
- Look at the bottom of the picture. Can you see any roots or soil?

Talk about it

1. Which of these plants would be the hardest weed to pull from a garden? Why?
2. How are all these plants competing with each other in this small clump?
3. Dürer found beauty in an ordinary patch of weeds. What could you learn by drawing a weed carefully?

Safety first. Wear gloves when weeding; some weeds have spines, prickles or irritating sap, and poison ivy can grow among them. Learn the rule “leaves of three, let it be.” Never eat wild plants. Use hoes and other sharp tools only with an adult nearby.

The Weed Competition Experiment and a Weed ID Page

You will grow bean plants with different numbers of “weeds” in the same pot and measure how competition affects the bean. You will also collect and identify five common weeds, the way 4-H and FFA members do in weed identification contests.

You will need

- 4 identical pots (6 to 8 inches) with drainage holes, filled with the same potting mix
- 4 bean seeds (bush beans work well) and a packet of fast grass seed, oats or radish seed to act as “weeds”
- A sunny window or outdoor spot, a ruler, and a kitchen scale (optional)
- Gloves, a trowel, paper and heavy books for pressing weeds, and your journal

Steps

1. Plant one bean seed in the center of each pot. Label pots 0, 5, 10 and 20.
2. Sprinkle 0, 5, 10 and 20 grass or radish seeds around the bean in the matching pots. Water all pots equally.
3. Each week for four weeks, measure the bean’s height and count its leaves. Note its color.
4. At the end, cut each bean at the soil line and weigh it if you have a scale, or compare sizes side by side.
5. Make a graph of bean height (or weight) against number of weeds. Write a conclusion about competition.
6. Weed ID: with gloves and permission, collect five common weeds from a lawn, garden edge or field. Dig up the roots too.
7. Press each weed flat between sheets of paper under books for a week. Mount them on a page and label each with its name, annual or perennial, and how it spreads (seed, taproot, runners or rhizomes).

8. For each weed, write the best control method: pull young, dig out the whole root, hoe, or smother with mulch.

Tips

- Use your state extension service's weed identification guide or a field guide.
- Some county fairs, FFA chapters and 4-H clubs hold weed and crop identification contests; ask your county extension office.
- Do not collect from areas that may have been sprayed with weed killer.

Check your work

- ☐ I can name four things weeds compete with crops for.
- ☐ I can tell an annual weed from a perennial weed and name two of each.
- ☐ My graph shows how the number of weeds affected the bean.

NATURE JOURNAL

1. Draw your warm-up weed with its roots and label the type of root system.
2. Draw your four bean pots side by side at the end of the experiment.
3. Make a careful, Dürer-style drawing of one small patch of weeds and grass, about 6 inches square, at ground level.

From history. Before herbicides, farm children spent long summer days “walking beans,” pulling and hoeing weeds row by row in soybean and corn fields. In many Midwest farm families, walking beans was a summer job remembered for generations, and it taught patience and hard work.

COMMON MISTAKES

- Letting weeds flower and drop seeds before pulling them.
- Breaking off a dandelion at the surface and leaving the taproot.
- Tilling a patch of bindweed or quackgrass, which chops it into many new plants.

Make it a game • Weed Showdown. Compete for pretend resources. You are a bean seedling and your parent is a weed; take turns grabbing paper cards for light, water, nutrients and space. Whoever collects more wins the round and explains why that weed outcompeted the crop. Then name an annual and a perennial weed and tell how each spreads. Play three rounds.

Scripture. “I went by the field of the slothful, and by the vineyard of the man void of understanding; And, lo, it was all grown over with thorns, and nettles had covered the face thereof, and the stone wall thereof was broken down.” (Proverbs 24:30-31, KJV)

The neglected field was not ruined in a day; weeds took over a little at a time.

Faithful, steady work keeps a garden fruitful.

UNIT 8

PLANT HEALTH

By early summer the garden is growing fast, and so are the creatures and germs that feed on it. In this unit you will become a garden doctor. You will learn how fungi, bacteria and viruses cause plant diseases and how the disease triangle explains when they strike; how insect pests grow through their life cycles and where they are easiest to stop; how beneficial insects and integrated pest management (IPM) keep pests in check without harsh chemicals; and how weeds compete with crops for light, water and nutrients.

Every lesson trains your eye with real scouting in a garden, a park or a few pots, careful records, and simple experiments. Good stewards of a garden are watchful, patient and diligent. The sluggard's field in Proverbs was "all grown over with thorns"; yours will be tended.

PREREQUISITES

- Knows plant nutrients and deficiency signs from Unit 5
- Knows crop rotation and plant families from Unit 7
- Can use a magnifying glass and keep a dated log

MASTERY CHECKLIST

- ☐ I can explain the disease triangle and tell fungal, bacterial and viral diseases apart by their signs.
- ☐ I can describe complete and incomplete metamorphosis and name the best stage to control a pest.
- ☐ I can identify at least four beneficial insects and list the steps of integrated pest management.
- ☐ I can explain how weeds compete with crops and choose the right way to control annual and perennial weeds.
- ☐ I can scout a garden and record what I find like a garden doctor.

LESSONS IN THIS UNIT

8.1 Plant Diseases: Fungi, Bacteria and Viruses

2 sessions of 45 minutes

8.2 Insect Pests and Their Life Cycles

2 sessions of 45 minutes

8.3 Beneficial Insects and Integrated Pest Management

2 sessions of 45 minutes

8.4 Weeds and Competition

2 sessions of 45 minutes

UNIT 8 REVIEW

Answer each question. Use complete sentences for explanations. The review is worth 50 points.

1. **5 pts**

Draw or describe the disease triangle and explain how removing one side prevents disease.

2. **5 pts**

Match each to fungus, bacterium or virus: powdery mildew; mosaic pattern spread by aphids; wilt spread by cucumber beetles.

3. **5 pts**

Name three ways to prevent fungal diseases on tomatoes.

4. **5 pts**

What are the stages of complete and incomplete metamorphosis? Give one garden pest for each.

5. **5 pts**

You find a cluster of shiny bronze eggs under a squash leaf. What are they and what should you do?

6. **5 pts**

Why should you leave a hornworm that is covered with small white cocoons?

7. **5 pts**

Name four beneficial insects and what each does.

8. **5 pts**

List the five steps of IPM in order.

9. **5 pts**

Name four things weeds compete with crops for.

10. **5 pts**

Why is tilling a bad way to control bindweed, and what does “one year’s seeding, seven years’ weeding” mean?

ANSWER KEY

1. Host, pathogen and favorable environment. Removing any one (for example, keeping leaves dry, planting a resistant variety, or removing the infected plant) stops the disease.
2. Powdery mildew: fungus. Mosaic spread by aphids: virus. Wilt spread by cucumber beetles: bacterium (bacterial wilt).
3. Any three: resistant varieties, crop rotation, spacing and pruning for air, watering the soil in the morning, mulching, not working among wet plants, removing diseased leaves.
4. Complete: egg, larva, pupa, adult (tomato hornworm, cabbageworm, Japanese beetle). Incomplete: egg, nymph, adult (squash bug, aphid).
5. Squash bug eggs. Scrape them off or press them with tape and destroy them before they hatch.
6. It has been parasitized by tiny wasps; it will die, and the new wasps that hatch will attack more hornworms.
7. Any four: ladybugs and larvae eat aphids; lacewing larvae eat aphids and mites; hover fly larvae eat aphids; parasitoid wasps lay eggs in pests; ground beetles eat slugs and cutworms; bees pollinate.
8. Prevent; scout and identify; set a threshold; control with the least harmful methods first; evaluate.
9. Light, water, nutrients and space.
10. Bindweed spreads by creeping roots, and tilling chops them into pieces that each grow a new plant. The saying means that weeds allowed to set seed fill the soil’s seed bank with seeds that keep sprouting for years.

PORTFOLIO PIECE: A GARDEN DOCTOR'S CASEBOOK

Make a casebook of the plant problems you found and studied this unit, like a plant clinic's records. Include your mold test, your disease scouting notes, your pest scouting log and life-cycle drawings, your helper flower pot observations and IPM plan, your weed competition graph and pressed-weed page. For at least three "cases," write the symptom, your diagnosis (disease, pest, weed or nutrient problem), the evidence, and your recommended treatment, choosing the least harmful method first.

LOOK FOR	WHAT IT MEANS
Careful scouting	Logs have dates, plant numbers, counts and clear drawings.
Correct diagnosis	Each case names the likely cause with evidence and tells disease, pest, weed and nutrient problems apart.
IPM thinking	Treatments follow IPM order, beginning with prevention and the least harmful controls.
Experiments	The mold test and weed competition experiment have data, graphs and conclusions.
Presentation	The casebook is neat, organized and well illustrated.