

GRADE 8 GARDENING & ANIMALS

First edition

8 units

32 lessons

A video for every lesson

FIRST EDITION

COURSE GUIDE

This is the capstone of the School Launch Gardening & Animals sequence. Students who have spent eight years planting seeds, keeping journals and caring for animals now learn the reasons behind the work at a level close to a high-school agriculture or biology course. They study soil as a chemical and living system, follow nitrogen, phosphorus and potassium through the farm, work Punnett squares for pea plants and chickens, read a feed tag, plan a rotation for a full vegetable garden, scout for insects with an economic threshold in mind, and learn how wildlife biologists count deer and band birds.

The year also widens the view from the backyard to the farm and the community. Students meet the market gardener who must price a bunch of carrots, the large-animal veterinarian on a farm call, the farrier at the anvil and the beekeeper renting hives for pollination. They see how the farm year has been organized since ancient times by *seedtime and harvest*, and how tools from the plow to the combine changed the work of a few hands into food for many.

The method stays the same as in earlier grades: observe carefully, learn the science, then tend and grow. Each week has a short teaching section, a video from a trustworthy source, a picture study of a great painting or natural-history plate, a real hands-on project and a nature-journal page. The year ends with a capstone project that the student chooses, plans in winter, carries out in spring and presents at a family harvest fair.

Most videos come from university extension services (Purdue, Penn State, K-State, UConn, UNH, Utah State, Texas A&M AgriLife and others), state wildlife agencies, the University of Guelph Honey Bee Research Centre, farm organizations, and established gardening and homestead educators such as Huw Richards, GrowVeg, Epic Gardening and Garden Fundamentals. A few are short science

explainers from educational channels. Some growers mention their own shop, seed company or course at the end; you can stop the video there. Every video was watched in preview for content, but please preview anything you are unsure of, and use the backup when a primary is unavailable.

Start with Lesson 1.1 →

WHO IT IS FOR

Students about 13–14 years old (Grade 8) who read well and can work independently for an hour, with an adult available for tools, heat, animals and farm visits. Earlier School Launch garden courses are helpful but not required. No yard, livestock or pets are needed: every project has a windowsill, balcony, farm-visit, library or planning option.

HOW TO USE THIS COURSE

1. **Weekly rhythm.** One lesson a week for 32 weeks, in two sessions of about 60 minutes. Session 1: warm-up, core ideas, video and picture study. Session 2: the hands-on project and the nature journal. The last week of each unit adds a third session for the unit review and the portfolio project.
2. **Calendar.** The units follow a school year that begins in late summer: harvest and preserving in early fall, wildlife in late fall, soil and animal care in early winter, plant science and hydroponics indoors in late winter, farm animals and bees in early spring, planting in spring, and plant health and the capstone as the garden grows. Shift the units to match your own frost dates; a family in a warm southern zone may plant earlier, and a northern family may need to wait.
3. **Plan the capstone early.** Lesson 8.4 is the capstone, but it is chosen in Unit 1 and planned through the winter. Read Lesson 8.4 in September so the student can begin keeping records from the start.
4. **Picture study.** Look at the picture quietly for two minutes. Then put it away and tell back, aloud or in writing, everything you remember. Look again with the questions in hand. Each picture is tied to the science or farm work of the lesson.
5. **Nature journal.** Keep one bound notebook for the year. Date every page, note the weather, and write measurements with units. In Grade 8 the journal becomes a

field notebook and lab book: data tables, sketches, labeled diagrams, observations and short conclusions.

6. **Unit review and portfolio.** Each unit ends with a written review of 10–12 questions (100 points) and a portfolio project that puts the unit to real use: a preservation log, a habitat plan, a soil report, a care-and-budget plan, a trait-inheritance chart, a farm-visit report, a garden plan, a scouting record.
7. **Safety and supervision.** An adult supervises canning and any use of a stove, sharp grafting knives, pruning saws, livestock and horses, beehives and fertilizers. Read every label with an adult. Wash hands after handling soil, manure, compost and animals. Never touch wild animals, and check for ticks after time outdoors. Children never handle pesticides.
8. **4-H, FFA and fairs.** This year prepares students to take part in youth agricultural programs: keeping project records, judging classes with oral reasons, exhibiting produce and honey, showmanship and illustrated talks. Homeschoolers join 4-H through the county extension office. FFA is part of school agricultural education programs (in some states from grade 5, more often grade 7); there is no national homeschool provision, but some states have homeschool chapters, so ask your state FFA association. Check your county fair book for youth classes and dates; eligibility and deadlines vary.
9. **Scripture.** About one lesson in three includes a verse from the King James Version tied to the work of the week. Read it together and talk about it briefly.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–4

Seedtime and Harvest

The agricultural calendar from ancient times to today, succession planting and harvest planning, the science of food preservation (lacto-fermentation, canning and root cellars), and the simple economics of a market garden.

- 1.1 Seedtime and Harvest: The Farm Year Through History
- 1.2 Succession Planting and Harvest Planning
- 1.3 Keeping the Harvest: Fermenting, Canning and Root Cellars
- 1.4 The Market Garden: Selling Produce and Simple Farm Economics

UNIT 3 • WEEKS 9–12

Soil Science Capstone

A capstone of soil science: texture, structure and chemistry together; nutrient cycling of N, P and K; the rhizosphere and its microbes; and soil conservation through no-till, cover crops and rotation.

- 3.1 Texture, Structure and Chemistry Together
- 3.2 Nutrient Cycling: Nitrogen, Phosphorus and Potassium
- 3.3 The Rhizosphere and Soil Biology
- 3.4 Soil Conservation and Regenerative Practices

UNIT 2 • WEEKS 5–8

Wildlife Management

How biologists count wildlife and why populations rise and fall; ticks, rabies and chronic wasting disease; bird migration, banding and backyard bird counts; and habitat stewardship on farms and homesteads.

- 2.1 Counting Wildlife: Populations and Surveys
- 2.2 Wildlife and Disease: Ticks, Rabies and Chronic Wasting Disease
- 2.3 Bird Migration, Banding and Backyard Counts
- 2.4 Stewardship of Habitat on Farms and Homesteads

UNIT 4 • WEEKS 13–16

Animal Care and Careers

Animal nutrition and feed labels; parasites, prevention and first aid; breeds and inherited traits with Punnett squares; and careers that serve animals and farms.

- 4.1 Animal Nutrition and Feed Labels
- 4.2 Animal Health: Parasites, Prevention and First Aid
- 4.3 Breeds and Inherited Traits
- 4.4 Careers with Animals and on the Farm

UNIT 5 • WEEKS 17–20

Plant Science

The chemistry of photosynthesis and cellular respiration, Mendel and how new varieties are bred (hybrids and heirlooms), plant growth regulators, and a working hydroponic garden.

- 5.1 Photosynthesis and Cellular Respiration
- 5.2 Plant Genetics: Mendel, Hybrids and Heirlooms
- 5.3 Plant Growth Regulators
- 5.4 Hydroponics: Growing Without Soil

UNIT 7 • WEEKS 25–28

Planting: Garden, Field and Orchard

Planning a full garden for succession, rotation, spacing and yield; propagation by grafting, layering and division; agronomy of field crops at scale; and orchards, berries and other perennial crops.

- 7.1 Planning a Full Garden: Rotation, Spacing and Yield
- 7.2 Propagation: Grafting, Layering and Division
- 7.3 Agronomy: Field Crops at Scale
- 7.4 Orchards, Berries and Perennial Crops

UNIT 6 • WEEKS 21–24

Farm Animals and Bees

Livestock production for beef, dairy, pork, poultry, sheep and goats; shelter, fencing and rotational grazing; horses and draft animals; and apiculture: honey science, beeswax, pollination services and varroa mites.

- 6.1 Livestock Production: Beef, Dairy, Swine, Poultry, Sheep and Goats
- 6.2 Husbandry: Shelter, Fencing, Grazing and Showmanship
- 6.3 Horses and Draft Animals
- 6.4 Apiculture: Honey, Beeswax, Pollination and Bee Health

UNIT 8 • WEEKS 29–32

Plant Health and the Capstone

Plant pathology, entomology and integrated pest management, weed science, and the capstone: plan, run and present a garden or animal-care project at a family harvest fair.

- 8.1 Plant Pathology: Diagnosing Plant Diseases
- 8.2 Entomology and Integrated Pest Management
- 8.3 Weed Science
- 8.4 Capstone: Record Book, Exhibit and Family Harvest Fair

WEEKLY PACING CALENDAR

WEEK	PLAN
I	Session 1: Lesson 1.1 Seedtime and Harvest: The Farm Year Through History: warm-up, video, teaching and picture study

WEEK	PLAN
	Session 2: Lesson 1.1 hands-on project and nature journal <i>Two sessions a week is the usual rhythm. Younger children can split a long session in two; older students can do both sessions in one sitting.</i>
2	- Session 1: Lesson 1.2 Succession Planting and Harvest Planning: warm-up, video, teaching and picture study - Session 2: Lesson 1.2 hands-on project and nature journal
3	- Session 1: Lesson 1.3 Keeping the Harvest: Fermenting, Canning and Root Cellars: warm-up, video, teaching and picture study - Session 2: Lesson 1.3 hands-on project and nature journal
4	- Session 1: Lesson 1.4 The Market Garden: Selling Produce and Simple Farm Economics: 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 Counting Wildlife: Populations and Surveys: warm-up, video, teaching and picture study - Session 2: Lesson 2.1 hands-on project and nature journal
6	- Session 1: Lesson 2.2 Wildlife and Disease: Ticks, Rabies and Chronic Wasting Disease: warm-up, video, teaching and picture study - Session 2: Lesson 2.2 hands-on project and nature journal
7	- Session 1: Lesson 2.3 Bird Migration, Banding and Backyard Counts: warm-up, video, teaching and picture study - Session 2: Lesson 2.3 hands-on project and nature journal
8	- Session 1: Lesson 2.4 Stewardship of Habitat on Farms and Homesteads: 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 Texture, Structure and Chemistry Together: warm-up, video, teaching and picture study - Session 2: Lesson 3.1 hands-on project and nature journal

WEEK	PLAN
10	• Session 1: Lesson 3.2 Nutrient Cycling: Nitrogen, Phosphorus and Potassium: warm-up, video, teaching and picture study • Session 2: Lesson 3.2 hands-on project and nature journal
11	• Session 1: Lesson 3.3 The Rhizosphere and Soil Biology: warm-up, video, teaching and picture study • Session 2: Lesson 3.3 hands-on project and nature journal
12	• Session 1: Lesson 3.4 Soil Conservation and Regenerative Practices: 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 Nutrition and Feed Labels: warm-up, video, teaching and picture study • Session 2: Lesson 4.1 hands-on project and nature journal
14	• Session 1: Lesson 4.2 Animal Health: Parasites, Prevention and First Aid: warm-up, video, teaching and picture study • Session 2: Lesson 4.2 hands-on project and nature journal
15	• Session 1: Lesson 4.3 Breeds and Inherited Traits: warm-up, video, teaching and picture study • Session 2: Lesson 4.3 hands-on project and nature journal
16	• Session 1: Lesson 4.4 Careers with Animals and on the Farm: warm-up, video, teaching and picture study • Session 2: Lesson 4.4 hands-on project and nature journal • Session 3: Unit 4 review and portfolio project
17	• Session 1: Lesson 5.1 Photosynthesis and Cellular Respiration: warm-up, video, teaching and picture study • Session 2: Lesson 5.1 hands-on project and nature journal
18	• Session 1: Lesson 5.2 Plant Genetics: Mendel, Hybrids and Heirlooms: 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 Plant Growth Regulators: warm-up, video, teaching and picture study • Session 2: Lesson 5.3 hands-on project and nature journal
20	• Session 1: Lesson 5.4 Hydroponics: Growing Without Soil: 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 Livestock Production: Beef, Dairy, Swine, Poultry, Sheep and Goats: warm-up, video, teaching and picture study • Session 2: Lesson 6.1 hands-on project and nature journal
22	• Session 1: Lesson 6.2 Husbandry: Shelter, Fencing, Grazing and Showmanship: 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 and Draft Animals: warm-up, video, teaching and picture study • Session 2: Lesson 6.3 hands-on project and nature journal
24	• Session 1: Lesson 6.4 Apiculture: Honey, Beeswax, Pollination and Bee Health: 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 Planning a Full Garden: Rotation, Spacing and Yield: warm-up, video, teaching and picture study • Session 2: Lesson 7.1 hands-on project and nature journal
26	• Session 1: Lesson 7.2 Propagation: Grafting, Layering and Division: warm-up, video, teaching and picture study • Session 2: Lesson 7.2 hands-on project and nature journal
27	• Session 1: Lesson 7.3 Agronomy: Field Crops at Scale: 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 Orchards, Berries and Perennial Crops: 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 Plant Pathology: Diagnosing Plant Diseases: warm-up, video, teaching and picture study • Session 2: Lesson 8.1 hands-on project and nature journal
30	• Session 1: Lesson 8.2 Entomology and Integrated Pest Management: warm-up, video, teaching and picture study • Session 2: Lesson 8.2 hands-on project and nature journal
31	• Session 1: Lesson 8.3 Weed Science: warm-up, video, teaching and picture study • Session 2: Lesson 8.3 hands-on project and nature journal
32	• Session 1: Lesson 8.4 Capstone: Record Book, Exhibit and Family Harvest Fair: 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

A bound sketchbook or lab notebook with unlined or grid pages, used all year for data, sketches and notes.

Pencils, colored pencils, fine black pen and a ruler

For labeled diagrams, data tables and graphs.

Hand lens (10×) and a kitchen scale

For soil, insects, seeds and weighing harvests.

Soil test kit (pH, N, P, K) and clear quart jars

For the soil unit; a university soil-lab test is a worthwhile optional extra.

Potting mix, pots or cups with drainage holes, seeds (peas, beans, lettuce, radishes, sunflowers)

For seed, genetics and planting projects.

Canning jars, a large pot, salt and a head of cabbage

For the preservation lesson; canning is always done with an adult.

Two or three wide-mouth jars, net cups or plastic cups, and hydroponic nutrient

For the Kratky hydroponics project in Unit 5.

Garden gloves, trowel, hand pruners and a sharp knife

Pruners and knives are used with an adult.

Yellow sticky cards and zip bags

For insect scouting and collecting diseased leaves for study.

Bird feeder and field guide (optional)

For backyard bird counts; a library field guide or a free bird-ID app works too.

Access to a farm, fair, stable or apiary (optional)

Visits make Units 4 and 6 come alive; every project also has a no-visit option.

A garden bed, large containers or a community-garden plot (optional)

For Units 7 and 8 and the capstone; a balcony with three or four large containers is enough.

GRADING

Grade 8 work is graded so that the student has a clear record for high school. Most of the grade comes from doing the work well: projects, the nature journal and the portfolio.

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

Scale: A 90–100, B 80–89, C 70–79, D 60–69, below 60 needs more work.

- Grade projects by the self-check statements in each lesson: each one met earns full marks for that part.

- Grade the journal for completeness, dates, units on every measurement, and honest observation, not artistic skill.
- Unit reviews total 100 points. The written answers reward clear reasoning in complete sentences.
- The capstone in Lesson 8.4 counts as two portfolio projects.

A NOTE TO PARENTS

This course asks more of your student than earlier grades: real data, real reasoning and real responsibility. Let your student lead, but stay close for anything involving heat, blades, animals or chemicals. Many lessons suggest a farm, stable, apiary, extension office or county fair visit. These are worth the drive; farmers, beekeepers and extension agents are usually generous with young people who come with good questions.

Farm animals are raised for eggs, milk, wool, work and meat, and the course says so plainly and respectfully, without showing or describing how animals are processed for meat. Wildlife disease is taught for safety. Throughout, we want students to see the world as God's good creation entrusted to our care, to work faithfully, and to give thanks for the harvest. *Fabricando fit faber*: by making, one becomes a maker, and by tending, one becomes a steward.

UNIT 1

SEEDTIME AND HARVEST

Every farm on earth runs on a calendar that God set in place: *seedtime and harvest, and cold and heat, and summer and winter*. In this unit we study that calendar as farmers have lived it, from the hand sickle to the combine. We will look at how the farm year is planned so that food keeps coming all season, how the harvest is kept safe through the winter, and how a small farm turns a good harvest into a living.

This is the first unit of a capstone year, so it is also a planning unit. As you read about succession planting and market gardens, start thinking about the project you will grow, raise or build this year and present at a family harvest fair in the spring. Write your ideas in the back of your nature journal.

PREREQUISITES

- Knowing the four seasons and why the tilt of the earth causes them
- Knowing your area's average last spring frost and first fall frost dates (look them up with your county extension office if you do not)
- Basic garden skills: sowing seeds, watering and harvesting
- A nature journal for the year

MASTERY CHECKLIST

- ☐ I can describe the main stages of the farm year and name tools that changed farming, such as the seed drill, the steel plow, the reaper and the tractor.
- ☐ I can plan succession sowings for a crop using days to maturity and my frost dates.
- ☐ I can explain how salt, acid, heat, cold and drying each protect food from spoilage microbes.
- ☐ I can explain why low-acid foods must be pressure canned and high-acid foods may be water-bath canned.
- ☐ I can figure the cost, price and profit of a simple market-garden product.

LESSONS IN THIS UNIT

1.1 Seedtime and Harvest: The Farm Year Through History

2 sessions of 60 minutes

1.2 Succession Planting and Harvest Planning

2 sessions of 60 minutes

1.3 Keeping the Harvest: Fermenting, Canning and Root Cellars

2 sessions of 60 minutes

1.4 The Market Garden: Selling Produce and Simple Farm Economics

2 sessions of 60 minutes

UNIT 1 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work on calculations. Total: 100 points.

1. 8 pts

Name the stages of the farm year in order and give one job for each season in a temperate climate.

2. 8 pts

Name three inventions that changed farming and explain what each one did.

3. 8 pts

What is the difference between a cool-season and a warm-season crop? Give two examples of each.

4. 8 pts

Name the four kinds of succession planting and give an example of each.

5. 9 pts

Your first fall frost is October 15. A bush bean takes 55 days to mature. Using a 14-day fall factor, what is the last date you should sow it? Show your work.

6. 8 pts

List four ways preserving methods keep microbes from spoiling food.

7. 9 pts

Explain how lacto-fermentation turns cabbage into sauerkraut and why the cabbage must stay under the brine.

8. **9 pts**

Why must green beans be pressure canned while strawberry jam may be water-bath canned?

9. **7 pts**

What temperature and humidity do carrots and potatoes need in storage, and why should apples be stored apart from them?

10. **8 pts**

A grower spends \$24 to produce 40 bags of salad mix and sells them at \$5 each. Find the gross revenue, net profit and break-even number of bags.

11. **8 pts**

Compare selling at a farmers market with selling through a CSA. Give one advantage of each.

12. **10 pts**

Short answer: In a paragraph, explain how a family could eat food from its own garden in February. Use at least three methods from this unit.

ANSWER KEY

1. Prepare the ground and sow (spring), tend and water (summer), harvest (late summer and fall), store, rest, repair and plan (winter). Any reasonable job for each season.
2. Any three: Jethro Tull's seed drill sowed seed evenly in rows; John Deere's steel plow cut sticky prairie sod; McCormick's reaper cut grain mechanically; the tractor replaced horses and allowed one family to farm more land.
3. Cool-season crops tolerate light frost and grow best in cool weather (peas, lettuce, spinach, kale, cabbage). Warm-season crops are killed by frost and need warm soil (tomatoes, beans, corn, squash, peppers).
4. Repeated sowings (lettuce every two weeks); different maturities (early, mid and late sweet corn sown together); relay planting (transplanting fall brassicas among finishing beans); follow-on crop (beans after garlic is harvested).
5. $55 + 14 = 69$ days. Counting back 69 days from October 15 gives about August 7.
6. Removing water (drying, salt, sugar), raising acidity (fermenting, pickling), cold (cellaring, refrigeration, freezing), and heat with sealing (canning).
7. Salt draws water out of the cabbage to make a brine and holds back spoilage organisms. Lactic acid bacteria on the leaves grow in the airless brine and turn sugars into lactic acid, lowering the pH so the cabbage keeps. Cabbage above the brine is exposed to air, where molds and spoilage microbes can grow.
8. Green beans are low-acid (above pH 4.6), where botulism spores can survive boiling and grow in a sealed jar; only pressure canning reaches about 240 °F, hot enough to destroy them. Jam is high-acid, so the spores cannot grow and boiling-water processing is enough.
9. About 32–40 °F with high humidity (about 90–95 percent). Apples give off ethylene gas, which makes potatoes sprout and carrots turn bitter.
10. Gross revenue $40 \times \$5 = \$200$. Net profit $\$200 - \$24 = \$176$ (before labor). Break-even $\$24 \div \$5 = 4.8$, so 5 bags.
11. Farmers market: full retail price and direct contact with customers. CSA: customers pay at the start of the season, giving the farmer money when seed and supplies are bought, and a known number of customers.
12. A strong answer names at least three methods (for example, sauerkraut made in fall, tomatoes and jam water-bath canned in summer, green beans pressure canned, carrots and potatoes in a root cellar, onions and squash stored dry, late

succession crops of kale or spinach under a cold frame) and explains briefly why each keeps.

PORTFOLIO PIECE: A HARVEST-KEEPING RECORD

Preserve at least two foods by two different methods this fall (for example, sauerkraut and stored carrots, or dried herbs and water-bath canned applesauce with an adult). Keep a record of each: the recipe or method and its source, dates, measurements (salt, pH, temperatures), and the result after one month. Add a one-page explanation of the science that keeps each food safe.

LOOK FOR	WHAT IT MEANS
Two methods	Two foods are preserved by two different methods, each from a tested or reputable source.
Records	Dates, amounts, temperatures and pH or other measurements are recorded clearly in a table.
Science	The explanation correctly names how each method stops spoilage microbes and enzymes.
Safety	Safety steps (adult help, clean tools, tested times, signs of spoilage) are described and followed.
Result	The condition of each food after a month is described honestly, with what would be done differently next time.

1.1 SEEDTIME AND HARVEST: THE FARM YEAR THROUGH HISTORY

OBJECTIVES

- Describe the main seasons of work on a temperate farm, from soil preparation to harvest and storage.
- Explain how inventions such as the seed drill, steel plow, reaper and tractor changed the amount of land one family could farm.
- Build a personal agricultural calendar for your own place using frost dates and day length.

Warm-up. List ten foods you ate this week. Beside each, write the month you think it is harvested where it grows. Circle any you are unsure of; you will check them at the end of the lesson.

WATCH

Mechanization on the Farm in the Early 20th Century.

Iowa PBS · 3:23

<https://www.youtube.com/watch?v=SI9K8ZJqAwE>

WHEN TO WATCH

After the core ideas. Watch for the moment the family's horses are replaced by a tractor, and note what changed in the daily work.

BACKUP VIDEO

Harvesting Knowledge: Jethro Tull - America's Heartland

America's Heartland · 1:45

<https://www.youtube.com/watch?v=Ofw5-YafPnc>

A short clip on Jethro Tull and his seed drill; watch it with the history note.

KEY TERMS

agricultural calendar

The yearly schedule of farm work (preparing ground, sowing, tending, harvesting, storing) set by the seasons, frost dates and day length of a place.

frost-free season

The number of days between the average last spring frost and the average first fall frost; the main limit on what tender crops can be grown.

seed drill

A machine that cuts a furrow, drops seed at an even depth and spacing, and covers it; Jethro Tull's horse-drawn drill of 1701 is the ancestor of modern planters.

mechanization

Replacing human and animal muscle with machines, such as the reaper, the steam engine and the tractor.

subsistence and market farming

Subsistence farming grows food mainly for the family; market farming grows food mainly to sell.

CORE IDEAS

Every farm, ancient or modern, follows the same pattern. The ground is prepared, seed is sown, the crop is tended, the harvest is gathered, and the harvest is stored so that the family can eat until the next one. In a temperate climate this pattern is fixed to the seasons: soil work and sowing in spring, tending in summer, harvest in late summer and fall, and in winter, rest, repair, feeding animals and planning. The Bible describes the same rhythm in Genesis 8:22, and old calendars such as the medieval *Books of Hours* painted one farm job for each month.

Your own agricultural calendar is set by three numbers: your **average last spring frost**, your **average first fall frost**, and the **day length**. Cool-season crops (peas, lettuce, spinach, cabbage, wheat sown in fall) tolerate light frost and grow best in the cool, lengthening days of spring and the shortening days of fall. Warm-season crops (tomatoes, beans, corn, squash) are killed by frost and need warm soil. A farmer works backward from frost dates: tomatoes are started indoors about six to eight weeks before the last frost and set out after it; garlic is planted in fall about a month before the ground freezes.

For most of history, nearly every family farmed, because one family's muscles could feed only a few more people. Then came a series of inventions. **Jethro Tull's seed drill** (1701) planted seed in straight rows at an even depth, saving seed and making weeding easier. **John Deere's steel plow** (1837) cut through the sticky prairie sod that clogged iron plows. **Cyrus McCormick's reaper** (patented 1834) let a few workers cut grain that once took a whole crew with cradles and sickles. Steam threshers followed, and in the early 1900s the gasoline **tractor** began to replace horses.

These changes are called **mechanization**. In 1900 about two in five American workers were farmers; today it is under two in a hundred, yet they grow far more food. Mechanization did not change the calendar of the seasons; it changed how much land one family could tend within it. The best farmers still watch the sky, the soil and the calendar as closely as their great-grandparents did.

Planning ahead is the farmer's main skill. Seed is ordered in winter, beds are prepared before they are needed, and storage is ready before the harvest. As Proverbs 6 says of the ant, she 'provideth her meat in the summer.' This year you will keep your own farm calendar in your journal and use it to plan your capstone project.

PICTURE STUDY



Haymaking, Pieter Bruegel the Elder, 1565 · Oil on panel · Lobkowitz Palace, Prague

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

Bruegel painted a series of pictures of the farm year for a merchant in Antwerp; five survive. This one shows early summer, when hay is cut, dried and stored for the animals' winter feed, and early produce comes in from the gardens.

Look closely

- Find the man at the lower left. What is he doing to his scythe, and why does a mower need to do it often?
- Follow the hay from the field to the wagon. How many stages of the work can you find: mowing, turning, raking, heaping, loading?
- Look at the baskets the villagers carry on their heads. What crops might be ripe in early summer?
- Find the women with rakes on the road. Where do you think they are going, and what time of day is it?

Talk about it

1. Why must hay be cut and dried during a stretch of dry weather? What happens to wet hay in a stack?
2. Which machines in this lesson would one day replace the scythes, rakes and hand-loaded wagon in this picture?

3. Where does this scene belong on your own farm calendar?

HANDS-ON PROJECT

My Place's Agricultural Calendar

You will build a twelve-month farm calendar for your own home, using your frost dates and day length. It will guide your planting all year and become the backbone of your capstone plan.

You will need

- Your nature journal or a large sheet of paper
- Ruler, pencil and colored pencils
- Your average last spring and first fall frost dates (from your county extension office or a frost-date map)
- Sunrise and sunset times for the 21st of each month (from an almanac or weather website)
- Seed packets or a seed catalog

Steps

1. Draw a circle and divide it into twelve wedges like a clock, one for each month, starting with January at the top.
2. Shade the frost-free season in green, from your last spring frost to your first fall frost. Count the days and write the number in the center.
3. Work out the day length on the 21st of each month (sunset minus sunrise) and write it on the outer edge of each wedge.
4. Choose six crops: two cool-season, two warm-season, one fall-planted (such as garlic or winter wheat) and one perennial (such as strawberries or asparagus).
5. For each crop, use the days to maturity on the packet and your frost dates to mark sowing (S), transplanting (T) and harvest (H) months on the wheel.
6. Add the non-planting jobs: ordering seed, starting seeds indoors, preparing beds, mulching, cleaning tools, and planning.
7. Check your warm-up list of foods from the start of the lesson. Correct any harvest months you guessed wrong.

8. Write two sentences under the wheel describing the busiest and the quietest months on your calendar.

Tips

- Frost dates are averages. A careful farmer waits a week or two past the average last frost before setting out tender plants.
- If you live in an apartment, make the calendar for a balcony container garden or for the farm where your family buys produce.

Check your work

- ☐ My calendar shows my frost-free season with the correct number of days.
- ☐ My calendar shows day length for each month.
- ☐ Six crops are marked with sowing, transplanting and harvest times that fit my frost dates.
- ☐ I can explain why cool-season crops are sown at different times than warm-season crops.

NATURE JOURNAL

1. Start a weather page you will keep all year: each week, record the date, high and low temperature, rainfall and one thing that is growing, blooming or being harvested near you.
2. Sketch one old farm tool you can find in a museum, a barn, an antique shop or a book (a scythe, a hand plow, a flail). Label its parts and write what job it did and what machine replaced it.
3. On a page in the back of your journal titled *Capstone Ideas*, list three projects you might grow, raise or build this year.

From history. Jethro Tull, an English farmer, built his horse-drawn seed drill in 1701 and wrote *Horse-Hoeing Husbandry* in 1731. Before his drill, most grain was sown by hand, flung broadcast across the field, and much of the seed was eaten by birds or buried too deep or too shallow. Bruegel painted his series of the seasons in 1565, more than a century before Tull.

COMMON MISTAKES

- Using the date of the last frost as the planting date for tomatoes and peppers. The soil is often still too cold; wait until nights stay above about 50 °F.

- Assuming every crop is planted in spring. Garlic, winter wheat and many cover crops are planted in fall.
- Thinking that machines made farming easy. They made one person able to farm more land, but the work still depends on timing, weather and care.

Make it a game • Farm Year Charades. Take turns acting out one farm job without speaking: plowing, sowing, haying, reaping, threshing or filling the cellar. The guesser names the job and the season it belongs to. Then the actor names which invention (seed drill, steel plow, reaper or tractor) made that job faster. First to five full answers wins.

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)

After the flood, God promised Noah that the seasons would keep their order. Every farm calendar rests on that faithful promise.

1.2 SUCCESSION PLANTING AND HARVEST PLANNING

OBJECTIVES

- Explain four kinds of succession planting: repeated sowings, relay planting, varieties with different maturity, and a follow-on crop after harvest.
- Use days to maturity and the frost-free season to schedule sowings for a steady harvest.
- Estimate the amount of a crop a family needs and plan the bed space to grow it.

Warm-up. Look at three seed packets or catalog listings. For each, find the days to maturity and figure the harvest date if you sowed it today. Would it ripen before your first fall frost?

WATCH

Succession Planting. | Amazing Way to Extend Your Cropping and Increases Your Garden's Productivity

Huw Richards · 8:17

<https://www.youtube.com/watch?v=tR08obFyK2U>

WHEN TO WATCH

After the core ideas. Pause after each type of succession Huw describes and write its name in your journal with one example.

BACKUP VIDEO

Succession planting ideas after harvests

Charles Dowding · 7:17

<https://www.youtube.com/watch?v=5v4oSD-WrqA>

Optional: a no-dig grower shows which crops he plants into beds the same day the first crop comes out.

KEY TERMS

succession planting

Planning sowings so that a bed stays productive all season and harvests come steadily instead of all at once.

days to maturity

The approximate number of days from sowing (or transplanting, for transplants) to first harvest, printed on seed packets.

relay planting

Sowing or transplanting a new crop among an older crop before the older one is finished, so the new one is already growing when the bed is cleared.

fall factor

Extra days (often about 14) added to days to maturity for crops sown in late summer, because cooler weather and shorter days slow growth.

yield

The amount of harvest from a given area, such as pounds per 10-foot row or per square foot.

CORE IDEAS

A single sowing of lettuce gives a flood of heads for two weeks and then nothing, because the plants all bolt together in the heat. A farmer who wants lettuce every week sows a short row every two weeks. That is **succession planting**: arranging sowings so the harvest is steady and the ground is never idle. It is how a small plot feeds a family all year, and how market gardeners have something to sell every week.

There are four main kinds. (1) **Repeated sowings** of the same quick crop (radishes, lettuce, bush beans, cilantro) every one to three weeks. (2) **Different maturities**: planting early, mid-season and late varieties of the same crop on the same day, such as 55-day, 70-day and 85-day sweet corn. (3) **Relay planting**: tucking young transplants between older plants before the first crop is done. (4) **Follow-on crops**: clearing a bed of early peas or garlic in early summer and replanting it the same week with beans, carrots for fall, or a fall brassica.

Timing comes from arithmetic. Count back from your first fall frost: days to maturity, plus about 14 days for the ‘fall factor’, plus the length of harvest you want. For a 60-day bush bean in a place with an October 10 frost: $60 + 14 = 74$ days, so the last sowing should be by about July 28. Frost-tender crops must be finished by frost; frost-hardy crops such as kale, spinach and carrots can keep growing and even sweeten after light frosts.

Good planning also asks how much you need. A family that eats a head of lettuce three times a week needs about three heads a week. If one 4-foot row gives 8 heads, a

4-foot sowing every two weeks will do. Write your needs, divide by expected yield, and you know the bed space. Extension services publish tables of typical yields per 10 feet of row, which help with this step.

Succession has costs too. Each sowing takes time, water and compost, and the soil must be fed between crops so it does not wear out. Adding an inch of compost when you clear a bed, and rotating plant families (Lesson 7.1), keeps a hard-working bed healthy.

PICTURE STUDY



The Kitchen Garden, Yerres, Gustave Caillebotte, 1877 · Oil on canvas · Private collection

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

Caillebotte painted the large walled vegetable garden of his family's country house near Paris. Kitchen gardens like this one supplied a big household with vegetables through the year by careful planning and succession.

Look closely

- Count the separate beds. Do the plants in every bed look the same size and age, or are some beds younger or bare?
- Find the bare, sunny bed on the left. What might a gardener sow there next?
- Notice the paths between the beds. How do they make sowing, weeding and harvesting in succession easier?
- Look at the high wall around the garden. How might it help the gardener in spring and fall?

Talk about it

1. If this garden must feed a household every week, what is your plan for the empty bed for the next three months?
2. What can you tell about the season and time of day from the light and the plants?

HANDS-ON PROJECT

A Succession Plan for One Bed

You will plan one bed (or three large containers) to produce food from early spring to late fall, using all four kinds of succession, and then make the first sowing.

You will need

- Your agricultural calendar from Lesson 1.1
- Seed packets or a catalog with days to maturity
- Graph paper, pencil and ruler
- A garden bed about 4 × 8 ft, or three containers at least 18 in across
- Seeds for a quick fall crop (lettuce, radishes, spinach or turnips) and compost

Steps

1. Measure your bed or containers and draw them to scale on graph paper.
2. Make a table with columns for crop, variety, days to maturity, sowing date, harvest window and space used.
3. Plan at least one example of each kind of succession: repeated sowings, different maturities, relay planting and a follow-on crop.
4. Use the fall-frost arithmetic from the core ideas to set your last sowing date for each frost-tender crop. Show your math.
5. Estimate your family's weekly need for two of the crops and check that your plan grows enough.
6. Draw a timeline bar for each crop from sowing to the end of harvest. Make sure two crops never need the same space at the same time.
7. Because it is now fall, make the first real sowing: clear a bed or fill a container, add an inch of compost, and sow a frost-hardy fall crop. Record the date.
8. Mark the next sowing date for that crop on your calendar.

Tips

- Fall sowings germinate in warm soil but finish in cool weather. Keep the seedbed moist; a board laid over a carrot row for a few days helps until sprouts appear.
- A cold frame or a sheet of row cover can extend your fall harvest by several weeks.
- Many county fairs have a youth vegetable class with plates of three to five matched vegetables; a succession plan that ripens a crop in fair week is exactly how exhibitors plan. Check your county fair book for dates and classes.

Check your work

- ☐ My plan uses all four kinds of succession.
- ☐ My last sowing dates are calculated from my first frost date, with the math shown.
- ☐ My timeline shows no two crops in the same space at the same time.
- ☐ I have sown a fall crop and recorded the date.

NATURE JOURNAL

1. Each week until frost, sketch your fall sowing and measure the tallest seedling in centimeters. Make a small growth table.
2. Visit a farmers market or grocery produce section and list which crops are from your region this week. Which ones are harvested in succession by local farmers?

COMMON MISTAKES

- Sowing everything on one weekend in spring and then having nothing ready in July or September.
- Forgetting the fall factor, so late crops are still small when frost arrives.
- Planting a follow-on crop without adding compost, so the second crop is pale and slow.

Make it a game • Beat the Frost Clock. Your parent names a crop, its days to maturity and a first fall frost date. You have sixty seconds to say the latest safe sowing date, remembering the fall factor, and to name one follow-on crop for that bed. One point for each correct answer. Play again with a new crop and beat your score.

1.3 KEEPING THE HARVEST: FERMENTING, CANNING AND ROOT CELLARS

OBJECTIVES

- Explain how microbes and enzymes spoil food, and how salt, acid, heat, cold and drying stop them.
- Describe how lacto-fermentation preserves cabbage as sauerkraut.
- Explain why high-acid foods may be water-bath canned but low-acid foods must be pressure canned, and why tested recipes matter.
- Store root crops under the right temperature and humidity.

Warm-up. Look in your kitchen and find five foods that keep for months without a refrigerator (for example, dry beans, honey, pickles, canned tomatoes, raisins). For each, guess what keeps it from spoiling.

WATCH

Program 9 -- The Science Behind Home Canning

K-State Extension · 5:02

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

WHEN TO WATCH

After the core idea about canning. Listen for why acidity decides which canning method is safe.

BACKUP VIDEO

The Best Way to Store Root Vegetables

GrowVeg · 8:07

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

Before the root-cellar part of the project: how to store carrots, beets, potatoes and onions.

KEY TERMS

lacto-fermentation

Preserving vegetables in salt or brine, where lactic acid bacteria turn natural sugars into lactic acid, which lowers the pH and keeps spoilage microbes out.

botulism

A dangerous illness caused by a toxin from *Clostridium botulinum*, whose spores survive boiling and grow in sealed, low-acid, airless food.

pressure canning

Processing jars in steam under pressure, which reaches about 240 °F and destroys botulism spores; required for low-acid vegetables, beans and meats.

pH

A scale of acidity from 0 to 14; foods at pH 4.6 or below are called high-acid in canning.

water-bath canning

Processing sealed jars in boiling water (212 °F at sea level); safe only for high-acid foods such as fruit, jams, pickles and acidified tomatoes.

root cellar

A cool, dark, humid storage space, often partly underground, that keeps root crops and apples for months.

CORE IDEAS

Fresh food spoils for two reasons. **Microbes** (bacteria, yeasts and molds) feed on it, and the food's own **enzymes** keep working after harvest, softening and browning it. Every preserving method stops one or both by taking away something microbes need: water (drying, sugar, salt), a low acidity they can tolerate (fermenting, pickling), warmth (cold storage, freezing), or by killing them with heat and sealing the food away from the air (canning).

Lacto-fermentation is one of the oldest methods. Shredded cabbage is mixed with about 2 percent salt by weight. The salt pulls water out of the cabbage to make a brine and holds back spoilage bacteria, while helpful *lactic acid bacteria* that live naturally on the leaves multiply under the brine, where there is no air. They turn the cabbage's sugars into lactic acid. In two to four weeks the pH drops below about 4, and the sauerkraut will keep for months in a cool place. The key rule is simple: keep the vegetables under the brine.

Canning heats food in sealed jars to destroy microbes and drive out air; as the jar cools, a vacuum pulls the lid down tight. The danger is **botulism**. *Clostridium botulinum* spores survive boiling, but they cannot grow when the pH is 4.6 or lower. So high-acid foods (most fruits, jams, pickles, and tomatoes with added lemon juice or citric acid) can be processed in a **boiling water bath**. Low-acid foods (green beans, corn, carrots, potatoes, meats) must be **pressure canned**, which reaches about 240 °F. Home canners always use a recipe tested by the USDA or an extension service, follow the times exactly, and adjust for altitude.

A **root cellar** uses cold instead of heat. Most root crops (carrots, beets, turnips, potatoes) keep best near 32–40 °F with high humidity (about 90–95 percent), so they do not shrivel. Onions, garlic and winter squash want it drier: onions and garlic cool and dry, squash about 50–55 °F. Apples give off ethylene gas, which makes potatoes sprout and carrots turn bitter, so they are stored apart. Without a cellar, a cool basement corner, an unheated garage that stays above freezing, or a cooler buried in the ground can work.

Preserving is how a family eats from its garden in February. It is also an act of gratitude: nothing God gives in the harvest is wasted.

PICTURE STUDY



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

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

In Spain, a *cantarero* was a cool, shaded window or larder where food was kept. Sánchez Cotán, who later became a lay brother in a monastery, painted fruit and vegetables stored in one. Hanging produce on strings let air move around it and kept it away from mice.

Look closely

- Find the two foods hanging on strings. Why would hanging a quince or a cabbage help it keep longer than leaving it in a heap?
- Compare the whole cabbage and quince with the cut melon. Which will spoil first, and why?
- Look at the stone window and the darkness behind it. What does this tell you about the temperature and light of the storage place?
- Notice the curve made by the four foods from top left to bottom right. Which is the freshest-looking?

Talk about it

1. Which preserving principle from this lesson does a cool, airy larder use?
2. Which of these four foods would you store in a root cellar, which would you ferment or pickle, and which would you eat right away?

Safety first. Canning uses boiling water, steam and heavy jars: an adult must supervise and handle the canner. Use only tested USDA or extension recipes. When fermenting, wash hands and tools, keep vegetables under the brine, and throw out any batch that is slimy, pink or fuzzy with mold, or smells rotten.

HANDS-ON PROJECT

A Small Batch of Sauerkraut and a Storage Test

You will make one quart of lacto-fermented sauerkraut and measure its pH as it ferments, and set up a small storage test with root vegetables.

You will need

- One medium head of cabbage (about 2 lb) and a kitchen scale
- Non-iodized salt (canning or sea salt)
- A clean quart canning jar with a lid, and a small jar or zip bag of brine to use as a weight
- Large bowl and knife (adult help with cutting)
- pH test strips (range 2–6) or a soil pH kit's strips
- Carrots or beets with tops removed, a bucket of damp sand or sawdust, and a thermometer

Steps

1. Remove the outer leaves of the cabbage, save one clean leaf, then quarter and core it and slice it thinly.
2. Weigh the shredded cabbage in grams and multiply by 0.02 to find the salt. Write the calculation in your journal.
3. Toss the cabbage with the salt in a bowl and squeeze and knead it for 5–10 minutes until it is limp and juicy.
4. Pack it tightly into the jar, pressing down until brine rises above it. Tuck the saved leaf on top and press a small brine-filled bag or jar on it to keep everything under the liquid.
5. Cover loosely and set the jar on a plate at cool room temperature (60–70 °F), out of sunlight.
6. Every two or three days, press the cabbage down, test a drop of brine with a pH strip, and record the date, pH, smell and appearance.
7. When the pH is about 3.5 or the taste is pleasantly sour (usually 2–4 weeks), cap and refrigerate it.

8. For the storage test, layer carrots or beets in damp sand in a bucket and set it in the coolest place you have that stays above freezing. Leave a few carrots loose in the same place for comparison. Record temperature and condition weekly for a month.

Tips

- Bubbles and a sour smell are signs that the lactic acid bacteria are working.
- A white film on top is often harmless yeast that can be skimmed off; fuzzy colored mold, sliminess or a rotten smell means throw it out.

Check your work

- ☐ I calculated the salt from the cabbage's weight.
- ☐ My fermentation log shows the pH dropping over time.
- ☐ I can explain why the cabbage must stay under the brine.
- ☐ I can explain why green beans must be pressure canned but sauerkraut and jam need not be.

NATURE JOURNAL

1. Graph your sauerkraut's pH against days. Mark pH 4.6 with a dashed line and note the day it crossed below it.
2. Draw a cross-section of a root cellar or your storage bucket, labeling temperature, humidity, air flow and where each crop belongs.

From history. In 1795 the French government offered a prize for a way to preserve food for soldiers and sailors. Nicolas Appert, a confectioner, won it by sealing food in glass bottles and boiling them, decades before Louis Pasteur showed that microbes cause spoilage. John Mason patented his screw-top jar in 1858.

COMMON MISTAKES

- Using iodized table salt or too little salt, which can lead to soft or spoiled kraut.
- Adapting a family canning recipe by adding low-acid vegetables or thickening it. Only tested recipes are safe.
- Storing apples next to potatoes and carrots, where their ethylene makes the vegetables sprout or turn bitter.

Make it a game · Spoiler Detective. Your parent plays a jar of food that is going bad. Question the jar like a detective: which microbes or enzymes are at work? Then choose the stopper that fits (salt, acid, heat, cold or drying) and explain why it works. Switch roles. Whoever explains lacto-fermentation of cabbage without a pause wins the round.

1.4 THE MARKET GARDEN: SELLING PRODUCE AND SIMPLE FARM ECONOMICS

OBJECTIVES

- Calculate the cost of growing a product, set a fair price, and find the profit.
- Compare ways a small farm sells: farmers markets, roadside stands, subscription shares (CSA) and selling to stores or restaurants.
- Describe how a market gardener uses quality, presentation and honesty to keep customers.

Warm-up. Visit (or recall) a farmers market or grocery store. Write the price of three vegetables and the unit (per pound, per bunch, each). Which do you think earns the grower the most for the space it takes?

WATCH

Farmers Market 101 | Our SECRETS To Sell More At Market

Market Gardener Institute · 10:26

<https://www.youtube.com/watch?v=i5xFxalePrY>

WHEN TO WATCH

After the core ideas. List each tip the farmer gives, then circle the ones you could use at a small stand.

Note: The grower mentions a free checklist and his training course at the end; you can stop there.

BACKUP VIDEO

Farmer's Markets: Advice and Marketing Tips

Purdue Extension · 4:47

https://www.youtube.com/watch?v=u2c_n8V6RiM

Optional: small Indiana farmers share how they built their customer base.

KEY TERMS

market garden

A small, intensive farm, often under a few acres, that grows a wide range of vegetables, fruit or flowers to sell directly to customers.

gross revenue and net profit

Gross revenue is all the money taken in; net profit is what is left after all costs are paid.

break-even point

The number of units you must sell for revenue to equal costs; beyond it, you make a profit.

cost of production

Everything it costs to grow and sell a product: seed, compost, water, supplies, packaging, market fees and the value of your time.

CSA

Community-supported agriculture: customers pay at the start of the season for a weekly share of the harvest.

CORE IDEAS

A **market garden** grows food to sell. Many are small, from a quarter acre to a few acres, and they earn their living by growing high-value crops intensively: salad greens, herbs, cherry tomatoes, carrots, cut flowers, garlic. Space, time and the length of the season are the limits, so a market gardener chooses crops that sell well, grow quickly, and can be harvested in succession (Lesson 1.2).

Every product has a **cost of production**. Suppose a bed 30 inches by 25 feet gives 60 bunches of radishes in four weeks. Seed costs \$6, compost \$10, bands and bags \$4, and the market booth share is \$10: \$30 in all. If each bunch sells for \$3, gross revenue is \$180 and net profit is \$150 before counting labor. If the work took 10 hours, that is \$15 an hour. The **break-even point** is $30 \div 3 = 10$ bunches. Writing these numbers down is how a farmer learns which crops are worth growing.

There are several ways to sell. At a **farmers market** the grower meets customers and gets the full retail price but spends the day at the booth. A **roadside stand** or honor-box stand costs little but depends on traffic. In a **CSA**, customers pay ahead, which gives the farmer money in spring when seed and supplies must be bought. Selling **wholesale** to a store or restaurant moves more food at a lower price per unit.

Customers return for quality, presentation and trust. Produce should be harvested in the cool of morning, washed and chilled quickly, bunched neatly and displayed in abundance. Prices should be clear. Scales must be honest; Scripture says a false balance is an abomination to the Lord. Many states have simple cottage-food and produce-sale rules; check with your county extension office before selling anything.

Farm economics is not only about money. A good market garden feeds neighbors, keeps farmland in use and teaches its workers diligence. But a farm that does not cover its costs cannot continue, so careful record-keeping is part of good stewardship.

PICTURE STUDY



Vegetable Market at Pontoise, Camille Pissarro, 1891 · Etching · National Gallery of Art, Washington

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

Pissarro lived in the farm town of Pontoise, near Paris, and often drew its weekly markets, where farm families sold their vegetables directly to townspeople.

Look closely

- Find the seller in front. What is she selling, and how is it displayed?
- Find the customer standing beside her. What is she carrying, and what do you think she is about to do?
- Look at the row of baskets in the middle of the picture. Why might sellers line them up this way?
- Find the people in the background. How can you tell this market is busy?

Talk about it

1. This farmer sells her own produce face to face. What are the advantages of selling this way compared with selling to a shop?
2. What would you need to bring to sell your own vegetables at a market like this one?

HANDS-ON PROJECT

A Market-Garden Business Plan for One Crop

You will choose one product you could realistically grow or make (a salad mix, a bunch of herbs, a jar of sauerkraut, a bouquet, eggs from a neighbor's flock) and write a simple one-page business plan.

You will need

- Your journal and a calculator
- Seed or supply prices from a catalog, store or website
- Prices from a farmers market or grocery store for the same product
- Optional: a spreadsheet program

Steps

1. Choose one product and describe it: what it is, the unit you will sell (bag, bunch, jar), and when it will be ready.
2. List every cost with a price: seed or supplies, compost, packaging, labels, market fees and any equipment you would need.
3. Estimate your yield: how many units one bed, row or batch will produce. Use a seed catalog, an extension yield table or your own records.
4. Find the cost per unit by dividing total cost by number of units.
5. Compare prices at two places and choose a fair price. Calculate gross revenue, net profit and the break-even number of units.
6. Estimate the hours of work and figure your profit per hour.
7. Choose a way to sell (stand, market, shares to neighbors) and write two sentences on how you will keep the product fresh and honest in weight.
8. Set up a simple project record like a 4-H project book: a table with date, what was done, hours, expense and income, so you can track the real results if you carry out your plan.
9. Ask an adult to review your plan. If you decide to try it, find out your local rules for selling produce first.

Tips

- Small quantities of herbs, greens and flowers often earn the most per square foot.
- Include your own time. A crop that loses money once your hours are counted is a hobby, which is fine, but know which it is.

Check your work

- ☐ My plan lists every cost and shows the cost per unit.
- ☐ I calculated gross revenue, net profit and the break-even point correctly.
- ☐ I chose a selling method and explained how I will keep quality and honesty.
- ☐ I can explain why recording costs helps a farmer choose crops.

NATURE JOURNAL

1. Sketch a market display for your product: the table, the containers, the sign with price and unit. Label what would catch a customer's eye.
2. Interview a farmer, a farmers market vendor or a grocery produce manager with three questions about what sells best and why. Record the answers.

COMMON MISTAKES

- Forgetting to count packaging, market fees or your own time, which makes a crop look more profitable than it is.
- Pricing far below other sellers to sell out quickly. A fair price respects your work and your neighbors' farms.
- Harvesting in the heat of the afternoon, so greens wilt before they reach the customer.

Make it a game • Pitch the Produce Stand. Pick a crop and invent its cost of production in pretend dollars. Your parent is a shopper who haggles. Set a fair price, state your break-even number, and calculate net profit on paper before the shopper counts to thirty. Then choose where to sell: market, roadside stand, CSA or restaurant. Defend the choice.

Scripture. "A false balance is abomination to the LORD: but a just weight is his delight." (Proverbs 11:1, KJV)

Every market sale depends on an honest scale and an honest price. Integrity is part of the work of farming.

UNIT 1

SEEDTIME AND HARVEST

Every farm on earth runs on a calendar that God set in place: *seedtime and harvest, and cold and heat, and summer and winter*. In this unit we study that calendar as farmers have lived it, from the hand sickle to the combine. We will look at how the farm year is planned so that food keeps coming all season, how the harvest is kept safe through the winter, and how a small farm turns a good harvest into a living.

This is the first unit of a capstone year, so it is also a planning unit. As you read about succession planting and market gardens, start thinking about the project you will grow, raise or build this year and present at a family harvest fair in the spring. Write your ideas in the back of your nature journal.

PREREQUISITES

- Knowing the four seasons and why the tilt of the earth causes them
- Knowing your area's average last spring frost and first fall frost dates (look them up with your county extension office if you do not)
- Basic garden skills: sowing seeds, watering and harvesting
- A nature journal for the year

MASTERY CHECKLIST

- ☐ I can describe the main stages of the farm year and name tools that changed farming, such as the seed drill, the steel plow, the reaper and the tractor.
- ☐ I can plan succession sowings for a crop using days to maturity and my frost dates.
- ☐ I can explain how salt, acid, heat, cold and drying each protect food from spoilage microbes.
- ☐ I can explain why low-acid foods must be pressure canned and high-acid foods may be water-bath canned.
- ☐ I can figure the cost, price and profit of a simple market-garden product.

LESSONS IN THIS UNIT

1.1 Seedtime and Harvest: The Farm Year Through History

2 sessions of 60 minutes

1.2 Succession Planting and Harvest Planning

2 sessions of 60 minutes

1.3 Keeping the Harvest: Fermenting, Canning and Root Cellars

2 sessions of 60 minutes

1.4 The Market Garden: Selling Produce and Simple Farm Economics

2 sessions of 60 minutes

UNIT 1 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work on calculations. Total: 100 points.

1. (8 pts)

Name the stages of the farm year in order and give one job for each season in a temperate climate.

2. (8 pts)

Name three inventions that changed farming and explain what each one did.

3. (8 pts)

What is the difference between a cool-season and a warm-season crop? Give two examples of each.

4. (8 pts)

Name the four kinds of succession planting and give an example of each.

5. (9 pts)

Your first fall frost is October 15. A bush bean takes 55 days to mature. Using a 14-day fall factor, what is the last date you should sow it? Show your work.

6. (8 pts)

List four ways preserving methods keep microbes from spoiling food.

7. (9 pts)

Explain how lacto-fermentation turns cabbage into sauerkraut and why the cabbage must stay under the brine.

8. **9 pts**

Why must green beans be pressure canned while strawberry jam may be water-bath canned?

9. **7 pts**

What temperature and humidity do carrots and potatoes need in storage, and why should apples be stored apart from them?

10. **8 pts**

A grower spends \$24 to produce 40 bags of salad mix and sells them at \$5 each. Find the gross revenue, net profit and break-even number of bags.

11. **8 pts**

Compare selling at a farmers market with selling through a CSA. Give one advantage of each.

12. **10 pts**

Short answer: In a paragraph, explain how a family could eat food from its own garden in February. Use at least three methods from this unit.

ANSWER KEY

1. Prepare the ground and sow (spring), tend and water (summer), harvest (late summer and fall), store, rest, repair and plan (winter). Any reasonable job for each season.
2. Any three: Jethro Tull's seed drill sowed seed evenly in rows; John Deere's steel plow cut sticky prairie sod; McCormick's reaper cut grain mechanically; the tractor replaced horses and allowed one family to farm more land.
3. Cool-season crops tolerate light frost and grow best in cool weather (peas, lettuce, spinach, kale, cabbage). Warm-season crops are killed by frost and need warm soil (tomatoes, beans, corn, squash, peppers).
4. Repeated sowings (lettuce every two weeks); different maturities (early, mid and late sweet corn sown together); relay planting (transplanting fall brassicas among finishing beans); follow-on crop (beans after garlic is harvested).
5. $55 + 14 = 69$ days. Counting back 69 days from October 15 gives about August 7.
6. Removing water (drying, salt, sugar), raising acidity (fermenting, pickling), cold (cellaring, refrigeration, freezing), and heat with sealing (canning).
7. Salt draws water out of the cabbage to make a brine and holds back spoilage organisms. Lactic acid bacteria on the leaves grow in the airless brine and turn sugars into lactic acid, lowering the pH so the cabbage keeps. Cabbage above the brine is exposed to air, where molds and spoilage microbes can grow.
8. Green beans are low-acid (above pH 4.6), where botulism spores can survive boiling and grow in a sealed jar; only pressure canning reaches about 240 °F, hot enough to destroy them. Jam is high-acid, so the spores cannot grow and boiling-water processing is enough.
9. About 32–40 °F with high humidity (about 90–95 percent). Apples give off ethylene gas, which makes potatoes sprout and carrots turn bitter.
10. Gross revenue $40 \times \$5 = \$200$. Net profit $\$200 - \$24 = \$176$ (before labor). Break-even $\$24 \div \$5 = 4.8$, so 5 bags.
11. Farmers market: full retail price and direct contact with customers. CSA: customers pay at the start of the season, giving the farmer money when seed and supplies are bought, and a known number of customers.
12. A strong answer names at least three methods (for example, sauerkraut made in fall, tomatoes and jam water-bath canned in summer, green beans pressure canned, carrots and potatoes in a root cellar, onions and squash stored dry, late

succession crops of kale or spinach under a cold frame) and explains briefly why each keeps.

PORTFOLIO PIECE: A HARVEST-KEEPING RECORD

Preserve at least two foods by two different methods this fall (for example, sauerkraut and stored carrots, or dried herbs and water-bath canned applesauce with an adult). Keep a record of each: the recipe or method and its source, dates, measurements (salt, pH, temperatures), and the result after one month. Add a one-page explanation of the science that keeps each food safe.

LOOK FOR	WHAT IT MEANS
Two methods	Two foods are preserved by two different methods, each from a tested or reputable source.
Records	Dates, amounts, temperatures and pH or other measurements are recorded clearly in a table.
Science	The explanation correctly names how each method stops spoilage microbes and enzymes.
Safety	Safety steps (adult help, clean tools, tested times, signs of spoilage) are described and followed.
Result	The condition of each food after a month is described honestly, with what would be done differently next time.

UNIT 2

WILDLIFE MANAGEMENT

Wild animals share every farm, garden and neighborhood. In earlier grades you learned to identify their tracks and keep a safe distance. This year you will look at wildlife the way a biologist does: as populations that can be counted, that rise and fall with food, cover and disease, and that people can help or harm by the way they manage land.

We will learn how deer and other animals are surveyed, how diseases such as Lyme disease, rabies and chronic wasting disease move between wildlife, pets and people, how birds are banded and counted by thousands of volunteers, and how a farm or homestead can be managed to give wildlife a place while still protecting crops and flocks. Good stewardship of creation starts with knowing what is really there.

PREREQUISITES

- Identifying common local mammals and birds and their tracks
- The rule never to touch, feed or approach wild animals
- Basic arithmetic with fractions and percents

MASTERY CHECKLIST

- ☐ I can explain population, density, carrying capacity and the factors that limit a population.
- ☐ I can estimate a population with the mark-recapture method and explain its assumptions.
- ☐ I can explain how Lyme disease, rabies and chronic wasting disease spread, and the precautions for each.
- ☐ I can describe how bird banding and volunteer bird counts help scientists study migration.
- ☐ I can map habitat on a piece of land and recommend improvements for food, water, cover and space.

LESSONS IN THIS UNIT

2.1 Counting Wildlife: Populations and Surveys

2 sessions of 60 minutes

2.2 Wildlife and Disease: Ticks, Rabies and Chronic Wasting Disease

2.3 Bird Migration, Banding and Backyard Counts

2 sessions of 60 minutes

2.4 Stewardship of Habitat on Farms and Homesteads

2 sessions of 60 minutes

UNIT 2 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work on calculations. Total: 100 points.

1. (8 pts)

Define carrying capacity and name three limiting factors for a deer population.

2. (8 pts)

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

3. (9 pts)

A biologist marks 40 rabbits and releases them. Later she catches 50 rabbits, and 8 of them are marked. Estimate the population. Show your work.

4. (8 pts)

Name three assumptions of the mark-recapture method.

5. (8 pts)

Name two methods biologists use to survey deer and what each measures.

6. (9 pts)

Describe the correct way to remove an attached tick and two ways to prevent tick bites.

7. (8 pts)

Which wild animals most often carry rabies in the United States, and what are three warning signs of a rabid animal?

8. **8 pts**

What causes chronic wasting disease, and why do many states forbid feeding deer?

9. **8 pts**

Name three ways birds navigate during migration.

10. **8 pts**

Why does Project FeederWatch ask you to record the highest number of each species seen at one time?

11. **8 pts**

List the four parts of habitat and one improvement that adds each on a farm.

12. **10 pts**

Short answer: A family wants more songbirds and rabbits on their land but also keeps chickens and a vegetable garden. Explain how they can plan their habitat work to do both.

ANSWER KEY

1. Carrying capacity is the largest population an area can support over time without damaging its food, water and cover. Limiting factors include late-winter food, cover, water, predators, disease, hunting and vehicle collisions (any three).
2. A height in a woods below which nearly all twigs and young plants have been eaten by deer. It tells the biologist the deer population is above what the habitat can support.
3. $N = M \times C \div R = 40 \times 50 \div 8 = 250$ rabbits.
4. Marks are not lost; marked animals mix freely with unmarked ones and are as likely to be caught; no births, deaths, or movement in or out during the survey; marking does not harm the animal (any three).
5. Any two: aerial counts (number of deer seen in an area), counts of fawns per 100 does (recruitment), trail camera grids (density and buck-doe-fawn ratios), spotlight counts (relative abundance), pellet-group counts (density), hunter harvest data (age structure and trends).
6. Grasp the tick with fine-tipped tweezers close to the skin and pull straight up with steady pressure, then wash the area and tell an adult. Prevention: long light-colored pants tucked into socks, EPA-registered repellent used with an adult, daily tick checks, staying in the center of trails, keeping grass short.
7. Raccoons, skunks, foxes and bats. Signs: a night animal out in daylight, unusual tameness or aggression, staggering or paralysis, drooling, attacking objects (any three).
8. Prions, misfolded proteins that cause brain proteins to misfold. Feeding crowds deer together where they share saliva and droppings, which spreads prions.
9. The sun's position, star patterns, the earth's magnetic field, and landmarks such as coastlines, rivers and mountains (any three).
10. So that the same individual birds are not counted again and again; it gives a reliable minimum count that can be compared across sites and years.
11. Food (fruiting native shrubs, wildflower strips), water (pond, birdbath, protected stream), cover (brush pile, hedgerow, evergreens), space/nesting (nest boxes, snags, delayed mowing). Any reasonable example for each.
12. A strong answer places brush piles, hedgerows and wildlife plantings at the far edges of the property away from the coop and garden; fences the garden; locks

hens in a secure coop at night; keeps feed and garbage secured; and explains that wildlife can thrive in some areas while being kept out of others.

PORTFOLIO PIECE: A WILDLIFE AND HABITAT REPORT

Combine your work from this unit into a short report on the wildlife of one property: your habitat map with scores, your backyard survey and bird-count data (with tables and a graph), your tick-risk map, and a page of recommendations for the next year. Present the report to your family as if you were a wildlife biologist advising a landowner.

LOOK FOR	WHAT IT MEANS
Data	Survey and bird-count data are recorded in clear tables with dates, methods and at least one graph.
Habitat analysis	The map is to scale and scores food, water, cover and space, naming the limiting factor.
Health and safety	The report includes tick risk zones and a disease-prevention plan for family and pets.
Recommendations	Recommendations are practical, protect gardens and flocks, and follow from the data.
Presentation	The report is neat, organized, and presented clearly to an audience.

2.1 COUNTING WILDLIFE: POPULATIONS AND SURVEYS

OBJECTIVES

- Define population, density, carrying capacity, birth rate and death rate.
- Describe how biologists survey deer and other wildlife, including aerial counts, trail cameras and pellet counts.
- Estimate a population with the mark-recapture method and explain when it works.

Warm-up. Look out a window or sit in your yard or a park for five minutes. Count every squirrel, rabbit or bird you see. Then write down: How sure are you of your count? Did you count any animal twice? Did you miss any?

WATCH

The State of Deer and Elk: Surveys

Idaho Fish and Game · 6:30

https://www.youtube.com/watch?v=8_rojLIU_t0

WHEN TO WATCH

After the core ideas. Write down each survey method the biologists use and what it tells them.

BACKUP VIDEO

Wildlife Population Surveys

Indiana Department of Natural Resources · 2:58

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

Optional: a state biologist explains why wildlife agencies survey populations every year.

KEY TERMS

population

All the individuals of one species living in one area at one time.

density

The number of individuals per unit of area, such as deer per square mile.

carrying capacity

The largest population an area can support over time without damaging its food, water and cover.

limiting factor

Anything that keeps a population from growing larger, such as winter food, predators, disease, or nesting places.

mark-recapture

A survey method in which animals are caught and marked, released, and caught again; the share of marked animals in the second catch is used to estimate the whole population.

recruitment

The number of young that survive to join the adult population in a year.

CORE IDEAS

A **population** grows when births and animals moving in are greater than deaths and animals moving out. Every population is held in check by **limiting factors**: food in late winter, cover from weather and predators, water, places to raise young, disease and predation. The largest population that the land can feed and shelter year after year, without wearing out its plants, is its **carrying capacity**. When deer go far beyond it, they eat young trees and wildflowers until the forest has a ‘browse line’, a height below which nearly every green twig is gone.

White-tailed deer show why counting matters. A doe usually has one fawn her first year and often twins after that. With good food and few predators, a herd can nearly double in two or three years. Biologists need to know whether a herd is growing or shrinking to set hunting seasons, protect farm crops and forests, and reduce collisions with cars. So state wildlife agencies survey herds every year.

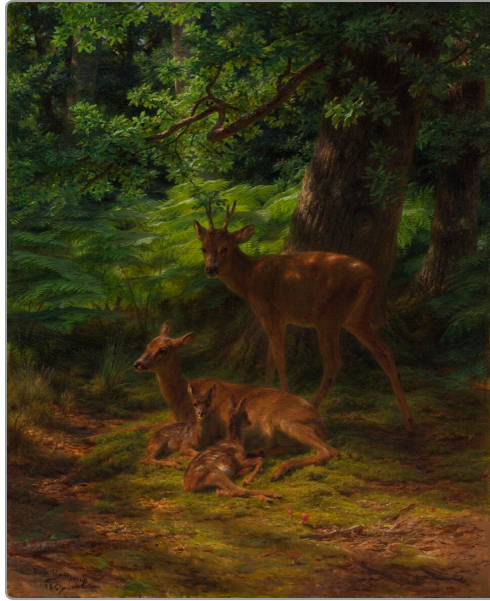
Biologists cannot count every animal, so they **sample**. In open country they fly over in winter and count deer and elk from the air, then correct for the animals they know they miss. They count young per hundred adult females to measure **recruitment**. In woods they use **trail cameras** on a grid, **spotlight counts** along roads at night, **pellet-group counts** in spring plots, and reports of how many animals hunters took and how old they were.

For smaller or hidden animals, biologists use **mark-recapture**. Catch and harmlessly mark some animals (M), release them, wait for them to mix, then catch a second sample (C) and count how many in it are marked (R). The estimate is $N = M \times C \div R$. If

20 squirrels are marked, and a later sample of 30 includes 6 marked ones, the population is about $20 \times 30 \div 6 = 100$. The method assumes marks are not lost, marked animals mix freely, and no animals are born, die or move during the survey.

Wildlife belongs to God, as Psalm 50 says, and is entrusted to people to manage wisely. Good management uses honest data, not guesses, and keeps both the animals and their habitat healthy.

PICTURE STUDY



Deer in Repose, Rosa Bonheur, 1867 · Oil on canvas · Detroit Institute of Arts

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

Rosa Bonheur was one of the finest animal painters of the 1800s. She studied living animals closely and kept many at her home near the Forest of Fontainebleau, where she painted this family of roe deer.

Look closely

- Count the animals. How many adults and how many young are there?
- Find the buck. How can you tell him from the doe? What is he doing while the others rest?
- Look at the fawns' coats. How do their spots help them in the dappled light of the forest floor?
- Look at the plants around the deer. What could they eat here, and where could they hide?

Talk about it

1. If every doe in a herd raised two fawns each year and few deer died, what would happen to the herd and to the plants around it?
2. A biologist counting deer from the air might miss animals lying in cover like this. How could she correct her count?

HANDS-ON PROJECT

A Mark-Recapture Simulation and a Backyard Survey

First you will test the mark-recapture method on a ‘population’ of dried beans whose true number you can check. Then you will design and run a simple survey of one real animal near your home.

You will need

- A large bag of dried white beans (or lima beans) and a paper bag
- A permanent marker
- A cup for sampling
- Your journal, a calculator and a watch
- Optional: a trail camera

Steps

1. Pour a large handful (or more) of beans into the paper bag without counting them. This is your unknown population.
2. Scoop out one cup of beans. Count them, mark each with a dot, and record this number as M. Return them to the bag and shake well so they mix.
3. Scoop out a second cup without looking. Count all the beans (C) and the marked beans among them (R). Return them and shake.
4. Calculate $N = M \times C \div R$. Repeat the second sample two more times and average your three estimates.
5. Now count every bean in the bag. How close was your average estimate? Calculate your percent error: $(\text{estimate} - \text{true}) \div \text{true} \times 100$.
6. Choose a real animal near you that is easy to see from a distance, such as gray squirrels, rabbits or a bird at a feeder.
7. Design a fair survey: the same route or the same window, the same time of day, the same length of time, on at least four days. Record date, time, weather and the highest number seen at one time.
8. Write a short conclusion: your best estimate, how confident you are, and one way a biologist could improve the survey.

Tips

- Recording the highest number seen at once avoids counting the same animal twice.
- Never try to catch or mark a wild animal yourself. Real mark-recapture studies need permits, training and safe methods.

Check your work

- ☐ I calculated three mark-recapture estimates and compared their average with the true count.
- ☐ I can name the assumptions of the mark-recapture method.
- ☐ My backyard survey used the same method on at least four days.
- ☐ I wrote a conclusion with an estimate and an honest statement of its limits.

NATURE JOURNAL

1. Draw a simple graph of a deer herd that grows past its carrying capacity: population on the vertical axis, years on the horizontal, and a dashed line for carrying capacity. Label what happens to the plants.
2. Walk a woodland edge or park and look for a browse line or signs of heavy browsing (clipped twigs, missing young trees). Sketch what you find, or note that you found none.

COMMON MISTAKES

- Adding up every animal seen over several days, which counts the same animals many times.
- Sampling the second time before the marked individuals have mixed back into the population.
- Thinking that more wildlife is always better. Too many animals for the habitat harm the land and, in the end, the animals.

Make it a game • Bean Mark-Recapture. Fill a bowl with dried beans, which stand in for deer. Scoop a handful, mark each with a pen dot, return them and stir. Scoop again, count marked ones, and estimate the whole population. Check by counting everything. Then name the limiting factor and carrying capacity for a herd. Best estimate wins.

Scripture. “For every beast of the forest is mine, and the cattle upon a thousand hills. I know all the fowls of the mountains: and the wild beasts of the field are mine.” (Psalm 50:10-11, KJV)

God knows every creature by name and number. When we count and care for wildlife, we are tending what belongs to Him.

2.2 WILDLIFE AND DISEASE: TICKS, RABIES AND CHRONIC WASTING DISEASE

OBJECTIVES

- Explain how Lyme disease is carried by blacklegged ticks and how to prevent and remove tick bites.
- Describe how rabies spreads, its warning signs in wildlife, and what to do after a bite or scratch.
- Explain what chronic wasting disease is and why feeding deer can help it spread.
- Define a zoonotic disease and give three examples.

Warm-up. Write down everything you already know about ticks. Then look at a dried poppy seed or a sesame seed and a sharpened pencil tip. A blacklegged tick nymph is about the size of the poppy seed. How easily could you miss one on your skin?

WATCH

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

Johns Hopkins Rheumatology · 6:34

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

WHEN TO WATCH

After the core idea about ticks. Write down the five tips and add them to your safety list for outdoor work.

KEY TERMS

zoonotic disease

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

vector

A living thing, such as a tick or mosquito, that carries a disease-causing organism from one host to another.

Lyme disease

An illness caused by the bacterium *Borrelia burgdorferi*, spread in the eastern and north-central U.S. by the bite of the blacklegged (deer) tick.

rabies

A virus of the nervous system, spread in saliva by the bite or scratch of an infected mammal; nearly always fatal once signs appear, but preventable with prompt treatment after exposure.

chronic wasting disease (CWD)

A fatal brain disease of deer, elk and moose caused by misfolded proteins called prions.

reservoir

A wild species in which a disease is commonly kept going, such as raccoons, skunks, foxes and bats for rabies.

CORE IDEAS

Many diseases move between wildlife, livestock, pets and people. These are called **zoonotic** diseases. Knowing how each one spreads lets you work outdoors with confidence instead of fear, and it is why farmers, hunters, gardeners and veterinarians all follow simple precautions.

Ticks and Lyme disease. The blacklegged tick, often called the deer tick, lives in leaf litter and tall grass, especially at woodland edges. Young ticks pick up the Lyme bacterium by feeding on infected mice and chipmunks; adults often feed on deer, which carry ticks far and wide. Most human cases come from tiny **nymphs** in late spring and summer. A tick usually needs to be attached for about a day or more to pass on Lyme bacteria, so daily tick checks matter. Wear light-colored long pants tucked into socks, use an EPA-registered repellent applied by or with an adult, and check your whole body after being outdoors. Remove an attached tick with fine-tipped tweezers, grasping it close to the skin and pulling straight up with steady pressure; then wash the area. Tell an adult and watch for a spreading rash, fever or aches over the next month.

Rabies. Rabies is a virus that attacks the nervous system and is spread in saliva, mainly by bites. In the United States most cases are in wild raccoons, skunks, foxes and bats. A rabid animal may act strangely: a night animal wandering in daylight, unusual tameness or aggression, staggering, or drooling. Never touch a wild mammal or a bat, even a dead one. If anyone is bitten or scratched, wash the wound with soap and running water for 15 minutes and see a doctor the same day;

treatment given soon after exposure prevents the disease. Keeping dogs, cats and ferrets up to date on their rabies shots protects both pets and families.

Chronic wasting disease affects deer, elk and moose. It is caused by **prions**, misfolded proteins that cause other proteins in the brain to misfold. Infected deer may look healthy for a year or more, then lose weight, drool and act listless; the disease is always fatal. Prions are shed in saliva, urine and droppings and can stay in soil for years. Because deer that crowd around feed piles or salt licks share saliva, many states forbid feeding or baiting deer. CWD has not been shown to infect people, but health agencies advise hunters in affected areas to have deer tested and not to eat meat from an animal that tests positive.

The common thread is respect: respect for wild animals' space, careful habits, and quick reporting. State wildlife agencies ask the public to report sick-looking deer and strange-acting wildlife.

PICTURE STUDY



Raccoon, After John James Audubon, 1900 (after an Audubon plate of the 1840s) · Color plate in John Burroughs, *Squirrels and Other Fur-Bearers* · Book illustration

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

This plate, based on the work of John James Audubon and his sons, illustrated a nature book by the American writer John Burroughs. Raccoons are clever, adaptable and common near homes, which is exactly why they are important in rabies prevention.

Look closely

- Find the raccoons' front paws. How are they built for climbing and handling food?
- Look at the black mask and ringed tail. Why do you think biologists use these marks to identify raccoons quickly?
- Notice that the raccoons are in a tree. Where else do raccoons den near farms and houses?
- These raccoons are active and alert. What behavior in a raccoon would make you suspect it was sick?

Talk about it

1. Why is a raccoon wandering a yard at noon, unafraid of people, a reason to call an adult and stay away?

2. How do trash, pet food left outside and open chicken coops bring raccoons into contact with pets and people?

Safety first. Never touch, feed or approach wild mammals or bats, alive or dead. Do tick checks after every outing in grass or woods, and remove ticks with tweezers as taught. Any bite or scratch from a wild animal or an unknown pet means washing with soap and water for 15 minutes and telling an adult right away so a doctor can be called.

HANDS-ON PROJECT

A Tick-Safety Survey and Family Disease-Prevention Plan

You will find where ticks are most likely around your home and write a practical plan to protect your family and pets from tick-borne disease and rabies.

You will need

- A map of your yard, a nearby park or a farm you visit (hand-drawn is fine)
- Colored pencils
- Optional, with an adult: a ‘tick drag’ made from a 3 × 3 ft piece of white flannel tacked to a dowel, tweezers, and a zip bag
- Your state health department’s or extension service’s tick and rabies pages

Steps

1. Draw a map of the area and color it in zones: mowed lawn, garden, tall grass, woodland edge, woods, leaf piles and stone walls.
2. Rate each zone as low, medium or high tick risk, based on what you learned about where ticks live.
3. Optional, with an adult and wearing long pants tucked into socks: slowly drag the white flannel over 20 steps of each zone and check it for ticks. Record the number in each zone. Seal any ticks in a zip bag and put it in the freezer for identification, or discard it.
4. Look up which tick-borne diseases and which rabies reservoir species occur in your state.
5. Write a one-page family plan with three parts: preventing tick bites (clothing, repellent with an adult, daily checks, yard changes such as a wood-chip border between lawn and woods), protecting pets (tick prevention and rabies shots from the vet), and what to do if a wild animal acts strangely or anyone is bitten.

6. Add the phone number for your county or state wildlife agency and your local animal-control office.
7. Share your plan with your family and post it where outdoor gear is kept.

Tips

- Ticks are most active from spring through fall, and adult blacklegged ticks are out on warm days even in winter.
- Keeping grass short and leaf litter away from paths and play areas lowers tick numbers.

Check your work

- ☐ My map shows tick-risk zones with reasons for each rating.
- ☐ My plan explains how to prevent and remove tick bites correctly.
- ☐ My plan tells what to do about a strange-acting wild animal or a bite.
- ☐ I can explain how CWD spreads and why feeding deer is discouraged.

NATURE JOURNAL

1. Draw the four life stages of a blacklegged tick (egg, larva, nymph, adult) to scale beside a ruler marked in millimeters, using a field guide or extension fact sheet.
2. Make a flow chart of the Lyme disease cycle: mouse, larva, nymph, person or deer, adult tick, eggs.

From history. In 1885 Louis Pasteur first treated a boy, Joseph Meister, after a rabid dog bit him, using a series of injections he had developed. The boy lived. Lyme disease was named in 1977 for Lyme, Connecticut, where doctors studied a cluster of cases; the bacterium was identified by Willy Burgdorfer in 1982.

COMMON MISTAKES

- Burning a tick or smothering it with petroleum jelly; these can make it release more fluid. Use fine-tipped tweezers.
- Picking up a bat found on the ground or in the house. Let an adult call animal control or the health department.
- Putting out corn or salt for deer to ‘help’ them. It crowds deer together and can spread disease.

Make it a game • Safe or Sorry Cards. Write eight situations on cards: a tick on your sock, a bat in the yard, a staggering deer, a scratch from a stray cat, and so on. Draw one and say aloud the disease, the vector or reservoir, and exactly what to do next. Your parent keeps score of complete answers. Beat your own tally.

2.3 BIRD MIGRATION, BANDING AND BACKYARD COUNTS

OBJECTIVES

- Explain why and how birds migrate, including the role of day length and the main North American flyways.
- Describe how bird banding works and what it has taught scientists.
- Conduct a standardized backyard bird count and submit or record the data like a citizen scientist.

Warm-up. List every bird you can name that you have seen near your home. Put a check by the ones you think stay all winter and a star by those you think leave in fall.

WATCH

Following the Birds: The Science of Bird Banding

Nebraska Game and Parks Commission · 3:54

<https://www.youtube.com/watch?v=4x-bR-PTy74>

WHEN TO WATCH

After the core idea about banding. Notice every measurement the banders take before releasing a bird.

BACKUP VIDEO

Project FeederWatch

Forestry and Natural Resources Extension · 7:04

<https://www.youtube.com/watch?v=xSafaHy5jFA>

Before the hands-on project: how to take part in the Cornell Lab of Ornithology's Project FeederWatch.

KEY TERMS

migration

The regular seasonal journey of animals between nesting and wintering areas.

flyway

A broad route that many migrating birds follow; North America has four: Atlantic, Mississippi, Central and Pacific.

photoperiod

The length of daylight, which birds sense and which triggers the hormones that prepare them to migrate.

bird banding

Placing a small, numbered metal band on a wild bird's leg so that it can be identified if it is caught again or found.

citizen science

Research in which ordinary volunteers collect data that scientists use.

CORE IDEAS

About half of North America's bird species migrate. Most travel to follow food: insects, nectar and open water disappear in a northern winter but are plentiful in the south, while northern summers offer long days, abundant insects and room to nest. As day length (**photoperiod**) changes, birds' hormones shift; they eat heavily, store fat (some songbirds nearly double their weight), and become restless at night. Many songbirds migrate at night, resting and feeding by day.

Birds find their way with remarkable equipment God built into them. They use the position of the sun, the pattern of stars around the North Star, the earth's magnetic field, and landmarks such as coastlines, rivers and mountain ridges. Many follow broad **flyways**. Some journeys are astonishing: a ruby-throated hummingbird, weighing about as much as a penny, crosses the Gulf of Mexico in one nonstop flight of around 500 miles.

Much of what we know comes from **bird banding**. Trained, federally permitted banders catch birds safely, usually in fine 'mist nets', place a lightweight numbered aluminum band on one leg, record the species, age, whether male or female, wing length, weight and fat, and release the bird within minutes. In North America the records go to the Bird Banding Laboratory, run since 1920. When a banded bird is caught again or found, the band shows where it has been and how long it has lived. Anyone who finds a band can report it online at reportband.gov.

Thousands of volunteers add to the data by counting birds. The **Christmas Bird Count** has been held every winter since 1900. **Project FeederWatch** (November to April) asks people to count birds at their feeders on two-day periods, recording the largest number of each species seen at once. The **Great Backyard Bird Count** takes place every February, and the eBird app collects sightings all year. Together these

counts show which species are increasing or declining and how migration timing changes from year to year.

Jeremiah observed that ‘the stork in the heaven knoweth her appointed times.’

Watching for the first returning robin or the last departing hummingbird is a way of noticing the order God set in creation.

PICTURE STUDY



Canada Goose, Plate 201 of The Birds of America, Robert Havell after John James Audubon, 1834 ·
Hand-colored etching and aquatint · National Gallery of Art, Washington

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

Audubon painted every bird life-size, so large birds like this goose had to be bent to fit the page. Canada geese are among the best-known migrants, flying in V-shaped flocks along all four flyways.

Look closely

- Find the white ‘chin strap’ on each goose. Field marks like this let birders identify species quickly.
- Look at the standing goose’s open bill and lifted head. What do you think it is doing?
- Look at the second goose resting low in the grass. Why might it stay so still?
- Look at the feet. How are they built for the goose’s life on water and land?

Talk about it

1. Why does a V-shaped flock help geese on a long migration?
2. Many Canada geese now stay all year in towns with lawns and ponds. What might change a bird’s need to migrate?

HANDS-ON PROJECT

A Citizen-Science Bird Count

You will carry out a standardized bird count using the rules of Project FeederWatch or the Great Backyard Bird Count, record your data carefully, and, if your family agrees, submit it.

You will need

- A bird feeder with black-oil sunflower seed, or a window or park bench with a view of trees and shrubs
- A field guide or a bird-identification app
- Binoculars (optional)
- Your journal and a watch

Steps

1. If you can, put out a feeder a week or two ahead so birds find it. Place it within 3 feet of a window or more than 30 feet away to reduce window strikes.
2. Choose two consecutive days for your count. Decide how long you will watch each day (at least 15 minutes, at the same time of day if possible).
3. Make a data table with columns for species, the highest number seen at one time, and notes (behavior, field marks).
4. Watch quietly. For each species, record only the largest number you see together at one moment, not the total of all sightings.
5. Record the weather, temperature, snow cover and how long you watched.
6. Identify any bird you are unsure of by its field marks: size, shape, bill, color pattern and behavior. If still unsure, note it as unknown rather than guessing.
7. With an adult, enter your count on the FeederWatch, Great Backyard Bird Count or eBird website if your family wishes, or keep it in your journal.
8. Repeat the count once a month through the winter and compare which species come and go.

Tips

- Clean feeders every two weeks with hot soapy water and let them dry, to keep birds from spreading disease.
- Bring feeders in if a bear, or a hawk taking birds repeatedly, becomes a problem; wildlife safety comes first.

Check your work

- ☐ My data table records the highest number of each species seen at once, not a running total.
- ☐ I recorded weather and watching time.
- ☐ I identified birds by field marks and marked uncertain ones honestly.
- ☐ I can explain how banding and counts help scientists study migration.

NATURE JOURNAL

1. Draw a careful field sketch of one feeder bird. Label its field marks: crown, eye line, wing bars, breast pattern, bill shape and tail.
2. Start a migration calendar: record the date you see the first and last of migrating species this year, such as robins, geese, hummingbirds or juncos.

COMMON MISTAKES

- Adding up every bird that visits, which counts the same chickadee many times.
- Guessing at a species instead of recording it as unknown; one wrong record can mislead scientists.
- Leaving feeders dirty, which can spread disease among birds.

Make it a game • Flyway Story Chain. Imagine you are a bird leaving in autumn. Tell the migration as a story chain, one sentence each with your parent. You must work in photoperiod, a flyway, a stopover, and how a bander would catch you and record your leg band. Anyone who stalls loses a turn. Finish with your safe arrival.

Scripture. “Yea, the stork in the heaven knoweth her appointed times; and the turtle and the crane and the swallow observe the time of their coming;” (Jeremiah 8:7, KJV)

The ‘turtle’ here is the turtledove. Migrating birds keep the times God set for them; the prophet asks whether God’s people will be as faithful.

2.4 STEWARDSHIP OF HABITAT ON FARMS AND HOMESTEADS

OBJECTIVES

- Identify the four parts of habitat (food, water, cover and space) and the value of edges.
- Describe practical habitat improvements for farms and yards: hedgerows, brush piles, nest boxes, native plants, buffer strips and timed mowing.
- Balance wildlife habitat with protecting crops, gardens and flocks.

Warm-up. Think of a place you know with lots of wildlife and a place with very little. List three differences between them.

WATCH

Brushpiles with Game Commission biologist Dan Mummert

PA Game Commission • 4:36

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

WHEN TO WATCH

Before the hands-on project. Notice how the biologist builds the base of the pile first and why.

BACKUP VIDEO

Habitat Hints - Brush Piles

MOconservation • 3:34

<https://www.youtube.com/watch?v=BnruokJz5h8>

Optional: a Missouri biologist explains which brush piles help wildlife and which do not.

KEY TERMS

habitat

The place where an animal finds the food, water, cover and space it needs to live and raise young.

edge

The border where two habitat types meet, such as a woods and a field; edges often hold many species.

hedgerow

A row of shrubs and small trees along a field boundary, giving birds and small animals food, nesting places and travel lanes.

riparian buffer

A strip of trees, shrubs and grasses along a stream that shades the water, holds the bank and filters runoff.

native plant

A plant that grew naturally in a region before people brought plants from elsewhere; native insects and birds are often fitted to depend on them.

CORE IDEAS

Every animal needs four things in its **habitat**: food, water, cover (shelter from weather and predators, and places to nest), and enough space. Usually one of these is in short supply, and that limiting part decides how many animals the land can hold. A bobwhite quail needs bare ground for chicks to forage, grassy cover to nest in, and brushy thickets to escape hawks, all within a small area.

Many species live along **edges**, where woods meet field or field meets stream. Old farms with hedgerows, fence rows, small woodlots and stream borders held a great variety of birds and animals. When every field is made larger and every corner cleared, much of that variety disappears. A farm family can bring some of it back without giving up much ground.

Practical improvements include: **brush piles** built with large logs at the bottom for rabbits and wrens; **hedgerows** of native shrubs such as elderberry, dogwood and serviceberry; **nest boxes** sized for each species (a 1½-inch hole for eastern bluebirds, mounted on a pole with a predator guard); leaving a few dead trees (snags) for woodpeckers where they cannot fall on people or buildings; strips of native wildflowers for pollinators; **riparian buffers** along streams; and delaying hay mowing until ground-nesting birds have fledged. The USDA Natural Resources Conservation Service helps farmers plan such practices.

Stewardship also means honesty about conflict. Deer eat gardens, raccoons and foxes take chickens, and groundhogs dig under barns. Good habitat work keeps wild homes away from the henhouse and the vegetable garden: put the brush pile at the

far edge of the property, keep feed and garbage locked up, fence gardens, and close poultry into a secure coop every night. Caring for wildlife and protecting what we raise are both part of dressing and keeping the land.

Even a small yard or apartment balcony can help: a native shrub, a pot of flowers for bees, a birdbath kept clean, or a nest box. Many small places together make a great deal of habitat.

PICTURE STUDY



The Cornfield, John Constable, 1826 · Oil on canvas · National Gallery, London

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

Constable painted the lanes and fields near his childhood home in Suffolk, England. His farms are full of hedges, streams and old trees, the kind of mixed landscape where wildlife and farming live side by side. (In England, ‘corn’ means grain, here wheat.)

Look closely

- Trace the hedges and trees along the lane. What food and cover could they give birds and small animals?
- Find the stream. Who is using it? What other creatures might depend on it?
- Find the field beyond the gate. Where is the edge between the field and the hedgerow?
- Find the old plow left by the gate. What does it tell you about the work done here?

Talk about it

1. If the hedges and trees along this lane were removed to make the field larger, what would be gained and what would be lost?
2. How does this farm show both ‘dressing’ the land (working it) and ‘keeping’ it (caring for it)?

Safety first. Use saws, loppers and drills only with an adult. Wear gloves and long sleeves when moving brush, and do a tick check afterward. Build brush piles well away from buildings, chicken coops and gardens.

HANDS-ON PROJECT

A Habitat Map and One Improvement

You will map the habitat on a property (your yard, a relative's farm, a church grounds or a park with permission), evaluate it for food, water, cover and space, and carry out one improvement.

You will need

- Graph paper, pencil and colored pencils
- A measuring tape or a pace count
- For the improvement, one of: branches and logs for a brush pile; a bluebird or wren box kit and a mounting pole with a guard; a native shrub or a pot of native flowers; a shallow birdbath
- Gloves, and adult help with tools

Steps

1. Pace or measure the property and draw it to scale on graph paper with buildings, lawn, gardens, trees, shrubs, water and fences.
2. Color-code the habitat: food sources (fruiting shrubs, seed plants, flowers), water, cover (dense shrubs, brush, evergreens), and nesting places.
3. Mark the edges where two habitat types meet. Mark areas that must stay wildlife-free, such as the vegetable garden and chicken coop.
4. Score each of the four habitat needs from 1 (poor) to 5 (excellent) and identify the limiting one.
5. Choose one improvement that addresses the limiting need and fits away from gardens and flocks. Mark its location on the map.
6. Build or plant your improvement with adult help. For a brush pile, lay three or four large logs parallel as a base, cross them with more logs, then add smaller branches on top until the pile is about 5 feet high and 10 feet across.
7. Photograph or sketch the improvement and record the date.
8. Write a one-page wildlife habitat management plan for the property, in the style of the 4-H Wildlife Habitat Evaluation Program (WHEP): the

landowner's goals, two or three target species, the limiting factor for each, and the practices you recommend with where and when to do them.

9. Observe it once a week for a month and record any wildlife use or signs.

Tips

- Mount bluebird boxes facing an open field, about 5 feet high, with a predator guard on the pole.
- Native plant nurseries and your county extension office can tell you which shrubs are native to your area.
- The 4-H Wildlife Habitat Evaluation Program (WHEP) holds county, state and national contests in which teams evaluate habitat and write management plans; ask your county extension office whether your county has a team.

Check your work

- ☐ My map is to scale and color-coded for food, water, cover and nesting.
- ☐ I identified the limiting habitat need with a reason.
- ☐ My improvement addresses that need and is placed away from gardens and flocks.
- ☐ I recorded observations of my improvement for a month.
- ☐ I wrote a WHEP-style management plan with goals, target species and recommended practices.

NATURE JOURNAL

1. Draw a cross-section of a hedgerow or a stream buffer, labeling the layers (tall trees, shrubs, grasses and flowers) and an animal that uses each.
2. Record wildlife signs around your habitat improvement each week: tracks, droppings, feathers, nests, birds perching.

COMMON MISTAKES

- Building a brush pile from small twigs only; it collapses into a flat heap. Start with big logs to make open spaces underneath.
- Placing habitat right next to the chicken coop or vegetable garden and then wondering why raccoons and rabbits move in.
- Planting showy non-native shrubs that native insects cannot feed on, when a native shrub would feed many more creatures.

Make it a game • Habitat Four Squares. Draw a quick four-square grid labeled food, water, cover and space. Your parent names a yard animal and you have sixty seconds to say what it needs in each square. Then suggest one improvement: hedgerow, brush pile, nest box, native plants, buffer strip or timed mowing. Trade places and be the animal.

UNIT 2

WILDLIFE MANAGEMENT

Wild animals share every farm, garden and neighborhood. In earlier grades you learned to identify their tracks and keep a safe distance. This year you will look at wildlife the way a biologist does: as populations that can be counted, that rise and fall with food, cover and disease, and that people can help or harm by the way they manage land.

We will learn how deer and other animals are surveyed, how diseases such as Lyme disease, rabies and chronic wasting disease move between wildlife, pets and people, how birds are banded and counted by thousands of volunteers, and how a farm or homestead can be managed to give wildlife a place while still protecting crops and flocks. Good stewardship of creation starts with knowing what is really there.

PREREQUISITES

- Identifying common local mammals and birds and their tracks
- The rule never to touch, feed or approach wild animals
- Basic arithmetic with fractions and percents

MASTERY CHECKLIST

- ☐ I can explain population, density, carrying capacity and the factors that limit a population.
- ☐ I can estimate a population with the mark-recapture method and explain its assumptions.
- ☐ I can explain how Lyme disease, rabies and chronic wasting disease spread, and the precautions for each.
- ☐ I can describe how bird banding and volunteer bird counts help scientists study migration.
- ☐ I can map habitat on a piece of land and recommend improvements for food, water, cover and space.

LESSONS IN THIS UNIT

2.1 Counting Wildlife: Populations and Surveys

2 sessions of 60 minutes

2.2 Wildlife and Disease: Ticks, Rabies and Chronic Wasting Disease

2.3 Bird Migration, Banding and Backyard Counts

2 sessions of 60 minutes

2.4 Stewardship of Habitat on Farms and Homesteads

2 sessions of 60 minutes

UNIT 2 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work on calculations. Total: 100 points.

1. (8 pts)

Define carrying capacity and name three limiting factors for a deer population.

2. (8 pts)

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

3. (9 pts)

A biologist marks 40 rabbits and releases them. Later she catches 50 rabbits, and 8 of them are marked. Estimate the population. Show your work.

4. (8 pts)

Name three assumptions of the mark-recapture method.

5. (8 pts)

Name two methods biologists use to survey deer and what each measures.

6. (9 pts)

Describe the correct way to remove an attached tick and two ways to prevent tick bites.

7. (8 pts)

Which wild animals most often carry rabies in the United States, and what are three warning signs of a rabid animal?

8. **8 pts**

What causes chronic wasting disease, and why do many states forbid feeding deer?

9. **8 pts**

Name three ways birds navigate during migration.

10. **8 pts**

Why does Project FeederWatch ask you to record the highest number of each species seen at one time?

11. **8 pts**

List the four parts of habitat and one improvement that adds each on a farm.

12. **10 pts**

Short answer: A family wants more songbirds and rabbits on their land but also keeps chickens and a vegetable garden. Explain how they can plan their habitat work to do both.

ANSWER KEY

1. Carrying capacity is the largest population an area can support over time without damaging its food, water and cover. Limiting factors include late-winter food, cover, water, predators, disease, hunting and vehicle collisions (any three).
2. A height in a woods below which nearly all twigs and young plants have been eaten by deer. It tells the biologist the deer population is above what the habitat can support.
3. $N = M \times C \div R = 40 \times 50 \div 8 = 250$ rabbits.
4. Marks are not lost; marked animals mix freely with unmarked ones and are as likely to be caught; no births, deaths, or movement in or out during the survey; marking does not harm the animal (any three).
5. Any two: aerial counts (number of deer seen in an area), counts of fawns per 100 does (recruitment), trail camera grids (density and buck-doe-fawn ratios), spotlight counts (relative abundance), pellet-group counts (density), hunter harvest data (age structure and trends).
6. Grasp the tick with fine-tipped tweezers close to the skin and pull straight up with steady pressure, then wash the area and tell an adult. Prevention: long light-colored pants tucked into socks, EPA-registered repellent used with an adult, daily tick checks, staying in the center of trails, keeping grass short.
7. Raccoons, skunks, foxes and bats. Signs: a night animal out in daylight, unusual tameness or aggression, staggering or paralysis, drooling, attacking objects (any three).
8. Prions, misfolded proteins that cause brain proteins to misfold. Feeding crowds deer together where they share saliva and droppings, which spreads prions.
9. The sun's position, star patterns, the earth's magnetic field, and landmarks such as coastlines, rivers and mountains (any three).
10. So that the same individual birds are not counted again and again; it gives a reliable minimum count that can be compared across sites and years.
11. Food (fruiting native shrubs, wildflower strips), water (pond, birdbath, protected stream), cover (brush pile, hedgerow, evergreens), space/nesting (nest boxes, snags, delayed mowing). Any reasonable example for each.
12. A strong answer places brush piles, hedgerows and wildlife plantings at the far edges of the property away from the coop and garden; fences the garden; locks

hens in a secure coop at night; keeps feed and garbage secured; and explains that wildlife can thrive in some areas while being kept out of others.

PORTFOLIO PIECE: A WILDLIFE AND HABITAT REPORT

Combine your work from this unit into a short report on the wildlife of one property: your habitat map with scores, your backyard survey and bird-count data (with tables and a graph), your tick-risk map, and a page of recommendations for the next year. Present the report to your family as if you were a wildlife biologist advising a landowner.

LOOK FOR	WHAT IT MEANS
Data	Survey and bird-count data are recorded in clear tables with dates, methods and at least one graph.
Habitat analysis	The map is to scale and scores food, water, cover and space, naming the limiting factor.
Health and safety	The report includes tick risk zones and a disease-prevention plan for family and pets.
Recommendations	Recommendations are practical, protect gardens and flocks, and follow from the data.
Presentation	The report is neat, organized, and presented clearly to an audience.

UNIT 3

SOIL SCIENCE CAPSTONE

Soil is not dirt. It is a living, breathing mixture of crushed rock, decaying organic matter, water, air and billions of living things, and it took God's slow work over a long time to make a few inches of it. Every crop, pasture and garden depends on it. In earlier grades you learned soil types, compost and pH. This unit brings it all together: how texture, structure and chemistry work as one system; how nitrogen, phosphorus and potassium cycle through soil, plants and animals; what happens in the thin zone of soil around every root; and how farmers keep soil from washing and blowing away.

You will run a full set of soil tests on your own soil, dig up legume roots to find nitrogen-fixing nodules, measure the work of soil microbes, and build a rainfall model to compare bare and covered ground. By the end you should be able to read a soil test report and recommend what a garden needs.

PREREQUISITES

- Knowing sand, silt, clay and loam, and what humus is
- Using a simple soil pH test
- Making and using compost
- Basic chemistry words: element, atom, ion

MASTERY CHECKLIST

- ☐ I can determine my soil's texture by the jar test and the ribbon test and place it on the texture triangle.
- ☐ I can explain how soil structure, organic matter and cation exchange capacity affect water and nutrients.
- ☐ I can trace nitrogen through fixation, mineralization, nitrification, uptake and loss, and explain how phosphorus and potassium behave differently.
- ☐ I can calculate the pounds of nitrogen, phosphate and potash in a bag of fertilizer from its label.
- ☐ I can describe the rhizosphere and the roles of bacteria, fungi and mycorrhizae.
- ☐ I can explain how no-till, cover crops, rotation and contour farming protect soil.

LESSONS IN THIS UNIT

3.1 Texture, Structure and Chemistry Together	2 sessions of 60 minutes
3.2 Nutrient Cycling: Nitrogen, Phosphorus and Potassium	2 sessions of 60 minutes
3.3 The Rhizosphere and Soil Biology	2 sessions of 60 minutes
3.4 Soil Conservation and Regenerative Practices	2 sessions of 60 minutes

UNIT 3 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work on calculations. Total: 100 points.

1. 8 pts

Give the particle-size ranges of sand, silt and clay, and describe how each feels when moist.

2. 8 pts

What is the difference between soil texture and soil structure? Which can a gardener change, and how?

3. 8 pts

In a jar test, the sand layer is 30 mm, the silt layer 25 mm and the clay layer 15 mm. What are the percentages of each?

4. 8 pts

Explain cation exchange capacity and why a sandy soil low in humus needs more frequent, smaller fertilizer applications.

5. 9 pts

Trace a nitrogen atom from the air into a bean plant, then into the soil as the plant decays, and finally into a corn plant.

6. 8 pts

Name two ways nitrogen is lost from soil and the conditions that cause each.

7. 8 pts

Why does phosphorus move so little in soil, and what does that mean for how it should be applied?

8. 9 pts

A 50-lb bag of fertilizer is labeled 12-4-8. How many pounds of N, P_2O_5 and K_2O does it contain? How many pounds of product supply 0.15 lb of N?

9. (8 pts)

What is the rhizosphere, and how do plants support the microbes that live there?

10. (8 pts)

Describe the partnership between mycorrhizal fungi and plants. What does each partner give?

11. (8 pts)

Name four soil conservation practices and the problem each solves.

12. (10 pts)

Short answer: Explain what caused the Dust Bowl and how the practices learned from it protect soil today.

ANSWER KEY

1. Sand 2–0.05 mm, gritty; silt 0.05–0.002 mm, smooth and floury; clay smaller than 0.002 mm, sticky and moldable.
2. Texture is the proportion of sand, silt and clay; structure is how particles are grouped into aggregates. Structure can be improved by adding organic matter, keeping living roots and mulch, and avoiding tilling or compacting wet soil.
3. Total 70 mm. Sand $30/70 \approx 43\%$, silt $25/70 \approx 36\%$, clay $15/70 \approx 21\%$. (This is a loam.)
4. CEC is the soil's ability to hold positively charged nutrient ions on negatively charged clay and humus. Sandy, low-humus soil has few such sites, so nutrients are not held and leach away; small, frequent applications reduce losses.
5. Rhizobium bacteria in bean root nodules fix N_2 from the air into ammonia used by the bean. When the bean decays, microbes mineralize the nitrogen into ammonium, nitrifying bacteria convert it to nitrate, and corn roots take up the nitrate (or ammonium).
6. Leaching of nitrate by heavy rain or overwatering, especially in sandy soil; denitrification to nitrogen gas by bacteria in waterlogged, airless soil. (Also erosion and volatilization of ammonia from surface manure or urea.)
7. It binds tightly to iron, aluminum and calcium and to soil particles. It should be placed in the root zone (worked in or banded near seed), and kept from eroding with soil into water.
8. N: $50 \times 0.12 = 6$ lb; P_2O_5 : $50 \times 0.04 = 2$ lb; K_2O : $50 \times 0.08 = 4$ lb. $0.15 \div 0.12 = 1.25$ lb of product.
9. The thin zone of soil directly around roots. Plants release root exudates (sugars, amino acids and other compounds) that feed the microbes.
10. Fungal hyphae extend into the soil and bring water, phosphorus and other nutrients to the roots; the plant gives the fungus sugars made by photosynthesis.
11. Any four: no-till (keeps residue cover, protects structure), cover crops (protect bare soil, add organic matter), rotation (breaks pests, balances nutrients), contour farming and terraces (slow runoff on slopes), grassed waterways (prevent gullies), windbreaks (reduce wind erosion), buffer strips (filter runoff before streams).
12. A strong answer explains that grassland was plowed and left bare, drought dried the soil, and wind carried it away; then names practices such as windbreaks, contour plowing, returning land to grass, cover crops, residue cover and no-till,

and the founding of the Soil Conservation Service under Hugh Hammond Bennett in 1935.

PORTFOLIO PIECE: A SOIL REPORT AND IMPROVEMENT PLAN

Write a soil report for your garden or a plot you can study, using your profile tests, nodule hunt, cotton-strip results and erosion model. If possible, send a sample to your state university's soil-testing lab and include the results. End with a one-year plan to build that soil: amendments with amounts, cover crops, mulch and how you will reduce tilling and erosion.

LOOK FOR	WHAT IT MEANS
Testing	Texture, structure (slake test), pH and biological activity are measured and recorded accurately.
Interpretation	Results are explained correctly using texture, structure, CEC, nutrient cycling and soil biology.
Calculations	Amendment and fertilizer amounts are calculated correctly from labels and bed area.
Conservation	The plan includes cover, reduced disturbance, living roots and erosion control suited to the site.
Presentation	The report is organized with tables, labeled diagrams and clear writing.

3.1 TEXTURE, STRUCTURE AND CHEMISTRY TOGETHER

OBJECTIVES

- Determine soil texture by feel and by a jar settling test, and classify it with the texture triangle.
- Describe the main kinds of soil structure and explain how aggregates form and why they matter.
- Explain cation exchange capacity (CEC) and how clay and humus hold nutrients.

Warm-up. Rub a pinch of three materials between your fingers: dry sand, flour (like silt) and wet modeling clay or very sticky mud. Write one word for how each feels. Which would let water pass through fastest? Which would hold it longest?

WATCH

Soil texture by feel

UCDavisGEO • 4:04

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

WHEN TO WATCH

Just before the texture-by-feel step of the project. Pause at each step and do it with your own moistened soil.

KEY TERMS

soil texture

The proportions of sand (2–0.05 mm), silt (0.05–0.002 mm) and clay (smaller than 0.002 mm) particles in a soil; it cannot easily be changed.

soil structure

The way soil particles are grouped into clumps called aggregates (granular, blocky, platy and others); it can be improved or damaged by management.

texture triangle

A chart used to name a soil's texture class (such as loam or silty clay loam) from its percentages of sand, silt and clay.

aggregate

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

cation exchange capacity (CEC)

A measure of how many positively charged nutrient ions (cations) such as calcium, magnesium, potassium and ammonium a soil can hold on its clay and humus.

pore space

The spaces between soil particles and aggregates that hold air and water; a healthy soil is about half pore space.

CORE IDEAS

A soil scientist looks at three properties together. **Texture** is the mix of particle sizes. Sand grains are large enough to see and feel gritty; silt feels smooth like flour; clay particles are so tiny that a single grain is invisible even under an ordinary microscope, and wet clay feels sticky. The share of each puts a soil on the **texture triangle**. A **loam**, roughly 40 percent sand, 40 percent silt and 20 percent clay, is prized because it balances drainage and water-holding. Texture comes from the parent rock and cannot be changed in a garden except by hauling in soil.

Structure is how those particles are arranged. In a healthy topsoil, particles are glued into crumbs (granular structure) by humus, sticky substances made by bacteria, fine roots and the threads of fungi. Between the crumbs are large pores that drain and let air in, and inside them small pores that hold water. Structure can be built by adding organic matter and keeping roots growing, and it can be destroyed by tilling wet soil, by heavy machinery, or by leaving soil bare to the pounding of rain, which makes a hard surface crust. A dry crumb that holds together in water (the 'slake test') shows good aggregate stability.

Chemistry decides what nutrients are available. Clay particles and humus carry negative electrical charges on their surfaces. Positively charged nutrient ions, called **cations** (calcium Ca^{2+} , magnesium Mg^{2+} , potassium K^{+} , ammonium NH_4^{+}), are attracted and held there, like iron filings on a magnet, so rain does not wash them away. Plant roots trade hydrogen ions for them. This ability is the **cation exchange capacity**. Sandy soils with little humus have a low CEC and need small, frequent feedings; clay and humus-rich soils have a high CEC and hold nutrients well. Negatively charged nutrients such as nitrate (NO_3^{-}) are not held and leach easily.

The three properties work together. A sandy soil drains fast and holds few nutrients, but adding compost raises its CEC and water-holding. A clay soil holds plenty but can be airless and sticky, yet with organic matter it forms crumbs that drain. **pH**

affects all of it: most nutrients are most available between about pH 6 and 7. That is why the cure for almost every soil problem in a garden begins with the same remedy: organic matter.

Soil forms slowly from weathered rock, plant remains and the work of countless creatures. Knowing your soil is the first step to keeping it well.

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 freshly plowed field near Arles in the autumn of 1888. He laid the paint on so thickly that the canvas itself has ridges, like the soil.

Look closely

- Look closely at the paint strokes in the foreground. How did van Gogh make the clods and furrows look lumpy and rough?
- Find the farmer and horse far away. What job are they doing?
- Compare the color of the plowed soil with the strip of green on the right. What do you think is growing there?
- Look at the sky. What weather would a farmer hope for after plowing, and why?

Talk about it

1. Freshly plowed soil looks loose and soft. What happens to its structure if heavy rain falls on it before a crop or cover grows?
2. From the color and the size of the clods, would you guess this soil is sandy, silty or clayey? What would you need to test to be sure?

HANDS-ON PROJECT

A Complete Soil Profile Report

You will run four tests on soil from your garden or yard: texture by feel, a jar settling test, an aggregate (slake) test and a pH test. Together they make a soil report you will use for the rest of the year.

You will need

- Two cups of soil from the top 6 inches of your garden or yard, plus one dry clod from the same spot and one from a bare or trampled area
- A straight-sided quart jar with a lid, water and 1 tablespoon of powdered dishwasher detergent (as a dispersant)
- A ruler and a marker
- Two clear glasses of water and two squares of window screen or hardware cloth
- A soil pH test kit
- A printed soil texture triangle

Steps

1. Texture by feel: moisten a walnut-sized ball of soil, knead it, and follow the steps in the video (ball, ribbon length, gritty or smooth). Record your best guess of the texture class.
2. Jar test: fill the jar one-third with soil (crumbled, stones and roots removed), add the detergent, fill almost to the top with water, cap it and shake hard for five minutes.
3. Set the jar down and mark the height of settled material after 1 minute (sand), after 2 hours (silt) and after 48 hours (clay). Measure each layer in millimeters.
4. Calculate the percentage of each layer of the total settled height, and find your texture class on the triangle. Compare it with your feel test.
5. Slake test: set each dry clod on a screen resting on the rim of a glass of water so the clod is just submerged. Watch for five minutes and record whether each holds together, crumbles or collapses into mud.

6. pH test: test your soil following the kit directions and record the pH.
7. Look at the soil with a hand lens. Record color, roots, organic bits, earthworms or other creatures, and smell.
8. Write a one-page soil report: texture class, structure (from the slake test), pH, observations, and two recommendations for improving the soil.

Tips

- If the water in the jar is still cloudy after 48 hours, very fine clay is still suspended; note it.
- A clod from an undisturbed lawn or garden with mulch usually holds together far better than one from a bare path.

Check your work

- ☐ I found my soil's texture class by two methods and compared them.
- ☐ My slake test compares two clods and explains the difference.
- ☐ My report includes pH, observations and two recommendations based on my results.
- ☐ I can explain how clay and humus hold nutrient cations.

NATURE JOURNAL

1. Draw a magnified view of a soil crumb, labeling sand, silt and clay particles, humus, a fungal thread, a root hair, a large air pore and a small water-filled pore.
2. Sketch your jar test after 48 hours to scale, with the layers labeled and measured.

COMMON MISTAKES

- Reading the jar too soon, before the clay has settled, which makes a soil look sandier than it is.
- Thinking that adding sand will loosen a clay soil. A little sand in clay can make a cement-like mix; organic matter is the cure.
- Confusing texture (particle sizes, which do not change) with structure (how particles are grouped, which management changes).

Make it a game • Jar and Feel Duel. Each of you scoops a spoonful of soil into a jar, adds water, shakes and waits. While it settles, rub a pinch between your fingers and guess the texture. Predict the layers, sand, silt and clay, from the bottom up. Check the texture triangle for a name. Closest prediction wins. Then say why aggregates matter.

3.2 NUTRIENT CYCLING: NITROGEN, PHOSPHORUS AND POTASSIUM

OBJECTIVES

- Trace nitrogen through fixation, mineralization, nitrification, plant uptake, and loss by leaching and denitrification.
- Explain how phosphorus and potassium cycle differently from nitrogen and why phosphorus moves so little in soil.
- Read a fertilizer label and calculate pounds of N, P₂O₅ and K₂O in a bag.

Warm-up. Look at a bag or box of fertilizer, compost or potting mix (or a photo of a label). Find three numbers separated by dashes. Write them down and guess what they stand for.

WATCH

NPK Fertilizer Numbers - what they really mean

Garden Fundamentals · 7:48

<https://www.youtube.com/watch?v=BGVU75oRKyo>

WHEN TO WATCH

After the core idea about fertilizer labels. Listen for why the label lists phosphate and potash instead of pure phosphorus and potassium.

BACKUP VIDEO

What Is The Nitrogen Cycle?

USDA-ARS · 3:37

https://www.youtube.com/watch?v=xN_c5pr87Ok

After the nitrogen-cycle core idea: USDA scientists explain why the nitrogen cycle matters to farming.

KEY TERMS

nitrogen fixation

Turning nitrogen gas (N₂) from the air into forms living things can use; done by bacteria such as *Rhizobium* in legume root nodules, by lightning, and by factories that make fertilizer.

mineralization

The release of plant-available nutrients, such as ammonium, when microbes decompose organic matter.

nitrification

The conversion of ammonium (NH_4^+) to nitrite and then nitrate (NO_3^-) by soil bacteria.

denitrification

The conversion of nitrate back to nitrogen gas by bacteria in waterlogged, airless soil.

leaching

The washing of dissolved nutrients, especially nitrate, down below the root zone by water.

mobile nutrient

A nutrient a plant can move from old leaves to new growth; N, P, K and magnesium are mobile, so their deficiency appears first on older, lower leaves.

CORE IDEAS

Plants need three nutrients in large amounts. **Nitrogen (N)** builds proteins and chlorophyll, so it drives green leafy growth; a nitrogen-starved plant is pale, with older lower leaves turning yellow first. **Phosphorus (P)** is part of DNA and of ATP, the molecule that carries energy in cells, and it is vital for roots, flowers and seeds; deficiency often shows as dark or purplish leaves and stunted growth, especially in cold soil. **Potassium (K)** regulates water movement and the opening of leaf pores and strengthens stems; deficiency shows as yellow or scorched edges on older leaves.

The nitrogen cycle. The air is about 78 percent nitrogen gas, but plants cannot use it. **Fixation** brings it into the living world: *Rhizobium* bacteria live in nodules on the roots of beans, peas, clover and alfalfa, where they turn N_2 into ammonia and trade it to the plant for sugars. When plants, animals and manure decay, microbes **mineralize** their nitrogen into ammonium (NH_4^+). Other bacteria quickly **nitrify** ammonium into nitrate (NO_3^-), the form most plants take up. Nitrate carries a negative charge and is not held by soil, so heavy rain can **leach** it away, and in waterlogged soil bacteria **denitrify** it back into gas. That is why farmers plant legumes, keep living roots in the soil, and apply nitrogen when crops can use it.

Phosphorus and potassium have no gas phase. They come from the slow weathering of minerals and from organic matter and manure. Phosphorus binds tightly to iron, aluminum and calcium in soil, so it moves only a fraction of an inch; roots and mycorrhizal fungi must grow to it. It is most available near pH 6.5. Phosphorus attached to eroding soil can wash into ponds and lakes, where it feeds algae, which is

why soil conservation also protects water. Potassium is held on the soil's exchange sites (Lesson 3.1) and released as plants take it up; sandy soils lose it more easily.

Reading a label. Fertilizer numbers are percentages by weight of N, phosphate (P_2O_5) and potash (K_2O), an old convention. A 40-pound bag of 10-10-10 contains 4 pounds of N, 4 pounds of P_2O_5 and 4 pounds of K_2O ; the other 28 pounds are other elements and filler. Compost and manure are low in N-P-K by the numbers (often about 1-1-1 or less) but add organic matter and feed soil life, releasing nutrients slowly. A soil test tells you which nutrients are actually short, so you add only what is needed.

Jesus told of a gardener who asked for one more year to 'dig about' a barren fig tree 'and dung it.' Feeding the soil patiently, instead of giving up on it, is the heart of good husbandry.

PICTURE STUDY



Red Clover, Plate 35 from Deutschlands Flora in Abbildungen, Jacob Sturm and Johann Georg Sturm, From a series begun in 1796 · Hand-colored engraving · Book illustration

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

This plate comes from a great German flora published over many decades by the engraver Jacob Sturm and his son Johann Georg Sturm. Red clover is one of the most important legumes on farms: it feeds livestock, feeds bees, and feeds the soil.

Look closely

- Find the roots at the base of the plant. Where on a real clover root would you look for nitrogen-fixing nodules?
- Find the three-part leaves. How do they help you tell clover from grasses in a pasture?
- Find the enlarged single flower labeled e. What kind of insect has a tongue long enough to reach its nectar?
- Find the seeds labeled i and k. Why would a farmer save or buy clover seed?

Talk about it

1. Why might a farmer plant red clover in a field one year and corn the next?
2. Clover makes its own nitrogen. Does it still need phosphorus and potassium from the soil? Explain.

Safety first. Wear gloves when handling fertilizer or manure and wash your hands afterward. An adult reads and handles any commercial fertilizer with you; never taste or inhale fertilizer dust.

Nodule Hunt and Fertilizer Math

You will dig up legume roots to see living nitrogen-fixing nodules, then use fertilizer labels to work out exactly how much of each nutrient a garden bed would receive.

You will need

- A legume plant: clover from a lawn or pasture, or pea or bean plants (sow some indoors three to four weeks ahead if needed)
- A trowel, a bucket of water and a white plate
- A hand lens and a small knife (with adult supervision)
- Two or three fertilizer or compost labels (from bags, boxes or websites)
- Calculator and journal

Steps

1. Dig up a clover, pea or bean plant with a wide ball of soil so you do not strip off the fine roots.
2. Soak the root ball in the bucket and gently swish it until the soil falls away.
3. Lay the roots on the white plate and look for small round or finger-shaped bumps. Count them.
4. With an adult, slice one large nodule open. Pink or red inside means it is actively fixing nitrogen (the color comes from a protein called leghemoglobin); white or green means it is young or inactive. Record and sketch.
5. Compare with the roots of a non-legume (such as a grass or radish) dug the same way. Record the differences.
6. For each fertilizer label, record the N-P-K numbers and the bag weight, and calculate pounds of N, P_2O_5 and K_2O in the whole bag.
7. A common recommendation for a vegetable garden is about 0.1–0.2 pound of nitrogen per 100 square feet. Calculate how much of each product would supply 0.15 pound of N to a 4×25 ft bed (100 square feet).

8. Write a paragraph: which product would you choose for a nitrogen-poor sandy bed and which for a bed that tests high in phosphorus? Explain.

Tips

- Nodules are easiest to find on plants that are flowering, in soil that is not heavily fertilized with nitrogen.
- Check your math by asking: does my answer make sense? A small bed should need ounces or a pound or two, not a whole bag.

Check your work

- ☐ I found, counted and sketched nodules and described their inside color.
- ☐ I calculated the pounds of N, P_2O_5 and K_2O in each product correctly.
- ☐ I calculated the amount of product needed for 0.15 pound of N on 100 square feet.
- ☐ I can explain why nitrate leaches but phosphorus stays where it is put.

NATURE JOURNAL

1. Draw the nitrogen cycle as a labeled diagram with arrows: air, lightning, legume nodules, plants, animals, manure, decomposers, ammonium, nitrate, leaching, denitrification.
2. Sketch three leaves showing nitrogen, phosphorus and potassium deficiency, using an extension fact sheet or your own garden, and label where each appears on the plant.

From history. In 1909 the German chemist Fritz Haber found a way to combine nitrogen from the air with hydrogen to make ammonia, and Carl Bosch turned it into a factory process. Synthetic nitrogen fertilizer from the Haber–Bosch process now helps grow a large share of the world’s food. Long before, farmers had learned by experience that a crop of clover or beans made the next crop better.

COMMON MISTAKES

- Thinking more fertilizer is always better. Excess nitrogen gives leafy plants with few fruits and washes into streams.
- Forgetting that the label’s middle number is phosphate (P_2O_5), not pure phosphorus.
- Applying a high-phosphorus ‘bloom’ fertilizer every year without a soil test; many garden soils already have plenty.

Make it a game • Follow the Nitrogen. Place six paper cups in a circle: fixation, mineralization, nitrification, uptake, leaching, denitrification. Hold a bean as the nitrogen atom and walk it through the cycle, saying what happens at each cup. Your parent may shout a stop and ask a question. Then explain why phosphorus barely moves. Beat your time through the loop.

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

The patient gardener in Jesus’ parable feeds the soil around the tree and waits for fruit. Building soil fertility is slow, faithful work.

3.3 THE RHIZOSPHERE AND SOIL BIOLOGY

OBJECTIVES

- Define the rhizosphere and explain how root exudates feed soil microbes.
- Describe the roles of bacteria, fungi (including mycorrhizae), actinomycetes, protozoa, nematodes and earthworms in the soil food web.
- Measure biological activity in different soils with a cotton-strip decomposition test.

Warm-up. Smell a handful of moist garden soil or compost. Describe the smell in your journal. (That earthy smell is made by a group of soil bacteria called actinomycetes; you will learn about them today.)

WATCH

Mycorrhiza: what connects fungus and plant

Bayerisches Umweltministerium · 2:30

<https://www.youtube.com/watch?v=iboE8UZBgkM>

WHEN TO WATCH

After the core idea on mycorrhizal fungi. Notice what the fungus gives the tree and what the tree gives back.

Note: A short animation from the Bavarian state environment ministry; it shows forest trees, but garden crops form the same partnership.

BACKUP VIDEO

Bacteria, Fungi, Protozoa and Nematodes from soil

Soil Foodweb Institute · 2:47

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

After the core idea on the soil food web: real microscope footage of living soil bacteria, fungi, protozoa and nematodes.

KEY TERMS

rhizosphere

The thin zone of soil, a few millimeters thick, directly around living roots, where root exudates support far more microbes than in the rest of the soil.

mycorrhizae

Partnerships between plant roots and fungi; fungal threads extend far into the soil and bring water and phosphorus to the plant in exchange for sugars.

actinomycetes

Thread-forming soil bacteria that break down tough materials and produce geosmin, the compound that gives soil its earthy smell.

root exudates

Sugars, amino acids and other compounds that roots release into the soil, feeding microbes that in turn help the plant.

hyphae

The thread-like filaments of a fungus, which together form a network called mycelium.

soil food web

The network of soil organisms that eat one another and organic matter, cycling nutrients from bacteria and fungi through protozoa, nematodes, mites and earthworms.

CORE IDEAS

A teaspoon of healthy topsoil holds hundreds of millions to billions of bacteria, yards of fungal threads, thousands of protozoa, and dozens of tiny worms called nematodes. Most of this life is crowded into the **rhizosphere**, the few millimeters of soil around each root. Plants feed it on purpose. Through their roots they release **exudates**, sugars and other compounds made by photosynthesis, a significant share of everything the plant makes. In return, the microbes help the plant in many ways.

Bacteria are the most numerous. They decompose fresh organic matter, release nutrients, and produce sticky gums that glue soil into crumbs. Some fix nitrogen, like *Rhizobium* in legume nodules; others protect roots by crowding out harmful microbes. **Actinomycetes**, thread-forming bacteria, break down tougher materials and give soil its earthy smell. **Fungi** break down woody material such as leaves and straw and spread long threads called **hyphae** that bind soil and carry water and nutrients.

Mycorrhizal fungi form partnerships with the roots of most crop plants (the cabbage family and beets are exceptions). Their hyphae, far thinner than root hairs, reach into soil pores the roots cannot enter and bring back phosphorus, zinc and water. The plant pays with sugars. Tilling, bare fallow and heavy phosphorus fertilizer all reduce mycorrhizae; living roots and little disturbance encourage them.

The food web keeps nutrients moving. Bacteria and fungi hold nutrients in their bodies. **Protozoa** and **nematodes** eat them and release the extra nitrogen as ammonium right next to the roots. Mites, springtails, beetles and **earthworms** shred residues, mix the soil and leave channels and castings rich in nutrients. A few organisms are harmful, such as root-knot nematodes and damping-off fungi, but a diverse, well-fed food web keeps them in check.

We cannot see most of this, yet the whole harvest depends on it. Psalm 104 says that God ‘causeth the grass to grow for the cattle’; part of how He does it is through these unseen servants in the soil.

PICTURE STUDY



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

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

Dürer cut a clump of ordinary wild plants from a field edge, set it on his table and painted it at eye level, as if he were a beetle in the grass. It is one of the first great nature studies in European art, and it shows the soil and roots that most painters ignored.

Look closely

- Find the soil at the bottom of the picture. Can you see any roots? What color and texture is the soil?
- Name the plants you recognize: grasses, dandelion, plantain. How are their roots and leaves different?
- Imagine the rhizosphere around each root. What would you find there with a microscope?
- Look at how many different plants grow in one small clump. Why might a mix of plants be good for soil life?

Talk about it

1. The grasses have fibrous roots and the dandelion has a taproot. How might each one help soil structure differently?

2. Dürer painted something most people walk past without noticing. What does that teach us about observation?

Safety first. Wear gloves when digging, especially in soil that may contain animal droppings, and wash your hands well afterward. Never put soil or compost near your mouth.

HANDS-ON PROJECT

The Cotton-Strip Test: Measuring Soil Life

Cotton is almost pure cellulose, food for soil fungi and bacteria. By burying identical strips of plain cotton in different soils and digging them up later, you can compare how active each soil's life is.

You will need

- An old plain white 100% cotton T-shirt or cotton muslin, cut into 6 strips about 2 × 8 inches
- A permanent marker and six garden labels or craft sticks
- A trowel, gloves and a ruler
- Three test sites: a mulched garden bed or compost-rich soil, a lawn, and a bare or trampled area (or three large pots: garden soil, potting mix, and sand)
- A camera or your journal for drawings
- Radish seeds, a clear cup and a paper towel for a root-hair observation

Steps

1. Label two cotton strips for each site. Photograph or trace one unused strip as your control.
2. At each site, cut a slit straight down about 6 inches deep with the trowel, slide one strip in vertically so about an inch shows above ground, and press the soil closed. Place the second strip a foot away.
3. Mark each spot with a label. Record the date, the soil temperature if you have a thermometer, and whether the soil is moist.
4. Meanwhile, sprout a few radish seeds on a moist paper towel in a clear cup. After three or four days, look at the fuzzy root hairs with a hand lens and sketch them. This fuzz is where the rhizosphere begins.
5. After four to six weeks (longer in cool weather), dig up the strips carefully and rinse them gently in a bucket of water.
6. Lay them out beside the control. Estimate the percentage of cotton that has disappeared or become brown and holey in each, and photograph or sketch

them.

7. Rank the three sites by biological activity and explain the differences using what you know about organic matter, moisture, compaction and living roots.

Tips

- Use plain cotton with no polyester, printing or wrinkle-resistant finish, which slow decay.
- Soil life slows in cold soil. If you start this in late fall, leave the strips longer or do the test indoors in pots kept at room temperature and evenly moist.

Check your work

- ☐ I buried strips in at least three different soils with labels and dates.
- ☐ I compared the strips with a control and estimated how much was decomposed.
- ☐ I sketched radish root hairs and explained what the rhizosphere is.
- ☐ My conclusion explains the differences using organic matter, moisture, compaction or roots.

NATURE JOURNAL

1. Draw a soil food web pyramid or web: plant roots and organic matter at the base, bacteria and fungi, protozoa and nematodes, mites and springtails, earthworms and beetles, and birds or moles that eat them.
2. Draw a root with mycorrhizal hyphae reaching out into soil pores, labeling root hair, hypha, soil particle, water film and phosphorus.

From history. In 1885 the German botanist Albert Bernhard Frank gave mycorrhizae their name, from Greek words meaning ‘fungus-root’. In 1904 another German scientist, Lorenz Hiltner, coined the word ‘rhizosphere’ for the busy zone of microbes around roots.

COMMON MISTAKES

- Thinking all soil microbes are germs. The great majority are helpful or harmless, and plants depend on them.
- Leaving garden soil bare all winter, which starves the soil food web of living roots and exudates.
- Buying mycorrhizal products for soil that is already full of native fungi; good management usually matters more than inoculants.

Make it a game · Soil Food Web Duel. Make cards for bacteria, fungi, actinomycetes, protozoa, nematodes and earthworms. Shuffle them face down. Draw one, and in ten seconds say who it eats, who eats it, and how it helps roots. Add the rhizosphere and root exudates as bonus cards. Collect the most correct cards, then match them into a food web.

3.4 SOIL CONSERVATION AND REGENERATIVE PRACTICES

OBJECTIVES

- Explain how water and wind erode soil and why topsoil loss is so serious.
- Describe conservation practices: no-till, cover crops, crop rotation, contour farming, terraces, grassed waterways and windbreaks.
- Test how ground cover affects runoff and erosion with a rainfall model.

Warm-up. Pour a cup of water slowly onto a patch of bare dirt and then onto a patch of grass or mulch. Watch where the water goes and what color it turns. Write what you see.

WATCH

Experiments with No-Till Cover Crops at Potomac Vegetable Farms

USDA NRCS Virginia • 8:22

<https://www.youtube.com/watch?v=boeSdALXz38>

WHEN TO WATCH

After the core ideas. Notice how the farmer plants vegetables into a rolled-down cover crop without plowing.

BACKUP VIDEO

No-Till, Cover Crops, Provide Home For Healthy Soils

No-Till Farmer • 4:31

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

Optional: a Pennsylvania grain farmer explains why he keeps living roots in his fields nearly all year.

KEY TERMS

erosion

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

no-till

Planting crops directly into the residue of the last crop or a cover crop without plowing or disking the soil.

cover crop

A crop such as cereal rye, oats, clover or vetch grown mainly to protect and improve soil between cash crops.

crop rotation

Growing different families of crops in a planned order on the same ground to break pest cycles and balance nutrients.

contour farming

Plowing and planting across a slope along lines of equal height, so rows act as little dams that slow runoff.

grassed waterway

A broad, shallow channel kept in grass where water naturally flows across a field, so it can drain without cutting a gully.

CORE IDEAS

Topsoil forms very slowly; under natural conditions an inch can take hundreds of years. Yet a single hard rain on bare, sloping ground can wash away tons of soil from an acre. Raindrops strike bare soil like tiny bombs, breaking crumbs apart; the loose particles clog pores, water runs off instead of soaking in, and it carries the richest topsoil, with its organic matter and phosphorus, into ditches and streams. Wind does the same on dry, bare, loose ground.

Americans learned this the hard way in the **Dust Bowl** of the 1930s. Millions of acres of Great Plains grassland had been plowed for wheat. When years of drought came, the bare soil blew away in great black clouds that darkened cities as far east as Washington, D.C. Hugh Hammond Bennett, a soil scientist, persuaded Congress to create the Soil Conservation Service in 1935 (today the Natural Resources Conservation Service), and farmers began planting windbreaks, plowing on the contour, and returning the worst land to grass.

Conservation practices follow a few principles: keep the soil **covered**, **disturb it as little as possible**, keep **living roots** in it as much of the year as possible, grow a **variety** of crops, and, where practical, **integrate livestock** through grazing. **No-till** leaves crop residue on the surface as armor and protects soil structure and fungi. **Cover crops** such as cereal rye and crimson clover hold soil in winter and feed soil life. **Rotation** breaks pest cycles. On slopes, **contour farming**, **terraces** and **grassed waterways** slow water; on the plains, **windbreaks** slow wind.

Practices that build soil instead of only holding it in place are often called **regenerative**. Each has trade-offs. No-till may need different weed control and special planters; cover crops cost seed and must be ended at the right time; grazing needs fences and water. Farmers weigh these against the long-term gain of soil that holds more water, needs less fertilizer and yields better in dry years. In a garden, the same ideas are simple: mulch, compost, cover crops in fall, and as little digging as possible.

In the law of Moses, God commanded a sabbath rest for the land every seventh year. Modern farmers rotate crops and rest fields for many reasons, but the principle is old: the land is not ours to use up.

PICTURE STUDY



Plowing in the Nivernais, Rosa Bonheur, 1849 · Oil on canvas · Musée d'Orsay, Paris

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

Rosa Bonheur painted this scene for the French government. It shows the first autumn plowing, called *sombrage*, in central France, where great Charolais oxen broke the heavy soil before sowing.

Look closely

- Count the oxen in each team. Why do you think so many were needed to pull one plow?
- Look at the turned earth in front. Describe the size and color of the clods. What does this tell you about the soil?
- Notice which way the teams are moving on the slope. Are they plowing up and down it or across it? How would that affect runoff?
- Find the green field in the distance. How is it different from the plowed soil?

Talk about it

1. What would happen to this bare, plowed hillside in a heavy autumn rain? How could the farmers protect it?
2. A modern no-till farmer would leave this field unplowed. What would he gain and what new problems would he have to solve?

HANDS-ON PROJECT

A Rainfall and Erosion Model

You will build three small ‘fields’ in trays, tilt them like a hillside, and pour the same rainfall on each to measure runoff and soil loss. Conservation agencies use this same experiment to teach farmers.

You will need

- Three identical shallow containers about 12 × 8 inches, such as aluminum baking pans or plastic storage-box lids, with a V-shaped notch cut at one end
- Garden soil to fill all three
- Mulch for one tray (straw, shredded leaves or wood chips) and a piece of sod or a tray of grass or wheat sown two to three weeks ahead
- Three clear jars to catch runoff
- A watering can with a sprinkler head or a plastic jug with holes punched in the cap
- A measuring cup, books or bricks to prop the trays, and a ruler

Steps

1. Fill each tray with the same soil to the same depth and press it down gently. Leave tray 1 bare, cover tray 2 with 1 inch of mulch, and use sod or sprouted grass for tray 3.
2. Prop all three at the same angle (about 15 degrees) with the notch at the low end hanging over a jar.
3. Measure 4 cups of water. From the same height, sprinkle it evenly over tray 1 for one minute. Repeat for the other trays.
4. Wait five minutes for dripping to stop. Measure the volume of water in each jar.
5. Line up the jars and compare how muddy each is. Let them settle overnight and measure the depth of soil at the bottom of each jar.
6. Record your data in a table and make a bar graph of runoff volume and soil loss for each tray.

7. Write a conclusion: which practice best protected the soil, and how does each tray represent a real farm practice (bare tilled ground, residue or mulch from no-till, and a living cover crop or pasture)?

Tips

- Keep every variable the same except the ground cover: the same soil, angle, water amount and pouring height.
- Do this outdoors or in a tub; it is muddy.
- Many soil and water conservation districts hold yearly youth poster and speech contests on soil and water conservation; ask your local district office about this year's theme.

Check your work

- ☐ I changed only one variable, the ground cover, and kept the rest the same.
- ☐ I measured runoff volume and settled soil for each tray.
- ☐ My bar graph and conclusion correctly compare the three trays.
- ☐ I can connect each tray to a real conservation practice.

NATURE JOURNAL

1. Draw a farm on a hillside using at least four conservation practices: contour rows, a terrace, a grassed waterway, a windbreak, a cover crop and a buffer strip along a stream. Label each.
2. After the next heavy rain, look for signs of erosion near your home: gullies, muddy runoff, soil splashed on walls, exposed roots. Sketch and describe one.

COMMON MISTAKES

- Leaving garden beds bare all winter after the harvest. A cover crop or a layer of leaves protects them.
- Tilling repeatedly to 'fluff up' soil. It breaks down structure and burns up organic matter.
- Thinking erosion only matters on big farms. A bare, sloping yard or garden loses soil the same way.

Make it a game • Rainstorm Rescue. Pour a cup of water onto a tray of loose soil tilted on a book, then watch what washes off. Now rescue the soil like a conservation team. Choose one practice (no-till, cover crop, rotation, contour rows, terrace, waterway or windbreak), build it with household items, and rerun the storm. Explain what changed.

Scripture. “But in the seventh year shall be a sabbath of rest unto the land, a sabbath for the LORD: thou shalt neither sow thy field, nor prune thy vineyard.” (Leviticus 25:4, KJV)

God gave Israel’s land a regular rest. Rotation, cover crops and gentle tillage carry the same lesson: the soil is a gift to be kept, not used up.

UNIT 3

SOIL SCIENCE CAPSTONE

Soil is not dirt. It is a living, breathing mixture of crushed rock, decaying organic matter, water, air and billions of living things, and it took God's slow work over a long time to make a few inches of it. Every crop, pasture and garden depends on it. In earlier grades you learned soil types, compost and pH. This unit brings it all together: how texture, structure and chemistry work as one system; how nitrogen, phosphorus and potassium cycle through soil, plants and animals; what happens in the thin zone of soil around every root; and how farmers keep soil from washing and blowing away.

You will run a full set of soil tests on your own soil, dig up legume roots to find nitrogen-fixing nodules, measure the work of soil microbes, and build a rainfall model to compare bare and covered ground. By the end you should be able to read a soil test report and recommend what a garden needs.

PREREQUISITES

- Knowing sand, silt, clay and loam, and what humus is
- Using a simple soil pH test
- Making and using compost
- Basic chemistry words: element, atom, ion

MASTERY CHECKLIST

- ☐ I can determine my soil's texture by the jar test and the ribbon test and place it on the texture triangle.
- ☐ I can explain how soil structure, organic matter and cation exchange capacity affect water and nutrients.
- ☐ I can trace nitrogen through fixation, mineralization, nitrification, uptake and loss, and explain how phosphorus and potassium behave differently.
- ☐ I can calculate the pounds of nitrogen, phosphate and potash in a bag of fertilizer from its label.
- ☐ I can describe the rhizosphere and the roles of bacteria, fungi and mycorrhizae.
- ☐ I can explain how no-till, cover crops, rotation and contour farming protect soil.

LESSONS IN THIS UNIT

3.1 Texture, Structure and Chemistry Together	2 sessions of 60 minutes
3.2 Nutrient Cycling: Nitrogen, Phosphorus and Potassium	2 sessions of 60 minutes
3.3 The Rhizosphere and Soil Biology	2 sessions of 60 minutes
3.4 Soil Conservation and Regenerative Practices	2 sessions of 60 minutes

UNIT 3 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work on calculations. Total: 100 points.

1. 8 pts

Give the particle-size ranges of sand, silt and clay, and describe how each feels when moist.

2. 8 pts

What is the difference between soil texture and soil structure? Which can a gardener change, and how?

3. 8 pts

In a jar test, the sand layer is 30 mm, the silt layer 25 mm and the clay layer 15 mm. What are the percentages of each?

4. 8 pts

Explain cation exchange capacity and why a sandy soil low in humus needs more frequent, smaller fertilizer applications.

5. 9 pts

Trace a nitrogen atom from the air into a bean plant, then into the soil as the plant decays, and finally into a corn plant.

6. 8 pts

Name two ways nitrogen is lost from soil and the conditions that cause each.

7. 8 pts

Why does phosphorus move so little in soil, and what does that mean for how it should be applied?

8. 9 pts

A 50-lb bag of fertilizer is labeled 12-4-8. How many pounds of N, P_2O_5 and K_2O does it contain? How many pounds of product supply 0.15 lb of N?

9. (8 pts)

What is the rhizosphere, and how do plants support the microbes that live there?

10. (8 pts)

Describe the partnership between mycorrhizal fungi and plants. What does each partner give?

11. (8 pts)

Name four soil conservation practices and the problem each solves.

12. (10 pts)

Short answer: Explain what caused the Dust Bowl and how the practices learned from it protect soil today.

ANSWER KEY

1. Sand 2–0.05 mm, gritty; silt 0.05–0.002 mm, smooth and floury; clay smaller than 0.002 mm, sticky and moldable.
2. Texture is the proportion of sand, silt and clay; structure is how particles are grouped into aggregates. Structure can be improved by adding organic matter, keeping living roots and mulch, and avoiding tilling or compacting wet soil.
3. Total 70 mm. Sand $30/70 \approx 43\%$, silt $25/70 \approx 36\%$, clay $15/70 \approx 21\%$. (This is a loam.)
4. CEC is the soil's ability to hold positively charged nutrient ions on negatively charged clay and humus. Sandy, low-humus soil has few such sites, so nutrients are not held and leach away; small, frequent applications reduce losses.
5. Rhizobium bacteria in bean root nodules fix N_2 from the air into ammonia used by the bean. When the bean decays, microbes mineralize the nitrogen into ammonium, nitrifying bacteria convert it to nitrate, and corn roots take up the nitrate (or ammonium).
6. Leaching of nitrate by heavy rain or overwatering, especially in sandy soil; denitrification to nitrogen gas by bacteria in waterlogged, airless soil. (Also erosion and volatilization of ammonia from surface manure or urea.)
7. It binds tightly to iron, aluminum and calcium and to soil particles. It should be placed in the root zone (worked in or banded near seed), and kept from eroding with soil into water.
8. N: $50 \times 0.12 = 6$ lb; P_2O_5 : $50 \times 0.04 = 2$ lb; K_2O : $50 \times 0.08 = 4$ lb. $0.15 \div 0.12 = 1.25$ lb of product.
9. The thin zone of soil directly around roots. Plants release root exudates (sugars, amino acids and other compounds) that feed the microbes.
10. Fungal hyphae extend into the soil and bring water, phosphorus and other nutrients to the roots; the plant gives the fungus sugars made by photosynthesis.
11. Any four: no-till (keeps residue cover, protects structure), cover crops (protect bare soil, add organic matter), rotation (breaks pests, balances nutrients), contour farming and terraces (slow runoff on slopes), grassed waterways (prevent gullies), windbreaks (reduce wind erosion), buffer strips (filter runoff before streams).
12. A strong answer explains that grassland was plowed and left bare, drought dried the soil, and wind carried it away; then names practices such as windbreaks, contour plowing, returning land to grass, cover crops, residue cover and no-till,

and the founding of the Soil Conservation Service under Hugh Hammond Bennett in 1935.

PORTFOLIO PIECE: A SOIL REPORT AND IMPROVEMENT PLAN

Write a soil report for your garden or a plot you can study, using your profile tests, nodule hunt, cotton-strip results and erosion model. If possible, send a sample to your state university's soil-testing lab and include the results. End with a one-year plan to build that soil: amendments with amounts, cover crops, mulch and how you will reduce tilling and erosion.

LOOK FOR	WHAT IT MEANS
Testing	Texture, structure (slake test), pH and biological activity are measured and recorded accurately.
Interpretation	Results are explained correctly using texture, structure, CEC, nutrient cycling and soil biology.
Calculations	Amendment and fertilizer amounts are calculated correctly from labels and bed area.
Conservation	The plan includes cover, reduced disturbance, living roots and erosion control suited to the site.
Presentation	The report is organized with tables, labeled diagrams and clear writing.

UNIT 4

ANIMAL CARE AND CAREERS

A good steward of animals knows what they need to eat, how to keep them healthy, and how their traits are passed from parents to offspring. In this unit you will read feed labels like a nutritionist, learn how farmers and veterinarians prevent and treat parasites and handle emergencies, work Punnett squares for real farm traits, and meet the people whose careers are spent caring for animals.

Proverbs 12:10 says, ‘A righteous man regardeth the life of his beast.’ Regarding an animal’s life means more than kindness; it means knowledge. Whether or not you keep animals now, the skills in this unit will serve you with a family dog, a backyard flock, a 4-H project or a future job.

PREREQUISITES

- The basic needs of pets and farm animals (food, water, shelter, health care)
- Gentle, safe handling of animals and washing hands afterward
- Calculating percentages
- Knowing that offspring inherit traits from both parents

MASTERY CHECKLIST

- ☐ I can name the six classes of nutrients and read the guaranteed analysis on a feed tag.
- ☐ I can convert a feed’s protein to a dry-matter basis to compare wet and dry feeds.
- ☐ I can describe common internal and external parasites and how they are prevented and monitored.
- ☐ I can give the normal temperature of a dog, horse and goat and assemble a basic animal first-aid kit.
- ☐ I can use a Punnett square to predict the offspring of a cross involving dominant, recessive and incompletely dominant traits.
- ☐ I can describe the training and daily work of at least four animal-care careers.

LESSONS IN THIS UNIT

4.1	Animal Nutrition and Feed Labels	2 sessions of 60 minutes
4.2	Animal Health: Parasites, Prevention and First Aid	2 sessions of 60 minutes
4.3	Breeds and Inherited Traits	2 sessions of 60 minutes
4.4	Careers with Animals and on the Farm	2 sessions of 60 minutes

UNIT 4 REVIEW

Answer each question in complete sentences unless a calculation or Punnett square is asked for; show your work. Total: 100 points.

1. 7 pts

Name the six classes of nutrients and give one function of each.

2. 8 pts

Why can a goat live on hay and pasture while a dog cannot?

3. 9 pts

A canned cat food is 10% protein and 80% moisture. A dry food is 32% protein and 10% moisture. Which has more protein on a dry-matter basis? Show your work.

4. 7 pts

What does the ingredient order on a feed label tell you?

5. 8 pts

Name two internal and two external parasites and one animal each affects.

6. 9 pts

Explain why veterinarians now recommend fecal egg counts and FAMACHA scoring instead of deworming every animal on a schedule.

7. **7 pts**

Give the normal temperature range of a dog and of a horse. Why is it useful to know these?

8. **9 pts**

Draw a Punnett square for two heterozygous polled cattle ($Pp \times Pp$). Give the genotype and phenotype ratios.

9. **9 pts**

In Andalusian chickens, black $\times$ splash gives blue. What do you expect from blue $\times$ blue, and what is this kind of inheritance called?

10. **8 pts**

What is hybrid vigor, and why do purebred herds still matter?

11. **8 pts**

Compare the training of a veterinarian and a veterinary technician.

12. **11 pts**

Short answer: A neighbor's goat is thin, has pale inner eyelids and has stopped eating well. Explain what might be wrong and the steps a responsible owner should take.

ANSWER KEY

1. Water (body processes, temperature), carbohydrates (energy), fats (concentrated energy), proteins (muscle, milk, eggs, enzymes), vitamins (body processes, e.g. vitamin D for bones), minerals (bones, eggshells, nerves, e.g. calcium, salt).
2. A goat is a ruminant; microbes in its four-part stomach ferment fiber it could not digest alone. A dog is monogastric with a simple stomach and cannot digest much fiber, so it needs concentrated food.
3. Canned: $10 \div 20 \times 100 = 50\%$. Dry: $32 \div 90 \times 100 \approx 35.6\%$. The canned food has more protein on a dry-matter basis.
4. Ingredients are listed by weight from most to least, so the first few make up most of the feed.
5. Internal (any two): roundworms (dogs, pigs), tapeworms (dogs, cats), coccidia (chicks, rabbits, calves), barber pole worm (sheep, goats). External (any two): fleas (dogs, cats), ticks (dogs, cattle, people), lice (chickens, cattle), mites (chickens, rabbits).
6. Frequent blanket deworming caused parasites to become resistant so dewormers stopped working. Testing identifies which animals actually need treatment, slowing resistance and saving money.
7. Dog about 101–102.5 °F; horse about 99–101 °F. A temperature outside the normal range is an early sign of illness or heat stress, and it helps the veterinarian.
8. PP, Pp, Pp, pp. Genotypes 1 PP : 2 Pp : 1 pp. Phenotypes 3 polled : 1 horned.
9. About 1 black : 2 blue : 1 splash. Incomplete dominance.
10. Hybrid vigor is the extra growth, health and fertility often seen in crossbred offspring. Purebred herds are needed as the reliable source of each breed's traits for future crosses.
11. A veterinarian usually completes four years of college plus four years of veterinary school and passes a licensing exam. A vet tech usually earns a two-year associate degree and passes a credentialing exam.
12. A strong answer suggests anemia from barber pole worms (or another illness), recommends calling the veterinarian, taking the temperature, a fecal egg count and FAMACHA score, treating only as the vet directs with an effective dewormer, separating the goat if needed, improving pasture rotation and nutrition, and monitoring weight and eyelid color afterward.

PORTFOLIO PIECE: AN ANIMAL CARE PLAN AND BUDGET

Write a complete care plan for one animal you keep or hope to keep (a dog, a rabbit, a backyard flock, a goat, a 4-H steer). Include housing, a daily and weekly feeding plan with feed-label analysis, a health calendar (immunizations, parasite monitoring, hoof or nail care), your first-aid kit list, a one-year budget, and, if the animal will be bred or shown, a section on the breed's traits and how they are inherited.

LOOK FOR	WHAT IT MEANS
Nutrition	The feeding plan fits the animal's digestive system and life stage and uses real feed-label data.
Health	The health calendar includes prevention, monitoring, a veterinarian's role and a first-aid plan.
Budget	The one-year budget lists realistic costs for feed, bedding, veterinary care, equipment and housing.
Knowledge	Breed traits, normal vital signs and parasite risks are described accurately.
Responsibility	The plan shows who does each chore and when, including backup care during travel or illness.

4.1 ANIMAL NUTRITION AND FEED LABELS

OBJECTIVES

- Name the six classes of nutrients and what each does for an animal.
- Compare the digestive systems of ruminants, horses and single-stomached animals and how they shape what each eats.
- Read a feed tag's guaranteed analysis and ingredient list, and convert protein to a dry-matter basis.

Warm-up. Find any food label in your kitchen and a pet-food or livestock-feed label if you have one (or look one up). List the first five ingredients on each. What do you notice about the order?

WATCH

Ron Gill - Cattle Nutrition - Reading a Feed Label

RanchTV at Texas A&M AgriLife Extension · 4:00

<https://www.youtube.com/watch?v=MowLhtXu3A8>

WHEN TO WATCH

After the core idea on feed tags. Pause when he points out crude protein and fiber, and find the same lines on your own label.

BACKUP VIDEO

How to read the information on a livestock feed bag tag

Hobby Farms · 3:52

<https://www.youtube.com/watch?v=ME3ggolQTs4>

Optional: a second walk-through of a livestock feed tag.

KEY TERMS

nutrient

A substance in food that an animal needs for life: water, carbohydrates, fats, proteins, vitamins or minerals.

ruminant

An animal such as a cow, sheep or goat with a four-compartment stomach whose microbes ferment grass and hay; ruminants chew cud.

monogastric

An animal with a single, simple stomach, such as a pig, dog, cat or chicken, which cannot digest much fiber.

guaranteed analysis

The part of a feed label that states the minimum crude protein and fat and the maximum fiber and moisture.

dry-matter basis

A nutrient's percentage after the water is mathematically removed, which allows fair comparison of wet and dry feeds.

forage

Plant material such as pasture grass, hay and silage that grazing animals eat.

CORE IDEAS

Every animal needs six classes of nutrients. **Water** is the most important; animals die of thirst far sooner than of hunger, and a dairy cow may drink 30 gallons a day. **Carbohydrates** (sugars, starches and fiber) and **fats** supply energy. **Proteins**, made of amino acids, build muscle, milk, eggs, wool and enzymes. **Vitamins** and **minerals** are needed in small amounts but are essential: calcium for bones and eggshells, salt for nerves, vitamin D for bone growth.

Digestive systems differ. **Ruminants** such as cattle, sheep and goats have a four-part stomach (rumen, reticulum, omasum and abomasum). Billions of microbes in the rumen ferment grass and hay, breaking down fiber that the animal itself cannot digest, and the animal later digests the microbes too. That is why ruminants can live well on pasture. Horses and rabbits are **hindgut fermenters**: their microbes work in a large cecum after the stomach, so they also need plenty of forage. **Monogastric** animals such as pigs, chickens, dogs and cats have simple stomachs and need more concentrated feeds.

A feed tag tells you what is in the bag. The **guaranteed analysis** lists minimum crude protein and crude fat and maximum crude fiber and moisture, often with calcium, phosphorus and salt. The **ingredient list** is in order by weight, heaviest first. There are also feeding directions and the purpose of the feed: a chick starter (about 18–20 percent protein), a layer feed (about 16 percent protein with extra calcium for shells), or a horse feed meant to go with hay. Dog and cat foods should carry a statement that they are 'complete and balanced' for the animal's life stage according to the AAFCO profiles.

To compare a canned food with a dry one, convert to a **dry-matter basis**: divide the nutrient percentage by the dry matter (100 minus moisture) and multiply by 100. A canned dog food with 8 percent protein and 78 percent moisture has 22 percent dry matter, so its protein on a dry-matter basis is $8 \div 22 \times 100 \approx 36$ percent. A dry kibble with 26 percent protein and 10 percent moisture is $26 \div 90 \times 100 \approx 29$ percent. The canned food is actually higher in protein once the water is removed.

Good feeding is a daily act of care. Change feeds gradually over a week or more, because sudden changes upset the microbes in an animal's gut. Keep feed dry and free of mold, store it where rodents cannot reach it, and always provide clean water.

PICTURE STUDY



Woman Feeding Chickens, Jean-François Millet, about 1853–1856 · Oil on panel · Art Institute of Chicago

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

Millet grew up on a farm in Normandy and spent his life painting the daily work of country people. Feeding the hens was one of the first chores of every farm day, often shared with the youngest children.

Look closely

- Find the woman's hand. What is she doing, and how are the hens responding?
- Look at the little girl. What do you think she is learning by watching?
- Find the stone wall and the plants around the yard. What else might the hens eat as they roam?
- Notice how Millet uses light and dark. Where is the brightest part of the picture?

Talk about it

1. Scattered grain is mostly carbohydrate. What else does a laying hen need in her diet to make strong eggshells and plenty of eggs?
2. How is feeding a modern backyard flock from a bag of layer feed different from this scene, and what is the same?

HANDS-ON PROJECT

A Feed-Tag Comparison

You will collect three or more feed labels and compare them like an animal nutritionist, including a dry-matter conversion.

You will need

- Three to five feed labels: for example a dry and a canned dog or cat food, a layer feed, a rabbit pellet and a horse or goat feed (from your home, a neighbor, a feed store, or manufacturers' websites)
- Calculator and journal
- Optional: a kitchen scale and a cup of the animal's daily ration

Steps

1. Make a table with columns for product, intended animal and life stage, crude protein, crude fat, crude fiber, moisture, calcium, and the first five ingredients.
2. Fill in the table from each label.
3. Calculate the dry-matter protein for each feed. Show your work for at least two.
4. Compare a feed for a ruminant or rabbit with one for a dog, cat or chicken. Which has more fiber, and why does that make sense?
5. Look for the AAFCO 'complete and balanced' statement on pet foods and note the life stage it is meant for.
6. If you care for an animal, weigh its daily ration and compare it with the feeding directions on the label for its weight. Is it being fed correctly?
7. Write a short recommendation: which feed would you choose for a specific animal, and why?

Tips

- 'Crude' protein is estimated from the nitrogen in the feed; it does not tell how digestible the protein is, which is why ingredient quality matters too.
- Rabbits, horses, goats and cattle should get most of their diet from hay or pasture; pellets and grain are supplements.

Check your work

- ☐ My table includes the guaranteed analysis and first ingredients of at least three feeds.
- ☐ I converted protein to a dry-matter basis correctly.
- ☐ I explained differences in fiber using what I know about digestive systems.
- ☐ I can name the six classes of nutrients.

NATURE JOURNAL

1. Draw and label the digestive system of a cow (rumen, reticulum, omasum, abomasum, intestines) and of a chicken (crop, proventriculus, gizzard, intestines). Write one sentence on how each system fits the animal's food.
2. Observe an animal eating (a pet, a neighbor's hens, cattle at pasture from a road) for ten minutes. Record what it eats, how it eats, and how long it spends.

COMMON MISTAKES

- Comparing wet and dry foods by their label percentages without converting to dry matter.
- Giving rabbits or horses mostly pellets or grain instead of hay, which can cause dental and digestive problems.
- Switching feeds suddenly, which upsets an animal's gut microbes and can make it sick.

Make it a game • Feed Tag Detective. Gather two food packages from the pantry. Pretend each is animal feed. Read the guaranteed analysis aloud and name the nutrient class each number stands for. Then answer quickly: would a ruminant, a horse or a single-stomached animal thrive on it, and why? Compare dry-matter basis in your head. Score one point per correct answer.

4.2 ANIMAL HEALTH: PARASITES, PREVENTION AND FIRST AID

OBJECTIVES

- Describe common internal and external parasites of pets and livestock and how they are monitored and prevented.
- Explain why deworming should be targeted and guided by a veterinarian.
- Know normal vital signs for common animals and assemble a basic animal first-aid kit.
- Respond safely to an injured animal until a veterinarian takes over.

Warm-up. With an adult's permission and a calm pet (or using a stuffed animal for practice), count a resting breathing rate by watching the chest rise and fall for 30 seconds and doubling it. Record it. Why might a veterinarian want to know an animal's normal rate?

WATCH

Preparing a Pet First Aid Kit

atDove · 9:25

<https://www.youtube.com/watch?v=J7vEnvn3OQs>

WHEN TO WATCH

Before you build the first-aid kit in the project. List each item and what it is for.

BACKUP VIDEO

How to Do a Fecal Egg Count | Parasite Testing in Goats & Sheep | Improve Deworming Decisions

KyStateU · 4:49

<https://www.youtube.com/watch?v=3XRYU93O-WQ>

With the core idea on parasites: Kentucky State University shows how manure samples are collected from goats and sheep for a parasite egg count.

KEY TERMS

internal parasite

A parasite that lives inside an animal, such as roundworms, tapeworms, coccidia or the barber pole worm of sheep and goats.

fecal egg count

A lab test in which parasite eggs in a weighed sample of manure are counted under a microscope to estimate how many worms an animal carries.

dewormer resistance

When parasites survive a dewormer because the drug was used too often or at the wrong dose, so it no longer works.

external parasite

A parasite that lives on the skin or hair, such as fleas, ticks, lice and mites.

FAMACHA

A chart for scoring the color of a sheep's or goat's inner eyelid; pale pink or white suggests anemia from barber pole worms.

biosecurity

Practices that keep diseases and parasites from entering or spreading on a farm, such as keeping new animals apart for several weeks and cleaning boots and equipment.

CORE IDEAS

A **parasite** lives on or in another animal and takes from it. **External parasites** include fleas (which can carry tapeworm larvae), ticks, lice and mites, which cause itching, hair loss, scaly legs in chickens and sometimes disease. **Internal parasites** include roundworms, hookworms and tapeworms in dogs and cats, **coccidia** (single-celled parasites) in young chicks, rabbits and calves, and the **barber pole worm** in sheep and goats, a blood-feeding stomach worm that can cause severe anemia.

Prevention starts with management. Clean, dry bedding; uncrowded housing; manure removed often; rotating pastures so animals do not graze where worm larvae are thickest; keeping feed and water off the ground; and year-round flea, tick and heartworm prevention for dogs and cats as prescribed by a veterinarian. New animals are kept apart for about 30 days to make sure they do not bring in parasites or disease.

Monitoring tells you when treatment is needed. A **fecal egg count** estimates the worm load. Shepherds check the color of the inner eyelid with the **FAMACHA** chart

and treat only the pale animals. For decades, farmers dewormed every animal on a schedule, and many worms became **resistant**. Today veterinarians recommend testing first, treating only animals that need it, and using the right drug at the right dose. Immunizations, such as rabies shots for dogs and cats or clostridial shots for sheep and goats, are given on a schedule set with a veterinarian.

Know what normal looks like so you can spot trouble. Typical resting rectal temperatures: dog 101–102.5 °F, cat 100.5–102.5 °F, horse 99–101 °F, goat and sheep about 101.5–103.5 °F, chicken about 105–107 °F. A healthy animal is alert, eats and drinks normally, has bright eyes and normal manure. Changes in appetite, behavior or droppings are often the first signs of illness.

In an emergency, keep yourself safe first: even a gentle pet may bite when hurt. Speak calmly, have an adult restrain the animal, and use a soft muzzle on an injured dog if it is not vomiting or struggling to breathe. Apply firm pressure with a clean cloth to bleeding, keep the animal warm and quiet, and call the veterinarian. A first-aid kit buys time; it does not replace the vet.

PICTURE STUDY



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

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

Landseer painted Paul Pry, a Newfoundland dog known for rescuing people from the water. The title is a joke and a compliment: the Royal Humane Society gave medals for lifesaving, and this dog deserved to be a member.

Look closely

- Look at the dog's eyes, coat and posture. What signs tell you this is a healthy, well-cared-for animal?
- Find the dog's large webbed paws. How are they suited to swimming?
- Look at the thick double coat. What care would a coat like this need to stay clean and free of parasites?
- Find the water and the mooring ring. Why might a rescue dog wait in a place like this?

Talk about it

1. Name three things you would check if this dog suddenly stopped eating and lay with its head down.
2. How does caring well for working animals, like this rescue dog, show that 'a righteous man regardeth the life of his beast'?

Safety first. Injured or frightened animals may bite, scratch or kick; an adult must restrain the animal, and you should never put your face near an injured animal's mouth. Wear gloves when handling manure samples and wash your hands afterward. Medicines and dewormers are given only as directed by a veterinarian and handled by an adult.

An Animal First-Aid Kit and Health Record

You will assemble a basic first-aid kit for a pet or farm animal and start a health record that a veterinarian would find useful.

You will need

- A sturdy plastic box with a lid
- Gauze pads and rolled gauze, self-adhesive bandage wrap, non-stick pads and adhesive tape
- Blunt-tipped scissors, tweezers or a tick remover, and disposable gloves
- A digital thermometer reserved for animals, and lubricant
- Saline eye wash, a clean towel, and a soft muzzle or a length of gauze for a dog
- Cards with the phone numbers of your veterinarian, an emergency animal hospital and the ASPCA Animal Poison Control Center
- A notebook or printed health-record form

Steps

1. Choose the animal your kit is for: your own pet, a neighbor's animal you care for, a 4-H project, or a 'planned' animal you hope to keep one day.
2. Research the animal's normal temperature, heart rate and breathing rate from a veterinary or extension source, and write them on a card inside the lid.
3. Gather the supplies and pack them so the most urgent items (gauze, wrap, gloves, phone card) are on top.
4. Label the box clearly and list the contents and expiration dates on the lid.
5. Start a health record with the animal's name, species, breed, birth date, weight, immunization dates, parasite prevention, feed and any health problems. For a planned animal, fill in what you would need to record.
6. With an adult and a calm animal, practice a gentle body check: eyes, ears, nose, coat and skin (look for fleas or ticks), feet, and body condition. Record what you find.

7. Write a one-paragraph emergency plan: who to call, where the kit is, and how you would safely move the animal.

Tips

- Never give an animal human medicines such as ibuprofen or acetaminophen; many are poisonous to pets.
- Weigh the animal regularly. A gradual weight loss is often the first sign of parasites or illness.

Check your work

- ☐ My kit contains basic wound-care supplies, a thermometer, gloves and emergency phone numbers.
- ☐ I recorded the normal vital signs for my chosen animal from a reliable source.
- ☐ My health record includes immunizations, parasite prevention and weight.
- ☐ I can explain why dewormers should be used only when testing shows they are needed.

NATURE JOURNAL

1. Draw the life cycle of a flea or of the barber pole worm, showing where it lives on or in the animal and where it lives in the environment, and mark where management can break the cycle.
2. Make a FAMACHA-style color scale in your journal from bright red-pink to white using colored pencils, and label which colors mean healthy and which mean anemia.

COMMON MISTAKES

- Deworming every animal on a calendar schedule, which breeds resistant worms. Test and treat only those that need it.
- Waiting to see if an animal ‘gets better’ when it stops eating; prey animals like rabbits and goats hide illness and need prompt care.
- Using a human thermometer and then putting it back in the family medicine cabinet.

Make it a game • Parasite Patrol. Your parent calls out a pet or livestock animal. You have sixty seconds to name one internal and one external parasite, how you would check for it, and one biosecurity step. Then explain why a fecal egg count or FAMACHA check comes before any dewormer. Beat your own count of correct answers.

4.3 BREEDS AND INHERITED TRAITS

OBJECTIVES

- Explain what a breed is and how farmers developed breeds by choosing parents with desired traits.
- Use Punnett squares to predict offspring for dominant–recessive traits and for incomplete dominance in farm animals.
- Explain hybrid vigor and why many farmers use crossbred animals.

Warm-up. List five breeds of dog, chicken, cattle or horse you know. Beside each, write one trait it is known for (size, color, eggs, milk, speed, herding).

WATCH

Dominant & Recessive Genetics | Basic Chicken Genetics Pt. 1

Cedar Shade Farm · 10:02

<https://www.youtube.com/watch?v=oNeVaoSC5XI>

WHEN TO WATCH

After the core idea about Punnett squares. Work each example along with the video in your journal.

KEY TERMS

breed

A group of animals within a species that share a consistent appearance and traits and pass them reliably to their offspring.

allele

One of the different forms of a gene, such as the form for black coat or for red coat.

genotype and phenotype

The genotype is the pair of alleles an animal carries; the phenotype is the trait you can see or measure.

homozygous and heterozygous

Homozygous means both alleles for a gene are the same (BB or bb); heterozygous means they differ (Bb).

incomplete dominance

When neither allele is fully dominant, so a heterozygous animal shows an in-between trait, as in blue Andalusian chickens.

hybrid vigor

The extra growth, health and fertility often seen in crossbred offspring of two different breeds; also called heterosis.

CORE IDEAS

God created animals to reproduce ‘after their kind,’ and within each kind He placed a great store of variety. For thousands of years farmers have used that variety by choosing which animals become parents. Keeping the best milkers, the gentlest horses or the hens that laid most, generation after generation, produced **breeds**: Holstein and Jersey cattle for milk, Angus and Hereford for beef, Leghorn hens for white eggs, Border Collies for herding, Percherons for pulling. A breed ‘breeds true’: its offspring look and perform like their parents.

Traits are carried by **genes**, and an animal receives one copy (**allele**) of each gene from each parent. Some alleles are **dominant** and show whenever present; others are **recessive** and show only when an animal has two. In cattle, the polled (hornless) allele P is dominant over horned p, and black B is dominant over red b. A black bull can be BB or Bb; you cannot tell by looking, which is why the genotype matters.

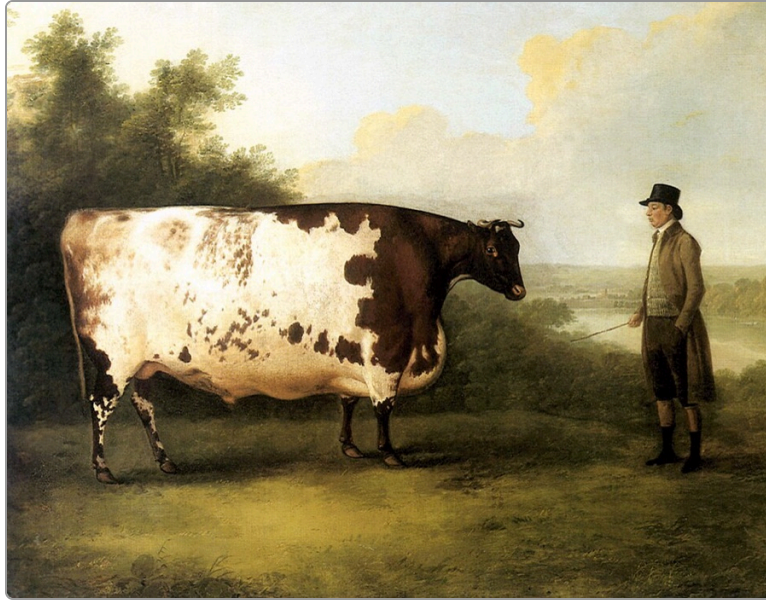
A **Punnett square** predicts the chances. Cross two black cattle that are both Bb: write B and b across the top and down the side, fill in the four boxes, and you get BB, Bb, Bb and bb. On average, three of four calves will be black and one red (a 3:1 ratio of phenotypes, 1:2:1 of genotypes). Each calf is a separate chance, like a coin toss, so a small herd may not match the ratio exactly.

Not every trait is simple. In **incomplete dominance**, the heterozygote is in between: crossing a black Andalusian chicken with a white (‘splash’) one gives all blue chicks, and two blues give about 1 black : 2 blue : 1 splash. Many important traits, such as milk yield or growth rate, are controlled by many genes plus environment, so breed associations publish **EPDs** (expected progeny differences), numbers that predict how a bull’s offspring will perform compared with others of the breed.

Commercial farmers often **crossbreed**, crossing two breeds to combine their strengths and gain **hybrid vigor**: crossbred calves often grow faster and stay healthier than either parent breed. Keeping purebred lines is still important,

because the purebreds are the source of the traits. Gregor Mendel worked these rules out with peas (Lesson 5.2), but they hold for chickens, cattle and dogs alike.

PICTURE STUDY



The Durham Ox, John Boulton, about 1802 · Oil on canvas · Private collection

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

The Durham Ox was a famous Shorthorn steer raised in northeast England around 1800. It grew so large (over 3,000 pounds) that it was carried around Britain in a special wagon for people to see, and paintings and prints of it made the new Shorthorn breed famous.

Look closely

- Look at the ox's shape: its long back, deep body and short legs. Which traits do you think farmers were choosing for?
- Find the color pattern. Shorthorns can be red, white or roan (a mix of red and white hairs). Which is this one?
- Look at the man beside the ox. How does he help you judge the animal's size?
- Notice the setting. What does the green pasture tell you about how this ox was raised?

Talk about it

1. In Shorthorns, a red parent and a white parent produce roan calves, whose coats mix red and white hairs. What colors would you expect from two roan parents, and in what ratio?

2. Why do you think breeders of the 1800s wanted paintings of their best animals?

HANDS-ON PROJECT

A Trait-Inheritance Workbook

You will work real farm-genetics problems with Punnett squares, test probability with coins, and plan the pairing of two animals to reach a goal.

You will need

- Journal, ruler and pencil
- Two coins and a strip of tape and marker
- Breed information from a library book, a breed association website or a 4-H animal science manual

Steps

1. Label one side of each coin B (black) and the other b (red). Each coin is a parent with genotype Bb.
2. Toss both coins together 40 times and record the genotype each time (BB, Bb or bb). Count the totals and the phenotypes (black or red).
3. Draw the Punnett square for Bb $\times$ Bb and compare the predicted ratio with your coin results. Explain any difference.
4. Work these crosses with Punnett squares, giving genotype and phenotype ratios: (a) a homozygous polled bull PP $\times$ a horned cow pp; (b) two heterozygous polled cattle Pp $\times$ Pp; (c) a red Shorthorn $\times$ a white Shorthorn (the calves are roan, with both red and white hairs); (d) two blue Andalusian chickens.
5. A farmer wants only black, polled calves. Which bull genotype should he choose, and why? Show the cross with his herd of black, horned cows (Bb pp).
6. Choose one species and research three breeds. Make a table of each breed's purpose, origin, appearance and key traits.
7. Write a paragraph explaining hybrid vigor and why a commercial farmer might cross two of the breeds you researched.

Tips

- Always write the dominant allele as a capital letter and the recessive as the same letter in lowercase.
- More coin tosses give results closer to the predicted ratio. That is why scientists use large numbers.

Check your work

- ☐ I completed 40 coin tosses and compared the results with the Punnett square.
- ☐ My four crosses show correct genotype and phenotype ratios.
- ☐ I chose a bull genotype that guarantees black, polled calves and showed why.
- ☐ My breed table compares three breeds by purpose and traits.

NATURE JOURNAL

1. Sketch two animals of different breeds of the same species side by side (for example a Jersey and a Hereford, or a Leghorn and an Orpington). Label the traits that differ.
2. Draw a three-generation family tree (pedigree) for a real or imaginary animal, showing coat color in each animal and the genotypes you can work out.

From history. Robert Bakewell, an English farmer of the 1700s, was one of the first to improve livestock systematically, keeping careful records and choosing parents for the traits he wanted in Longhorn cattle, Leicester sheep and Shire horses. His methods spread across Britain, and the Shorthorn, like the Durham Ox, was one of the breeds improved in this way.

COMMON MISTAKES

- Assuming an animal showing the dominant trait must be homozygous. It may carry a hidden recessive.
- Expecting every litter or clutch to match the Punnett square ratio exactly. Ratios are probabilities.
- Thinking a crossbred animal will breed true. Its offspring will vary because it carries alleles from two breeds.

Make it a game • Punnett Square Showdown. Your parent names a farm trait, dominant or incomplete dominance, and the parents' genotypes. Draw the Punnett square on paper before the timer rings at ninety seconds. State the genotype and phenotype ratios and whether hybrid vigor might apply. One point for each correct ratio. Switch roles and write a tricky cross for your parent.

4.4 CAREERS WITH ANIMALS AND ON THE FARM

OBJECTIVES

- Describe the training, daily work and challenges of at least four careers: veterinarian, veterinary technician, farrier, trainer, farmer or rancher.
- Identify related careers in agricultural science, extension, wildlife and food safety.
- Interview or shadow someone who works with animals or crops and report what you learn.

Warm-up. Write down three jobs you can think of that involve animals or farming. Then write one thing about each you think would be hard and one thing that would be rewarding.

WATCH

Inside a Day with a Large Animal Vet

VirginiaFarmBureau · 7:35

<https://www.youtube.com/watch?v=mgVNg1Kgp5w>

WHEN TO WATCH

After the core ideas. List every task the veterinarian does and the tools she uses.

BACKUP VIDEO

A day in the life of a farrier 🐾🔪 | ABC Australia

ABC Australia · 4:59

<https://www.youtube.com/watch?v=EVcXHoqly68>

With the farrier core idea: an Australian farrier at work trimming and shoeing horses.

KEY TERMS

veterinarian (DVM)

A doctor of veterinary medicine, who completes college plus four years of veterinary school and passes a national licensing exam.

veterinary technician

A trained professional, usually with a two-year degree and a credentialing exam, who assists veterinarians with nursing, lab work, anesthesia and imaging.

farrier

A craftsman who trims horses' hooves and makes and fits horseshoes.

extension agent

An educator employed through a state university who brings research-based help on crops, livestock, gardening, food and 4-H to the public.

supervised agricultural experience (SAE)

A hands-on project in FFA and agricultural education, such as raising animals, working on a farm or doing research, in which students keep records and build skills.

CORE IDEAS

Caring for animals and land is honorable work, and it needs many kinds of skill. **Veterinarians** diagnose and treat illness and injury, perform surgery, and work to prevent disease. Some care for dogs and cats in clinics; others are **large-animal or mixed-practice vets** who drive from farm to farm, often at night and in bad weather, caring for cattle, horses, sheep and goats. Becoming a vet usually takes four years of college with strong science and math, four years of veterinary school, and a licensing exam. Many rural areas need more large-animal vets.

Veterinary technicians are the nurses of the animal world: they take X-rays, run lab tests, monitor anesthesia, give treatments and teach owners. Most earn a two-year associate degree and pass a national exam. **Farriers** trim and shoe horses every six to eight weeks, combining blacksmithing, anatomy and the patience to handle a horse safely; most learn at a farriery school and through years as an apprentice. **Trainers** teach dogs, horses or other animals using consistent rewards and clear signals.

Farmers and ranchers are business owners, mechanics, biologists, accountants and weather-watchers in one. A dairy farmer milks two or more times every day of the year; a cattle rancher manages grass, water, herd health and markets. Many farm families also work off the farm, and many young people start small, with a flock of hens or a market garden.

Agriculture has many more careers. In **horticulture**, people manage greenhouses, nurseries, orchards and landscapes, work as plant breeders and arborists, and run market gardens. **Extension** agents and specialists, employed through each state's land-grant university, teach farmers, gardeners and 4-H members; many hold a bachelor's or master's degree in agriculture, horticulture, animal science or family and consumer science. Others work as animal nutritionists, agricultural teachers, soil scientists, beekeepers, wildlife biologists and game wardens, USDA inspectors, livestock auctioneers and equipment technicians. Common college degrees include animal science, agronomy, horticulture, agricultural business, agricultural education and pre-veterinary studies; two-year programs and apprenticeships lead to many skilled jobs.

Youth programs are the first step on these paths. **4-H** (about ages 8–18, with Cloverbuds for younger children) is open to homeschoolers through the county extension office, with projects, record books, fairs, judging contests and illustrated talks. **FFA** is part of school agricultural education programs, usually from grade 7 and in some states from grade 5; there is no national homeschool provision, though some states have homeschool chapters, so families should ask their state FFA association. FFA members keep a Supervised Agricultural Experience (SAE) record and can earn degrees such as the Discovery, Greenhand, Chapter, State and American FFA Degrees. Both programs offer scholarships to members with strong records.

Whatever your calling, Scripture says to do it 'heartily, as to the Lord.' Diligence, honesty and gentleness with animals are worth as much as any degree. Start now: volunteer, ask questions, keep good records, and learn to work.

PICTURE STUDY



Shoeing, Sir Edwin Landseer, 1844 · Oil on canvas · Tate, London

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

Landseer painted the forge of a village blacksmith, who was also the farrier. The mare, Old Betty, belonged to a friend of the painter. The scene shows a skilled trade that is still practiced today.

Look closely

- Find the farrier. How is he holding the horse's leg, and where is he standing in relation to the horse?
- Find the tools in the box on the floor. Which ones can you name?
- Look at the horse's face and posture. How can you tell she is calm and used to being shod?
- Find the donkey and the dog. What do they add to the story of the picture?

Talk about it

1. Why does a farrier need to know a horse's anatomy and behavior as well as metalwork?
2. Which modern career in this lesson would you most like to learn more about, and why?

HANDS-ON PROJECT

Career Interview and Report

You will interview (or, if possible, shadow) someone whose work involves animals, crops or land, and research the training needed for that career.

You will need

- Journal and pencil, or a phone to record with permission
- A list of possible people: your family's veterinarian or vet tech, a farrier, a farmer, an extension agent, a 4-H leader, a beekeeper, a feed-store owner, a dog trainer, a wildlife officer
- Career information from your state university or a library

Steps

1. With an adult, contact the person, explain that you are a student studying agricultural careers, and ask for a 20–30 minute interview or a few hours of job shadowing.
2. Prepare at least eight questions: how they chose the work, what training they needed, a typical day, the hardest and best parts, the skills that matter most, how the work has changed, safety concerns, and advice for a young person.
3. Conduct the interview politely, take careful notes, and thank the person. Send a written thank-you note afterward.
4. Research the career further: education or training required, certification or license, typical work hours and conditions, and where people in this career work in your state.
5. Write a two-page report: an introduction to the person and career, what you learned from the interview, your research, and whether you might consider this work and why.
6. Add a section listing three things you could do in the next two years to prepare (a 4-H project, volunteering, a science class, a job on a farm).

Tips

- Busy professionals are often glad to help a student who is prepared and respectful of their time.

- If you cannot meet someone in person, a phone or video interview works too.
- Ask your interviewee whether they were in 4-H or FFA and what they learned there.

Check your work

- ☐ I prepared at least eight thoughtful questions.
- ☐ I conducted the interview and wrote a thank-you note.
- ☐ My report includes training requirements and a description of daily work.
- ☐ I listed three practical steps I could take to prepare.

NATURE JOURNAL

1. Draw the hoof of a horse from below, labeling the wall, sole, frog, white line and bars, and add where a horseshoe and nails go.
2. Make a chart of six agricultural careers with columns for training needed, an example task, and indoor or outdoor work.

COMMON MISTAKES

- Thinking a veterinarian's job is mostly playing with animals. It also means long hours, hard decisions and much science.
- Waiting until after high school to explore careers. Volunteering and 4-H or FFA projects now help you find out what you love.
- Forgetting that every farm job, from milking to bookkeeping, matters to the whole operation.

Make it a game • Career Mystery Guest. Think of one farm career without saying it: veterinarian, technician, farrier, trainer, farmer, extension agent. Your parent asks yes-or-no questions about daily work and training until she guesses. Reverse roles. Finally, each describe one hard part of the job and what supervised agricultural experience would let a student try it.

Scripture. “And whatsoever ye do, do it heartily, as to the Lord, and not unto men;” (Colossians 3:23, KJV)

Whether you become a veterinarian, a farmer or something else, work done carefully and cheerfully is service to God.

UNIT 4

ANIMAL CARE AND CAREERS

A good steward of animals knows what they need to eat, how to keep them healthy, and how their traits are passed from parents to offspring. In this unit you will read feed labels like a nutritionist, learn how farmers and veterinarians prevent and treat parasites and handle emergencies, work Punnett squares for real farm traits, and meet the people whose careers are spent caring for animals.

Proverbs 12:10 says, ‘A righteous man regardeth the life of his beast.’ Regarding an animal’s life means more than kindness; it means knowledge. Whether or not you keep animals now, the skills in this unit will serve you with a family dog, a backyard flock, a 4-H project or a future job.

PREREQUISITES

- The basic needs of pets and farm animals (food, water, shelter, health care)
- Gentle, safe handling of animals and washing hands afterward
- Calculating percentages
- Knowing that offspring inherit traits from both parents

MASTERY CHECKLIST

- ☐ I can name the six classes of nutrients and read the guaranteed analysis on a feed tag.
- ☐ I can convert a feed’s protein to a dry-matter basis to compare wet and dry feeds.
- ☐ I can describe common internal and external parasites and how they are prevented and monitored.
- ☐ I can give the normal temperature of a dog, horse and goat and assemble a basic animal first-aid kit.
- ☐ I can use a Punnett square to predict the offspring of a cross involving dominant, recessive and incompletely dominant traits.
- ☐ I can describe the training and daily work of at least four animal-care careers.

LESSONS IN THIS UNIT

4.1	Animal Nutrition and Feed Labels	2 sessions of 60 minutes
4.2	Animal Health: Parasites, Prevention and First Aid	2 sessions of 60 minutes
4.3	Breeds and Inherited Traits	2 sessions of 60 minutes
4.4	Careers with Animals and on the Farm	2 sessions of 60 minutes

UNIT 4 REVIEW

Answer each question in complete sentences unless a calculation or Punnett square is asked for; show your work. Total: 100 points.

1. 7 pts

Name the six classes of nutrients and give one function of each.

2. 8 pts

Why can a goat live on hay and pasture while a dog cannot?

3. 9 pts

A canned cat food is 10% protein and 80% moisture. A dry food is 32% protein and 10% moisture. Which has more protein on a dry-matter basis? Show your work.

4. 7 pts

What does the ingredient order on a feed label tell you?

5. 8 pts

Name two internal and two external parasites and one animal each affects.

6. 9 pts

Explain why veterinarians now recommend fecal egg counts and FAMACHA scoring instead of deworming every animal on a schedule.

7. **7 pts**

Give the normal temperature range of a dog and of a horse. Why is it useful to know these?

8. **9 pts**

Draw a Punnett square for two heterozygous polled cattle ($Pp \times Pp$). Give the genotype and phenotype ratios.

9. **9 pts**

In Andalusian chickens, black $\times$ splash gives blue. What do you expect from blue $\times$ blue, and what is this kind of inheritance called?

10. **8 pts**

What is hybrid vigor, and why do purebred herds still matter?

11. **8 pts**

Compare the training of a veterinarian and a veterinary technician.

12. **11 pts**

Short answer: A neighbor's goat is thin, has pale inner eyelids and has stopped eating well. Explain what might be wrong and the steps a responsible owner should take.

ANSWER KEY

1. Water (body processes, temperature), carbohydrates (energy), fats (concentrated energy), proteins (muscle, milk, eggs, enzymes), vitamins (body processes, e.g. vitamin D for bones), minerals (bones, eggshells, nerves, e.g. calcium, salt).
2. A goat is a ruminant; microbes in its four-part stomach ferment fiber it could not digest alone. A dog is monogastric with a simple stomach and cannot digest much fiber, so it needs concentrated food.
3. Canned: $10 \div 20 \times 100 = 50\%$. Dry: $32 \div 90 \times 100 \approx 35.6\%$. The canned food has more protein on a dry-matter basis.
4. Ingredients are listed by weight from most to least, so the first few make up most of the feed.
5. Internal (any two): roundworms (dogs, pigs), tapeworms (dogs, cats), coccidia (chicks, rabbits, calves), barber pole worm (sheep, goats). External (any two): fleas (dogs, cats), ticks (dogs, cattle, people), lice (chickens, cattle), mites (chickens, rabbits).
6. Frequent blanket deworming caused parasites to become resistant so dewormers stopped working. Testing identifies which animals actually need treatment, slowing resistance and saving money.
7. Dog about 101–102.5 °F; horse about 99–101 °F. A temperature outside the normal range is an early sign of illness or heat stress, and it helps the veterinarian.
8. PP, Pp, Pp, pp. Genotypes 1 PP : 2 Pp : 1 pp. Phenotypes 3 polled : 1 horned.
9. About 1 black : 2 blue : 1 splash. Incomplete dominance.
10. Hybrid vigor is the extra growth, health and fertility often seen in crossbred offspring. Purebred herds are needed as the reliable source of each breed's traits for future crosses.
11. A veterinarian usually completes four years of college plus four years of veterinary school and passes a licensing exam. A vet tech usually earns a two-year associate degree and passes a credentialing exam.
12. A strong answer suggests anemia from barber pole worms (or another illness), recommends calling the veterinarian, taking the temperature, a fecal egg count and FAMACHA score, treating only as the vet directs with an effective dewormer, separating the goat if needed, improving pasture rotation and nutrition, and monitoring weight and eyelid color afterward.

PORTFOLIO PIECE: AN ANIMAL CARE PLAN AND BUDGET

Write a complete care plan for one animal you keep or hope to keep (a dog, a rabbit, a backyard flock, a goat, a 4-H steer). Include housing, a daily and weekly feeding plan with feed-label analysis, a health calendar (immunizations, parasite monitoring, hoof or nail care), your first-aid kit list, a one-year budget, and, if the animal will be bred or shown, a section on the breed's traits and how they are inherited.

LOOK FOR	WHAT IT MEANS
Nutrition	The feeding plan fits the animal's digestive system and life stage and uses real feed-label data.
Health	The health calendar includes prevention, monitoring, a veterinarian's role and a first-aid plan.
Budget	The one-year budget lists realistic costs for feed, bedding, veterinary care, equipment and housing.
Knowledge	Breed traits, normal vital signs and parasite risks are described accurately.
Responsibility	The plan shows who does each chore and when, including backup care during travel or illness.

UNIT 5

PLANT SCIENCE

Late winter is the season for the deepest plant science of the year, done indoors while the garden sleeps. You will look inside the leaf at the chemistry of photosynthesis and respiration, follow Gregor Mendel through his pea garden to the laws of heredity, meet the hormones that tell a plant when to root, grow, ripen and rest, and grow lettuce with no soil at all.

Every one of these topics is used by real growers. Seed companies rely on Mendel's rules to produce new varieties; nurseries use rooting hormones; shippers control ripening with ethylene; and greenhouse farms grow lettuce in water. The more you understand how God designed plants to work, the better you can tend them.

PREREQUISITES

- The parts of a plant and their jobs
- Knowing that plants make food from light, water and carbon dioxide
- Punnett squares for one trait (Lesson 4.3)
- The roles of nitrogen, phosphorus and potassium (Lesson 3.2)

MASTERY CHECKLIST

- ☐ I can write and explain the balanced equations for photosynthesis and cellular respiration and tell where each happens in the cell.
- ☐ I can measure the rate of photosynthesis with floating leaf disks and explain how light affects it.
- ☐ I can explain Mendel's laws of segregation and independent assortment and solve a two-trait Punnett square.
- ☐ I can explain the difference between heirloom, open-pollinated and F1 hybrid seed and why hybrid seed does not come true.
- ☐ I can name five plant hormones and one use of each in gardening or farming.
- ☐ I can set up and maintain a Kratky hydroponic jar and keep a cost and growth record.

LESSONS IN THIS UNIT

5.1 Photosynthesis and Cellular Respiration

2 sessions of 60 minutes

5.2 Plant Genetics: Mendel, Hybrids and Heirlooms

2 sessions of 60 minutes

5.3 Plant Growth Regulators

2 sessions of 60 minutes

5.4 Hydroponics: Growing Without Soil

2 sessions of 60 minutes

UNIT 5 REVIEW

Answer each question in complete sentences unless an equation, calculation or Punnett square is asked for; show your work. Total: 100 points.

1. 8 pts

Write the balanced equation for photosynthesis and name the organelle where it happens.

2. 8 pts

Write the equation for cellular respiration. When and where does it happen in a plant?

3. 8 pts

What happens in the light-dependent reactions, and what happens in the Calvin cycle?

4. 8 pts

In the floating leaf-disk test, why do the disks float, and why did disks near the lamp float sooner?

5. 8 pts

State Mendel's law of segregation and law of independent assortment.

6. 9 pts

In peas, tall (T) is dominant over short (t). Cross $Tt \times tt$. Give the genotype and phenotype ratios.

7. 8 pts

What phenotype ratio results from crossing two plants heterozygous for two independent traits ($RrYy \times RrYy$)?

8. 8 pts

Explain why a gardener who saves seed from an F1 hybrid tomato may be disappointed, while one who saves heirloom seed is not.

9. **8 pts**

Name the hormone involved in each: (a) a stem bends toward a window; (b) green tomatoes ripen in a bag with a banana; (c) seeds stay dormant through winter; (d) a cutting forms roots after being dipped in powder.

10. **8 pts**

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

11. **9 pts**

In a Kratky jar, how do roots get oxygen, and why should you not refill the jar to the top?

12. **10 pts**

Short answer: Give two advantages and two disadvantages of hydroponics compared with growing in soil, and explain why most of the world's food will still be grown in soil.

ANSWER KEY

1. $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$. In the chloroplast.
2. $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy (ATP)}$. In the mitochondria of every living cell, including roots, day and night.
3. Light reactions (thylakoids): chlorophyll absorbs light, water is split, oxygen is released, ATP and NADPH are made. Calvin cycle (stroma): RuBisCO fixes CO_2 and ATP and NADPH are used to build sugars.
4. Photosynthesis produces oxygen that collects in the leaf tissue and makes the disks buoyant. More light gives a faster rate of photosynthesis, so oxygen builds up sooner.
5. Segregation: each parent passes on only one of its two alleles for a trait, by chance. Independent assortment: alleles for different traits are passed on independently of each other.
6. Tt, Tt, tt, tt. Genotypes 1 Tt : 1 tt; phenotypes 1 tall : 1 short.
7. 9 round-yellow : 3 round-green : 3 wrinkled-yellow : 1 wrinkled-green.
8. F1 hybrids are heterozygous for many traits, so their seed segregates into many different types. An heirloom is open-pollinated and pure-line, so its seed grows plants like the parent if kept from crossing.
9. (a) auxin; (b) ethylene; (c) abscisic acid; (d) auxin (synthetic auxin such as IBA).
10. It removes the shoot tip, the source of the auxin that keeps side buds dormant (apical dominance), so side shoots grow.
11. As the plant drinks, the solution level drops and leaves an air gap; upper roots take oxygen from the air there. Refilling to the top drowns those air roots, so they cannot respire and may rot.
12. Advantages (any two): fast growth, uses less water, clean produce, can grow indoors or in winter, no soil-borne weeds. Disadvantages (any two): equipment and electricity costs, nutrient management, pump failure, rapid disease spread, unsuitable for large field crops. Staple crops like wheat, corn, rice and potatoes are grown on huge areas far more cheaply in soil.

PORTFOLIO PIECE: A PLANT SCIENCE LAB NOTEBOOK

Assemble your three experiments from this unit (floating leaf disks, the hormone test, and the hydroponic lettuce) into a lab notebook. Each experiment has a question, hypothesis, materials, method, data table, graph, conclusion and a list of sources of error. Add your seed-saving plan, and include the expense table from your hydroponic project. Prepare it as you would a science-fair or 4-H exhibit.

LOOK FOR	WHAT IT MEANS
Method	Each experiment has a clear question, hypothesis, variables and a control.
Data	Data are recorded with units and dates and shown in correct, labeled graphs.
Science	Conclusions are explained accurately with photosynthesis, genetics or hormone concepts.
Records	The hydroponic record includes growth, pH and a correct cost-per-head calculation.
Presentation	The notebook is neat and organized enough to exhibit at a science fair or county fair.

5.1 PHOTOSYNTHESIS AND CELLULAR RESPIRATION

OBJECTIVES

- Write and balance the equations for photosynthesis and cellular respiration.
- Describe the light-dependent reactions and the Calvin cycle and where each takes place in the chloroplast.
- Measure how light intensity affects the rate of photosynthesis with a floating leaf-disk test.

Warm-up. A small willow tree planted in a tub of soil grows into a big tree in five years, yet the soil in the tub weighs almost the same. Write down where you think the tree's new wood came from. You will find out today.

WATCH

Photosynthesis and Cellular Respiration - Energy Cycle of Life

Point Source Science · 4:10

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

WHEN TO WATCH

After the core ideas. Pause at each equation and copy it into your journal.

KEY TERMS

photosynthesis

The process by which plants use light energy to make glucose from carbon dioxide and water, releasing oxygen:

$$6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2.$$

chloroplast

The organelle in leaf cells where photosynthesis happens; it contains the green pigment chlorophyll in stacks of membranes called thylakoids.

cellular respiration

The process by which cells break down glucose with oxygen to release usable energy (ATP), producing carbon dioxide and water: $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy}.$

Calvin cycle

The light-independent reactions in the fluid (stroma) of the chloroplast, where the enzyme RuBisCO fixes carbon dioxide into sugar using energy from the light reactions.

ATP

Adenosine triphosphate, the molecule that carries energy within cells.

stomata

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

CORE IDEAS

Plants build themselves mostly out of air and water. In the 1600s Jan Baptist van Helmont grew a willow in a tub for five years; it gained about 164 pounds while the soil lost only about 2 ounces. He thought the weight came from water. We now know most of a plant's dry weight is carbon taken from the carbon dioxide in the air. The balanced equation for **photosynthesis** is $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$ (glucose) + 6O_2 . Six molecules of carbon dioxide and six of water make one molecule of sugar and six of oxygen.

Photosynthesis happens in two stages inside the **chloroplast**. In the **light-dependent reactions**, on the thylakoid membranes, chlorophyll absorbs red and blue light (it reflects green, which is why leaves look green). That energy splits water molecules, releasing oxygen as a by-product and producing the energy carriers ATP and NADPH. In the **Calvin cycle**, in the surrounding stroma, the enzyme RuBisCO attaches carbon dioxide to a five-carbon sugar, and the ATP and NADPH are used to build three-carbon sugars that become glucose, sucrose, starch and cellulose.

Cellular respiration runs the reaction the other way: $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy (ATP)}$. It happens in the mitochondria of every living cell, plant and animal, day and night. Plants respire all the time, including their roots, which is why roots need air in the soil. A plant grows only when photosynthesis makes more sugar than respiration burns. In very low light, or when warm nights speed up respiration, a plant can use up its stores.

Growers use this chemistry every day. Seedlings stretch and grow weak in dim windows because they cannot make enough sugar. Greenhouses vent or add carbon dioxide. Overwatered soil kills roots because it shuts out the oxygen they need to respire. Leaves are the factories of the farm, so a gardener protects them from disease and pests.

The two processes form a cycle: plants and animals breathe out the carbon dioxide that plants take in, and plants give off the oxygen that both use. As Psalm 104 says, God 'causeth the grass to grow for the cattle, and herb for the service of man.'

PICTURE STUDY



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

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

Van Gogh painted this picture in Arles to decorate the room of a friend. He painted sunflowers again and again, fascinated by how they change from bud to bloom to seed.

Look closely

- Find a sunflower in full bloom, one that has lost its petals, and one that is drying into seed. Put them in order of their life.
- Look at the leaves on the stems. What has happened to many of them since the flowers were cut?
- Find the green centers of the youngest flowers and the brown seed heads of the oldest. Where is the plant storing the sugar it made by photosynthesis?
- Notice that almost every color in the painting is a kind of yellow. How does that make you feel about sunlight?

Talk about it

1. A sunflower seed is packed with oil and protein. Where did the carbon atoms in that oil come from?
2. Why do these cut flowers wilt and fade even though they sit in water? Which process keeps going after photosynthesis stops?

HANDS-ON PROJECT

Floating Leaf Disks: Measuring Photosynthesis

Leaf disks with the air pulled out of them sink in water. As they photosynthesize, oxygen collects in the leaf and the disks float. Counting how fast they rise lets you measure the rate of photosynthesis under different light.

You will need

- Fresh spinach leaves
- Baking soda (as a source of carbon dioxide) and a drop of dish soap
- A plastic syringe of 10 mL or more without a needle (from a pharmacy or feed store)
- A single-hole paper punch or a drinking straw
- Two or three clear cups, a lamp with a bright bulb, a ruler and a timer

Steps

1. Make a solution of 1/8 teaspoon of baking soda in 1 cup of water with one small drop of dish soap. Stir gently.
2. Punch 10 disks from a spinach leaf, avoiding the big veins.
3. Pull the plunger out of the syringe, drop the disks in, replace the plunger and push out the air. Draw in about 5 mL of solution.
4. Hold your finger over the tip and pull back on the plunger to make a vacuum for 10 seconds; release. Repeat several times until the disks sink.
5. Pour the disks and solution into a cup with 1 inch of the same solution. Place the cup 10 cm from the lamp and start the timer.
6. Every minute, record how many disks are floating, until all float or 20 minutes pass.
7. Repeat with new disks at 30 cm from the lamp, and once in a dark cupboard as a control.
8. Graph the number of floating disks against time for each light level. Find the time when half the disks floated (ET50) for each, and write a conclusion about light intensity and photosynthesis.

Tips

- If the disks will not sink, add one more drop of soap or repeat the vacuum step more times.
- Keep the water temperature the same in each trial; a hot bulb close to the cup can warm it. A cup of water between the lamp and the disks absorbs heat.

Check your work

- ☐ I ran at least two light levels and a dark control.
- ☐ My graph shows floating disks over time for each trial.
- ☐ I calculated the time for half the disks to float and explained my results.
- ☐ I can write both equations and say where in the cell each process happens.

NATURE JOURNAL

1. Draw a labeled diagram of a chloroplast showing the thylakoids, stroma and where the light reactions and Calvin cycle occur, with arrows for light, water, oxygen, carbon dioxide and sugar.
2. Draw a leaf cross-section with upper epidermis, palisade cells, spongy layer, a vein and stomata, and show the path of a carbon dioxide molecule from the air to a chloroplast.

From history. Joseph Priestley showed in 1771 that a sprig of mint could ‘restore’ air in which a candle had burned out, and Jan Ingenhousz found in 1779 that plants do this only in light. Melvin Calvin and his colleagues traced the path of carbon in photosynthesis in the 1940s and 1950s, which is why the sugar-making cycle carries his name.

COMMON MISTAKES

- Thinking plants do photosynthesis and animals do respiration. Plants respire too, every hour of the day and night.
- Thinking plants get their food from the soil. Soil supplies water and minerals; the sugar is made from air and water using light.
- Leaving seedlings in a dim window and blaming the seed when they grow tall and weak.

Make it a game • Equation Relay. Write the photosynthesis equation on one sheet and cellular respiration on another. Read both, then turn them face down. Race to rewrite them from memory with balanced coefficients while your parent times you. Then point to where the light reactions and the Calvin cycle happen in a chloroplast sketch. Beat your own best time.

5.2 PLANT GENETICS: MENDEL, HYBRIDS AND HEIRLOOMS

OBJECTIVES

- Describe Gregor Mendel's experiments and his laws of segregation and independent assortment.
- Solve a two-trait (dihybrid) Punnett square and explain the 9:3:3:1 ratio.
- Explain the difference between heirloom, open-pollinated and F1 hybrid varieties, and plan seed saving that keeps a variety true.

Warm-up. Look at three seed packets or catalog pages. Find the words 'heirloom', 'open-pollinated', 'hybrid' or 'F1'. Write down which seeds you think you could save and replant next year, and why.

WATCH

How Mendel's pea plants helped us understand genetics - Hortensia Jiménez Díaz

TED-Ed • 3:06

<https://www.youtube.com/watch?v=Mehz7tCxjSE>

WHEN TO WATCH

After the core idea about Mendel. Watch for how he crossed purple- and white-flowered peas.

BACKUP VIDEO

SEEDS EXPLAINED: Heirloom, Hybrid, Organic, and GMO Seeds 🍅

Epic Gardening • 10:31

<https://www.youtube.com/watch?v=Edk7cYBsXgc>

With the core idea on hybrids and heirlooms: a grower explains the seed words on catalog pages.

KEY TERMS

law of segregation

Mendel's finding that each parent passes on only one of its two alleles for a trait, chosen by chance.

law of independent assortment

Mendel's finding that alleles for different traits (on different chromosomes) are passed on independently of each other.

pure line

A line of plants always producing offspring like the parent when self-pollinated, because the plant is homozygous for its traits.

F1 hybrid

The first-generation offspring of a deliberate cross between two different pure-line parent lines; uniform and often vigorous, but its seed does not come true.

open-pollinated

A variety that produces offspring like itself when pollinated by plants of the same variety, so its seed can be saved.

heirloom

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

CORE IDEAS

Gregor Mendel (1822–1884) was an Augustinian friar at the abbey of St. Thomas in Brno, in what is now the Czech Republic. Between 1856 and 1863 he grew and studied thousands of pea plants in the abbey garden, tracking seven traits that came in two clear forms: round or wrinkled seeds, yellow or green seeds, purple or white flowers, tall or short stems, and others. Peas were ideal because they normally pollinate themselves, so he could control every cross by moving pollen with a small brush.

When Mendel crossed pure-line purple-flowered peas with white ones, every offspring (the F1) was purple. When he let those F1 plants self-pollinate, about three-quarters of the next generation (F2) were purple and one-quarter white. He reasoned that each plant carries two ‘factors’ (we call them alleles) for each trait, that one can hide the other (dominance), and that each parent passes on only one of its two, by chance: the **law of segregation**. Tracking two traits at once, round-yellow × wrinkled-green, he found that they sorted independently, giving about 9 round-yellow : 3 round-green : 3 wrinkled-yellow : 1 wrinkled-green in the F2: the **law of independent assortment**.

Mendel published his work in 1866, but few understood it until 1900, when three other scientists rediscovered his rules. Today every plant breeder uses them. An **open-pollinated** variety, if kept from crossing with others, produces seed like itself; many are **heirlooms**, such as Brandywine tomatoes or Kentucky Wonder beans, passed down for generations. An **F1 hybrid** comes from crossing two different pure-line parent lines. Like the F1 peas, the hybrid plants are uniform and often vigorous

(hybrid vigor), but if you save their seed, the F2 plants segregate into a mixture of types. That is why hybrid seed is bought new each year.

To save seed that comes true, know how a crop is pollinated. Peas, beans, lettuce and most tomatoes are mostly **self-pollinating**, so a few feet or a short distance between varieties is usually enough. Corn, squash, cucumbers, melons and the cabbage family are **cross-pollinated** by wind or insects and must be separated by long distances (often a quarter mile or more for corn) or hand-pollinated and bagged. Save seed from many healthy plants that show the traits you want, not just one.

Mendel was a man of faith and of careful observation who saw in his garden an order that could be counted. Genesis 1 says that God made plants ‘yielding seed after his kind.’ Within each kind lies a rich store of variety for patient gardeners to discover and keep.

PICTURE STUDY



Garden Pea (Pisum sativum), from *Thomé's Flora von Deutschland*, Otto Wilhelm Thomé (text); plates by Walter Müller, 1885 · Chromolithograph · Book illustration

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

This plate from a famous German flora was printed only twenty years after Mendel published his pea experiments. It shows the very structures Mendel worked with: the closed flower that pollinates itself, and the seeds whose color and shape he counted.

Look closely

- Find detail 1, the flower cut open. Can you see how the petals wrap around the stamens and pistil? Why does this make peas self-pollinate?
- Find the stamens (detail 2) with their orange pollen sacs. How would Mendel remove them to stop a flower from pollinating itself?
- Find the seeds (details 6 and 7). Which two seed traits did Mendel record?
- Find the tendrils. What job do they do for the plant?

Talk about it

1. Why was the pea such a good choice for Mendel's experiments?
2. If you saved seed from a round-yellow pea that was heterozygous for both traits, what kinds of seeds would you expect next year?

HANDS-ON PROJECT

A Dihybrid Cross and a Seed-Saving Plan

You will solve Mendel's two-trait cross on paper, test it with a model, and then write a seed-saving plan for one variety you grow this year.

You will need

- Journal, ruler and pencil
- Four paper bags and 40 beans of two colors (or two kinds of dried beans) to model alleles
- Seed catalogs or seed company websites
- Optional: an ear of multicolored ornamental corn

Steps

1. Draw the 16-box Punnett square for $RrYy \times RrYy$ (R = round, r = wrinkled, Y = yellow, y = green). List the four kinds of gametes each parent makes: RY, Ry, rY, ry.
2. Fill in all 16 boxes and count the phenotypes. Confirm the 9:3:3:1 ratio.
3. Model it: label bags 'Parent 1 seed shape', 'Parent 1 seed color', 'Parent 2 seed shape', 'Parent 2 seed color'. Put 10 dark beans (dominant) and 10 light beans (recessive) in each.
4. Draw one bean from each bag without looking to make one offspring, record its phenotype, and return the beans. Repeat 48 times.
5. Compare your counts with the expected 27 : 9 : 9 : 3 for 48 offspring. Explain why they differ a little.
6. Optional: count the kernels of each color on several rows of an ornamental corn ear and see whether any color appears in about one-quarter of the kernels.
7. Choose one open-pollinated or heirloom variety you could grow this spring. Research and write a seed-saving plan: how it is pollinated, isolation distance, how many plants to save from, when the seed is ripe, how to clean, dry and store it, and how to label it.

8. Write a short paragraph explaining to a family member why seed saved from an F1 hybrid tomato might not look like its parent.

Tips

- Seed stays alive longest when stored cool, dark and dry, such as in a labeled envelope inside a sealed jar in the refrigerator.
- Many county fairs and 4-H programs have classes for home-saved seed or heirloom vegetables; check your fair book.

Check your work

- ☐ My 16-box Punnett square is complete and shows the 9:3:3:1 ratio.
- ☐ I ran 48 model offspring and compared results with the expected numbers.
- ☐ My seed-saving plan includes pollination type, isolation and storage.
- ☐ I can explain why F1 hybrid seed does not come true.

NATURE JOURNAL

1. Draw the cross Mendel made with purple and white flowers through the P, F1 and F2 generations, showing genotypes and phenotypes at each step.
2. Draw and label the parts of a bean or pea flower (petals, stamens, pistil) and mark where pollen must go for a seed to form.

COMMON MISTAKES

- Saving seed from a single plant, which narrows the variety. Save from many good plants.
- Saving squash or corn seed without isolation and getting a surprise cross next year.
- Thinking 'hybrid' means genetically engineered. F1 hybrids are made by ordinary cross-pollination between two parent lines.

Make it a game • Mendel's Garden Quiz. Be Gregor Mendel on trial and answer your parent's questions in his voice: what was your pea experiment, what do segregation and independent assortment mean? Then draw a dihybrid square for round-yellow crosses and explain the 9:3:3:1 ratio. Your parent slips in one false claim about heirlooms; catch it.

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

Each plant carries its seed ‘in itself’, after its kind. Mendel’s laws describe how that seed carries traits from one generation to the next.

5.3 PLANT GROWTH REGULATORS

OBJECTIVES

- Name the five main groups of plant hormones (auxins, gibberellins, cytokinins, ethylene and abscisic acid) and what each does.
- Explain how gardeners and farmers use hormones to root cuttings, control ripening and break dormancy.
- Design and run a controlled test of ethylene ripening or of rooting hormone on cuttings.

Warm-up. Think of a time when a bowl of fruit ripened faster than you expected, or a cut houseplant stem grew roots in a glass of water. Write what you think made it happen.

WATCH

GCSE Biology - Plant Hormones - Uses of Auxin, Gibberellin and Ethene

Cognito · 4:43

<https://www.youtube.com/watch?v=0GTVp0iaes8>

WHEN TO WATCH

After the core ideas. Note that in Britain ethylene is called 'ethene'.

BACKUP VIDEO

Uses of Plant Hormones | Plants | Biology | FuseSchool

FuseSchool - Global Education · 3:15

<https://www.youtube.com/watch?v=TTLgTlipmA8>

Optional: a short animated review of how growers use plant hormones.

KEY TERMS

plant hormone

A chemical made in small amounts in one part of a plant that controls growth or development elsewhere; also called a plant growth regulator.

auxin

A hormone made in shoot tips that causes cells to stretch, controls bending toward light, keeps side buds dormant (apical dominance), and promotes roots on cuttings.

gibberellin

A hormone that promotes stem lengthening, seed germination and, in some crops, larger fruit.

cytokinin

A hormone made mostly in roots that promotes cell division and side shoots and delays leaf aging.

ethylene

A gas hormone that triggers fruit ripening, leaf and fruit drop, and responses to stress.

abscisic acid (ABA)

A hormone that keeps seeds and buds dormant and closes stomata during drought.

CORE IDEAS

Plants have no brain or nerves, yet they ‘know’ which way is up, when to send out roots, when to ripen fruit and when to rest for winter. They coordinate these actions with **hormones**, chemical messengers made in tiny amounts. The five main groups are auxins, gibberellins, cytokinins, ethylene and abscisic acid. They often work in balance with one another.

Auxin is made in shoot tips and moves down the stem. When light comes from one side, auxin collects on the shady side, those cells stretch more, and the stem bends toward the light. Auxin from the top bud also keeps side buds from growing; this is **apical dominance**. When you pinch the tip of a basil or tomato plant, the auxin supply stops and side shoots grow, making a bushier plant. At the base of a cutting, auxin encourages new roots, which is why nurseries dip cuttings in rooting hormone (a synthetic auxin such as IBA).

Gibberellins lengthen stems and wake seeds from dormancy; grape growers spray them to make seedless grapes larger. **Cytokinins**, made mostly in roots, promote cell division and side shoots. The balance of auxin and cytokinin decides whether plant tissue grown in a lab forms roots or shoots. **Abscisic acid** keeps seeds and buds dormant through winter and closes leaf pores when a plant is short of water.

Ethylene is unusual: it is a gas. Ripening apples, bananas and tomatoes give off ethylene, which speeds the ripening of fruit around them, so ‘one bad apple spoils the barrel’ is true. Bananas and tomatoes are often picked green, shipped cool, and ripened in rooms with controlled ethylene. You can ripen a hard avocado faster in a paper bag with a ripe banana, and you should store apples away from carrots and potatoes (Lesson 1.3). Ethylene also causes leaves to fall in autumn.

Using these God-given signals wisely lets growers multiply good plants, time harvests and reduce waste. Like any tool, they are used carefully: synthetic auxins are also the basis of some weed killers, which children never handle.

PICTURE STUDY



Basket of Apples, Vincent van Gogh, 1885 · Oil on canvas · Van Gogh Museum, Amsterdam

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

Van Gogh painted this basket of apples in the Dutch village of Nuenen in the autumn of 1885, when he was learning to paint with the dark, earthy colors of the peasants and harvests he loved.

Look closely

- Look at the apples crowded together in the basket. What gas are they all giving off as they ripen?
- Find apples of different colors. Which look riper and which look less ripe?
- Find the apples that have rolled out of the basket. Would they ripen faster or slower than the ones packed inside? Why?
- Notice the dark colors van Gogh chose. What season and what kind of storage room do they suggest to you?

Talk about it

1. If one apple in this basket began to rot, what would happen to the others, and why?
2. How would a farmer store a large apple harvest to slow ripening for months?

Safety first. Wear gloves when using rooting-hormone powder and do not breathe the dust; an adult helps with sharp pruners or knives when taking cuttings. Children never handle weed killers or other hormone-based sprays.

HANDS-ON PROJECT

A Hormone Experiment: Ethylene or Auxin

You will design a controlled experiment testing one plant hormone. Choose Option A (ethylene and ripening) or Option B (auxin and rooting cuttings), or do both.

You will need

- Option A: six green (unripe) tomatoes, pears or avocados of similar size; one ripe banana; three paper bags
- Option B: twelve 4-inch stem cuttings from one healthy plant (coleus, pothos, basil, willow or forsythia); rooting hormone powder or gel; two pots of moist perlite or seed-starting mix; clear plastic bags
- Labels, journal and ruler

Steps

1. Write a hypothesis, the independent variable, the dependent variable and the controlled variables for your experiment.
2. Option A: put two fruits alone in a closed paper bag, two in a closed bag with the ripe banana, and leave two uncovered on the counter. Keep all three at the same temperature.
3. Option A: each day for a week, record the color, firmness (press gently) and smell of each fruit, using a 1–5 ripeness scale you define.
4. Option B: with an adult, cut each stem just below a leaf joint and remove the lower leaves. Dip the base of six cuttings in rooting hormone; leave six untreated.
5. Option B: stick each group in its own labeled pot, water, cover loosely with a clear bag, and keep in bright light out of direct sun.
6. Option B: after two and three weeks, gently pull up the cuttings, count the roots on each, and measure the longest root.
7. Make a data table and a graph of your results.
8. Write a conclusion that answers your hypothesis and explains the result using what you know about ethylene or auxin.

Tips

- Willow stems release natural rooting compounds; some gardeners soak cuttings in ‘willow water’ as a home-made rooting aid you could test as a third group.
- Use the same kind and ripeness of fruit in every group; otherwise your test is not fair.

Check your work

- ☐ I wrote a hypothesis and identified my variables.
- ☐ My experiment had a control group and kept other conditions the same.
- ☐ I recorded data for at least a week (Option A) or two weeks (Option B) and graphed it.
- ☐ I can name five plant hormones and one use of each.

NATURE JOURNAL

1. Draw a seedling bending toward a window and show with arrows and shading where auxin collects and which cells stretch.
2. Draw a basil or tomato plant before and after pinching the tip, and label the side shoots that grow because apical dominance was removed.

From history. In 1880 two English scientists covered the tips of grass seedlings and found that the seedlings no longer bent toward light: the signal came from the tip. Frits Went isolated auxin in 1928. Long before anyone named ethylene, growers noticed that fruit ripened faster in rooms warmed by kerosene heaters, whose fumes contain ethylene; in 1934 the British scientist Richard Gane showed that ripening fruit makes ethylene itself.

COMMON MISTAKES

- Storing ripe apples or bananas with vegetables, which then spoil or sprout early.
- Taking cuttings from weak or flowering stems, which root poorly with or without hormone.
- Changing more than one thing between groups, so you cannot tell what caused the result.

Make it a game • Hormone Hot Seat. Each of you picks a hormone secretly: auxin, gibberellin, cytokinin, ethylene or abscisic acid. Give three clues about what it does without naming it, and the other guesses. Then name a gardener's use: rooting cuttings, ripening, or breaking dormancy. Whoever guesses all five hormones with the correct job first wins.

5.4 HYDROPONICS: GROWING WITHOUT SOIL

OBJECTIVES

- Explain what plant roots need from their environment and how hydroponic systems supply water, nutrients and oxygen without soil.
- Compare common hydroponic systems: Kratky, deep water culture, nutrient film, ebb and flow, and aquaponics.
- Build a Kratky lettuce jar and keep a growth, pH and cost record like a 4-H project book.

Warm-up. Put a stem of pothos, mint or a sweet potato in a glass of water (or recall one you have seen). It grows roots and leaves with no soil. List what the plant gets from the water and what it might be missing.

WATCH

Hydroponics Systems

Penn State Extension · 6:29

<https://www.youtube.com/watch?v=D-PyhyZZ5bs>

WHEN TO WATCH

After the core ideas. Penn State growers walk through the hydroponic systems in their greenhouse; write down each system you see and sketch how the water and nutrients move.

BACKUP VIDEO

How Do Hydroponics Work? Underground Farming | Earth Science

BBC Earth Science · 5:22

<https://www.youtube.com/watch?v=FecuxU0tMmE>

Optional, after the main video: a visit to a hydroponic farm built in old tunnels under London, growing salad greens and herbs under LED lights.

KEY TERMS

hydroponics

Growing plants with their roots in a nutrient solution instead of soil, sometimes supported by an inert medium such as perlite or coconut coir.

Kratky method

A passive hydroponic system in which a plant sits above a container of solution; as the plant drinks, the water level drops and leaves an air gap where upper roots get oxygen.

aquaponics

A system that combines fish and plants: bacteria turn fish waste into nitrate that feeds the plants, and the plants clean the water for the fish.

nutrient solution

Water with dissolved mineral nutrients (N, P, K, calcium, magnesium and micronutrients) in the right proportions for plants.

electrical conductivity (EC)

A measure of how much dissolved fertilizer salt is in a solution; growers use it to check nutrient strength.

CORE IDEAS

Soil does four things for roots: it holds them up, supplies water, supplies mineral nutrients, and lets air reach them. **Hydroponics** provides all four without soil. Roots hang in or near water containing a balanced **nutrient solution**; a net cup and an inert medium such as rockwool, coconut coir, clay pebbles or perlite hold the plant up; and oxygen reaches the roots through an air gap, moving water or an air pump. Remember from Lesson 5.1 that roots respire and need oxygen; a root drowned in still, airless water rots.

There are several common systems. In the **Kratky method**, the simplest, the plant sits in a lid over a jar of solution, with the bottom of the net cup just touching the water. As the plant drinks, the level falls and an air gap forms for the upper roots; there are no pumps. **Deep water culture** uses an air pump and airstone to bubble oxygen into a tub. **Nutrient film technique** sends a thin stream of solution along

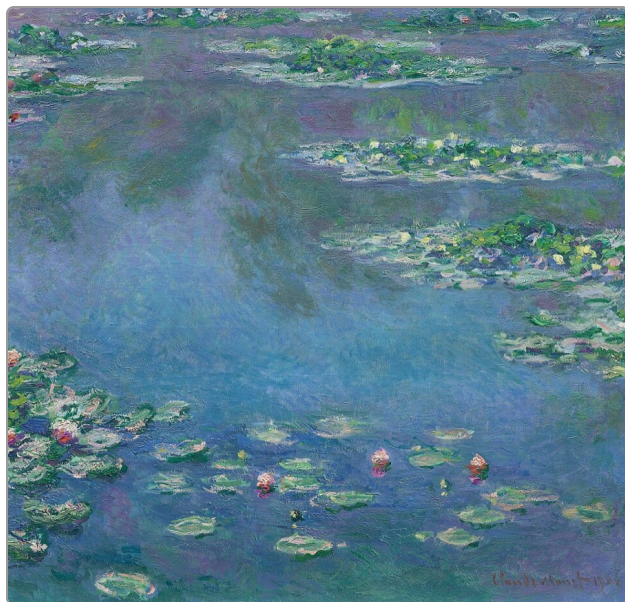
channels, and **ebb and flow** floods and drains a tray. **Aquaponics** joins fish tanks to plant beds, using the same nitrifying bacteria you met in the nitrogen cycle.

Managing the solution is the grower's main job. Most leafy greens grow best at a pH of about 5.5 to 6.5, where nutrients stay dissolved and available. The strength is checked with an EC or ppm meter. Hydroponic fertilizer must include calcium, magnesium and micronutrients that soil would normally supply; ordinary garden fertilizer is not complete enough. Algae grow wherever light hits the solution, so containers are kept dark.

Hydroponics has real advantages: fast growth, clean leaves, much less water than field growing because little is lost, and the ability to grow in a greenhouse, a city warehouse or a classroom in winter. It has limits too: electricity for lights and pumps, the cost of equipment and nutrients, the risk of a pump failure or disease spreading quickly through shared water, and crops such as corn, wheat and potatoes that are impractical to grow this way. Most of the world's food will always come from soil.

Many county fairs, 4-H clubs and science fairs welcome hydroponic projects. A neat record of dates, measurements, costs and lessons learned is what judges look for.

PICTURE STUDY



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

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

Monet dug a pond in his garden at Giverny and planted it with water lilies, then painted it about 250 times. Water plants like these take much of their nourishment from the water around them, a natural cousin of hydroponics.

Look closely

- Find the lily pads. How do their flat, round shapes help them float and catch light?
- Find the blossoms. Which colors did Monet use for them?
- Look for the reflections of sky and trees in the water. Where are the real plants and where are only reflections?
- Notice that there is no shoreline in the picture. How does that make you feel about the pond?

Talk about it

1. Water lilies root in the mud at the bottom of the pond. How is that different from a lettuce plant in a Kratky jar?
2. Why does still pond water stay healthy for plants and fish, while still water in a closed jar can turn green and smelly?

HANDS-ON PROJECT

A Kratky Lettuce Jar with a Project Record

You will grow lettuce in a jar of nutrient solution, compare it with lettuce grown in soil, and keep a record like a 4-H or FFA project book, including costs.

You will need

- Two wide-mouth quart jars, wrapped in foil, dark paper or an old sock to block light
- Two 2-inch net cups (or plastic cups with many slits cut in them) that sit in the jar mouths
- Rockwool cubes, coconut coir or perlite as a growing medium
- Leaf lettuce seed (such as 'Black Seeded Simpson' or 'Buttercrunch')
- A complete hydroponic nutrient (two-part or a lettuce formula) and pH test strips or a pH kit
- A pot of potting mix for a soil-grown comparison plant
- A sunny window or a grow light, ruler and journal

Steps

1. Start three lettuce seeds in rockwool cubes or moist coir, and three in the soil pot. Keep them moist and in light until the seedlings have two true leaves (about 10–14 days).
2. Mix the nutrient solution following the label for leafy greens. Test the pH and adjust toward 6.0 if needed (an adult can help with pH-adjusting drops).
3. Fill each jar so the solution just touches the bottom of the net cup. Set one seedling in each cup. Thin the soil pot to one plant.
4. Do not top off the jars. As the lettuce drinks, the water level will fall and leave an air gap for the roots. If the jar is nearly empty before harvest, add solution only to the halfway mark.
5. Twice a week, record the date, the number of leaves, the width of the plant, the solution level, and the pH for each jar and for the soil plant.
6. Keep an expense table: list every item with its cost, and divide the cost of reusable items (jars, nutrient) by the number of crops they will grow.

7. After four to six weeks, harvest and weigh each plant. Calculate the cost per head and compare with the price of a head of lettuce at the store.
8. Write a project summary: what you did, your data and graph, your costs, what went well, what went wrong, and what you would change next time.

Tips

- Keep light off the solution. Green slime in the jar is algae competing for nutrients.
- Lettuce likes cool temperatures, about 60–70 °F. In a hot room it may turn bitter or bolt.

Check your work

- ☐ My jar lettuce grew with an air gap and no pump.
- ☐ I recorded growth, solution level and pH twice a week for at least four weeks.
- ☐ My expense table calculates cost per head and compares it with a store price.
- ☐ My summary compares hydroponic and soil-grown lettuce and explains the results.

NATURE JOURNAL

1. Draw cross-sections of three hydroponic systems (Kratky, deep water culture and nutrient film), labeling where the roots get water, nutrients and oxygen.
2. Sketch your lettuce jar each week, showing the roots and the falling water level, and label the air roots and water roots.

From history. In the 1860s the German botanists Julius von Sachs and Wilhelm Knop showed that plants could grow in water with dissolved minerals. In the 1930s William Gericke of the University of California grew tomato vines over 20 feet tall in nutrient tanks and gave the method its name, ‘hydroponics.’ Bernard Kratky of the University of Hawaii published his simple non-circulating method in the early 2000s.

COMMON MISTAKES

- Refilling a Kratky jar to the top, which drowns the air roots and causes root rot.
- Using ordinary garden fertilizer, which lacks calcium, magnesium or micronutrients that soil normally supplies.
- Letting light reach the solution, so algae take over.

Make it a game • Jar System Pitch. Choose a hydroponic system by drawing it quickly: Kratky, deep water culture, nutrient film, ebb and flow or aquaponics. Your parent plays a gardener with no soil and asks what roots need. Answer with water, nutrients and oxygen, and say where each comes from. Trade places and guess each other's sketches.

UNIT 5

PLANT SCIENCE

Late winter is the season for the deepest plant science of the year, done indoors while the garden sleeps. You will look inside the leaf at the chemistry of photosynthesis and respiration, follow Gregor Mendel through his pea garden to the laws of heredity, meet the hormones that tell a plant when to root, grow, ripen and rest, and grow lettuce with no soil at all.

Every one of these topics is used by real growers. Seed companies rely on Mendel's rules to produce new varieties; nurseries use rooting hormones; shippers control ripening with ethylene; and greenhouse farms grow lettuce in water. The more you understand how God designed plants to work, the better you can tend them.

PREREQUISITES

- The parts of a plant and their jobs
- Knowing that plants make food from light, water and carbon dioxide
- Punnett squares for one trait (Lesson 4.3)
- The roles of nitrogen, phosphorus and potassium (Lesson 3.2)

MASTERY CHECKLIST

- ☐ I can write and explain the balanced equations for photosynthesis and cellular respiration and tell where each happens in the cell.
- ☐ I can measure the rate of photosynthesis with floating leaf disks and explain how light affects it.
- ☐ I can explain Mendel's laws of segregation and independent assortment and solve a two-trait Punnett square.
- ☐ I can explain the difference between heirloom, open-pollinated and F1 hybrid seed and why hybrid seed does not come true.
- ☐ I can name five plant hormones and one use of each in gardening or farming.
- ☐ I can set up and maintain a Kratky hydroponic jar and keep a cost and growth record.

LESSONS IN THIS UNIT

5.1 Photosynthesis and Cellular Respiration

2 sessions of 60 minutes

5.2 Plant Genetics: Mendel, Hybrids and Heirlooms

2 sessions of 60 minutes

5.3 Plant Growth Regulators

2 sessions of 60 minutes

5.4 Hydroponics: Growing Without Soil

2 sessions of 60 minutes

UNIT 5 REVIEW

Answer each question in complete sentences unless an equation, calculation or Punnett square is asked for; show your work. Total: 100 points.

1. 8 pts

Write the balanced equation for photosynthesis and name the organelle where it happens.

2. 8 pts

Write the equation for cellular respiration. When and where does it happen in a plant?

3. 8 pts

What happens in the light-dependent reactions, and what happens in the Calvin cycle?

4. 8 pts

In the floating leaf-disk test, why do the disks float, and why did disks near the lamp float sooner?

5. 8 pts

State Mendel's law of segregation and law of independent assortment.

6. 9 pts

In peas, tall (T) is dominant over short (t). Cross $Tt \times tt$. Give the genotype and phenotype ratios.

7. 8 pts

What phenotype ratio results from crossing two plants heterozygous for two independent traits ($RrYy \times RrYy$)?

8. 8 pts

Explain why a gardener who saves seed from an F1 hybrid tomato may be disappointed, while one who saves heirloom seed is not.

9. **8 pts**

Name the hormone involved in each: (a) a stem bends toward a window; (b) green tomatoes ripen in a bag with a banana; (c) seeds stay dormant through winter; (d) a cutting forms roots after being dipped in powder.

10. **8 pts**

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

11. **9 pts**

In a Kratky jar, how do roots get oxygen, and why should you not refill the jar to the top?

12. **10 pts**

Short answer: Give two advantages and two disadvantages of hydroponics compared with growing in soil, and explain why most of the world's food will still be grown in soil.

ANSWER KEY

1. $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$. In the chloroplast.
2. $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy (ATP)}$. In the mitochondria of every living cell, including roots, day and night.
3. Light reactions (thylakoids): chlorophyll absorbs light, water is split, oxygen is released, ATP and NADPH are made. Calvin cycle (stroma): RuBisCO fixes CO_2 and ATP and NADPH are used to build sugars.
4. Photosynthesis produces oxygen that collects in the leaf tissue and makes the disks buoyant. More light gives a faster rate of photosynthesis, so oxygen builds up sooner.
5. Segregation: each parent passes on only one of its two alleles for a trait, by chance. Independent assortment: alleles for different traits are passed on independently of each other.
6. Tt, Tt, tt, tt. Genotypes 1 Tt : 1 tt; phenotypes 1 tall : 1 short.
7. 9 round-yellow : 3 round-green : 3 wrinkled-yellow : 1 wrinkled-green.
8. F1 hybrids are heterozygous for many traits, so their seed segregates into many different types. An heirloom is open-pollinated and pure-line, so its seed grows plants like the parent if kept from crossing.
9. (a) auxin; (b) ethylene; (c) abscisic acid; (d) auxin (synthetic auxin such as IBA).
10. It removes the shoot tip, the source of the auxin that keeps side buds dormant (apical dominance), so side shoots grow.
11. As the plant drinks, the solution level drops and leaves an air gap; upper roots take oxygen from the air there. Refilling to the top drowns those air roots, so they cannot respire and may rot.
12. Advantages (any two): fast growth, uses less water, clean produce, can grow indoors or in winter, no soil-borne weeds. Disadvantages (any two): equipment and electricity costs, nutrient management, pump failure, rapid disease spread, unsuitable for large field crops. Staple crops like wheat, corn, rice and potatoes are grown on huge areas far more cheaply in soil.

PORTFOLIO PIECE: A PLANT SCIENCE LAB NOTEBOOK

Assemble your three experiments from this unit (floating leaf disks, the hormone test, and the hydroponic lettuce) into a lab notebook. Each experiment has a question, hypothesis, materials, method, data table, graph, conclusion and a list of sources of error. Add your seed-saving plan, and include the expense table from your hydroponic project. Prepare it as you would a science-fair or 4-H exhibit.

LOOK FOR	WHAT IT MEANS
Method	Each experiment has a clear question, hypothesis, variables and a control.
Data	Data are recorded with units and dates and shown in correct, labeled graphs.
Science	Conclusions are explained accurately with photosynthesis, genetics or hormone concepts.
Records	The hydroponic record includes growth, pH and a correct cost-per-head calculation.
Presentation	The notebook is neat and organized enough to exhibit at a science fair or county fair.

UNIT 6

FARM ANIMALS AND BEES

This unit looks at farm animals the way a farmer, an extension agent and a 4-H or FFA judge do. You will see how the beef, dairy, pork, poultry, sheep and goat industries are organized; how good shelter, fencing and grazing management keep animals healthy and pastures productive; how horses and mules were, and still are, partners in farm work; and how a beekeeper produces honey and beeswax, rents hives for pollination and fights the varroa mite.

You will also practice the skills youth exhibitors use at fairs: judging a class of animals and giving oral reasons, handling and showing a small animal, keeping an expense and income record, and preparing a jar of honey the way a fair judge expects. Farm animals are raised for food, fiber and work, including meat, and Scripture calls the farmer to ‘know the state of thy flocks.’ Knowing them well is the heart of good husbandry.

PREREQUISITES

- Animal nutrition and feed labels (Lesson 4.1)
- Parasites, health and first aid (Lesson 4.2)
- The parts of a honeybee colony: queen, workers and drones
- Safe behavior around large animals

MASTERY CHECKLIST

- ☐ I can describe the main segments of the beef, dairy, swine and poultry industries and what each produces.
- ☐ I can place a class of four market animals or pictures, fill in a placing card, and give organized oral reasons.
- ☐ I can explain rotational grazing and plan paddocks and rest periods for a small pasture.
- ☐ I can handle and show a rabbit or chicken in a 4-H showmanship style, or explain how it is done.
- ☐ I can describe the harness and care of a draft horse and the safety rules around horses.
- ☐ I can explain how honey and beeswax are made, why honey keeps, and how beekeepers monitor varroa mites.

LESSONS IN THIS UNIT

6.1 Livestock Production: Beef, Dairy, Swine, Poultry, Sheep and Goats

2 sessions of 60 minutes

6.2 Husbandry: Shelter, Fencing, Grazing and Showmanship 2 sessions of 60 minutes

6.3 Horses and Draft Animals 2 sessions of 60 minutes

6.4 Apiculture: Honey, Beeswax, Pollination and Bee Health 2 sessions of 60 minutes

UNIT 6 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work. Total: 100 points.

1. 8 pts

List the segments of the beef industry in order from birth to beef.

2. 7 pts

What do dairy, swine, poultry, sheep and goat farms each produce?

3. 8 pts

Name four traits judges evaluate in market livestock.

4. 9 pts

Write the opening sentence and the top-pair reasons for a class of market lambs you placed 3-2-1-4, inventing details.

5. 8 pts

Explain 'take half, leave half' and why rested paddocks grow back better.

6. 8 pts

Give three benefits of rotational grazing besides more grass.

7. 8 pts

In showmanship, who is being judged? Name four things the judge looks for.

8. 8 pts

Name the harness parts through which a horse's pulling force passes, from the horse to the plow.

9. 8 pts

A 2,000-lb draft horse eats 2% of its body weight in hay daily. How many pounds of hay does it eat in a year, and how many 50-lb bales is that?

10. 9 pts

Describe how bees turn nectar into honey and give two reasons honey does not spoil.

11. **8 pts**

How do beekeepers monitor varroa mites, and what is a common action threshold?

12. **11 pts**

Short answer: You are preparing a jar of honey for the county fair. Describe what the judge will look for and how you will prepare the jar.

ANSWER KEY

1. Cow-calf operation, stocker or backgrounding, feedlot, packer or processor (then retail). Some farms raise grass-fed beef from start to finish.
2. Dairy: milk and dairy products (and calves, beef). Swine: pork. Poultry: eggs (layers) and meat (broilers, turkeys). Sheep: wool, meat, some milk. Goats: milk, meat, fiber.
3. Structural correctness (feet, legs, topline, movement), muscle, condition or finish (fat cover), balance and style (also size and frame).
4. Example: 'I placed this class of market lambs 3-2-1-4. In my top pair, I placed 3 over 2 because 3 is a heavier-muscled, wider-based lamb that is thicker through the leg and loin. I grant that 2 is longer-bodied and leveler in his top.' Any organized answer with comparative terms and a grant.
5. Animals are moved when they have eaten the grass to about half its height. Leaving leaf area lets plants keep photosynthesizing and keep deep roots; the rest period lets them regrow before being grazed again.
6. Better soil and root health, more even manure spreading, fewer weeds, fewer parasites because larvae die during rest, less hay needed, healthier animals (any three).
7. The exhibitor. Calm, safe handling; clean, well-groomed animal; correct posing and examination; neat appearance; courtesy; eye contact with the judge; knowledge in answering questions (any four).
8. Collar, hames, traces, singletree (or doubletree), then the hitch to the plow.
9. $2,000 \times 0.02 = 40$ lb a day; $40 \times 365 = 14,600$ lb a year; $14,600 \div 50 = 292$ bales.
10. Foragers bring nectar; house bees add invertase to split sucrose into glucose and fructose, spread it in cells and fan it until water drops to about 17–18%, then cap it with wax. It keeps because the concentrated sugar draws water out of microbes, it is acidic, and it produces small amounts of hydrogen peroxide.
11. They take a sample of about 300 bees (half a cup) and dislodge mites with powdered sugar or alcohol, then count them. About 3 mites per 100 bees is a common threshold for action.
12. A strong answer names low water content (capped honey, under about 18.6%), clarity, freedom from foam, wax bits and crystals, uniform fill to the shoulder, a spotless jar and clean new lid, correct label per the fair book, and good flavor

and aroma; and describes straining, gentle warming, skimming foam, careful pouring and cleaning.

PORTFOLIO PIECE: A FARM VISIT REPORT AND PROJECT RECORD

Visit a livestock farm, dairy, stable, apiary or county fair barn (or, if a visit is impossible, study one through extension publications and videos). Write a report on the operation: the animals, what they produce, their shelter, fencing, feeding and health care, and the daily and yearly chores. Include one judging class you placed with written reasons, and a sample project record with an expense and income table for an animal project you could carry out in 4-H or FFA.

LOOK FOR	WHAT IT MEANS
Operation	The report accurately describes the animals, products, housing, feeding and health care.
Husbandry	Shelter, fencing, grazing or hive management is evaluated with specific suggestions.
Judging	A class of four is placed with organized reasons using comparative terms and grants.
Records	The project record includes a log and an expense and income table with correct calculations.
Courtesy and presentation	The visit was arranged politely with thanks sent, and the report is neat and well organized.

6.1 LIVESTOCK PRODUCTION: BEEF, DAIRY, SWINE, POULTRY, SHEEP AND GOATS

OBJECTIVES

- Describe the segments of the beef industry and the work of dairy, swine, poultry, sheep and goat farms.
- Explain what judges look for in market and replacement (parent) livestock: structure, muscle, condition and balance.
- Judge a class of four animals, mark a placing card, and give oral reasons.

Warm-up. List everything you used or ate in the last day that came from a farm animal (milk, eggs, cheese, meat, leather, wool, gelatin, even some medicines). Which animal did each come from?

WATCH

The Beef Lifecycle: Cow-Calf Operation

NortheastBeef • 4:46

<https://www.youtube.com/watch?v=qTMXp4cwpQ0>

WHEN TO WATCH

After the core idea on the beef industry. Notice the daily and seasonal jobs on a cow-calf farm.

KEY TERMS

cow-calf operation

A farm or ranch that keeps a herd of beef cows and raises their calves on pasture until weaning.

market animal

An animal raised to be sold for meat, judged on muscle, finish (fat cover), structure and balance.

feedlot

A farm where cattle are fed a high-energy ration for the last several months before they are marketed for beef.

replacement animal

An animal kept to become a parent, judged on structure, soundness, femininity or masculinity, and how well it will produce.

placing card

A card on which a livestock judge marks the order of a class of four animals, such as 2-1-4-3.

oral reasons

A short, organized spoken explanation of why a judge placed a class in a certain order, comparing each pair of animals.

CORE IDEAS

Beef moves through several kinds of farms. A **cow-calf operation** keeps cows on pasture; calves are born in spring or fall and nurse their mothers for six to eight months. After weaning, many go to a **stocker** or backgrounding farm to grow on grass, then to a **feedlot** for several months on a grain-based ration, and finally to a packing plant, where they are processed into beef under USDA inspection. Many small farms raise grass-fed beef from start to finish.

Dairy cows, such as Holsteins and Jerseys, give milk after they have a calf. They are milked two or three times a day, every day of the year, in a milking parlor or by robotic milkers; a good Holstein gives over 20,000 pounds of milk a year. **Swine** farms may be farrow-to-finish (sows and their piglets raised to market weight, about 280 pounds at six months), or specialize in one stage. **Poultry** farms raise broilers for meat (ready in about six to eight weeks) or keep laying hens, each laying 250–300 eggs a year. **Sheep** give wool, meat and, in some breeds, milk; **goats** give milk, meat and fiber such as mohair and cashmere.

In 4-H and FFA, young people raise **market animals** (a steer, a lamb, a hog, a pen of broilers or meat rabbits) to sell at a fair auction, and **replacement animals**, such as heifers, ewes and does, to keep as future parents. Judges look at a few key things.

Structural correctness: sound feet and legs, a strong level back, free movement.

Muscle: thickness through the loin and hindquarter. **Condition or finish:** the right amount of fat cover for market, not too thin or too fat. **Balance and style:** parts that fit together smoothly. For replacement stock, judges also consider capacity, femininity or masculinity, and, for dairy cattle, a strong, well-attached udder.

A **judging class** has four animals, numbered 1–4. You study them from the side, front and rear, decide a placing such as 2-1-4-3, and mark it on a **placing card**. In senior contests you then give **oral reasons** from notes or memory: ‘I placed this class of market lambs 2-1-4-3. In my top pair, I placed 2 over 1 because 2 is a heavier-muscled, longer-bodied lamb that is thicker through the leg. I grant that 1 is more

correct on his feet and legs...' and so on through the middle and bottom pairs. Good reasons are accurate, organized, use comparative words (heavier-muscled, more correct, leaner), and take about two minutes.

Livestock judging trains the eye and the tongue: careful looking, quick decisions, and the courage to explain them clearly and respectfully. Those skills serve farmers, buyers and future leaders alike.

PICTURE STUDY



Peasants and Cattle by the River Merwede, Aelbert Cuyp, about 1658–1660 · Oil on panel · National Gallery, London

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

Aelbert Cuyp lived in Dordrecht in the Netherlands, a country famous for its dairy cattle and rich river pastures. He painted cows in calm evening light so often that they became his trademark.

Look closely

- Count the cattle. How many are lying down, and how many are standing?
- The resting cattle are probably chewing their cud. What does that tell you about their stomachs?
- Judge the standing cow as you would in a class: look at her topline, depth of body and legs.
- Find the herdsman and the rider. What jobs might they be doing for this herd?

Talk about it

1. Are these more likely dairy or beef cattle? What clues helped you decide?
2. If you had to place four of these cattle in a judging class, what would you look at first, and why?

Safety first. Around cattle, hogs, sheep and goats, stay with an adult, move calmly, never get between a mother and her young, and keep a fence or gate between you and any animal you do not know. Wash your hands after visiting a barn or fair.

HANDS-ON PROJECT

Judge a Class and Give Oral Reasons

You will judge a class of four animals, mark a placing card, write and deliver oral reasons, and compare your placing with an official or experienced placing.

You will need

- A class of four animals: four live animals at a fair or farm, or four side-view photographs of the same species from a breed association, extension judging site or livestock show results page
- Index cards for placing cards and reasons notes
- Journal, pencil, and a timer

Steps

1. Number the four animals 1–4. Study each one from the side first, then from the front and rear if you can.
2. For each animal, write three strengths and three weaknesses using the judging traits: structure, muscle, condition, balance (and for replacement animals, capacity and udder or masculinity).
3. Decide your placing (for example 3-1-4-2) and mark it on a placing card with your name and the class name.
4. Write reasons notes for the top pair, middle pair and bottom pair. For each pair, give two or three comparative reasons and one 'grant' (something the lower animal does better).
5. Practice your reasons aloud without reading, standing straight and speaking clearly. Aim for under two minutes.
6. Deliver your reasons to a family member acting as the judge, who times you with a stopwatch: two minutes is the limit in most contests. Ask them to score you on accuracy, organization, terms and delivery.
7. If you used a published class, compare your placing with the official one and write what you would change.

Tips

- Use comparative words that end in ‘-er’: ‘2 is a longer, leaner, heavier-muscled lamb than 1.’
- Many county extension offices hold youth livestock judging practices and contests; check with yours or with your local FFA chapter.

Check your work

- ☐ I placed a class of four and marked a placing card.
- ☐ My reasons cover the top, middle and bottom pairs with comparative terms and grants.
- ☐ I delivered my reasons aloud, from memory, within a timed two minutes.
- ☐ I can describe the segments of the beef industry and what a dairy, swine or poultry farm produces.

NATURE JOURNAL

1. Draw a side view of a steer or a market lamb and label the parts a judge looks at: topline, loin, hindquarter, rib, chest floor, pasterns and feet.
2. Make a chart of six farm species with columns for what they give us, how long until market or production, and one daily chore.

COMMON MISTAKES

- Judging only from one side. Always look from the side, front and rear before placing.
- Giving reasons that describe one animal without comparing it to another. Reasons are comparisons.
- Forgetting the ‘grant’: a fair judge admits what the lower-placed animal does better.

Make it a game • Judge the Class. Set four household objects, such as mugs, in a row as a pretend class of market lambs. Rank them top to bottom by a made-up standard of structure, muscle, condition and balance. Give two minutes of oral reasons to your parent, using comparing words like but and while. Then compare the rankings for a placing card.

6.2 HUSBANDRY: SHELTER, FENCING, GRAZING AND SHOWMANSHIP

OBJECTIVES

- Describe good shelter and fencing for cattle, sheep, goats and poultry.
- Explain rotational grazing and plan paddocks, stocking and rest periods for a small pasture.
- Handle and show a rabbit or chicken in 4-H showmanship style and describe what larger-livestock showing involves.
- Keep an expense and income record for an animal project.

Warm-up. Walk around your yard or a park and imagine three sheep had to live there for a year. List what they would need that is not there now: shelter, water, fence, shade, grass. Then circle the most expensive item.

WATCH

Building a Solar Charged Polywire Paddock for Rotational Grazing

Noble Research Institute • 8:03

https://www.youtube.com/watch?v=1_A8P-GNQ_I

WHEN TO WATCH

After the core idea on rotational grazing. Note each piece of fence equipment and what it does.

BACKUP VIDEO

4-H Swine Showmanship

NDSU Extension 4-H • 7:15

<https://www.youtube.com/watch?v=plknAqfh0dg>

With the core idea on showmanship: North Dakota State University 4-H explains how a young exhibitor shows a market hog. The same habits apply to lambs, goats and steers.

KEY TERMS

husbandry

The care, feeding, housing and management of farm animals.

rotational grazing

Moving animals through a series of small pastures (paddocks) so each one is grazed briefly and then rested to regrow.

paddock

A small fenced section of pasture used in rotational grazing.

stocking rate

The number of animals kept on an area of land over the grazing season, such as one cow-calf pair per two acres.

showmanship

A youth class in which the exhibitor, not the animal, is judged on how well they handle, groom and present the animal and answer questions about it.

CORE IDEAS

Shelter for most livestock does not need to be fancy. Cattle, sheep and goats need dry footing, protection from wind and wet, shade in summer and fresh air. A three-sided shed with its open side away from the prevailing winter wind works well for many small farms. Poor ventilation is a common mistake: damp, stale air in a closed barn leads to pneumonia. Poultry need a secure coop with about 4 square feet per bird inside, roosts, nest boxes, ventilation high in the walls, and doors and hardware cloth that keep out raccoons and foxes every night.

Fencing keeps animals safe and neighbors happy. Woven wire works for sheep and goats; goats are famous escape artists and need tight, tall fences. High-tensile electric fence, polywire and electric netting are cheaper and easy to move. An electric fence works by training animals to respect it: when they touch it, they get a short, safe shock that teaches them to stay back. It must be properly grounded and kept clear of weeds.

Rotational grazing divides a pasture into paddocks. Animals graze one paddock for a few days, then move to the next, and the grazed paddock rests for about 30–45 days in the growing season. A common rule is ‘take half, leave half’: move animals when

they have eaten the grass to about half its height. Grass with a rest period regrows deep roots, the manure is spread more evenly, weeds have less room, and parasite larvae on the grass die off before the animals return. Farmers who rotate can often carry more animals on the same land and need less hay.

Daily husbandry also prepares an animal for the show ring. In **showmanship**, the judge scores the young exhibitor. With a **rabbit**, you carry it securely with its hindquarters supported, pose it on the table, and turn it over gently to show the teeth, eyes, ears, nose, toenails and coat while explaining what you check. With a **chicken**, you remove it from the cage head first, hold it with its legs between your fingers, and show the wings, comb, eyes, feet and feathers. With **large livestock**, such as a steer, lamb or goat, you lead on a halter or by the jaw, set the animal's feet square, keep it between you and the judge, and always keep your eye on the judge. Judges look for an animal that is clean, groomed and calm, and an exhibitor who is neat, courteous and knowledgeable.

Every animal project should keep records. A 4-H or FFA project book tracks dates, weights, feed used, health care, expenses and income. At the end you can figure the cost of gain and whether the project made or lost money, and, more importantly, what you learned.

PICTURE STUDY



Shepherdess with Her Flock, Jean-François Millet, 1863 · Oil on canvas · Musée d'Orsay, Paris

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

Millet painted the plain near the village of Barbizon, where shepherds grazed their flocks on common land, moving them each day to fresh grass. This shepherdess knits as she watches, never idle.

Look closely

- Find the sheepdog. Where is it standing, and what is its job?
- Look at how closely the sheep are bunched together as they graze. How does a flock grazing tightly together affect the grass?
- Look at the ground in the foreground. Is the pasture thick or thin? What season might it be?
- Find the shepherdess's crook and her knitting. What do they tell you about her day?

Talk about it

1. This shepherdess moves her flock across open land every day. How is that like modern rotational grazing behind electric fence?
2. What would a shepherd need to check each day to 'know the state of his flocks'?

Safety first. Electric fence is installed and turned on only by an adult; never touch it on purpose or let anyone climb it. Small animals are handled gently with their bodies fully supported, and you wash your hands after every handling session.

HANDS-ON PROJECT

A Grazing Plan, a Showmanship Practice and a Project Record

You will plan a rotational grazing system for a small farm, practice showmanship with a small animal (or study it closely), and set up an expense and income record for an animal project.

You will need

- Graph paper, ruler and colored pencils
- A real or imaginary pasture of 5–10 acres (or the area of a park field, measured on an online map with an adult)
- A rabbit, chicken or guinea pig and an adult helper (your own, a neighbor's or a 4-H club member's), or showmanship videos and a stuffed animal for practice
- A 4-H showmanship scorecard from your county extension office or online
- A notebook or spreadsheet for the project record

Steps

1. Draw the pasture to scale. Mark the water source, shade, the barn or shelter, and gates.
2. Divide it into at least eight paddocks of about equal grass. Plan a lane or portable water so every paddock reaches water.
3. Choose a livestock species and a number of animals. Using a stocking guide from your extension office, check that the land can support them.
4. Make a rotation schedule: days per paddock and rest days, so that each paddock rests at least 30 days in summer.
5. Practice showmanship with an adult. Follow the steps on the scorecard: approach, pose, examine each body part while naming what you check, and answer questions about the breed, feed and health care.
6. Have the adult score you with the scorecard and write two things to improve. Practice again and rescore.

7. Set up a project record with sections for animal information, a daily log, feed used, health care, and an expense and income table.
8. Fill in the expense table with real prices for the animal, feed, bedding, equipment and health care for one year, and estimate income (eggs, sale, premium). Calculate profit or loss.

Tips

- In showmanship, the judge often asks questions: know your animal's breed, age, weight, feed, normal temperature and one common disease.
- Check your county fair book or extension office for the rules of youth showmanship classes.
- Biosecurity: after visiting another farm, a fair barn or a poultry show, change clothes and clean or change your boots before going near your own animals, and keep new or returning show animals apart for about 30 days.

Check your work

- ☐ My grazing plan has at least eight paddocks, water access and a rest schedule of 30 days or more.
- ☐ I practiced showmanship (or studied it step by step) and was scored with a real scorecard.
- ☐ My project record includes a daily log and an expense and income table with a profit or loss.
- ☐ I can explain how rotational grazing helps grass, soil and animal health.

NATURE JOURNAL

1. Draw a grass plant before grazing, after 'take half, leave half', and after overgrazing, showing the roots of each. Label how the roots respond.
2. Visit a pasture (from a road or with permission) and sketch the fences, water and shelter you see. Note the animals' behavior and the height of the grass.

COMMON MISTAKES

- Overgrazing a paddock to the ground, which weakens roots and lets weeds take over.
- Closing up a barn tightly in winter so the air is damp and stale.
- Practicing showmanship only the week before the fair. Calm handling takes weeks of daily practice.

Make it a game • Paddock Rotation Race. Lay out a paper map divided into four paddocks and use buttons as cattle. Move the herd to a fresh paddock whenever your parent calls grazed down. You must say the rest period, the stocking rate and one fencing or shelter need each time. Fewest mistakes wins. Then practice showmanship stance silently.

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

Good husbandry is daily attention: looking at grass, water, fences and every animal. Records and showmanship both grow from that diligence.

6.3 HORSES AND DRAFT ANIMALS

OBJECTIVES

- Describe the draft breeds and the history of horses, mules and oxen in farm work.
- Name the parts of a work harness and explain how a horse pulls a load.
- Explain the daily and seasonal care of a horse and the safety rules for working around horses.

Warm-up. Look at a picture of a horse and a picture of a tractor. List the jobs both can do on a farm. Then list one advantage each has over the other.

WATCH

Horse Plowing With Farmer Bob

Farmer Bob · 7:06

https://www.youtube.com/watch?v=Ctn-01Z_NOY

WHEN TO WATCH

After the core idea on harness. Watch how the team works together and how the farmer guides them with the lines and his voice.

BACKUP VIDEO

How To Clean A Horse's Hooves (The Easy Way)

Carmella Abel - Equine Helper · 10:56

<https://www.youtube.com/watch?v=ASPqDHTQD3Y>

With the core idea on horse care: a step-by-step guide to picking up and cleaning a horse's hooves safely.

KEY TERMS

draft horse

A large, heavily muscled horse bred for pulling, such as the Belgian, Percheron, Clydesdale, Shire or Suffolk Punch.

mule

The offspring of a male donkey and a female horse; strong, sure-footed, long-lived and usually unable to have offspring of its own.

collar and hames

The padded collar that fits around a horse's neck and shoulders, and the metal arms fastened to it, where the pulling force is applied.

traces

The straps or chains that run from the hames back to the load or doubletree.

lines

The long reins a teamster uses to guide a team from behind.

farrier

A craftsman who trims hooves and fits shoes (Lesson 4.4).

CORE IDEAS

For thousands of years oxen, horses and mules pulled the plows, wagons and harvesters of the world. In 1920 there were over 25 million horses and mules on American farms. Tractors replaced most of them by the 1950s, but draft animals are still used today by Amish and other Plain communities, small farmers, loggers in sensitive forests, and people who love the work. Horses also serve on cattle ranches, in therapy programs and for riding.

Draft horses are the heavyweights: Belgians and Percherons (the most common in America), Clydesdales and Shires with their feathered legs, and the chestnut Suffolk Punch. They often weigh 1,600–2,200 pounds and were bred for calm temperaments and great strength. **Mules**, from a donkey sire and a horse mother, combine the horse's size with the donkey's toughness and caution; many farmers prefer them in hot climates. **Oxen** are trained steers that pull with a wooden yoke.

A horse pulls with its shoulders, not its neck. The padded **collar** must fit exactly; the **hames** fasten to it, and the **traces** run back to a **singletree** or **doubletree** that connects to the plow or wagon. The **bridle** and **bit** let the teamster guide with long **lines**, together with voice commands: 'get up' to go, 'whoa' to stop, 'gee' for right and 'haw' for left. A poorly fitted collar causes sores; good teamsters check the fit and the shoulders every day.

Horse care is daily work. A horse needs plenty of good hay or pasture (roughly 1.5 to 2.5 percent of its body weight in forage each day), clean water (often 10 gallons or more), salt, and grain only if its work requires it. Hooves are picked out daily and trimmed or shod every six to eight weeks. Teeth keep growing and may need a

veterinarian to file ('float') sharp points. Horses are also immunized and checked for parasites on a schedule set with a veterinarian.

Safety around horses: approach at the shoulder, speaking so the horse knows you are there; never walk directly behind a horse or stand where it can kick; lead from the left side with the rope never wrapped around your hand; tie with a quick-release knot; wear boots and, when riding, a helmet. Horses are prey animals that flee first and think later, so calm, consistent handling makes them trustworthy partners.

PICTURE STUDY



The Horse Fair, Rosa Bonheur, 1852–1855 · Oil on canvas · Metropolitan Museum of Art, New York

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

Rosa Bonheur visited the Paris horse market twice a week for a year and a half to sketch the horses. The great gray horses are Percherons, the draft breed from Normandy that later became the most popular draft horse in America.

Look closely

- Find the largest dappled gray horses. What features show they are built for pulling rather than speed?
- Find the horse that is rearing. How is its handler staying safe? What would you do in his place?
- Look at the handlers' positions. Which side of the horses do most of them lead from?
- Follow the circle of movement around the painting. Why do you think buyers watched horses move before buying?

Talk about it

1. If you were a farmer buying a draft horse at this fair, what three things would you check first?
2. Why is a calm temperament as important as strength in a draft horse?

Safety first. Work around horses only with an experienced adult. Never stand directly behind a horse, never wrap a lead rope around your hand, wear sturdy boots, and wear a helmet when riding or driving.

HANDS-ON PROJECT

A Draft Horse Study and Care Plan

You will study a draft horse or mule (at a farm, a fair, a plowing day, a stable or through books and video) and write a care plan for one working horse for a year.

You will need

- Access to a stable, farm, county fair draft horse show or plowing day (optional), or library books and videos
- Journal, pencil and colored pencils
- Feed prices from a feed store or online for hay and grain
- A list of costs from a farrier and veterinarian (ask, or use extension estimates)

Steps

1. If you can, visit draft horses with an adult. Ask the owner to show you the harness and explain each part. Follow every safety instruction.
2. Draw a horse in harness and label the bridle, bit, lines, collar, hames, traces, back pad, belly band and breeching.
3. Research one draft breed: origin, average height (in hands) and weight, color, temperament and uses today.
4. Calculate the hay a 1,800-pound draft horse would eat in a year at 2 percent of body weight per day. Convert to the number of 50-pound bales.
5. List the yearly care: daily feeding and water, hoof care every six to eight weeks, teeth, immunizations, parasite checks, grooming and exercise.
6. Build a one-year budget for the horse: hay, grain if needed, bedding, farrier, veterinarian and harness care.
7. Write a short paragraph comparing the yearly cost and benefits of a draft team with those of a small tractor for a five-acre farm.

Tips

- Horses are measured in ‘hands’; one hand is 4 inches, measured from the ground to the top of the withers.

- Many county and state fairs hold draft horse shows and pulling contests; check the fair book for dates.

Check your work

- ☐ My labeled harness drawing includes at least eight parts.
- ☐ I calculated a year's hay correctly in pounds and in bales.
- ☐ My care plan and budget include feed, hooves, teeth, health care and grooming.
- ☐ I can state four safety rules for working around horses.

NATURE JOURNAL

1. Draw a horse's leg and hoof from the side, labeling the knee or hock, cannon, fetlock, pastern, coronet band and hoof wall.
2. If you visit horses, sketch one standing at rest and note its breed, color, markings (blaze, star, socks) and estimated height in hands.

From history. In 1920, U.S. farms had more than 25 million horses and mules and about a quarter of all cropland grew feed for them. When tractors replaced them, that land was freed to grow food for people. Today the Amish of Pennsylvania, Ohio and Indiana still farm with Belgian and Percheron teams, and county fairs across the country hold draft horse classes and plowing matches.

COMMON MISTAKES

- Walking behind a horse without speaking, which can startle it into kicking.
- Feeding a horse mostly grain instead of forage, which can cause colic and hoof problems.
- Using a collar that does not fit; it rubs sores and wastes the horse's strength.

Make it a game • Harness Parts Dash. Draw a horse and label harness parts from memory: collar, hames, traces and lines. Your parent names a part and you point and explain how it helps the horse pull. Then act as a team, with you as the draft animal. Say what the farrier does, and why mules or oxen sometimes did the work instead.

Scripture. “Be ye not as the horse, or as the mule, which have no understanding: whose mouth must be held in with bit and bridle, lest they come near unto thee.” (Psalm 32:9, KJV)

The psalmist knew horses and mules well enough to use the bit and bridle as a picture. God would rather guide us by understanding than by force.

6.4 APICULTURE: HONEY, BEESWAX, POLLINATION AND BEE HEALTH

OBJECTIVES

- Explain how bees turn nectar into honey and why honey keeps without spoiling.
- Describe how beeswax is made and used, and how beekeepers rent hives for crop pollination.
- Explain the threat of varroa mites and how beekeepers monitor and manage them.
- Prepare and judge jars of honey to fair-exhibit standards.

Warm-up. Taste (or look at) two different honeys, such as clover and buckwheat or wildflower. Compare their color, smell, thickness and flavor. Write a guess about why they differ.

WATCH

Varroa Mite Control - Alternative Methods

University of Guelph Honey Bee Research Centre • 8:36

https://www.youtube.com/watch?v=3j_i4nRel-w

WHEN TO WATCH

After the core idea on varroa mites. List each method the apiary manager shows and how it works.

BACKUP VIDEO

Beekeeping Basics - How To Use a Honey Refractometer - The Norfolk Honey Co.

The Norfolk Honey Company • 6:19

<https://www.youtube.com/watch?v=7ljt7E7rZ0A>

With the core idea on honey science: how a beekeeper checks the water content of honey before extracting it.

KEY TERMS

apiculture

The science and practice of keeping honeybees.

invertase

An enzyme bees add to nectar that splits sucrose into the simpler sugars glucose and fructose.

hygroscopic

Able to absorb water from the air; honey is hygroscopic, so it must be kept sealed.

refractometer

An instrument that measures how light bends through a liquid, used to find the water content of honey.

varroa mite

A tiny reddish-brown parasite that feeds on honeybees and their developing young and spreads viruses; the most serious threat to managed colonies.

pollination service

Renting honeybee colonies to farmers to pollinate crops such as almonds, apples, blueberries and cucumbers.

CORE IDEAS

Honey begins as nectar, a thin sugar water that is often 70–80 percent water. Forager bees carry it home in their honey stomachs and pass it to house bees, who add the enzyme **invertase**, which splits sucrose into glucose and fructose. They spread it in cells and fan their wings to evaporate the water until the honey is about 17–18 percent water, then cap the cells with wax. To make one pound of honey, a colony's foragers visit roughly two million flowers. A single worker makes only about a twelfth of a teaspoon in her life.

Honey keeps for years because it is a poor home for microbes. Its sugar is so concentrated that it pulls water out of any bacterium or yeast that lands in it; it is acidic (about pH 3.9); and another enzyme the bees add produces small amounts of hydrogen peroxide. But honey is **hygroscopic**: if it is harvested before it is capped, or left open in humid air, its water rises above about 19 percent and natural yeasts can make it ferment. That is why beekeepers harvest capped frames and check honey with a **refractometer**, and why fair judges test moisture.

Beeswax is made by young worker bees from glands on the underside of the abdomen; they eat honey to produce it, several pounds of honey for each pound of wax. Beekeepers melt down cappings from the honey harvest and old comb, strain it, and use the clean wax for candles, polishes, lip balms, waterproofing and foundation sheets for new frames. **Pollination services** may earn a commercial beekeeper as much as honey: every February more than two million colonies are trucked into California's almond orchards, and others pollinate apples, blueberries, cherries, melons and pumpkins.

The greatest threat to honeybees is the **varroa mite**. It rides on adult bees, reproduces in capped brood cells, feeds on the developing bees, and spreads viruses that cripple wings and weaken colonies. Without management, most colonies in North America die within two or three years. Beekeepers monitor mites by taking a half-cup sample of about 300 bees and dislodging the mites (with powdered sugar or alcohol), then counting them; a common action threshold is about 3 mites per 100 bees. Management combines methods: screened bottom boards, removing drone brood where mites prefer to breed, breaks in the brood cycle, mite-resistant stock, and approved treatments applied by the beekeeper according to the label.

Honey has delighted people since Bible times, when Canaan was ‘a land flowing with milk and honey.’ County and state fairs have honey classes in which jars are judged on water content, clarity, cleanliness, freedom from crystals and foam, uniform fill and a neat label. A beekeeper’s honey is a picture of patient, careful work.

PICTURE STUDY



The Beekeepers, Pieter Bruegel the Elder, about 1568 · Pen and brown ink on paper ·
Kupferstichkabinett, Berlin

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

Bruegel drew this scene of Flemish beekeepers about 450 years ago. They kept bees in skeps, woven straw hives, and had to break the comb out to harvest honey. Modern removable-frame hives were invented by Lorenzo Langstroth in 1852.

Look closely

- Find the masks over the beekeepers' faces. What are they made of, and why might they be shaped that way?
- Count the skeps you can see. How is the skep that is being carried different from the one lying on its side?
- Find the bench with a roof over the hives. Why would beekeepers shelter their skeps?
- Find the boy in the tree. What do you think he is doing, and is it a good idea near beehives?

Talk about it

1. How would harvesting honey from a skep be harder on the bees than harvesting from a modern frame hive?

2. What protective gear do modern beekeepers wear, and how is it like what these beekeepers wore?

Safety first. Visit hives only with an experienced adult beekeeper, wearing a veil and protective clothing. Anyone with a known bee-sting allergy should not go near hives, and an adult should know where the emergency medicine is. Hot wax and melting equipment are handled only by an adult.

A Honey Exhibit and Judging Class

You will compare honeys scientifically, judge four jars as a fair judge would, and prepare one jar of honey (yours, a local beekeeper's, or a store jar for practice) to exhibit standards.

You will need

- Four jars of honey from different sources or floral types (local beekeepers or a farmers market)
- A clean, clear glass jar with a new lid for the exhibit
- A flashlight, white paper and a ruler
- Optional: a honey refractometer (some beekeeping clubs will lend one)
- A judging scorecard from a county or state fair honey class (from the fair book or extension office)

Steps

1. Number the four jars 1–4. Hold each against the flashlight on white paper and record color (water white to dark amber), clarity, and any foam, wax bits or crystals.
2. Check the fill line and lid of each jar. Is it filled evenly to the shoulder? Is the lid clean?
3. If you have a refractometer, measure each honey's water content. Note any above 18.6 percent, the usual limit for top-grade honey.
4. Taste each with a clean spoon and record aroma and flavor.
5. Using the fair scorecard, score and place the four jars 1–4. Write short reasons for each pair, as in Lesson 6.1.
6. Prepare one exhibit jar: warm honey gently in a warm-water bath if needed to remove foam bubbles, pour it slowly into a spotless jar to the shoulder, skim any foam, wipe the threads and put on a new lid.
7. Make a neat label with the beekeeper's or your name (as the fair book directs), floral source and date. Photograph your exhibit.

8. Research one fact about varroa mites in your state from your state apiarist or extension office and add it to your journal.

Tips

- Judges notice fingerprints, sticky lids and uneven fill as quickly as color and flavor.
- Many state beekeeping associations run youth scholarship or junior beekeeper programs that provide a mentor and a hive; check with yours.
- 4-H members can enter the national 4-H Honey Bee Essay Contest, run each year through state 4-H offices with a national deadline around May 1; check the current topic and rules with your county extension office.

Check your work

- ☐ I compared four honeys by color, clarity, moisture (if measured), aroma and flavor.
- ☐ I placed the jars 1–4 with a scorecard and wrote reasons.
- ☐ My exhibit jar is clean, evenly filled, free of foam and correctly labeled.
- ☐ I can explain how bees make honey, why it keeps, and how varroa mites are monitored.

NATURE JOURNAL

1. Draw a cross-section of a modern Langstroth hive: bottom board, brood boxes, queen excluder, honey supers, inner cover and outer cover, and label what happens in each.
2. Draw a varroa mite on a honeybee to scale using a reference image, and write the action threshold beside it.

COMMON MISTAKES

- Harvesting uncapped honey, which has too much water and may ferment.
- Treating for mites without counting them first, or skipping counts altogether until the colony is failing.
- Overheating honey to make it pour, which darkens it and destroys its delicate flavors and enzymes.

Make it a game • From Flower to Honey. Tell the whole journey of nectar to honey in sixty seconds: forager bees, invertase, fanning, capping. Your parent holds up a score card and interrupts with one wrong detail about hygroscopic honey, beeswax or varroa mites. Spot the error. Then explain why a farmer rents hives for a field crop. Trade roles and repeat.

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 compared God’s words to the sweetest thing he knew, honey fresh from the comb. Every beekeeper’s harvest is a reminder of that sweetness.

UNIT 6

FARM ANIMALS AND BEES

This unit looks at farm animals the way a farmer, an extension agent and a 4-H or FFA judge do. You will see how the beef, dairy, pork, poultry, sheep and goat industries are organized; how good shelter, fencing and grazing management keep animals healthy and pastures productive; how horses and mules were, and still are, partners in farm work; and how a beekeeper produces honey and beeswax, rents hives for pollination and fights the varroa mite.

You will also practice the skills youth exhibitors use at fairs: judging a class of animals and giving oral reasons, handling and showing a small animal, keeping an expense and income record, and preparing a jar of honey the way a fair judge expects. Farm animals are raised for food, fiber and work, including meat, and Scripture calls the farmer to ‘know the state of thy flocks.’ Knowing them well is the heart of good husbandry.

PREREQUISITES

- Animal nutrition and feed labels (Lesson 4.1)
- Parasites, health and first aid (Lesson 4.2)
- The parts of a honeybee colony: queen, workers and drones
- Safe behavior around large animals

MASTERY CHECKLIST

- ☐ I can describe the main segments of the beef, dairy, swine and poultry industries and what each produces.
- ☐ I can place a class of four market animals or pictures, fill in a placing card, and give organized oral reasons.
- ☐ I can explain rotational grazing and plan paddocks and rest periods for a small pasture.
- ☐ I can handle and show a rabbit or chicken in a 4-H showmanship style, or explain how it is done.
- ☐ I can describe the harness and care of a draft horse and the safety rules around horses.
- ☐ I can explain how honey and beeswax are made, why honey keeps, and how beekeepers monitor varroa mites.

LESSONS IN THIS UNIT

6.1 Livestock Production: Beef, Dairy, Swine, Poultry, Sheep and Goats

2 sessions of 60 minutes

6.2 Husbandry: Shelter, Fencing, Grazing and Showmanship 2 sessions of 60 minutes

6.3 Horses and Draft Animals 2 sessions of 60 minutes

6.4 Apiculture: Honey, Beeswax, Pollination and Bee Health 2 sessions of 60 minutes

UNIT 6 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work. Total: 100 points.

1. 8 pts

List the segments of the beef industry in order from birth to beef.

2. 7 pts

What do dairy, swine, poultry, sheep and goat farms each produce?

3. 8 pts

Name four traits judges evaluate in market livestock.

4. 9 pts

Write the opening sentence and the top-pair reasons for a class of market lambs you placed 3-2-1-4, inventing details.

5. 8 pts

Explain 'take half, leave half' and why rested paddocks grow back better.

6. 8 pts

Give three benefits of rotational grazing besides more grass.

7. 8 pts

In showmanship, who is being judged? Name four things the judge looks for.

8. 8 pts

Name the harness parts through which a horse's pulling force passes, from the horse to the plow.

9. 8 pts

A 2,000-lb draft horse eats 2% of its body weight in hay daily. How many pounds of hay does it eat in a year, and how many 50-lb bales is that?

10. 9 pts

Describe how bees turn nectar into honey and give two reasons honey does not spoil.

11. **8 pts**

How do beekeepers monitor varroa mites, and what is a common action threshold?

12. **11 pts**

Short answer: You are preparing a jar of honey for the county fair. Describe what the judge will look for and how you will prepare the jar.

ANSWER KEY

1. Cow-calf operation, stocker or backgrounding, feedlot, packer or processor (then retail). Some farms raise grass-fed beef from start to finish.
2. Dairy: milk and dairy products (and calves, beef). Swine: pork. Poultry: eggs (layers) and meat (broilers, turkeys). Sheep: wool, meat, some milk. Goats: milk, meat, fiber.
3. Structural correctness (feet, legs, topline, movement), muscle, condition or finish (fat cover), balance and style (also size and frame).
4. Example: 'I placed this class of market lambs 3-2-1-4. In my top pair, I placed 3 over 2 because 3 is a heavier-muscled, wider-based lamb that is thicker through the leg and loin. I grant that 2 is longer-bodied and leveler in his top.' Any organized answer with comparative terms and a grant.
5. Animals are moved when they have eaten the grass to about half its height. Leaving leaf area lets plants keep photosynthesizing and keep deep roots; the rest period lets them regrow before being grazed again.
6. Better soil and root health, more even manure spreading, fewer weeds, fewer parasites because larvae die during rest, less hay needed, healthier animals (any three).
7. The exhibitor. Calm, safe handling; clean, well-groomed animal; correct posing and examination; neat appearance; courtesy; eye contact with the judge; knowledge in answering questions (any four).
8. Collar, hames, traces, singletree (or doubletree), then the hitch to the plow.
9. $2,000 \times 0.02 = 40$ lb a day; $40 \times 365 = 14,600$ lb a year; $14,600 \div 50 = 292$ bales.
10. Foragers bring nectar; house bees add invertase to split sucrose into glucose and fructose, spread it in cells and fan it until water drops to about 17–18%, then cap it with wax. It keeps because the concentrated sugar draws water out of microbes, it is acidic, and it produces small amounts of hydrogen peroxide.
11. They take a sample of about 300 bees (half a cup) and dislodge mites with powdered sugar or alcohol, then count them. About 3 mites per 100 bees is a common threshold for action.
12. A strong answer names low water content (capped honey, under about 18.6%), clarity, freedom from foam, wax bits and crystals, uniform fill to the shoulder, a spotless jar and clean new lid, correct label per the fair book, and good flavor

and aroma; and describes straining, gentle warming, skimming foam, careful pouring and cleaning.

PORTFOLIO PIECE: A FARM VISIT REPORT AND PROJECT RECORD

Visit a livestock farm, dairy, stable, apiary or county fair barn (or, if a visit is impossible, study one through extension publications and videos). Write a report on the operation: the animals, what they produce, their shelter, fencing, feeding and health care, and the daily and yearly chores. Include one judging class you placed with written reasons, and a sample project record with an expense and income table for an animal project you could carry out in 4-H or FFA.

LOOK FOR	WHAT IT MEANS
Operation	The report accurately describes the animals, products, housing, feeding and health care.
Husbandry	Shelter, fencing, grazing or hive management is evaluated with specific suggestions.
Judging	A class of four is placed with organized reasons using comparative terms and grants.
Records	The project record includes a log and an expense and income table with correct calculations.
Courtesy and presentation	The visit was arranged politely with thanks sent, and the report is neat and well organized.

UNIT 7

PLANTING: GARDEN, FIELD AND ORCHARD

Spring is the season for planting, and in this capstone year you plan like a professional grower. You will design a whole garden for succession, rotation, spacing and yield; multiply plants by grafting, layering and division; study how corn, soybeans and wheat are grown on thousands of acres; and plant for the long term with fruit trees, berries and other perennial crops.

Along the way you will judge a class of crop samples as 4-H and FFA members do, give a short how-to talk, and plan a row of produce to share with neighbors in need. The garden you plan in Lesson 7.1 can become the heart of your capstone project in Unit 8.

PREREQUISITES

- Your agricultural calendar and succession plan (Lessons 1.1 and 1.2)
- Your soil report (Unit 3)
- Seed starting, transplanting and hardening off
- Plant hormones and rooting cuttings (Lesson 5.3)

MASTERY CHECKLIST

- ☐ I can draw a scaled garden plan that uses rotation by plant family, correct spacing, succession and yield estimates.
- ☐ I can explain how grafting, layering and division make new plants identical to the parent, and do at least one of them.
- ☐ I can describe how a field crop is planted, managed and harvested at scale, and calculate yield per acre.
- ☐ I can judge a class of four crop samples and give oral reasons.
- ☐ I can plant a fruit tree or berry bush correctly and explain basic pruning.
- ☐ I can give a 3–5 minute how-to talk on a garden skill.

LESSONS IN THIS UNIT

7.1 Planning a Full Garden: Rotation, Spacing and Yield

2 sessions of 60 minutes

7.2 Propagation: Grafting, Layering and Division

2 sessions of 60 minutes

7.3 Agronomy: Field Crops at Scale

2 sessions of 60 minutes

7.4 Orchards, Berries and Perennial Crops

2 sessions of 60 minutes

UNIT 7 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work. Total: 100 points.

1. 8 pts

Name the plant family of each crop: tomato, broccoli, bean, squash, onion, potato.

2. 8 pts

Why is crop rotation done by plant family rather than by individual crop? Give an example.

3. 8 pts

A family wants 60 pounds of tomatoes. If each plant yields about 12 pounds, how many plants should they grow, and at 2-foot spacing in a 4-foot-wide bed (two staggered rows), how long a bed do they need?

4. 8 pts

Why are apple trees grafted instead of grown from seed?

5. 8 pts

In a graft, which layer must line up, and why?

6. 8 pts

Describe how to divide a clump of daylilies.

7. 8 pts

Describe the planting-to-harvest year of winter wheat.

8. **9 pts**

In 1/1,000 acre of corn you count 32 ears averaging 16 rows $\times$ 35 kernels.

Estimate the yield in bushels per acre using the formula (ears $\times$ kernels per ear) $\div$ 90.

9. **8 pts**

Name four things a judge looks for in a fair exhibit of ten ears of corn or five potatoes.

10. **8 pts**

What are chill hours, and why does a gardener in a warm southern state need to know them?

11. **8 pts**

List four steps for planting a bare-root fruit tree correctly.

12. **11 pts**

Short answer: Describe your plan for a service project that shares produce with people in need, and explain how it reflects good stewardship.

ANSWER KEY

1. Tomato: nightshade; broccoli: brassica; bean: legume; squash: cucurbit; onion: allium; potato: nightshade.
2. Related plants share pests, diseases and nutrient needs. Following tomatoes with potatoes keeps early blight and potato beetles in the same soil, so they must move to a bed of a different family.
3. $60 \div 12 = 5$ plants. With two rows at 2 ft spacing, 5 plants need about 3 positions per row, so about 6 feet of bed (5–6 ft acceptable).
4. Seedlings do not come true; each is a new genetic combination, usually inferior. Grafting makes a clone of the chosen variety, and the rootstock controls size, hardiness and disease resistance.
5. The cambium, because it is the layer of dividing cells that grows together to join scion and rootstock.
6. In early spring or fall, dig the clump, shake off soil, separate it into pieces each with roots and a fan of leaves or buds, replant at the same depth, and water well.
7. Sown in fall, it sprouts and survives the winter as a small plant, grows quickly in spring, heads out, and is harvested in early summer when the grain is dry.
8. Kernels per ear $16 \times 35 = 560$. $32 \times 560 = 17,920$. $17,920 \div 90 \approx 199$ bushels per acre.
9. Uniformity of size and shape, true to the variety, freedom from blemishes, damage, disease and insects, cleanliness and condition, correct number as the fair book requires (any four).
10. Hours between about 32 and 45 °F a fruit tree needs in winter to bloom and fruit normally. Varieties needing more chill than the climate provides will bloom poorly and give little fruit.
11. Soak the roots; dig a hole wider than the roots but not deeper; spread roots over a mound; keep the graft union above the soil; backfill with native soil; water deeply; mulch away from the trunk (any four).
12. A strong answer names a specific partner (food pantry, church ministry, gleaning group), a crop or activity, dates and amounts, how produce will be harvested and packed, and how donations and hours will be recorded, and connects it to passing on God's provision and caring for neighbors.

PORTFOLIO PIECE: THIS SEASON'S GARDEN: PLAN, PROPAGATION AND PLANTING

Assemble your garden plan, planting calendar, propagation record and how-to-talk outline, your perennial planting record with photos, your crop judging card and reasons, and your service-project plan. Keep adding harvest weights and service records through the season; this portfolio becomes part of your capstone record book in Unit 8.

LOOK FOR	WHAT IT MEANS
Garden plan	The plan is scaled, rotated by family, correctly spaced and based on yield calculations.
Propagation and planting	Propagation and perennial planting are done correctly and recorded with dates, photos and results.
Judging and talk	The judging card and reasons are complete and organized, and the how-to talk outline has clear steps.
Service	The service plan names a real partner, crop or activity, dates and how donations will be recorded.
Records	Garden records include dates, varieties, costs and harvest amounts, kept up to date.

7.1 PLANNING A FULL GARDEN: ROTATION, SPACING AND YIELD

OBJECTIVES

- Group vegetables by plant family and plan a rotation that keeps families out of the same bed for at least three years.
- Use correct spacing and intensive methods to fit the most production into the space.
- Estimate yields and plan a garden that meets a family's needs, with succession for steady harvests.

Warm-up. Sort these crops into families: tomato, potato, pepper, cabbage, broccoli, radish, bean, pea, cucumber, squash, carrot, onion, lettuce. Use a seed catalog if you need help. Which families are largest?

WATCH

The Step By Step Guide to Crop Rotation

GrowVeg • 8:16

<https://www.youtube.com/watch?v=64YapgN6G2w>

WHEN TO WATCH

After the core idea on rotation. Copy the plant-family groups and the order of rotation into your journal.

BACKUP VIDEO

We Ignored Plant Spacing Rules, Here's What Happened

Epic Gardening • 10:49

<https://www.youtube.com/watch?v=AEywwrYKl24>

With the core idea on spacing: a side-by-side trial of crowded and correctly spaced plants.

KEY TERMS

plant family

A group of related plants that often share pests, diseases and nutrient needs, such as the nightshades (tomato, potato, pepper) or brassicas (cabbage, broccoli, radish).

crop rotation

Moving plant families to different beds each year in a planned cycle.

intensive planting

Growing plants in wide beds at even, close spacing instead of single rows, so leaves shade out weeds and space is used efficiently.

intercropping

Growing two crops together, such as quick lettuce between young tomatoes, to use space and time.

yield per square foot

The amount of harvest from each square foot of bed, used to plan how much space a crop needs.

CORE IDEAS

A good garden plan starts on paper in winter. List what your family eats and how much, measure your space and sun, and note your soil test results. Then group crops by **plant family**. Common groups: nightshades (tomatoes, potatoes, peppers, eggplant), brassicas (cabbage, broccoli, kale, radish, turnip), legumes (peas, beans), cucurbits (squash, cucumbers, melons), alliums (onions, garlic, leeks), and roots and greens (carrots, beets, lettuce, spinach).

Rotation moves each family to a new bed every year, returning after three or four years. Pests and diseases that live in soil, such as early blight on tomatoes, clubroot on cabbage, or Colorado potato beetles that spend the winter in the soil, are left behind. Nutrient demand balances too: heavy feeders such as tomatoes and corn can follow legumes, which leave nitrogen-rich roots. A simple four-bed plan is legumes → brassicas and greens → nightshades and cucurbits → roots and alliums, then back again.

Spacing matters as much as rotation. Plants set too close compete for light, water and nutrients, stay small and get more fungal disease because air cannot move.

Plants set too far apart waste space and leave room for weeds. Intensive beds 3–4 feet wide, with plants set in a staggered grid at the spacing listed on the seed packet ‘between plants’ (not ‘between rows’), give the best results. Taller crops go on the north side so they do not shade shorter ones.

Plan for **yield**. Extension guides list typical harvests, such as about 10–15 pounds of tomatoes per plant or 1 pound of bush beans per foot of row over the season. Divide what your family needs by the yield to find the number of plants, then the bed space. Add **succession** (Lesson 1.2) and **intercropping**: lettuce and radishes between slow tomatoes, a fall crop after early peas. Keep a garden record of dates, varieties, harvest weights and problems; next year’s plan depends on this year’s notes.

Planning is a form of stewardship. Jesus spoke of the builder who ‘sitteth down first, and counteth the cost’ (Luke 14:28). A gardener who counts, measures and plans wastes less seed, water and work.

PICTURE STUDY



Vegetable Gardens and Windmills on Montmartre, Vincent van Gogh, 1887 · Oil on canvas · Van Gogh Museum, Amsterdam

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

In 1887 the hill of Montmartre, now in the middle of Paris, was still dotted with windmills and small market gardens. Van Gogh painted the neat plots that working families tended to feed themselves and to sell produce in the city.

Look closely

- Find the gardeners. What do you think each is doing in early spring?
- Look at the shape of the plots and the paths. How are the beds divided, and how would you rotate crops among them?
- Find the fences. Why might each family fence its plot?
- Find the windmills. What did windmills do for a farming community?

Talk about it

1. The plots look bare. What could a gardener be planting this early in the season?
2. If you had one of these small plots, how would you use succession and intercropping to get the most from it?

HANDS-ON PROJECT

A Complete Garden Plan

You will draw a full, scaled garden plan for this season, with rotation, spacing, succession and yield goals, using your own space or a plot you could use (a large container garden, a relative's yard, a community garden).

You will need

- Graph paper, ruler and colored pencils (or a free garden-planning program)
- Measurements of your garden area and notes on sun and shade
- Your soil report from Unit 3
- Seed catalogs and an extension vegetable-planting guide for your state

Steps

1. List the crops your family wants and estimate how much of each you would eat in a season.
2. Look up the yield per plant or per foot of row for each crop, and calculate the number of plants needed.
3. Measure the garden and draw it to scale with north marked. Divide it into at least four beds for rotation.
4. Assign plant families to beds for this year, and write the plan for the next three years so each family moves each year.
5. Draw each crop in its bed at the correct spacing, with tall crops on the north side.
6. Add succession and intercropping: mark which beds get a second or third crop and when.
7. Make a planting calendar table with crop, variety, start indoors, transplant or sow outdoors, and expected harvest dates.
8. Estimate the total cost of seed and supplies, and the expected harvest value at store prices, in a simple expense and income table.

Tips

- Leave paths wide enough for a wheelbarrow and your feet; beds you can reach across without stepping in stay loose and healthy.
- If you plan to enter vegetables at the county fair, mark which crops and varieties you will grow for exhibit and when they will be ready.

Check your work

- ☐ My plan is drawn to scale with at least four rotation beds and north marked.
- ☐ My rotation keeps each family out of the same bed for at least three years.
- ☐ Plant numbers come from yield calculations, and spacing follows the seed packets.
- ☐ My calendar and expense and income table are complete.

NATURE JOURNAL

1. Start a garden record page for this season: a table with date, bed, crop, variety, action (sowed, transplanted, harvested), amount and notes.
2. Draw one plant family with three of its members side by side (for example a tomato, a potato and a pepper), showing the flowers they share.

COMMON MISTAKES

- Rotating crops by name instead of by family, so tomatoes are followed by potatoes, which share the same diseases.
- Using the 'between rows' spacing in a wide bed, which wastes space, or crowding plants, which invites disease.
- Planting far more of one crop than the family can eat, preserve or share.

Make it a game • Rotation Puzzle Race. Write vegetable names on slips and sort them by plant family on the table. Then fill a four-bed paper map with a three-year rotation so no family repeats too soon. Your parent adds a surprise: one bed must also take an intercrop. Race to fix it and state yield per square foot guesses. Beat your time.

7.2 PROPAGATION: GRAFTING, LAYERING AND DIVISION

OBJECTIVES

- Explain the difference between seed propagation and vegetative (asexual) propagation (cuttings, layering, division and grafting), and why growers use each.
- Describe how a graft unites a scion and a rootstock and why most fruit trees are grafted.
- Propagate a plant by layering or division and present a 3–5 minute how-to talk on the skill.

Warm-up. If you planted a seed from a store-bought Honeycrisp apple, would the tree grow Honeycrisp apples? Write your prediction and your reason using what you learned about genetics in Lesson 5.2.

WATCH

Air Layering Plants Tutorial for Beginners with Carl Johnson

UConn Extension • 6:14

<https://www.youtube.com/watch?v=6c9fT5lr1lg>

WHEN TO WATCH

Before the layering option in the project. Pause after each step and note the materials he uses.

KEY TERMS

asexual propagation

Making new plants from a piece of a parent plant, so the new plant is genetically identical to it (a clone).

rootstock

The lower part of a grafted plant, which provides the roots and often controls the tree's size, hardiness and disease resistance.

scion

The short piece of stem with buds, taken from the desired variety, that is grafted onto a rootstock.

cambium

The thin layer of dividing cells just under the bark; in a graft, the cambium of scion and rootstock must touch to grow together.

layering

Causing a stem to form roots while it is still attached to the parent plant, either by bending it to the soil or by wrapping a wounded section in moist moss (air layering).

division

Splitting a clump-forming perennial, such as a hosta, daylily or rhubarb, into several pieces, each with roots and shoots.

CORE IDEAS

Seeds mix the genes of two parents, so a seedling may differ from both (Lesson 5.2). That is wonderful for creating new varieties but a problem when you want an exact copy. A seed from a Honeycrisp apple grows into a new, unknown apple, usually a poor one. So growers use **asexual propagation**, which makes clones: cuttings (Lesson 5.3), layering, division, and grafting. Every Honeycrisp tree in the world is a clone of the original.

Grafting joins a **scion** of the variety you want to a **rootstock** chosen for its roots. The two must be closely related, such as apple on apple. The grafter makes matching cuts, often a whip-and-tongue graft for pencil-thick wood, so that the green **cambium** layers of both pieces touch, then binds them tightly and seals the cut. In a few weeks the cambium cells grow together. Rootstocks control tree size: a dwarfing apple rootstock makes a tree about 8–10 feet tall that bears in two or three years, while a seedling rootstock may grow a 25-foot tree.

Layering lets a stem root while the parent still feeds it. In simple layering, a low, flexible branch of a shrub such as forsythia, blueberry or grape is bent to the ground, nicked on the underside, pinned and covered with soil; it roots in a season and is then cut free. In **air layering**, a ring of bark is removed from a stem, the wound is wrapped in moist sphagnum moss and plastic, and roots form inside the moss. Strawberries layer themselves with runners, and raspberries and blackberries root where their cane tips touch the ground.

Division is the easiest method. Many perennials (hostas, daylilies, irises, chives, rhubarb, mint) grow in expanding clumps. In early spring or early fall, dig the clump, cut or pull it apart into pieces that each have healthy roots and buds, replant them at the same depth, and water well. Dividing every few years also keeps old clumps vigorous. Shallots and garlic are a kind of division too: each clove grows a new plant.

Jesus said, 'I am the vine, ye are the branches' (John 15:5). A grafted branch lives only while it stays joined to the root. Propagation lets a gardener share good plants generously with neighbors and church friends.

PICTURE STUDY



Farmer Inserting a Graft on a Tree, Jean-François Millet, 1855 · Oil on canvas · Neue Pinakothek, Munich

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

Millet painted a young farmer grafting a fruit tree while his wife and child look on. Grafting was a skill every country family needed, and a tree grafted today would feed this child for many years.

Look closely

- Find the stump the farmer is working on. What has he done to the top of it to prepare for the graft?
- Look at the tools on the ground: the mallet and the basket. What might be in the basket?
- Look at the trees and the season. Why is grafting done in late winter or early spring, before the buds open?
- Look at the wife and baby. What do you think Millet is saying about planting trees for the future?

Talk about it

1. This farmer is probably doing a cleft graft into a cut stump. Why would he graft a new variety onto an old tree instead of planting a new one?
2. How long might it be before this graft bears fruit, and who will enjoy it?

Safety first. Grafting knives are extremely sharp; cut away from your body, keep your other hand behind the blade, and work with an adult. Wear gloves when dividing perennials with a spade or saw.

Propagate a Plant and Give a How-To Talk

You will make new plants by division or layering (and grafting if an adult with experience can help), then present a 3–5 minute how-to talk in the style of a 4-H illustrated talk.

You will need

- Option A, division: a clump of a perennial (hosta, daylily, chives, mint, or a potted houseplant such as a spider plant or snake plant), a spade or knife, pots and potting mix
- Option B, layering: a shrub with low branches (forsythia, blueberry, grape) or a large houseplant (pothos, rubber plant), a knife, landscape pins or a bent wire, moist sphagnum moss and plastic wrap
- Option C, grafting (with an experienced adult): apple rootstocks and dormant scion wood, a grafting knife, grafting tape or rubber strips and sealing compound
- Poster board or a few large cards for the talk

Steps

1. Choose an option and gather materials. Record the date, plant and method in your garden record.
2. Division: dig or unpot the clump, shake off soil, and separate it into pieces each with roots and at least one bud or shoot. Replant at the same depth and water well.
3. Layering: nick the underside of a low branch, dust with rooting hormone if you have it, pin it into the soil and cover with 2–3 inches of soil; or air layer a stem by removing a 1-inch ring of bark, wrapping it in moist moss and plastic, and tying both ends.
4. Grafting (with an adult): make matching whip-and-tongue cuts on scion and rootstock of the same thickness, fit them so the cambium lines up on at least one side, wrap tightly, and seal.
5. Label your new plants and check them weekly. Record when new growth or roots appear.

6. Prepare a 3–5 minute how-to talk teaching your method. Plan an introduction, three to five clear steps you show with real materials, and a summary. Make two or three simple posters or cards with key words.
7. Practice the talk until you can give it without reading, then present it to your family or a group. Ask for scores on knowledge, clear steps, eye contact and voice, and answer two questions at the end.

Tips

- Many county 4-H programs hold illustrated-talk contests in spring; this talk is the right length to enter. Check with your county extension office.
- Divided perennials make good gifts for neighbors and church plant sales.

Check your work

- ☐ I propagated at least one plant by division, layering or grafting and recorded its progress.
- ☐ I can explain why propagated plants are identical to the parent.
- ☐ My how-to talk had an introduction, clear steps with real materials, and a summary, and lasted 3–5 minutes.
- ☐ I answered questions from my audience.

NATURE JOURNAL

1. Draw a whip-and-tongue graft in three steps: the two cuts, the pieces fitted together, and the wrapped graft. Label scion, rootstock and cambium.
2. Draw a simple layer in cross-section, showing the parent plant, the pinned stem, the wound, new roots and soil.

COMMON MISTAKES

- Lining up the bark instead of the cambium in a graft; the bark of a thick rootstock is thicker, so the cambium layers may miss each other.
- Dividing perennials in the heat of summer, when the pieces wilt and struggle to root.
- Reading a how-to talk from notes instead of showing the steps with your hands.

Make it a game • Graft It Out. Act out grafting using two pencils: one is the scion, one the rootstock. Line up their cambium layers while narrating each step to your parent. Then draw layering and division in ten seconds each. Your parent calls cuttings, seed or grafting for a plant and you answer why a grower would choose that method.

7.3 AGRONOMY: FIELD CROPS AT SCALE

OBJECTIVES

- Describe how corn, soybeans and wheat are planted, managed and harvested on large farms.
- Calculate yield in bushels per acre from a small sample.
- Judge a class of four crop samples and give oral reasons.

Warm-up. Look at the ingredients on three packaged foods in your kitchen. Circle every ingredient that came from corn, soybeans or wheat (cornmeal, corn syrup, soybean oil, soy lecithin, flour). How many did you find?

WATCH

The Journey of Wheat - from Field to Table

Kansas Wheat • 4:58

<https://www.youtube.com/watch?v=3ihTep7zMNI>

WHEN TO WATCH

After the core idea on wheat. List the machines and steps from seed to bread, and compare them with the harvest in the picture study.

KEY TERMS

agronomy

The science of producing field crops and managing soil on a large scale.

plant population

The number of plants per acre; for corn often about 30,000–36,000.

planter

A machine that places seeds at a set depth and spacing in many rows at once; modern planters can sow 16–48 rows in one pass.

combine

A harvesting machine that cuts or picks the crop, threshes the grain from the plant, separates it from chaff and stores it in a tank.

bushel

A unit of grain measure; a bushel of corn weighs 56 pounds, of soybeans and wheat 60 pounds.

yield

The harvest per unit of land, such as bushels per acre.

CORE IDEAS

Three crops cover most of America's cropland. **Corn** is planted in spring when the soil reaches about 50 °F, in rows usually 30 inches apart, at about 30,000–36,000 seeds per acre. It is a heavy feeder of nitrogen and is wind-pollinated: pollen falls from the tassel onto the silks, and each silk that receives pollen makes one kernel. It is harvested in fall when the kernels are dry, and becomes livestock feed, ethanol fuel, cornmeal, corn syrup, starch and many other products. U.S. farms average well over 170 bushels per acre.

Soybeans are legumes that fix their own nitrogen (Lesson 3.2). They are planted after corn in many rotations, often no-till into the corn stubble, and are harvested in fall for oil and protein-rich meal for livestock. **Wheat** is a cool-season grass. Winter wheat is sown in fall, survives the winter as a small plant, grows quickly in spring and is harvested in early summer; spring wheat is sown in spring in the far north. Hard red wheat makes bread flour; soft wheat makes pastry and cracker flour.

The **agronomist's year** follows the same steps as a garden at a larger scale: soil testing and fertility planning; seed and variety choice; planting at the right date, depth and population; weed, insect and disease scouting (Unit 8); and harvest timing. Modern farmers use GPS-guided tractors, planters that space every seed precisely, and yield monitors on combines that map the harvest across the field. One farmer with a combine can harvest more in a day than a hundred workers with sickles could in Bruegel's time.

Farmers and judges evaluate grain and crops by quality. At county and state fairs, field-crop classes judge samples such as ten ears of corn or a peck of wheat on uniformity, being true to the variety, size, fill (kernels to the tip), freedom from damage, disease and insects, and cleanliness. FFA and 4-H crops contests also test plant, seed and weed identification.

In Bruegel's painting of the harvest, a whole village labors in one field to bring in bread for a year. Today very few people grow grain, but all of us depend on them. Give thanks for the farmers who feed us.

PICTURE STUDY



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

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

This painting is part of the same series of the seasons as *Haymaking* in Lesson 1.1. It shows the wheat harvest, the most important and exhausting work of the farm year, and the welcome rest at midday.

Look closely

- Follow the steps of the harvest: cutting, gathering, binding into sheaves, and standing them in shocks. Who does each job?
- Find the path cut through the tall wheat. How tall is the wheat compared with the people? How does modern wheat compare?
- Find the workers eating lunch. What foods can you see?
- Look into the distance for a loaded wagon. Where is the grain going next?

Talk about it

1. Why did the whole village have to harvest wheat quickly once it was ripe?
2. Which single modern machine does all the jobs you see in this picture?

HANDS-ON PROJECT

Yield Calculation and a Crop Judging Class

You will estimate a corn yield the way agronomists do, and judge a class of four crop samples with a placing card and oral reasons.

You will need

- Access to a cornfield in late summer or fall (with the farmer's permission), or ear and population numbers from an extension example
- A tape measure and a calculator
- Four samples for judging: four bags of 10 ears of corn, four plates of 5 potatoes or onions, or four jars of dry beans (from a farm stand or store), or four photos of crop exhibits from a fair
- Index cards for placing cards and reasons

Steps

1. Yield estimate: in a row of corn, measure 17 feet 5 inches ($1/1,000$ of an acre for 30-inch rows) and count the ears.
2. Pick three typical ears. For each, count the rows of kernels around and the kernels in one row, and multiply to get kernels per ear. Average them.
3. Use the extension formula: bushels per acre $\approx$ (ears in $1/1,000$ acre $\times$ average kernels per ear) $\div 90$. Show your work. (If you cannot visit a field, use 34 ears and 560 kernels per ear.)
4. Compare your estimate with your state's average corn yield.
5. Judging: number the four samples 1–4. For each, note uniformity of size and shape, true-to-type color and form, freedom from blemishes, damage and disease, cleanliness, and condition.
6. Place the class and mark a placing card.
7. Write reasons for the top, middle and bottom pairs using comparative terms ('more uniform', 'cleaner', 'freer from blemishes') and one grant for each pair.
8. Deliver your reasons aloud in under two minutes, timed by a family member.

Tips

- Fair crop exhibits are judged against the fair book: count the exact number of ears, tubers or pods required, and choose matching samples rather than the single biggest.
- Many FFA chapters and 4-H clubs hold crops and agronomy contests; ask your county extension office or state FFA association about events for your age.

Check your work

- ☐ I calculated an estimated corn yield with the formula and showed my work.
- ☐ I judged four samples using uniformity, type, blemishes and cleanliness.
- ☐ My reasons compare each pair with comparative terms and grants.
- ☐ I can describe how corn, soybeans and wheat are planted and harvested.

NATURE JOURNAL

1. Draw a corn plant at tasseling, labeling the tassel, silks, ear, leaves, stalk, brace roots and roots, and show how pollen reaches the silks.
2. Draw a wheat head and a soybean pod with seeds, and label each with its main uses.

From history. Cyrus McCormick first showed his reaper in Virginia in 1831, and Hiram and John Pitts patented an improved threshing machine in 1837. Combining the two jobs in one machine came later: horse-drawn combines pulled by twenty or more mules worked the wheat fields of California in the 1880s, and self-propelled combines spread across America after the 1940s.

COMMON MISTAKES

- Counting only the biggest ears for a yield estimate, which inflates the result. Choose typical ears.
- Choosing exhibit samples by size alone. Judges value uniformity and true-to-type more than giant size.
- Thinking modern farming is easy because of machines. Timing, weather, soil and markets still decide success.

Make it a game • Bushel Estimator. Count corn kernels or dried beans on one sample row and calculate a yield per acre, using a pretend plant population your parent gives. Do the math on paper and announce the bushels per acre. Closest to the true answer wins. Then describe how the planter and combine would handle that field. Beat your own accuracy next round.

7.4 ORCHARDS, BERRIES AND PERENNIAL CROPS

OBJECTIVES

- Describe the needs of fruit trees, berry bushes and other perennial food crops, including pollination partners and chill hours.
- Plant a fruit tree, berry bush or perennial crop correctly and explain basic pruning.
- Plan a service project to grow or glean produce for neighbors in need.

Warm-up. List every perennial food plant you know of: plants that produce for many years from the same roots (apple, peach, blueberry, strawberry, asparagus, rhubarb, grapes, nuts). Circle the ones that grow in your area.

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

Before the planting project. Pause at each step and compare it with the steps in the core ideas.

BACKUP VIDEO

Simple DIY Soil Drainage Test (Do This Before Planting a Fruit Tree!)

The Fruit Grove • 4:10

<https://www.youtube.com/watch?v=bd6Q8AJjOVk>

Optional, before choosing a planting site: a simple drainage test for fruit trees and bushes.

KEY TERMS

perennial crop

A food plant that lives and produces for many years, such as fruit trees, berries, asparagus and rhubarb.

cross-pollination

Pollen moving from one variety to another; most apples, pears and sweet cherries need a second compatible variety blooming at the same time to set fruit.

chill hours

The number of hours between about 32 and 45 °F that a fruit tree needs in winter to bloom and fruit normally in spring.

bare-root

A dormant tree or shrub sold with no soil around its roots, planted in early spring before it leafs out.

central leader and open center

Two common ways to prune fruit trees: a central leader keeps one main trunk with tiers of branches (apples), while an open center removes the middle to form a vase shape (peaches).

CORE IDEAS

A **perennial crop** is planted once and harvested for years: an apple tree may bear for 30 years or more, an asparagus bed for 15–20, a blueberry bush for decades. That makes the first planting decisions very important. Choose varieties suited to your **hardiness zone** and **chill hours**, a site with full sun, good air drainage (cold air settles in low spots and can freeze blossoms), and well-drained soil. Blueberries need acid soil, about pH 4.5–5.5, so many gardeners grow them in raised beds amended with peat or in large containers.

Most fruit trees need **pollination partners**. Apples, pears, sweet cherries and plums usually need a different compatible variety blooming at the same time within a few hundred feet, and bees to carry the pollen. Peaches, tart cherries and many plums are self-fruitful. Blueberries set bigger crops with two or more varieties. This is why orchardists rent honeybee colonies at bloom (Lesson 6.4).

To **plant** a bare-root tree: soak the roots for a few hours, dig a hole wider than the roots but no deeper, spread the roots over a small mound, keep the graft union 2–3 inches above the soil line, backfill with the native soil, water deeply, and mulch in a wide ring kept a few inches from the trunk. Container plants are planted the same way after loosening circling roots. **Pruning** in late winter shapes the tree, opens it to light and air (less disease, better fruit color), and removes dead, damaged, crossing and water-sprout branches. Young trees are pruned lightly to build a strong framework.

Berries and perennial vegetables fit even small spaces. Strawberries bear the year after planting; June-bearers give one big crop and everbearing types give smaller crops through the season. Raspberries and blackberries fruit on canes that are removed after bearing. Asparagus is not harvested the first year, lightly the second, and fully from the third year on. Rhubarb stalks are eaten, but its leaves are poisonous and must never be eaten.

An orchard is planted in faith and patience, often for the next generation. Psalm 1 compares the righteous person to ‘a tree planted by the rivers of water, that bringeth forth his fruit in his season.’ Gardeners can share that fruit: many communities have gleaning groups that harvest extra fruit for food pantries, and programs such as Plant a Row invite gardeners to grow an extra row for the hungry.

PICTURE STUDY



Orchard in Bloom, Louveciennes, Camille Pissarro, 1872 · Oil on canvas · National Gallery of Art, Washington

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

Pissarro painted this orchard near his home at Louveciennes, west of Paris, in the spring of 1872. The trees are in full bloom, the moment when an orchard's whole year's crop depends on good weather and busy bees.

Look closely

- Look at the blossoms. Are all the trees blooming at the same stage? Why does that matter for cross-pollination?
- Find the pile of cut branches at the left. What job was done in this orchard over the winter?
- Look at the ground under the trees. How has it been managed, and what might be planted between the trees?
- Find the two people working. What spring orchard jobs might they be doing?

Talk about it

1. A hard frost on the night after this painting was made could ruin the year's crop. How do orchardists choose sites to reduce frost damage?
2. How many years might it take for a newly planted tree to bloom like these?

Safety first. Use pruners, loppers and saws only with an adult, and never prune from a ladder without an adult holding it. Rhubarb leaves are poisonous; eat only the stalks.

Plant a Perennial and Plan a Plant-a-Row Service Project

You will plant one perennial food crop correctly and plan a way to share produce with people in need through a food pantry, church or gleaning group.

You will need

- One perennial plant: a bare-root or potted fruit tree, a blueberry or raspberry bush, a dozen strawberry plants, asparagus crowns, or a rhubarb crown (a large container works for blueberries and strawberries)
- Spade, compost, mulch and a soil pH test
- Hand pruners and gloves (with an adult)
- Contact information for a local food pantry, church food ministry or gleaning group

Steps

1. Research your plant's needs: zone, chill hours, pollination partner, soil pH, spacing and years to first harvest. Record them.
2. Test the soil pH where you will plant. For blueberries, plan to lower it (with an adult and a labeled product) or use a container with an acid mix.
3. Plant following the method in the core ideas: correct depth, graft union above the soil, water deeply, mulch.
4. If you planted a tree or bush, make any light pruning cuts an extension guide recommends for planting time, with an adult.
5. Record the planting in your garden record with date, variety, source and cost, and take a photo for your capstone record.
6. Call or visit a food pantry or gleaning group with an adult and ask what fresh produce they can use, when, and how it must be packed.
7. Plan a service project: an extra row of a crop from your garden plan, a few hours of gleaning at an orchard, or a fruit drive. Write the plan with dates and amounts.
8. After the harvest, record what you donated in pounds and the hours you served.

Tips

- Food pantries usually prefer produce that keeps well and is familiar: potatoes, onions, squash, apples, tomatoes and green beans.
- Service hours and donations are often part of 4-H record books and FFA community service activities.

Check your work

- ☐ I researched and recorded my plant's needs before planting.
- ☐ I planted at the correct depth, watered and mulched properly.
- ☐ I contacted a food pantry, church ministry or gleaning group and wrote a service plan.
- ☐ I can explain cross-pollination, chill hours and why fruit trees are pruned.

NATURE JOURNAL

1. Draw a young apple tree before and after a first pruning, marking which branches you would remove and why.
2. Draw an apple blossom and label the petals, stamens, pistil and ovary, and show where the apple will form.

COMMON MISTAKES

- Planting a tree too deep or burying the graft union, which can let the scion root and lose the dwarfing rootstock.
- Buying a single apple or sweet cherry tree with no pollination partner nearby.
- Harvesting asparagus heavily in the first two years, which weakens the crowns for good.

Make it a game • Orchard Partners. Draw three fruit trees on a map. Your parent says what they require: chill hours, a cross-pollination partner, or open center versus central leader pruning. Place each tree and defend it. Then explain bare-root planting step by step, hole depth first. Lose a point whenever you need a hint. Switch and quiz your parent.

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 well-planted tree bears fruit for many years. God's Word roots a life the same way, and the fruit is meant to be shared.

UNIT 7

PLANTING: GARDEN, FIELD AND ORCHARD

Spring is the season for planting, and in this capstone year you plan like a professional grower. You will design a whole garden for succession, rotation, spacing and yield; multiply plants by grafting, layering and division; study how corn, soybeans and wheat are grown on thousands of acres; and plant for the long term with fruit trees, berries and other perennial crops.

Along the way you will judge a class of crop samples as 4-H and FFA members do, give a short how-to talk, and plan a row of produce to share with neighbors in need. The garden you plan in Lesson 7.1 can become the heart of your capstone project in Unit 8.

PREREQUISITES

- Your agricultural calendar and succession plan (Lessons 1.1 and 1.2)
- Your soil report (Unit 3)
- Seed starting, transplanting and hardening off
- Plant hormones and rooting cuttings (Lesson 5.3)

MASTERY CHECKLIST

- ☐ I can draw a scaled garden plan that uses rotation by plant family, correct spacing, succession and yield estimates.
- ☐ I can explain how grafting, layering and division make new plants identical to the parent, and do at least one of them.
- ☐ I can describe how a field crop is planted, managed and harvested at scale, and calculate yield per acre.
- ☐ I can judge a class of four crop samples and give oral reasons.
- ☐ I can plant a fruit tree or berry bush correctly and explain basic pruning.
- ☐ I can give a 3–5 minute how-to talk on a garden skill.

LESSONS IN THIS UNIT

7.1 Planning a Full Garden: Rotation, Spacing and Yield

2 sessions of 60 minutes

7.2 Propagation: Grafting, Layering and Division

2 sessions of 60 minutes

7.3 Agronomy: Field Crops at Scale

2 sessions of 60 minutes

7.4 Orchards, Berries and Perennial Crops

2 sessions of 60 minutes

UNIT 7 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work. Total: 100 points.

1. **8 pts**

Name the plant family of each crop: tomato, broccoli, bean, squash, onion, potato.

2. **8 pts**

Why is crop rotation done by plant family rather than by individual crop? Give an example.

3. **8 pts**

A family wants 60 pounds of tomatoes. If each plant yields about 12 pounds, how many plants should they grow, and at 2-foot spacing in a 4-foot-wide bed (two staggered rows), how long a bed do they need?

4. **8 pts**

Why are apple trees grafted instead of grown from seed?

5. **8 pts**

In a graft, which layer must line up, and why?

6. **8 pts**

Describe how to divide a clump of daylilies.

7. **8 pts**

Describe the planting-to-harvest year of winter wheat.

8. **9 pts**

In $\frac{1}{1,000}$ acre of corn you count 32 ears averaging $16 \text{ rows} \times 35 \text{ kernels}$.

Estimate the yield in bushels per acre using the formula $(\text{ears} \times \text{kernels per ear}) \div 90$.

9. **8 pts**

Name four things a judge looks for in a fair exhibit of ten ears of corn or five potatoes.

10. **8 pts**

What are chill hours, and why does a gardener in a warm southern state need to know them?

11. **8 pts**

List four steps for planting a bare-root fruit tree correctly.

12. **11 pts**

Short answer: Describe your plan for a service project that shares produce with people in need, and explain how it reflects good stewardship.

ANSWER KEY

1. Tomato: nightshade; broccoli: brassica; bean: legume; squash: cucurbit; onion: allium; potato: nightshade.
2. Related plants share pests, diseases and nutrient needs. Following tomatoes with potatoes keeps early blight and potato beetles in the same soil, so they must move to a bed of a different family.
3. $60 \div 12 = 5$ plants. With two rows at 2 ft spacing, 5 plants need about 3 positions per row, so about 6 feet of bed (5–6 ft acceptable).
4. Seedlings do not come true; each is a new genetic combination, usually inferior. Grafting makes a clone of the chosen variety, and the rootstock controls size, hardiness and disease resistance.
5. The cambium, because it is the layer of dividing cells that grows together to join scion and rootstock.
6. In early spring or fall, dig the clump, shake off soil, separate it into pieces each with roots and a fan of leaves or buds, replant at the same depth, and water well.
7. Sown in fall, it sprouts and survives the winter as a small plant, grows quickly in spring, heads out, and is harvested in early summer when the grain is dry.
8. Kernels per ear $16 \times 35 = 560$. $32 \times 560 = 17,920$. $17,920 \div 90 \approx 199$ bushels per acre.
9. Uniformity of size and shape, true to the variety, freedom from blemishes, damage, disease and insects, cleanliness and condition, correct number as the fair book requires (any four).
10. Hours between about 32 and 45 °F a fruit tree needs in winter to bloom and fruit normally. Varieties needing more chill than the climate provides will bloom poorly and give little fruit.
11. Soak the roots; dig a hole wider than the roots but not deeper; spread roots over a mound; keep the graft union above the soil; backfill with native soil; water deeply; mulch away from the trunk (any four).
12. A strong answer names a specific partner (food pantry, church ministry, gleanng group), a crop or activity, dates and amounts, how produce will be harvested and packed, and how donations and hours will be recorded, and connects it to passing on God's provision and caring for neighbors.

PORTFOLIO PIECE: THIS SEASON'S GARDEN: PLAN, PROPAGATION AND PLANTING

Assemble your garden plan, planting calendar, propagation record and how-to-talk outline, your perennial planting record with photos, your crop judging card and reasons, and your service-project plan. Keep adding harvest weights and service records through the season; this portfolio becomes part of your capstone record book in Unit 8.

LOOK FOR	WHAT IT MEANS
Garden plan	The plan is scaled, rotated by family, correctly spaced and based on yield calculations.
Propagation and planting	Propagation and perennial planting are done correctly and recorded with dates, photos and results.
Judging and talk	The judging card and reasons are complete and organized, and the how-to talk outline has clear steps.
Service	The service plan names a real partner, crop or activity, dates and how donations will be recorded.
Records	Garden records include dates, varieties, costs and harvest amounts, kept up to date.

UNIT 8

PLANT HEALTH AND THE CAPSTONE

As the garden grows, so do its troubles: leaf spots and blights, hungry insects, and weeds that spring up faster than crops. In this last unit you will diagnose plant problems like a plant pathologist, scout insects and decide when to act like an integrated pest management (IPM) specialist, and manage weeds like a weed scientist, always choosing the safest effective method first.

Then you will finish your capstone. Since the fall you have been planning, growing or raising something and keeping records. Now you will complete a full record book in the style of a 4-H project book or an FFA Supervised Agricultural Experience, prepare a fair-quality exhibit, give a talk, and host a family harvest fair. Finally you will look ahead to high school 4-H, FFA and the work God may be preparing you for.

PREREQUISITES

- Soil biology and nutrient deficiencies (Unit 3)
- Your garden plan and records from Unit 7
- Judging with oral reasons (Lessons 6.1 and 7.3)
- A capstone project chosen and under way

MASTERY CHECKLIST

- ☐ I can use the disease triangle and a step-by-step method to diagnose a plant problem and tell biotic from abiotic causes.
- ☐ I can identify insect life cycles, tell pests from beneficial insects, and apply IPM thresholds and the IPM ladder.
- ☐ I can classify weeds as annual, biennial or perennial and choose a management plan for each.
- ☐ I can keep a complete project record book with inventory, expenses, income, hours and a project story.
- ☐ I can prepare a fair exhibit to judges' standards and present my project in a short talk.

LESSONS IN THIS UNIT

8.1 Plant Pathology: Diagnosing Plant Diseases

2 sessions of 60 minutes

8.2 Entomology and Integrated Pest Management

2 sessions of 60 minutes

8.3 Weed Science

2 sessions of 60 minutes

8.4 Capstone: Record Book, Exhibit and Family Harvest Fair

2 sessions of 60 minutes

UNIT 8 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work. Total: 100 points.

1. 8 pts

Draw and label the disease triangle and give one management practice for each side.

2. 8 pts

What is the difference between a sign and a symptom? Give an example of each.

3. 8 pts

Squash, beans and tomatoes in one garden all suddenly show scorched leaves the day after a very hot, windy day. Is the cause more likely biotic or abiotic? Explain.

4. 8 pts

List the seven steps for diagnosing a plant problem.

5. 8 pts

Compare complete and incomplete metamorphosis and give an example of a garden insect for each.

6. 8 pts

Name the rungs of the IPM ladder in order.

7. 8 pts

You find a tomato hornworm covered with small white cocoons. What should you do and why?

8. **8 pts**

Why should annual weeds never be allowed to go to seed? What is different about controlling perennial weeds?

9. **8 pts**

What is the critical weed-free period, and how should it guide a gardener's weeding schedule?

10. **9 pts**

A capstone project had expenses of \$86 (seed \$18, compost \$30, supplies \$38) and income of \$140 in sales plus \$45 of produce used by the family. Find total income and net income.

11. **8 pts**

Name five things a judge looks for in a fair exhibit plate of vegetables.

12. **11 pts**

Short answer: Describe your capstone project and explain what your record book shows about what you learned, including one mistake and how you would change your plan next year.

ANSWER KEY

1. Host: plant resistant varieties. Pathogen: rotate crops, remove infected plants, clean tools and seed. Environment: space plants for airflow, water the soil not the leaves, mulch.
2. A symptom is the plant's response, such as yellowing or a leaf spot; a sign is the pathogen itself, such as white powdery mildew growth, fungal spores or bacterial ooze.
3. Abiotic. The problem appeared suddenly on several unrelated kinds of plants after a weather event, which points to heat and wind injury rather than a pathogen, which usually affects one kind of plant and spreads over time.
4. Identify the plant and know healthy; describe symptoms and look for signs; note the pattern; check roots and soil; review history (weather, water, fertilizer, sprays); compare with extension fact sheets; send a sample to the extension office or diagnostic lab if unsure.
5. Complete: egg, larva, pupa, adult; young look different from adults (tomato hornworm to sphinx moth, Colorado potato beetle, cabbage worm). Incomplete: egg, nymph, adult; young look like small wingless adults (aphid, squash bug).
6. Prevention, monitoring (scouting), comparing with thresholds, then controls from least to most risk: cultural, mechanical, biological, and chemical last (by adults, following the label).
7. Leave it. The cocoons are parasitic wasps that have parasitized the hornworm; it will stop feeding and the new wasps will emerge to attack other hornworms.
8. Annuals spread only by seed, and their seeds build the seed bank and live in soil for years. Perennials regrow from roots, rhizomes or bulbs, so their roots must be dug out or exhausted by repeated cutting or smothering.
9. The early weeks of a crop's growth (often the first four to six) when weed competition causes the most yield loss. Weed early and often then, while weeds are small; later weeds matter less once the crop canopy shades them.
10. Total income $\$140 + \$45 = \$185$. Net income $\$185 - \$86 = \$99$.
11. Correct number of specimens as the fair book requires, uniformity, true to type, proper ripeness, freedom from blemishes, damage and disease, cleanliness, correct trimming and labeling (any five).

12. A strong answer describes the project specifically, cites records (inventory, log, expenses, income, hours), names a real problem honestly, explains the cause using concepts from the course, and gives a practical change for next year.

PORTFOLIO PIECE: CAPSTONE RECORD BOOK AND HARVEST FAIR PRESENTATION

Your capstone is the year's final portfolio: a complete record book (goals, inventory, log, expenses, income, net income, hours, skills, service and a project story with photos), one fair-quality exhibit, a 3–5 minute talk at your family harvest fair, and a written plan for your next project in high school 4-H, FFA or your own garden or flock. It counts as two portfolio projects.

LOOK FOR	WHAT IT MEANS
Records	The record book is complete, dated and accurate, with inventory, expenses, income, net income and hours calculated correctly.
Project story	The story honestly explains goals, methods, problems, results and lessons learned, with captioned photos.
Exhibit	The exhibit meets fair-book standards for number, uniformity, type, cleanliness and labeling.
Presentation	The talk is 3–5 minutes, organized, uses real objects or photos, and handles questions well.
Next steps	The plan for next year is specific and names real programs, people and first steps.

8.1 PLANT PATHOLOGY: DIAGNOSING PLANT DISEASES

OBJECTIVES

- Explain the disease triangle and how fungi, bacteria, viruses and nematodes cause plant disease.
- Distinguish signs from symptoms and biotic from abiotic problems.
- Diagnose a plant problem step by step and choose prevention and management practices.

Warm-up. Walk through a garden, park or houseplant collection and find three plants with something wrong (spots, yellowing, holes, wilting). Sketch each quickly and guess the cause. Keep your guesses for the end of the lesson.

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 the questions the extension specialist asks before naming a cause.

BACKUP VIDEO

Plant Disease Sign or Symptom

Penn State Extension · 3:02

<https://www.youtube.com/watch?v=m6GoSy8RjUM>

With the core idea on signs and symptoms: Penn State shows examples of each.

KEY TERMS

plant pathology

The science of plant diseases: their causes, how they spread and how to manage them.

disease triangle

The idea that disease occurs only when three things meet: a susceptible host, a pathogen, and a favorable environment.

pathogen

An organism that causes disease, such as a fungus, bacterium, virus or nematode.

symptom and sign

A symptom is the plant's response (yellowing, wilting, spots); a sign is the pathogen itself (fungal threads, spores, bacterial ooze).

biotic and abiotic

Biotic problems are caused by living things (pathogens, insects, animals); abiotic problems by non-living causes (drought, frost, nutrient shortage, herbicide drift).

resistant variety

A variety bred to tolerate or resist a particular disease; seed catalogs mark them with codes such as V, F or EB.

CORE IDEAS

A plant disease happens only when three things come together: a **susceptible host**, a **pathogen**, and a **favorable environment**. This is the **disease triangle**. Take away any one side and there is no disease. That is why management focuses on all three: resistant varieties (host), clean seed, rotation and sanitation (pathogen), and spacing, watering at the base and mulching (environment).

Fungi cause most plant diseases. Early blight makes target-like brown rings on lower tomato leaves; powdery mildew coats squash leaves with white powder; damping-off rots seedlings at the soil line. Fungal spores spread by wind, splashing rain and tools, and most need leaves to stay wet for hours to infect. **Bacteria** enter through wounds and natural openings: bacterial wilt of cucumbers is spread by cucumber beetles, and fire blight blackens apple and pear shoots. **Viruses**, such as tomato mosaic, are spread by insects like aphids, by hands and tools, and sometimes by seed; there is no cure, so infected plants are removed. **Nematodes**, microscopic worms, can form knots on roots.

Not every sick plant has a disease. **Abiotic** problems are common: drought or overwatering, frost or sunscald, compacted soil, nutrient deficiencies (Lesson 3.2), salt, or herbicide drift. A clue is the pattern. Problems caused by weather or chemicals tend to appear suddenly, on many kinds of plants, often in a regular pattern; diseases usually start on one plant or one kind of plant and spread over days.

Diagnose step by step: (1) Identify the plant and know what healthy looks like. (2) Describe the **symptoms** and look for **signs** with a hand lens. (3) Note the pattern in the planting and on the plant (old or new leaves, top or bottom). (4) Check the roots and soil. (5) Review the history: weather, watering, fertilizer, sprays, planting date. (6) Compare with extension fact sheets. (7) If unsure, take a sample in a sealed bag to your county extension office or a university plant diagnostic lab. In the 1840s, potato late blight, a water mold, destroyed Ireland's potato crop and led to famine, which shows how much depends on recognizing disease early.

Management follows from the diagnosis: remove and destroy (not compost) badly infected plants, rotate crops, water the soil and not the leaves, space for airflow, mulch to stop soil splashing onto leaves, clean tools, and plant resistant varieties. Any fungicide, even an organic one, is chosen and applied only by an adult following the label.

PICTURE STUDY



Blue Mould, Schema 12 from Micrographia, Robert Hooke, 1665 · Engraving · Micrographia, London

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

Robert Hooke was one of the first scientists to look at living things through a microscope. In his book *Micrographia* he drew the blue mould growing on a piece of leather (Fig. 1) and rust-like spots on a rose leaf (Fig. 2), revealing that these ‘blemishes’ were made of tiny living things.

Look closely

- In Fig. 1, find the round heads on long stalks. Hooke saw that some had burst open (D). What do you think was released?
- Look at the scale line between the two figures. How much has the mould been enlarged?
- In Fig. 2, find the clusters of dark, seed-like bodies rising from bumps on the leaf. Are these signs or symptoms?
- Compare the two figures. How does each fungus grow from the surface it lives on?

Talk about it

1. How does seeing spores under magnification explain how fungal diseases spread from leaf to leaf?

2. Hooke had no idea that these molds were related to plant diseases. What does his careful drawing teach about observation in science?

Safety first. Wear gloves when handling diseased plants, seal samples in bags, and wash your hands and tools afterward. Fungicides and other garden chemicals are handled only by an adult following the label.

HANDS-ON PROJECT

A Plant Doctor's Case File

You will diagnose at least two real plant problems with a step-by-step method, document them like a plant diagnostic lab, and recommend management.

You will need

- Two or more plants with a problem (garden, yard, houseplants, a neighbor's garden or a community garden with permission)
- A hand lens, a ruler, a trowel and zip bags
- A camera or colored pencils
- Extension fact sheets or a plant diagnostic guide for your state
- Optional: a clear jar of water for a bacterial ooze test and a paper towel in a zip bag for a moist-chamber test

Steps

1. For each case, record the plant, location, date and weather for the past two weeks.
2. Photograph or sketch the whole plant, a close-up of the symptoms, and the pattern in the planting.
3. Examine the symptoms with a hand lens. Look for signs: fungal threads, powder, spore dots, insects or ooze.
4. Check the roots: gently dig and look for rot, knots, damage or dry soil.
5. Optional tests: place a leaf with spots on a damp paper towel in a sealed bag for two days and look for fuzzy fungal growth; cut a wilted stem and hold it in a jar of water to look for milky bacterial streaming.
6. Decide whether the cause is biotic or abiotic, and name the most likely cause, using extension fact sheets to confirm.
7. Draw the disease triangle for each case, filling in host, pathogen (or abiotic cause) and environment.
8. Write management recommendations for this year and prevention for next year. If you cannot identify a problem, take a sealed sample to your county extension office and record their answer.

Tips

- Compare your warm-up guesses with your final diagnoses. Most beginners guess ‘disease’ too often when the cause is watering or nutrients.
- A plant diagnosis case file makes a strong 4-H or FFA educational exhibit and good practice for crops and horticulture contests.

Check your work

- ☐ I diagnosed at least two problems using all the steps.
- ☐ I distinguished signs from symptoms and biotic from abiotic causes.
- ☐ Each case has a completed disease triangle and management recommendations.
- ☐ I can explain how changing one side of the triangle prevents disease.

NATURE JOURNAL

1. Draw the disease triangle and write two management practices on each side.
2. Sketch a tomato leaf with early blight, a squash leaf with powdery mildew, and a leaf with nutrient deficiency, labeling the features that tell them apart.

From history. Robert Hooke published *Micrographia* in 1665, the same book in which he named the ‘cell’ after seeing cork under his microscope. Two centuries later, in 1861, Anton de Bary proved that a living organism caused potato late blight, helping to found the science of plant pathology.

COMMON MISTAKES

- Spraying before diagnosing. Many problems are caused by watering, weather or nutrients, which no spray can fix.
- Composting badly diseased plants in a cool home compost pile, which may not get hot enough to kill pathogens.
- Watering leaves in the evening, which keeps them wet overnight and invites fungal disease.

Make it a game • Plant Doctor Rounds. Your parent describes a sick plant case using only symptoms. Think like a plant doctor: name the disease triangle (host, pathogen, environment), decide biotic or abiotic, and separate the signs from the symptoms. Give three questions you would ask. One point per correct diagnosis. Then recommend a resistant variety or a cultural fix.

8.2 ENTOMOLOGY AND INTEGRATED PEST MANAGEMENT

OBJECTIVES

- Describe insect body parts and the two main kinds of metamorphosis, and identify common garden pests and beneficial insects.
- Scout a garden, record insect counts and use action thresholds to decide whether to act.
- Apply the IPM ladder: prevention, monitoring, cultural, mechanical, biological, and chemical controls only as a last resort by adults.

Warm-up. Go outside for ten minutes and find as many different insects as you can (look under leaves, on flowers, under a board). Sketch three and count their legs and body sections. Are they all insects?

WATCH

5 IPM (integrated pest management) strategies to keep your garden pest free!

MU Extension Integrated Pest Management · 8:31

https://www.youtube.com/watch?v=-h4ny_sqY4k

WHEN TO WATCH

After the core idea on IPM. Write each strategy as a rung on the IPM ladder in your journal.

BACKUP VIDEO

IPM Principles

UNH Extension · 8:39

<https://www.youtube.com/watch?v=16AFuMguhrA>

Optional: an extension specialist explains thresholds and monitoring.

KEY TERMS

entomology

The scientific study of insects.

complete metamorphosis

A life cycle with four stages, egg, larva, pupa and adult, as in beetles, butterflies, moths and flies.

incomplete metamorphosis

A life cycle with three stages, egg, nymph and adult, in which the young look like small wingless adults, as in aphids, squash bugs and grasshoppers.

integrated pest management (IPM)

A decision-making approach that combines prevention, monitoring and several kinds of control to keep pests below damaging levels with the least risk to people and the environment.

action threshold

The pest level at which the damage would cost more than control, so action is taken.

beneficial insect

An insect that helps the gardener, such as pollinators and natural enemies like lady beetles, lacewings, ground beetles and parasitic wasps.

CORE IDEAS

Insects have three body sections (head, thorax, abdomen), six legs and usually two pairs of wings. Most of the insects in a garden are harmless or helpful; only a few are pests. Knowing the **life cycle** tells you when a pest is easiest to stop. In **complete metamorphosis** (beetles, moths, butterflies, flies), the larva does the eating and looks nothing like the adult: a tomato hornworm becomes a sphinx moth. In **incomplete metamorphosis** (aphids, squash bugs, leafhoppers), nymphs look like small adults and feed the same way.

Common pests include aphids (sap-suckers that also spread viruses), cabbage worms, Colorado potato beetles, squash bugs and squash vine borers, cucumber beetles, Japanese beetles, flea beetles and tomato hornworms. Their natural enemies are many: lady beetles and their larvae eat aphids; lacewing larvae, syrphid fly larvae and minute pirate bugs eat small pests; ground beetles eat slugs and caterpillars; tiny parasitic wasps lay eggs inside aphids and caterpillars. A hornworm covered in white cocoons has been parasitized and should be left so the wasps can emerge.

Integrated pest management is a way of deciding, not a single product. It works like a ladder. First, **prevention**: healthy soil, resistant varieties, rotation, good spacing and timing. Second, **monitoring**: scout weekly, turning over leaves, using yellow sticky cards, and counting pests and beneficials. Third, compare with an **action threshold**. A few holes in leaves are not worth treating; many home-garden guides suggest acting when, for example, more than one in ten plants has a significant pest population or damage begins to reach the part you harvest. Fourth, choose the least risky effective controls: **cultural** (rotation, trap crops, planting dates), **mechanical** (hand-picking, row covers, barriers, a strong spray of water for aphids), and **biological** (encouraging or releasing natural enemies, *Bt* for caterpillars). Only last, and only by an adult following the label, come pesticides chosen to spare beneficial insects.

Farmers use IPM on thousands of acres, hiring crop scouts to walk fields weekly and using economic thresholds from university research. The same thinking saves money, protects pollinators and keeps food safe. The goal is not a garden with no insects, but a balanced garden where pests are kept below the level of real harm.

Scripture often uses insects, such as the locust and the ant, as pictures of judgment and of diligence. A gardener who scouts faithfully each week, like the ant, prevents most problems before they grow.

PICTURE STUDY



Plate from Metamorphosis insectorum Surinamensium, Maria Sibylla Merian, 1705 · Hand-colored engraving · Book illustration

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

Maria Sibylla Merian was a German naturalist and artist who in 1699 sailed to Suriname in South America to study insects. She raised caterpillars on the plants they ate and drew every stage of their lives on one page, at a time when many people still believed insects arose from mud.

Look closely

- Find each stage of the life cycle on the plate: egg or cocoon, larva, pupa and adult. Which kind of metamorphosis is this?
- Look at the leaves. Which stage has been eating them, and how can you tell?
- Compare the caterpillar with the moths. Would a gardener recognize them as the same insect?
- Notice that Merian drew the insect on its food plant. Why is that important information for a farmer?

Talk about it

1. If this insect were a pest of your crop, at which stage would you try to control it, and why?
2. How does Merian's method of raising insects and recording every stage resemble scouting in IPM?

Safety first. Wear gloves when hand-picking pests (some caterpillars have stinging hairs), and never handle pesticides; an adult reads the label and applies any product. Watch for bees and wasps while scouting flowers.

HANDS-ON PROJECT

A Four-Week Scouting Record and IPM Plan

You will scout a garden weekly for four weeks, record pests and beneficial insects, compare counts with thresholds, and write an IPM plan.

You will need

- A garden, community garden plot or several large containers of vegetables
- Yellow sticky cards and stakes
- A hand lens, a clipboard and a scouting data sheet you design
- An insect field guide or extension pest guide
- Row cover, a bucket of soapy water and gloves for mechanical controls

Steps

1. Choose 10 plants of one or two crops and number them. Put up two yellow sticky cards at plant height.
2. Design a data sheet with columns for date, plant number, pest name and stage, number, damage rating (0–3), and beneficial insects seen.
3. Each week at the same time, check the top, middle and underside of leaves on each numbered plant and record what you find. Count insects on the sticky cards and replace them.
4. Identify each insect to at least its group and record whether it has complete or incomplete metamorphosis.
5. After each scouting, decide whether any pest has reached your action threshold. Record your decision and why.
6. When action is needed, use the lowest rung of the ladder that works: hand-pick into soapy water, spray aphids off with water, add row cover, or remove a badly infested leaf. Record what you did and the result the next week.
7. Graph pest and beneficial counts over four weeks.
8. Write a one-page IPM plan for next season: prevention, monitoring schedule, thresholds, and the controls you would use in order.

Tips

- Scout early in the morning when insects are slow, and look under leaves where many pests hide.
- Entomology and insect-collection projects are offered in many 4-H programs; your scouting record is a good start.

Check your work

- ☐ I scouted the same numbered plants for four weeks and recorded data each time.
- ☐ I identified pests and beneficials and their type of metamorphosis.
- ☐ I used an action threshold to decide when to act and used the lowest effective control.
- ☐ My graph and IPM plan are complete.

NATURE JOURNAL

1. Draw the four stages of complete metamorphosis for one garden insect and the three stages of incomplete metamorphosis for another, labeling where each stage lives.
2. Draw the IPM ladder with prevention at the bottom and pesticides at the top, and write one example on each rung.

From history. In the 1880s the cottony cushion scale nearly destroyed California's citrus groves. The entomologist Charles V. Riley sent Albert Koebele to Australia, where he found the vedalia lady beetle feeding on the scale. Released in 1888, the beetles brought the pest under control within two years, one of the first great successes of biological control.

COMMON MISTAKES

- Killing every insect seen, including beneficials such as lady beetle larvae, which look strange and are often mistaken for pests.
- Waiting until damage is severe instead of scouting weekly from the start.
- Reaching for a spray before trying cultural and mechanical controls.

Make it a game • Bug Scouting Sprint. Draw an insect with its three body parts, then sort six bugs you know into complete or incomplete metamorphosis. Your parent reads a scouting record of pest counts and an action threshold. Decide: act or wait? Name a beneficial insect that might do the job. Win a point for each decision with a reason.

8.3 WEED SCIENCE

OBJECTIVES

- Classify weeds by life cycle (annual, biennial, perennial) and by type (grass, broadleaf, sedge).
- Explain how weeds compete with crops, the weed seed bank and the critical weed-free period.
- Plan weed management using mulch, cultivation, the stale seedbed, cover crops and timing.

Warm-up. Pull up three different weeds from a garden or sidewalk crack, roots and all. Compare the roots: fibrous, taproot or spreading underground stems. Which do you think would be hardest to get rid of, and why?

WATCH

Weed Life Cycles

Penn State Extension · 7:46

<https://www.youtube.com/watch?v=S6kZR6pk0E0>

WHEN TO WATCH

After the core ideas. Pause for each life cycle and list the weeds named as examples.

KEY TERMS

weed

A plant growing where it is not wanted, which competes with crops for light, water and nutrients.

biennial weed

A weed that forms a rosette the first year and flowers and seeds the second, such as wild carrot and burdock.

annual weed

A weed that completes its life in one year and spreads by seed, such as lambsquarters, pigweed and crabgrass.

perennial weed

A weed that lives for years and often spreads by roots, rhizomes or bulbs as well as seed, such as dandelion, bindweed and quackgrass.

weed seed bank

The store of weed seeds in the soil, which can stay alive for years and sprout whenever conditions are right.

critical weed-free period

The weeks early in a crop's life when weeds must be controlled to prevent yield loss.

CORE IDEAS

Since the curse of Genesis 3, 'thorns also and thistles' have come up in every field. A **weed** is simply a plant in the wrong place, but weeds are tough competitors. They take light, water and nutrients, harbor pests and diseases, and can cut yields sharply if left early in the season. Some, such as poison ivy, wild parsnip and jimsonweed, are harmful to touch or eat.

Knowing a weed's **life cycle** is the key to controlling it. **Annuals** spread only by seed, so the rule is never let them go to seed; one lambsquarters plant can make tens of thousands of seeds. 'One year's seeding, seven years' weeding': seeds in the **seed bank** can live in soil for years. **Biennials** are easiest to kill in their first-year rosette. **Perennials** regrow from roots, rhizomes or bulbs, so pulling the tops is not enough: you must dig out the roots, repeatedly cut or smother them until their stored food is exhausted. Weeds are also grouped as **grasses**, **broadleaves** and **sedges** (triangular stems), which matters for identification.

Weeds hurt most early. Research shows each crop has a **critical weed-free period**, often the first four to six weeks after planting, when competition does the most damage. After the crop canopy closes, it shades out many later weeds. So weeding is most valuable early and often, when weeds are tiny and easy to kill with a hoe.

The weed-management toolbox includes: **mulch** (straw, leaves, wood chips, cardboard) that blocks light; **cultivation** with a sharp hoe in dry weather, shallowly so you do not bring up new seeds; the **stale seedbed** (prepare the bed, let the first flush of weeds sprout, kill them, then plant); dense planting and **cover crops** that crowd weeds out; and **prevention**, such as clean equipment and weed-free straw and compost. Farmers also use herbicides, applied by trained adults; children never handle them.

Proverbs describes the field of the sluggard, 'all grown over with thorns.' Weeding is the daily faithfulness that keeps a garden fruitful.

PICTURE STUDY



The Weeders, Jules Breton, 1868 · Oil on canvas · Metropolitan Museum of Art, New York

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

Jules Breton painted the farm women of his village in northern France at work in the fields. Hand weeding young crops was long, back-bending work, often done until the last light of evening.

Look closely

- Look at how the women are working: kneeling, crouching, bending. What does this tell you about the size of the crop and the weeds?
- Find the sack at the left. What is in it, and why carry weeds out of the field instead of leaving them?
- Find the woman standing. What do you think she is feeling after a day of weeding?
- Look at the setting sun and the moon. What time of day is it, and why might weeding be done in the cool evening?

Talk about it

1. These women are weeding while the crop is young. Why is early weeding worth so much more than late weeding?
2. Which modern tools or methods from this lesson would make their work easier?

Safety first. Learn to recognize poison ivy, poison oak and wild parsnip before weeding, and wear gloves and long sleeves. Never taste wild plants. Herbicides are used only by trained adults.

A Weed Survey and Management Trial

You will identify and classify the weeds in a garden, then compare weed control methods in small test plots.

You will need

- A weed identification guide from your extension office or a reliable app
- Four stakes and string to mark a square-yard (or square-meter) quadrat
- A bed or patch of bare soil that can be divided into three or four plots of equal size
- Mulch (straw, shredded leaves or cardboard), a hoe, and gloves
- A plastic sheet or old window to try a stale seedbed (optional)

Steps

1. Mark a square-yard quadrat in a weedy area. Count and identify every weed inside. Record each species, number, life cycle and type (grass, broadleaf, sedge).
2. Repeat in two more quadrats in different spots. Calculate the average number of weeds per square yard.
3. Press one specimen of each common weed between newspaper pages under heavy books, and when dry, mount and label it with common and scientific name and life cycle.
4. Divide a bed into three or four equal plots: (A) no weeding, (B) hoeing once a week, (C) 3 inches of mulch, and optionally (D) stale seedbed before planting.
5. Plant the same crop (bush beans or lettuce) in each plot on the same day.
6. Each week for five weeks, count the weeds in each plot and record the time spent weeding.
7. At the end, weigh the harvest or measure the crop plants in each plot.
8. Graph weed counts and crop results, and write a conclusion about which method worked best for the time spent.

Tips

- Hoe on a dry, sunny day so the cut weeds dry out instead of rerooting.
- Weed identification is part of many FFA and 4-H crops and horticulture contests; a pressed weed collection makes good study cards.

Check your work

- ☐ I identified and classified the weeds in three quadrats and averaged them.
- ☐ I made a labeled pressed collection of the common weeds.
- ☐ My trial compared at least three methods with the same crop and planting date.
- ☐ My graph and conclusion compare weed counts, crop results and time spent.

NATURE JOURNAL

1. Draw a weed of each life cycle with its roots, labeling how it spreads and the best time to control it.
2. Draw a timeline of a bean crop's first eight weeks and shade the critical weed-free period.

COMMON MISTAKES

- Letting a few weeds go to seed 'just this once', which refills the seed bank for years.
- Pulling only the tops of perennial weeds like bindweed or quackgrass, which regrow from their roots.
- Tilling deeply to remove weeds, which brings buried weed seeds to the surface to sprout.

Make it a game • Weed Identity Parade. Write annual, biennial and perennial on three sheets of paper and grass, broadleaf and sedge on three more. Your parent names a weed or a description and you place it on one of each pair, quickly. Then explain what the seed bank and the critical weed-free period mean. Beat your best streak.

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)

Weeds take over a neglected field quickly. Faithful, timely work keeps a garden, and a life, fruitful.

8.4 CAPSTONE: RECORD BOOK, EXHIBIT AND FAMILY HARVEST FAIR

OBJECTIVES

- Complete a project record book in the style of a 4-H project book or FFA Supervised Agricultural Experience, with inventory, expenses, income, hours and a project story with photos.
- Prepare a fair-quality exhibit and judge exhibits as a fair judge would.
- Present the capstone in a 3–5 minute talk at a family harvest fair, and plan next steps in high school 4-H, FFA or other agricultural programs.

Warm-up. Look back through your nature journal from the first page in late summer. Choose the three pages you are proudest of and the one experiment that surprised you most. Write a sentence about each.

WATCH

4-H Market Swine

Iowa PBS · 3:12

<https://www.youtube.com/watch?v=3McdO9uRvsQ>

WHEN TO WATCH

Before you plan your exhibit and talk. Notice how the young exhibitors talk about the months of daily care and records behind one day at the fair.

KEY TERMS

record book

The written record of a 4-H or FFA project: goals, inventory, daily log, expenses, income, hours, skills learned and a project story.

Supervised Agricultural Experience (SAE)

The hands-on project every FFA member carries out, such as owning a business, working on a farm, doing research or community service, with careful records.

inventory

A list of what a project owns at the beginning and end (animals, plants, tools, supplies) and their value.

net income

Total income minus total expenses for the project.

exhibit

A product or display entered at a fair to be judged against a standard, such as a plate of vegetables, a jar of honey, a potted plant or an educational poster.

true to type

Having the size, shape and color typical of the variety; judges reward it more than unusual size.

CORE IDEAS

Every capstone project ends with a **record book**. In 4-H and FFA, the record book is how judges, scholarship committees and future employers see what you really did. Model yours on an FFA **Supervised Agricultural Experience**: (1) project goals; (2) a beginning and ending **inventory** of plants, animals, tools and supplies with values; (3) a dated **log** of work done; (4) an **expense** table and an **income** table (sales, and the value of produce your family used), with net income; (5) **hours** worked; (6) skills learned and leadership or service; and (7) a **project story** with photos that tells what you did, what went wrong, and what you would do next time.

A **fair exhibit** is judged against a standard, not against your neighbor's biggest tomato. For a vegetable plate, read the fair book for the exact number (often 3, 5 or 10). Choose specimens that are **uniform** in size, shape and color, **true to type** for the variety, at the right stage of ripeness, and free from blemishes, insect damage and disease. Clean them gently (brush root crops; do not scrub or polish), trim as the fair book directs (for example, leave 1/2 inch of stem on peppers), and label them with the correct variety name. Potted plants should be healthy, well groomed, clean and in a clean pot; educational posters should be accurate, neat and easy to read from a few feet away.

Your project is also a story to tell. A 3–5 minute talk follows the shape you practiced in Lesson 7.2: an introduction that catches attention, the main steps or findings shown with real objects and photos, and a short summary. Look at your audience, speak clearly and slowly, and be ready for questions. The **family harvest fair** is your first audience: set out your exhibit, record book and journal; let guests judge a class of four; give your talk; and give thanks together for the harvest.

Next steps. High school opens wider doors. In **4-H**, which homeschoolers join through the county extension office, senior members (usually 14 and older) can take leadership roles, enter state-level contests and complete advanced project records. **FFA** serves students in school agricultural education programs, from grade 7 in many states and from grade 5 where a school program allows; there is no national homeschool provision, but some states have homeschool chapters (for example, Homefires FFA in Illinois and North Star FFA in North Carolina), so ask your state FFA association. National FFA Career Development Events are for grades 9–12; middle-school events are run by each state. High school students can also enter contests such as the National Ag Day Video Essay Contest (grades 9–12). Check eligibility and deadlines with the organizers each year.

The psalmist says God ‘crownest the year with thy goodness.’ Whatever your project, the harvest of this year is skill, knowledge, character and gratitude, and it is ready to be shared.

PICTURE STUDY



The Angelus, Jean-François Millet, 1857–1859 · Oil on canvas · Musée d'Orsay, Paris

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

Millet painted a young farm couple pausing at the end of a day of digging potatoes when the church bell rings for evening prayer. It became one of the most loved paintings in the world. It is a fitting picture for the end of a year of work: the harvest, and the thanks.

Look closely

- Find the tools and the harvest: the fork, the basket, the wheelbarrow and the sacks. What crop have they been harvesting?
- Look at the couple's posture. What are they doing, and what does it tell you about them?
- Find the church steeple on the horizon. Why did Millet include it?
- Look at the light. What time of day is it, and how does the light make you feel?

Talk about it

1. What is the harvest of your own year of work in this course, besides food?
2. Why is giving thanks a fitting way to end a season of work?

Safety first. Handle exhibit produce and animals with clean hands, and follow your fair's health rules. At a family harvest fair with animals present, provide a place for guests to wash their hands.

HANDS-ON PROJECT

Finish the Capstone and Hold a Family Harvest Fair

You will complete your capstone record book, prepare a fair-quality exhibit, give a talk, and host a family harvest fair where guests see your work.

You will need

- Your capstone records, journal, photos and portfolio pieces from the year
- A binder or folder, or a 4-H or FFA record book form from your county extension office or state FFA association
- Your best produce, plant, honey, animal project photos or educational poster for an exhibit
- Paper plates, labels and a table cloth for display
- Four similar items (four plates of vegetables, four potted plants or four photos) for guests to judge

Steps

1. Write your project goals as you set them in the fall, and an honest one-paragraph statement of how well you met each.
2. Complete the beginning and ending inventory with values, the dated work log, the hours total, and the expense and income tables with net income.
3. Write the project story (one to two pages) with at least six captioned photos or drawings: what you did, problems and how you solved them, what you learned, and your plans for next year.
4. Prepare one exhibit to fair standards: choose uniform, true-to-type specimens in the number your county fair book lists, clean and trim them correctly, and label them with the variety. Score it yourself with a fair scorecard.
5. Plan a 3–5 minute talk about your capstone with an introduction, three main points shown with real objects or photos, and a summary. Practice it at least three times.
6. Set up a family harvest fair: display the record book, exhibit, journal and portfolio pieces. Set out a judging class of four for guests to place, and give

your own official placing and reasons at the end.

7. Give your talk, answer questions, and thank your guests and everyone who helped you this year.
8. Write a one-page plan for next year: a high school 4-H project, an FFA SAE if you will have a school agricultural program, a fair entry, or a garden or animal project of your own, with the first three steps and the people to contact.

Tips

- Many county fairs have youth and open classes for vegetables, honey, potted plants, posters and nature-journal displays; read your fair book early for entry dates and rules.
- Keep copies of your record book. Scholarship and award applications in 4-H and FFA often ask for several years of records.

Check your work

- ☐ My record book has goals, inventory, log, expenses, income, hours and a project story with photos.
- ☐ My exhibit meets the fair-book standard for number, uniformity, cleanliness and labeling.
- ☐ I gave a 3–5 minute talk with real objects and answered questions.
- ☐ I wrote a plan for next year's project and how I will connect with 4-H, FFA or another program.

NATURE JOURNAL

1. Draw a plan of your harvest fair table: where the exhibit, record book, journal and judging class will go, with labels.
2. Write a final journal entry: the most important thing you learned this year about the land, plants and animals, and one verse of thanks.

COMMON MISTAKES

- Leaving the record book until the end, so dates, costs and hours must be guessed. Records are kept as the work is done.
- Choosing the biggest vegetables instead of the most uniform and typical ones.
- Reading a talk from paper instead of speaking to the audience with your project in hand.

Make it a game • Fair Judge for a Day. Gather a small exhibit: three items of garden or kitchen produce. Be the fair judge. Choose which is true to type, name three reasons, and write a short comment card for each. Then your parent asks five record-book questions: inventory, expenses, income, hours and net income. Answer without looking at your book.

Scripture. “Thou crownest the year with thy goodness; and thy paths drop fatness.” (Psalm 65:11, KJV)

The year ends as it began, with seedtime and harvest under God’s care. Give thanks for all He has provided through your work.

UNIT 8

PLANT HEALTH AND THE CAPSTONE

As the garden grows, so do its troubles: leaf spots and blights, hungry insects, and weeds that spring up faster than crops. In this last unit you will diagnose plant problems like a plant pathologist, scout insects and decide when to act like an integrated pest management (IPM) specialist, and manage weeds like a weed scientist, always choosing the safest effective method first.

Then you will finish your capstone. Since the fall you have been planning, growing or raising something and keeping records. Now you will complete a full record book in the style of a 4-H project book or an FFA Supervised Agricultural Experience, prepare a fair-quality exhibit, give a talk, and host a family harvest fair. Finally you will look ahead to high school 4-H, FFA and the work God may be preparing you for.

PREREQUISITES

- Soil biology and nutrient deficiencies (Unit 3)
- Your garden plan and records from Unit 7
- Judging with oral reasons (Lessons 6.1 and 7.3)
- A capstone project chosen and under way

MASTERY CHECKLIST

- ☐ I can use the disease triangle and a step-by-step method to diagnose a plant problem and tell biotic from abiotic causes.
- ☐ I can identify insect life cycles, tell pests from beneficial insects, and apply IPM thresholds and the IPM ladder.
- ☐ I can classify weeds as annual, biennial or perennial and choose a management plan for each.
- ☐ I can keep a complete project record book with inventory, expenses, income, hours and a project story.
- ☐ I can prepare a fair exhibit to judges' standards and present my project in a short talk.

LESSONS IN THIS UNIT

8.1 Plant Pathology: Diagnosing Plant Diseases

2 sessions of 60 minutes

8.2 Entomology and Integrated Pest Management

2 sessions of 60 minutes

8.3 Weed Science

2 sessions of 60 minutes

8.4 Capstone: Record Book, Exhibit and Family Harvest Fair

2 sessions of 60 minutes

UNIT 8 REVIEW

Answer each question in complete sentences unless a calculation is asked for; show your work. Total: 100 points.

1. 8 pts

Draw and label the disease triangle and give one management practice for each side.

2. 8 pts

What is the difference between a sign and a symptom? Give an example of each.

3. 8 pts

Squash, beans and tomatoes in one garden all suddenly show scorched leaves the day after a very hot, windy day. Is the cause more likely biotic or abiotic? Explain.

4. 8 pts

List the seven steps for diagnosing a plant problem.

5. 8 pts

Compare complete and incomplete metamorphosis and give an example of a garden insect for each.

6. 8 pts

Name the rungs of the IPM ladder in order.

7. 8 pts

You find a tomato hornworm covered with small white cocoons. What should you do and why?

8. **8 pts**

Why should annual weeds never be allowed to go to seed? What is different about controlling perennial weeds?

9. **8 pts**

What is the critical weed-free period, and how should it guide a gardener's weeding schedule?

10. **9 pts**

A capstone project had expenses of \$86 (seed \$18, compost \$30, supplies \$38) and income of \$140 in sales plus \$45 of produce used by the family. Find total income and net income.

11. **8 pts**

Name five things a judge looks for in a fair exhibit plate of vegetables.

12. **11 pts**

Short answer: Describe your capstone project and explain what your record book shows about what you learned, including one mistake and how you would change your plan next year.

ANSWER KEY

1. Host: plant resistant varieties. Pathogen: rotate crops, remove infected plants, clean tools and seed. Environment: space plants for airflow, water the soil not the leaves, mulch.
2. A symptom is the plant's response, such as yellowing or a leaf spot; a sign is the pathogen itself, such as white powdery mildew growth, fungal spores or bacterial ooze.
3. Abiotic. The problem appeared suddenly on several unrelated kinds of plants after a weather event, which points to heat and wind injury rather than a pathogen, which usually affects one kind of plant and spreads over time.
4. Identify the plant and know healthy; describe symptoms and look for signs; note the pattern; check roots and soil; review history (weather, water, fertilizer, sprays); compare with extension fact sheets; send a sample to the extension office or diagnostic lab if unsure.
5. Complete: egg, larva, pupa, adult; young look different from adults (tomato hornworm to sphinx moth, Colorado potato beetle, cabbage worm). Incomplete: egg, nymph, adult; young look like small wingless adults (aphid, squash bug).
6. Prevention, monitoring (scouting), comparing with thresholds, then controls from least to most risk: cultural, mechanical, biological, and chemical last (by adults, following the label).
7. Leave it. The cocoons are parasitic wasps that have parasitized the hornworm; it will stop feeding and the new wasps will emerge to attack other hornworms.
8. Annuals spread only by seed, and their seeds build the seed bank and live in soil for years. Perennials regrow from roots, rhizomes or bulbs, so their roots must be dug out or exhausted by repeated cutting or smothering.
9. The early weeks of a crop's growth (often the first four to six) when weed competition causes the most yield loss. Weed early and often then, while weeds are small; later weeds matter less once the crop canopy shades them.
10. Total income $\$140 + \$45 = \$185$. Net income $\$185 - \$86 = \$99$.
11. Correct number of specimens as the fair book requires, uniformity, true to type, proper ripeness, freedom from blemishes, damage and disease, cleanliness, correct trimming and labeling (any five).

12. A strong answer describes the project specifically, cites records (inventory, log, expenses, income, hours), names a real problem honestly, explains the cause using concepts from the course, and gives a practical change for next year.

PORTFOLIO PIECE: CAPSTONE RECORD BOOK AND HARVEST FAIR PRESENTATION

Your capstone is the year's final portfolio: a complete record book (goals, inventory, log, expenses, income, net income, hours, skills, service and a project story with photos), one fair-quality exhibit, a 3–5 minute talk at your family harvest fair, and a written plan for your next project in high school 4-H, FFA or your own garden or flock. It counts as two portfolio projects.

LOOK FOR	WHAT IT MEANS
Records	The record book is complete, dated and accurate, with inventory, expenses, income, net income and hours calculated correctly.
Project story	The story honestly explains goals, methods, problems, results and lessons learned, with captioned photos.
Exhibit	The exhibit meets fair-book standards for number, uniformity, type, cleanliness and labeling.
Presentation	The talk is 3–5 minutes, organized, uses real objects or photos, and handles questions well.
Next steps	The plan for next year is specific and names real programs, people and first steps.