

GRADE 7 GARDENING & ANIMALS

First edition

8 units

32 lessons

A video for every lesson

FIRST EDITION

COURSE GUIDE

This seventh-grade course turns the gardener and animal keeper into a young field scientist. Students learn why one corner of a yard is a full zone warmer than another, how a cold frame captures the sun, and how a farmer decides when a crop is ready and how to keep it fresh after picking. They read tracks and browse lines, learn how deer, voles and coyotes live, and plan how to protect a garden or flock. They study how rock becomes soil, why soil structure matters as much as nutrients, and how bacteria, fungi and actinomycetes build fertility, then practise cover cropping and no-till methods that build soil year after year.

In winter the course turns to animals: how reinforcement shapes behaviour, the work and care of dogs, the health of cats, and the aquarium as a small ecosystem governed by water chemistry. Late winter brings plant physiology (water movement, mineral nutrition, photoperiod and plant hormones), and spring brings poultry science and candling, swine, horse care and riding safety, colony management and the honey harvest. The year ends in the garden and orchard with greenhouse work, repotting large plants, planting and pruning fruit trees, field crops and their machines, and a careful, step-by-step method for diagnosing plant problems.

The method is the same in every lesson: observe closely, learn the science, then tend and grow. Each week has a short warm-up, a carefully chosen video, solid teaching, a picture study of a great painting or natural-history plate, a real hands-on project and a nature-journal page. We study creation as the work of a wise Creator, and we take seriously the charge to “dress it and to keep it” (Genesis 2:15). *Fabricando fit faber*: by making, one becomes a maker.

Most videos come from university extension services (Purdue, Penn State, Cornell and others), state wildlife agencies, established gardening and homestead educators (Gardener Scott, GrowVeg, Epic Gardening, Justin Rhodes, OYR Frugal & Sustainable Organic

Gardening and others), veterinarians, trainers and beekeeping educators. Each was chosen for this lesson and checked frame by frame. Some growers close with a word about their own seed shop or online course, and a few extension videos end with a standard legal notice; skip those parts. A parent note under a video points out anything else worth knowing.

Start with Lesson 1.1 →

WHO IT IS FOR

Students about 12 to 13 years old who read independently and can follow multi-step directions, measure, record data and write a paragraph. No earlier School Launch course is required, though Grade 6 is good preparation. No yard, livestock or pets are required: every project has a windowsill, balcony, library or farm-visit option.

HOW TO USE THIS COURSE

1. **Weekly rhythm.** Do one lesson a week in two sessions of 50–60 minutes, for 32 weeks. Session 1: warm-up, video, core ideas, key terms and picture study. Session 2: the hands-on project and the nature-journal page. Many projects run for several days or weeks; start them in Session 2 and log them briefly each day after.
2. **Calendar.** Units follow a school year that starts in late summer: harvest and wildlife in fall, soil and pets in early winter, plant physiology indoors in late winter, farm animals and bees in early spring, planting in spring and plant health as the garden grows. Look up your own average first and last frost dates and shift units earlier or later to match them. In a mild climate you may swap Units 7 and 8; in a cold one you may hold Unit 7 until the soil warms.
3. **Picture study.** Look quietly at the picture for two minutes. Then put it away and tell back everything you remember, as exactly as you can. Look again with the “look” prompts, then talk through the questions. The prompts tie the picture to the week’s science or care.
4. **Nature journal.** Keep one bound notebook all year. Date every page, note the weather, and draw from life with labels and measurements. At this level, journal pages should also hold data tables, simple graphs and short written explanations.

5. **Unit review and portfolio.** At the end of each unit, take the unit review (100 points, closed notes, with one or two written answers) and complete the portfolio project. Portfolio projects are real work: a season-extension device with a temperature log, a wildlife-sign survey, a soil-building plan, a training log, a pruning plan, a diagnosis report.
6. **4-H, FFA, fairs and contests.** This course prepares students for real youth programs. Homeschoolers can usually join 4-H through the county extension office. FFA membership can begin in grade 5 where a school-based agriculture program exists, and the Discovery FFA Degree is for grades 7–8; homeschool access varies by state, and some states have homeschool chapters. Junior Master Gardener, junior beekeeping programs, conservation-district poster contests and county and state fair youth classes are also good goals. Along the way students keep project-book records (dates, work done, costs, feed or water used, measurements, results and what was learned), place judging classes with placing cards and oral reasons, prepare fair exhibits, practice showmanship and give an illustrated talk. Rules and ages vary, so check your county extension office or fair book.
7. **Safety and supervision.** Read each lesson's safety note before the project. Power tools, ladders, pruning saws, livestock, beehives and any garden chemical need a supervising adult. Wash hands after soil, compost, manure, animals and reptiles. Never touch or feed wild animals, and check for ticks after time outdoors.
8. **No yard, no animals?** Every project gives an alternative: a pot on a balcony, a houseplant, a visit to a farm, orchard, county fair, extension office, pet store or shelter, or a carefully researched plan and budget.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–4

Harvest and the Seasons

Climate zones and microclimates, season extension with cold frames, row covers and greenhouses, harvest timing and post-harvest handling, and seed saving, heirlooms and how new varieties are developed.

- 1.1 Climate Zones and Microclimates
- 1.2 Season Extension: Cold Frames, Row Covers and Greenhouses
- 1.3 Harvest and Post-Harvest Handling
- 1.4 Seed Saving, Heirlooms and New Varieties

UNIT 3 • WEEKS 9–12

Soil Science

How soil forms from parent material, soil structure, porosity and water-holding, the microbes that make soil alive, and building soil with cover crops, no-till methods and manure.

- 3.1 Soil Formation and Parent Material
- 3.2 Soil Structure, Porosity and Water
- 3.3 Soil Microbes: Bacteria, Fungi and Actinomycetes
- 3.4 Building Soil: Cover Crops, No-Till and Manure

UNIT 2 • WEEKS 5–8

Wildlife

Field identification and tracking, deer biology and management, small mammals underground and how to control rodent damage, and protecting livestock from predators with fences, housing and guardian animals.

- 2.1 Field Identification and Tracking
- 2.2 Deer Biology and Management
- 2.3 Small Mammals Underground: Mice, Moles and Voles
- 2.4 Predators and Protecting Livestock

UNIT 4 • WEEKS 13–16

Pets: Behavior, Training and Care

How animals learn and how reinforcement shapes behaviour, dogs and their work and care, cat health and behaviour, and the aquarium as an ecosystem governed by water chemistry.

- 4.1 Animal Behavior and Training: Reinforcement
- 4.2 Dogs: Breeds, Working Dogs and Care
- 4.3 Cats: Health and Behavior
- 4.4 The Aquarium as an Ecosystem

UNIT 5 • WEEKS 17–20

Plant Physiology

Plant physiology: water movement and transpiration, mineral nutrition and deficiency signs, photoperiod and flowering, and plant hormones such as auxin and ethylene.

5.1 Water Movement and Transpiration

5.2 Mineral Nutrition and Deficiencies

5.3 Photoperiod: Short-Day and Long-Day Plants

5.4 Plant Hormones: Auxin, Cuttings and Ethylene

UNIT 7 • WEEKS 25–28

Planting: Greenhouse, Containers, Orchard and Field

Greenhouse and seed-starting operations, repotting large plants and trees, planting and pruning fruit trees, and field crops and farm machinery.

7.1 Greenhouse and Seed-Starting Operations

7.2 Containers and Repotting Large Plants and Trees

7.3 The Orchard: Planting and Pruning Fruit Trees

7.4 Field Crops and Farm Machinery

UNIT 6 • WEEKS 21–24

Farm Animals and Bees

Poultry science and incubation, swine, horses and riding safety, and colony management, swarms and the honey harvest.

6.1 Poultry Science: The Egg, Incubation and Showmanship

6.2 Swine

6.3 Horses: Anatomy, Care and Riding Safety

6.4 Beekeeping: Colony Management, Swarms and the Honey Harvest

UNIT 8 • WEEKS 29–32

Plant Health: Diagnosis, Pathogens, Pests and Abiotic Problems

A step-by-step method for diagnosing plant problems, fungal and bacterial pathogens, insect pests and action thresholds in IPM, and abiotic problems such as frost, sunscald, drought and nutrient or chemical injury.

8.1 Diagnosing Plant Problems Step by Step

8.2 Fungal and Bacterial Pathogens

8.3 Insect Pests and IPM Thresholds

8.4 Abiotic Problems: Frost, Sunscald, Drought, Nutrient and Chemical Injury

WEEKLY PACING CALENDAR

WEEK	PLAN
1	• Session 1: Lesson 1.1 Climate Zones and Microclimates: warm-up, video, teaching and picture study • Session 2: Lesson 1.1 hands-on project and nature journal

WEEK	PLAN
	<i>Two sessions a week is the usual rhythm. Younger children can split a long session in two; older students can do both sessions in one sitting.</i>
2	• Session 1: Lesson 1.2 Season Extension: Cold Frames, Row Covers and Greenhouses: warm-up, video, teaching and picture study • Session 2: Lesson 1.2 hands-on project and nature journal
3	• Session 1: Lesson 1.3 Harvest and Post-Harvest Handling: warm-up, video, teaching and picture study • Session 2: Lesson 1.3 hands-on project and nature journal
4	• Session 1: Lesson 1.4 Seed Saving, Heirlooms and New Varieties: 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 Field Identification and Tracking: warm-up, video, teaching and picture study • Session 2: Lesson 2.1 hands-on project and nature journal
6	• Session 1: Lesson 2.2 Deer Biology and Management: warm-up, video, teaching and picture study • Session 2: Lesson 2.2 hands-on project and nature journal
7	• Session 1: Lesson 2.3 Small Mammals Underground: Mice, Moles and Voles: warm-up, video, teaching and picture study • Session 2: Lesson 2.3 hands-on project and nature journal
8	• Session 1: Lesson 2.4 Predators and Protecting Livestock: warm-up, video, teaching and picture study • Session 2: Lesson 2.4 hands-on project and nature journal • Session 3: Unit 2 review and portfolio project
9	• Session 1: Lesson 3.1 Soil Formation and Parent Material: warm-up, video, teaching and picture study • Session 2: Lesson 3.1 hands-on project and nature journal
10	• Session 1: Lesson 3.2 Soil Structure, Porosity and Water: warm-up, video, teaching and picture study

WEEK	PLAN
	Session 2: Lesson 3.2 hands-on project and nature journal
11	- Session 1: Lesson 3.3 Soil Microbes: Bacteria, Fungi and Actinomycetes: warm-up, video, teaching and picture study - Session 2: Lesson 3.3 hands-on project and nature journal
12	- Session 1: Lesson 3.4 Building Soil: Cover Crops, No-Till and Manure: 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 Animal Behavior and Training: Reinforcement: warm-up, video, teaching and picture study - Session 2: Lesson 4.1 hands-on project and nature journal
14	- Session 1: Lesson 4.2 Dogs: Breeds, Working Dogs and Care: warm-up, video, teaching and picture study - Session 2: Lesson 4.2 hands-on project and nature journal
15	- Session 1: Lesson 4.3 Cats: Health and Behavior: warm-up, video, teaching and picture study - Session 2: Lesson 4.3 hands-on project and nature journal
16	- Session 1: Lesson 4.4 The Aquarium as an Ecosystem: 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 Water Movement and Transpiration: warm-up, video, teaching and picture study - Session 2: Lesson 5.1 hands-on project and nature journal
18	- Session 1: Lesson 5.2 Mineral Nutrition and Deficiencies: warm-up, video, teaching and picture study - Session 2: Lesson 5.2 hands-on project and nature journal

WEEK	PLAN
19	• Session 1: Lesson 5.3 Photoperiod: Short-Day and Long-Day Plants: warm-up, video, teaching and picture study • Session 2: Lesson 5.3 hands-on project and nature journal
20	• Session 1: Lesson 5.4 Plant Hormones: Auxin, Cuttings and Ethylene: 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 Poultry Science: The Egg, Incubation and Showmanship: warm-up, video, teaching and picture study • Session 2: Lesson 6.1 hands-on project and nature journal
22	• Session 1: Lesson 6.2 Swine: warm-up, video, teaching and picture study • Session 2: Lesson 6.2 hands-on project and nature journal
23	• Session 1: Lesson 6.3 Horses: Anatomy, Care and Riding Safety: 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: Colony Management, Swarms and the Honey Harvest: 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 Greenhouse and Seed-Starting Operations: warm-up, video, teaching and picture study • Session 2: Lesson 7.1 hands-on project and nature journal
26	• Session 1: Lesson 7.2 Containers and Repotting Large Plants and Trees: warm-up, video, teaching and picture study • Session 2: Lesson 7.2 hands-on project and nature journal
27	• Session 1: Lesson 7.3 The Orchard: Planting and Pruning Fruit Trees: warm-up, video, teaching and picture study • Session 2: Lesson 7.3 hands-on project and nature journal

WEEK	PLAN
28	• Session 1: Lesson 7.4 Field Crops and Farm Machinery: warm-up, video, teaching and picture study • Session 2: Lesson 7.4 hands-on project and nature journal • Session 3: Unit 7 review and portfolio project
29	• Session 1: Lesson 8.1 Diagnosing Plant Problems Step by Step: warm-up, video, teaching and picture study • Session 2: Lesson 8.1 hands-on project and nature journal
30	• Session 1: Lesson 8.2 Fungal and Bacterial Pathogens: warm-up, video, teaching and picture study • Session 2: Lesson 8.2 hands-on project and nature journal
31	• Session 1: Lesson 8.3 Insect Pests and IPM Thresholds: warm-up, video, teaching and picture study • Session 2: Lesson 8.3 hands-on project and nature journal
32	• Session 1: Lesson 8.4 Abiotic Problems: Frost, Sunscald, Drought, Nutrient and Chemical Injury: 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 (bound sketchbook or notebook)

For drawings, data tables, graphs, logs and written explanations all year.

Pencils, colored pencils, ruler and a 10× hand lens

For close observation and labeled drawings of leaves, insects, soil and tracks.

Two thermometers (a min–max thermometer if possible)

For microclimate, cold frame, compost and germination measurements.

Pots with drainage holes, potting mix, seed-starting trays and seeds

Beans, peas, lettuce, radishes, tomatoes, marigolds and a cover-crop mix (oats, crimson clover or winter rye) are enough for the year.

Clear jars, zip bags, paper towels, a spray bottle and a measuring cup

For soil, germination and water-movement experiments.

Simple soil test kit (pH, N, P, K)

Used in Units 3, 5 and 8. Inexpensive garden-center kits are fine.

Aquarium test strips or a liquid test kit (ammonia, nitrite, nitrate, pH)

Optional; for Unit 4 if you keep or visit an aquarium.

Trowel, hand pruners, garden gloves and a watering can

Pruning saws and any power tools are used only with an adult.

Floating row cover fabric and an old window or clear plastic sheet

For the Unit 1 season-extension project. A clear storage tote works too.

Food coloring, celery stalks and white carnations

For the Unit 5 water-movement experiment.

A dozen fresh eggs and a bright flashlight

For the Unit 6 egg-anatomy and candling lesson.

Access to a farm, orchard, county fair, extension office or animal shelter

Optional but valuable; several projects offer a visit as one choice.

A pet, a neighbor's pet to observe, or a library book on animal training

Optional; Unit 4 projects work with or without your own animal.

Your county fair book and extension office contact (optional)

For youth class rules, 4-H clubs, FFA chapters and contest deadlines.

GRADING

Grades come from steady project work, careful journal pages, unit reviews and portfolio projects. Effort, accuracy and care for living things count for more than talent.

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

Scale: A 90–100, B 80–89, C 70–79, D 60–69, below 60 not yet passing (redo and resubmit).

- Grade a project on whether the student followed the steps, recorded honest data and can explain the result, not on whether the plant thrived. A failed seedling with a good explanation of why is good science.
- Journal pages earn full credit when they are dated, include the weather, and show careful drawing from life with labels, measurements or data.
- Unit reviews are worth 100 points each. Allow one retake after review if a student scores below 70.
- Portfolio rubrics are given in each unit. Score each criterion 1–4 and convert to a percentage.

A NOTE TO PARENTS

Twelve- and thirteen-year-olds can do real work. This year your student will build a cold frame, run multi-week experiments, train an animal with positive reinforcement, candle eggs, prune a tree with you and diagnose sick plants methodically. Let them take ownership, and expect them to explain their reasoning. Your role is to supervise tools, animals and chemicals, ask good questions and help arrange the occasional farm, orchard or fair visit.

Farm animals are discussed honestly: they are raised for eggs, milk, wool, work and meat, and the course says so plainly while never describing or showing how animals are killed or processed. Predators and wildlife management are taught with care and accuracy, without disturbing images. Life cycles are described modestly.

Throughout, the course treats plants and animals as good gifts of a wise Creator, entrusted to our care, and it seeks to build the habits of patient observation, faithful daily chores, kindness to animals and gratitude for the harvest.

UNIT 1

HARVEST AND THE SEASONS

Every garden sits inside a climate, but every plant lives in a microclimate: the few square feet of air, sun and soil right around it. A south-facing brick wall, a frost pocket at the bottom of a slope or a breezy corner can change the growing season by weeks. In this unit you will learn to read your own yard the way a grower does, and then to change it, using cold frames, row covers and greenhouses to stretch the season at both ends.

You will also learn the other half of growing food: harvesting at the right moment and keeping produce fresh afterward, because a vegetable is still alive after it is picked. Finally you will save your own seed, learn what makes an heirloom variety “breed true,” and see how growers have patiently shaped the vegetables we eat. God promised that “seedtime and harvest ... shall not cease” (Genesis 8:22); this unit is about working wisely within that rhythm.

PREREQUISITES

- Knows the four seasons and that Earth’s tilt causes them
- Can read a thermometer and record data in a table
- Has grown at least one plant from seed
- Knows the basic parts of a flower (petals, stamens, pistil)

MASTERY CHECKLIST

- ☐ I can explain the difference between a climate zone and a microclimate and find microclimates in my own yard.
- ☐ I can explain how cold frames, row covers and greenhouses trap heat, and build a simple season-extension device.
- ☐ I can tell when common crops are ready to harvest and explain why cooling and curing keep produce fresh.
- ☐ I can save seed from a self-pollinating crop and explain the difference between heirloom, open-pollinated and hybrid varieties.
- ☐ I can keep a dated temperature log and draw a conclusion from it.

LESSONS IN THIS UNIT

1.1 Climate Zones and Microclimates

2 sessions of 50–60 minutes

1.2 Season Extension: Cold Frames, Row Covers and Greenhouses

2 sessions of 50–60 minutes

1.3 Harvest and Post-Harvest Handling

2 sessions of 50–60 minutes

1.4 Seed Saving, Heirlooms and New Varieties

2 sessions of 50–60 minutes

UNIT 1 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **8 pts**

What does a USDA hardiness zone tell a gardener, and what does it not tell?

2. **8 pts**

Name four factors that can create a microclimate.

3. **6 pts**

Why does the bottom of a hill often get frost first?

4. **8 pts**

Explain how a cold frame keeps plants warmer than the open garden.

5. **6 pts**

What is the main danger of a closed cold frame on a sunny day, and what should you do?

6. **6 pts**

Give two signs that sweet corn is ready to pick.

7. **8 pts**

Why do growers harvest leafy greens early in the morning and cool them quickly?

8. **8 pts**

What is curing? Name two crops that are cured before storage.

9. **8 pts**

What is the difference between an heirloom variety and an F1 hybrid?

10. **6 pts**

Why is it easier to save true seed from beans than from squash?

11. **14 pts**

Written answer: You want to grow spinach through November in a cold region. Describe where you would put it, what device you would use, when you would plant and how you would care for it.

12. **14 pts**

Written answer: Explain step by step how to save tomato seed so that it stays healthy and grows the same variety next year.

ANSWER KEY

1. It tells the average coldest winter temperature, so which perennials can survive the winter. It does not tell summer heat, rainfall, the length of the season or when to plant vegetables.
2. Any four of: aspect (direction faced), slope and low spots, walls and paving that store heat, wind and windbreaks, nearby water, shade from trees or buildings.
3. Cold air is heavier than warm air and drains downhill on still nights, collecting in low spots called frost pockets.
4. Sunlight passes through the clear lid and warms the soil and air inside; the lid traps the warm air and slows heat loss at night and shelters plants from wind.
5. It can overheat and scorch plants. Vent it by propping the lid open, then close it in late afternoon.
6. The silks are brown and dry, and a kernel pressed with a thumbnail gives milky juice (about three weeks after silking; ears feel full).
7. Picked produce keeps respiring and losing water; heat speeds respiration. Cool morning harvest and quick removal of field heat slow respiration and wilting and extend shelf life.
8. Holding crops under warm or dry conditions after harvest so skins harden and wounds heal before storage. Examples: winter squash, sweet potatoes, onions, garlic, potatoes.
9. An heirloom is an old open-pollinated variety whose saved seed comes true to type. An F1 hybrid is the first-generation cross of two parent lines; its saved seed does not come true.
10. Beans usually pollinate themselves, so they rarely cross. Squash is pollinated by insects and crosses easily with other squash varieties nearby.
11. A good answer places the bed in a warm microclimate (south-facing, sheltered, not in a frost pocket); uses a cold frame or row cover on hoops; sows in late summer so plants are near full size before short days; vents on sunny days and closes at night; adds thermal mass or extra covers in hard freezes; harvests leaves gradually.
12. Choose a ripe fruit from a healthy open-pollinated (heirloom) plant, not a hybrid; squeeze seeds and gel into a jar with water; ferment 3–4 days, stirring; pour off film and floaters; rinse the sinking seeds; dry on a plate for a week or

more; store cool, dry and dark in a labeled envelope; test germination before planting.

PORTFOLIO PIECE: A SEASON-EXTENSION REPORT

Present your cold frame (or other season-extension device) with your microclimate map, your two-week temperature log and graph, and photos or drawings of the crop growing in it. Add one page explaining what you learned and what you would change next season, and attach the labeled seed packets you saved.

LOOK FOR	WHAT IT MEANS
Site choice	Uses the microclimate map to explain why the device was placed where it was.
Data	A complete, dated temperature log with a clear graph and correctly calculated averages.
Crop care	Shows the crop sown, vented and watered faithfully, with growth recorded in drawings or photos.
Explanation	Correctly explains heat trapping, venting and thermal mass in the student's own words.
Seed packets	Saved seed is clean, dry and fully labeled with variety, date and germination rate.

1.1 CLIMATE ZONES AND MICROCLIMATES

OBJECTIVES

- Explain what a USDA plant hardiness zone measures and what it does not.
- Identify the factors that create microclimates: sun exposure, slope, walls and pavement, wind, water and plants.
- Measure and map the microclimates of a yard, balcony or school ground.

Warm-up. Stand outside (or at a window) for three minutes. List every place you can see that is probably warmer than average and every place that is probably colder. Next to each, write one word for why: sun, shade, wall, wind, low spot, pavement.

WATCH

Understanding Microclimates - Change Climates in Your Garden

Gardener Scott • 14:03

<https://www.youtube.com/watch?v=F0-5DGNJL7Q>

WHEN TO WATCH

After the core ideas. As you watch, list each microclimate factor Scott names and one example he shows in his own yard.

BACKUP VIDEO

Identifying Microclimates

Oregon State University Ecampus • 2:50

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

A short university summary of slope, aspect, structures and water; good for review.

KEY TERMS

climate

The usual pattern of weather in a region over many years: average temperatures, rainfall, frost dates and seasons.

hardiness zone

A band on the USDA map based on the average coldest winter night. Zone 6, for example, averages -10 to 0 °F at its coldest. It tells you which perennials can survive winter, not how hot or long your summer is.

frost date

The average date of the last frost in spring or the first frost in fall. The days between them make the frost-free growing season.

microclimate

A small area whose temperature, light, wind or moisture differs from the area around it, such as the warm foot of a sunny wall.

aspect

The direction a slope or wall faces. In the Northern Hemisphere, south-facing sites get the most sun and warm up first.

frost pocket

A low spot where cold, heavy air drains and collects on still nights, so frost comes earlier and lasts longer there.

CORE IDEAS

A region's **climate** is set by latitude, elevation, distance from large bodies of water and prevailing winds. Gardeners in the United States use two tools to describe it. The USDA **hardiness zone** map divides the country by the average lowest winter temperature in 10 °F bands (each split into “a” and “b” halves). It answers one question: will this tree, shrub or perennial survive my winters? It says nothing about summer heat, rainfall or the length of the season. For vegetables, the more useful numbers are your average last spring frost and first fall frost, which you can get from your county extension office.

Inside any climate are many **microclimates**. Dark pavement and masonry soak up sun all day and give back heat at night, so the foot of a south-facing brick wall can be like a garden one zone farther south. North sides of buildings stay shaded and cool, which is useful for lettuce in summer. Cold air is heavier than warm air and flows downhill like water, so the bottom of a slope or a hollow becomes a **frost pocket**, while the middle of a gentle south-facing slope is often the warmest spot on a property. Wind dries plants and strips away the thin layer of warm air around leaves; a hedge or fence can cut wind speed for a distance of several times its own height.

Water moderates temperature because it holds a great deal of heat. Gardens near a lake or the ocean have later fall frosts and cooler springs than gardens inland. On a smaller scale, a barrel of water in a greenhouse or a mulched, moist bed changes temperature more slowly than dry, bare soil. Trees and lawns cool the air around them by shading and by evaporating water from their leaves.

Good growers use microclimates on purpose. They plant tomatoes, peppers and figs against warm walls, put spinach where it will get afternoon shade in summer, keep tender fruit-tree blossoms out of frost pockets and plant windbreaks on the windy side. The only way to learn your own microclimates is to observe and measure them: where frost lingers in the morning, where snow melts first, where the soil warms first in spring. That patient attention to the place God has given you is the beginning of good stewardship.

PICTURE STUDY



Golding Constable's Kitchen Garden, John Constable, 1815 · Oil on canvas · Christchurch Mansion, Ipswich, England

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

Constable painted his father's vegetable garden from an upstairs window of the family house in Suffolk. Look at it as a grower would: where are the walls, hedges and open fields, and where would the warmest and coldest spots be?

Look closely

- Find the hedges, fences and trees around the garden. Which side of a hedge would be warmest in the afternoon?
- Look at the beds. Can you see which parts get full sun and which are shaded by trees?
- Find the open fields beyond the garden. Would they be windier or calmer than the sheltered garden?
- Find the gardener. What part of the garden is he working in?

Talk about it

1. Why do you think old English kitchen gardens were so often surrounded by walls or hedges?
2. If you were planting a fig tree or a peach in this garden, where would you put it, and why?

3. Where in the painting would frost probably come first on a still autumn night?

Safety first. Stay on your own property or school ground, and ask before climbing anything to place a thermometer. Do not leave glass thermometers where they could break; a digital one is safer.

HANDS-ON PROJECT

Microclimate Map

You will measure temperatures at several spots around your home over three days and turn your data into a labeled microclimate map, just as a landscape designer or orchardist would before planting.

You will need

- One or two thermometers (digital or a min-max thermometer is best)
- A watch or phone for the time
- Graph paper or your nature journal
- Colored pencils
- A compass or compass app

Steps

1. Draw a rough plan of your yard, balcony or school ground from above. Mark north with an arrow and draw buildings, walls, fences, paving, trees and slopes.
2. Choose five or six test spots that look different: a south-facing wall, a north side, an open lawn, a low spot, under a tree and near pavement. Number them on your map.
3. Make a data table with columns for date, time, spot number, temperature, sun or shade, and wind (calm, light, strong).
4. Measure each spot at about the same height (about 1 foot above the ground) in early morning, at midday and in late afternoon. Give the thermometer 3–5 minutes to settle at each spot, out of direct sun on the bulb if possible.
5. Repeat for three days, including one clear, still morning if you can. Note any frost, dew or wet spots you see.
6. Find the average temperature for each spot and time. Circle the warmest and coldest spots.
7. Color your map: red and orange for warm spots, blue for cold ones, green for average. Add arrows for wind and shade.

8. Write a planting plan in three sentences: where you would put a heat-loving crop, a cool-season crop and a tender fruit tree, and why.

Tips

- Readings in full sun mostly measure the thermometer heating up. Shade the bulb with a piece of card held a few inches above it.
- If you only have a balcony, compare the sunny rail, the floor by the wall and an inside corner.
- Look up your hardiness zone and average frost dates at your county extension office's website and write them at the top of the map.

Check your work

- ☐ I measured at least five spots at three times of day for three days.
- ☐ My map shows north, warm and cold spots, wind and shade.
- ☐ I can explain why my warmest spot was warmest.
- ☐ I wrote a planting plan based on my data.

NATURE JOURNAL

1. Draw the warmest spot you found, with the wall, paving or slope that makes it warm. Label the direction of the sun at noon.
2. Graph your morning temperatures for each spot as a bar graph. Write one sentence describing the pattern.
3. Record today's weather: high, low, sky and wind. Start a weather line at the top of every journal page this year.

From history. Seventeenth- and eighteenth-century English gardeners built “fruit walls” of brick, sometimes with fireplaces and flues hidden inside, so that peaches, apricots and grapes could ripen far north of their native lands. Some walls were even built in a zigzag or a curving “crinkle-crankle” shape to catch more sun and stand without buttresses.

COMMON MISTAKES

- Thinking the hardiness zone tells you when to plant vegetables. Zones are about winter cold; frost dates tell you when to plant.
- Measuring in direct sun and recording how hot the thermometer gets rather than the air.
- Comparing readings taken at different times of day.

- Planting fruit trees in the lowest part of a yard, where frost pockets kill the blossoms.

Make it a game · Microclimate Treasure Map. Draw your yard or street on paper. Parent hides a pretend frost pocket and a warm sunny spot, and you hunt them using clues: aspect, slope, walls, pavement, wind, water and plants. Mark each find on the map and explain what a hardiness zone measures and what it does not. Fewest wrong guesses wins.

1.2 SEASON EXTENSION: COLD FRAMES, ROW COVERS AND GREENHOUSES

OBJECTIVES

- Explain how clear covers trap solar heat and slow heat loss at night.
- Compare row covers, cloches, cold frames, hoop houses and greenhouses for cost, warmth and use.
- Build a small cold frame and measure how much warmer it stays than the open air.

Warm-up. On a sunny day, sit in a closed car for one minute (with an adult nearby and the door unlocked) or put your hand inside a clear jar that has sat in the sun. Then describe in two sentences where the extra heat came from and why it does not escape quickly.

WATCH

Extending the Growing Season - Using Row Covers, Cold Frames etc to Protect Crops from Cold Weather

GrowVeg • 5:53

<https://www.youtube.com/watch?v=6n9rhz1RxzY>

WHEN TO WATCH

After the core ideas. Pause at each method (cloche, cold frame, row cover, hoop house, greenhouse) and add it to a comparison table.

Note: The last minute shows the channel's garden-planning software; you may skip it.

BACKUP VIDEO

DIY Cold Frame • Easy How-to Tutorial with Niki Jabbour, 4-Season Gardener, Author & Educator

Johnny's Selected Seeds • 4:01

<https://www.youtube.com/watch?v=0iAFbpPusAc>

Watch before building, if you will make a cold frame from an old window sash.

KEY TERMS

season extension

Any method that lets crops grow earlier in spring or later in fall than the open garden allows.

row cover

A lightweight spun fabric laid over crops or on wire hoops. It lets light and water through and holds in a few degrees of warmth.

venting

Opening a cold frame or greenhouse on sunny days so it does not overheat and cook the plants.

cold frame

A bottomless box with a clear, sloping lid, set over soil. It traps the sun's heat by day and shelters plants from wind and frost.

hoop house

A tunnel of plastic film stretched over metal or plastic hoops; also called a high tunnel when it is tall enough to walk in.

thermal mass

Heavy material such as water, stone or soil that stores heat by day and releases it slowly at night.

CORE IDEAS

Sunlight passes easily through glass and clear plastic and warms the soil, plants and air inside. The warm air is trapped instead of blowing away, and the cover slows the loss of heat back to the cold night sky. That is why a closed car gets hot in the sun. Every season-extension device uses this simple principle; they differ in how much heat they hold and how much they cost.

The lightest tool is a **row cover**, a spun polyester fabric laid directly on crops or over wire hoops. Lightweight covers give roughly 2–4 °F of frost protection; heavier ones give more but let through less light. Row covers also keep out insects such as flea beetles and cabbage moths. A **cloche** (French for “bell”) is a small cover for one plant: a glass bell, a cut milk jug or a plastic dome. A **cold frame** is a box with a clear lid, usually sloped toward the south to catch the low winter sun. A **hoop house** or high tunnel covers whole beds, and a **greenhouse** is a permanent building that may be heated.

The greatest danger in a cold frame is not cold but heat. On a sunny day in March, the air inside a closed frame can climb past 90 °F while it is 40 °F outside, which can scorch seedlings. Growers **vent** the lid, propping it open a few inches on sunny days

and closing it in late afternoon to trap warmth for the night. Automatic vent openers use a wax cylinder that expands when warm and pushes the lid up. Adding **thermal mass**, such as dark jugs of water, evens out the swings between day and night.

Season extension works best with cold-hardy crops. Spinach, kale, lettuce, mâche, scallions, carrots and many Asian greens survive frost and, under cover, keep growing slowly into early winter. In much of the U.S., day length falls below about ten hours in late fall, and growth nearly stops; the plants simply hold in the frame like a living refrigerator until you harvest. Plant fall crops in late summer so they are nearly full size before short days arrive. In spring, the same frame warms soil early for sowing and is the perfect place to harden off seedlings.

PICTURE STUDY



Greenhouse under Construction, Édouard Joseph Dantan, 1890 · Oil on canvas · Private collection

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

In the nineteenth century, cheaper glass and iron let gardeners build large greenhouses for the first time. Dantan painted one being built. Look closely at how a greenhouse is made to catch and hold the sun.

Look closely

- Find the iron framework and the panes of glass. Which parts are finished?
- Look at the brick wall at the base. Why might a greenhouse have a solid lower wall?
- Find the workers. What job is each one doing?
- Look through the glass at the trees. What season is it, and why might builders work then?

Talk about it

1. Why do you think a greenhouse roof is sloped rather than flat?
2. What problems might a greenhouse have on a hot, sunny day, and how could the gardeners solve them?
3. How is a cold frame like a tiny version of this building?

Safety first. Old windows may have sharp edges or lead paint; wear gloves, and let an adult handle cutting, drilling and any glass. Never leave a pet or child in a closed car or greenhouse on a sunny day.

Build and Test a Mini Cold Frame

You will build a small cold frame, sow cold-hardy greens in it, and keep a two-week log comparing its temperature with the open air.

You will need

- Option A: four boards and an old window or a sheet of clear polycarbonate for the lid
- Option B: a large clear plastic storage tote turned upside down over a bed or a big pot
- Two thermometers (one inside, one outside in shade)
- Seeds of spinach, lettuce, kale or radish
- Compost or potting mix
- A stick or block to prop the lid for venting

Steps

1. Choose a spot that gets full sun from late morning through afternoon, out of a frost pocket. Use your microclimate map from Lesson 1.1.
2. Build the box. Make the back about 4–6 inches taller than the front, so the lid slopes toward the south. With an adult, screw the corners together. (If using a tote, simply cut a few small vent holes near the top.)
3. Loosen the soil inside and mix in an inch of compost. Sow two short rows of spinach, lettuce or radish and water gently.
4. Set one thermometer inside the frame at plant height, shaded by a card, and one outside in the shade at the same height.
5. Every day for two weeks, record the inside and outside temperatures in the early morning and in mid-afternoon. Note the weather.
6. Vent the lid with a block on any day the inside temperature passes 75 °F. Close it about two hours before sunset.
7. On a predicted frost night, close the frame and add a blanket or a jug of warm water if you like. Record the morning result.

8. At the end, calculate the average difference between inside and outside for mornings and for afternoons, and compare the seedlings with any sown in the open.

Tips

- Paint jugs of water black and stand them along the back wall for thermal mass.
- Bank leaves or straw around the outside of the box for extra insulation.
- No yard? A clear tote over a large pot on a sunny balcony works the same way.

Check your work

- ☐ I built a working cold frame and sowed cold-hardy greens in it.
- ☐ I logged inside and outside temperatures twice a day for two weeks.
- ☐ I can explain why the frame is warmer and why it must be vented.
- ☐ I calculated the average temperature difference.

NATURE JOURNAL

1. Draw a labeled cross-section of your cold frame showing the sun's rays coming in, the slope of the lid and where heat is lost.
2. Make a line graph of inside and outside afternoon temperatures over two weeks, using two colors.
3. Draw one seedling from your frame each week with its height in millimeters.

From history. French market gardeners around Paris in the 1800s fed the city through the winter by growing in hotbeds of fresh horse manure covered with glass frames and thousands of glass bell cloches. As the manure decomposed it gave off steady heat, and the gardeners raised salad greens, melons and early vegetables months ahead of season.

COMMON MISTAKES

- Forgetting to vent on a sunny day and cooking the seedlings.
- Sowing fall crops too late. They need to be almost full size before days grow short.
- Using a cold frame for frost-tender crops like tomatoes or basil in late fall; they will still be damaged by hard freezes.
- Placing the frame in the shade of a building, where it never warms up.

Make it a game • Cover Type Showdown. Set up five paper cards: row cover, cloche, cold frame, hoop house, greenhouse. Parent names a situation, such as an early lettuce bed or a hot afternoon, and you slap the best card and justify it by cost, warmth and use. Explain how clear covers trap heat, why venting matters, and thermal mass.

1.3 HARVEST AND POST-HARVEST HANDLING

OBJECTIVES

- Recognize signs of ripeness and readiness in common garden crops.
- Explain why harvested produce keeps respiring and losing water, and how cooling slows this.
- Distinguish crops that need cooling from crops that need curing, and handle each correctly.
- Prepare a matched plate of vegetables to fair standards and place a judging class of four with oral reasons.

Warm-up. Look at three pieces of produce from your kitchen (for example a banana, a carrot and an apple). For each, write how you would know if it was picked at the right time, and what would happen if you left it on the counter for a week.

WATCH

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

GrowVeg • 5:29

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

WHEN TO WATCH

After the first two core ideas. Make a two-column list: crop, and the sign it is ready.

BACKUP VIDEO

The Best Way to Store Root Vegetables

GrowVeg • 8:07

<https://www.youtube.com/watch?v=k7rk-ViwAtE>

Watch with the last core idea, about storing roots after harvest.

KEY TERMS

maturity

The stage when a crop is ready to harvest for its intended use. A crop can be mature but not yet fully ripe, as with green tomatoes that ripen indoors.

field heat

The warmth a crop carries from the field when it is picked. Removing it quickly slows respiration and spoilage.

shelf life

How long produce stays good to eat after harvest.

respiration

The process by which living cells, including those in picked fruits and vegetables, burn stored sugars for energy, giving off heat, water and carbon dioxide.

curing

Holding certain crops (such as winter squash, sweet potatoes, onions and potatoes) in warm or dry conditions after harvest so skins toughen and wounds heal before storage.

CORE IDEAS

Each crop has its own signs of readiness. Sweet corn is ready about three weeks after the silks appear, when the silks are brown and dry and a kernel pressed with a thumbnail gives milky juice. Winter squash is ready when the rind is too hard to dent with a fingernail and the stem has turned corky. Onions are ready when most of the tops have flopped over. Bush beans and cucumbers are best young and slender, before the seeds swell. Melons such as cantaloupe “slip” easily from the vine when ripe. Tomatoes can be picked at the first blush of color and will finish ripening indoors.

Harvested produce is still alive. Its cells keep **respiring**, burning stored sugars and giving off heat, carbon dioxide and water. Sweet corn can lose a large share of its sugar within a day at summer temperatures, which is why corn picked the same day tastes so much sweeter. Leafy greens lose water through their pores and wilt. The rate of respiration roughly doubles or triples for every 18 °F (10 °C) rise in temperature, so heat is the great enemy of freshness.

That is why growers pick in the cool of the morning, keep harvested crops in the shade and remove **field heat** quickly. Lettuce, spinach, broccoli, peas and carrots are plunged in cold water, drained and refrigerated in bags that keep humidity high. Handle produce gently: bruises and cuts let in rot organisms and speed respiration. Not everything belongs in the cold, though. Tomatoes, basil, cucumbers, peppers, winter squash and sweet potatoes are damaged by chilling below about 50 °F; they lose flavor or develop pits and rot.

Some crops must be **cured** before storage. Winter squash and pumpkins are kept warm (about 80–85 °F) for one to two weeks so the rind hardens, and sweet potatoes are cured warm and humid so cuts heal and starch turns to sugar. Onions and garlic are dried in an airy, shaded place for two or three weeks until the necks are tight and papery. Potatoes are held in the dark for about two weeks so their skins set; light turns them green and bitter. After curing, each crop is stored under its own best conditions: potatoes and roots cold and humid, onions cool and dry, squash moderately cool and dry. A well-stored harvest can feed a family through the winter.

Many county fairs have youth and open vegetable classes, and judges look for exactly what good harvest handling produces. A plate of three to five vegetables should be **uniform** in size, shape and color, **true to type** for the variety, at the right stage of ripeness, free of blemishes, insect damage and bruises, gently cleaned (brushed, not scrubbed, for most roots) and correctly labeled with the variety name. In 4-H and FFA judging contests, students rank a class of four plates and defend their placing with short, clear oral reasons.

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 this scene of the wheat harvest as one of a series showing the months of the year. It is a picture of hard work, rest and plenty, and of the careful timing of a harvest.

Look closely

- Find the workers cutting grain and the ones tying it into sheaves. What tools are they using?
- Look at the color of the wheat. How can you tell it is ripe and dry?
- Find the people resting under the tree. What are they eating, and why might they rest at midday?
- Look for other harvests going on in the background: fruit, hay or carts carrying grain.

Talk about it

1. Why would a farmer want to cut the whole field quickly once the grain is ripe?
2. What could happen to this harvest if it rained before it was gathered in?
3. How do the workers keep themselves and their food out of the heat?

The Freshness Experiment

You will test how temperature and handling affect the shelf life of fresh greens, and cure or store one crop correctly.

You will need

- Two equal heads of lettuce or two bunches of the same greens (from your garden or a market)
- A bowl of ice water and a towel
- Two zip bags
- A kitchen scale (optional)
- One curing crop if available: a winter squash, sweet potatoes, onions or potatoes

Steps

1. If you have a garden, harvest the greens in the early morning. Otherwise, buy two equal bunches.
2. Weigh each bunch if you have a scale, and photograph or sketch both.
3. Plunge bunch A in ice water for 10 minutes, shake it dry, put it in a zip bag with a dry paper towel, and refrigerate it.
4. Leave bunch B unwashed and unbagged on the kitchen counter for four hours (to imitate a hot afternoon after harvest), then bag it and refrigerate it.
5. Each day for seven days, rate each bunch from 1 (wilted or slimy) to 5 (crisp) and weigh it again if you can.
6. Meanwhile, cure or store your second crop correctly for its type, using the core ideas. Record the conditions you chose and why.
7. Graph the freshness ratings for both bunches and write a conclusion explaining the result using the words respiration and field heat.
8. Fair practice: choose five matched vegetables or fruits (tomatoes, peppers, potatoes, onions or apples, from your garden or a market) for an exhibit plate. Then set out four plates of the same crop, place them 1 to 4 on a

placing card, and give one minute of oral reasons comparing each pair on uniformity, trueness to type, ripeness and blemishes.

Tips

- Change only one thing between the two bunches. Same variety, same size, same fridge shelf.
- If you have no curing crop at home, visit a farm stand and ask the grower how they store squash, onions or potatoes; record the answer.
- Check your county fair book for each crop's rules: how many to show, whether stems stay on and whether onions and potatoes may be washed.

Check your work

- ☐ I ran a fair test with one variable.
- ☐ I recorded a freshness rating every day for a week.
- ☐ I can explain why cooling slows spoilage.
- ☐ I can name two crops that should be cured and two that should never be refrigerated.

NATURE JOURNAL

1. Draw a ripe ear of corn with the husk peeled back, labeling the brown silk and the milky kernel test.
2. Make a chart of six crops showing the best storage temperature and humidity for each.
3. Sketch your two lettuce bunches on day one and day seven side by side.

COMMON MISTAKES

- Harvesting in the heat of the afternoon and leaving produce in the sun.
- Washing and storing onions, garlic and squash wet instead of curing them dry.
- Refrigerating tomatoes and basil, which are damaged by cold.
- Leaving beans, zucchini and cucumbers to grow huge, which makes them tough and slows new production.

Make it a game • Freshness Clock Challenge. Set a one-minute timer and name every sign of ripeness you know across common garden crops. Parent keeps a tally. Next round, explain why harvested produce keeps respiring and losing water, and how cooling slows it. Finish with a ranked list of which crops spoil fastest. Beat your own total of correct signs.

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

God’s promise after the flood is the reason a farmer can plan at all. We sow and harvest trusting that the seasons He made will keep their order.

1.4 SEED SAVING, HEIRLOOMS AND NEW VARIETIES

OBJECTIVES

- Explain the difference between open-pollinated, heirloom and hybrid (F1) varieties.
- Explain why some crops cross-pollinate easily and how growers keep seed true to type.
- Save, clean, dry, label and test tomato or bean seed.

Warm-up. Look at a handful of dry beans or a seed packet. List every trait you can see or read (color, size, shape, days to maturity, disease resistance). Star the traits you would want to keep if you were saving seed.

WATCH

How to Save True-To-Type Heirloom Tomato Seeds

OYR Frugal & Sustainable Organic Gardening · 7:23

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

WHEN TO WATCH

After the core ideas. Pause at the flower diagram and name each part before he does.

Note: The host mentions his Amazon affiliate link in the description, not in the video.

BACKUP VIDEO

How to Save Tomato Seeds for Next Year

Next Level Gardening · 10:48

https://www.youtube.com/watch?v=_K9OPQsXyNg

Watch before the project for a detailed look at the fermenting method.

KEY TERMS

open-pollinated

A variety pollinated naturally by wind, insects or itself, whose saved seed grows plants like the parent if no crossing with another variety occurs.

heirloom

An open-pollinated variety that has been saved and handed down for many years, often fifty or more.

hybrid (F1)

The first-generation offspring of a deliberate cross between two different parent lines. F1 plants are uniform and vigorous, but their saved seed produces a mix of types.

self-pollinating

A plant whose flowers usually pollinate themselves, such as beans, peas, lettuce and most tomatoes, so seed is easy to keep true.

cross-pollination

Pollen moving from a flower of one plant to another plant. Squash, corn and many brassicas cross easily between varieties.

isolation distance

The space growers leave between varieties of the same crop so they do not cross. It can be a few feet for tomatoes or a quarter mile or more for corn.

CORE IDEAS

Every seed carries instructions from its parents. When pollen from one plant fertilizes a flower, the seed that forms combines traits from both. If a plant pollinates itself, as beans, peas, lettuce and most garden tomatoes usually do, the seed grows into a plant almost exactly like its parent. These **self-pollinating** crops are the best place to start saving seed. Squash, cucumbers, melons, corn, spinach, beets and cabbage-family crops are mostly **cross-pollinated** by insects or wind, so varieties grown near each other will mix unless they are kept apart by an **isolation distance**, grown at different times, or hand-pollinated and bagged.

An **open-pollinated** variety is one whose saved seed “comes true.” An **heirloom** is an open-pollinated variety with a long family or regional history, such as Brandywine tomatoes, Kentucky Wonder pole beans or Moon and Stars watermelon. A **hybrid**, marked F1 on seed packets, comes from crossing two carefully kept parent lines. F1 plants are uniform and often vigorous and disease-resistant, but seed saved from them grows into an unpredictable mix, so growers buy new F1 seed each year.

Farmers and gardeners have shaped crops for thousands of years by choosing which plants to save seed from. Keep seed from the healthiest, most productive, best-tasting plants, and over many seasons a variety becomes better fitted to your own soil and climate. Plant breeders do the same thing deliberately: they cross two varieties to combine, say, the flavor of one tomato with the disease resistance of another, then grow and choose among the offspring for many generations until the

new variety breeds true. The enormous variety of beans, tomatoes and apples we enjoy is the fruit of this patient work within the kinds God created.

To save seed well: let the fruit or pod ripen fully on the plant (dry beans rattle in the pod; tomatoes should be fully ripe). Tomato seeds sit in a gel that keeps them from sprouting inside the fruit; a few days of **fermenting** the pulp in a jar of water breaks down the gel and helps control some seed-borne diseases. Rinse the good seeds that sink, spread them on a plate (not a paper towel, which they stick to) and dry them for a week. Store seed cool, dry and dark in labeled envelopes with the variety and date. Most vegetable seed keeps three to five years this way; onion and parsnip seed are best used within a year or two. Test old seed by sprouting ten seeds in a damp paper towel to find the germination rate.

PICTURE STUDY



Beans, from Les Plantes Potagères, Vilmorin-Andrieux et Cie, 1880s · Chromolithograph plate · Vilmorin-Andrieux seed company, Paris

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

The Vilmorin family ran one of the most famous seed houses in the world, in Paris, and published careful descriptions of hundreds of vegetable varieties. This plate shows some of the bean varieties gardeners grew in the nineteenth century, many of them heirlooms still saved today.

Look closely

- Find the dry seed drawn in each panel. How do the seeds differ in color and size?
- Compare the pods. Which look like snap beans to eat green, and which look like beans grown for dry seed?
- Read the variety names. Which ones are wax (yellow) beans?
- Find the flowers. What color are they, and do they differ between varieties?

Talk about it

1. Why do you think a seed company would print such careful pictures of each variety?
2. If you grew two of these beans side by side, would you expect them to cross? Why or why not?

3. Which variety would you choose to save, and what trait would you be keeping?

Safety first. Seed that has been coated with a colored fungicide (often pink, blue or green) must not be eaten or handled by young children; wash hands after handling any treated seed.

HANDS-ON PROJECT

Save, Label and Test Your Own Seed

You will save seed from a self-pollinating crop, clean and dry it properly, and run a germination test, then make labeled seed packets for next spring.

You will need

- One or two fully ripe heirloom or open-pollinated tomatoes, or a handful of dry bean pods
- A small jar, a spoon, a fine strainer and a ceramic plate
- Paper envelopes and a pen
- Paper towels and a zip bag for the germination test

Steps

1. Choose fruit from your best, healthiest plant. If you have no garden, buy an heirloom tomato at a farmers' market (hybrids will not come true).
2. Tomatoes: cut the fruit across its middle and squeeze the seeds and gel into a jar. Add about as much water as pulp and label the jar with the variety.
3. Set the jar in a warm spot out of the sun for 3–4 days, stirring once a day. A white film will form on top; this is normal.
4. Pour off the film and floating seeds. Rinse the heavy seeds that sink in a strainer until clean.
5. Spread the seeds on a ceramic plate and let them dry for 7–10 days, stirring daily so they do not clump.
6. Beans: leave pods on the plant until they are dry and rattle. Shell them and dry the beans another two weeks indoors. Freeze them for 48 hours to kill any bean weevil eggs.
7. Germination test: roll 10 seeds in a damp paper towel, put it in a zip bag in a warm place and count sprouts after 5–10 days. Germination rate = $\text{sprouts} \div 10 \times 100\%$.
8. Make envelopes labeled with the crop, variety, date saved, where it grew and your germination rate.

Tips

- Fully dry seed snaps rather than bends. Damp seed will mold in storage.
- Keep packets in a sealed jar in a cool closet or the refrigerator, away from humidity.

Check your work

- ☐ I can explain why I chose a self-pollinating, open-pollinated variety.
- ☐ I cleaned and dried seed until it was fully dry.
- ☐ I ran a germination test and calculated the percentage.
- ☐ My seed packets are fully labeled.

NATURE JOURNAL

1. Draw a cross-section of a tomato flower and label the anthers, stigma, style and ovary. Explain in one sentence why the flower usually pollinates itself.
2. Draw five beans of different varieties actual size and describe each one's color and markings.
3. Record your germination test as a table and a percentage.

From history. Thomas Jefferson was a devoted seed saver. In his Monticello garden he grew about 330 varieties of some 70 different vegetables, traded seed with friends across America and Europe, and kept a careful "Garden Book" for nearly sixty years. He wrote that "the greatest service which can be rendered any country is to add an useful plant to its culture."

COMMON MISTAKES

- Saving seed from F1 hybrid plants and expecting the same plant next year.
- Saving seed from squash grown next to other squash varieties and getting strange crosses.
- Drying tomato seeds on a paper towel, where they stick fast.
- Storing seed in a warm, damp place such as a garage or kitchen windowsill.

Make it a game • Seed Type Sort. Write variety words on cards: open-pollinated, heirloom, hybrid F1, self-pollinating, cross-pollination. Parent reads a definition and you slap the card. Then solve an isolation-distance puzzle: parent names two squash varieties planted side by side and you explain what happens to seed and how to keep it true to type.

Scripture. “And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good.” (Genesis 1:12, KJV)

God made plants to carry their seed “in itself” and to bring forth after their kind. Every seed you save is a small witness to that design.

UNIT 1

HARVEST AND THE SEASONS

Every garden sits inside a climate, but every plant lives in a microclimate: the few square feet of air, sun and soil right around it. A south-facing brick wall, a frost pocket at the bottom of a slope or a breezy corner can change the growing season by weeks. In this unit you will learn to read your own yard the way a grower does, and then to change it, using cold frames, row covers and greenhouses to stretch the season at both ends.

You will also learn the other half of growing food: harvesting at the right moment and keeping produce fresh afterward, because a vegetable is still alive after it is picked. Finally you will save your own seed, learn what makes an heirloom variety “breed true,” and see how growers have patiently shaped the vegetables we eat. God promised that “seedtime and harvest ... shall not cease” (Genesis 8:22); this unit is about working wisely within that rhythm.

PREREQUISITES

- Knows the four seasons and that Earth’s tilt causes them
- Can read a thermometer and record data in a table
- Has grown at least one plant from seed
- Knows the basic parts of a flower (petals, stamens, pistil)

MASTERY CHECKLIST

- ☐ I can explain the difference between a climate zone and a microclimate and find microclimates in my own yard.
- ☐ I can explain how cold frames, row covers and greenhouses trap heat, and build a simple season-extension device.
- ☐ I can tell when common crops are ready to harvest and explain why cooling and curing keep produce fresh.
- ☐ I can save seed from a self-pollinating crop and explain the difference between heirloom, open-pollinated and hybrid varieties.
- ☐ I can keep a dated temperature log and draw a conclusion from it.

LESSONS IN THIS UNIT

1.1 Climate Zones and Microclimates

2 sessions of 50–60 minutes

1.2 Season Extension: Cold Frames, Row Covers and Greenhouses

2 sessions of 50–60 minutes

1.3 Harvest and Post-Harvest Handling

2 sessions of 50–60 minutes

1.4 Seed Saving, Heirlooms and New Varieties

2 sessions of 50–60 minutes

UNIT 1 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **8 pts**

What does a USDA hardiness zone tell a gardener, and what does it not tell?

2. **8 pts**

Name four factors that can create a microclimate.

3. **6 pts**

Why does the bottom of a hill often get frost first?

4. **8 pts**

Explain how a cold frame keeps plants warmer than the open garden.

5. **6 pts**

What is the main danger of a closed cold frame on a sunny day, and what should you do?

6. **6 pts**

Give two signs that sweet corn is ready to pick.

7. **8 pts**

Why do growers harvest leafy greens early in the morning and cool them quickly?

8. **8 pts**

What is curing? Name two crops that are cured before storage.

9. **8 pts**

What is the difference between an heirloom variety and an F1 hybrid?

10. **6 pts**

Why is it easier to save true seed from beans than from squash?

11. **14 pts**

Written answer: You want to grow spinach through November in a cold region. Describe where you would put it, what device you would use, when you would plant and how you would care for it.

12. **14 pts**

Written answer: Explain step by step how to save tomato seed so that it stays healthy and grows the same variety next year.

ANSWER KEY

1. It tells the average coldest winter temperature, so which perennials can survive the winter. It does not tell summer heat, rainfall, the length of the season or when to plant vegetables.
2. Any four of: aspect (direction faced), slope and low spots, walls and paving that store heat, wind and windbreaks, nearby water, shade from trees or buildings.
3. Cold air is heavier than warm air and drains downhill on still nights, collecting in low spots called frost pockets.
4. Sunlight passes through the clear lid and warms the soil and air inside; the lid traps the warm air and slows heat loss at night and shelters plants from wind.
5. It can overheat and scorch plants. Vent it by propping the lid open, then close it in late afternoon.
6. The silks are brown and dry, and a kernel pressed with a thumbnail gives milky juice (about three weeks after silking; ears feel full).
7. Picked produce keeps respiring and losing water; heat speeds respiration. Cool morning harvest and quick removal of field heat slow respiration and wilting and extend shelf life.
8. Holding crops under warm or dry conditions after harvest so skins harden and wounds heal before storage. Examples: winter squash, sweet potatoes, onions, garlic, potatoes.
9. An heirloom is an old open-pollinated variety whose saved seed comes true to type. An F1 hybrid is the first-generation cross of two parent lines; its saved seed does not come true.
10. Beans usually pollinate themselves, so they rarely cross. Squash is pollinated by insects and crosses easily with other squash varieties nearby.
11. A good answer places the bed in a warm microclimate (south-facing, sheltered, not in a frost pocket); uses a cold frame or row cover on hoops; sows in late summer so plants are near full size before short days; vents on sunny days and closes at night; adds thermal mass or extra covers in hard freezes; harvests leaves gradually.
12. Choose a ripe fruit from a healthy open-pollinated (heirloom) plant, not a hybrid; squeeze seeds and gel into a jar with water; ferment 3–4 days, stirring; pour off film and floaters; rinse the sinking seeds; dry on a plate for a week or

more; store cool, dry and dark in a labeled envelope; test germination before planting.

PORTFOLIO PIECE: A SEASON-EXTENSION REPORT

Present your cold frame (or other season-extension device) with your microclimate map, your two-week temperature log and graph, and photos or drawings of the crop growing in it. Add one page explaining what you learned and what you would change next season, and attach the labeled seed packets you saved.

LOOK FOR	WHAT IT MEANS
Site choice	Uses the microclimate map to explain why the device was placed where it was.
Data	A complete, dated temperature log with a clear graph and correctly calculated averages.
Crop care	Shows the crop sown, vented and watered faithfully, with growth recorded in drawings or photos.
Explanation	Correctly explains heat trapping, venting and thermal mass in the student's own words.
Seed packets	Saved seed is clean, dry and fully labeled with variety, date and germination rate.

UNIT 2

WILDLIFE

Wild animals share every farm, garden and back yard, even when we never see them. Most are active at dawn, dusk or night, so a naturalist learns to read the evidence they leave behind: tracks, trails, droppings, chewed twigs, tunnels and mounds. In this unit you will learn to identify animals from their signs, then study three groups that matter most to growers and keepers of animals: deer, the small mammals that work underground, and the predators that hunt poultry and lambs.

Good stewardship means seeing wildlife clearly, neither as cute pets nor as villains. Deer are beautiful and graceful, and they can also strip a garden overnight and carry ticks. Moles aerate soil and eat grubs, while voles girdle young fruit trees. Coyotes and hawks keep rodent numbers down, and they also take chickens. You will learn how each animal is designed for its way of life, how to keep a safe distance, and how to protect gardens and flocks with fences, housing and guardian animals rather than guesswork.

PREREQUISITES

- Can measure in inches and centimeters and record data
- Knows the basic needs of animals: food, water, shelter, space
- Knows the rule never to touch or feed wild animals
- Knows how to check for ticks after being outdoors

MASTERY CHECKLIST

- ☐ I can identify common animal tracks by toe count, claws, shape and gait pattern.
- ☐ I can recognize deer browse and explain how deer populations affect forests and gardens.
- ☐ I can tell vole, mole and mouse signs apart and choose a fitting control method.
- ☐ I can name the common predators of poultry and livestock and design housing and fencing to stop them.
- ☐ I can explain the safety rules for ticks, rodent droppings and animals that may carry rabies.

LESSONS IN THIS UNIT

2.1 Field Identification and Tracking

2 sessions of 50–60 minutes

2.2 Deer Biology and Management

2 sessions of 50–60 minutes

2.3 Small Mammals Underground: Mice, Moles and Voles

2 sessions of 50–60 minutes

2.4 Predators and Protecting Livestock

2 sessions of 50–60 minutes

UNIT 2 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. (8 pts)

How can you tell a dog or coyote track from a cat track?

2. (6 pts)

In a rabbit's hopping trail, which feet land in front, and why?

3. (6 pts)

Name three wildlife signs other than tracks.

4. (6 pts)

How can you tell whether a twig was eaten by a deer or a rabbit?

5. (8 pts)

Describe the yearly antler cycle of a white-tailed buck.

6. (8 pts)

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

7. (6 pts)

What should you do if you find a fawn lying alone?

8. (8 pts)

Give two differences between a mole and a vole.

9. (6 pts)

Why is chicken wire not enough to protect chickens at night?

10. **8 pts**

How does a livestock guardian dog protect a flock?

11. **15 pts**

Written answer: A family's young apple trees are dying, and the bark around the base of the trunks has been chewed away under last winter's snow. Explain what animal is most likely responsible, why the trees died and three things the family should do.

12. **15 pts**

Written answer: Explain why tick checks matter, and describe the link between mice, deer and the blacklegged tick.

ANSWER KEY

1. Dog-family tracks are oval with four toes and claw marks, and an X fits between the pads. Cat tracks are rounder, usually show no claws and have a larger, three-lobed heel pad.
2. The large hind feet land ahead of the front feet, because the rabbit swings its hind legs past its front legs as it hops.
3. Any three: trails, scat, chewed nuts or twigs, buck rubs, scrapes, burrows or dens, feathers or fur, owl pellets or whitewash.
4. Deer have no upper front teeth, so they tear twigs and leave a ragged end. Rabbits leave a clean, slanted cut.
5. Antlers grow in spring and summer covered in velvet, harden in late summer when the velvet is rubbed off, are carried through fall, and are shed in late winter, then regrown.
6. A line in the woods, about 5–6 feet high, below which deer have eaten almost all leaves and twigs. It shows deer numbers are above the land's carrying capacity.
7. Leave it alone and walk away. Its mother hides it and returns to nurse it.
8. Any two: moles are insectivores and voles are rodents; moles have huge paddle-like front feet and a pointed snout, voles a blunt nose and short tail; moles make ridges and molehills, voles make surface runways and small holes; moles eat grubs and worms, voles eat roots, bulbs and bark.
9. Raccoons can tear or reach through it and weasels and rats can slip through it. Half-inch hardware cloth is needed.
10. Raised with the flock from puppyhood, it bonds with the animals, lives with them, patrols, barks and places itself between the flock and predators, usually driving them away.
11. Voles. They gnawed the bark all the way around (girdling), cutting off the flow of sugars to the roots. The family should wrap trunks with ¼-inch hardware cloth set below the soil and above the snow line, pull mulch away from trunks and mow grass short around the trees, and set snap traps or encourage natural predators, avoiding poison baits.
12. Blacklegged ticks can carry the Lyme disease bacterium. Young ticks feed mostly on white-footed mice, which often carry the bacterium; adult ticks feed on deer, which carry and spread them. Ticks usually must be attached more

than a day to pass on Lyme disease, so finding and removing them quickly after time in grass or woods prevents infection.

PORTFOLIO PIECE: A WILDLIFE STEWARDSHIP REPORT

Combine your track and sign survey, your deer browse survey and your underground detective map into one report about the wildlife on a property you know. End with a stewardship plan: which animals to welcome, which to manage, and the specific fences, housing or habitat changes you recommend to protect a garden or a flock.

LOOK FOR	WHAT IT MEANS
Evidence	Signs are recorded with dates, places, measurements and drawings or photos.
Identification	Animals are identified correctly with clear reasons, and uncertainty is stated honestly.
Science	Explains each animal's design, diet and role accurately, including disease and tick risks.
Stewardship plan	Recommendations are practical, humane, specific and matched to the animals found.

2.1 FIELD IDENTIFICATION AND TRACKING

OBJECTIVES

- Identify common mammal tracks by toe count, claw marks, shape and size.
- Recognize the four main gait patterns: diagonal walkers, waddlers, bounders and hoppers or gallopers.
- Find and record other wildlife signs: trails, scat, feeding signs, rubs and dens.

Warm-up. Walk on all fours across a sandy or snowy patch (or on paper with damp feet and hands), first walking slowly, then hopping like a rabbit. Look at the patterns you left. Which hand and foot prints landed together, and which landed in front?

WATCH

Animal Tracks Part One: Track Patterns

MontanaFWP · 3:39

<https://www.youtube.com/watch?v=r4GjV6aUXzk>

WHEN TO WATCH

After the core ideas. Draw the four pattern shapes she sketches on the board and write one animal for each.

BACKUP VIDEO

Identifying Animal Tracks

Jessamine County Public Library · 13:12

<https://www.youtube.com/watch?v=Oov9ZF9UwtY>

Before the project. A Master Naturalist presses real track replicas into sand and explains each one; pause to sketch them.

KEY TERMS

track

A single footprint. A series of tracks is called a trail.

gait

The way an animal moves (walking, trotting, bounding, hopping or galloping), which shows up as a pattern of tracks.

direct register

When an animal places its hind foot exactly in the print of its front foot, as foxes, cats, coyotes and deer often do when walking.

straddle

The width of a trail from the outside of the left prints to the outside of the right prints.

stride

The distance from one track to the next print of the same foot or the same group of feet.

scat

Animal droppings. Their size, shape and contents help identify the animal and show what it has been eating.

CORE IDEAS

A track tells you three things at once: how many toes the animal has, whether its claws show, and the shape and size of its foot. Dogs, coyotes and foxes leave four toes with claw marks in an oval print; you can usually draw an “X” between the toe pads and the heel pad without touching them. Cats, including bobcats, leave a rounder print with four toes and usually no claw marks, because cats pull their claws in. Raccoons leave five long, finger-like toes that look like a small child’s hand. Opossums have five toes on each foot, and the hind foot has a thumb that points sideways. Deer leave a split, heart-shaped hoof print whose point shows the direction of travel. Rodents and rabbits have four toes on the front feet and five on the hind feet.

The pattern of a trail shows the animal’s **gait**. **Diagonal walkers** (deer, foxes, coyotes, cats) move opposite legs together and often **direct register**, leaving a neat line of single prints that saves energy in deep snow. **Waddlers** (raccoons, opossums, skunks, porcupines, bears) are wide-bodied and slow and leave a broad, shuffling trail. **Bounders** such as weasels and mink leap with front and hind feet landing close together, leaving pairs of prints. **Hoppers and gallopers** (rabbits, squirrels and mice) land with the hind feet in front of the front feet, so the large hind prints are ahead in each group of four. Squirrels’ front feet land side by side; a rabbit’s usually land one behind the other.

Tracks are not the only sign. Look for trails worn through grass, scat on rocks and logs, nibbled nuts and pine cones, buck rubs on saplings in fall, scrapes, dens and burrows, feathers or fur caught on fences, and the white wash under an owl roost. Note where you find each sign: animals use edges where field meets woods, stream

banks and fence lines. Wildlife biologists use these clues to survey which animals live in an area without ever trapping or disturbing them.

Good trackers measure. Record the length and width of a print, the stride and the straddle, and the surface (mud, sand, snow) and its age. Prints in mud are clearest a day or two after rain; fresh snow is best of all. Never pick up scat with bare hands, since it can carry parasites, and never follow a trail toward a den or close to an animal. Tracking teaches the patient, careful attention to detail that Charlotte Mason called the habit of observation.

PICTURE STUDY



The Fox Hunt, Winslow Homer, 1893 · Oil on canvas · Pennsylvania Academy of the Fine Arts, Philadelphia

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

Winslow Homer painted this winter scene near his home on the coast of Maine. In a hard winter, deep snow makes life difficult even for a skilled hunter like the fox. Look at the painting as a tracker would.

Look closely

- Find the fox's trail in the snow. How deep does the fox sink with each step?
- Look at the fox's body and tail. How is it built for cold weather?
- Find the crows. What do you think they are doing, and why might they follow the fox?
- Look for the red berries. What other animals might come to eat them?

Talk about it

1. What would the fox's tracks look like in this snow, and would they be single-file or scattered?
2. Why might deep snow make winter harder for foxes and easier for the mice they hunt?
3. What other signs (not tracks) might you find in a winter scene like this?

Safety first. Never touch scat, bones or dead animals; use a stick or take a photo. Stay well back from dens and burrows. Check yourself for ticks after walking in long grass or woods, and tell an adult about any animal acting strangely or out in daytime when it usually is not.

HANDS-ON PROJECT

A Track and Sign Survey

You will make a tracking station, record every wildlife sign you can find around your home or a park for one week, and identify the animals that left them.

You will need

- A shallow tray or a 2-foot square of smooth, damp sand or fine soil (a tracking station)
- A ruler or measuring tape
- Your nature journal and a pencil
- A camera or phone (optional)
- A field guide to tracks from the library (optional)
- Plaster of Paris and a strip of cardboard for casting (optional, with an adult)

Steps

1. Smooth a patch of damp sand or soil near a garden edge, fence line or woodland edge. Rake it flat each evening.
2. Each morning, check the station. Photograph or draw any prints next to a ruler, and record length, width, number of toes and claw marks.
3. Once during the week, walk a set route around your yard or a park and list every other sign: trails, scat (look only), chewed plants, burrows, rubs, feathers.
4. For each sign, record the date, place and your best identification, with the clues that support it.
5. If you find a clear print in mud, make a plaster cast with an adult: ring it with cardboard, pour plaster the thickness of pancake batter, let it set 30 minutes and lift it gently.
6. At the end of the week, make a table of animals detected, the evidence for each and how sure you are (certain, likely, possible).
7. Write a short paragraph: which animals use your area, at what times, and what that tells you about food and shelter there.

Tips

- Tracks are easiest to read in low, slanting light early or late in the day.
- A dab of peanut butter on a stick in the middle of the station attracts visitors without feeding them a meal.
- Apartment dwellers can set a station on a balcony planter or visit a park with a muddy trail.
- Many 4-H programs have wildlife, outdoor-skills and natural-resources projects, and some fairs accept educational posters or journal displays; a clear track-and-sign survey makes a fine exhibit.

Check your work

- ☐ I recorded measurements, not just guesses.
- ☐ I identified at least three different animals or signs and gave evidence for each.
- ☐ I can name the four gait patterns and an animal for each.
- ☐ I kept a safe distance and did not touch scat or dens.

NATURE JOURNAL

1. Draw actual-size tracks of a dog or fox, a cat, a raccoon, a deer and a rabbit, and label toes, claws and heel pads.
2. Draw the trail patterns of a diagonal walker and a hopper as seen from above.
3. Sketch the best track from your station next to a ruler, with notes on surface and weather.

From history. Ernest Thompson Seton, an artist and naturalist, filled his notebooks with careful drawings of animal tracks. His book *Two Little Savages* (1903) taught readers how to read tracks and signs, and his writing helped start the scouting movement in North America, teaching generations of young people to read the woods.

COMMON MISTAKES

- Reading a rabbit's large hind prints as the back of the group; in a hopping trail they land in front.
- Confusing a large cat print with a dog print. Look for claws and the shape of the heel pad.
- Forgetting that tracks spread and grow larger as snow melts.

- Naming an animal from one blurry print instead of looking for several clues.

Make it a game · Track Gait Charades. Take turns acting out a gait on the floor, diagonal walker, waddler, bounder, hopper or galloper, while your parent guesses it. Then draw a track with toe count and claw marks, and your parent names the animal. Add a stride and straddle measurement using a ruler. First to four correct IDs wins.

2.2 DEER BIOLOGY AND MANAGEMENT

OBJECTIVES

- Describe how white-tailed deer are designed for browsing, alertness and speed, and the yearly cycle of antlers and fawns.
- Explain how deer populations grow when food is plentiful and predators are few, and how this affects forests and gardens.
- Compare ways to protect gardens from deer, and explain the link between deer, mice and Lyme disease ticks.

Warm-up. Look at a twig from a shrub that has been chewed (or a rose or hosta stem). Is the cut end clean and slanted, or torn and ragged? Write a guess about which animal did it and why the end looks that way.

WATCH

From Nubs To Growing Antlers: An Incredible Process

MSU Deer Lab TV · 1:49

<https://www.youtube.com/watch?v=nyRgxQal7Dw>

WHEN TO WATCH

After the core idea about antlers. Dr. Demarais of Mississippi State's Deer Lab shows a buck just after it has dropped last year's antlers; watch how the new antler begins as a soft, velvet-covered nub.

Note: The freshly shed antler base looks red for a moment; this is normal and heals over within days.

BACKUP VIDEO

Keeping Deer Out of the Garden With Only a 4' Fence: Our "Deer Moat" is Working!

Well Grounded Gardens · 4:39

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

With the last core idea, about protecting gardens.

KEY TERMS

browse

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

antler

A branched bone that grows from a buck's head every year, is covered with living velvet while it grows, and is shed in late winter.

browse line

A clear line in a woods below which deer have eaten almost every leaf and twig, about 5–6 feet off the ground.

ruminant

A hoofed animal with a four-chambered stomach that chews its cud, such as deer, cattle, sheep and goats.

carrying capacity

The largest population of a species that an area's food, water and shelter can support year after year without being damaged.

blacklegged tick

Also called the deer tick; the tick that can carry the bacterium that causes Lyme disease.

CORE IDEAS

The white-tailed deer is the most widespread large wild animal in the eastern and central United States. Deer are built for alertness and escape. Their eyes on the sides of the head give a very wide field of view, their large ears swivel toward sounds, and their sense of smell is far keener than ours. Long legs let them run about 30 miles an hour and clear an 8-foot fence. When alarmed, a deer raises its white tail like a flag, a signal that warns other deer. Deer are **ruminants**: they eat quickly, store food in the first chamber of the stomach, and later bring it back up to chew as cud in safety.

Deer have no upper front teeth, only a hard pad. When they bite a twig, they tear it, leaving a ragged end, while rabbits snip a clean, slanted cut. Deer eat buds, twigs, leaves, acorns, fruit and many garden plants, especially hostas, tulips, lettuce, beans, roses and young fruit trees. A buck grows **antlers** of real bone each spring and summer, covered in soft, blood-rich velvet. In late summer the velvet dries and is rubbed off on saplings, the antlers harden, and in late winter they drop off to be regrown. Fawns are born in late spring with white spots that camouflage them. The mother leaves the fawn hidden alone for hours and returns to nurse it, so a fawn lying quietly by itself is almost never abandoned. Leave it where it is.

When food is plentiful and few predators remain, deer numbers grow quickly, since a healthy doe may raise one to three fawns each year. Many eastern suburbs and farm regions now hold far more deer than the land can support. You can see the result in a **browse line**, an open woods where no young trees or wildflowers survive, and in damaged crops and many deer-vehicle collisions. State wildlife agencies manage deer populations within the **carrying capacity** of the land, mainly by setting regulated hunting seasons and limits, along with protecting habitat. A healthy herd and a healthy forest go together.

Deer also play a part in the life of the **blacklegged tick**. Young ticks mostly feed on white-footed mice, which often carry the Lyme disease bacterium; adult ticks feed and gather on deer. That is why tick checks matter after any walk in tall grass or woods: ticks must usually stay attached for more than a day to pass on Lyme disease, so finding them early protects you. To protect a garden, the most reliable defense is a fence: an 8-foot fence, or two 4- to 5-foot fences about 4 feet apart, because deer will not jump into a narrow space where they cannot see a safe landing. Repellents and “deer-resistant” plants such as daffodils, lavender, sage and other strong-scented or fuzzy plants help, but a hungry deer in winter will eat almost anything.

PICTURE STUDY



Common or Virginian Deer, John Woodhouse Audubon, for John James Audubon's *Viviparous Quadrupeds of North America*, 1845 · Hand-colored lithograph · *The Viviparous Quadrupeds of North America*

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

After finishing his famous bird paintings, John James Audubon set out with his sons to picture every mammal of North America. His son John Woodhouse Audubon painted many of the plates, including this one of the white-tailed deer, then called the Virginian deer.

Look closely

- Find the antlers. How many points (tines) can you count? Are they in velvet or hard?
- Look at the deer's ears and eyes. How are they placed for watching and listening?
- Find the white parts of the coat. Where are they, and how would a deer use its tail as a signal?
- Look at the legs and hooves. What do they tell you about how a deer moves?

Talk about it

1. What season do you think this picture shows? What clues help you decide?
2. Why would a deer's coat be reddish in summer and gray-brown in winter?
3. How is this deer built to escape from predators?

Safety first. Do a full tick check after time in tall grass or woods, including behind the ears, in the hair and behind the knees, and have an adult remove any attached tick with fine tweezers. Never approach a deer, especially a buck in fall or a doe with a fawn.

HANDS-ON PROJECT

Deer Browse Survey and Garden Defense Plan

You will survey a woods edge, park or yard for deer signs, measure the browse line, and design a deer-defense plan for a garden.

You will need

- A tape measure or yardstick
- Your nature journal
- A camera or phone (optional)
- Graph paper
- A library book or extension fact sheet on deer-resistant plants

Steps

1. With an adult, walk the edge of a woods, park or large yard. Look for deer tracks, droppings (small, dark pellets in piles), beds of flattened grass and torn-off twigs.
2. Choose ten young shrubs or saplings. For each, record the species if you know it, its height and whether its twig ends are torn (deer), cleanly cut (rabbit) or untouched.
3. Look for a browse line under the trees. If you see one, measure its height from the ground.
4. Calculate the percentage of plants browsed. Decide whether deer pressure here is low, moderate or high.
5. On graph paper, draw a garden 20 by 30 feet. Design a deer defense for it: either an 8-foot fence or a double fence, with a gate.
6. List the length of fencing needed and estimate the cost using prices from a farm-supply website or catalog.
7. Add a planting border of six deer-resistant plants and explain why each discourages deer.

Tips

- Deer droppings in summer may be soft and clumped; in winter they are hard, separate pellets.

- Tick season peaks from spring through fall; tuck pants into socks for the survey.

Check your work

- ☐ I recorded twig damage on ten plants and calculated a percentage.
- ☐ I can tell deer browse from rabbit damage.
- ☐ My garden plan shows fence height, layout, length and cost.
- ☐ I did a full tick check afterward.

NATURE JOURNAL

1. Draw a deer-browsed twig and a rabbit-cut twig side by side, close up, and label the difference.
2. Draw the yearly antler cycle as a circle diagram: growing in velvet, hard antler, shed, regrowing.
3. Draw a blacklegged tick next to a dog tick (from a guide), actual size and enlarged.

COMMON MISTAKES

- “Rescuing” a fawn found alone. Its mother is nearby and returns to nurse it.
- Relying on one repellent all season; deer get used to a single smell, so rotate them.
- Building a single 5-foot fence, which a deer can easily clear.
- Skipping tick checks because it is cool outside; adult ticks are active on mild winter days.

Make it a game • Deer Year Wheel. Draw a circle divided into the deer's year: antlers growing, rut, antlers shed, fawns born. Spin a pencil on it and explain what is happening where it lands. Add the design features for browsing, alertness and speed. Finish with the cause-and-effect chain from plentiful food to a browse line, using carrying capacity.

Scripture. “As the hart panteth after the water brooks, so panteth my soul after thee, O God.” (Psalm 42:1, KJV)

The psalmist watched deer seek water with all their strength and saw a picture of a soul that longs for God. Careful observation of creation often opens our eyes to spiritual truth.

2.3 SMALL MAMMALS UNDERGROUND: MICE, MOLES AND VOLES

OBJECTIVES

- Tell moles, voles, shrews, mice and pocket gophers apart by body shape, diet and the signs they leave.
- Explain which of these animals harm gardens and which help.
- Plan humane, effective control: habitat changes, barriers, exclusion and traps.

Warm-up. Draw three quick outline sketches from memory: a mouse, a mole and a vole. Then list how you think each one makes its living. Check your drawings against the video afterward.

WATCH

Identifying Moles vs Voles

CurrituckCES · 2:07

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

WHEN TO WATCH

After the first core idea. Note the clues the extension agent gives for telling the two apart, including the tunnels and runways.

KEY TERMS

insectivore

An animal that eats mainly insects, grubs and earthworms. Moles and shrews are insectivores, not rodents.

rodent

A mammal with a single pair of ever-growing front teeth (incisors) in each jaw, used for gnawing; mice, voles, squirrels and gophers are rodents.

runway

A narrow, beaten path about 1-2 inches wide through grass, made by voles traveling under cover.

girdling

Chewing the bark all the way around a trunk or stem, which cuts off the flow of sugars to the roots and kills the plant.

exclusion

Keeping animals out with barriers, such as sealing gaps in buildings or wrapping tree trunks in wire mesh.

CORE IDEAS

Several small mammals live in or on the soil, and they are easily confused. **Moles** are insectivores built for digging: they have huge, outward-turned front paws like paddles, a pointed, hairless snout, velvety fur that lies either way so they can back up in a tunnel, and eyes and ears so tiny they are hidden in fur. They eat earthworms and grubs. Their signs are raised ridges across a lawn and volcano-shaped molehills. **Voles** are rodents: stocky, with a blunt nose, small eyes and ears, and a short tail. They make surface runways through grass and shallow burrow holes about the size of a quarter. **Mice** have large ears, large eyes and long tails. **Shrews** are tiny insectivores with long, pointed snouts, and **pocket gophers** (in the central and western states) push up fan-shaped mounds with a plugged hole to one side.

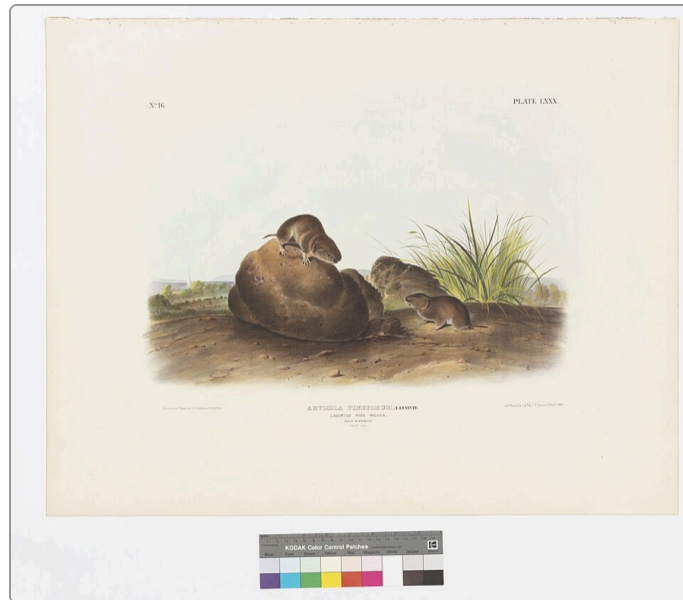
Moles rarely eat plants. They can make a lawn bumpy and uproot seedlings while tunneling, but they also loosen and aerate soil and eat many grubs. Voles do the real damage: they eat roots, bulbs, tubers and seedlings, and in winter, hidden under snow, they gnaw bark and can girdle young fruit trees and shrubs. Mice eat seeds and stored grain, chew wiring and contaminate feed. Deer mice can carry hantavirus in their droppings, a rare but serious disease, so droppings must be cleaned up correctly, never swept or vacuumed dry.

Control starts with knowing which animal you have. For voles, remove the cover they need: keep grass mowed around garden beds, pull mulch back several inches from tree trunks, and wrap young trunks in a cylinder of ¼-inch hardware cloth that reaches a few inches below the soil and above the snow line. Bulbs can be planted in wire baskets. For mice, use **exclusion**: a mouse can squeeze through a gap the size of a dime, so seal holes around pipes and doors with steel wool and caulk, and store feed and seed in metal cans with tight lids. Snap traps, set along walls and baited with peanut butter, work well for mice and voles, and adults should place them where pets and children cannot reach.

Natural predators help too. Owls, hawks, foxes, snakes and barn cats eat large numbers of rodents. Poison baits are risky: an owl or a pet that eats a poisoned

mouse can be poisoned too, so most extension services advise families to use traps and habitat changes instead, and to leave any poison to professionals. God fitted each of these small creatures to its work in the soil; our job is to manage the few that cause trouble and to welcome those that help.

PICTURE STUDY



Le Conte's Pine Mouse, John Woodhouse Audubon, for John James Audubon's *Viviparous Quadrupeds of North America*, 1845–1848 · Hand-colored lithograph · *The Viviparous Quadrupeds of North America*
Image: [Wikimedia Commons](#), public domain

Audubon called this little animal a “pine mouse,” but today we know it as the pine vole, a burrowing rodent of the eastern states. Orchard growers know it well, because it feeds on the roots of apple trees underground.

Look closely

- Look at the animal's ears, eyes and tail. How are they different from a house mouse's?
- Look at the fur. Why would short, dense fur suit an animal that lives in tunnels?
- Look at the grass and soil in the picture. Where would this animal make its runways?
- Compare the two animals. How did the artist show different sides of the body?

Talk about it

1. Is this animal a rodent or an insectivore? What clue in the picture tells you?
2. Why would a vole that lives underground be hard for an orchard grower to notice until trees start to fail?

3. How might a grower protect young apple trees from this animal?

Safety first. Never handle wild rodents, living or dead. If you find mouse droppings, do not sweep or vacuum them: an adult should wear gloves, spray them with a disinfectant or a bleach solution, wait five minutes and wipe them up with paper towels. Traps are set by adults only.

HANDS-ON PROJECT

Underground Detective Survey and Rodent-Proofing Audit

You will map mole, vole and mouse signs in a yard or garden and audit a shed, garage or feed room for ways rodents could get in.

You will need

- Flags or craft sticks to mark signs
- A tape measure and graph paper
- A flashlight
- A dime (to test gap size)
- Your nature journal

Steps

1. Walk a lawn, garden or field edge slowly. Mark every molehill, raised ridge, surface runway and small burrow hole with a flag.
2. Measure the width of runways and holes, and note whether the soil is pushed into cone-shaped hills, fan-shaped mounds or none.
3. Draw a map on graph paper showing each type of sign with a different symbol.
4. Check the base of young trees and shrubs for chewed bark, and look in the garden for nibbled roots or bulbs.
5. Decide from the evidence which animals are present and whether each is helpful, harmful or both.
6. With an adult, inspect a shed, garage or feed room with a flashlight. Look for droppings (do not touch), gnaw marks and gaps. Use the dime to test each gap.
7. Write an action plan: three habitat changes, two exclusion repairs and whether traps are needed, with reasons.

Tips

- Step on a few raised mole ridges and check them the next day. Ridges pushed back up are active tunnels.

- No yard? Survey a park lawn or a community garden, or audit your home's pantry and basement for mouse entry points.

Check your work

- ☐ I can tell a molehill from a vole hole and a gopher mound.
- ☐ My map shows signs with a key.
- ☐ I found and measured at least three possible rodent entry points.
- ☐ My action plan avoids poison and explains why.

NATURE JOURNAL

1. Draw a mole's front paw and a vole's front paw side by side, enlarged and labeled.
2. Draw a cross-section of soil showing a mole tunnel, a molehill and a vole burrow with its runway.
3. Record the date, weather and any new mounds that appeared since your survey.

From history. Farmers in ancient Egypt kept cats to protect stored grain from mice, and for centuries barns in Europe and America have kept a cat or two for the same reason. Barn owls nest in barns and church towers, and farmers who put up nest boxes for them gain a quiet, tireless mouser.

COMMON MISTAKES

- Blaming moles for eaten bulbs and roots; voles usually do it, often using mole tunnels.
- Piling mulch against tree trunks, which gives voles cover to gnaw bark.
- Sweeping up mouse droppings dry, which can raise harmful dust.
- Storing chicken feed or birdseed in paper bags or plastic bins that rodents chew through.

Make it a game • Underground Suspects Lineup. Make five suspect cards: mole, vole, shrew, mouse and pocket gopher. Parent reads a clue about body shape, diet or signs like runways and girdling; you point to the suspect. Then sort the animals into garden harmers and helpers and name an exclusion fix. Get all five suspects right in one round.

2.4 PREDATORS AND PROTECTING LIVESTOCK

OBJECTIVES

- Identify common predators of poultry and small livestock and the signs of each.
- Design secure housing and fencing for a flock using the right materials.
- Explain how livestock guardian dogs, donkeys and llamas protect animals.

Warm-up. List every animal you think might want to eat a chicken. Next to each, write when it hunts (day or night) and whether it would come by air, over a fence, under a fence or through a gap.

WATCH

How to Protect Your Chickens Against Predators | 7 Tricks You Probably Haven't Heard of

Justin Rhodes • 14:19

<https://www.youtube.com/watch?v=Xq98Ksm6RIg>

WHEN TO WATCH

After the core ideas. Write down each of his seven methods and which predator it stops.

Note: Justin Rhodes is a homesteader and author who raises poultry on pasture. A brief night-camera clip shows a raccoon near a coop; no animal is harmed on screen.

BACKUP VIDEO

Sheep farming Livestock Guardian Dogs

Farm & Food Care • 2:33

https://www.youtube.com/watch?v=9AdPZL8_bbM

With the core idea on guardian animals. Two Ontario sheep farmers explain how their dogs live with the flock.

KEY TERMS

predator

An animal that hunts and eats other animals.

apron

Wire mesh laid flat on the ground outward from a fence or coop, or buried along it, to stop animals from digging under.

electric netting

Portable fencing of plastic mesh with electrified strands that gives a sharp, harmless shock to animals that touch it.

hardware cloth

A stiff, welded wire mesh with small square openings ($\frac{1}{4}$ or $\frac{1}{2}$ inch). Unlike chicken wire, it stops raccoons, weasels and rats.

livestock guardian dog

A large working dog, such as a Great Pyrenees, Anatolian Shepherd or Maremma, raised with livestock to live with and protect them.

CORE IDEAS

Poultry and young livestock have many predators. By night: raccoons, which have clever hands and can open simple latches and reach through chicken wire; opossums; skunks, which mostly take eggs; great horned owls; and weasels and mink, which can slip through a hole about an inch wide. By day or at dusk: hawks, foxes, coyotes and bobcats. Loose domestic dogs are among the most common killers of chickens, sheep and goats. Each predator leaves different signs: missing birds with scattered feathers may mean a fox, coyote or hawk; birds taken from inside a closed coop point to a raccoon, weasel or rat; eggs eaten in the nest suggest a skunk, opossum, rat or snake.

The first defense is a secure coop, closed every night at dusk. Use $\frac{1}{2}$ -inch **hardware cloth**, not chicken wire, over every window and vent; chicken wire keeps chickens in but does not keep predators out. Bury the mesh 12 inches deep or lay a 2-foot **apron** outward along the ground to stop diggers, and use two-step latches that a raccoon cannot work open. For birds that range by day, cover a run with wire or netting against hawks, give them shrubs or shelters to hide under, and use **electric netting**

or electrified wires around a pasture to turn back coyotes, foxes and dogs. Collect eggs daily so they do not draw egg-eaters.

Hawks and owls are protected by federal law and may not be harmed. The right response is to protect your birds, not to attack the predator. Coyotes and foxes are smart; they learn when a gate is left open or a flock is left out after dark, and they test fences. Removing attractions helps: store feed in metal cans, keep compost covered and do not leave pet food outside.

Guardian animals add another layer. Livestock guardian dog breeds have been developed over centuries to live with sheep and goats rather than herd them. Raised among the flock from puppyhood, they bond with the animals, patrol the pasture, bark at night and stand between the flock and any intruder, usually driving predators off without a fight. Donkeys dislike dogs and coyotes and will chase them, and llamas also guard sheep. A rooster watches the sky and calls an alarm. Jesus described Himself as the good shepherd who does not flee when the wolf comes (John 10:11–12); a faithful keeper of animals plans ahead to protect them.

PICTURE STUDY



Flock of Sheep with Shepherd in the Snow, Anton Mauve, about 1887–1888 · Oil on canvas ·
Rijksmuseum, Amsterdam

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

Anton Mauve, a Dutch painter, loved to paint shepherds and their flocks on the heath. Here a shepherd brings his sheep across deep snow. A flock in winter depends completely on its keeper for food, shelter and protection.

Look closely

- Find the shepherd. Where is he walking in relation to the flock?
- Look at how close together the sheep are. Why might sheep bunch up like this?
- Look at the open, snowy landscape. Where could a predator approach from?
- Look for any dog or guardian with the flock.

Talk about it

1. What is the difference between a herding dog and a guardian dog?
2. Why would a shepherd bring the flock into a fold or barn at night in winter?
3. What modern tools do shepherds use to protect a flock that this shepherd did not have?

Safety first. Never approach a coyote, fox or other predator, and tell an adult right away if one seems sick or unafraid. Working guardian dogs are on duty; do not enter their pasture or pet them without the owner. Wear gloves when handling wire mesh, and leave electric fence installation to adults.

HANDS-ON PROJECT

Design a Predator-Proof Coop and Run

You will design a coop and run for six hens that stops every predator on your list, and price the materials. If you can, you will also visit a farm or 4-H keeper and inspect a real coop with them.

You will need

- Graph paper, ruler and colored pencils
- A farm-supply catalog or website for prices
- Your list of local predators
- Optional: a visit to a neighbor's, farm's or 4-H member's flock

Steps

1. List the predators in your area (ask an extension office or local farmer if unsure) and how each attacks.
2. Plan the coop size: about 3–4 square feet of floor per hen inside and about 10 square feet per hen in the run.
3. Draw a plan view and a side view of the coop and run to scale. Mark roosts, nest boxes, door, windows and vents.
4. Label every opening with the material that covers it ($\frac{1}{2}$ -inch hardware cloth, solid wood) and show the apron or buried mesh.
5. Choose latches, a roof for the run (wire or netting) and any electric fence. Explain which predator each feature stops.
6. Make a materials list with quantities and estimated costs.
7. If you can, visit a real flock and use your list to inspect its coop with the owner's permission. Note any weak spots and good ideas.

Tips

- Raccoons can reach several inches through mesh, so keep roosts away from walls covered with wire.
- An automatic door that closes at dusk protects birds on evenings when the keeper is late.

Check your work

- ☐ My design blocks predators coming over, under and through.
- ☐ I used hardware cloth, not chicken wire, for openings.
- ☐ I can explain how a guardian dog differs from a herding dog.
- ☐ My plan includes a materials list and cost.

NATURE JOURNAL

1. Draw a cross-section of a coop wall and the ground beside it, showing the buried mesh or apron.
2. Make a chart of six predators with columns for day or night, method of attack and best defense.
3. Draw a livestock guardian dog with its flock, from a photo or a visit.

COMMON MISTAKES

- Using chicken wire to protect birds at night.
- Leaving the coop door open after dusk “just this once.”
- Assuming a fence stops a predator that can climb, dig or fly.
- Treating a guardian dog puppy as a house pet instead of raising it with the stock.

Make it a game • Predator-Proof Coop Inspector. Be the coop inspector. Draw a coop and run, then parent adds an intentional flaw: chicken wire instead of hardware cloth, no apron, a latch a raccoon can open. Spot every flaw and name the predator that would use it. Compare electric netting and a livestock guardian dog. Find all flaws to earn an inspection stamp.

Scripture. “I am the good shepherd: the good shepherd giveth his life for the sheep. But he that is an hireling, and not the shepherd, whose own the sheep are not, seeth the wolf coming, and leaveth the sheep, and fleeth: and the wolf catcheth them, and scattereth the sheep.” (John 10:11-12, KJV)

A good shepherd knows the dangers and stays with his flock. Christ is that shepherd for us, and His example calls every keeper of animals to faithful, watchful care.

UNIT 2

WILDLIFE

Wild animals share every farm, garden and back yard, even when we never see them. Most are active at dawn, dusk or night, so a naturalist learns to read the evidence they leave behind: tracks, trails, droppings, chewed twigs, tunnels and mounds. In this unit you will learn to identify animals from their signs, then study three groups that matter most to growers and keepers of animals: deer, the small mammals that work underground, and the predators that hunt poultry and lambs.

Good stewardship means seeing wildlife clearly, neither as cute pets nor as villains. Deer are beautiful and graceful, and they can also strip a garden overnight and carry ticks. Moles aerate soil and eat grubs, while voles girdle young fruit trees. Coyotes and hawks keep rodent numbers down, and they also take chickens. You will learn how each animal is designed for its way of life, how to keep a safe distance, and how to protect gardens and flocks with fences, housing and guardian animals rather than guesswork.

PREREQUISITES

- Can measure in inches and centimeters and record data
- Knows the basic needs of animals: food, water, shelter, space
- Knows the rule never to touch or feed wild animals
- Knows how to check for ticks after being outdoors

MASTERY CHECKLIST

- ☐ I can identify common animal tracks by toe count, claws, shape and gait pattern.
- ☐ I can recognize deer browse and explain how deer populations affect forests and gardens.
- ☐ I can tell vole, mole and mouse signs apart and choose a fitting control method.
- ☐ I can name the common predators of poultry and livestock and design housing and fencing to stop them.
- ☐ I can explain the safety rules for ticks, rodent droppings and animals that may carry rabies.

LESSONS IN THIS UNIT

2.1 Field Identification and Tracking

2 sessions of 50–60 minutes

2.2 Deer Biology and Management

2 sessions of 50–60 minutes

2.3 Small Mammals Underground: Mice, Moles and Voles

2 sessions of 50–60 minutes

2.4 Predators and Protecting Livestock

2 sessions of 50–60 minutes

UNIT 2 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. (8 pts)

How can you tell a dog or coyote track from a cat track?

2. (6 pts)

In a rabbit's hopping trail, which feet land in front, and why?

3. (6 pts)

Name three wildlife signs other than tracks.

4. (6 pts)

How can you tell whether a twig was eaten by a deer or a rabbit?

5. (8 pts)

Describe the yearly antler cycle of a white-tailed buck.

6. (8 pts)

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

7. (6 pts)

What should you do if you find a fawn lying alone?

8. (8 pts)

Give two differences between a mole and a vole.

9. (6 pts)

Why is chicken wire not enough to protect chickens at night?

10. **8 pts**

How does a livestock guardian dog protect a flock?

11. **15 pts**

Written answer: A family's young apple trees are dying, and the bark around the base of the trunks has been chewed away under last winter's snow. Explain what animal is most likely responsible, why the trees died and three things the family should do.

12. **15 pts**

Written answer: Explain why tick checks matter, and describe the link between mice, deer and the blacklegged tick.

ANSWER KEY

1. Dog-family tracks are oval with four toes and claw marks, and an X fits between the pads. Cat tracks are rounder, usually show no claws and have a larger, three-lobed heel pad.
2. The large hind feet land ahead of the front feet, because the rabbit swings its hind legs past its front legs as it hops.
3. Any three: trails, scat, chewed nuts or twigs, buck rubs, scrapes, burrows or dens, feathers or fur, owl pellets or whitewash.
4. Deer have no upper front teeth, so they tear twigs and leave a ragged end. Rabbits leave a clean, slanted cut.
5. Antlers grow in spring and summer covered in velvet, harden in late summer when the velvet is rubbed off, are carried through fall, and are shed in late winter, then regrown.
6. A line in the woods, about 5–6 feet high, below which deer have eaten almost all leaves and twigs. It shows deer numbers are above the land's carrying capacity.
7. Leave it alone and walk away. Its mother hides it and returns to nurse it.
8. Any two: moles are insectivores and voles are rodents; moles have huge paddle-like front feet and a pointed snout, voles a blunt nose and short tail; moles make ridges and molehills, voles make surface runways and small holes; moles eat grubs and worms, voles eat roots, bulbs and bark.
9. Raccoons can tear or reach through it and weasels and rats can slip through it. Half-inch hardware cloth is needed.
10. Raised with the flock from puppyhood, it bonds with the animals, lives with them, patrols, barks and places itself between the flock and predators, usually driving them away.
11. Voles. They gnawed the bark all the way around (girdling), cutting off the flow of sugars to the roots. The family should wrap trunks with ¼-inch hardware cloth set below the soil and above the snow line, pull mulch away from trunks and mow grass short around the trees, and set snap traps or encourage natural predators, avoiding poison baits.
12. Blacklegged ticks can carry the Lyme disease bacterium. Young ticks feed mostly on white-footed mice, which often carry the bacterium; adult ticks feed on deer, which carry and spread them. Ticks usually must be attached more

than a day to pass on Lyme disease, so finding and removing them quickly after time in grass or woods prevents infection.

PORTFOLIO PIECE: A WILDLIFE STEWARDSHIP REPORT

Combine your track and sign survey, your deer browse survey and your underground detective map into one report about the wildlife on a property you know. End with a stewardship plan: which animals to welcome, which to manage, and the specific fences, housing or habitat changes you recommend to protect a garden or a flock.

LOOK FOR	WHAT IT MEANS
Evidence	Signs are recorded with dates, places, measurements and drawings or photos.
Identification	Animals are identified correctly with clear reasons, and uncertainty is stated honestly.
Science	Explains each animal's design, diet and role accurately, including disease and tick risks.
Stewardship plan	Recommendations are practical, humane, specific and matched to the animals found.

UNIT 3

SOIL SCIENCE

Soil is not just dirt. It is weathered rock mixed with the remains of plants and animals, held together by roots, fungi and microbes, full of air and water, and alive with more creatures in a handful than there are people on earth. In this unit you will learn where soil comes from, why its structure matters as much as its nutrients, and who the tiny workers are that keep it fertile.

You will run weathering and soil-structure experiments, test how fast water soaks into different ground, bury cotton strips to measure soil life, and sow a cover crop. By the end you will be able to explain how farmers and gardeners can build soil up instead of wearing it out, using cover crops, mulch, careful tillage and well-composted manure. When God placed Adam in the garden “to dress it and to keep it” (Genesis 2:15), soil was the first thing in his care.

PREREQUISITES

- Knows the three soil particle sizes: sand, silt and clay
- Has made or seen a soil jar (shake) test
- Knows that compost is made from decomposed plant material
- Can use a ruler, timer and measuring cup accurately

MASTERY CHECKLIST

- ☐ I can name the five soil-forming factors and explain how rock weathers into soil.
- ☐ I can describe soil horizons and the common kinds of parent material.
- ☐ I can explain the difference between soil texture and soil structure, and why pore space matters.
- ☐ I can describe what bacteria, fungi, actinomycetes, protozoa and nematodes do in soil.
- ☐ I can plan a soil-building program using cover crops, reduced tillage, mulch and properly aged manure.

LESSONS IN THIS UNIT

3.1 Soil Formation and Parent Material

2 sessions of 50–60 minutes

3.2 Soil Structure, Porosity and Water

2 sessions of 50–60 minutes

3.3 Soil Microbes: Bacteria, Fungi and Actinomycetes

2 sessions of 50–60 minutes

3.4 Building Soil: Cover Crops, No-Till and Manure

2 sessions of 50–60 minutes

UNIT 3 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. 8 pts

Name the five soil-forming factors.

2. 8 pts

Give one example each of physical, chemical and biological weathering.

3. 6 pts

What is the A horizon, and why is it important?

4. 6 pts

What is loess?

5. 8 pts

Explain the difference between soil texture and soil structure. Which can a gardener change?

6. 8 pts

Why do roots need both large and small pores in soil?

7. 6 pts

What is field capacity?

8. 8 pts

What do actinomycetes do in soil, and what do they give soil?

9. (6 pts)

How do mycorrhizal fungi help plants, and what do they get in return?

10. (6 pts)

Name one grass, one legume and one brassica cover crop and the main benefit of each.

11. (15 pts)

Written answer: A garden's clay soil crusts after rain, puddles for hours and is hard as brick by midsummer. The owner tills it every spring. Explain what is wrong with its structure and give a three-part plan to fix it.

12. (15 pts)

Written answer: Explain how to use horse or chicken manure safely in a vegetable garden.

ANSWER KEY

1. Parent material, climate, organisms, topography (relief) and time.
2. Physical: freeze-thaw cracking, roots wedging cracks, abrasion by water or wind. Chemical: acidic rain dissolving limestone, iron rusting, feldspar turning to clay. Biological: lichens releasing acids, roots and microbes drawing minerals from rock.
3. The topsoil: the dark upper layer rich in humus, roots and soil life, where most plant growth happens.
4. Fine silt carried and dropped by the wind, which forms deep, fertile soils.
5. Texture is the proportion of sand, silt and clay; structure is how particles are grouped into aggregates with pores between. Gardeners can change structure but not texture.
6. Large pores drain excess water and let air (oxygen) reach roots; small pores hold water for plants to use.
7. The water a soil holds after gravity drains away the excess, a day or two after a soaking.
8. They are thread-like bacteria that break down tough materials in soil and compost, and they produce geosmin, the earthy smell of soil.
9. Their hyphae gather water and phosphorus from a wide area and pass them to the roots; the plant gives the fungus sugars.
10. For example: cereal rye or oats (organic matter, erosion control, catches leftover nitrogen); crimson clover, hairy vetch or peas (adds nitrogen); forage radish (breaks up compaction).
11. Aggregates have broken down from tillage and lack of organic matter, so pores have collapsed (compaction and crusting) and water cannot soak in. Plan: stop tilling and use permanent paths; add compost and mulch to keep the surface covered and feed soil life; grow cover crops (rye, clover, radish) so living roots build aggregates; work soil only when moist, not wet.
12. Compost it in a hot pile or age it at least six months; never put fresh hot manure on plants. If raw manure is used, apply it at least 120 days before harvest for crops that touch soil (90 days for others). Wear gloves and wash hands and produce. Use only plant-eating animals' manure, not dog, cat or human waste. Ask the source about persistent herbicides in hay.

PORTFOLIO PIECE: A SOIL REPORT CARD

Write a “report card” for the soil of one garden bed, yard or field. Include your soil profile drawing, the slake and infiltration test results, the cotton-strip data and photos of your cover crop. Grade the soil on structure, water movement and biological life, and finish with your two-year soil-building plan.

LOOK FOR	WHAT IT MEANS
Observation	Profile drawing and test results are measured, dated and clearly presented.
Science	Correctly explains formation, structure, pores and soil life using unit vocabulary.
Experimental care	Tests were fair, with controls and repeated measurements where possible.
Soil-building plan	Plan is specific, timed and uses cover crops, reduced tillage and safe use of compost or manure.

3.1 SOIL FORMATION AND PARENT MATERIAL

OBJECTIVES

- Name and explain the five soil-forming factors: parent material, climate, organisms, topography and time.
- Describe physical, chemical and biological weathering with examples.
- Identify soil horizons (O, A, E, B, C and R) and common kinds of parent material.

Warm-up. Look closely at an old brick wall, sidewalk, gravestone or boulder with a hand lens. Find three signs that the surface is slowly breaking down (cracks, crumbling, lichens, stains, moss). Draw one and guess what caused it.

WATCH

Soil Basics: Formation

Purdue Extension • 7:13

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

WHEN TO WATCH

After the core ideas. As Professor Graveel shows each soil column, write down its parent material (glacial till, loess, alluvium, lake sediment, organic) and one way it differs from the others.

Note: The video ends with Purdue's standard legal notice; you may stop when the teaching ends.

KEY TERMS

parent material

The rock or loose sediment from which a soil forms, such as weathered bedrock, glacial till, wind-blown loess or river-deposited alluvium.

soil horizon

A layer of soil, roughly parallel to the surface, that differs from the layers above and below in color, texture or structure.

weathering

The breaking down of rock into smaller pieces and new minerals by physical forces, chemical reactions and living things.

topsoil

The dark, upper A horizon, rich in humus and roots, where most plant growth and soil life happens.

loess

Fine, silty sediment carried and dropped by the wind; it makes deep, fertile farm soils in parts of the Midwest.

alluvium

Sand, silt and clay laid down by rivers and floods, often forming rich bottomland soils.

CORE IDEAS

Every soil begins as **parent material**. In some places it is bedrock that has weathered in place. In much of the northern United States it is **glacial till**, a jumbled mix of clay, sand, gravel and boulders left by ice sheets. Other soils formed in **loess**, fine wind-blown silt; in **alluvium**, laid down by rivers; in old lake bottoms; or in **colluvium** that slid down hillsides. The parent material sets the soil's starting texture and many of its minerals: a soil from sandstone will be sandy, while one from shale or limestone tends toward clay.

Rock turns into soil by **weathering**. Physical weathering breaks rock without changing its minerals: water seeps into cracks, freezes and expands by about 9 percent, and pries the rock apart; roots grow into cracks and wedge them wider; rivers and wind grind particles against each other. Chemical weathering changes the minerals themselves: rainwater, slightly acidic from dissolved carbon dioxide, dissolves limestone; iron minerals rust, giving many subsoils their red and yellow colors; and feldspar slowly changes into clay. Biological weathering joins in when lichens release acids on bare rock and roots, fungi and bacteria pull nutrients out of minerals.

Soil scientists describe five **soil-forming factors**: parent material, climate (warmth and rainfall speed weathering and leaching), organisms (plants, animals and microbes add organic matter and mix the soil), topography (hilltops lose soil and are thin and dry; low spots gather soil and water) and time. Together these explain why the soil in one county can be deep, black prairie loam and in the next, thin and stony. Building a deep topsoil is slow work; it can take many lifetimes, which is why losing it to erosion is so serious.

As soil develops, it forms layers called **horizons**. On top is the O horizon of leaf litter and partly decayed matter. Below it the dark A horizon, or **topsoil**, holds most of the humus, roots and life. In forests a pale E horizon may lie below, where water has washed out clay and minerals. The B horizon, or subsoil, collects clay, iron and other

materials washed down from above and is often redder or more blocky. The C horizon is loosely weathered parent material, and R is solid bedrock. A cut in a roadside bank or a deep garden hole shows this record plainly.

PICTURE STUDY



Quarry, Albrecht Dürer, about 1495 · Watercolor and gouache on paper · Kunsthalle Bremen, Germany (formerly)

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

Dürer painted this quarry near Nuremberg on his walks, studying rock as carefully as he later studied hares and grasses. Look at it as a soil scientist would: you are seeing the very beginnings of soil.

Look closely

- Find layers in the rock. Are they flat, tilted or broken?
- Find places where the rock is cracked or crumbling. What might be breaking it apart?
- Find plants growing from the rock. What are their roots doing to the cracks?
- Look for loose material gathered on ledges or at the bottom. What is it slowly becoming?

Talk about it

1. Which kinds of weathering can you see evidence of in this picture?
2. If this quarry were left alone for centuries, what would happen to its ledges and floor?
3. Why do you think quarry workers and builders cared about how rock breaks?

Safety first. Wear safety glasses for the freeze-thaw and shaking experiments, and never hammer rocks yourself; ask an adult. Stay away from steep road cuts, quarries and the edges of deep holes.

HANDS-ON PROJECT

Weathering Experiments and a Soil Profile

You will model three kinds of weathering, then dig or find a soil profile and describe its horizons.

You will need

- Small pieces of soft rock or brick (sandstone, chalk, or broken clay brick), about the size of walnuts
- Two small plastic containers with lids
- A freezer
- A sturdy plastic jar with lid
- White vinegar and a piece of chalk or limestone
- A shovel, ruler, white paper and a spray bottle

Steps

1. Freeze-thaw: soak two rock or brick pieces in water overnight. Put one in a container in the freezer and leave one at room temperature. Each day for a week, thaw the frozen piece and refreeze it. Look for cracks and flakes, and weigh or photograph both.
2. Abrasion: put a handful of angular rock pieces and some water in a plastic jar. Shake hard for 5 minutes, then look at the water and the rock edges. Shake 5 more minutes and compare.
3. Chemical: drop a piece of chalk or limestone into a glass of vinegar and watch the bubbles. Record what happens over 30 minutes.
4. Soil profile: with an adult, dig a straight-sided hole about 18–24 inches deep in a garden or lawn edge (or look at a fresh garden-bed edge or a safe, low cut bank).
5. Spray one side lightly with water so colors show. Measure the depth of each change in color or texture from the top.
6. Take a pinch from each layer, rub it between your fingers and note color, texture (gritty, smooth, sticky) and roots.

7. Draw and label the profile, naming the horizons you think you see. Then fill the hole carefully.

Tips

- Use the same size pieces in each test so the comparison is fair.
- No place to dig? Fill a tall clear jar with soil from a bagged garden mix, a scoop of subsoil and gravel to model horizons, or look up your county's soil survey on the USDA Web Soil Survey with an adult.

Check your work

- ☐ I modeled physical and chemical weathering and recorded results.
- ☐ I measured and drew a soil profile with horizons labeled.
- ☐ I can name the five soil-forming factors.
- ☐ I can explain what parent material my local soil likely came from.

NATURE JOURNAL

1. Draw a soil profile from O to R with each horizon colored and labeled, and a note on what happens in each.
2. Draw a rock with a crack before and after freezing, showing how ice pries it open.
3. Sketch a lichen on rock with a hand lens and describe its color and shape.

From history. In the 1880s the Russian scientist Vasily Dokuchaev studied the black prairie soils of Russia and showed that soils form in layers by the action of climate, living things, parent material, landscape and time. He is often called the father of soil science, and American soil surveys still use his ideas.

COMMON MISTAKES

- Thinking soil is the same everywhere. Parent material and topography make it vary even across one field.
- Confusing weathering (breaking rock down in place) with erosion (moving soil away).
- Calling every dark layer topsoil without checking for roots, humus and crumb structure.

Make it a game • Five Factors Memory Chain. Recite the five soil-forming factors from memory as a chain: parent material, climate, organisms, topography and time. Then parent names a soil scene, like loess hills or river alluvium, and you give the factor and a weathering example: physical, chemical or biological. Add one more factor example each round. Keep going until you stumble.

3.2 SOIL STRUCTURE, POROSITY AND WATER

OBJECTIVES

- Distinguish soil texture from soil structure and name common structure types.
- Explain how pore space holds air and water, and the meaning of field capacity and wilting point.
- Measure aggregate stability and water infiltration in two soils.

Warm-up. Hold a dry sponge, a handful of dry rice and a lump of modeling clay.

Predict which would soak up and hold the most water, and which would let water run through fastest. Write your predictions, then test with a spoonful of water each.

WATCH

Soil Basics: Structure

Purdue Extension · 4:39

<https://www.youtube.com/watch?v=nkw07WdRXoc>

WHEN TO WATCH

After the first two core ideas. Name each structure type (granular, platy, blocky, prismatic, massive) as he holds up the sample.

Note: The video ends with Purdue's standard legal notice; you may stop when the teaching ends.

BACKUP VIDEO

Soil Stability Test (Slake Test) Measure Soil Aggregate Stability

Garden Fundamentals · 5:26

<https://www.youtube.com/watch?v=KdVA9FKH-FE>

Before the project; it shows the slake test you will run.

KEY TERMS

soil texture

The proportions of sand, silt and clay in a soil. Texture is set by parent material and changes very little.

soil structure

The way soil particles are grouped into clumps called aggregates or peds, and the spaces between them. Structure can be built up or destroyed.

aggregate

A crumb of soil in which particles are glued together by clay, humus, root and fungal threads and microbial gums.

porosity

The fraction of a soil's volume that is pore space, filled with air or water. A healthy topsoil is about half pore space.

field capacity

The amount of water a soil holds after gravity has drained away the excess, a day or two after a soaking rain.

compaction

Squeezing soil so that pores collapse, usually from feet, vehicles or working wet soil. It blocks air, water and roots.

CORE IDEAS

Texture and **structure** are different. Texture is what the soil is made of: sand (2 to 0.05 mm), silt (0.05 to 0.002 mm) and clay (smaller than 0.002 mm). You cannot change it in a garden. Structure is how those particles are arranged into crumbs, or **aggregates**, and it can be built up or ruined. Good topsoil has granular or crumb structure, like cottage cheese. Subsoils are often blocky or prismatic. Platy structure, in flat layers, often forms where soil is compacted, and “massive” soil has no structure at all, like a brick.

Aggregates are glued together by clay, humus, sticky substances given off by roots and microbes, and the fine threads of fungi. Earthworms make aggregates too; their castings are excellent crumbs. Between and inside aggregates are pores. Large pores (macropores) let water drain and air move; small pores (micropores) hold water against gravity, like the tiny spaces in a sponge. A healthy topsoil is roughly half solid and half pore space, and after a rain drains, about half of that pore space holds water and half holds air. Roots need both, because roots breathe oxygen.

After a soaking rain, gravity drains water from the large pores within a day or two; what remains is **field capacity**. As plants use water, the soil dries until the remaining water clings so tightly to particles that roots cannot pull it out: the **wilting point**. The water between these two is what plants can use. Sandy soil has big pores, drains fast and holds little water; clay has tiny pores, holds much water but drains slowly and can lack air. Good structure gives clay soils better drainage and sandy soils better water-holding, because aggregates create a mix of pore sizes.

Structure is fragile. Tilling or digging wet soil smears and breaks aggregates; heavy feet and machines cause **compaction**; and bare soil pounded by rain forms a hard crust that sheds water. Soil with weak aggregates falls apart in water, so rain runs off instead of soaking in, carrying soil with it. Structure is built by roots growing year-round, by adding organic matter, by keeping the soil covered, by not walking on growing beds and by working soil only when it is moist, not wet. A simple test: a handful that crumbles when you squeeze and poke it is ready; one that forms a sticky ball is too wet to work.

PICTURE STUDY



Ploughed Fields (The Furrows), Vincent van Gogh, 1888 · Oil on canvas · Van Gogh Museum, Amsterdam

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

Van Gogh painted this field near Arles in southern France right after it was ploughed. He used thick paint so the furrows and clods almost stand up off the canvas. Look at the soil itself.

Look closely

- Follow the furrows with your eye. Which way do they run, and how far?
- Look at the clods. Are they fine crumbs or large lumps?
- Find the colors Van Gogh used for the soil. What might a darker or lighter color tell a farmer?
- Look at the sky. Does it look like the soil is wet or dry?

Talk about it

1. What does ploughing do to soil structure, both good and bad?
2. If a heavy rain fell on this bare field, what might happen to the soil?
3. How could a farmer protect this field's soil until a crop covers it?

Slake and Infiltration Tests

You will compare the structure of two soils, such as a garden bed and a path or lawn, by testing how well their aggregates hold together and how fast water soaks in.

You will need

- Two tall clear glasses or jars of water
- A piece of wire mesh or hardware cloth to hold a soil clod at the top of each glass
- Two dry clods of soil about the size of a walnut, from two different places
- A large tin can with both ends cut off (an adult should file the edges), or a section of 6-inch pipe
- A ruler, a timer, a measuring cup and a block of wood

Steps

1. Collect two clods from different places: one from a garden bed or under long grass, and one from a path, a compacted area or a recently tilled bed. Let them air-dry for a day.
2. Slake test: set a clod on the mesh so it sits just under the water surface in a glass. Watch for 5 minutes and record when it starts to fall apart and how much is left. Repeat with the second clod.
3. Rate each clod: falls apart within 1 minute (poor), 1–5 minutes (good), holds together longer (excellent).
4. Infiltration test: at each site, push the can 3 inches into the soil by tapping the block on top. Mark a line on the inside 1 inch above the soil.
5. Pour water quickly to the line and time how long it takes to soak in. Refill and time a second inch, which shows the rate once the soil is wet.
6. Convert to inches per hour ($60 \div$ minutes for one inch).
7. Write a conclusion comparing the two soils and explaining the results using the words aggregate, pore and compaction.

Tips

- Do the infiltration test when the soil is not already soaked from rain.
- No yard? Compare a bag of potting mix with soil from a park path (with permission), or two houseplant pots.

Check your work

- ☐ I tested two soils the same way.
- ☐ I recorded slake times and infiltration rates.
- ☐ I can explain the difference between texture and structure.
- ☐ I can explain why compacted soil drains slowly.

NATURE JOURNAL

1. Draw an enlarged soil aggregate with sand, silt, clay, humus, a root hair and fungal threads labeled, and the pores shaded blue (water) and white (air).
2. Draw the five structure types (granular, platy, blocky, prismatic, massive) as small diagrams.
3. Record your infiltration data as a bar graph.

COMMON MISTAKES

- Adding sand to clay to “loosen” it. Without lots of organic matter, sand and clay can set almost like concrete.
- Digging or tilling when the soil is wet, which smears and compacts it.
- Walking on growing beds. Use paths so the beds stay loose.
- Thinking more water is always better; waterlogged soil has no air for roots.

Make it a game • Pore Space Pouring Test. Fill two cups with the same volume of dry rice and dried beans. Pour in water and see which holds more in its pore spaces. Guess before you pour, estimation duel style. Then explain texture versus structure, field capacity, wilting point and compaction. Your parent presses on the soil and you tell what happens.

3.3 SOIL MICROBES: BACTERIA, FUNGI AND ACTINOMYCETES

OBJECTIVES

- Describe the main groups of soil organisms and the work each does.
- Explain decomposition, nutrient cycling and the partnerships of nitrogen-fixing bacteria and mycorrhizal fungi.
- Measure differences in soil biological activity with a buried cotton-strip test.

Warm-up. Smell a handful of moist garden soil or compost, then a handful of dry potting mix or sand. Describe each smell in a few words. Where do you think the “earthy” smell comes from?

WATCH

Soil Basics: Soil Microbiology

Purdue Extension · 2:41

https://www.youtube.com/watch?v=3-fFpd_7Egw

WHEN TO WATCH

After the first core idea. Then watch the backup to see actinomycetes in real compost.

Note: The video ends with Purdue’s standard legal notice.

BACKUP VIDEO

Actinomycetes: The White Stuff in Your Hot Compost

Urban Worm Company · 2:40

<https://www.youtube.com/watch?v=duexU98G3Sw>

With the third core idea.

KEY TERMS

decomposer

An organism, especially a bacterium or fungus, that breaks down dead plant and animal matter and releases its nutrients.

actinomycetes

Bacteria that grow in fine, branching threads like fungi. They break down tough materials and give soil its earthy smell.

hyphae

The thin, thread-like filaments that make up the body of a fungus; a mass of them is called mycelium.

mycorrhizae

Partnerships between fungi and plant roots in which the fungus brings water and phosphorus to the root and receives sugars in return.

nitrogen fixation

Turning nitrogen gas from the air into forms plants can use, done by certain bacteria such as *Rhizobium* in the root nodules of beans, peas and clover.

mineralization

The release of nutrients such as nitrogen from organic matter into plant-available form, as microbes and the creatures that eat them do their work.

CORE IDEAS

A teaspoon of healthy soil can contain somewhere between a hundred million and a billion **bacteria**, according to the USDA, along with yards of fungal threads, thousands of protozoa and dozens of tiny nematodes. Together these make up the soil food web. Most are invisible without a microscope, but their work is visible everywhere: fallen leaves disappear, roots find nutrients, crumbs of soil hold together and pests and diseases are kept in check. Most soil microbes are helpful; only a small fraction cause plant disease.

Bacteria are single cells, tiny and enormously numerous. They are the first to attack fresh, soft material such as green leaves, grass clippings and manure, and they multiply fast when conditions are warm and moist. Some bacteria do special jobs. **Rhizobium** bacteria live in nodules on the roots of beans, peas, clover and alfalfa, where they turn nitrogen from the air into a form the plant can use; slice a healthy nodule and its inside is pink. Other bacteria change ammonium into nitrate, the form of nitrogen most plants take up.

Fungi grow as long threads called **hyphae**. They break down tough, woody materials such as straw, bark and dry leaves that bacteria struggle with, and their threads bind soil into aggregates. Many plants form **mycorrhizae** with fungi: the hyphae spread far beyond the roots, gathering water and phosphorus and trading them to the plant for sugars. **Actinomycetes** are bacteria that grow in branching threads, like small fungi. They work on tough materials in compost (the white, cobwebby layer in a hot compost pile) and produce geosmin, the chemical that gives freshly turned soil and

the air after rain their earthy smell. Several important medicines, including streptomycin, were first discovered in soil actinomycetes.

Protozoa and nematodes eat bacteria and fungi. Because bacteria hold more nitrogen than their predators need, the extra is released into the soil, right where roots are growing; this **mineralization** is a major way plants get nitrogen. Soil life needs food (organic matter and living roots), water, air and shelter from disturbance. Bare, tilled, compacted or waterlogged soil has far less life. Keeping the ground covered, adding compost and keeping roots growing feeds this hidden workforce, and they in turn feed our crops. As Paul wrote of another kind of growth, one plants and another waters, but God gives the increase (1 Corinthians 3:6).

PICTURE STUDY



Blue Mould and Mushroom, Scheme XII from Micrographia, Robert Hooke, 1665 · Engraving · Micrographia, London

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

Robert Hooke was one of the first scientists to use a microscope carefully and draw what he saw. In *Micrographia* he showed his readers a hidden world, including the fungi that grow on old leather and bread. You are looking at some of the first pictures ever made of fungal threads and spore heads.

Look closely

- Find the long stalks with round heads. These are the mould's threads and spore cases.
- Look for the gills or folds of the mushroom. What might come out of them?
- Compare the size of the drawings with the real objects. How much did Hooke magnify them?
- Find the most delicate detail in the plate. How did the engraver show it?

Talk about it

1. Why do you think people were amazed when they first saw pictures like this?
2. How are the mould's threads like the fungal hyphae in soil?
3. What helpful work do fungi do in soil and compost?

Safety first. Wear gloves when handling compost and soil, and wash your hands well afterward. Do not grow unknown microbes in sealed dishes at home, and never smell or eat mushrooms or moulds you find.

HANDS-ON PROJECT

The Cotton Strip Test

Soil microbes eat cotton, because it is almost pure cellulose from a plant. You will bury identical cotton strips in different soils and measure how much the microbes eat in a few weeks.

You will need

- An old 100% cotton white T-shirt or cotton fabric (check the label), cut into strips about 2 by 8 inches
- A permanent marker and plant labels
- A trowel and gloves
- Three sites: a garden bed or compost-rich soil, a lawn or path, and a pot of soil baked in an oven by an adult (sterilized) as a control
- A ruler, a camera and white paper

Steps

1. Label each strip in permanent marker with the site and date. Make two strips for each site.
2. At each site, cut a slit in the soil with the trowel about 6 inches deep, slide a strip in vertically so the top inch sticks out, and press the soil closed.
3. Keep all sites moist (water them equally if it does not rain).
4. After 2 weeks, gently dig up one strip from each site. After 4 weeks, dig up the second.
5. Rinse each strip gently, lay it on white paper and photograph it. Estimate the percentage of each strip that has been eaten away or turned brown and holey.
6. Make a table and a bar graph of decomposition at each site and time.
7. Write a conclusion: which soil has the most microbial activity, and why? Use the words decomposer, organic matter and control.

Tips

- Warm, moist soil gives faster results. In cold weather, use pots of soil kept indoors.

- Look for white threads (fungi or actinomycetes) on the strips with a hand lens before rinsing.

Check your work

- ☐ I set up a fair test with a control.
- ☐ I recorded decomposition after 2 and 4 weeks.
- ☐ I can name four groups of soil organisms and their jobs.
- ☐ I can explain how bacteria in root nodules help beans grow.

NATURE JOURNAL

1. Draw a soil food web: plant roots, bacteria, fungi, protozoa, nematodes, earthworms and a mite, with arrows showing who eats whom.
2. Dig up a bean, pea or clover plant and draw its root nodules with a hand lens; slice one and record its color.
3. Draw the white threads of actinomycetes or fungi in a compost pile.

From history. In 1943 Albert Schatz, a graduate student working in Selman Waksman's laboratory at Rutgers University in New Jersey, discovered streptomycin in a soil actinomycete. It was the first effective medicine against tuberculosis, and Waksman, who had spent his career studying soil microbes, received the Nobel Prize in 1952.

COMMON MISTAKES

- Thinking all microbes are germs to be killed. Most soil microbes are essential helpers.
- Leaving soil bare, which starves soil life of roots and organic matter.
- Assuming legumes always add nitrogen; they need the right *Rhizobium* bacteria, and much of the nitrogen leaves with harvested seeds.

Make it a game • Soil Crew Job Interviews. Hold pretend job interviews for soil workers. Your parent is the farmer hiring. Each applicant is a soil organism: bacteria, fungus, actinomycete, nitrogen-fixer, mycorrhiza. You play each and say what you do for decomposition, mineralization or nutrient cycling. Parent hires the best candidates for a healthy field. Switch roles after five interviews.

3.4 BUILDING SOIL: COVER CROPS, NO-TILL AND MANURE

OBJECTIVES

- Explain how cover crops of grasses, legumes and brassicas protect and build soil.
- Explain the benefits and challenges of no-till and reduced tillage.
- Use manure and compost safely: aging, composting, timing and which manures to avoid.

Warm-up. Look out at a garden or field after harvest (or a photo of one). List everything that could happen to bare soil there between now and spring: rain, wind, freezing, weeds, sun. Next to each, write whether it helps or harms the soil.

WATCH

Building Your Soil Over the Winter—Two Cheap Methods with Cover Crops + Leaves

Well Grounded Gardens · 9:34

<https://www.youtube.com/watch?v=ZQgVUeT8DH0>

WHEN TO WATCH

After the core ideas, before the project. Note which cover crops she sows and when.

BACKUP VIDEO

Cover Cropping: The LAZIEST Way to Improve Your Soil

Epic Gardening · 7:17

<https://www.youtube.com/watch?v=tgYJDI6hpw0>

A second look at sowing and ending a cover crop in raised beds.

KEY TERMS

cover crop

A crop grown mainly to protect and improve the soil rather than to harvest, such as cereal rye, oats, crimson clover or radish.

green manure

A cover crop that is cut and left on or worked into the soil while green, to add organic matter and nutrients.

no-till

Growing crops without plowing or digging the soil, planting into residue or mulch instead.

terminate

To end a cover crop's growth by mowing, crimping, smothering with a tarp or (on farms) other means, before it sets seed.

hot manure

Fresh manure high in nitrogen, such as chicken manure, that can burn plants and must be composted or aged before use.

CORE IDEAS

Bare soil loses. Rain splashes and crusts it, wind and water carry it away, nutrients wash down past the roots and soil life starves for lack of roots. A **cover crop** keeps living roots in the ground and a blanket over the surface when no food crop is growing. Grasses such as **cereal rye** and **oats** grow fast, make a great deal of organic matter, hold soil against erosion and soak up leftover nitrogen. Legumes such as **crimson clover**, hairy vetch and field peas add nitrogen through their root nodules. Brassicas such as **forage radish** drive thick roots deep into compacted soil and leave channels when they rot. Mixtures combine these benefits.

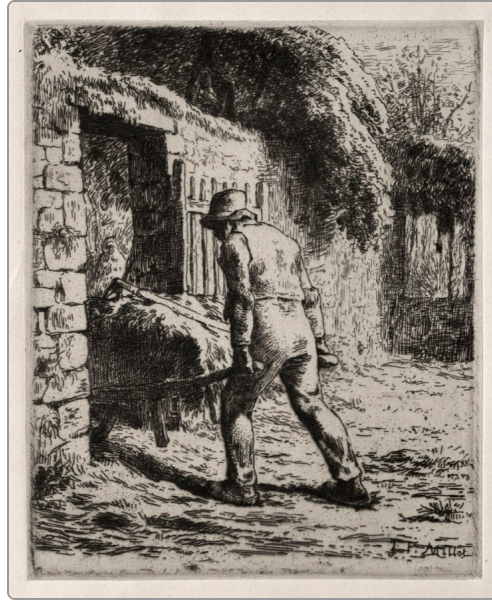
Timing matters. Most fall cover crops are sown in late summer or early fall, about four to six weeks before the first hard frost, so they establish before winter. Oats are killed by hard freezes in cold climates (zone 6 and colder), leaving a mulch that is easy to plant into in spring. Cereal rye survives winter and grows fast in spring, so it must be **terminated** two to three weeks before planting, usually by mowing or crimping it at flowering, or smothering it under a tarp. Never let a cover crop go to seed, or it becomes a weed.

No-till means planting without plowing or digging. Plowing buries weeds and loosens soil for a time, but it breaks up aggregates and fungal threads, speeds the burning up of organic matter, brings new weed seeds to the surface and leaves soil bare to erosion. No-till gardeners keep beds covered with mulch, compost or cover-crop residue and plant through it. No-till farmers use special planters that slice through residue. Soils managed this way gradually gain organic matter, structure

and earthworms, though they may warm more slowly in spring and need good weed control.

Manure adds organic matter and nutrients, but it must be handled with care. Fresh manure, especially **hot** chicken manure, is high in nitrogen and salts and can burn plants; it can also carry germs such as E. coli and salmonella and weed seeds. Compost it in a hot pile, or age it for six months or more before use. The national organic standard requires raw manure to be applied at least 120 days before harvesting crops whose edible part touches the soil, and 90 days for other crops; composted manure is safer. Use manure from plant-eating animals (cows, horses, goats, sheep, rabbits, chickens), never from dogs, cats or people. And ask where it came from: some hay and pasture sprays persist in manure and can damage tomatoes and beans. Jesus' parable of the fig tree shows a patient gardener who would "dig about it, and dung it" before giving up on it; building soil is that same patient work.

PICTURE STUDY



Peasant Returning from the Manure Heap, Jean-François Millet, 1855 · Etching · Cleveland Museum of Art

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

Millet made prints of the ordinary, hard work of French farm life with deep respect. Here a farmer wheels a load of manure from the stable. Moving and piling manure so it can rot down before it goes on the fields is work farmers have done for thousands of years.

Look closely

- Find the wheelbarrow and its load. How heavy does it look?
- Look at the barn. Where do you think the animals are kept?
- Look at the farmer's posture. How is he using his body to push the load?
- Find any signs of the season or weather.

Talk about it

1. Why do farmers pile and age manure before spreading it on fields?
2. What does manure add to soil besides nutrients?
3. How could this farmer keep his manure pile from washing away in the rain?

Safety first. Always wear gloves when handling manure or compost, and wash your hands and any vegetables carefully. Never use dog, cat or human waste in a garden. Use only composted or well-aged manure on vegetable beds.

HANDS-ON PROJECT

Sow a Cover Crop and Write a Soil-Building Plan

You will sow a cover crop in a garden bed or in pots, observe its roots, and write a two-year soil-building plan for a garden.

You will need

- Seeds of two or three cover crops: oats or cereal rye, crimson clover or field peas, and forage radish if available
- A garden bed, or three large pots with garden soil
- A rake, watering can and plant labels
- A ruler and a clear plastic cup for root viewing (optional)
- Graph paper

Steps

1. Choose a bed that has been harvested, or fill three pots with garden soil. Pull weeds and rake the surface smooth.
2. Sow each cover crop in its own section or pot at the rate on the packet. Scatter the seed, rake it lightly into the top half-inch and water well.
3. Optional: sow a few seeds against the side of a clear plastic cup of soil, wrapped in paper, so you can watch the roots.
4. Measure height and count plants each week for four weeks. After four weeks, gently dig one plant of each kind and draw its roots. Look for nodules on the legume.
5. Draw a map of a 4-by-8-foot (or larger) garden bed and plan two years: what grows in each season, when you sow and terminate cover crops, and when to add compost or aged manure.
6. Include a no-till method for ending the cover crop (mow and mulch, crimp, or tarp) and the date you would do it.
7. Write one paragraph explaining how your plan will improve structure, organic matter, nitrogen and soil life.
8. Record keeping: in your journal, keep a project-book page for the cover crop with dates, seed cost, water used, heights and what you learned, as a 4-H

crops project would.

Tips

- Pots of oats or rye on a sunny windowsill make a fine indoor cover crop and are good for root drawing.
- Inoculant powder for peas and clover adds the right nodule bacteria and is cheap at farm stores.
- Many soil and water conservation districts hold a yearly youth poster contest on a soil or conservation theme; your soil-building plan could become an entry. Ask your local conservation district for the theme and deadline.

Check your work

- ☐ I sowed at least two different cover crops and recorded their growth.
- ☐ I drew the roots and looked for nodules.
- ☐ My plan shows dates for sowing, ending cover crops and adding compost or manure.
- ☐ I can explain the 120-day rule and which manures not to use.

NATURE JOURNAL

1. Draw a cereal rye plant, a clover plant and a radish plant side by side with their roots, and label what each adds to the soil.
2. Make a chart comparing grass, legume and brassica cover crops.
3. Record your cover crop heights in a table each week.

From history. George Washington Carver, working at Tuskegee Institute in Alabama from 1896, taught Southern farmers whose land had been worn out by growing cotton year after year to plant peanuts, cowpeas and sweet potatoes in rotation. The legumes restored nitrogen to the soil, and Carver found hundreds of uses for the new crops so farmers could sell them.

COMMON MISTAKES

- Sowing fall cover crops too late, after the soil turns cold.
- Letting a cover crop go to seed and become a weed problem.
- Putting fresh chicken manure directly on plants.
- Tilling every year out of habit, which slowly burns up organic matter and breaks down structure.

Make it a game • Cover Crop Matchmaker. Write cover crops on cards, a grass, a legume and a brassica, and soil problems on others: erosion, low nitrogen, compaction. Parent flips a problem and you match the best cover crop and defend the choice. Then argue for and against no-till and say when to terminate a cover crop and what hot manure risks.

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

The gardener in Jesus’ parable does not give up on the barren tree. He feeds its roots and waits. Building soil takes the same patience and hope.

UNIT 3

SOIL SCIENCE

Soil is not just dirt. It is weathered rock mixed with the remains of plants and animals, held together by roots, fungi and microbes, full of air and water, and alive with more creatures in a handful than there are people on earth. In this unit you will learn where soil comes from, why its structure matters as much as its nutrients, and who the tiny workers are that keep it fertile.

You will run weathering and soil-structure experiments, test how fast water soaks into different ground, bury cotton strips to measure soil life, and sow a cover crop. By the end you will be able to explain how farmers and gardeners can build soil up instead of wearing it out, using cover crops, mulch, careful tillage and well-composted manure. When God placed Adam in the garden “to dress it and to keep it” (Genesis 2:15), soil was the first thing in his care.

PREREQUISITES

- Knows the three soil particle sizes: sand, silt and clay
- Has made or seen a soil jar (shake) test
- Knows that compost is made from decomposed plant material
- Can use a ruler, timer and measuring cup accurately

MASTERY CHECKLIST

- ☐ I can name the five soil-forming factors and explain how rock weathers into soil.
- ☐ I can describe soil horizons and the common kinds of parent material.
- ☐ I can explain the difference between soil texture and soil structure, and why pore space matters.
- ☐ I can describe what bacteria, fungi, actinomycetes, protozoa and nematodes do in soil.
- ☐ I can plan a soil-building program using cover crops, reduced tillage, mulch and properly aged manure.

LESSONS IN THIS UNIT

3.1 Soil Formation and Parent Material

2 sessions of 50–60 minutes

3.2 Soil Structure, Porosity and Water

2 sessions of 50–60 minutes

3.3 Soil Microbes: Bacteria, Fungi and Actinomycetes

2 sessions of 50–60 minutes

3.4 Building Soil: Cover Crops, No-Till and Manure

2 sessions of 50–60 minutes

UNIT 3 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. (8 pts)

Name the five soil-forming factors.

2. (8 pts)

Give one example each of physical, chemical and biological weathering.

3. (6 pts)

What is the A horizon, and why is it important?

4. (6 pts)

What is loess?

5. (8 pts)

Explain the difference between soil texture and soil structure. Which can a gardener change?

6. (8 pts)

Why do roots need both large and small pores in soil?

7. (6 pts)

What is field capacity?

8. (8 pts)

What do actinomycetes do in soil, and what do they give soil?

9. (6 pts)

How do mycorrhizal fungi help plants, and what do they get in return?

10. (6 pts)

Name one grass, one legume and one brassica cover crop and the main benefit of each.

11. (15 pts)

Written answer: A garden's clay soil crusts after rain, puddles for hours and is hard as brick by midsummer. The owner tills it every spring. Explain what is wrong with its structure and give a three-part plan to fix it.

12. (15 pts)

Written answer: Explain how to use horse or chicken manure safely in a vegetable garden.

ANSWER KEY

1. Parent material, climate, organisms, topography (relief) and time.
2. Physical: freeze-thaw cracking, roots wedging cracks, abrasion by water or wind. Chemical: acidic rain dissolving limestone, iron rusting, feldspar turning to clay. Biological: lichens releasing acids, roots and microbes drawing minerals from rock.
3. The topsoil: the dark upper layer rich in humus, roots and soil life, where most plant growth happens.
4. Fine silt carried and dropped by the wind, which forms deep, fertile soils.
5. Texture is the proportion of sand, silt and clay; structure is how particles are grouped into aggregates with pores between. Gardeners can change structure but not texture.
6. Large pores drain excess water and let air (oxygen) reach roots; small pores hold water for plants to use.
7. The water a soil holds after gravity drains away the excess, a day or two after a soaking.
8. They are thread-like bacteria that break down tough materials in soil and compost, and they produce geosmin, the earthy smell of soil.
9. Their hyphae gather water and phosphorus from a wide area and pass them to the roots; the plant gives the fungus sugars.
10. For example: cereal rye or oats (organic matter, erosion control, catches leftover nitrogen); crimson clover, hairy vetch or peas (adds nitrogen); forage radish (breaks up compaction).
11. Aggregates have broken down from tillage and lack of organic matter, so pores have collapsed (compaction and crusting) and water cannot soak in. Plan: stop tilling and use permanent paths; add compost and mulch to keep the surface covered and feed soil life; grow cover crops (rye, clover, radish) so living roots build aggregates; work soil only when moist, not wet.
12. Compost it in a hot pile or age it at least six months; never put fresh hot manure on plants. If raw manure is used, apply it at least 120 days before harvest for crops that touch soil (90 days for others). Wear gloves and wash hands and produce. Use only plant-eating animals' manure, not dog, cat or human waste. Ask the source about persistent herbicides in hay.

PORTFOLIO PIECE: A SOIL REPORT CARD

Write a “report card” for the soil of one garden bed, yard or field. Include your soil profile drawing, the slake and infiltration test results, the cotton-strip data and photos of your cover crop. Grade the soil on structure, water movement and biological life, and finish with your two-year soil-building plan.

LOOK FOR	WHAT IT MEANS
Observation	Profile drawing and test results are measured, dated and clearly presented.
Science	Correctly explains formation, structure, pores and soil life using unit vocabulary.
Experimental care	Tests were fair, with controls and repeated measurements where possible.
Soil-building plan	Plan is specific, timed and uses cover crops, reduced tillage and safe use of compost or manure.

UNIT 4

PETS: BEHAVIOR, TRAINING AND CARE

A good keeper of animals understands how animals learn. Dogs, cats, horses, chickens and even fish change their behavior according to what happens after they act, and once you understand that, you can teach an animal kindly and clearly instead of scolding it for doing what comes naturally. This unit begins with the science of reinforcement and then applies it to the two most common pets, dogs and cats.

You will learn how breeds of dogs were developed for real work, what working dogs do today and what every dog needs; how cats communicate and how to spot a sick cat early; and how an aquarium works as a small, balanced ecosystem in which invisible bacteria keep fish alive. You will train an animal a new skill, observe a cat's behavior like a scientist, and test aquarium water. Through it all, remember that “a righteous man regardeth the life of his beast” (Proverbs 12:10).

PREREQUISITES

- Knows the basic needs of pets: food, water, shelter, exercise, cleaning and vet care
- Knows how to approach an unfamiliar animal safely (ask the owner first)
- Can keep a daily log and make a simple graph
- Knows the nitrogen cycle in soil from Unit 3 (helpful for the aquarium lesson)

MASTERY CHECKLIST

- ☐ I can explain positive and negative reinforcement and punishment, and why reward-based training works well.
- ☐ I can use a marker and shaping to teach an animal a new behavior.
- ☐ I can name the dog breed groups, describe several kinds of working dogs and list what every dog needs.
- ☐ I can read cat body language and name warning signs that a cat needs a vet.
- ☐ I can explain the aquarium nitrogen cycle and test aquarium water.

LESSONS IN THIS UNIT

4.1 Animal Behavior and Training: Reinforcement

2 sessions of 50–60 minutes

4.2 Dogs: Breeds, Working Dogs and Care

2 sessions of 50–60 minutes

4.3 Cats: Health and Behavior

2 sessions of 50–60 minutes

4.4 The Aquarium as an Ecosystem

2 sessions of 50–60 minutes

UNIT 4 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **8 pts**

Define positive reinforcement and give an example.

2. **8 pts**

What is negative reinforcement? Give an example from horse training.

3. **6 pts**

Why does a trainer use a clicker or marker word?

4. **6 pts**

What is shaping?

5. **8 pts**

Name four of the seven AKC breed groups and one breed in each.

6. **6 pts**

Name three foods that are poisonous to dogs.

7. **8 pts**

Describe the body language of a friendly, relaxed cat and of a frightened cat.

8. **8 pts**

Why is a male cat straining in the litter box an emergency?

9. **8 pts**

Put these in order in the aquarium nitrogen cycle: nitrate, ammonia, nitrite.
Which is least harmful?

10. **4 pts**

Why must tap water be treated before it goes in an aquarium?

11. **15 pts**

Written answer: A family's new puppy jumps on everyone who comes to the door. Using what you know about reinforcement, explain why the puppy keeps doing it and describe a kind, effective training plan.

12. **15 pts**

Written answer: A student fills a new aquarium, adds ten fish the same day, and within two weeks several fish die. Explain what went wrong and how to set up a tank correctly.

ANSWER KEY

1. Adding something the animal wants right after a behavior so the behavior increases; for example, giving a treat when a dog sits.
2. Removing something unpleasant right after a behavior so it increases; for example, a rider releases leg pressure the moment the horse moves forward.
3. It marks the exact moment of the correct behavior and, through classical conditioning, predicts a reward, so the animal knows what earned it.
4. Teaching a complex behavior by rewarding small steps that come closer and closer to the final goal.
5. Any four, e.g., Sporting (Labrador retriever), Hound (beagle), Working (Newfoundland), Terrier (Jack Russell), Toy (Chihuahua), Non-Sporting (poodle), Herding (border collie).
6. Any three: chocolate, grapes or raisins, onions, garlic, xylitol.
7. Relaxed: tail up, ears forward, slow blinks, soft body. Frightened: ears flat or sideways, dilated pupils, crouched body, puffed tail, arched back, hissing.
8. It may be a urinary blockage, which stops urine from passing and can kill the cat within a day or two without a vet.
9. Ammonia, then nitrite, then nitrate. Nitrate is least harmful.
10. Chlorine and chloramine in tap water harm fish and kill the helpful nitrifying bacteria.
11. Jumping is reinforced by attention (touching, talking, even pushing away). Plan: remove the reward by turning away and ignoring jumping; teach and reward an incompatible behavior such as sitting for greetings, using a marker and treats; have guests greet only when all four paws are on the floor; practice with family first in short sessions; be consistent; meet exercise needs; never hit or hurt.
12. The tank was not cycled: there were too few nitrifying bacteria, so ammonia and then nitrite built up and poisoned the fish (new tank syndrome). Correctly: treat tap water with dechlorinator, run the filter and cycle the tank for four to six weeks with a small ammonia source, test until ammonia and nitrite are zero and nitrate appears, add a few fish at a time, feed lightly, test regularly and change 10–25% of the water weekly.

PORTFOLIO PIECE: AN ANIMAL KEEPER’S HANDBOOK

Make a short handbook for one pet: a dog, a cat, a fish tank or another animal you know. Include your training log and graph, your care plan and budget, your behavior study or water-testing data, and a one-page guide to warning signs that the animal needs a vet.

LOOK FOR	WHAT IT MEANS
Accuracy	Care, nutrition, health and safety facts are correct and specific to the animal.
Data	Training, behavior or water-testing data are recorded clearly and graphed.
Kindness and reasoning	Training and care methods are humane and explained with the science of behavior.
Presentation	The handbook is organized, illustrated and useful to a real keeper.

4.1 ANIMAL BEHAVIOR AND TRAINING: REINFORCEMENT

OBJECTIVES

- Define reinforcement and punishment, positive and negative, with an example of each.
- Explain classical conditioning and how a marker (clicker or word) works.
- Use shaping and good timing to teach an animal a new behavior and keep a training log.

Warm-up. Play the “training game” with a family member. They leave the room while you choose a simple action (touch a lamp, sit in a certain chair). When they return, you may only say “yes!” each time they move closer to the right action. No other hints. Time how long it takes, then switch roles.

WATCH

What is Clicker Training?

Kikopup · 6:36

https://www.youtube.com/watch?v=_wv1uvvqaSw

WHEN TO WATCH

After the core ideas. Note how quickly the trainer clicks after the behavior, and how small the treats are.

KEY TERMS

reinforcement

Anything that follows a behavior and makes that behavior more likely to happen again.

negative reinforcement

Taking away something unpleasant right after a behavior, so the behavior increases; for example, a rider releasing leg pressure the moment a horse moves forward.

positive reinforcement

Adding something the animal wants (food, play, praise) right after a behavior, so the behavior increases.

classical conditioning

Learning that one thing predicts another, as Pavlov’s dogs learned that a sound meant food was coming.

marker

A distinct signal, such as a click or the word “yes,” that tells the animal exactly which moment earned the reward.

shaping

Teaching a complex behavior by rewarding small steps that come closer and closer to the final goal.

CORE IDEAS

Animals, like people, repeat what works for them. Behavior that is followed by something good becomes more frequent; behavior that earns nothing gradually fades. Scientists describe four ways consequences shape behavior. **Positive reinforcement** adds something good (a treat after a dog sits). **Negative reinforcement** removes something unpleasant (pressure on a horse’s side stops when it steps over). Positive punishment adds something unpleasant to stop a behavior, and negative punishment takes away something good (you stop playing when a puppy nips). “Positive” and “negative” here mean adding and taking away, not good and bad.

Most modern trainers, veterinarians and animal behaviorists recommend building training mainly on positive reinforcement. It teaches the animal what *to* do, not just what not to do; it builds trust; and it avoids the fear, stress and aggression that harsh punishment can cause. Training should never involve hitting, shouting or hurting. Many unwanted behaviors are solved by meeting the animal’s needs (exercise, chewing, company) and teaching a better behavior in its place: a dog cannot jump on guests and sit at the same time.

Classical conditioning explains how a **marker** works. If a click is always followed by a treat, the click itself soon becomes a promise of good things. That lets the trainer mark the exact instant a behavior happens, even if the treat comes a second later. Timing matters: reinforcement works best within about a second of the behavior. Rewards should be small (pea-sized for a dog), and sessions short, about five minutes, ending on success.

Shaping builds a behavior step by step. To teach a dog to lie on a mat, you might first click for looking at the mat, then stepping toward it, then one paw on it, then all four, then sitting, then lying down, raising the standard a little each time. Once a behavior is reliable, add a cue word, then gradually reward less often and less predictably, which keeps the behavior strong. The same principles train horses, chickens, rabbits, parrots and zoo animals. Patient, kind training is a form of

stewardship: it lets us care for animals with less stress, for example teaching them to step on a scale or accept a nail trim calmly.

PICTURE STUDY



Sympathy, Briton Rivière, 1878 · Oil on canvas · Tate Britain, London

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

Briton Rivière was one of the best-loved animal painters of Victorian England. Here a girl sits on the stairs, perhaps sent there for misbehaving, and her dog has come to keep her company. Look at what the dog's body tells us.

Look closely

- Look at the dog's ears, eyes and head. Is it relaxed, worried or eager?
- Look at how close the dog sits. What does that tell you about their relationship?
- Look at the girl's posture. How might the dog be reading her mood?
- Find any details that show this is an ordinary home.

Talk about it

1. How do dogs learn to read our moods and actions?
2. What kind of training builds this sort of trust between a person and an animal?
3. If this girl wanted to teach her dog a new trick, how would you tell her to start?

Safety first. Train only an animal you know well, with its owner's permission. Keep sessions short, use tiny healthy treats, and stop if the animal shows stress (lip licking, yawning, turning away, growling). Never use punishment or force.

Shape a New Behavior

You will use a marker and shaping to teach an animal one new behavior over ten short sessions and keep a training log with data.

You will need

- An animal you know well (dog, cat, rabbit, guinea pig, chickens, horse with an adult) or, if none, a family member and the training game
- A clicker, or a short marker word like “yes”
- Small, healthy treats suitable for the animal (for chickens, a few mealworms or seeds; for a rabbit, tiny pieces of herb or leafy green)
- A timer and your nature journal

Steps

1. Choose a simple goal behavior: touch your hand with the nose (target), spin in a circle, go to a mat, ring a bell, or for chickens, peck a colored lid.
2. Charge the marker: click or say “yes,” then give a treat, ten times in a row, before asking for any behavior.
3. Write a shaping plan of 4–6 small steps from where the animal is now to the goal.
4. Session 1: click the first small step the instant it happens, then treat. Do 10–15 repetitions in under five minutes.
5. In each session, raise the standard only when the animal succeeds about 8 times out of 10. If it struggles, go back a step.
6. Record each session: date, step, number of tries, number of successes, and notes on the animal’s mood.
7. When the behavior is reliable, add a cue word just before it happens, then start rewarding only the best responses.
8. After ten sessions, graph the success rate over time and write a paragraph on what worked and what you would change.

Tips

- End every session on a success, even if you have to ask for something easy.

- Train before a meal, when the animal is a little hungry, in a quiet place.
- If you click by mistake, still give the treat. The click is a promise.
- 4-H dog, cat, rabbit, cavy and poultry projects all keep training and care logs like this one, and many county fairs hold youth dog obedience and showmanship classes; check your county extension office.

Check your work

- ☐ I charged the marker before training.
- ☐ I wrote a shaping plan and followed it in small steps.
- ☐ My log shows ten sessions with data and a graph.
- ☐ I can explain each of the four kinds of consequences with an example.

NATURE JOURNAL

1. Draw a four-box chart (add or remove, increases or decreases behavior) with an animal example in each box.
2. Draw your animal's body language when it is relaxed and when it is stressed, labeling ears, eyes, mouth and tail.
3. Make a line graph of your training success rate across ten sessions.

From history. Around 1900 the Russian scientist Ivan Pavlov was studying digestion in dogs when he noticed they began to drool before food arrived, at the sound of footsteps or a signal that meant food was coming. His careful experiments on this “conditioned reflex” earned him fame and laid a foundation for the modern science of animal learning.

COMMON MISTAKES

- Clicking late, after the animal has moved on to something else.
- Raising the standard too fast, so the animal gives up.
- Using big treats that fill the animal up in a few tries.
- Repeating a cue word over and over before the animal knows what it means.

Make it a game • Marker Training Game. Teach your parent a silly behavior by shaping, using a marker word like 'yes' and a small reward chip, with no instructions. Your parent plays the learner. Then label each example as positive reinforcement, negative reinforcement, positive punishment or negative punishment, and explain classical conditioning. Whoever teaches the behavior in fewer steps wins.

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

To “regard” an animal’s life is to pay attention to its needs and feelings. Gentle, patient training is one way we show that regard.

4.2 DOGS: BREEDS, WORKING DOGS AND CARE

OBJECTIVES

- Name the seven AKC breed groups and explain how breeds were developed for particular work.
- Describe what herding, guardian, scent, guide and rescue dogs do.
- Plan a dog's daily, weekly and yearly care, including nutrition, exercise, grooming, vet care and safety.

Warm-up. Write down five dog breeds you know. For each, guess what job it was first bred to do. Check your guesses after the lesson.

WATCH

Sheepdog commands explained

Seanthesheepman · 12:45

<https://www.youtube.com/watch?v=hVmQE0tcV1Y>

WHEN TO WATCH

After the core ideas. List each whistle or spoken command and what the dog does.

Note: A Scottish shepherd working with his border collies on a hill farm.

KEY TERMS

breed

A group of dogs with a shared ancestry and a predictable look and temperament, developed by people choosing which dogs to raise puppies from.

herding dog

A dog bred to move livestock by circling, staring and driving, such as the border collie, Australian shepherd and corgi.

scent hound

A dog bred to follow smells, such as the beagle and bloodhound; used today to find lost people and detect forbidden foods at airports.

guide dog

A dog trained to lead a person who is blind safely around obstacles, across streets and through crowds.

heartworm

A parasitic worm spread by mosquitoes that lives in a dog's heart and lungs; prevented with regular medicine.

CORE IDEAS

Dogs come in hundreds of breeds, from a 4-pound Chihuahua to a 150-pound mastiff, yet they are one kind of animal. People shaped breeds over centuries by choosing which dogs to raise puppies from, keeping those best at a particular job. The American Kennel Club sorts breeds into seven groups: **Sporting** (retrievers, spaniels, pointers that work with hunters), **Hound** (scent hounds and sight hounds), **Working** (guarding, pulling, rescue: Great Pyrenees, Newfoundland, Saint Bernard), **Terrier** (bred to go after rats and other vermin), **Toy** (small companions), **Non-Sporting** (a mixed group) and **Herding**.

Many dogs still work. A **herding dog** such as a border collie gathers and moves sheep using a crouching stalk and an intense stare called “eye,” responding to its shepherd’s whistles: “come bye” to circle clockwise, “away to me” to circle counterclockwise, “lie down” to stop and “walk up” to move in. One good dog can do the work of several people on a hill farm. Livestock guardian dogs, as you learned in Unit 2, live with and protect flocks. **Scent dogs** find lost hikers, people trapped after disasters and illegal food or plants in airport luggage; a dog’s nose has far more scent receptors than ours. **Guide dogs**, often Labradors, golden retrievers or German shepherds, train for many months to lead people who are blind.

Every dog needs a complete and balanced diet in the right amount, fresh water, daily exercise suited to its breed and age, grooming, nail trims and tooth care, and a safe place to sleep. A border collie or Labrador needs an hour or more of active exercise and a job to do; a bored, high-energy dog often becomes destructive. Yearly vet visits include a checkup and shots, including rabies, which the law requires. Monthly

preventives protect against heartworm, fleas and ticks. Some foods are poisonous to dogs: chocolate, grapes and raisins, onions and garlic, and xylitol, a sweetener in some gum and peanut butter.

Dogs also need training and good manners, and people need dog-safety manners. Always ask an owner before petting a dog, let it sniff your hand, and pet its shoulder or chest rather than reaching over its head. Never approach a dog that is eating, sleeping, tied up or caring for puppies. A dog that stiffens, stares, raises its lips or growls is asking you to back away slowly. Choosing a dog wisely means matching its size, energy and grooming needs to a family's time, space and budget; a dog may live 10 to 15 years.

PICTURE STUDY



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

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

Landseer was the most famous animal painter of his day. This Newfoundland, named Paul Pry, belonged to a London family. The title is a joke with a serious side: the Royal Humane Society honored people who rescued others from drowning, and Newfoundlands were famous for pulling swimmers from the water.

Look closely

- Look at the dog's size and build. What would make it a strong swimmer?
- Look at its coat. How might thick, oily fur help in cold water?
- Look at its eyes and posture. Is it resting, watching or ready to act?
- Find the water. Why did Landseer place the dog right at its edge?

Talk about it

1. What job was the Newfoundland breed developed for?
2. How is this dog's body suited to its work compared with a border collie's?
3. What care would a large, heavy-coated dog like this need?

Safety first. Ask the owner before approaching any dog, and never approach a working dog in harness, a guardian dog in its pasture or a dog that is eating, tied or with puppies. Report any bite to an adult, and wash it with soap and water.

HANDS-ON PROJECT

A Dog Care Plan and Budget

You will research one breed (or a mixed-breed dog you know), plan its care for a year and estimate the true cost of keeping it. If possible, you will watch a working-dog trial, a 4-H dog club or a shelter.

You will need

- Library books or reputable websites (AKC, ASPCA, a veterinary hospital)
- A pet-store or farm-store catalog for prices
- Your nature journal
- Optional: a dog you can observe, with the owner

Steps

1. Choose a breed or a dog you know. Record its group, original job, adult size, life span, energy level and grooming needs.
2. Make a daily schedule: feeding times and amounts, water, walks and play, training practice and bathroom breaks.
3. Make a weekly and yearly list: brushing, nail trims, tooth care, monthly preventives, yearly vet visit and shots.
4. Make an expense and income table for one year: list food, treats, preventives, vet visits, license, grooming, toys and bedding, plus one-time costs (crate, leash, bowls, adoption fee). Add any income or savings (for example, dog-walking you could do) and total the true yearly cost.
5. List five household dangers to this dog and how to prevent each.
6. If you can, watch a working-dog trial, 4-H dog show or shelter dog for 20 minutes and record what you notice about its behavior.
7. Write a paragraph: would this dog fit your family? Explain why or why not.

Tips

- Look up adult weight first; food, medicine and boarding often cost more for bigger dogs.
- Shelters often know a dog's energy level and manners; ask the staff.

Check your work

- ☐ I can name the seven AKC groups.
- ☐ My plan includes daily, weekly and yearly care.
- ☐ My budget includes both one-time and yearly costs.
- ☐ I can list at least four foods that are poisonous to dogs.

NATURE JOURNAL

1. Draw a border collie in its herding crouch, labeling the low head, fixed stare and ready legs.
2. Draw a sheepdog course from above showing the paths for “come bye” and “away to me.”
3. Sketch a dog you know from life in three quick poses.

From history. The first American guide-dog school, The Seeing Eye, was founded in 1929 after a blind young man named Morris Frank traveled to Switzerland to train with a German shepherd named Buddy. Frank and Buddy toured the country showing that a well-trained dog could lead a blind person safely through busy streets.

COMMON MISTAKES

- Choosing a dog by looks alone and ignoring its energy and grooming needs.
- Feeding table scraps, which can upset digestion or poison a dog.
- Skipping heartworm prevention in winter in warm climates.
- Reaching over a strange dog’s head to pet it.

Make it a game • Breed Group Roll Call. Name the seven AKC breed groups from memory, then play a matching round: parent says a job, such as herding sheep, scent tracking, guiding or rescue, and you name the group and a breed. Explain how breeds were developed for work. Add heartworm prevention as a last question. Beat your own number of groups recalled.

4.3 CATS: HEALTH AND BEHAVIOR

OBJECTIVES

- Describe how cats are designed as hunters and what that means for their diet and behavior.
- Read cat body language and meet a cat's needs for scratching, climbing, play and a clean litter box.
- Recognize signs of illness and emergencies in cats, and household dangers.

Warm-up. Look at three photos of cats (or a real cat) and write what you think each one is feeling. Note the clues you used: ears, eyes, tail, whiskers, body.

WATCH

Cat Body Language 101

Fear Free Happy Homes · 4:49

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

WHEN TO WATCH

After the core idea on body language. Pause on each pose and name the emotion before the narrator does.

KEY TERMS

obligate carnivore

An animal that must eat meat to stay healthy. Cats need nutrients such as taurine that come from animal tissue.

scratching

A normal cat behavior that sharpens claws, stretches muscles and leaves scent marks from glands in the paws.

slow blink

A cat's relaxed, half-closed blink toward a person or cat it trusts; a sign of comfort.

urinary blockage

A life-threatening emergency, most common in male cats, in which the cat strains in the litter box but cannot pass urine.

enrichment

Toys, climbing places, hiding spots and play that let an animal use its natural behaviors.

CORE IDEAS

The house cat is a small, skilled hunter. Its eyes gather light so well that it sees in about one-sixth the light we need; its whiskers sense air currents and gaps in the dark; its claws retract to stay sharp; and it can sprint and pounce with great precision. Cats are **obligate carnivores**: they need nutrients found only in animal tissue, such as the amino acid taurine, so they must eat a balanced cat food, never a dog food or a meat-free diet. Many cats drink little, so wet food helps keep them hydrated.

Cats speak mostly with their bodies. A tail held straight up, often with a little hook at the tip, is a friendly greeting. A **slow blink** means trust; you can slow-blink back. Ears turned sideways or flattened, a lashing tail, dilated pupils and a crouched body mean fear or irritation; a puffed tail and arched back mean the cat feels threatened. A cat rolling over is showing trust, but its belly is often not an invitation to be touched. Purring usually means contentment, though sick or hurt cats purr too.

Many “problem” behaviors are normal behaviors with no proper outlet. Cats must scratch, so give them a sturdy, tall scratching post covered in rough material near where they sleep. They need high perches, hiding places and daily play with wand toys that let them stalk, chase and pounce. They are very particular about litter boxes: experts suggest one box per cat plus one, scooped every day, in quiet places away from food. Keeping cats indoors, with plenty of **enrichment**, protects them from cars, predators and disease, and protects songbirds too.

Cats hide illness, so owners must watch closely. Call a vet promptly if a cat stops eating for more than a day (a fasting cat can develop serious liver disease), vomits repeatedly, hides and will not come out, drinks and urinates much more than usual or loses weight. A cat straining in the litter box with little or no urine, especially a male, is an emergency: **urinary blockage** can kill within a day or two. Yearly checkups include shots, dental exams and weighing. Dangers at home include lilies (every part is deadly to cats), string and thread, antifreeze and dog flea products containing permethrin, which are toxic to cats.

PICTURE STUDY



Kittens at Play, Henriëtte Ronner-Knip, late 1800s · Oil on panel · Museum Boijmans Van Beuningen, Rotterdam

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

Henriëtte Ronner-Knip, a Dutch painter, kept cats in a glass-fronted box in her studio so she could study them closely, and she painted them for more than sixty years. Look at her kittens as a cat behaviorist would.

Look closely

- Find a kitten that is about to pounce. Which parts of its body show it is ready?
- Look at the ears and eyes of each kitten. Which look playful, and which look cautious?
- Find the tails. What is each tail doing?
- Look for any object the kittens are playing with. What hunting behavior are they practicing?

Talk about it

1. Why do kittens play so much? What are they learning?
2. What toys could an owner give an indoor cat to let it practice these behaviors?
3. How could you tell if play between kittens was turning into a real fight?

Safety first. Let a cat come to you; do not pick up a cat you do not know. Cat bites and deep scratches infect easily: wash them right away with soap and water and tell an adult, who may need to call a doctor. Wash hands after cleaning a litter box.

HANDS-ON PROJECT

A Cat Behavior Study

You will observe a cat like an animal behaviorist, recording what it does in timed sessions, and finish with a simple health and environment check.

You will need

- A cat you can observe (your own, a neighbor's or a relative's, with permission) or a shelter cat room or a long, unedited cat-cam video
- A timer and your nature journal
- An ethogram sheet: a list of behaviors to tally (sleeping, grooming, eating, scratching, playing, watching, exploring, vocalizing)

Steps

1. Make an ethogram: list 8–10 behaviors with a one-line definition of each.
2. Observe the cat for three 15-minute sessions at different times of day (morning, afternoon, evening). Every 30 seconds, tally what the cat is doing.
3. Each session, record body-language notes: tail, ears, eyes and any sounds.
4. Calculate the percentage of time spent on each behavior and make a pie chart or bar graph.
5. With the owner, do a gentle environment check: food and water, number and cleanliness of litter boxes, scratching posts, perches, hiding places and toys.
6. With the owner, note simple health signs: clear eyes, clean ears, smooth coat, healthy weight (ribs felt but not seen).
7. Write a report with your data and three suggestions to improve this cat's life.

Tips

- Sit quietly and let the cat ignore you. A cat that is watching you is not behaving naturally.
- Cats sleep 12–16 hours a day, so expect lots of “resting” tallies.

Check your work

- ☐ I wrote clear behavior definitions before observing.
- ☐ I recorded at least three timed sessions and graphed the results.

- ☐ I can name four signs that a cat needs a vet.
- ☐ I can explain why lilies and dog flea medicine are dangerous to cats.

NATURE JOURNAL

1. Draw four cat heads showing relaxed, alert, fearful and angry expressions, labeling ears, eyes and whiskers.
2. Draw a cat's retractable claw extended and pulled in, from a diagram.
3. Sketch a sleeping cat from life, noting its position and the room temperature.

From history. For thousands of years cats earned their keep on farms, in granaries and aboard ships, where they protected grain and food stores from rats and mice. Many ships carried a cat as part of the crew, and farm families counted a good mousing cat as a valued helper.

COMMON MISTAKES

- Thinking a purring cat is always happy.
- Feeding a cat dog food or a meat-free diet.
- Keeping one litter box for several cats and cleaning it rarely.
- Punishing a cat for scratching furniture instead of giving it a good scratching post.

Make it a game • Cat Language Pantomime. Take turns acting out cat body language and needs: the slow blink, tail up, flattened ears, scratching and climbing. Parent guesses the message. Then explain why cats are hunters and obligate carnivores, what a clean litter box means and why a urinary blockage is an emergency. Set up a pretend cat enrichment shelf as a bonus.

4.4 THE AQUARIUM AS AN ECOSYSTEM

OBJECTIVES

- Explain the aquarium nitrogen cycle from fish waste to ammonia, nitrite and nitrate.
- Describe how temperature, oxygen, pH and hardness affect fish, and why tap water must be treated.
- Test aquarium water and interpret the results.

Warm-up. Look at a fish tank, pond or photo of one. List every living thing you can see and every non-living part (water, gravel, filter, light). Draw arrows for anything you think one part gives to another.

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 first two core ideas. Draw the cycle as it is explained.

Note: The channel belongs to an aquarium supply store, and the host mentions some of its products.

KEY TERMS

nitrogen cycle

In an aquarium, the process by which bacteria turn toxic ammonia from fish waste into nitrite and then into much less harmful nitrate.

ammonia

A nitrogen compound released by fish gills and decaying food and waste; toxic to fish even in small amounts.

nitrifying bacteria

Bacteria that live on filter media, gravel and surfaces and turn ammonia into nitrite and nitrite into nitrate.

cycling

Growing a population of nitrifying bacteria in a new aquarium, which usually takes four to six weeks, before adding many fish.

pH

A measure of how acidic or basic water is, on a scale of 0 to 14 with 7 as neutral; most community fish do well around 6.5–7.5.

dechlorinator

A water conditioner that removes chlorine and chloramine from tap water, which otherwise harm fish and kill helpful bacteria.

CORE IDEAS

An aquarium is a small ecosystem in a glass box. Fish eat, breathe and give off waste; uneaten food decays. Both release **ammonia**, which burns fish gills and can kill them. In a pond or stream, huge volumes of water and natural bacteria deal with it. In an aquarium, the keeper must make sure the right bacteria are present to do that work.

Two groups of **nitrifying bacteria** carry out the **nitrogen cycle**. The first turns ammonia into nitrite, which is also toxic. The second turns nitrite into nitrate, which fish tolerate at moderate levels. These bacteria live mostly on surfaces, especially the sponge or media in the filter and the gravel, not floating in the water. A new tank has almost none, so it must be **cycled**: given a small, steady source of ammonia for four to six weeks until tests show ammonia and nitrite at zero and nitrate rising. Many fish die in new tanks because owners add them too fast, a problem called “new tank syndrome.” It is the same nitrogen cycle you met in soil, carried out by similar bacteria.

Nitrate slowly builds up, so keepers change 10–25 percent of the water each week, and live plants and algae take up nitrate and ammonia as fertilizer. Plants also give off oxygen by day and use it at night. Oxygen enters water mainly at the surface, so filters and air stones that ripple the surface help; warm water holds less oxygen than cool water. Never rinse filter media under the tap, because chlorine kills the bacteria; rinse it gently in old tank water instead. Always treat new tap water with a **dechlorinator**.

Fish are also sensitive to temperature, pH and hardness. Tropical fish need steady warmth of about 75–80 °F from a heater; goldfish are cool-water fish and need a large tank or pond, not a small bowl, because they grow big and produce a lot of waste. pH and hardness (GH, the dissolved minerals; KH, the buffering that keeps pH steady) should suit the species and change slowly. Feed only what fish eat in a minute or two, and hold new fish in a separate tank for a few weeks before adding them, so they do not bring disease. A balanced aquarium shows in miniature how God ordered living things to depend on one another.

PICTURE STUDY



Plate I from The Aquarium: An Unveiling of the Wonders of the Deep Sea, Philip Henry Gosse, 1854 ·

Hand-colored lithograph · *The Aquarium*, London

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

Philip Henry Gosse, an English naturalist and devout Christian, helped make the home aquarium popular in the 1850s. He showed that a tank could stay healthy for months if plants and animals were kept in balance. His book's colored plates, like this one of a wrasse among seaweeds, delighted Victorian families.

Look closely

- Find the seaweeds. What do they give to the animals?
- Find all the animals. Which ones swim, and which crawl on the rocks?
- Look at the rocks and shells. Where would helpful bacteria live?
- Look at the fish's mouth, eye and fins. How is it suited to life among weeds and rocks?

Talk about it

1. Why did Gosse think plants were so important in an aquarium?
2. What would happen to a tank like this if too many fish were added at once?
3. What modern equipment does a home aquarium have that Gosse's did not?

Safety first. Keep electrical cords for heaters and filters dry, with a “drip loop” below the outlet, and unplug equipment before putting your hands in the tank. Wash hands after working in an aquarium, and keep test-kit chemicals away from young children.

HANDS-ON PROJECT

Aquarium Water Testing Log

You will test an aquarium's water several times over two weeks, record the results and explain what they show about its nitrogen cycle and health.

You will need

- Access to an aquarium: your own, a school, library or friend's tank, or permission to test water at a pet store
- An aquarium test kit or strips for ammonia, nitrite, nitrate and pH
- A thermometer
- Your nature journal

Steps

1. Describe the tank: its size in gallons, the kinds and number of fish, plants, filter type and how often water is changed.
2. Test ammonia, nitrite, nitrate and pH, and record the temperature, following the kit directions exactly.
3. Repeat the tests at least four times over two weeks, at the same time of day, including just before and after a water change if one is done.
4. Make a table and a line graph of nitrate over time, marking water changes.
5. Compare each result with safe ranges: ammonia 0, nitrite 0, nitrate under about 40 parts per million, pH suited to the fish.
6. Observe the fish each time: breathing rate, color, fins and appetite.
7. Write a report explaining whether the tank is fully cycled and healthy, and recommend any changes in feeding, stocking or water changes.

Tips

- Shake liquid test bottles well; some must be shaken for 30 seconds for accurate results.
- No aquarium? Set up a jar with pond water and water plants on a bright windowsill and test it, or test a backyard pond with permission.

Check your work

- ☐ I tested and recorded at least four times.
- ☐ I graphed nitrate and marked water changes.
- ☐ I can explain each step of the nitrogen cycle.
- ☐ I can explain why new tanks must be cycled and why tap water must be treated.

NATURE JOURNAL

1. Draw the aquarium nitrogen cycle as a circle diagram: fish and food, ammonia, nitrite, nitrate, plants and water changes.
2. Draw one fish from life, labeling gills, fins, lateral line and eyes.
3. Record your test results in a table each time you test.

From history. In 1853 the London Zoo opened the first public aquarium, called the Fish House, with help from Philip Henry Gosse, who also popularized the word “aquarium.” Soon Victorian families everywhere kept tanks of fish, snails and water plants in their parlors.

COMMON MISTAKES

- Adding a tank full of fish on the first day.
- Overfeeding, which floods the tank with ammonia.
- Washing filter media under tap water and killing the helpful bacteria.
- Keeping goldfish in a small bowl.

Make it a game • Tank Cycle Detective. Make cards for fish waste, ammonia, nitrifying bacteria, nitrite and nitrate. Shuffle and rebuild the nitrogen cycle in order. Parent plays a worried new fish owner whose fish are gasping, and you diagnose the likely cause among ammonia, a missing dechlorinator, wrong pH or low oxygen. Explain cycling. Solve three owner cases.

UNIT 4

PETS: BEHAVIOR, TRAINING AND CARE

A good keeper of animals understands how animals learn. Dogs, cats, horses, chickens and even fish change their behavior according to what happens after they act, and once you understand that, you can teach an animal kindly and clearly instead of scolding it for doing what comes naturally. This unit begins with the science of reinforcement and then applies it to the two most common pets, dogs and cats.

You will learn how breeds of dogs were developed for real work, what working dogs do today and what every dog needs; how cats communicate and how to spot a sick cat early; and how an aquarium works as a small, balanced ecosystem in which invisible bacteria keep fish alive. You will train an animal a new skill, observe a cat’s behavior like a scientist, and test aquarium water. Through it all, remember that “a righteous man regardeth the life of his beast” (Proverbs 12:10).

PREREQUISITES

- Knows the basic needs of pets: food, water, shelter, exercise, cleaning and vet care
- Knows how to approach an unfamiliar animal safely (ask the owner first)
- Can keep a daily log and make a simple graph
- Knows the nitrogen cycle in soil from Unit 3 (helpful for the aquarium lesson)

MASTERY CHECKLIST

- ☐ I can explain positive and negative reinforcement and punishment, and why reward-based training works well.
- ☐ I can use a marker and shaping to teach an animal a new behavior.
- ☐ I can name the dog breed groups, describe several kinds of working dogs and list what every dog needs.
- ☐ I can read cat body language and name warning signs that a cat needs a vet.
- ☐ I can explain the aquarium nitrogen cycle and test aquarium water.

LESSONS IN THIS UNIT

4.1 Animal Behavior and Training: Reinforcement

2 sessions of 50–60 minutes

4.2 Dogs: Breeds, Working Dogs and Care

2 sessions of 50–60 minutes

4.3 Cats: Health and Behavior

2 sessions of 50–60 minutes

4.4 The Aquarium as an Ecosystem

2 sessions of 50–60 minutes

UNIT 4 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **8 pts**

Define positive reinforcement and give an example.

2. **8 pts**

What is negative reinforcement? Give an example from horse training.

3. **6 pts**

Why does a trainer use a clicker or marker word?

4. **6 pts**

What is shaping?

5. **8 pts**

Name four of the seven AKC breed groups and one breed in each.

6. **6 pts**

Name three foods that are poisonous to dogs.

7. **8 pts**

Describe the body language of a friendly, relaxed cat and of a frightened cat.

8. **8 pts**

Why is a male cat straining in the litter box an emergency?

9. **8 pts**

Put these in order in the aquarium nitrogen cycle: nitrate, ammonia, nitrite.
Which is least harmful?

10. **4 pts**

Why must tap water be treated before it goes in an aquarium?

11. **15 pts**

Written answer: A family's new puppy jumps on everyone who comes to the door. Using what you know about reinforcement, explain why the puppy keeps doing it and describe a kind, effective training plan.

12. **15 pts**

Written answer: A student fills a new aquarium, adds ten fish the same day, and within two weeks several fish die. Explain what went wrong and how to set up a tank correctly.

ANSWER KEY

1. Adding something the animal wants right after a behavior so the behavior increases; for example, giving a treat when a dog sits.
2. Removing something unpleasant right after a behavior so it increases; for example, a rider releases leg pressure the moment the horse moves forward.
3. It marks the exact moment of the correct behavior and, through classical conditioning, predicts a reward, so the animal knows what earned it.
4. Teaching a complex behavior by rewarding small steps that come closer and closer to the final goal.
5. Any four, e.g., Sporting (Labrador retriever), Hound (beagle), Working (Newfoundland), Terrier (Jack Russell), Toy (Chihuahua), Non-Sporting (poodle), Herding (border collie).
6. Any three: chocolate, grapes or raisins, onions, garlic, xylitol.
7. Relaxed: tail up, ears forward, slow blinks, soft body. Frightened: ears flat or sideways, dilated pupils, crouched body, puffed tail, arched back, hissing.
8. It may be a urinary blockage, which stops urine from passing and can kill the cat within a day or two without a vet.
9. Ammonia, then nitrite, then nitrate. Nitrate is least harmful.
10. Chlorine and chloramine in tap water harm fish and kill the helpful nitrifying bacteria.
11. Jumping is reinforced by attention (touching, talking, even pushing away). Plan: remove the reward by turning away and ignoring jumping; teach and reward an incompatible behavior such as sitting for greetings, using a marker and treats; have guests greet only when all four paws are on the floor; practice with family first in short sessions; be consistent; meet exercise needs; never hit or hurt.
12. The tank was not cycled: there were too few nitrifying bacteria, so ammonia and then nitrite built up and poisoned the fish (new tank syndrome). Correctly: treat tap water with dechlorinator, run the filter and cycle the tank for four to six weeks with a small ammonia source, test until ammonia and nitrite are zero and nitrate appears, add a few fish at a time, feed lightly, test regularly and change 10–25% of the water weekly.

PORTFOLIO PIECE: AN ANIMAL KEEPER’S HANDBOOK

Make a short handbook for one pet: a dog, a cat, a fish tank or another animal you know. Include your training log and graph, your care plan and budget, your behavior study or water-testing data, and a one-page guide to warning signs that the animal needs a vet.

LOOK FOR	WHAT IT MEANS
Accuracy	Care, nutrition, health and safety facts are correct and specific to the animal.
Data	Training, behavior or water-testing data are recorded clearly and graphed.
Kindness and reasoning	Training and care methods are humane and explained with the science of behavior.
Presentation	The handbook is organized, illustrated and useful to a real keeper.

UNIT 5

PLANT PHYSIOLOGY

Physiology is the study of how living things work. In this unit you will look inside the plant to see how it lifts water higher than any pump without moving a muscle, how it gathers seventeen essential elements from soil and air, how it knows the season by measuring the length of the night, and how it uses chemical messengers called hormones to bend toward light, grow roots and ripen fruit.

This is the science behind everyday gardening decisions: when to water, how to read a yellow leaf, why spinach bolts in June and poinsettias bloom at Christmas, how to root a cutting and why one ripe apple can ripen a whole bag of green bananas. It is late winter, the perfect time for indoor experiments. As you watch these hidden processes, remember that every plant is “fearfully and wonderfully made” by the same Designer who made you.

PREREQUISITES

- Knows the parts of a plant and their basic jobs
- Knows that plants make sugar by photosynthesis using light, water and carbon dioxide
- Knows what N, P and K stand for on a fertilizer label
- Can measure in millimeters and milliliters and keep an experiment log

MASTERY CHECKLIST

- ☐ I can trace the path of water from soil to air through a plant and explain transpiration pull.
- ☐ I can name the macronutrients and several micronutrients and diagnose common deficiency symptoms.
- ☐ I can explain the difference between mobile and immobile nutrients and why it matters for diagnosis.
- ☐ I can explain short-day, long-day and day-neutral plants and how growers use photoperiod.
- ☐ I can describe what auxin and ethylene do and use them in rooting and ripening experiments.

LESSONS IN THIS UNIT

5.1 Water Movement and Transpiration

2 sessions of 50–60 minutes

5.2 Mineral Nutrition and Deficiencies

2 sessions of 50–60 minutes

5.3 Photoperiod: Short-Day and Long-Day Plants

2 sessions of 50–60 minutes

5.4 Plant Hormones: Auxin, Cuttings and Ethylene

2 sessions of 50–60 minutes

UNIT 5 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. (8 pts)

Trace the path of water from the soil to the air through a plant.

2. (8 pts)

How does water rise to the top of a tall tree without a pump?

3. (6 pts)

Why do stomata close during drought, and what is the cost to the plant?

4. (8 pts)

Name the three primary macronutrients and one job of each.

5. (8 pts)

A plant's older leaves are turning yellow all over while the new leaves are green. Which nutrient is most likely short, and why do the old leaves show it first?

6. (6 pts)

Why can a blueberry plant be yellow even when there is iron in the soil?

7. (6 pts)

How many pounds of nitrogen are in a 40-pound bag of 10-5-5 fertilizer?

8. (8 pts)

What do short-day plants actually measure, and how did scientists show it?

9. **6 pts**

Why does spinach often bolt in early summer?

10. **6 pts**

Why does pinching the tip of a basil plant make it bushier?

11. **15 pts**

Written answer: Explain how a grocery chain can sell ripe bananas grown thousands of miles away, using the words climacteric and ethylene.

12. **15 pts**

Written answer: A tomato plant has yellow, scorched edges on its lower leaves, and several fruits have dark, sunken spots on their bottoms. Explain what may be wrong and what the gardener should do first.

ANSWER KEY

1. Soil water enters root hairs, crosses the root into the xylem, rises through the stem into leaf veins, evaporates from cells inside the leaf and leaves through the stomata as vapor.
2. Transpiration from leaves pulls on a continuous column of water in the xylem; cohesion holds the water molecules together and adhesion holds them to the xylem walls (cohesion-tension). The sun's energy drives the evaporation.
3. Closing saves water, but it also stops carbon dioxide from entering, so photosynthesis and growth slow.
4. Nitrogen: proteins and chlorophyll, leafy growth. Phosphorus: DNA and energy molecules, roots, flowers and seeds. Potassium: controls stomata and water and sugar movement, disease and drought resistance.
5. Nitrogen. It is mobile, so the plant moves it from old leaves to new growth, leaving the old leaves yellow.
6. The soil pH is too high (alkaline), which locks up iron so the plant cannot take it up.
7. 4 pounds (10% of 40).
8. The length of the uninterrupted night. A brief flash of light in the middle of a long night prevents flowering, while darkness in the middle of the day does not.
9. Spinach is a long-day plant; the short nights of late spring and summer trigger flowering.
10. It removes the source of auxin that held back the side buds (apical dominance), so the side buds grow into new shoots.
11. Bananas are climacteric fruit, which keep ripening after picking. They are harvested mature but green, shipped cool so ripening is slowed, then placed in sealed ripening rooms where ethylene gas is added at controlled temperature; the ethylene triggers starch-to-sugar conversion, softening and yellowing, so they arrive in stores at the right ripeness.
12. Scorched lower-leaf edges suggest potassium deficiency (a mobile nutrient). Blossom-end rot is calcium not reaching the fruit, usually because of uneven watering. First test the soil (nutrients and pH) and check watering; water deeply and evenly and mulch; add potassium or adjust pH only if the test shows a need.

PORTFOLIO PIECE: A PLANT PHYSIOLOGY LAB NOTEBOOK

Assemble your four investigations (transpiration, nutrients, photoperiod and hormones) into a lab notebook. For each, include the question, a hypothesis, materials, procedure, data table, graph and a conclusion that uses the unit's vocabulary. End with one page explaining how these four processes work together in a single tomato plant through the summer.

LOOK FOR	WHAT IT MEANS
Experimental design	Each investigation has a clear question, a control and only one variable changed.
Data	Measurements are complete, dated and presented in clear tables and graphs.
Explanation	Conclusions explain results correctly using transpiration, nutrients, photoperiod and hormones.
Synthesis	The final page connects all four processes in one plant accurately.

5.1 WATER MOVEMENT AND TRANSPIRATION

OBJECTIVES

- Trace the path of water from the soil through roots, xylem and leaves into the air.
- Explain transpiration, cohesion and adhesion, and how stomata control water loss.
- Measure transpiration and observe stomata in a hands-on experiment.

Warm-up. Hold a paper towel strip with its tip just touching a glass of colored water and watch for three minutes. Measure how high the water climbs. Then write how high you think water climbs in the tallest tree and how it gets there.

WATCH

How do trees pump water?

[ScienceSketch](#) · 5:13

https://www.youtube.com/watch?v=Z_nHU0_MbiU

WHEN TO WATCH

After the first two core ideas. Pause at each drawing and label the parts in your journal.

KEY TERMS

xylem

Tube-like vessels in roots, stems and leaves that carry water and dissolved minerals upward from the roots.

phloem

Living tissue that carries sugars made in the leaves to roots, fruits and growing tips.

transpiration

The evaporation of water from a plant's leaves, mostly through the stomata, which pulls more water up from the roots.

stomata

Tiny pores, mostly on the undersides of leaves, opened and closed by a pair of guard cells, through which carbon dioxide enters and water vapor leaves.

cohesion

The attraction of water molecules to each other, which lets a column of water in the xylem hang together like a chain.

turgor

The pressure of water inside plant cells that keeps soft stems and leaves firm; when it is lost, the plant wilts.

CORE IDEAS

Water enters a plant through millions of microscopic **root hairs**, moves inward across the root and into the **xylem**, a network of hollow, pipe-like cells that runs from the root tips up the stem and into every leaf vein. Inside the leaf, water spreads into the spongy cells and evaporates from their wet surfaces into the air spaces, then escapes through the **stomata**. This evaporation is **transpiration**, and it is enormous: of all the water a plant takes up, usually well over 90 percent is transpired. The U.S. Geological Survey estimates that a large oak tree can transpire about 40,000 gallons in a year.

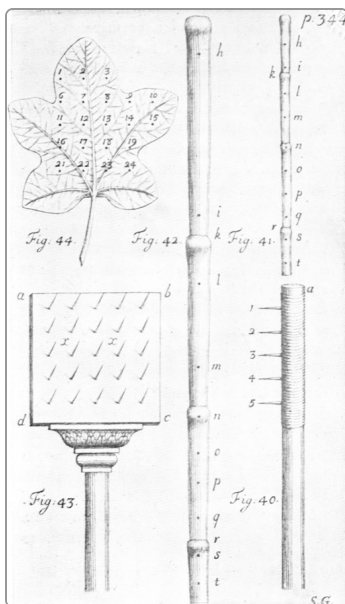
How does water climb a 300-foot redwood with no pump? Each water molecule clings to its neighbors (**cohesion**) and to the walls of the narrow xylem tubes (**adhesion**). As water evaporates from a leaf, it pulls on the unbroken column of water behind it, all the way down to the roots, like pulling a chain up a well. This is called the cohesion–tension explanation, and the energy for it comes from the sun, which drives the evaporation. Meanwhile the **phloem** carries sugar in the other direction, from leaves to roots, fruits and growing tips.

Plants face a trade-off. The stomata must open to let in carbon dioxide for photosynthesis, but open stomata let water out. Two curved **guard cells** around each pore swell and open it in light, and go limp and close it in darkness or when the plant is short of water. Transpiration speeds up in heat, sun, wind and dry air, and slows in cool, still, humid weather. When roots cannot keep up, cells lose **turgor** and the plant wilts. Many plants wilt a little on hot afternoons and recover by evening; a plant still wilted in the cool of the morning needs water.

This explains good watering practice. Water deeply and less often, so roots grow down where soil stays moist, rather than sprinkling a little every day. Water in the morning, so leaves dry quickly and less is lost to evaporation. Mulch slows evaporation from the soil. Newly transplanted seedlings with few roots should be shaded and protected from wind for a few days so they do not transpire faster than

they can drink. As the psalm says, a tree planted by the rivers of water does not wither; a gardener's task is to keep the roots supplied.

PICTURE STUDY



Measuring Growth, Plate from Vegetable Staticks, Stephen Hales, 1727 · Engraving · Vegetable Staticks, London

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

Stephen Hales was an English country minister and one of the first scientists to measure what happens inside plants. He weighed potted sunflowers morning and evening to measure the water they lost, and, as this plate shows, he marked young leaves and shoots with evenly spaced dots to see which parts grew. Careful measurement was his great gift.

Look closely

- Find the leaf marked with numbered dots. What would happen to the spacing of the dots as the leaf grew?
- Find the shoots marked with letters. Which parts do you think stretched most?
- Find the tool covered with points. How did Hales use it?
- Look for any scale or measuring marks in the plate.

Talk about it

1. Why would marking a leaf with evenly spaced dots tell Hales where it grew?
2. Why would weighing a potted plant morning and evening tell him how much water it lost?

3. How is your transpiration-bag experiment like Hales's careful measuring?

Transpiration Investigations

You will run three short investigations: watch water travel up a stem, measure how much water leaves transpire, and find where the stomata are.

You will need

- Celery stalks with leaves or white carnations
- Food coloring (blue or red) and clear glasses
- Clear plastic bags and twist ties
- A potted plant or a leafy tree or shrub branch outdoors
- Petroleum jelly
- A kitchen scale and measuring cup
- Clear nail polish and clear tape (for stomata peels); a microscope or strong hand lens if available

Steps

1. Dye test: put a freshly cut celery stalk or carnation in water with 15 drops of food coloring. After 2, 6 and 24 hours, cut a thin slice across the stalk and draw the colored dots (the xylem bundles). Note any color in the leaves or petals.
2. Bag test: slip clear plastic bags over three leafy shoots of a plant (one in sun, one in shade, one in sun with the leaves removed) and seal them with twist ties. After 24 hours, pour any collected water into a measuring cup and record the volume.
3. Leaf surface test: on four similar leaves of a potted plant, coat (a) the top surface, (b) the bottom surface, (c) both surfaces with petroleum jelly, and leave (d) uncoated. After 3–4 days, compare which leaves wilted or yellowed.
4. Stomata peel: paint a small patch of clear nail polish on the underside of a leaf and the top of another. When dry, press clear tape on it, peel it off and stick it to a slide or dark paper. Look with a microscope or hand lens and count stomata in one field of view on each side.
5. Record all results in tables with dates and weather.

6. Write a conclusion explaining where water leaves the plant and what conditions speed transpiration.

Tips

- Use a sunny, warm day for the bag test; results are small on cloudy, humid days.
- Bean, spinach, lettuce and geranium leaves give good stomata peels.

Check your work

- ☐ I traced the path of dye through the xylem.
- ☐ I measured transpired water and compared sun and shade.
- ☐ I found which leaf surface has more stomata.
- ☐ I can explain cohesion and transpiration pull.

NATURE JOURNAL

1. Draw a cross-section of a celery stalk after the dye test, showing the colored xylem bundles.
2. Draw a diagram of water moving from soil to air through root hair, root, stem, leaf and stoma, with arrows.
3. Draw what you saw in your stomata peel, labeling guard cells and pores.

From history. Stephen Hales, a minister in the village of Teddington near London, published *Vegetable Staticks* in 1727. By carefully weighing plants and measuring sap, he showed that leaves give off large amounts of water and that sap rises with real force. He did all this in his spare time while caring for his parish.

COMMON MISTAKES

- Watering a little every day, which keeps roots shallow.
- Watering a plant that is wilting at 3 p.m. on a hot day when the soil is still moist; check the soil first.
- Thinking plants drink through their leaves. Almost all water enters through the roots.
- Forgetting that wind dries plants as much as heat does.

Make it a game • Water Path Chain. Trace the path of water from soil to air by passing a damp cotton ball, or a bean standing for a water drop, along stations: root, xylem, leaf, stomata. Narrate transpiration, cohesion and adhesion. Parent calls 'guard cells close' and you tell what happens. Do it again faster. Beat your time without a mistake.

Scripture. “And he shall be like a tree planted by the rivers of water, that bringeth forth his fruit in his season; his leaf also shall not wither; and whatsoever he doeth shall prosper.” (Psalm 1:3, KJV)

A tree by water never wilts because its roots are always supplied. The psalmist uses that picture for a person whose life is rooted in God’s word.

5.2 MINERAL NUTRITION AND DEFICIENCIES

OBJECTIVES

- Name the essential macronutrients and several micronutrients and what each does.
- Use the difference between mobile and immobile nutrients to diagnose deficiency symptoms on old or new leaves.
- Read a fertilizer label, calculate the nutrients in a bag and explain why soil pH affects nutrient availability.

Warm-up. Look at a houseplant or garden plant and find its oldest leaves (at the bottom) and newest leaves (at the tip). Compare their color, size and shape, and write down any differences.

WATCH

Nutrient Deficiencies In Plants - What You Need To Know

Geeky Greenhouse • 7:12

<https://www.youtube.com/watch?v=pgF7dVmqVL4>

WHEN TO WATCH

After the core ideas. Make a table: nutrient, old or new leaves, symptom.

KEY TERMS

macronutrient

An element plants need in large amounts: nitrogen, phosphorus and potassium (primary), plus calcium, magnesium and sulfur (secondary).

chlorosis

Yellowing of leaf tissue because chlorophyll is not being made, often a sign of nutrient deficiency.

micronutrient

An element plants need in tiny amounts, such as iron, manganese, zinc, copper, boron, molybdenum and chlorine.

interveinal chlorosis

Yellowing between the veins while the veins stay green; typical of magnesium deficiency on old leaves and iron deficiency on new ones.

mobile nutrient

A nutrient the plant can move from old leaves to new growth when short of it, so symptoms appear first on older leaves (N, P, K, Mg).

fertilizer analysis

The three numbers on a fertilizer bag giving the percentage by weight of nitrogen, phosphate and potash, such as 10-10-10.

CORE IDEAS

Plants need seventeen essential elements. Carbon, hydrogen and oxygen come from air and water. The rest come from the soil, dissolved in water. **Nitrogen** (N) builds proteins and chlorophyll and drives leafy growth. **Phosphorus** (P) is part of DNA and the molecules that carry energy in cells; it is vital for roots, flowers and seeds. **Potassium** (K) controls the opening of stomata and the movement of water and sugar, and strengthens plants against disease and drought. Calcium builds cell walls, magnesium sits at the center of every chlorophyll molecule, and sulfur is part of some proteins. Micronutrients such as iron, zinc and boron are needed in tiny amounts, but a plant cannot grow well without any one of them.

A plant short of a nutrient shows a pattern of symptoms, and the first clue is *where*. **Mobile nutrients** (nitrogen, phosphorus, potassium, magnesium) can be moved from old leaves to new growth, so deficiency shows first on older, lower leaves. Nitrogen shortage turns whole lower leaves pale yellow; phosphorus shortage makes plants stunted and dark, often with purplish leaves; potassium shortage scorches the edges of older leaves yellow and brown; magnesium shortage yellows the tissue between green veins on older leaves. Immobile nutrients (calcium, iron, sulfur, boron and others) stay where they were first used, so symptoms appear on new growth: iron shortage yellows young leaves between green veins, and calcium shortage causes blossom-end rot in tomatoes and tip-burn in lettuce.

Often the nutrient is in the soil but the plant cannot get it. Soil **pH** controls availability: most nutrients are easiest for plants to take up between pH 6.0 and 7.0. In alkaline soils iron and manganese become locked up, so blueberries and azaleas turn yellow; in very acid soils phosphorus, calcium and magnesium are scarce. Cold, waterlogged or compacted soil, and uneven watering (the usual cause of blossom-end rot), also block uptake. That is why a soil test comes before fertilizer, and why many “deficiencies” are fixed by correcting pH, drainage or watering.

A fertilizer label lists N-P-K as percentages by weight. A 50-pound bag of 10-10-10 contains 5 pounds each of nitrogen, phosphate and potash; the rest is other material that carries them. Compost and manures feed plants slowly and build soil; synthetic fertilizers act fast. More is not better: too much nitrogen gives lush, soft growth that attracts aphids and delays fruit, too much fertilizer of any kind can burn roots with salts, and excess washes into streams and lakes. The nineteenth-century chemist Justus von Liebig taught that growth is limited by whichever essential nutrient is scarcest, like a barrel that can only hold water up to its shortest stave.

PICTURE STUDY



The Large Piece of Turf, Albrecht Dürer, 1503 · Watercolor and gouache on paper · Albertina, Vienna

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

Dürer painted this ordinary clump of weeds and grasses with the same care others gave to kings. Five hundred years later, botanists can still name nearly every plant in it. Look at the leaves as a plant doctor would.

Look closely

- Find the oldest and newest leaves on the dandelion or plantain. Are they the same color?
- Look for any yellowing, browning or spots on the leaves. Where are they?
- Look at the soil at the bottom. Is it wet or dry? Dark or pale?
- Count how many different kinds of plants you can find.

Talk about it

1. If one of these plants had yellow lower leaves, what nutrient might it need?
2. Why can so many different plants grow together in one small patch of soil?
3. What can we learn about a plant's health just by looking closely, as Dürer did?

Safety first. Wear gloves when handling fertilizer, read the label with an adult, and store it out of reach of children and pets. Never taste or inhale fertilizer dust, and wash your hands afterward.

HANDS-ON PROJECT

The Nutrient Experiment

You will grow seedlings with and without nutrients in a soilless medium, so you can watch deficiency develop, and practice fertilizer math.

You will need

- Nine small pots or cups with drainage holes
- Clean sand, perlite or vermiculite (no compost or potting mix with fertilizer)
- Bean, pea, radish or sunflower seeds
- A balanced water-soluble fertilizer (such as 20-20-20) and a measuring spoon
- Labels, a ruler and a watering container

Steps

1. Fill nine pots with clean sand or perlite and plant two seeds in each. Label three “water only,” three “half strength” and three “full strength.”
2. Water all pots with plain water until the seedlings have their first true leaves.
3. Then, twice a week, water each group with its own solution: plain water, fertilizer mixed at half the label rate, or at the full label rate. Use the same volume for every pot.
4. Each week for four weeks, measure plant height, count leaves and describe leaf color, noting whether any yellowing begins on old or new leaves.
5. At the end, compare the groups in a table and bar graph. Photograph or draw one plant from each group.
6. Fertilizer math: from the label, calculate how many grams of nitrogen are in one tablespoon of your fertilizer, and how many pounds of N, P and K are in a 50-pound bag of 10-10-10 and of 5-10-5.
7. Write a conclusion naming the deficiency symptoms you saw and which nutrient likely caused them.

Tips

- Keep every condition the same except the nutrient solution: same light, same pot, same water volume.
- Beans store food in their seed leaves, so deficiency may take two or three weeks to show.
- Write up the experiment the way a 4-H or Junior Master Gardener record book would: dates, what you did, costs of fertilizer and seed, measurements and what you learned.

Check your work

- ☐ I ran a controlled experiment with three groups and repeated pots.
- ☐ I recorded height, leaf count and color weekly.
- ☐ I can tell mobile from immobile nutrient symptoms.
- ☐ I calculated nutrients from a fertilizer label correctly.

NATURE JOURNAL

1. Draw a plant outline and mark where symptoms of N, P, K, Mg, Fe and Ca deficiency appear, with a color key.
2. Draw Liebig's barrel with staves labeled with nutrients, water and light.
3. Record your weekly seedling measurements in a table.

From history. In 1843 John Bennet Lawes and Joseph Henry Gilbert began field experiments on wheat at Rothamsted, a farm in England, comparing plots given different fertilizers and manure. Some of those same plots are still being studied today, making them among the longest-running scientific experiments in the world.

COMMON MISTAKES

- Adding more fertilizer to a yellow plant without checking pH, watering or drainage.
- Confusing nitrogen deficiency (whole lower leaves yellow) with iron deficiency (new leaves yellow between green veins).
- Over-fertilizing with nitrogen, which gives big leaves but few fruits.
- Treating blossom-end rot with calcium when the real problem is uneven watering.

Make it a game • Old Leaf or New Leaf?. Draw a plant with old leaves at the bottom and new leaves at the top. Parent names a deficiency, such as nitrogen, iron or magnesium. You point to where symptoms show and explain mobile versus immobile nutrients. Add interveinal chlorosis in your drawing. Then read a fertilizer analysis like 10-10-10 aloud. Ten correct diagnoses wins.

5.3 PHOTOPERIOD: SHORT-DAY AND LONG-DAY PLANTS

OBJECTIVES

- Explain how plants measure night length and what short-day, long-day and day-neutral plants are.
- Give examples of how photoperiod affects flowering, bolting, bulbing and variety choice.
- Set up a photoperiod experiment with a short-day plant.

Warm-up. Look up today's sunrise and sunset times and calculate the length of the day. Compare it with the longest day of the year (about June 21) and the shortest (about December 21) where you live. How much does day length change?

WATCH

How plants tell time - Dasha Savage

TED-Ed · 4:19

<https://www.youtube.com/watch?v=3jIW5wW2WC0>

WHEN TO WATCH

After the first core idea. Pause when the night-break experiment is shown and predict the result.

KEY TERMS

photoperiod

The length of daylight and darkness in a 24-hour day, which many plants use to sense the season.

long-day plant

A plant that flowers when nights are shorter than a critical length, in late spring and summer: spinach, lettuce, radish, wheat, oats.

short-day plant

A plant that flowers when nights are longer than a critical length, in late summer, fall or winter: chrysanthemum, poinsettia, Christmas cactus, kalanchoe, soybean.

day-neutral plant

A plant whose flowering does not depend on day length, such as tomatoes, cucumbers, peppers and day-neutral strawberries.

phytochrome

A light-sensitive pigment in leaves that changes form in red and far-red light and lets the plant measure the length of the night.

bolting

When a leafy crop such as lettuce or spinach suddenly sends up a flower stalk, turning bitter.

CORE IDEAS

Temperature varies from year to year, but day length on any calendar date is always the same at a given place. Many plants use it as a reliable calendar. Leaves contain **phytochrome**, a pigment that switches between two forms in red and far-red light and slowly changes back in darkness. In effect the plant measures how long the night is. Scientists proved it is the dark period that matters: interrupting a long night with just a few minutes of light keeps a short-day plant from flowering, while interrupting a long day with darkness has no such effect.

Short-day plants (really long-night plants) flower when nights grow longer than a critical length. Chrysanthemums, asters, poinsettias, Christmas cactus, kalanchoe and soybeans flower in late summer, fall or winter. **Long-day plants** flower when nights are short, in late spring and summer: spinach, lettuce, radishes, beets, wheat, oats and many clovers. **Day-neutral plants** such as tomatoes, peppers, cucumbers and day-neutral strawberries flower once they are big enough, whatever the day length.

Photoperiod explains many garden puzzles. Spinach and lettuce sown in spring often **bolt** as June days lengthen, which is why they are best grown in spring and fall. Onions form bulbs in response to day length: “long-day” onion varieties need 14–16 hours of light and are grown in the North, while “short-day” varieties bulb with 10–12 hours and are grown in the South; plant the wrong kind and you get green tops but no bulbs. Soybean farmers choose varieties suited to their latitude so the crop flowers at the right time.

Growers also control photoperiod on purpose. To make poinsettias color up for Christmas, greenhouses give them about 14 hours of total darkness every night from early October for eight to ten weeks; even a streetlight or a lamp switched on at night can stop them. Chrysanthemum growers pull black cloth over the benches to make mums bloom in any season, and they use night lighting to delay flowering. God set

the sun “to rule the day” and gave plants a way to read its rhythm, so that each one flowers “in his season.”

PICTURE STUDY



Chrysanthemums and Bee, Katsushika Hokusai, about 1833–1834 · Color woodblock print · From the series *Large Flowers*

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

Hokusai, the great Japanese printmaker, made a series of large flower prints. In Japan the chrysanthemum is the flower of autumn, celebrated each fall when it blooms. Look at it as a plant physiologist would: this flower is responding to the lengthening nights.

Look closely

- Find the open flowers and the buds. Are all the flowers at the same stage?
- Find the bee. Why would a bee still be visiting flowers this late in the year?
- Look at the leaves. Are they fresh and green or starting to age?
- Count the different flower colors.

Talk about it

1. Why do chrysanthemums bloom in fall rather than spring?
2. What would happen if these plants were lit by a bright lamp for a few minutes every night in September?
3. How do flower growers sell blooming mums in May?

The Long-Night Experiment

You will give one group of short-day plants long nights and another group short nights, and record whether and when they form flower buds.

You will need

- Two to four small kalanchoe, Christmas cactus or poinsettia plants (kalanchoe is cheapest), or soybean seedlings
- A dark closet or a large cardboard box that blocks all light
- A lamp on a timer (optional)
- Labels and your nature journal

Steps

1. Label half the plants “long night” and half “short night.” Write down how many flower buds each has at the start (ideally none).
2. Long-night group: every evening at 5 p.m., put the plants in total darkness (closet or box) and take them out at 7 a.m., giving 14 hours of darkness. Keep them in a bright window during the day.
3. Short-night group: keep these plants in a room where lights stay on until bedtime, or give them an hour of lamp light in the middle of the night.
4. Water both groups the same way, and keep them at the same temperature.
5. Every three or four days for six to eight weeks, count flower buds and record any color change.
6. Graph buds over time for each group.
7. Write a conclusion explaining the results using the words photoperiod, short-day plant and phytochrome.

Tips

- Even a crack of light under a closet door can spoil the long-night treatment. Use a box or cover the gap.
- Start in late fall or winter so natural day length does not confuse your results.

Check your work

- ☐ I gave the long-night group 14 hours of total darkness consistently.
- ☐ I counted buds on a regular schedule and graphed them.
- ☐ I can name two short-day, two long-day and two day-neutral plants.
- ☐ I can explain why onion varieties are chosen by latitude.

NATURE JOURNAL

1. Make a graph of day length at your location for the 1st of each month (from an almanac or weather website).
2. Draw a kalanchoe or chrysanthemum shoot with flower buds, enlarged.
3. Draw a 24-hour clock diagram showing light and dark for your two experiment groups.

From history. In 1920 two U.S. Department of Agriculture scientists, Wightman Garner and Harry Allard, puzzled over a giant tobacco plant called Maryland Mammoth that would not flower in summer but bloomed in a winter greenhouse. By moving plants in and out of a dark shed, they discovered that day length controls flowering, and they named the effect photoperiodism.

COMMON MISTAKES

- Thinking short-day plants need short days. They actually need long, unbroken nights.
- Leaving a lamp or nightlight on near a poinsettia in the fall.
- Planting spinach in late spring and wondering why it bolts.
- Buying onion sets suited to the wrong latitude.

Make it a game • Night Length Verdict. Be the judge in a plant courtroom. Parent presents a plant and a claim: 'it flowers when nights are short.' You rule short-day, long-day or day-neutral and explain phytochrome. Add examples about bolting lettuce and bulbing onions. Choose variety advice for the growing season. Five correct verdicts earns the gavel. Swap roles.

Scripture. “To every thing there is a season, and a time to every purpose under the heaven: A time to be born, and a time to die; a time to plant, and a time to pluck up that which is planted;” (Ecclesiastes 3:1-2, KJV)

Photoperiod is one of the ways God built the seasons into plants themselves. Wise gardeners learn the time for each crop.

5.4 PLANT HORMONES: AUXIN, CUTTINGS AND ETHYLENE

OBJECTIVES

- Describe the main plant hormones and their effects: auxin, gibberellin, cytokinin, abscisic acid and ethylene.
- Explain phototropism, apical dominance and rooting of cuttings in terms of auxin.
- Explain ripening by ethylene, the difference between fruits that do and do not ripen after picking, and how growers use this.

Warm-up. Look at a houseplant on a windowsill, or a bean seedling. Which way are the stems leaning? Turn the pot halfway around and predict what the plant will look like in three days. Check your prediction later this week.

WATCH

How Supermarkets get Fruit to Ripen Faster | Earth Science

[BBC Earth Science](#) · 3:54

<https://www.youtube.com/watch?v=jzjBAAv9nxc>

WHEN TO WATCH

With the ethylene core idea. Note how ethylene gas, and ripe apples, are used to ripen green bananas in a closed drum.

KEY TERMS

hormone

A chemical messenger made in one part of a living thing that causes a response in another part, often in tiny amounts.

phototropism

Growth of a plant toward or away from light.

auxin

A plant hormone made in shoot tips that makes cells stretch, causes bending toward light, keeps side buds dormant and starts roots on cuttings.

apical dominance

The way the main shoot tip, through auxin, holds back the growth of side buds below it.

ethylene

A gaseous plant hormone that triggers fruit ripening, leaf drop and aging.

climacteric fruit

A fruit that keeps ripening after it is picked, with a burst of ethylene and respiration, such as bananas, tomatoes, apples, pears and avocados.

CORE IDEAS

Plants have no nervous system, but they coordinate their growth with **hormones**, chemical messengers active in tiny amounts. **Auxin** is made in shoot tips and young leaves and travels downward. It loosens cell walls so cells stretch. When light comes from one side, auxin collects on the shaded side of the stem, those cells stretch more, and the stem bends toward the light. This is **phototropism**, and it is why windowsill plants lean toward the glass.

Auxin flowing down from the main tip also holds back the side buds below it; this is **apical dominance**. When you pinch off the tip of a basil, coleus or tomato sucker, the auxin supply stops, side buds grow, and the plant becomes bushier. Gardeners prune fruit trees with this in mind. Auxin also starts roots: a stem cutting forms new roots at its base where auxin collects, and commercial rooting powders contain synthetic auxins such as IBA that make rooting faster and more even.

Other hormones work alongside auxin. **Gibberellins** make stems lengthen and help seeds break dormancy. **Cytokinins** promote cell division and keep leaves green longer. **Absciscic acid** closes stomata during drought and keeps seeds dormant until conditions are right. The balance among hormones, not any one alone, decides how a plant grows.

Ethylene is a gas, so it spreads through the air from one fruit to another. In **climacteric fruits** such as bananas, tomatoes, apples, pears, peaches and avocados, a burst of ethylene sets off ripening: starch turns to sugar, flesh softens, green chlorophyll breaks down and aromas develop. These fruits can be picked mature but unripe and ripened later, which is how bananas cross oceans green and are ripened in ethylene rooms near the store. Non-climacteric fruits such as strawberries, grapes, cherries, citrus and watermelon do not ripen further after picking, so they must be picked ripe. Ethylene from ripe fruit also makes carrots bitter, lettuce spotted and flowers wilt, so store apples away from vegetables. One bad apple really can spoil the bunch.

PICTURE STUDY



The Basket of Apples, Paul Cézanne, about 1893 · Oil on canvas · Art Institute of Chicago

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

Cézanne painted apples again and again, studying their round forms and changing colors. Fruit sat in his studio for weeks while he painted, slowly ripening, softening and changing color. Look at these apples as a plant scientist would.

Look closely

- Find apples of different colors. Which look ripest, and which least ripe?
- Look at the apples touching each other in the basket. What gas might be passing between them?
- Find the stems. Can you tell which apples were picked recently?
- Look for any apple that looks softer or older than the rest.

Talk about it

1. If Cézanne left a green banana in this basket, what would happen to it, and why?
2. Why should apples be stored apart from carrots and lettuce?
3. What problems would an artist have painting fruit that keeps ripening?

Safety first. Use rooting powder with gloves, pour a little into a separate dish rather than dipping into the jar, and do not breathe the dust. Let an adult help with sharp knives or pruners.

HANDS-ON PROJECT

Rooting and Ripening Experiments

You will test whether rooting hormone speeds root growth on cuttings, and whether ethylene from a ripe apple speeds the ripening of green fruit.

You will need

- A coleus, basil, mint, pothos or tomato plant for cuttings
- Rooting hormone powder (optional) and clean pruners
- Small pots with damp perlite or potting mix, or glasses of water
- Clear plastic bags or a clear tote for humidity
- Three green bananas or green tomatoes, or six hard avocados or pears
- Three paper bags and one ripe apple

Steps

1. Cuttings: take eight cuttings about 4 inches long, cutting just below a leaf node, and remove the lower leaves.
2. Dip four cuttings in rooting hormone (tap off extra) and leave four untreated. Plant all in the same medium, label them and cover with a clear bag.
3. After 7, 10 and 14 days, gently lift each cutting and count the roots and measure the longest one. Replant carefully.
4. Ripening: put one green fruit in a closed paper bag with a ripe apple, one in a closed paper bag alone, and one on the open counter.
5. Each day for a week, rate each fruit's color and softness from 1 (unripe) to 5 (fully ripe), and photograph them.
6. Make tables and graphs for both experiments.
7. Write a conclusion for each: what did auxin and ethylene do, and how could a grower or cook use this?

Tips

- Willow twigs soaked in water make a natural rooting solution you can test as a third group.
- Keep all bags at the same room temperature, out of direct sun.

Check your work

- ☐ I set up both experiments with controls.
- ☐ I recorded root counts and ripeness ratings over time.
- ☐ I can explain phototropism and apical dominance using auxin.
- ☐ I can name three fruits that ripen after picking and three that do not.

NATURE JOURNAL

1. Draw a seedling bending toward light, showing auxin collecting on the shaded side and the longer cells there.
2. Draw a basil plant before and after pinching, with arrows to the side buds that grow.
3. Draw your best-rooted cutting actual size.

From history. In 1926 a young Dutch scientist, Frits Went, cut the tips off oat seedlings, set them on tiny blocks of gelatin-like agar, and then placed the blocks on the cut stems. The stems bent and grew as if they still had their tips, proving that a chemical messenger flowed down from the tip. That substance was later named auxin.

COMMON MISTAKES

- Storing apples in the crisper drawer with carrots and lettuce.
- Picking strawberries or watermelon early and expecting them to ripen on the counter.
- Taking cuttings from flowering stems, which root more slowly than leafy ones.
- Never turning windowsill plants, so they grow lopsided.

Make it a game • Hormone Role Call. Make cards for auxin, gibberellin, cytokinin, abscisic acid and ethylene. Parent describes an effect, like a stem bending toward light, a banana ripening in a bag, or buds sprouting after pruning, and you slap the right hormone. Then explain apical dominance and how rooting powder uses auxin. Reach eight in a row.

UNIT 5

PLANT PHYSIOLOGY

Physiology is the study of how living things work. In this unit you will look inside the plant to see how it lifts water higher than any pump without moving a muscle, how it gathers seventeen essential elements from soil and air, how it knows the season by measuring the length of the night, and how it uses chemical messengers called hormones to bend toward light, grow roots and ripen fruit.

This is the science behind everyday gardening decisions: when to water, how to read a yellow leaf, why spinach bolts in June and poinsettias bloom at Christmas, how to root a cutting and why one ripe apple can ripen a whole bag of green bananas. It is late winter, the perfect time for indoor experiments. As you watch these hidden processes, remember that every plant is “fearfully and wonderfully made” by the same Designer who made you.

PREREQUISITES

- Knows the parts of a plant and their basic jobs
- Knows that plants make sugar by photosynthesis using light, water and carbon dioxide
- Knows what N, P and K stand for on a fertilizer label
- Can measure in millimeters and milliliters and keep an experiment log

MASTERY CHECKLIST

- ☐ I can trace the path of water from soil to air through a plant and explain transpiration pull.
- ☐ I can name the macronutrients and several micronutrients and diagnose common deficiency symptoms.
- ☐ I can explain the difference between mobile and immobile nutrients and why it matters for diagnosis.
- ☐ I can explain short-day, long-day and day-neutral plants and how growers use photoperiod.
- ☐ I can describe what auxin and ethylene do and use them in rooting and ripening experiments.

LESSONS IN THIS UNIT

5.1 Water Movement and Transpiration

2 sessions of 50–60 minutes

5.2 Mineral Nutrition and Deficiencies

2 sessions of 50–60 minutes

5.3 Photoperiod: Short-Day and Long-Day Plants

2 sessions of 50–60 minutes

5.4 Plant Hormones: Auxin, Cuttings and Ethylene

2 sessions of 50–60 minutes

UNIT 5 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **8 pts**

Trace the path of water from the soil to the air through a plant.

2. **8 pts**

How does water rise to the top of a tall tree without a pump?

3. **6 pts**

Why do stomata close during drought, and what is the cost to the plant?

4. **8 pts**

Name the three primary macronutrients and one job of each.

5. **8 pts**

A plant's older leaves are turning yellow all over while the new leaves are green. Which nutrient is most likely short, and why do the old leaves show it first?

6. **6 pts**

Why can a blueberry plant be yellow even when there is iron in the soil?

7. **6 pts**

How many pounds of nitrogen are in a 40-pound bag of 10-5-5 fertilizer?

8. **8 pts**

What do short-day plants actually measure, and how did scientists show it?

9. **6 pts**

Why does spinach often bolt in early summer?

10. **6 pts**

Why does pinching the tip of a basil plant make it bushier?

11. **15 pts**

Written answer: Explain how a grocery chain can sell ripe bananas grown thousands of miles away, using the words climacteric and ethylene.

12. **15 pts**

Written answer: A tomato plant has yellow, scorched edges on its lower leaves, and several fruits have dark, sunken spots on their bottoms. Explain what may be wrong and what the gardener should do first.

ANSWER KEY

1. Soil water enters root hairs, crosses the root into the xylem, rises through the stem into leaf veins, evaporates from cells inside the leaf and leaves through the stomata as vapor.
2. Transpiration from leaves pulls on a continuous column of water in the xylem; cohesion holds the water molecules together and adhesion holds them to the xylem walls (cohesion-tension). The sun's energy drives the evaporation.
3. Closing saves water, but it also stops carbon dioxide from entering, so photosynthesis and growth slow.
4. Nitrogen: proteins and chlorophyll, leafy growth. Phosphorus: DNA and energy molecules, roots, flowers and seeds. Potassium: controls stomata and water and sugar movement, disease and drought resistance.
5. Nitrogen. It is mobile, so the plant moves it from old leaves to new growth, leaving the old leaves yellow.
6. The soil pH is too high (alkaline), which locks up iron so the plant cannot take it up.
7. 4 pounds (10% of 40).
8. The length of the uninterrupted night. A brief flash of light in the middle of a long night prevents flowering, while darkness in the middle of the day does not.
9. Spinach is a long-day plant; the short nights of late spring and summer trigger flowering.
10. It removes the source of auxin that held back the side buds (apical dominance), so the side buds grow into new shoots.
11. Bananas are climacteric fruit, which keep ripening after picking. They are harvested mature but green, shipped cool so ripening is slowed, then placed in sealed ripening rooms where ethylene gas is added at controlled temperature; the ethylene triggers starch-to-sugar conversion, softening and yellowing, so they arrive in stores at the right ripeness.
12. Scorched lower-leaf edges suggest potassium deficiency (a mobile nutrient). Blossom-end rot is calcium not reaching the fruit, usually because of uneven watering. First test the soil (nutrients and pH) and check watering; water deeply and evenly and mulch; add potassium or adjust pH only if the test shows a need.

PORTFOLIO PIECE: A PLANT PHYSIOLOGY LAB NOTEBOOK

Assemble your four investigations (transpiration, nutrients, photoperiod and hormones) into a lab notebook. For each, include the question, a hypothesis, materials, procedure, data table, graph and a conclusion that uses the unit's vocabulary. End with one page explaining how these four processes work together in a single tomato plant through the summer.

LOOK FOR	WHAT IT MEANS
Experimental design	Each investigation has a clear question, a control and only one variable changed.
Data	Measurements are complete, dated and presented in clear tables and graphs.
Explanation	Conclusions explain results correctly using transpiration, nutrients, photoperiod and hormones.
Synthesis	The final page connects all four processes in one plant accurately.

FARM ANIMALS AND BEES

Early spring is the busiest season on a farm: eggs go into incubators, feeder pigs arrive, horses shed their winter coats and honeybee colonies grow from a few thousand bees to tens of thousands. In this unit you will study four animals that people have kept for thousands of years, looking closely at how each is made and what good husbandry requires.

You will learn the anatomy of an egg and how a chick develops in 21 days, how pigs are raised for pork and why they need shade and mud, how to be safe and useful around horses, and how beekeepers manage colonies, prevent swarms and harvest honey. Because many students your age join 4-H or FFA, you will also learn how young people show poultry and pigs, keep a project record book with expenses and income, judge a class and give oral reasons, and prepare a jar of honey for the county fair. “Be thou diligent to know the state of thy flocks” (Proverbs 27:23).

PREREQUISITES

- Knows the basic needs of farm animals: feed, water, shelter, space and care
- Knows that farm animals are raised for eggs, milk, wool, work and meat
- Knows the three castes of honeybees: queen, workers and drones
- Knows the rules for washing hands after handling animals and never standing behind a horse

MASTERY CHECKLIST

- ☐ I can label the parts of an egg, candle eggs and explain the main conditions for incubation.
- ☐ I can handle and show a chicken calmly and correctly.
- ☐ I can explain how pigs differ from ruminants, how they are housed and fed, and keep a project budget with expenses and income.
- ☐ I can name the main points of a horse and follow the safety rules for handling, grooming and riding.
- ☐ I can explain colony management, swarming and how honey is harvested, and prepare a fair honey exhibit.
- ☐ I can place a class of four and give oral reasons.

LESSONS IN THIS UNIT

6.1 Poultry Science: The Egg, Incubation and Showmanship

2 sessions of 50–60 minutes

6.2 Swine

2 sessions of 50–60 minutes

6.3 Horses: Anatomy, Care and Riding Safety

2 sessions of 50–60 minutes

6.4 Beekeeping: Colony Management, Swarms and the Honey Harvest

2 sessions of 50–60 minutes

UNIT 6 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **8 pts**

Name four parts of an egg and the job of each.

2. **8 pts**

Give the incubation conditions for chicken eggs, and the number of days to hatch.

3. **6 pts**

What do you see when you candle a developing egg at day 7, and what does a clear egg mean?

4. **6 pts**

In poultry showmanship, what is being judged?

5. **8 pts**

Why do pigs need mud, shade or misters in hot weather?

6. **8 pts**

A feeder pig gains 220 pounds with a feed conversion of 3 to 1. How many pounds of feed does it eat, and how many 50-pound bags?

7. **6 pts**

Name four points of the horse.

8. **8 pts**

Give four safety rules for working around horses.

9. **8 pts**

Why do honeybee colonies swarm, and name two ways beekeepers prevent it.

10. **4 pts**

Why must honey be capped before it is harvested?

11. **15 pts**

Written answer: You placed a class of four jars of honey 3-1-4-2. Write the oral reasons you would give for your top and bottom pairs, using real judging terms.

12. **15 pts**

Written answer: Explain how a market-pig project teaches responsibility and farm economics, and what records a good record book contains.

ANSWER KEY

1. Any four: shell (protects, lets air through pores), membranes (protect against bacteria), air cell (air supply at large end), albumen (water and protein, cushions yolk), chalazae (hold yolk centered), yolk (food), germinal disc (where a chick forms in a fertile egg).
2. About 99.5 °F in a forced-air incubator, 40–50% humidity, turned three or more times a day until day 18; then stop turning and raise humidity to about 65–70%. Hatch is about day 21.
3. A dark spot with a web of fine veins. A clear egg was not fertile.
4. The exhibitor: how calmly and correctly the bird is handled and presented, and the exhibitor's knowledge of its breed, care and health.
5. Pigs have very few working sweat glands and cannot cool themselves well; mud, shade and water cool them and prevent heat stress and sunburn.
6. 660 pounds of feed; 13.2, so 14 bags.
7. Any four, e.g., poll, withers, croup, fetlock, pastern, hock, cannon, coronet, frog, flank.
8. Any four: approach from the shoulder at an angle and speak; never stand directly behind; keep a hand on the horse when moving around it; lead from the left, never wrap the rope around your hand; tie with a quick-release knot; wear boots; wear a certified helmet when riding; work with an experienced adult.
9. Swarming is how colonies reproduce, usually when crowded in spring. Prevent by adding boxes or supers before crowding, making splits, or managing queen cells.
10. Capping shows the bees have dried it to about 17–18% water; uncapped honey has too much water and can ferment.
11. A good answer uses comparative language: e.g., "I placed 3 over 1 because 3 is clearer, free of wax specks and foam, and filled exactly to the shoulder, while 1 shows fine bubbles at the top. I placed 2 last because it shows crystallization and lint, has an uneven fill line and a sticky lid; I grant that 2 has a pleasing light color." Reasons should compare pairs, name specific faults and merits, and be clear and confident.
12. Daily feeding, watering, cleaning, health checks and walking build faithful habits. Economics: tracking expenses (pig, feed, bedding, vet, equipment, fees) against income from sale shows profit or loss and break-even price. Records

include dates, weights and gains, feed used, all costs and income, health notes, show results and a summary of what was learned.

PORTFOLIO PIECE: A 4-H STYLE PROJECT RECORD

Choose one animal from this unit (poultry, a pig, a horse or a bee colony) and make a complete project record as a 4-H or FFA member would: a care calendar, an expense and income table, a record of observations (egg grades, weights, inspections or care visits), your judging card and written reasons, and a page on what you learned. If you can, add a photo or drawing of you handling or caring for the animal.

LOOK FOR	WHAT IT MEANS
Care plan	Daily, seasonal and yearly care are complete, accurate and humane.
Records and budget	Observations are dated and measured; the expense and income table is complete and correct.
Judging	Placing card and reasons compare pairs using specific, accurate terms.
Reflection	The “what I learned” page is honest and specific about skills, mistakes and next steps.

6.1 POULTRY SCIENCE: THE EGG, INCUBATION AND SHOWMANSHIP

OBJECTIVES

- Label the parts of an egg and explain the job of each.
- Explain how eggs are incubated and candled, and what is seen on candling days 7, 14 and 18.
- Handle and present a chicken in the 4-H showmanship style, and judge a class of four laying hens by past-production signs with oral reasons.

Warm-up. Crack a raw egg onto a white plate. Without touching it, find and sketch as many parts as you can: shell, membranes, white, yolk, the white twisted cords and the small pale spot on the yolk. Label what you can before the lesson.

WATCH

Candling Chick Eggs at Day 7

Lancaster County 4-H (Nebraska) • 3:42

https://www.youtube.com/watch?v=Uyr_jliSkJ0

WHEN TO WATCH

After the incubation core idea. Note how a developing egg looks different from a clear one.

KEY TERMS

air cell

The pocket of air between the shell membranes at the large end of an egg. It grows as the egg ages or as a chick develops.

germinal disc

The small pale spot on the yolk where, in a fertile egg, the chick begins to form.

chalazae

Twisted, rope-like strands of white that hold the yolk in the center of the egg.

incubation

Keeping fertile eggs at the right temperature and humidity, and turning them, until they hatch; 21 days for chickens.

candling

Shining a bright light through an egg in a dark room to see the air cell, yolk and any developing chick.

showmanship

A contest in which young exhibitors are judged on how well they handle, present and know their animal, not on the animal itself.

CORE IDEAS

An egg is a complete life-support system. The **shell** is mostly calcium carbonate and has thousands of tiny pores that let oxygen in and carbon dioxide and moisture out. A thin outer coating called the bloom or cuticle seals the pores against bacteria, which is why farm-fresh eggs are often left unwashed until used. Inside are two shell membranes; at the large end they separate to form the **air cell**. The white, or albumen, is mostly water and protein and cushions the yolk. The **chalazae** hold the yolk centered, and the yolk is food: fat, protein, vitamins and minerals for a growing chick. On the yolk sits the **germinal disc**.

Eggs from a flock without a rooster are not fertile and never develop; they are the eggs we eat. A fertile egg from a flock with a rooster begins to develop only when it is kept warm. In an **incubator**, chicken eggs need a steady 99.5 °F (in a forced-air incubator), humidity of about 40–50 percent, and turning three or more times a day so the embryo does not stick to the membranes. On day 18 turning stops and humidity is raised to about 65–70 percent so the membranes stay soft for hatching, which comes about day 21. A broody hen does all this herself: she turns her eggs, leaves the nest briefly each day, and keeps them at just the right warmth.

Candling lets the keeper watch without opening the egg. By day 7 a developing egg shows a dark spot with a web of fine veins spreading from it; a clear egg was never fertile and is removed. By day 14 the egg is mostly dark with a clear air cell. By day 18 the chick fills the egg and you may see it move. An egg that showed veins and then stopped developing is also removed, so it does not spoil. Candling is also how eggs are graded for sale: Grade AA eggs have a tiny air cell and a firm, centered yolk.

Many county fairs have 4-H and open poultry classes. In **showmanship**, the judge scores the exhibitor: how calmly the bird is taken from its cage head first, held securely with its body along the forearm and legs held between the fingers, and turned to show the head, comb, eyes and beak, then each wing spread, the breast and keel, the feathers, and the legs and feet. The exhibitor answers questions about

breed, care and health. Birds should be clean, healthy and gently handled; good showmanship is simply good animal care on display. Check your county extension office or fair book for rules, ages and health requirements. In a 4-H laying-hen judging class, judges use “past production” signs to tell which hens have laid most. A hen in lay has a large, bright red, waxy comb. In yellow-skinned breeds, the yellow pigment fades from the body in a set order as a hen keeps laying, from the vent area to the eye ring and earlobes, then the beak and finally the shanks, so a hen with pale beak and shanks has been laying for months.

PICTURE STUDY



A Cock, Hens and Chicks, Melchior d'Hondecoeter, about 1660–1670 · Oil on canvas · The National Gallery, London

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

Melchior d'Hondecoeter, a Dutch painter, spent his life painting poultry and birds so exactly that many breeds can still be recognized. Look at these birds the way a poultry judge would.

Look closely

- Find the rooster. How is he different from the hens in size, comb, tail and posture?
- Look at the chicks. Where are they standing, and why?
- Look at the hens' feathers, combs and legs. Do they look healthy?
- Find any differences in color or pattern among the hens.

Talk about it

1. If you were judging these hens, what would you look for first?
2. How does a broody hen protect and warm her chicks?
3. What signs of health would you check if you were holding one of these birds?

Safety first. Wash your hands after handling eggs, chickens or incubators, because poultry can carry salmonella. Hold birds securely and never squeeze or carry them by the legs or wings. Keep incubators away from young children and electrical cords dry.

HANDS-ON PROJECT

Egg Anatomy, Candling and a Judging Class

You will dissect and measure an egg, candle and grade a dozen eggs, and judge a class of four laying hens from photos in the 4-H style with a placing card and oral reasons.

You will need

- A dozen eggs (farm-fresh if possible, plus a few older store eggs)
- A bright flashlight and a toilet-paper tube or cardboard with an egg-sized hole
- A white plate, a ruler and a kitchen scale
- Index cards for a placing card

Steps

1. In a dark room, hold each egg large end up against the tube on the flashlight. Sketch the air cell size and yolk shadow, and give each egg a grade (AA, A or B) based on air cell depth.
2. Weigh each egg and record its size class (medium, large, extra-large).
3. Crack two eggs (one fresh, one older) onto plates. Measure the height of the thick white and the yolk with a ruler, and compare.
4. Judging class: find four photos of laying hens of the same yellow-skinned breed (from a breed book, extension guide or a 4-H judging site). Judge them by past production: comb size and color, and the yellow or bleached color of the beak and shanks. You may also judge four eggs for uniform size, shape, color and clean, sound shells.
5. Rank them 1 to 4 and write the placing on a card, for example 2-1-4-3.
6. Write reasons in the 4-H style: "I placed 2 over 1 because 2 is cleaner and more uniform in shape...", giving at least one reason for each pair.
7. Give your reasons aloud to a parent in under two minutes, standing straight, without notes if you can.
8. If you have access to a calm hen (your own, a neighbor's or a 4-H member's), practice the showmanship handling steps with an adult.

Tips

- Good reasons compare: “2 is longer and deeper bodied than 1,” not just “2 is nice.”
- Practice holding a chicken many times before a show; calm handling comes from repetition.
- Biosecurity matters for every flock: change shoes and wash hands after visiting other birds, keep new birds and birds returning from a fair apart from your flock for at least two to four weeks, and do not share equipment with other flocks.

Check your work

- ☐ I can label all the parts of an egg.
- ☐ I candled and graded a dozen eggs.
- ☐ I placed a class of four and gave oral reasons.
- ☐ I can describe the showmanship handling steps in order.

NATURE JOURNAL

1. Draw a labeled cross-section of an egg with shell, membranes, air cell, white, chalazae, yolk and germinal disc.
2. Draw what a fertile egg looks like when candled on days 7, 14 and 18.
3. Record your egg weights and grades in a table.

From history. Ancient Egyptians built large brick “egg ovens” heated by slow fires, where attendants hatched thousands of chicks at a time by testing the warmth of the eggs against their eyelids. Modern 4-H embryology projects let classrooms watch the same 21-day wonder in a small incubator.

COMMON MISTAKES

- Letting incubator temperature swing up and down; a few degrees too hot or cold ruins a hatch.
- Turning eggs an even number of times, so they sit the same way every night (an odd number alternates).
- Washing eggs for incubation and removing the protective bloom.
- In showmanship, gripping a bird too tightly or turning its head away from the judge.

Make it a game • Egg Anatomy Draw-Off. Draw an egg cross section from memory in sixty seconds, labeling air cell, chalazae, germinal disc, yolk and shell. Swap with your parent and check each other's. Then explain what candling reveals on days 7, 14 and 18 of incubation. Parent hides one label; name it. Beat your own labeling time.

6.2 SWINE

OBJECTIVES

- Explain how a pig's single stomach differs from a ruminant's, and what pigs eat.
- Describe how pigs are housed and kept healthy, including heat stress and biosecurity.
- Plan a market-pig project with a feeding plan, a record book and a budget of expenses and income, and explain the basics of showing a pig.

Warm-up. List everything you know or think you know about pigs. Mark each item as fact, guess or myth. Revisit the list at the end of the lesson.

WATCH

4H Swine

Iowa PBS · 5:06

https://www.youtube.com/watch?v=ljiPAq_AVG8

WHEN TO WATCH

After the core ideas. Watch how the young exhibitors drive their pigs in the ring, and listen to what the judge and exhibitors say about their projects.

Note: Public-television coverage of a state fair 4-H market swine show. The last minute is a fundraising message; skip it.

BACKUP VIDEO

4-H Swine Showmanship

NDSU Extension 4-H · 7:15

<https://www.youtube.com/watch?v=plknAqfh0dg>

With the showmanship core idea.

KEY TERMS

monogastric

Having one simple stomach, like pigs, horses, dogs and people, instead of the four-chambered stomach of ruminants.

feeder pig

A young pig, usually 40–60 pounds, bought to be raised to market weight.

feed conversion

How many pounds of feed an animal eats to gain one pound of body weight.

heat stress

Dangerous overheating. Pigs have very few working sweat glands, so they rely on shade, water and mud to stay cool.

biosecurity

Practices that keep diseases from entering or spreading on a farm, such as clean boots, limiting visitors and isolating new animals.

show stick

A cane or light whip used to guide a pig in the show ring by gently tapping its side or shoulder.

CORE IDEAS

Pigs are intelligent, curious and strong. They are **monogastric**, with one stomach like ours, so they cannot digest much grass or hay the way cattle can. They are omnivores and need concentrated feed: on most farms, a ration of ground corn for energy and soybean meal for protein, with vitamins and minerals, matched to the pig's age. Pigs drink a great deal, several gallons a day, more in hot weather. A pig's strong snout is made for rooting in the soil for roots, grubs and fallen nuts, which is why pigs can tear up a pasture or clear a garden plot quickly.

Pigs have very few working sweat glands, so they suffer from **heat stress**. They need shade, plenty of cool water, and in summer a wallow, sprinkler or mister; mud on the skin cools them as it dries and protects against sunburn. In winter they need a dry, draft-free shelter with bedding. Pigs are kept in strong pens or behind electric fence set low to the ground. Clean pens, fresh water and good **biosecurity** keep them healthy. Laws regulate feeding food scraps to pigs, because raw meat in scraps can spread serious diseases; ask your extension office before feeding any kitchen waste.

Most pigs are raised for pork. A **feeder pig** bought in spring at 40–60 pounds grows to a market weight of around 250–280 pounds in roughly four to five months, eating about 3 pounds of feed for every pound it gains. Common breeds include the Yorkshire, Duroc, Hampshire, Berkshire and Chester White. Keeping a market pig is a common 4-H and FFA project because it teaches daily responsibility and real farm economics: the young keeper records every cost and the pig's weight gain in a **project record book**, then compares expenses with the sale price at the fair or to a buyer.

In the show ring, an exhibitor drives the pig with a **show stick** and brush, keeping it moving at a calm walk about 8–10 feet from the judge, staying between the pig and the judge without blocking the view, and glancing often at the judge. The pig is clean and trained by many short daily walks at home. The judge looks for a pig that is sound on its feet and legs, well muscled and correctly finished; in showmanship, the judge scores the exhibitor's control, calmness and knowledge. Whether or not you ever show, those daily walks, weigh-ins and records are the habits of a faithful keeper.

PICTURE STUDY



Pigs, George Morland, about 1790s · Oil on canvas · Birmingham Museums Trust, England

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

George Morland was an English painter famous for scenes of country life, and pigs were among his favorite subjects. These are old English farm pigs, kept in a simple sty.

Look closely

- Look at the pigs' snouts, ears and eyes. Are they relaxed or alert?
- Find the bedding and the shelter. How are these pigs kept warm and dry?
- Find the food on the ground. What are the pigs being fed?
- Compare the two pigs' shapes and markings.

Talk about it

1. How is this sty different from a modern pig barn or a 4-H pen?
2. Would vegetable scraps like these be enough for a growing pig? What else does it need?
3. What would a pig keeper need to check every day here?

Safety first. Pigs are strong and can bite; work with pigs only with an adult, and never get between a sow and her piglets. Wear boots you can clean, wash hands after every chore, and follow the farm's biosecurity rules.

HANDS-ON PROJECT

A Market-Pig Record Book and Budget

You will plan a market-pig project the way a 4-H or FFA member does, with a feeding plan, a daily chore list, a record-book page and an expense and income table. If you can, you will visit a pig barn or the swine barn at a county fair.

You will need

- Local prices for a feeder pig, feed per 50-pound bag, bedding and vet care (from a farm store, extension office or 4-H leader)
- Graph paper or a spreadsheet
- Your nature journal
- Optional: a visit to a pig farm or fair swine barn

Steps

1. Set the project: one feeder pig bought at 50 pounds, to be raised to 270 pounds.
2. Calculate the weight gain needed and the feed required at 3 pounds of feed per pound of gain. Convert to 50-pound bags.
3. Make an expense table: feeder pig, feed, bedding, vet care, equipment (feeder, waterer), fair entry fees. Total it.
4. Make an income line: estimate the pig's value at market price per pound, or a fair sale price your leader suggests. Calculate profit or loss and the break-even price per pound.
5. Write a daily and weekly chore schedule: feed, water, check health, clean pen, walk and train.
6. Make a record-book page with columns for date, weight, feed used, costs and notes, and fill in three sample weeks with realistic numbers.
7. If you can, visit a swine barn and ask an exhibitor how they train their pig to walk in the ring. Record the answer.

Tips

- 4-H record books usually ask for "what I learned" at the end; write that section honestly.

- Weigh tapes estimate a pig's weight from its heart girth; ask an extension office to show you one.

Check your work

- ☐ My expense and income table is complete and adds up correctly.
- ☐ I calculated feed needed and break-even price.
- ☐ I can explain why pigs need shade and mud.
- ☐ I can describe how a pig is shown in the ring.

NATURE JOURNAL

1. Draw a pig and label the snout, ears, shoulder, loin, ham, legs and feet.
2. Draw a simple diagram comparing a pig's single stomach with a cow's four-part stomach.
3. Graph a pig's expected weight from 50 to 270 pounds over 18 weeks.

From history. In the early 1900s, many American farm boys and girls joined “corn clubs” and “pig clubs” run by county agents, raising one animal or one acre and keeping records of costs and results. These clubs grew into 4-H, whose four H's stand for Head, Heart, Hands and Health.

COMMON MISTAKES

- Forgetting water. A pig without water in hot weather can die quickly.
- Feeding the wrong ration for the pig's age.
- Leaving costs out of the record book, which hides the true profit or loss.
- Chasing or hitting a pig in training instead of guiding it with patience.

Make it a game • Pig Stomach Compare. Draw two stomachs on paper: one pig, single compartment, and one ruminant, four compartments. Parent names a food and you tell what each animal does with it. Then play lightning round: pig housing, heat stress, feed conversion and biosecurity terms. Parent gives a farm scenario, and you say what to do. Score a bean per correct answer.

6.3 HORSES: ANATOMY, CARE AND RIDING SAFETY

OBJECTIVES

- Name the main points of the horse and describe how its digestion and senses shape its care.
- Describe daily horse care: feeding, water, grooming, hoof care and health checks.
- Follow the safety rules for approaching, leading, grooming and riding a horse.

Warm-up. Stand still and look straight ahead. Have a partner walk slowly behind you from one side to the other. Say “now” when you can no longer see them. Then learn that a horse’s blind spots are directly behind it and right in front of its nose.

WATCH

Horse safe-handling

University of Minnesota Equine Extension Program • 6:51

<https://www.youtube.com/watch?v=B5KeqtLZoUA>

WHEN TO WATCH

After the safety core idea. List each rule the extension specialist shows.

KEY TERMS

hand

The unit for measuring a horse’s height, 4 inches, measured from the ground to the top of the withers.

hindgut fermenter

An animal, like the horse, that digests fiber with microbes in a large cecum and colon after the small stomach and intestine.

frog

The rubbery, V-shaped pad on the bottom of the hoof that absorbs shock and helps pump blood.

withers

The ridge between a horse’s shoulder blades, where the neck joins the back; the highest point of the back.

colic

Belly pain in a horse; it can be mild or life-threatening and always needs attention.

farrier

A trained craftsman who trims hooves and fits horseshoes, usually every six to eight weeks.

CORE IDEAS

A horse is built to graze and to run. Its eyes, set on the sides of the head, see almost all the way around, but it has blind spots directly behind and right in front of its nose. It is a prey animal: its first response to fright is to flee, and if cornered it may kick or strike. Learning the **points of the horse** lets you talk with owners, vets and farriers: poll, crest, withers, back, loin, croup, flank, shoulder, chest, forearm, knee, cannon, fetlock, pastern, coronet and hoof. Height is measured in **hands** of 4 inches to the withers; a 15-hand horse is 60 inches tall there.

Although large, a horse has a small stomach and is a **hindgut fermenter**: it digests hay and grass with microbes in its huge cecum. It is built to eat small amounts of forage almost all day, about 1.5–2.5 percent of its body weight a day, mostly as hay or pasture, and to drink perhaps 10 or more gallons of water. Sudden feed changes, too much grain, moldy hay or lack of water can cause **colic**, which can be deadly because horses cannot vomit. Signs include pawing, looking at the flank, rolling repeatedly and not eating; call a vet at once.

“No hoof, no horse,” say horsemen. Hooves are picked out daily with a hoof pick, working from heel to toe beside the **frog**, checking for stones, cracks and the black, smelly signs of thrush. A **farrier** trims hooves and, if needed, fits shoes every six to eight weeks. Grooming follows an order: a rubber curry comb in circles to loosen dirt, a stiff brush with the hair, a soft brush for the face and legs, then mane and tail. Grooming is also a daily health check for cuts, heat, swelling and ticks. Teeth are checked and filed by a vet about once a year.

Safety around horses is a set of habits. Always approach from the front of the shoulder at an angle, speaking so the horse knows you are there. Keep a hand on the horse as you move around it, and never stand directly behind it; walk close around the hindquarters or well out of kicking range. Lead from the left side with the rope in both hands, never wrapped around your hand. Tie with a quick-release knot. Wear boots with a heel, and when riding always wear an approved riding helmet. Young riders and beginners ride only with a trained adult and on a quiet, experienced horse. Many 4-H horse projects teach these skills step by step, even for members who do not own a horse.

PICTURE STUDY



Shoeing, Sir Edwin Landseer, 1844 · Oil on canvas · Tate Britain, London

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

Landseer painted the bay mare Old Betty being shod in a village forge. Look at how calm the horse is and at the tools of the farrier's trade.

Look closely

- Find the hoof being worked on. How is the farrier holding it, and where is he standing?
- Look at the mare's head, ears and eyes. Does she look relaxed or nervous?
- Find the farrier's tools and the horseshoes in the box.
- Find the other animals. What are they doing?

Talk about it

1. Why is it important for a horse to stand quietly while its feet are handled?
2. How often does a horse need its hooves trimmed or reshod today?
3. Where should a helper stand to stay safe in a scene like this?

Safety first. Work around horses only with a knowledgeable adult. Never stand directly behind a horse, never wrap a lead rope around your hand, wear sturdy boots, and always wear a certified riding helmet when mounted.

HANDS-ON PROJECT

A Horse Care Visit and Safety Checklist

You will visit a stable, 4-H horse club, riding lesson barn or a neighbor's horse with an adult, help with grooming and hoof care, and make a safety checklist and care calendar.

You will need

- Access to a horse with an experienced adult (a lesson barn, 4-H horse club or neighbor), or a library book on horse care
- Boots with heels and long pants
- Your nature journal
- Optional: a horse-height measuring stick or tape

Steps

1. Before the visit, write ten safety rules from this lesson as a checklist.
2. At the barn, watch an experienced person approach, halter and lead the horse. Tick off each safety rule you see them follow.
3. With the adult, groom the horse in the correct order, then watch or help pick out its hooves. Note the frog, sole and wall of the hoof.
4. Measure the horse's height in hands if the owner allows, and estimate its weight from the owner's records or a weight tape.
5. Ask the owner what the horse eats each day, how much water it drinks and how often the farrier and vet come.
6. Make a care calendar for one year: daily, weekly, every 6–8 weeks and yearly tasks.
7. No horse available? Label a large horse diagram with 16 points, and write a care calendar from a library book or extension guide.

Tips

- Move calmly and speak softly. Horses notice quick movements and loud voices.
- Ask the owner's rules first; every barn has its own.

Check your work

- ☐ I followed every safety rule on my checklist.
- ☐ I can name at least 12 points of the horse.
- ☐ I know how to groom in order and how to pick a hoof safely.
- ☐ I can name four signs of colic.

NATURE JOURNAL

1. Draw a horse from the side and label at least 12 points.
2. Draw the bottom of a hoof and label the wall, sole, frog and heel bulbs.
3. Draw a bird's-eye diagram of a horse showing its field of vision and blind spots.

COMMON MISTAKES

- Walking up behind a horse without speaking.
- Feeding large amounts of grain or making sudden feed changes.
- Looping a lead rope around a hand.
- Riding without a helmet, even for a “quick ride.”

Make it a game • Horse Points Hunt. Draw a horse outline and hide ten point labels on separate cards, including withers, frog and hand. Parent shuffles them and you place each at the right spot. Then answer the care questions: how a hindgut fermenter eats, signs of colic and daily hoof care with a farrier. Make a safety checklist for the barn.

Scripture. “Hath thou given the horse strength? hast thou clothed his neck with thunder?” (Job 39:19, KJV)

God asked Job whether he had made the horse's power and courage. A horse's strength is a gift from its Maker, and it calls for humble, careful handling from us.

6.4 BEEKEEPING: COLONY MANAGEMENT, SWARMS AND THE HONEY HARVEST

OBJECTIVES

- Describe how a beekeeper inspects and manages a colony through the season.
- Explain why colonies swarm and how beekeepers prevent and collect swarms.
- Explain how honey is made, harvested and extracted, and prepare a jar of honey for a fair exhibit.

Warm-up. Taste a drop each of two or three different honeys (unless you are allergic). Compare color, thickness, flavor and smell, and guess what flowers each came from.

WATCH

Swarm Prevention

University of Guelph Honey Bee Research Centre • 5:11

<https://www.youtube.com/watch?v=4MrT5FmuW64>

WHEN TO WATCH

After the swarm core idea. Note each method the researchers use to give the colony room.

KEY TERMS

brood

The eggs, larvae and pupae of bees in the comb. Capped worker brood under tan wax caps should form a solid pattern.

swarm

The old queen and roughly half the workers leaving the hive together to found a new colony, the natural way colonies multiply.

super

A box added on top of the hive where bees store surplus honey for the beekeeper to harvest.

queen cell

A large, peanut-shaped cell hanging from a comb in which workers raise a new queen.

varroa mite

A tiny parasitic mite that feeds on bees and spreads viruses; the most serious pest of honeybees today.

extractor

A drum that spins uncapped frames so honey is flung out of the comb without destroying it.

CORE IDEAS

A beekeeper inspects a colony about every 7 to 10 days in spring and early summer, on warm, calm days, using a smoker and hive tool and wearing a veil and protective clothing. Each inspection asks a few questions. Is there a laying queen? (Look for eggs, which stand upright in the bottom of cells like tiny grains of rice.) Is the **brood** pattern solid? Do the bees have enough honey and pollen? Do they need more room? Are there queen cells, disease or pests? Beekeepers now count **varroa mites** several times a year and treat colonies when counts are high, because mites are the leading cause of colony losses.

Swarming is how a colony reproduces: when the hive is crowded in spring, workers raise new queens, and just before one emerges the old queen leaves with about half the bees. They cluster on a branch while scouts search for a new home. A swarm is usually gentle because the bees are full of honey and have no home to defend, but only trained beekeepers should collect one. To prevent swarming, beekeepers give room before the hive is crowded by adding boxes and **supers**, and they may divide a strong colony into two (a “split”), which also increases the number of hives.

Honey begins as nectar, which is about 70–80 percent water. Foragers carry it home and pass it to house bees, who add enzymes that change its sugars, then spread it in cells and fan their wings until the water drops to about 17–18 percent. Then they cap the cell with wax. Capped honey will keep for years. Beekeepers harvest only surplus honey from the supers, using a bee escape or gentle brushing to clear bees, then cutting off the wax caps with a heated knife, spinning the frames in an **extractor**, straining the honey and bottling it. They always leave enough honey for the bees’ winter, often 60 pounds or more in cold climates.

Many county and state fairs have honey classes, and 4-H and beekeeping clubs often have youth beekeeping programs; check your county extension office or fair book. Judges examine a jar of extracted honey for moisture (too much water lets it ferment), clarity (no wax specks, bubbles, foam or lint), uniform color within the class, a clean, full jar filled exactly to the shoulder, and a clean lid. A good exhibit

shows the same care as a good harvest. Never give honey to a baby under one year old, because it can carry spores that make infants very sick. Young beekeepers can also write: the Foundation for the Preservation of Honey Bees runs the 4-H Honey Bee Essay Contest each year for 4-H members, with a new topic each year (the 2026 topic was “The Power of Pollen”), essays of about 750 words with cited sources, and a national deadline around May 1. Check with your county 4-H office for current rules.

PICTURE STUDY



The Beekeepers, Pieter Bruegel the Elder, about 1568 · Pen and ink · Kupferstichkabinett, Berlin

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

In Bruegel's time, bees were kept in straw skeps, and honey could only be harvested by breaking up the comb. Here masked beekeepers carry their skeps, perhaps after collecting a swarm, while a boy climbs a tree to watch, or to find a wild nest.

Look closely

- Find the straw skeps. How many can you count, and how are they being carried?
- Look at the beekeepers' clothing and masks. How are they protecting themselves?
- Find the boy in the tree. What might he be looking for?
- Look for any sign of bees or a swarm.

Talk about it

1. Why do you think the beekeepers cover their faces?
2. How is a modern hive with movable frames better for inspecting bees and harvesting honey than a skep?
3. Why might a swarm end up high in a tree?

Safety first. Only visit hives with an experienced adult beekeeper, wearing a veil and protective clothing. Anyone allergic to bee stings must stay away from hives and carry the medicine their doctor prescribes. If a bee stings you, scrape the stinger out sideways and walk away calmly. Never give honey to a baby under one year old.

HANDS-ON PROJECT

A Honey Exhibit and a Colony Calendar

You will prepare and judge honey as a fair judge would, and make a yearly management calendar for one colony. If you can, you will join a local beekeeper for a hive inspection.

You will need

- Three or four jars of different honey (local if possible)
- A clean, clear glass jar with a lid, of the kind your fair book requires
- A flashlight and a white card
- Labels
- Optional: a visit to a beekeeper or a local beekeepers' club field day

Steps

1. Judge the honeys as a class of four: hold each jar against a flashlight and white card and check clarity, specks, foam and bubbles; compare color, aroma and thickness; check that jars are clean and evenly filled.
2. Place them 1 to 4 on a placing card and give oral reasons comparing each pair.
3. Prepare an exhibit jar: warm a jar of honey gently in warm water if needed, pour slowly down the side of a spotless jar to the shoulder, let bubbles rise for a day and skim any foam with plastic wrap.
4. Clean the jar and lid and label it exactly as your fair book asks (often no brand labels are allowed).
5. Make a 12-month colony calendar: what the beekeeper does in each month, including inspections, swarm prevention, adding supers, mite checks, harvest and winter preparation.
6. If possible, visit a hive with a beekeeper and record what you see: brood, honey, pollen, eggs and any queen cells.
7. Optional: research and write a 750-word essay with cited sources in the format of the 4-H Honey Bee Essay Contest, on this year's topic or on how bees make and store honey.

Tips

- Look up your county fair's honey class rules; jar size, lid type and fill level are often specified.
- Many beekeepers' clubs welcome young members and lend equipment; ask your county extension office.
- For the essay, use reputable sources such as university extension bee pages and books, list them at the end, and have someone check your word count and facts.

Check your work

- ☐ I judged four honeys and gave oral reasons.
- ☐ I prepared a clean, correctly filled exhibit jar.
- ☐ My colony calendar covers all 12 months.
- ☐ I can explain why bees swarm and how beekeepers prevent it.

NATURE JOURNAL

1. Draw a frame from a hive showing capped honey at the top, pollen in a band and capped brood below, with labels.
2. Draw a queen cell and a worker cell side by side.
3. Draw a swarm cluster on a branch and write what the scouts are doing.

From history. In 1851 Lorenzo Langstroth, a Pennsylvania minister, discovered “bee space,” a gap of about three-eighths of an inch that bees leave open rather than filling with comb or wax. By spacing hanging frames exactly that far apart, he invented the movable-frame hive still used around the world, letting beekeepers inspect colonies and harvest honey without destroying the comb.

COMMON MISTAKES

- Waiting until the hive is crowded to add space, by which time the bees may already be preparing to swarm.
- Harvesting honey that is not capped, which has too much water and may ferment.
- Taking too much honey and leaving the colony too little for winter.
- Pouring honey quickly into an exhibit jar and trapping bubbles.

Make it a game • Swarm Alarm Role-Play. Play the beekeeper. Parent describes colony signs: queen cells, crowded brood boxes, few empty cells, varroa mites. You decide whether the colony is preparing to swarm and name the fix, like adding a super or splitting. Explain how to collect a swarm safely. Then plan the colony calendar from spring to winter.

Scripture. “More to be desired are they than gold, yea, than much fine gold: sweeter also than honey and the honeycomb.” (Psalm 19:10, KJV)

The psalmist knew how precious and sweet honey was, and said God’s words are sweeter still. Every jar of honey is a reminder of that comparison.

FARM ANIMALS AND BEES

Early spring is the busiest season on a farm: eggs go into incubators, feeder pigs arrive, horses shed their winter coats and honeybee colonies grow from a few thousand bees to tens of thousands. In this unit you will study four animals that people have kept for thousands of years, looking closely at how each is made and what good husbandry requires.

You will learn the anatomy of an egg and how a chick develops in 21 days, how pigs are raised for pork and why they need shade and mud, how to be safe and useful around horses, and how beekeepers manage colonies, prevent swarms and harvest honey. Because many students your age join 4-H or FFA, you will also learn how young people show poultry and pigs, keep a project record book with expenses and income, judge a class and give oral reasons, and prepare a jar of honey for the county fair. “Be thou diligent to know the state of thy flocks” (Proverbs 27:23).

PREREQUISITES

- Knows the basic needs of farm animals: feed, water, shelter, space and care
- Knows that farm animals are raised for eggs, milk, wool, work and meat
- Knows the three castes of honeybees: queen, workers and drones
- Knows the rules for washing hands after handling animals and never standing behind a horse

MASTERY CHECKLIST

- ☐ I can label the parts of an egg, candle eggs and explain the main conditions for incubation.
- ☐ I can handle and show a chicken calmly and correctly.
- ☐ I can explain how pigs differ from ruminants, how they are housed and fed, and keep a project budget with expenses and income.
- ☐ I can name the main points of a horse and follow the safety rules for handling, grooming and riding.
- ☐ I can explain colony management, swarming and how honey is harvested, and prepare a fair honey exhibit.
- ☐ I can place a class of four and give oral reasons.

LESSONS IN THIS UNIT

6.1 Poultry Science: The Egg, Incubation and Showmanship

2 sessions of 50–60 minutes

6.2 Swine

2 sessions of 50–60 minutes

6.3 Horses: Anatomy, Care and Riding Safety

2 sessions of 50–60 minutes

6.4 Beekeeping: Colony Management, Swarms and the Honey Harvest

2 sessions of 50–60 minutes

UNIT 6 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **8 pts**

Name four parts of an egg and the job of each.

2. **8 pts**

Give the incubation conditions for chicken eggs, and the number of days to hatch.

3. **6 pts**

What do you see when you candle a developing egg at day 7, and what does a clear egg mean?

4. **6 pts**

In poultry showmanship, what is being judged?

5. **8 pts**

Why do pigs need mud, shade or misters in hot weather?

6. **8 pts**

A feeder pig gains 220 pounds with a feed conversion of 3 to 1. How many pounds of feed does it eat, and how many 50-pound bags?

7. **6 pts**

Name four points of the horse.

8. **8 pts**

Give four safety rules for working around horses.

9. **8 pts**

Why do honeybee colonies swarm, and name two ways beekeepers prevent it.

10. **4 pts**

Why must honey be capped before it is harvested?

11. **15 pts**

Written answer: You placed a class of four jars of honey 3-1-4-2. Write the oral reasons you would give for your top and bottom pairs, using real judging terms.

12. **15 pts**

Written answer: Explain how a market-pig project teaches responsibility and farm economics, and what records a good record book contains.

ANSWER KEY

1. Any four: shell (protects, lets air through pores), membranes (protect against bacteria), air cell (air supply at large end), albumen (water and protein, cushions yolk), chalazae (hold yolk centered), yolk (food), germinal disc (where a chick forms in a fertile egg).
2. About 99.5 °F in a forced-air incubator, 40–50% humidity, turned three or more times a day until day 18; then stop turning and raise humidity to about 65–70%. Hatch is about day 21.
3. A dark spot with a web of fine veins. A clear egg was not fertile.
4. The exhibitor: how calmly and correctly the bird is handled and presented, and the exhibitor's knowledge of its breed, care and health.
5. Pigs have very few working sweat glands and cannot cool themselves well; mud, shade and water cool them and prevent heat stress and sunburn.
6. 660 pounds of feed; 13.2, so 14 bags.
7. Any four, e.g., poll, withers, croup, fetlock, pastern, hock, cannon, coronet, frog, flank.
8. Any four: approach from the shoulder at an angle and speak; never stand directly behind; keep a hand on the horse when moving around it; lead from the left, never wrap the rope around your hand; tie with a quick-release knot; wear boots; wear a certified helmet when riding; work with an experienced adult.
9. Swarming is how colonies reproduce, usually when crowded in spring. Prevent by adding boxes or supers before crowding, making splits, or managing queen cells.
10. Capping shows the bees have dried it to about 17–18% water; uncapped honey has too much water and can ferment.
11. A good answer uses comparative language: e.g., “I placed 3 over 1 because 3 is clearer, free of wax specks and foam, and filled exactly to the shoulder, while 1 shows fine bubbles at the top. I placed 2 last because it shows crystallization and lint, has an uneven fill line and a sticky lid; I grant that 2 has a pleasing light color.” Reasons should compare pairs, name specific faults and merits, and be clear and confident.
12. Daily feeding, watering, cleaning, health checks and walking build faithful habits. Economics: tracking expenses (pig, feed, bedding, vet, equipment, fees) against income from sale shows profit or loss and break-even price. Records

include dates, weights and gains, feed used, all costs and income, health notes, show results and a summary of what was learned.

PORTFOLIO PIECE: A 4-H STYLE PROJECT RECORD

Choose one animal from this unit (poultry, a pig, a horse or a bee colony) and make a complete project record as a 4-H or FFA member would: a care calendar, an expense and income table, a record of observations (egg grades, weights, inspections or care visits), your judging card and written reasons, and a page on what you learned. If you can, add a photo or drawing of you handling or caring for the animal.

LOOK FOR	WHAT IT MEANS
Care plan	Daily, seasonal and yearly care are complete, accurate and humane.
Records and budget	Observations are dated and measured; the expense and income table is complete and correct.
Judging	Placing card and reasons compare pairs using specific, accurate terms.
Reflection	The “what I learned” page is honest and specific about skills, mistakes and next steps.

UNIT 7

PLANTING: GREENHOUSE, CONTAINERS, ORCHARD AND FIELD

Spring planting happens at every scale, from a tray of seedlings on a basement shelf to a lemon tree in a big pot, a new apple orchard and a thousand acres of corn. In this unit you will work through each scale in turn and learn the skills professionals use: scheduling and growing transplants under controlled conditions, repotting and root-pruning large container plants, planting and pruning fruit trees, and understanding the machines that plant and harvest field crops.

Along the way you will run a small transplant business with real costs and income, give a 4-H style illustrated talk, prepare a potted plant the way a fair judge wants to see it, and estimate the yield of a cornfield with nothing but a tape measure and a little math. Jesus said that a branch that bears fruit is pruned “that it may bring forth more fruit” (John 15:2). Careful planting and pruning are acts of hope in the harvest to come.

PREREQUISITES

- Has started seeds indoors and knows what seedlings need: warmth, light, water and air
- Knows what root-bound means
- Knows what hardening off is
- Can measure, multiply and divide decimals

MASTERY CHECKLIST

- ☐ I can schedule, start and grow transplants with correct temperature, light, water and air flow, and harden them off.
- ☐ I can keep an expense and income table for a small plant business.
- ☐ I can repot or root-prune a large container plant safely and give a illustrated talk on it.
- ☐ I can plant a bare-root fruit tree correctly and make the basic pruning cuts.
- ☐ I can explain what a planter, grain drill and combine do and estimate a corn yield.

LESSONS IN THIS UNIT

7.1 Greenhouse and Seed-Starting Operations

2 sessions of 50–60 minutes

7.2 Containers and Repotting Large Plants and Trees

2 sessions of 50–60 minutes

7.3 The Orchard: Planting and Pruning Fruit Trees

2 sessions of 50–60 minutes

7.4 Field Crops and Farm Machinery

2 sessions of 50–60 minutes

UNIT 7 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. (8 pts)

Your last frost date is May 10. On about what date should you sow peppers indoors (8–10 weeks before)? Tomatoes (6–8 weeks)?

2. (8 pts)

Name three causes of leggy seedlings and how to fix each.

3. (6 pts)

What is damping off, and name two ways to prevent it.

4. (8 pts)

Name four signs that a large potted plant needs repotting.

5. (6 pts)

What is root pruning, and when would you choose it instead of moving to a bigger pot?

6. (8 pts)

Why must the graft union of a fruit tree stay above the soil?

7. (6 pts)

What is a pollinizer, and which fruits usually need one?

8. (8 pts)

List the order of pruning decisions on a dormant fruit tree.

9. **8 pts**

Describe what happens to corn inside a combine.

10. **4 pts**

Why are grain bins dangerous?

11. **15 pts**

Written answer: In 1/1000 acre you count 32 ears. The ears average 16 rows of 35 kernels. Estimate the yield in bushels per acre and explain each step.

12. **15 pts**

Written answer: Outline a 3–5 minute illustrated talk on repotting a root-bound plant, with an introduction, steps and summary.

ANSWER KEY

1. Peppers: about March 1–15. Tomatoes: about March 15–29.
2. Too little light (lower lights, 14–16 hours on a timer); too warm after germination (move off heat mat, cooler room); too crowded (thin to one per cell). Also no air movement (add a fan).
3. A seedling rot at the soil line in cold, wet, stale conditions. Prevent with sterile mix and clean trays, not overwatering, air movement and good light.
4. Roots out the drainage hole or circling, water runs straight through, wilts soon after watering, salt crust, top-heavy pot, slowed growth.
5. Trimming 1–2 inches of outer roots and replanting in the same pot with fresh mix; chosen when the plant is already as large as you want or the pot is as large as practical.
6. If buried, the fruiting variety can form its own roots, losing the size control and other benefits of the rootstock.
7. A different compatible variety blooming at the same time nearby to supply pollen; most apples, pears and sweet cherries.
8. Remove dead, damaged and diseased wood; then crossing or rubbing branches; then water sprouts and suckers; then thin to shape (central leader or open center), removing no more than about a quarter of the live wood.
9. The header gathers and snaps ears; the feeder house carries them in; the rotor or cylinder threshes kernels loose against the concave; sieves and a fan clean out chaff; augers carry grain to the tank; cobs and stalks are spread behind.
10. Flowing grain can pull a person under and trap or suffocate them within seconds.
11. $32 \times 16 \times 35 = 17,920$; $\div 90 \approx 199$ bushels per acre. Ears per 1/1000 acre times kernels per ear gives thousands of kernels per acre; dividing by about 90 (thousand kernels per bushel) converts to bushels per acre.
12. Introduction: name, topic, why repotting matters. Steps (shown with real materials): water the day before; signs of root-bound; slide plant out; inspect roots; loosen or root-prune; choose a pot 2–4 inches wider with drainage; fresh potting mix at the same depth; firm and water; aftercare out of strong sun. Summary: restate key steps and benefits; invite questions.

PORTFOLIO PIECE: A PLANTING SEASON PORTFOLIO

Present your transplant business records (sowing calendar, growth log and expense and income table), your illustrated-talk outline and a photo or drawing of your exhibit-ready potted plant, your orchard plan or pruning before-and-after, and your corn yield estimate with the combine diagram. Add one page on what you learned about planting at each scale, from tray to field.

LOOK FOR	WHAT IT MEANS
Records	Calendar, growth log and expense and income table are complete, dated and correct.
Skill	Transplants, repotting and pruning or planting were done correctly, with evidence.
Communication	Illustrated talk outline is well organized and was delivered clearly.
Math and science	Yield estimate and explanations of machines, rootstocks and pruning are accurate.
Exhibit standards	The potted plant was prepared and self-scored against a judge's points.

7.1 GREENHOUSE AND SEED-STARTING OPERATIONS

OBJECTIVES

- Schedule seed sowing by counting back from the last frost date.
- Control germination temperature, light, water and air flow to grow stocky, healthy transplants and prevent damping off.
- Run a small transplant project with a record of expenses and income.

Warm-up. Look at two seedlings (or two photos): one tall, pale and floppy, one short, dark green and sturdy. List every cause you can think of for the difference.

WATCH

How Greenhouses Start Their Flowers - Go Behind The Scenes of a Commercial Greenhouse

Sharkey's Greenhouses • 7:13

<https://www.youtube.com/watch?v=w0lDipltgV0>

WHEN TO WATCH

After the core ideas. Note the tray sizes, the germination room and how plants move from one stage to the next.

BACKUP VIDEO

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>

Before you set up your own lights.

KEY TERMS

plug tray

A tray of many small cells (for example 72 or 128) used by greenhouses to grow uniform young seedlings called plugs.

heat mat

A waterproof electric mat that warms seed trays from below to speed germination of warm-season crops.

leggy

Describes seedlings that are tall, thin and pale from too little light or too much warmth.

damping off

A disease in which fungus-like organisms in wet, stale conditions rot seedlings at the soil line, so they topple and die.

potting up

Moving a seedling into a larger container before it becomes root-bound.

hardening off

Gradually exposing indoor-grown seedlings to sun, wind and cool nights over 7–10 days before planting them outside.

CORE IDEAS

Commercial greenhouses grow millions of plants by controlling every condition and following a schedule. You can do the same at home. Begin with your average last frost date and count back. Peppers and eggplants need about 8–10 weeks indoors, tomatoes 6–8 weeks, cabbage, broccoli and lettuce 4–6 weeks, and squash and cucumbers only 2–4 weeks because they dislike being transplanted. Mark each sowing date on a calendar.

Germination depends on soil temperature. Tomatoes and peppers sprout fastest at about 75–85 °F, so growers use germination chambers or **heat mats**; lettuce and spinach prefer about 60–70 °F and may not sprout at all if too warm. Once seedlings emerge, move them off the heat to a cooler spot (about 60–70 °F) with strong light. Light is the most common problem indoors: a sunny window is rarely enough, and seedlings stretch toward it and turn **leggy**. Use LED or fluorescent shop lights kept close (follow the maker's distance, often just a few inches for fluorescent tubes), on a timer for 14–16 hours a day.

Use a fresh, sterile seed-starting mix, clean trays and labels. Water from below or gently, letting the surface dry slightly between waterings, and run a small fan for air movement. These steps prevent **damping off**, which thrives in cold, wet, stale conditions. Air movement also makes stems sturdier. When the first true leaves appear, feed with a quarter- to half-strength fertilizer, and **pot up** into larger cells or pots before roots circle the container.

Seven to ten days before transplanting, **harden off**: set plants outside in shade for an hour or two, then more each day, adding sun and leaving them out overnight once nights are mild. This thickens leaf surfaces and stems so they are not scorched or broken by sun and wind. Professional growers also keep careful records: sowing dates, germination rates, problems, costs and sales. Many young people sell extra transplants at a farm stand or church sale, which turns this skill into a small business.

PICTURE STUDY



In the Greenhouse, Dennis Miller Bunker, 1888 · Oil on canvas · Amon Carter Museum of American Art, Fort Worth, Texas

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

Dennis Miller Bunker, an American painter, painted the inside of a flower greenhouse in the summer of 1888. In the nineteenth century, many large houses and nurseries kept greenhouses to start plants and grow flowers out of season.

Look closely

- Find the different flower colors. How many kinds of plants do you think are growing here?
- Look at the light. Where is it coming from, and how strong is it?
- Look at how closely the plants are packed. What could that mean for air flow and disease?
- Find the path. How would a gardener reach the plants to water and care for them?

Talk about it

1. What conditions does a greenhouse control that the open garden cannot?
2. What chores would this greenhouse need every day?
3. How is your seed-starting setup at home like a small greenhouse?

Safety first. Keep water away from lights, heat mats and plugs, use a GFCI outlet, and hang lights securely with chains or strong hooks. Ask an adult to check all electrical setups.

HANDS-ON PROJECT

A Transplant Business

You will plan, grow and keep records for a flat of transplants as a small business, with a sowing schedule, a growing log and an expense and income table. You may sell or give away the plants at the end.

You will need

- A plug tray or reused cell packs with drainage, and a solid tray beneath
- Seed-starting mix
- Seeds of 2–3 crops (for example tomatoes, peppers, lettuce or marigolds)
- A light fixture on a timer, a small fan and a heat mat if available
- Plant labels, a thermometer and your nature journal

Steps

1. Find your last frost date and count back to set sowing dates for each crop. Write a calendar.
2. List every expense (seeds, mix, trays, labels, fertilizer, electricity estimate) with its cost.
3. Sow two seeds per cell, label each row and record the sowing date. Use the heat mat for warm-season crops.
4. Record the date each crop emerges and calculate the germination rate. Thin to one seedling per cell by snipping the weaker one.
5. Grow the seedlings under lights 14–16 hours a day with a fan. Record watering, feeding, height and any problems twice a week.
6. Pot up any that outgrow their cells. Harden them off for 7–10 days before transplant or sale.
7. Set a fair price per plant by checking local prices. Record income from sales (or the value of plants given away or planted in your own garden).
8. Complete an expense and income table and calculate profit or loss and the cost per plant. Write what you would do differently.

Tips

- A fan on low for a few hours a day makes stems noticeably sturdier.
- Check your town's rules before selling; many families sell transplants at church, school or farm-stand sales.
- Service idea: grow an extra tray of vegetable transplants and give them to a community garden, a church garden or a food pantry's garden program.

Check your work

- ☐ I sowed on a schedule counted back from my frost date.
- ☐ I recorded germination rate and growth twice a week.
- ☐ My seedlings were stocky, not leggy, and I hardened them off.
- ☐ My expense and income table is complete and correct.

NATURE JOURNAL

1. Draw a side view of your seed-starting setup labeling light, timer, fan, heat mat, tray and seedlings.
2. Draw one seedling at emergence, first true leaf and transplant size.
3. Make a sowing calendar showing weeks before the last frost for each crop.

From history. Many county fairs have youth classes for vegetable transplants and bedding plants, and some 4-H and FFA chapters run spring plant sales from their own greenhouses to raise money for their clubs. Check your county extension office or fair book for classes near you.

COMMON MISTAKES

- Starting seeds too early, so plants are root-bound and overgrown by planting time.
- Keeping seedlings on the heat mat after they sprout.
- Lights too far away, which makes leggy seedlings.
- Skipping hardening off and losing transplants to sunscald and wind.

Make it a game • Count-Back Calendar. Choose a pretend last frost date. Parent calls a crop and its weeks to transplant, such as peppers at eight weeks, and you count back on a calendar to find the sow date. Do six crops fast. Then explain how heat mats, light and air flow make stocky seedlings and prevent damping off. Beat your own speed.

7.2 CONTAINERS AND REPOTTING

LARGE PLANTS AND TREES

OBJECTIVES

- Recognize when a large container plant needs repotting, root pruning or top-dressing.
- Choose containers and potting mixes and repot or root-prune a plant safely.
- Give a 3–5 minute illustrated talk and prepare a potted plant to fair-exhibit standards.

Warm-up. Water a potted houseplant and time how long it takes for water to run out of the bottom. Then tip it gently and look at the drainage hole. Are roots showing? Write what you think the speed of drainage and the roots tell you.

WATCH

Root bound plants - 2 ways to loosen the roots plus what NEVER to do!

Backyard Farmer Pat · 7:39

<https://www.youtube.com/watch?v=i811VMaDrls>

WHEN TO WATCH

After the core ideas. Note the two methods for loosening a root ball.

KEY TERMS

root-bound

Describes a container plant whose roots have filled the pot and circle the inside, leaving little soil to hold water and nutrients.

top-dressing

Replacing the top inch or two of old potting mix with fresh mix or compost when a plant is too big to repot.

root pruning

Trimming the outer roots of a container plant so it can go back into the same pot with fresh mix, keeping it at a manageable size.

potting mix

A light, soilless blend (usually peat or coir, bark, perlite and compost) made for containers; garden soil packs down and drains poorly in pots.

illustrated talk

A short, organized talk in which a speaker shows how to do something step by step, as in a 4-H illustrated talk.

CORE IDEAS

Large container plants, such as a potted lemon, fig, palm or fiddle-leaf fig, live in a small world. As they grow, roots fill the pot and circle the walls; the plant dries out quickly, water rushes straight through, salts build up as a white crust, and growth slows. Signs that repotting is due: roots out the drainage hole or circling on top, water running through without soaking in, a plant that wilts within a day of watering, and a pot that tips over easily. Repot in early spring, just before the main flush of growth, so roots recover quickly.

Choose a pot only 2–4 inches wider than the old one. A pot far too big holds wet mix the roots cannot reach, which can lead to root rot. Every pot must drain. Terracotta breathes and dries quickly; plastic and glazed pots hold water longer; fabric grow bags air-prune roots. Use a quality **potting mix**, never plain garden soil, which packs down into a brick in a container. Set the plant at the same depth it grew before.

When a plant is already as big as you want it, **root prune** instead. Slide the root ball out, cut 1–2 inches off the sides and bottom with a clean pruning saw or old bread knife, tease out circling roots, and replant in the same pot with fresh mix around the edges. This is the old secret behind bonsai and the potted orange trees of European palaces. Water thoroughly and keep the plant out of hot sun for a week or two. When a plant is too big to move at all, **top-dress** it instead. Big pots are heavy: use a hand truck or plant dolly, work with a partner, and lift with your legs.

Many fairs have potted-plant classes for young exhibitors; check your county fair book for rules. Judges look for a healthy, well-shaped plant in proportion to its pot; clean, unchipped containers; clean leaves with no dead or yellow foliage, pests or disease; correct labels; and a plant the exhibitor grew for the required time.

Preparing an exhibit is simply good care made visible. In 4-H, members also give **illustrated talks**: a short, well-organized talk that shows a skill step by step, with an introduction, clear steps with real materials, a summary and time for questions.

PICTURE STUDY



The Orange Trees, Gustave Caillebotte, 1878 · Oil on canvas · Museum of Fine Arts, Houston

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

Caillebotte painted his family's garden at Yerres, near Paris, where orange trees were grown in big wooden boxes. In winter the boxes were wheeled into a shed or orangery; in summer they were set out along the paths.

Look closely

- Find the wooden planters. How big are they compared with the people?
- Look at the shape of the orange trees. Have they been pruned?
- Look at where the trees are placed. Are they in sun or shade?
- Find anything that would help move such heavy boxes.

Talk about it

1. Why would a gardener near Paris grow orange trees in boxes rather than in the ground?
2. How might a gardener keep these trees healthy in the same boxes for many years?
3. What would a fair judge look for in a potted tree like these?

Safety first. Big pots and wet root balls are heavy: work with an adult, use a dolly, and lift with your legs, not your back. Let an adult handle pruning saws and knives. Wear gloves, since potting mix can contain fungi and bacteria, and wash hands afterward.

Repot, Root-Prune and Present

You will repot or root-prune a large container plant, give a 3–5 minute illustrated talk on the skill, and prepare a potted plant to fair-exhibit standards.

You will need

- A large potted houseplant, patio plant or small potted tree that needs care
- A new pot 2–4 inches wider (or the same pot, for root pruning)
- Fresh potting mix
- A pruning saw or old bread knife, pruners, a chopstick and gloves
- A tarp or old sheet
- A plant dolly if the pot is heavy

Steps

1. Water the plant the day before so the root ball holds together.
2. Lay down the tarp. With a helper, tip the pot on its side, tap the rim and slide the plant out.
3. Examine the roots: color, smell, circling and any dark, mushy rot. Record what you find with a sketch.
4. Either loosen circling roots and repot into the larger pot at the same depth, or root-prune 1–2 inches from the sides and bottom and return the plant to its pot with fresh mix.
5. Work fresh mix into gaps with a chopstick, water deeply until it drains, and keep the plant out of strong sun for a week.
6. Prepare your illustrated talk: an introduction, 5–7 clear steps shown with your real materials, a summary and an answer to one expected question. Practice until it takes 3–5 minutes.
7. Give the talk to your family or a group, standing straight and speaking clearly.
8. Groom a potted plant for exhibit: remove dead leaves, wipe leaves clean, clean the pot, and write a neat label with the plant's name. Score it yourself on the judge's points.

Tips

- Make a large poster or cards listing your steps; 4-H judges like neat, readable visuals.
- No large plant? Repot a small houseplant for the talk and explain how the method scales up.

Check your work

- ☐ I repotted or root-pruned a plant correctly and safely.
- ☐ I gave a 3–5 minute illustrated talk with an introduction, steps and summary.
- ☐ I can name four signs a plant needs repotting.
- ☐ I prepared and scored a potted plant to exhibit standards.

NATURE JOURNAL

1. Draw the root ball before and after root pruning, showing where you cut.
2. Draw a cross-section of a well-potted plant: drainage hole, mix, root ball, soil line and the space below the rim.
3. Write your illustrated-talk outline on one page.

From history. In the 1600s King Louis XIV's gardeners at Versailles kept more than a thousand orange trees in wooden boxes. The famous "Versailles planter" has sides that can be unbolted, so gardeners can open the box, prune the roots and add fresh soil without lifting the tree out. Some of the trees in the palace orangery today are said to be hundreds of years old.

COMMON MISTAKES

- Moving a plant into a pot much too large.
- Using garden soil in a container.
- Burying the stem deeper than it grew before.
- Repotting in the heat of midsummer or while a plant is in full flower.

Make it a game • Repot Decision Cards. Make a stack of situation cards: roots circling the pot, water running straight through, wilting despite watering, healthy roots. Parent flips one and you decide to repot, root-prune or top-dress. Say which container size and potting mix to choose. Explain each decision. Get eight right in ten cards to win.

7.3 THE ORCHARD: PLANTING AND PRUNING FRUIT TREES

OBJECTIVES

- Choose a good orchard site, rootstock and pollination partners for fruit trees.
- Plant a bare-root or container fruit tree correctly.
- Make correct pruning cuts and explain central-leader and open-center training.

Warm-up. Look at a tree in winter (or a photo). Draw its main shape quickly: one main trunk going up, or several main branches spreading like a vase? Mark any branches that cross or rub.

WATCH

How to Plant a Bare-root Fruit Tree Step by Step

GrowVeg • 5:16

<https://www.youtube.com/watch?v=PbHjoc1r56U>

WHEN TO WATCH

With the planting core idea. Note how deep the tree is set and where the graft union sits.

BACKUP VIDEO

How To PRUNE Your Apple Trees for a Bountiful Harvest Next Year #apples #appletree #appletrees

Sharkey's Greenhouses • 5:21

<https://www.youtube.com/watch?v=LH6SSG1K8Xo>

After the pruning core idea. Name each cut before he makes it.

KEY TERMS

rootstock

The root system onto which a fruit variety is grafted; it controls the tree's size, such as dwarf, semi-dwarf or standard.

graft union

The swollen place on the trunk where the fruiting variety (scion) was joined to the rootstock. It must stay above the soil.

pollinizer

A different, compatible variety planted nearby to provide pollen, needed by most apples, pears and sweet cherries.

central leader

A training system with one main upright trunk and tiers of side branches, like a Christmas tree; used for apples and pears.

open center

A vase-shaped training system with no central trunk, letting light into the middle; used for peaches, nectarines and plums.

branch collar

The slightly swollen ring at the base of a branch where it joins the trunk; cutting just outside it lets the wound seal well.

CORE IDEAS

An orchard is planted for decades, so the site matters. Fruit trees need full sun, deep, well-drained soil and good air drainage. A gentle slope is ideal, because cold air flows away from the blossoms on frosty spring nights; avoid frost pockets. Most fruit trees are **grafted**: a branch of a named variety such as Honeycrisp is joined to a **rootstock** that controls size. A dwarf apple may reach 8–10 feet and bear in two or three years but needs staking; a standard tree may reach 25 feet and live a century. Most apples, pears and sweet cherries also need a **pollinizer**, a different variety that blooms at the same time within about 50–100 feet, so bees can carry pollen between them.

Bare-root trees are planted while dormant in early spring. Soak the roots for a few hours, dig a hole wider than the roots but no deeper, spread the roots over a small mound of soil, and set the tree so the **graft union** is 2–3 inches above the final soil line. If it is buried, the variety will root and the dwarfing effect is lost. Backfill with the native soil, firm it, water deeply, and mulch in a wide ring kept a few inches away from the trunk. Wrap the trunk in a hardware-cloth guard against voles and rabbits.

Pruning is done mainly in late winter while trees are dormant. First remove the three D's: dead, damaged and diseased wood. Then remove branches that cross or rub, upright **water sprouts** and **suckers** from the roots. A **thinning cut** removes a whole branch at its origin, just outside the **branch collar**, and opens the tree to light; a heading cut shortens a branch and makes it bush out. Apples and pears are usually trained to a **central leader**; peaches and plums to an **open center**. Remove no more

than about a quarter of the live wood in a year. Use sharp bypass pruners, loppers and a pruning saw, and clean blades between trees when cutting out disease.

Good orchard care continues all season. Thin young apples to one fruit per cluster, about 6–8 inches apart, so the remaining fruit grows large and the tree does not exhaust itself. Water wisely: young trees need about an inch of water a week in dry weather, given deeply once or twice a week rather than lightly every day. Drip irrigation or a soaker hose delivers water slowly to the roots with little lost to evaporation or runoff, and a simple watering schedule in your journal (date, amount, rainfall) keeps you from guessing. Using water carefully is part of stewardship, a theme of Junior Master Gardener's *Operation Water*. Pick up dropped fruit, which harbors pests. Pruning seems harsh, but it is for the tree's good: Jesus used this very picture, saying the Father prunes fruitful branches so they bear more fruit.

PICTURE STUDY



The Pink Orchard, Vincent van Gogh, 1888 · Oil on canvas · Van Gogh Museum, Amsterdam

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

In the spring of 1888, Van Gogh painted the orchards around Arles in blossom again and again, racing to capture them before the petals fell. Look at these trees as an orchardist would.

Look closely

- Look at the shape of the trees. Do they have one central trunk or an open vase shape?
- Look at the spacing of the trees. Why plant them this far apart?
- Look at the ground beneath the trees. Is it bare, grassy or mulched?
- Find trees that are blooming more fully than others. Why might they differ?

Talk about it

1. Why is bloom time the riskiest time of year for an orchard?
2. Which insects would be busy in this orchard, and why does the grower need them?
3. If you were pruning these trees next winter, what would you remove first?

Safety first. Use sharp tools only with an adult; ladders, pruning saws and chain saws are adult jobs. Wear gloves and safety glasses when pruning, and never prune near power lines.

HANDS-ON PROJECT

Plant or Prune: An Orchard Workday

You will either plant a fruit tree or berry bush, or prune a fruit tree or shrub with an adult, and make a five-year orchard plan.

You will need

- Option A: a bare-root or potted fruit tree or berry bush, a shovel, compost-free native soil, mulch and a hardware-cloth trunk guard
- Option B: a fruit tree or shrub to prune, bypass pruners, loppers and gloves (adult handles saws)
- Graph paper and colored pencils
- A nursery catalog (online or print)

Steps

1. Option A: choose a sunny, well-drained spot. Dig a wide hole no deeper than the roots, set the graft union 2–3 inches above the soil, backfill, firm, water deeply, mulch in a ring away from the trunk and add a trunk guard.
2. Option B: with an adult, study the tree from all sides. Mark dead, damaged and diseased wood first and remove it.
3. Then mark crossing branches, water sprouts and suckers. Make each thinning cut just outside the branch collar. Stop before removing a quarter of the tree.
4. Photograph or draw the tree before and after.
5. Plan a small orchard on graph paper: choose 4–6 trees or bushes from a catalog, with rootstock size, pollinizer pairs, bloom times and spacing. Mark sun, slope and any frost pocket from your Unit 1 map.
6. Write a five-year care calendar: planting, first pruning, training, thinning and the expected first harvest.

Tips

- No yard? Plan an orchard for a church, school or relative's yard, or plant a dwarf apple, blueberry or fig in a large container.

- Visit a pick-your-own orchard in spring or fall and ask the grower how they prune.

Check your work

- ☐ I can explain rootstocks, pollinizers and why the graft union stays above ground.
- ☐ I planted or pruned correctly and recorded before and after.
- ☐ My orchard plan shows varieties, pollinizers and spacing.
- ☐ I can explain central-leader and open-center training.

NATURE JOURNAL

1. Draw a central-leader apple tree and an open-center peach tree side by side.
2. Draw a branch collar and show where a correct cut and an incorrect flush cut would be.
3. Draw a blossom cluster on an apple spur from life, labeling the king bloom in the center.
4. Make a four-week watering log for a young tree or bed: date, rainfall from a rain gauge, water given and soil moisture by finger test.

From history. John Chapman, remembered as Johnny Appleseed, traveled the Ohio River country in the early 1800s planting apple nurseries ahead of the settlers, so families arriving on new land could buy young trees. He was also a traveling preacher who handed out pages of devotional writing along with his seedlings.

COMMON MISTAKES

- Burying the graft union when planting.
- Planting a single apple variety with no pollinizer nearby.
- Cutting flush against the trunk or leaving long stubs.
- Pruning hard in late summer, which can push tender growth that freezes.

Make it a game • Orchard Planner Challenge. Draw an orchard on paper. Parent names a fruit tree and you choose the site, rootstock and pollinizer partner. Then label a young tree's graft union and plant it above the soil line. Compare central leader and open center pruning by sketching each. Parent hides a pruning mistake in a drawing; spot the branch collar error.

Scripture. “Every branch in me that beareth not fruit he taketh away: and every branch that beareth fruit, he purgeth it, that it may bring forth more fruit.” (John 15:2, KJV)

To “purge” here means to prune. Every orchardist knows that careful cutting brings a better harvest, and Jesus used that work to describe how God shapes His people.

7.4 FIELD CROPS AND FARM MACHINERY

OBJECTIVES

- Describe the yearly cycle of corn, soybeans and wheat in the United States.
- Explain what a planter, grain drill and combine harvester do, and how they work.
- Estimate the yield of a cornfield using the yield-component method, and explain farm machinery safety.

Warm-up. Look at a bag of cornmeal, a box of cereal, a bottle of vegetable oil and a loaf of bread. For each, write which field crop it came from and guess how many people and machines it took to get from seed to store.

WATCH

How a Combine Works: A view inside the combine [4k video]

Griggs Farms LLC · 6:20

<https://www.youtube.com/watch?v=ZMDw9mUoG2M>

WHEN TO WATCH

After the combine core idea. Follow one ear of corn through each part of the machine.

KEY TERMS

row-crop planter

A machine with many row units that open a furrow, drop single seeds at a set spacing and depth, and close the soil over them.

combine harvester

A machine that cuts or gathers a crop, threshes the grain from it, separates and cleans it, and stores it in a tank, all in one pass.

grain drill

A machine that plants small grains and soybeans in many narrow rows; Jethro Tull's 1701 seed drill was an early version.

threshing

Loosening grain from the ears, heads or pods.

bushel

A unit for grain; a bushel of shelled corn weighs 56 pounds, and a bushel of soybeans or wheat weighs 60 pounds.

PTO

Power take-off: a spinning shaft that carries power from a tractor to a machine; one of the most dangerous parts of a farm.

CORE IDEAS

The great field crops of the United States are corn, soybeans and wheat, grown on hundreds of millions of acres. Corn and soybeans are planted in spring, often rotated year by year, and harvested in fall; soybeans, as legumes, add nitrogen that helps the next corn crop. Winter wheat is sown in fall, grows a little, rests under snow, and is harvested in early summer. These crops become food, livestock feed, oil and many other products. A few farmers with modern machines can now raise crops on thousands of acres.

Planting begins with seedbed preparation, either tillage (plowing, disking or chisel plowing) or no-till, planting directly into last year's residue. A **row-crop planter** plants corn in rows usually 30 inches apart. Each row unit has disc openers that slice a furrow, a seed meter that singles out seeds and drops them at an exact spacing, gauge wheels that set depth (about 1.5–2 inches for corn), and closing wheels that press soil over the seed. A **grain drill** plants wheat and often soybeans in narrow rows. Modern machines use GPS to steer and to record exactly where each seed was planted.

At harvest, the **combine** does what once took a whole crew. The header cuts the crop or snaps off the ears; the feeder house carries it inside; a spinning rotor or cylinder rubs it against a curved grate called the concave, **threshing** the grain loose; shaking sieves and a strong fan clean away chaff; and augers carry the clean grain to the tank. Straw and cobs are spread behind as residue. A yield monitor measures the grain flowing in, making a map of the best and worst parts of the field.

Farmers estimate yield before harvest by counting. For corn in 30-inch rows, measure 17 feet 5 inches of row (one-thousandth of an acre), count the harvestable ears, and on several ears count rows of kernels around and kernels along one row. Multiply ears × average rows × average kernels per row and divide by about 90 (the approximate number of kernels in a bushel, in thousands) to estimate bushels per acre. Farms are also dangerous places. Young people must stay away from **PTO**

shafts, augers, moving machines and grain bins, where flowing grain can trap a person in seconds. Many 4-H and FFA programs teach farm safety and offer tractor safety training for teenagers.

PICTURE STUDY



The Threshing Machine, Camille Pissarro, 1868 · Oil on canvas · Private collection

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

Camille Pissarro painted French country life in every season. In the 1860s, new threshing machines powered by horses or steam were changing the harvest. Here a crew works together to feed the machine.

Look closely

- Find the threshing machine. What goes in, and what comes out?
- Count the workers. What job is each one doing?
- Look for the source of power for the machine.
- Find the straw and the grain. Where does each end up?

Talk about it

1. How does a modern combine do the jobs of this machine and these workers in one pass?
2. What dangers can you see for workers around a machine like this?
3. Why would neighbors often share a threshing machine and help each other at harvest?

Safety first. Never go near a running tractor, PTO shaft, auger, combine or grain bin.
Never ride on farm equipment unless there is a proper seat and an adult allows it.
Stay where the operator can see you.

HANDS-ON PROJECT

Estimate a Corn Yield

You will estimate the yield of a cornfield (or of ears from a market) using the method agronomists use, and diagram how a combine handles the crop.

You will need

- Permission to walk the edge of a cornfield in late summer, or 6–10 ears of field or sweet corn from a market
- A tape measure
- A calculator and your nature journal

Steps

1. With permission and an adult, walk at least 30 steps into a cornfield from the edge (stay off the edge rows). Measure 17 feet 5 inches along one row.
2. Count the harvestable ears in that length. Repeat in two more places and average the counts.
3. Pick (with permission) or use every fifth ear, up to five ears. For each, count the number of kernel rows around and the number of kernels in one row from base to tip.
4. Calculate: $\text{average ears} \times \text{average rows} \times \text{average kernels per row} \div 90 = \text{estimated bushels per acre}$.
5. No field? Use market ears and assume 32 ears per one-thousandth acre; explain that assumption.
6. Convert your estimate to pounds per acre ($\text{bushels} \times 56$) and, using a recent local price per bushel, to dollars per acre.
7. Draw a labeled diagram of a combine showing header, feeder house, rotor, concave, sieves, fan, grain tank and unloading auger, with arrows for grain and for straw.

Tips

- Show every number in your calculation so someone else could check it.
- Ask a farmer or extension agent how close your estimate is to their real yield; it is often within about 10–20 percent.

Check your work

- ☐ I measured and counted carefully in more than one spot.
- ☐ My calculation is complete and correct.
- ☐ My combine diagram follows the grain and the straw.
- ☐ I can name four farm machinery dangers.

NATURE JOURNAL

1. Draw an ear of corn with the husk pulled back and label the kernel rows, silk, shank and tip.
2. Draw one planter row unit with its parts labeled.
3. Make a calendar wheel showing when corn, soybeans and winter wheat are planted and harvested.

From history. In 1831 Cyrus McCormick showed a horse-drawn reaper in Virginia that cut grain many times faster than a man with a cradle scythe, and in 1837 John Deere, a blacksmith in Illinois, made a polished steel plow that could cut through sticky prairie soil. Their inventions helped open the American prairie to farming.

COMMON MISTAKES

- Measuring yield only at the field edge, where plants are different.
- Forgetting that a bushel of corn is 56 pounds, not 60.
- Thinking a machine is safe because it is moving slowly.
- Assuming bigger machines always mean better farming; good soil care matters as much as equipment.

Make it a game • Machine Match and Yield. Match farm machines to jobs on cards: row-crop planter, grain drill, combine harvester. Parent calls the job and you slap the card, then narrate the yearly cycle of corn, soybeans or wheat. Add a yield estimate duel: guess bushels per acre from a pretend field. Closest estimate wins a point.

UNIT 7

PLANTING: GREENHOUSE, CONTAINERS, ORCHARD AND FIELD

Spring planting happens at every scale, from a tray of seedlings on a basement shelf to a lemon tree in a big pot, a new apple orchard and a thousand acres of corn. In this unit you will work through each scale in turn and learn the skills professionals use: scheduling and growing transplants under controlled conditions, repotting and root-pruning large container plants, planting and pruning fruit trees, and understanding the machines that plant and harvest field crops.

Along the way you will run a small transplant business with real costs and income, give a 4-H style illustrated talk, prepare a potted plant the way a fair judge wants to see it, and estimate the yield of a cornfield with nothing but a tape measure and a little math. Jesus said that a branch that bears fruit is pruned “that it may bring forth more fruit” (John 15:2). Careful planting and pruning are acts of hope in the harvest to come.

PREREQUISITES

- Has started seeds indoors and knows what seedlings need: warmth, light, water and air
- Knows what root-bound means
- Knows what hardening off is
- Can measure, multiply and divide decimals

MASTERY CHECKLIST

- ☐ I can schedule, start and grow transplants with correct temperature, light, water and air flow, and harden them off.
- ☐ I can keep an expense and income table for a small plant business.
- ☐ I can repot or root-prune a large container plant safely and give a illustrated talk on it.
- ☐ I can plant a bare-root fruit tree correctly and make the basic pruning cuts.
- ☐ I can explain what a planter, grain drill and combine do and estimate a corn yield.

LESSONS IN THIS UNIT

7.1 Greenhouse and Seed-Starting Operations

2 sessions of 50–60 minutes

7.2 Containers and Repotting Large Plants and Trees

2 sessions of 50–60 minutes

7.3 The Orchard: Planting and Pruning Fruit Trees

2 sessions of 50–60 minutes

7.4 Field Crops and Farm Machinery

2 sessions of 50–60 minutes

UNIT 7 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. (8 pts)

Your last frost date is May 10. On about what date should you sow peppers indoors (8–10 weeks before)? Tomatoes (6–8 weeks)?

2. (8 pts)

Name three causes of leggy seedlings and how to fix each.

3. (6 pts)

What is damping off, and name two ways to prevent it.

4. (8 pts)

Name four signs that a large potted plant needs repotting.

5. (6 pts)

What is root pruning, and when would you choose it instead of moving to a bigger pot?

6. (8 pts)

Why must the graft union of a fruit tree stay above the soil?

7. (6 pts)

What is a pollinizer, and which fruits usually need one?

8. (8 pts)

List the order of pruning decisions on a dormant fruit tree.

9. **8 pts**

Describe what happens to corn inside a combine.

10. **4 pts**

Why are grain bins dangerous?

11. **15 pts**

Written answer: In 1/1000 acre you count 32 ears. The ears average 16 rows of 35 kernels. Estimate the yield in bushels per acre and explain each step.

12. **15 pts**

Written answer: Outline a 3–5 minute illustrated talk on repotting a root-bound plant, with an introduction, steps and summary.

ANSWER KEY

1. Peppers: about March 1–15. Tomatoes: about March 15–29.
2. Too little light (lower lights, 14–16 hours on a timer); too warm after germination (move off heat mat, cooler room); too crowded (thin to one per cell). Also no air movement (add a fan).
3. A seedling rot at the soil line in cold, wet, stale conditions. Prevent with sterile mix and clean trays, not overwatering, air movement and good light.
4. Roots out the drainage hole or circling, water runs straight through, wilts soon after watering, salt crust, top-heavy pot, slowed growth.
5. Trimming 1–2 inches of outer roots and replanting in the same pot with fresh mix; chosen when the plant is already as large as you want or the pot is as large as practical.
6. If buried, the fruiting variety can form its own roots, losing the size control and other benefits of the rootstock.
7. A different compatible variety blooming at the same time nearby to supply pollen; most apples, pears and sweet cherries.
8. Remove dead, damaged and diseased wood; then crossing or rubbing branches; then water sprouts and suckers; then thin to shape (central leader or open center), removing no more than about a quarter of the live wood.
9. The header gathers and snaps ears; the feeder house carries them in; the rotor or cylinder threshes kernels loose against the concave; sieves and a fan clean out chaff; augers carry grain to the tank; cobs and stalks are spread behind.
10. Flowing grain can pull a person under and trap or suffocate them within seconds.
11. $32 \times 16 \times 35 = 17,920$; $\div 90 \approx 199$ bushels per acre. Ears per 1/1000 acre times kernels per ear gives thousands of kernels per acre; dividing by about 90 (thousand kernels per bushel) converts to bushels per acre.
12. Introduction: name, topic, why repotting matters. Steps (shown with real materials): water the day before; signs of root-bound; slide plant out; inspect roots; loosen or root-prune; choose a pot 2–4 inches wider with drainage; fresh potting mix at the same depth; firm and water; aftercare out of strong sun. Summary: restate key steps and benefits; invite questions.

PORTFOLIO PIECE: A PLANTING SEASON PORTFOLIO

Present your transplant business records (sowing calendar, growth log and expense and income table), your illustrated-talk outline and a photo or drawing of your exhibit-ready potted plant, your orchard plan or pruning before-and-after, and your corn yield estimate with the combine diagram. Add one page on what you learned about planting at each scale, from tray to field.

LOOK FOR	WHAT IT MEANS
Records	Calendar, growth log and expense and income table are complete, dated and correct.
Skill	Transplants, repotting and pruning or planting were done correctly, with evidence.
Communication	Illustrated talk outline is well organized and was delivered clearly.
Math and science	Yield estimate and explanations of machines, rootstocks and pruning are accurate.
Exhibit standards	The potted plant was prepared and self-scored against a judge's points.

PLANT HEALTH: DIAGNOSIS, PATHOGENS, PESTS AND ABIOTIC PROBLEMS

When a plant looks sick, the temptation is to guess and spray. Professionals do something better: they diagnose. Like a doctor, a plant diagnostician gathers clues (symptoms, signs, patterns, history and the condition of the roots) and rules out causes one by one before deciding what to do. In this unit you will learn that step-by-step method and then study the main groups of causes: fungal and bacterial diseases, insect pests and the many non-living, or abiotic, problems such as frost, sunscald, drought, poor drainage and chemical injury.

You will practice integrated pest management, deciding when a pest is worth acting on rather than reacting to every bug, and choosing the gentlest effective control. By the end of the year's garden you should be able to walk through a garden, notice what is wrong, explain why and plan a sensible response. Diligent watching is part of stewardship; as Proverbs warns, the field of the slothful was soon "all grown over with thorns."

PREREQUISITES

- Knows the parts of a plant and the signs of nutrient deficiency from Unit 5
- Knows the difference between bacteria and fungi from Unit 3
- Knows the life cycle stages of insects (egg, larva, pupa, adult)
- Can use a hand lens and keep a dated log

MASTERY CHECKLIST

- ☐ I can follow a step-by-step method to diagnose a plant problem and fill out a diagnostic form.
- ☐ I can tell symptoms from signs, and uniform (abiotic) patterns from spreading (biotic) patterns.
- ☐ I can identify common fungal and bacterial diseases and explain how to prevent them.
- ☐ I can scout for pests, use an action threshold and choose IPM controls from least to most intensive.
- ☐ I can recognize frost, sunscald, drought, waterlogging, salt and herbicide injury.

LESSONS IN THIS UNIT

8.1 Diagnosing Plant Problems Step by Step

2 sessions of 50–60 minutes

8.2 Fungal and Bacterial Pathogens

2 sessions of 50–60 minutes

8.3 Insect Pests and IPM Thresholds

2 sessions of 50–60 minutes

8.4 Abiotic Problems: Frost, Sunscald, Drought, Nutrient and Chemical Injury

2 sessions of 50–60 minutes

UNIT 8 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. (6 pts)

What is the difference between a symptom and a sign? Give an example of each.

2. (8 pts)

How does the pattern of damage help you decide whether a problem is biotic or abiotic?

3. (6 pts)

Name the three sides of the disease triangle.

4. (8 pts)

How can you tell early blight from Septoria leaf spot on tomato?

5. (8 pts)

How do bacteria enter and spread through plants, and what do bacterial leaf spots often look like?

6. (8 pts)

List five cultural practices that prevent plant disease.

7. (8 pts)

What is an action threshold, and why do IPM growers use one?

8. (6 pts)

Put these IPM controls in order from least to most intensive: chemical, cultural, biological, mechanical.

9. (6 pts)

Why should you leave a hornworm covered with small white cocoons?

10. (6 pts)

What does growth-regulator herbicide injury look like on tomatoes or beans?

11. (15 pts)

Written answer: After a still, clear night in mid-May, the beans and tomatoes in the lowest corner of a garden are black and limp, while the same plants near the house wall look fine. Diagnose the problem step by step and recommend what to do now and next year.

12. (15 pts)

Written answer: A gardener spreads horse manure from a neighbor's farm on her vegetable beds. Weeks later, her tomatoes and beans have twisted, cupped new leaves, but her corn looks normal. Explain the likely cause, how she could have tested for it, and what she should do now.

ANSWER KEY

1. A symptom is the plant's response (wilting, yellowing, spots); a sign is evidence of the cause itself (aphids, mold, spores, bacterial ooze, frass).
2. Abiotic problems appear suddenly, affect many plant kinds and line up with a cause (wind, slope, driveway); biotic problems start on one kind of plant, appear scattered and spread over time.
3. Susceptible host, pathogen and favorable environment.
4. Early blight makes larger brown spots with concentric target rings on lower leaves; Septoria makes many small round spots with dark borders and pale centers, often with tiny black specks.
5. Through stomata, wounds and cuts; spread by splashing water, hands, tools and insects. Spots often look water-soaked, greasy and angular because veins limit them.
6. Any five: resistant varieties, crop rotation, spacing and pruning for air flow, watering soil in the morning, mulching, staying out of wet plants, removing infected leaves, cleaning tools, end-of-season cleanup.
7. The pest level at which control becomes worth the cost and effort; it prevents unnecessary spraying, saves money and protects beneficial insects.
8. Cultural, mechanical, biological, chemical (cultural and mechanical may be swapped; chemical is always last).
9. The cocoons are parasitic wasps that will hatch and attack more hornworms; they are beneficial insects.
10. Cupped, twisted, curled leaves, narrow strap-like new leaves and bending stems.
11. Pattern: sudden, several plant kinds, only in the low spot and not by the warm wall, after a clear still night: abiotic, frost injury in a frost pocket (Unit 1). Now: wait a few days to see if growing points recover, trim dead tissue, replant if killed. Next year: plant tender crops after the last frost date, avoid the frost pocket or use row covers and cold frames, watch forecasts and cover plants on frost nights.
12. Likely persistent herbicide residue in the manure, from hay or pasture treated with a broadleaf herbicide; it passed through the horses and stayed active. Corn (a grass) is tolerant; tomatoes and beans are very sensitive. A bean or pea bioassay (sample mixed with potting mix versus a control) would have shown it. Now: ask the farm about herbicides used, stop using that manure, plant tolerant crops such as corn in those beds, add clean organic matter and allow time for

breakdown, and test the soil again with a bioassay before planting sensitive crops.

PORTFOLIO PIECE: A PLANT DOCTOR'S CASE FILES

Assemble a case file of at least five diagnosed plant problems from this unit and from your garden all year: at least one fungal or bacterial disease, one insect pest with your IPM log and threshold, and two abiotic problems, including your bioassay. For each case include photos or drawings, your diagnostic form, the evidence, your conclusion and what you did. Finish with a one-page “Garden Health Plan” for next season.

LOOK FOR	WHAT IT MEANS
Method	Each case follows the diagnostic steps and separates symptoms, signs and patterns.
Accuracy	Diagnoses are reasonable, supported by evidence and checked against extension references.
IPM reasoning	Actions start with the least intensive control and are tied to a written threshold.
Records	Photos, drawings, counts and dates are clear and complete.
Health plan	Next season's plan uses prevention: rotation, resistant varieties, spacing, watering, sanitation and scouting.

8.1 DIAGNOSING PLANT PROBLEMS STEP BY STEP

OBJECTIVES

- Follow a step-by-step diagnostic method: know the plant, describe the problem, look for patterns, check the whole plant and ask about history.
- Distinguish symptoms from signs and biotic from abiotic patterns.
- Complete a diagnostic form and know when to send a sample to an extension plant clinic.

Warm-up. Your friend says, “My tomato is dying. What should I spray?” Write five questions you would ask before giving any advice.

WATCH

Guidelines for Diagnosing Plant Problems

UNH Extension · 6:42

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

WHEN TO WATCH

After the core ideas. List each guideline and match it to a step in your diagnostic form.

KEY TERMS

symptom

The plant’s response to a problem, such as wilting, yellowing, spots or stunting.

biotic

Caused by a living thing: a fungus, bacterium, virus, insect, mite, nematode or animal.

sign

Visible evidence of the cause itself: fungal growth or spores, bacterial ooze, insects, eggs, webbing or frass (insect droppings).

abiotic

Caused by a non-living factor: weather, water, soil, nutrients, chemicals or mechanical damage.

diagnosis

Identifying the cause of a problem by gathering evidence and ruling out other causes.

plant diagnostic clinic

A laboratory, usually run by a state university extension service, that identifies plant diseases and pests from samples.

CORE IDEAS

Good diagnosis starts with knowing the plant. What is it, and what does it look like when healthy? Some “problems” are normal: the lower leaves of many plants yellow and drop with age, and some varieties have spotted or purple leaves. Next, describe the problem exactly. Which parts are affected (roots, stem, leaves, flowers, fruit), old or new growth, one side or all over? When did it begin, and is it getting worse?

Separate **symptoms**, the plant’s reaction, from **signs**, evidence of the cause itself. Yellow leaves are a symptom; aphids underneath are a sign. Then look at the **pattern**. A problem that appeared all at once, affects several different kinds of plants and has sharp edges (for example, all plants along a driveway, or every leaf facing the wind) points to an **abiotic** cause such as frost, chemical drift or salt. A problem that starts on a few plants of one kind, appears scattered, and spreads over days or weeks points to a **biotic** cause, a living pest or pathogen.

Look at the whole plant, including the roots. Many leaf problems start below ground: rotted, brown, mushy roots from waterlogging, roots circling in a pot, girdling by voles, or a trunk wound from a mower. Gently dig at the edge of the root zone. Healthy roots are usually white or tan and firm. Ask about history: recent weather (frost, heat, heavy rain, drought), watering, fertilizer, sprays on the lawn or by neighbors, new mulch or manure, construction or soil disturbance.

Put the evidence together, list possible causes and test each against the clues. Use reliable references, such as your state extension service’s fact sheets. If you are unsure, take good photos (the whole plant, the affected part and a close-up) or send a fresh sample to your county extension office or state **plant diagnostic clinic**. Only then choose a response. Many problems need no spray at all: better watering, a soil test, removing an infected leaf or simply waiting for weather to improve.

PICTURE STUDY



Hollyhocks and Other Flowers in a Vase, Jan van Huysum, about 1702–1720 · Oil on canvas · The National Gallery, London

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

Jan van Huysum was the most admired flower painter of his age. He painted each blossom from life, and his bouquets often include tiny insects, wilting petals and leaves with holes and spots, painted with complete honesty. Look at it as a plant diagnostician would.

Look closely

- Find a leaf with holes, spots or browning. Is the damage a symptom or a sign?
- Find any insects, snails or other small creatures. What might they be doing to the flowers?
- Find flowers at different stages: buds, fresh blooms and fading ones.
- Look for any drooping stems or petals. What could cause them?

Talk about it

1. Which damage in this painting do you think was caused by a living thing, and which by age or dryness?
2. Why do you think van Huysum painted imperfect leaves instead of perfect ones?

3. What questions would you ask the gardener who grew these flowers?

HANDS-ON PROJECT

The Plant Detective Casebook

You will diagnose three real plant problems using a diagnostic form, and record your evidence and conclusions as a professional would.

You will need

- Three plants with problems (garden, houseplants, a park or a neighbor's yard with permission)
- A hand lens, a trowel, a ruler and a camera
- A diagnostic form you make in your journal
- Extension fact sheets for your state (online or print)

Steps

1. Make a one-page diagnostic form with sections: plant name, normal appearance, symptoms, signs, parts affected, pattern (in the plant and across the garden), roots and soil, recent history, possible causes, most likely cause, evidence, recommended action.
2. For each of three problem plants, fill out the form completely. Photograph the whole plant, the affected part and a close-up.
3. Check the roots of at least one plant by gently digging at the edge of the root zone.
4. List at least three possible causes for each case and explain which evidence rules each in or out.
5. Check your conclusion against an extension fact sheet.
6. Recommend an action for each case, starting with the least intensive.
7. Optional: with an adult, contact your county extension office to submit a sample of a puzzling case and compare the result with your diagnosis.

Tips

- Look at healthy plants of the same kind nearby; comparison is one of the best diagnostic tools.
- Many Master Gardener programs run plant clinics at farmers' markets and county fairs; watching one is great practice.

Check your work

- ☐ I completed three diagnostic forms with evidence.
- ☐ I separated symptoms from signs.
- ☐ I used the pattern to decide between biotic and abiotic causes.
- ☐ My recommended actions start with the least intensive.

NATURE JOURNAL

1. Draw a diagnostic flow chart from “Is the problem on one kind of plant or many?” to biotic or abiotic.
2. Draw one symptom and one sign from your cases, enlarged and labeled.
3. Draw a garden bed map showing where problem plants are, to show the pattern.

From history. Every state’s land-grant university runs an extension service, and most have a plant diagnostic clinic. Many county fairs host Master Gardener booths where volunteers help visitors identify plant problems, and some 4-H and FFA programs hold plant and insect identification contests; check your county extension office or fair book.

COMMON MISTAKES

- Spraying before diagnosing.
- Blaming the insect you happen to see, when it may be harmless or even a predator.
- Looking only at the leaves and never at roots, soil or watering.
- Mistaking normal aging of lower leaves for disease.

Make it a game • Plant Detective Questions. Parent invents a mystery plant problem and gives clues only when you ask the five diagnostic steps in order: know the plant, describe the problem, look for patterns, check the whole plant, ask about history. Decide symptom or sign, biotic or abiotic. Solve the case in fewer questions than your last one.

8.2 FUNGAL AND BACTERIAL PATHOGENS

OBJECTIVES

- Explain the disease triangle and how fungi, water molds and bacteria infect plants and spread.
- Identify common diseases such as early blight, Septoria leaf spot, powdery mildew, late blight, bacterial spot, bacterial wilt and fire blight.
- Plan cultural controls that prevent disease, and explain when fungicides are used and who should apply them.

Warm-up. Look at a moldy piece of fruit or bread through a sealed clear bag (do not open or smell it). Draw what you see with a hand lens. How do you think the mold got there, and how might it spread?

WATCH

Scouting and Identifying Tomato Diseases

Penn State Extension • 8:20

<https://www.youtube.com/watch?v=eQjmP9Jr6hA>

WHEN TO WATCH

After the core ideas. For each disease shown, note the symptoms and whether you see a sign.

KEY TERMS

pathogen

A living organism that causes disease, such as a fungus, water mold, bacterium, virus or nematode.

spore

A tiny reproductive cell of a fungus or water mold that spreads by wind, water splash, insects or tools.

disease triangle

The idea that disease needs three things at once: a susceptible host, a pathogen and a favorable environment.

lesion

A spot of diseased tissue on a leaf, stem or fruit.

resistant variety

A variety bred to resist certain diseases; tomato labels use codes such as V (verticillium), F (fusarium) and N (nematodes).

sanitation

Removing diseased plant material and cleaning tools so pathogens do not spread or survive to next season.

CORE IDEAS

Disease happens only when three things meet: a susceptible **host**, a **pathogen** and a favorable **environment**, usually warmth plus moisture. This **disease triangle** is the key to prevention: take away any one side and disease cannot develop. Most fungal **spores** need a film of water on the leaf for several hours to germinate and enter through stomata or wounds. That is why wet leaves at night, crowded plants and splashing rain or sprinklers favor disease, and why watering the soil in the morning helps so much.

Fungi often show **signs** you can see with a hand lens: powdery growth, fuzzy mold or tiny black specks of fruiting bodies. **Early blight** of tomato makes brown spots with target-like rings, starting on the lowest leaves; **Septoria leaf spot** makes many small, round spots with dark borders and pale centers, often with black specks inside. **Powdery mildew** coats squash, cucumber and many other leaves with white powder, especially when days are dry and nights humid. **Late blight**, caused by a water mold (a fungus-like organism), makes large, greasy, gray-green lesions with white fuzz under the leaf in cool, wet weather, and can destroy tomatoes and potatoes within days.

Bacteria are single cells. They cannot pierce a leaf, so they enter through stomata, wounds and pruning cuts, and they spread in splashing water, on hands and tools and by insects. Bacterial lesions often look water-soaked or greasy and angular, because the veins hem them in, and may ooze in wet weather. **Bacterial spot** pocks tomato and pepper leaves and fruit. **Bacterial wilt** of cucumbers and melons is spread by cucumber beetles; cut a wilted stem and touch the cut ends together, and fine, sticky strands may stretch between them. **Fire blight** makes the tips of pear and apple shoots blacken and bend into a shepherd's crook, as if scorched by fire.

Prevention is far easier than cure. Choose **resistant varieties**, rotate crop families so pathogens in the soil die out, space and prune plants for air flow, water the soil rather than the leaves, mulch to stop soil splashing onto lower leaves, stay out of the

garden when plants are wet, remove infected leaves promptly and clean pruners between plants when cutting out disease. At season's end, remove diseased plants rather than composting them in a cool pile. Fungicides, including copper and sulfur products, can protect healthy tissue but cannot cure infected leaves; any spraying is an adult's job, done only after reading and following the label.

PICTURE STUDY



Potato Planters, Jean-François Millet, about 1861 · Oil on canvas · Museum of Fine Arts, Boston

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

Millet painted a farm couple planting potatoes in spring, working together in rhythm. Only fifteen years earlier, a new disease, late blight, had destroyed potato crops across Europe. Look at this picture with that history in mind.

Look closely

- Find the seed potatoes being dropped into the ground. What could they carry into the new field?
- Look at the spacing between holes. Why does spacing matter for disease?
- Look at the weather and soil. Is it wet or dry today?
- Find the basket and tools. How could tools spread disease from one field to another?

Talk about it

1. Why do farmers today buy certified disease-free seed potatoes?
2. What weather would worry this farmer most later in the summer, and why?
3. How could crop rotation protect next year's potatoes?

Safety first. Wear gloves when handling diseased plants and wash your hands and tools afterward. Never handle fungicides or other garden chemicals yourself; an adult must read and follow the label.

HANDS-ON PROJECT

Disease Scouting and a Prevention Plan

You will scout tomato, squash, bean or other garden plants (or houseplants) for disease once a week for three weeks, identify what you find, and write a prevention plan for next season.

You will need

- Garden plants, a community garden plot or houseplants
- A hand lens, a camera and plant labels
- Clean pruners and a bucket of soapy water or rubbing alcohol for cleaning blades (adult supervision)
- Extension fact sheets on common diseases in your state

Steps

1. Choose five plants of the same kind and label them. Each week, inspect every leaf from bottom to top, both sides.
2. Record the number of leaves with spots or other symptoms, and describe and photograph each kind of symptom. Look for signs with the hand lens.
3. Identify each problem using extension fact sheets, and decide whether it is fungal, bacterial or something else.
4. With an adult, remove badly infected leaves into a bag (not the compost), cleaning pruners between plants. Record what you removed.
5. Note the weather each week: rain, dew, temperature. Look for links between weather and new disease.
6. Graph the number of diseased leaves per plant over three weeks.
7. Write a prevention plan for next year using the disease triangle: resistant varieties, rotation, spacing, watering, mulch and sanitation.

Tips

- Scout in the morning after dew dries, so you do not spread spores on wet leaves.
- Disease often starts on the lowest, oldest leaves; begin your inspection there.

Check your work

- ☐ I scouted on a regular schedule and recorded counts.
- ☐ I identified at least two problems and classified them.
- ☐ I can explain each side of the disease triangle.
- ☐ My prevention plan has at least five specific steps.

NATURE JOURNAL

1. Draw the disease triangle and write a prevention method next to each side.
2. Draw leaves with early blight, Septoria leaf spot and bacterial spot side by side, labeling differences.
3. Draw a fire blight shoot showing the shepherd's crook.

From history. In 1845 late blight swept through Europe's potato fields, and in Ireland, where many poor families depended almost entirely on potatoes, the result was famine and great suffering. In 1861 the German scientist Anton de Bary showed by careful experiments that a living organism caused the disease, helping to establish the science of plant pathology.

COMMON MISTAKES

- Watering with a sprinkler in the evening, which leaves foliage wet all night.
- Composting diseased plants in a cool pile that does not kill pathogens.
- Planting tomatoes and potatoes in the same spot every year.
- Expecting a fungicide to cure leaves that are already infected.

Make it a game • Name That Blight. Parent describes a disease by leaf spots, rings, fuzz, wilting or oozing, and you name it: early blight, Septoria leaf spot, powdery mildew, late blight, bacterial spot, bacterial wilt or fire blight. Say if it is fungal, water mold or bacterial and how it spreads. Name one sanitation step. Beat your streak of correct names.

8.3 INSECT PESTS AND IPM THRESHOLDS

OBJECTIVES

- Explain the steps of integrated pest management: prevention, monitoring, identification, thresholds and control.
- Scout plants with counts and use an action threshold to decide whether to act.
- Choose controls from least to most intensive, protecting beneficial insects and pollinators.

Warm-up. Look under five leaves of a garden plant or houseplant. Count every insect or mite you see, and sort them into “eating the plant,” “eating other insects” and “not sure.” How many did you see in total?

WATCH

Integrated Pest Management (IPM) Scouting in Vegetable Crops

Penn State Pesticide Education Program • 6:07

https://www.youtube.com/watch?v=3U3hQuKN_nE

WHEN TO WATCH

After the core ideas, before the project. Note how the scout chooses plants and records counts.

KEY TERMS

integrated pest management (IPM)

A decision-making approach that combines prevention, monitoring and several kinds of control, using chemicals only when needed and as precisely as possible.

action threshold

The pest level at which damage becomes serious enough that control is worth its cost and effort.

scouting

Regularly inspecting a sample of plants and counting pests, damage and beneficial insects.

beneficial insect

An insect that helps the grower, such as a pollinator or a predator or parasite of pests.

complete metamorphosis

A life cycle with egg, larva, pupa and adult stages, as in beetles, moths and flies; the larva often does the most feeding damage.

frass

Insect droppings, often a sign of caterpillars or borers.

CORE IDEAS

Most insects in a garden are harmless or helpful: pollinators, decomposers and predators such as lady beetles, lacewings, ground beetles, spiders and tiny parasitic wasps. Only a few are serious pests. **Integrated pest management** starts with **prevention**: healthy soil, the right plant in the right place, resistant varieties, crop rotation, row covers on young crops and flowers that feed beneficial insects. Then comes **monitoring**, or **scouting**: once or twice a week, inspect a set number of plants in a set pattern, look under leaves, and count pests, eggs, damage and beneficials.

Correct identification matters. Squash bugs lay clusters of shiny, bronze eggs on leaf undersides; their gray nymphs feed in groups. Squash vine borers are moth larvae that tunnel into stems, leaving piles of sawdust-like **frass**. Colorado potato beetles lay orange egg clusters; their humpbacked red larvae strip leaves. Tomato hornworms are big green caterpillars; one covered in small white cocoons is hosting parasitic wasps and should be left alone. Knowing the life cycle shows when a pest is easiest to control: eggs and young larvae are easier to stop than adults.

An **action threshold** is the point at which the pest is worth acting on. Farmers set economic thresholds from research: below them, control costs more than the damage it prevents. Gardeners set their own, based on how much damage they can accept. A few aphids on a healthy plant with lady beetles present need no action; a colony spreading on young seedlings may. Thresholds keep growers from spraying out of fear, which wastes money and kills the beneficial insects that were keeping pests in check.

When action is needed, IPM moves from the least intensive control to the most.

Cultural: change planting dates, rotate, remove crop debris. **Mechanical and physical**: hand-pick beetles into soapy water, scrape off egg clusters, blast aphids with water, use row covers, traps and barriers. **Biological**: protect and attract predators and parasites. **Chemical**, last: the least toxic, most targeted product,

applied only by an adult following the label, at a time when bees are not foraging.
Then keep scouting to see whether the action worked.

PICTURE STUDY



Metamorphosis of a Small Emperor Moth on a Damson Plum, Maria Sibylla Merian, 1679 · Hand-colored engraving · *The Caterpillar Book*; J. Paul Getty Museum, Los Angeles

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

Maria Sibylla Merian was a German naturalist and artist who raised caterpillars at home and drew each stage of their lives on the plants they ate. At a time when many people thought insects came from mud, she showed their real life cycles. This plate shows every stage of one moth on a plum branch.

Look closely

- Find each stage of the life cycle: egg, caterpillar, cocoon and adult moth.
- Find leaves that have been eaten. Which stage does the damage?
- Look at the caterpillar's colors. How do they help it hide on the plant?
- Find the fruit. Has it been damaged?

Talk about it

1. At which stage would a fruit grower most want to find and control this insect?
2. Why is it important to identify an insect before deciding to control it?
3. How did Merian's method of raising insects make her pictures more accurate?

Safety first. Wear gloves when hand-picking beetles or caterpillars, since some have irritating hairs or spines. Never handle insecticides; any spraying is done by an adult following the label. Watch for stinging insects, and tell an adult right away if you are stung and have an allergy.

HANDS-ON PROJECT

A Three-Week IPM Scouting Program

You will scout a crop twice a week for three weeks, set an action threshold, take action only when it is reached, and record everything in an IPM log.

You will need

- A garden crop (squash, beans, potatoes, cabbage-family plants or roses) or houseplants
- A hand lens, a clipboard or journal, and a white sheet of paper or tray for tapping insects onto
- A jar of soapy water for hand-picked pests
- Yellow sticky cards (optional)
- Extension fact sheets on pests and beneficial insects

Steps

1. Choose 10 plants spread across the bed. Number them and scout the same plants each time.
2. On each plant, check three leaves (top, middle and bottom), both sides. Count pests, egg clusters, damaged leaves and beneficial insects. Tap one branch over white paper to dislodge small insects.
3. Identify each pest and beneficial with fact sheets. Draw any you cannot identify.
4. Set your action threshold in writing before you start, for example “act when more than 3 of 10 plants have squash bug egg clusters” or “act when 25 percent of leaves have holes.”
5. When the threshold is reached, choose the least intensive effective control (scrape eggs, hand-pick, row cover, water spray) and record what you did.
6. Keep scouting to measure whether the control worked. Graph pest counts and beneficial counts over three weeks.
7. Write a report: did you reach your threshold? Which controls worked? How did beneficial insects affect the pests?

Tips

- Scout at the same time of day each visit; many insects hide in the heat of the afternoon.
- Leave hornworms with white cocoons in place; the wasps inside will hatch and find more hornworms.

Check your work

- ☐ I scouted the same plants on a schedule and recorded counts.
- ☐ I wrote an action threshold before acting.
- ☐ I used the least intensive control that worked.
- ☐ My graph compares pests and beneficial insects over time.

NATURE JOURNAL

1. Draw the life cycle of one garden pest (egg, larva or nymph, pupa if any, adult) with the damaging stage circled.
2. Draw a lady beetle larva actual size and enlarged; many gardeners mistake it for a pest.
3. Draw the IPM ladder from prevention at the bottom to chemical control at the top.

From history. When cotton farmers in the American South were battling the boll weevil in the early 1900s, extension agents like Seaman Knapp set up model farms to show neighbors that changes in planting and field cleanup could reduce the damage. Ideas like these grew into today's integrated pest management.

COMMON MISTAKES

- Spraying at the first sight of any insect.
- Killing lady beetle larvae or parasitized hornworms by mistake.
- Scouting only once, too late, after the damage is done.
- Spraying flowering plants while bees are foraging.

Make it a game • Threshold Decision Game. Parent hides paper pests on a pretend plant row in three weekly rounds. You scout, count and record, then compare to an action threshold the parent states. Decide: act or keep watching? Name the IPM step you are on and a beneficial insect that might help. Frass counts as evidence. Make the right decision all three weeks.

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 wise man noticed what had gone wrong in a neglected field and learned from it. Regular scouting is the diligent gardener’s way of seeing problems before they take over.

8.4 ABIOTIC PROBLEMS: FROST, SUNSCALD, DROUGHT, NUTRIENT AND CHEMICAL INJURY

OBJECTIVES

- Recognize the symptoms of frost, heat and sunscald, drought, waterlogging, salt and fertilizer burn, and mechanical injury.
- Recognize herbicide injury and explain how herbicides can reach a garden through drift, lawn care and contaminated manure or compost.
- Run a bioassay to test compost or manure for herbicide residue.

Warm-up. Walk around your home or school and find three plants that look damaged. For each, look at the pattern: does the damage line up with a wall, a driveway, the direction of the wind or the sun? Write your guesses.

WATCH

Abiotic Disorders

UNH Extension • 6:32

<https://www.youtube.com/watch?v=W1vBXFotKlc>

WHEN TO WATCH

After the core ideas. List each abiotic disorder shown and the clue that identifies it.

KEY TERMS

frost injury

Damage from ice forming in plant tissue; leaves look water-soaked, then turn black or brown and limp.

sunscald

Sun damage to tissue suddenly exposed to strong light: white, papery patches on fruit, or cracked bark on the southwest side of young tree trunks in winter.

leaf scorch

Browning of leaf edges and tips from drought, heat, wind or salt, when water cannot reach the leaf edges fast enough.

herbicide drift

Weed-killer spray or vapor moving through the air from where it was applied onto other plants.

persistent herbicide

A weed killer that stays active for months or years in hay, manure and compost and can damage sensitive garden plants.

bioassay

A test that uses living organisms, such as bean seedlings, to detect a substance.

CORE IDEAS

Many plant problems have no pest or pathogen at all. These **abiotic** disorders often show a telltale pattern: sudden onset, many kinds of plants affected, and damage that lines up with a cause, such as the windward side, the low spot, the edge by the driveway or the leaves facing the sun. They do not spread from plant to plant over time, although weakened plants may later be attacked by pests and diseases.

Weather is the most common cause. **Frost** makes tender leaves look water-soaked, then black and limp; it strikes low spots and exposed plants first, and the edges between damaged and healthy tissue are sharp. Heat and drought cause wilting, **leaf scorch** on leaf edges, blossom drop and small fruit. **Sunscald** leaves white, papery patches on tomatoes and peppers that lost their leaf cover, and in winter it splits the southwest side of young tree trunks as bark warms by day and freezes at night; painting trunks with white latex paint or wrapping them prevents it. Waterlogged soil drowns roots, so plants wilt and yellow even though the soil is wet. Hail shreds leaves and bruises fruit on the side facing the storm.

Soil and care problems are abiotic too. Nutrient deficiencies (Unit 5) and pH problems cause typical yellowing patterns. Too much fertilizer or road salt burns roots and browns leaf edges. **Blossom-end rot** of tomatoes is calcium not reaching the fruit, usually because of uneven watering. Mechanical injury includes mower and string-trimmer wounds on trunks, broken roots from construction, compacted soil and girdling ties left on trees. Correcting the cause, not spraying, is the cure.

Herbicides cause some of the most confusing damage. Growth-regulator weed killers used on lawns and fields make tomato, grape, bean and pepper leaves cup, twist and curl, with stems bending and leaves narrowing into strap shapes. They can reach a garden by **drift** on windy or hot days, from lawn treatments near the garden, or in hay, straw, manure and compost from fields treated with **persistent herbicides**, which pass through animals and stay active in manure for a long time. Ask suppliers about any herbicides used, and test unknown manure or compost with a simple **bioassay** before using it on vegetables.

PICTURE STUDY



Hoarfrost, Camille Pissarro, 1873 · Oil on canvas · Musée d'Orsay, Paris

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

Pissarro painted a winter morning outside Pontoise, France, when frost lay white over the ploughed fields. Look at where the frost lies and where it has already melted.

Look closely

- Find where the frost is thickest and where it has melted. What is different about those places?
- Look at the long shadows. Where is the sun, and what time of day might it be?
- Look at the slope of the fields. Where would cold air settle?
- Find any trees or hedges. Would they protect plants from frost?

Talk about it

1. Why does frost stay longest in shadows and low places?
2. What would a frost like this do to tender plants such as tomatoes or beans?
3. How could a gardener protect plants on a night when hoarfrost is expected?

Safety first. Wear gloves and wash hands after handling manure, compost or soil samples. Never handle herbicides or other garden chemicals yourself, and stay indoors or away when an adult is spraying.

HANDS-ON PROJECT

Herbicide Bioassay and Abiotic Survey

You will test compost or manure for herbicide residue with a bean bioassay, and survey your yard or a park for abiotic problems.

You will need

- Two or three samples of compost, manure or soil you plan to use, and bagged potting mix as a control
- Six small pots and labels
- Bush bean or pea seeds (very sensitive to many herbicides)
- A ruler, camera and your nature journal

Steps

1. Mix each test sample half and half with potting mix. Fill two pots per sample, and two pots with plain potting mix as the control. Label all pots.
2. Plant three bean or pea seeds in each pot. Keep all pots together in the same light and water them the same.
3. After the seedlings have three sets of true leaves (about 2–3 weeks), compare test plants with the control. Look for cupped, twisted, crinkled or strap-like leaves and bent stems.
4. Record and photograph the results. Decide whether each sample is safe for vegetables.
5. Survey your yard, school or a park for abiotic problems. Find at least four examples (frost, sunscald, scorch, salt, waterlogging, mower injury, compaction) and record the pattern and evidence for each.
6. For each, write the most likely cause and a correction.

Tips

- Some persistent herbicide damage shows up only on new leaves, so wait until the third set of leaves before judging.
- Spring is a good time to look for winter injury on evergreens and young trees, and late spring for frost damage.

Check your work

- ☐ I ran a bioassay with a control and compared results carefully.
- ☐ I can describe the leaf symptoms of herbicide injury.
- ☐ I found and explained at least four abiotic problems using their patterns.
- ☐ I can explain how herbicides can get into manure and compost.

NATURE JOURNAL

1. Draw a normal bean leaf and a herbicide-injured bean leaf side by side.
2. Draw a young tree trunk with sunscald on the southwest side and a white-painted trunk beside it.
3. Record the dates of your first and last frost this year and compare them with the averages from Unit 1.

From history. Old farmers' almanacs and county extension offices have long kept records of frost dates and weather. Many county fairs still give awards for the best-kept garden record book; a journal like yours, with dates, weather and observations, is exactly what judges look for.

COMMON MISTAKES

- Treating abiotic damage with fungicides or insecticides.
- Using manure or straw from an unknown source on the vegetable garden without asking or testing.
- Pruning away the leaves that shade tomato fruit, which leads to sunscald.
- Assuming every wilting plant needs more water, when the soil may already be waterlogged.

Make it a game • Injury Clue Sort. Make cards for frost, sunscald, drought, waterlogging, fertilizer burn and herbicide injury, then a pile of symptom clues. Parent reads a clue and you sort it, explaining the pattern. Explain how herbicide drift, lawn products or contaminated manure can reach a garden and what a bioassay tests. Sort twelve clues correctly to win.

PLANT HEALTH: DIAGNOSIS, PATHOGENS, PESTS AND ABIOTIC PROBLEMS

When a plant looks sick, the temptation is to guess and spray. Professionals do something better: they diagnose. Like a doctor, a plant diagnostician gathers clues (symptoms, signs, patterns, history and the condition of the roots) and rules out causes one by one before deciding what to do. In this unit you will learn that step-by-step method and then study the main groups of causes: fungal and bacterial diseases, insect pests and the many non-living, or abiotic, problems such as frost, sunscald, drought, poor drainage and chemical injury.

You will practice integrated pest management, deciding when a pest is worth acting on rather than reacting to every bug, and choosing the gentlest effective control. By the end of the year's garden you should be able to walk through a garden, notice what is wrong, explain why and plan a sensible response. Diligent watching is part of stewardship; as Proverbs warns, the field of the slothful was soon "all grown over with thorns."

PREREQUISITES

- Knows the parts of a plant and the signs of nutrient deficiency from Unit 5
- Knows the difference between bacteria and fungi from Unit 3
- Knows the life cycle stages of insects (egg, larva, pupa, adult)
- Can use a hand lens and keep a dated log

MASTERY CHECKLIST

- ☐ I can follow a step-by-step method to diagnose a plant problem and fill out a diagnostic form.
- ☐ I can tell symptoms from signs, and uniform (abiotic) patterns from spreading (biotic) patterns.
- ☐ I can identify common fungal and bacterial diseases and explain how to prevent them.
- ☐ I can scout for pests, use an action threshold and choose IPM controls from least to most intensive.
- ☐ I can recognize frost, sunscald, drought, waterlogging, salt and herbicide injury.

LESSONS IN THIS UNIT

8.1 Diagnosing Plant Problems Step by Step

2 sessions of 50–60 minutes

8.2 Fungal and Bacterial Pathogens

2 sessions of 50–60 minutes

8.3 Insect Pests and IPM Thresholds

2 sessions of 50–60 minutes

8.4 Abiotic Problems: Frost, Sunscald, Drought, Nutrient and Chemical Injury

2 sessions of 50–60 minutes

UNIT 8 REVIEW

Answer each question in complete sentences without notes. Questions 11 and 12 need a short paragraph. Total: 100 points.

1. **6 pts**

What is the difference between a symptom and a sign? Give an example of each.

2. **8 pts**

How does the pattern of damage help you decide whether a problem is biotic or abiotic?

3. **6 pts**

Name the three sides of the disease triangle.

4. **8 pts**

How can you tell early blight from Septoria leaf spot on tomato?

5. **8 pts**

How do bacteria enter and spread through plants, and what do bacterial leaf spots often look like?

6. **8 pts**

List five cultural practices that prevent plant disease.

7. **8 pts**

What is an action threshold, and why do IPM growers use one?

8. (6 pts)

Put these IPM controls in order from least to most intensive: chemical, cultural, biological, mechanical.

9. (6 pts)

Why should you leave a hornworm covered with small white cocoons?

10. (6 pts)

What does growth-regulator herbicide injury look like on tomatoes or beans?

11. (15 pts)

Written answer: After a still, clear night in mid-May, the beans and tomatoes in the lowest corner of a garden are black and limp, while the same plants near the house wall look fine. Diagnose the problem step by step and recommend what to do now and next year.

12. (15 pts)

Written answer: A gardener spreads horse manure from a neighbor's farm on her vegetable beds. Weeks later, her tomatoes and beans have twisted, cupped new leaves, but her corn looks normal. Explain the likely cause, how she could have tested for it, and what she should do now.

ANSWER KEY

1. A symptom is the plant's response (wilting, yellowing, spots); a sign is evidence of the cause itself (aphids, mold, spores, bacterial ooze, frass).
2. Abiotic problems appear suddenly, affect many plant kinds and line up with a cause (wind, slope, driveway); biotic problems start on one kind of plant, appear scattered and spread over time.
3. Susceptible host, pathogen and favorable environment.
4. Early blight makes larger brown spots with concentric target rings on lower leaves; Septoria makes many small round spots with dark borders and pale centers, often with tiny black specks.
5. Through stomata, wounds and cuts; spread by splashing water, hands, tools and insects. Spots often look water-soaked, greasy and angular because veins limit them.
6. Any five: resistant varieties, crop rotation, spacing and pruning for air flow, watering soil in the morning, mulching, staying out of wet plants, removing infected leaves, cleaning tools, end-of-season cleanup.
7. The pest level at which control becomes worth the cost and effort; it prevents unnecessary spraying, saves money and protects beneficial insects.
8. Cultural, mechanical, biological, chemical (cultural and mechanical may be swapped; chemical is always last).
9. The cocoons are parasitic wasps that will hatch and attack more hornworms; they are beneficial insects.
10. Cupped, twisted, curled leaves, narrow strap-like new leaves and bending stems.
11. Pattern: sudden, several plant kinds, only in the low spot and not by the warm wall, after a clear still night: abiotic, frost injury in a frost pocket (Unit 1). Now: wait a few days to see if growing points recover, trim dead tissue, replant if killed. Next year: plant tender crops after the last frost date, avoid the frost pocket or use row covers and cold frames, watch forecasts and cover plants on frost nights.
12. Likely persistent herbicide residue in the manure, from hay or pasture treated with a broadleaf herbicide; it passed through the horses and stayed active. Corn (a grass) is tolerant; tomatoes and beans are very sensitive. A bean or pea bioassay (sample mixed with potting mix versus a control) would have shown it. Now: ask the farm about herbicides used, stop using that manure, plant tolerant crops such as corn in those beds, add clean organic matter and allow time for

breakdown, and test the soil again with a bioassay before planting sensitive crops.

PORTFOLIO PIECE: A PLANT DOCTOR'S CASE FILES

Assemble a case file of at least five diagnosed plant problems from this unit and from your garden all year: at least one fungal or bacterial disease, one insect pest with your IPM log and threshold, and two abiotic problems, including your bioassay. For each case include photos or drawings, your diagnostic form, the evidence, your conclusion and what you did. Finish with a one-page “Garden Health Plan” for next season.

LOOK FOR	WHAT IT MEANS
Method	Each case follows the diagnostic steps and separates symptoms, signs and patterns.
Accuracy	Diagnoses are reasonable, supported by evidence and checked against extension references.
IPM reasoning	Actions start with the least intensive control and are tied to a written threshold.
Records	Photos, drawings, counts and dates are clear and complete.
Health plan	Next season's plan uses prevention: rotation, resistant varieties, spacing, watering, sanitation and scouting.