

SCHOOL LAUNCH · EXPLORE TRACKS

EXPLORE ANIMALS · RANGER

The Animals track for curious Rangers: six trails and sixty stops among mammals, birds, reptiles and amphibians, ocean life, insects and the amazing things animals do. Short, self-paced stops with true stories, great pictures, diagrams, hands-on projects and a Field Notebook.

First edition

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

COURSE GUIDE

Explore Tracks are for children who want more of what they love. Each track is a trail of short stops. At every stop the child reads a true story, studies a great picture, works with a map or diagram, does something by hand, plays a game and writes a short entry in a Field Notebook.

This is the Animals track at the  Ranger level (ages 10–13). It goes deeper than the Scout level, with more facts and numbers, named sources and the reasons behind what scientists observe. Trail A meets the mammals, from the lion of Judah to the American bison's comeback. Trail B follows the birds, from the eagle of Isaiah 40:31 to Audubon and a real backyard bird count. Trail C visits reptiles and amphibians, from crocodiles and Galápagos tortoises to poison dart frogs. Trail D goes to sea, from sharks and coral reefs to the deep sea, Jonah and Leviathan. Trail E looks closely at insects and small creatures, from the ant of Proverbs 6:6 to Fabre the insect watcher. Trail F gathers the amazing things animals do: echolocation, camouflage, long journeys, the sled dogs of the 1925 Nome serum run, and Adam naming the animals in Genesis 2:19.

Each stop links to the matching lesson in a School Launch course, such as Life Science, Earth Science, Geography, Gardening & Animals, History or Art, so a child who wants more can go deeper there. The trails are independent and can be done in any order.

WHO IT IS FOR

Written for children about ages 10–13 who read on their own and talk over what they read with a parent. Younger siblings can join in at the  Scout level of the same stops. Nothing earlier is required, and the Scout level does not need to be done first.

HOW TO USE THIS COURSE

1. **One stop at a time.** A stop takes 20–30 minutes at the Ranger level: read the story, study the picture and the map or diagram, do the hands-on part, play the game and write the notebook entry. Two or three stops a week works well.
2. **Any order.** The six trails are independent. Finish one trail before starting the next, or move between them as the child's interest leads.
3. **Field Notebook.** Every stop ends with a short notebook entry: a labeled drawing, a diagram, a fact list or a few sentences in the child's own words. At the end of each trail the entries become a booklet, and the parent signs the trail certificate.
4. **Goes deeper in.** Each stop names a School Launch course lesson for more on the same subject. These are optional.
5. **Badge quizzes.** Every five stops earn a printable badge, so each trail has two short, optional badge quizzes. They can be done orally or in writing, and they are for review, not grades.

SCOPE AND SEQUENCE

Trail 1: Animals 🐾 **Trail A: Mammals** (Self-paced)

Trail 2: Animals 🐾 **Trail B: Birds** (Self-paced)

Trail 3: Animals 🐾 **Trail C: Reptiles and Amphibians** (Self-paced)

Trail 4: Animals 🐾 **Trail D: Ocean Life** (Self-paced)

Trail 5: Animals 🐾 **Trail E: Insects and Small Creatures** (Self-paced)

Trail 6: Animals 🐾 **Trail F: Animals Doing Amazing Things** (Self-paced)

MATERIALS

- **Field Notebook (a sketchbook or composition book)** One for the whole track, or one per trail.
- **Colored pencils, a ruler, scissors and glue** For labeled drawings, diagrams and maps.
- **A world map or atlas** For finding where each animal lives and tracing migrations and long journeys.
- **Household and craft things** Each hands-on project lists what it needs. Some use plaster of Paris (track casts), a milk carton or scrap wood (a feeder), cardstock (trading cards) or a shoebox (a diorama).
- **Binoculars and a hand lens (optional)** Helpful for the bird count and the insect stops; not required.
- **A Bible (KJV)** For the verse at each stop.

GRADING

Explore Tracks are not graded. A stop is done when the child has read the story, done the hands-on part and written a notebook entry.

Badges are earned every five stops, and a trail certificate is earned by finishing the ten stops of a trail.

A NOTE TO PARENTS

You do not need to be an expert. Let the child read the story, then look at the picture together and ask, “What do you notice?” and “How do we know that?” Each stop has a short *For families* note with background, sources and any facts that scientists still discuss or that could not be confirmed.

The Animals track reads creation as God’s good work and Scripture as true. Bible stops (the lion of Judah, the great whales of Genesis 1:21, the ostrich of Job 39, the locusts of Exodus 10, Jonah and Leviathan, Adam naming the animals) take the text as written in the King

James Version. Where a modern animal name is matched to a Hebrew word, such as Leviathan, the stop says plainly that Bible readers have understood it in more than one way.

Some stops describe how animals hunt and eat, as part of how God made them. These are told plainly and without gory detail. Stop F8 tells of the 1925 serum run to Nome, Alaska, during a diphtheria outbreak; the sickness is named but not dwelt on.

Safety: hands-on projects that use plaster, tools, food for birds or live creatures (bug hotels, frogs, insects) carry a safety line. Wash hands after handling soil, animals or animal signs, watch wild animals from a distance, leave nests and eggs where they are, and return any small creature to where it was found. Poison dart frogs, Gila monsters, venomous snakes and spiders are studied from books and pictures only.

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- 1.4 Bats
- 1.5 Horses
- 1.6 Wolves and Dogs
- 1.7 Bears
- 1.8 Cheetahs, the Fastest Runner
- 1.9 Kangaroos
- 1.10 The American Bison’s Comeback

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- 2.2 Owls: Hunters of the Night
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- 6.7 Long Journeys: Animals That Travel the World
- 6.8 Animals That Helped People: The 1925 Serum Run to Nome
- 6.9 Design Copied by Engineers
- 6.10 Adam Names the Animals

Trails may be done in any order.

ANIMALS TRAIL A: MAMMALS

The first trail of the Animals track visits ten of God's mammals: the lion and the Lion of Judah, the elephant, the "great whales" of Genesis 1:21, bats, horses, wolves and dogs, bears, the cheetah, the kangaroo and the American bison's comeback. Each stop has a true story with facts and numbers, a picture study of a public-domain painting or print, a map or diagram to make, a short notebook entry, practice questions, a game and a verse of Scripture.

This is the  **Ranger** level, written for ages 10 to 13. The student reads each stop alone, makes the map or diagram, writes a one-paragraph notebook entry and checks the practice answers with a parent. A stop takes about 25 to 35 minutes. Every stop stands by itself, so the stops may be done in any order, but the trail flows best from A1 to A10.

Five stops earn the **Mammal Ranger badge, part 1**, and ten stops earn part 2 and the **Trail A certificate**. The two badge quizzes at the end of the trail are optional; badges are earned by doing the stops.

BEFORE YOU BEGIN

- Read a page of about 500 words alone and tell back the main points.
- Use an atlas to find the continents, the oceans and the countries named in a stop, and read a map key and scale bar.

MASTERY CHECKLIST

- ☐ I can say what makes an animal a mammal and explain why whales and bats are mammals.
- ☐ I can describe at least one design feature and one number (size, speed or weight) for each animal on this trail.
- ☐ I can make a labeled map or diagram with a title, key and scale.
- ☐ I can connect each animal to a passage of Scripture and explain what it teaches.
- ☐ I can tell how people have harmed and helped animals, and explain stewardship from Genesis 2:15.

OPTIONAL BOOKS AND RESOURCES

- **Smithsonian's National Zoo and Conservation Biology Institute** (<https://nationalzoo.si.edu/animals>): Free animal fact pages and live animal cameras for elephants, lions, cheetahs and more.
- **NOAA Fisheries: Species Directory** (<https://www.fisheries.noaa.gov/species-directory>): Free fact sheets, sizes and range maps for blue, humpback, gray and sperm whales (Stop A3).

- **National Park Service: Yellowstone** (<https://www.nps.gov/yell>): Pages on Yellowstone's wolves, bears and bison for Stops A6, A7 and A10.
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free old natural history books, including Audubon's *Viviparous Quadrupeds of North America*, for copying plates into the Field Notebook.
- **Your public library** (<https://www.worldcat.org>): Find a world atlas and a mammal field guide (for example, a Peterson or National Audubon Society guide) at a nearby library.

1.1 LIONS AND THE LION OF JUDAH

OBJECTIVES

- Describe how a lion pride lives and hunts, with at least three facts and numbers.
- Map where lions live today and where they once lived, including the land of Israel.
- Explain why Jesus is called “the Lion of the tribe of Juda” (Revelation 5:5).

Warm-up. A male lion’s roar can be heard up to about 5 miles (8 kilometers) away. On a map of your town, find a place about 5 miles from your home. If a lion roared at your front door, could someone there hear it?

Video slot. Video coming. African lions: a pride hunting, cubs, and a male lion roaring; Asiatic lions of the Gir Forest. Search approved channels (BBC Earth, National Geographic, Smithsonian’s National Zoo, San Diego Zoo Wildlife Alliance); preview first.

KEY TERMS

pride

A family group of lions: related lionesses, their cubs and one or a few grown males.

predator

An animal that hunts and eats other animals (its prey).

territory

An area an animal or group lives in and defends against others of its kind.

retractable claws

Claws that can be pulled back into the paw to stay sharp and drawn out to grip.

Judah

The fourth son of Jacob and the tribe named for him; King David and, later, Jesus came from this tribe.

CORE IDEAS

The story. Just before dawn on the Serengeti plain of Tanzania, a male lion stands up in the long grass, fills his great chest and roars. The sound rolls out across the plain and can carry about five miles. Other lions answer from far away. The roar is a message: *this land belongs to our pride, so keep out*. Then, like most lions, he lies down again. Lions may rest 18 to 20 hours a day, saving their strength for short, powerful bursts of action.

The pride. Lions are the only big cats that truly live in groups. A pride is usually built around several related lionesses and their cubs, with one to a few grown males. Most prides have somewhere between a handful and twenty members, though some are larger. The lionesses do most of the hunting, and they work together: some circle wide around a herd of

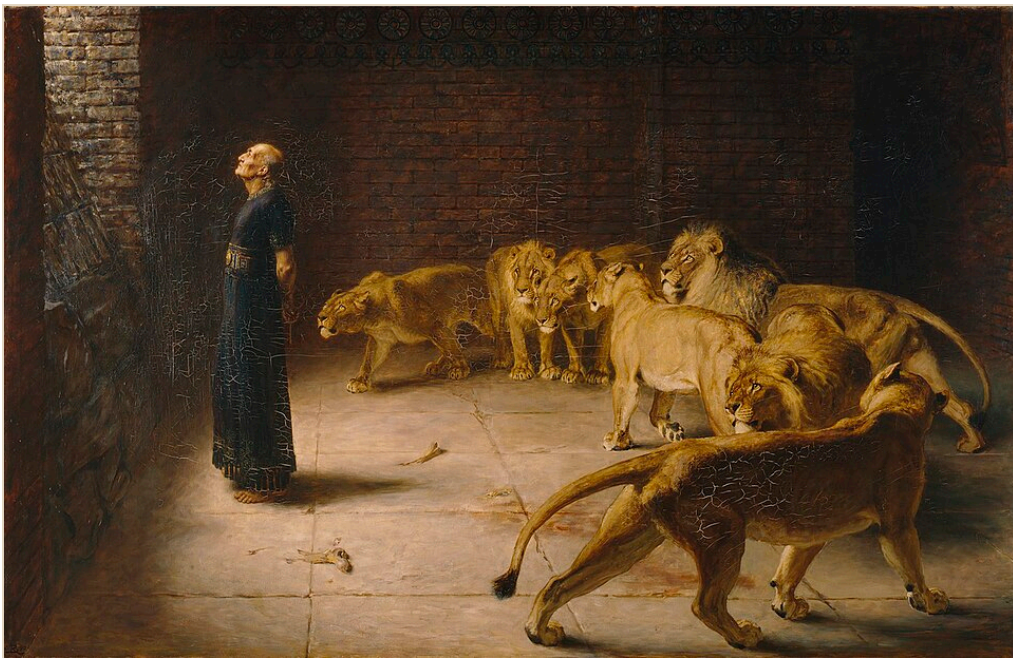
zebra or wildebeest while others wait low in the grass. The males guard the **territory**. A grown male weighs about 420 pounds (190 kg) and a lioness about 280 pounds (126 kg).

Designed to hunt. A lion is a **predator** made for the ambush. It cannot run far, but it can sprint close to 50 miles per hour for a short dash. Its **retractable claws** stay sharp inside its paws until it needs them. A mirror-like layer at the back of its eyes helps it see at night. Its tongue is covered with tiny, hooked spines, rough enough to scrape meat from a bone. The male's mane makes him look bigger and helps protect his neck.

Lions in the Bible lands. Lions once lived not only in Africa but across the Middle East and into India. The Bible mentions lions well over a hundred times. Samson tore apart a young lion with his hands (Judges 14:5-6); the shepherd boy David killed a lion and a bear to save his sheep (1 Samuel 17:34-36); and God shut the lions' mouths for Daniel (Daniel 6:22). Lions disappeared from the land of Israel around the time of the Crusades. Today about 20,000 to 25,000 wild lions live in Africa, and a small group of Asiatic lions, about 670 at the 2020 count, lives in the Gir Forest of India, where they are carefully protected.

The Lion of Judah. When old Jacob blessed his twelve sons, he called his son Judah "a lion's whelp" (Genesis 49:9). King David came from the tribe of Judah, and so, many centuries later, did Jesus. In Revelation 5, the apostle John weeps because no one can open God's sealed book. An elder tells him, "Weep not: behold, the Lion of the tribe of Juda... hath prevailed." Yet when John turns to look, he sees a Lamb that had been slain (Revelation 5:6). Christ is both: strong and kingly like a lion, gentle and self-giving like a lamb.

PICTURE STUDY



Daniel's Answer to the King, Briton Rivière, 1890 · Oil on canvas · Manchester Art Gallery, Manchester, England

Wikimedia Commons · Public domain

Briton Rivière was an English painter famous for his animals, especially lions and dogs. He studied real lions at the London Zoo. Here he shows Daniel the morning after he was thrown into the den, when King Darius calls down to ask whether his God has saved him (Daniel 6:20–22).

Look closely

- Count the lions. Are they attacking Daniel, or are they doing something else?
- Find where the light comes from. Where is Daniel looking?
- Look at Daniel’s hands. What does that tell you about how he came into the den?

Talk about it

1. Why do you think the painter hid Daniel’s face and showed us only his back?
2. Rivière painted the lions as real animals, not as monsters. How does that make the miracle feel more real?

HANDS-ON: MAP: WHERE LIONS LIVE, THEN AND NOW

Make a two-color map that shows how much of the world lions once roamed and where they still live.

You will need

- An outline map of Africa, the Middle East and India (print one, or trace from an atlas)
- Two colored pencils (for example, light yellow and dark orange)
- A pencil and a ruler
- An atlas or online map

Steps

1. Title your map “Where Lions Live, Then and Now.”
2. With the light color, shade the old range: almost all of Africa, plus the Middle East (including the land of Israel), Persia (Iran) and northern India.
3. With the dark color, shade the lions’ main range today: the savannas of eastern and southern Africa, with smaller patches in western and central Africa. Add a small dark dot on the west coast of India for the Gir Forest.
4. Label: Serengeti (Tanzania), Kruger National Park (South Africa), Gir Forest (India), Jerusalem, and the Mediterranean Sea.
5. Make a key showing what each color means, and add a compass rose.

Check your work

- My map has a title, a key and a compass rose.
- I shaded the old range and the range today in two different colors.
- I labeled at least five places, including the Gir Forest and Jerusalem.

FIELD NOTEBOOK

1. **Diagram.** Draw a lion from the side and label five parts God gave it for hunting: mane, eyes, retractable claws, rough tongue, strong shoulders.
2. **Notebook entry.** Write a paragraph (5–7 sentences): Why is Jesus called both “the Lion of the tribe of Judah” and the Lamb in Revelation 5? Use at least one fact about real lions in your answer.

Did you know? The four great bronze lions around Nelson’s Column in Trafalgar Square, London, were designed by the animal painter Sir Edwin Landseer and unveiled in 1867. A lion’s roar is so loud partly because of the special shape of its voice box; house cats can purr but cannot roar. A lion can eat about 15 pounds of meat at a time when food is plentiful, and a big male can eat even more.

Map or diagram. When you finish your map, compare the light and dark areas. About how much of the old range is still lion country? Write your estimate (for example, “about one-tenth”) under your key.

Goes deeper in. Life Science, the unit on animal groups and food chains (coming soon); Geography, the unit on Africa (coming soon); and Literature, where C. S. Lewis’s Aslan in *The Lion, the Witch and the Wardrobe* (1950) is a picture of the Lion of Judah.

For families. Weights and pride sizes vary by region; the figures are typical averages from zoo and wildlife sources. Wild African lion estimates range roughly from 20,000 to 25,000 (IUCN lists the species as Vulnerable). India’s 2020 Gir count was 674 Asiatic lions. Lions are thought to have vanished from the land of Israel around the 12th–14th centuries; the exact date is uncertain. The Rivièrè painting is listed by Manchester Art Gallery; no Commons file name is given here, so please search with the query provided. Revelation 5:5 in the KJV spells the tribe “Juda.”

PRACTICE

1. **EASY** Who does most of the hunting in a lion pride, and why do they hunt together?
2. **EASY** Name the three Bible heroes from this stop who met lions, and what happened to each.
3. **MEDIUM** A male lion weighs about 420 pounds and a lioness about 280 pounds. How much heavier is the male? About how many times as heavy is he?
4. **MEDIUM** Where do wild lions live outside Africa today, and about how many are there?
5. **CHALLENGE** In Revelation 5, John is told to look at a Lion but sees a Lamb. What do these two pictures together teach about Jesus?

Make it a game • Pride Hunt. One player is the “zebra” and stands in the middle of a yard. Three or four “lionesses” start at the edges. The lionesses may only creep forward while the zebra’s back is turned; if the zebra turns and sees a lioness moving, she must

go back to the edge. The lionesses must plan together (with signals, not words) to surround and tag the zebra. Then switch roles.

Scripture. “And one of the elders saith unto me, Weep not: behold, the Lion of the tribe of Juda, the Root of David, hath prevailed to open the book, and to loose the seven seals thereof.” (Revelation 5:5, KJV)

Jacob called Judah a lion’s whelp, and David’s kings came from Judah. Jesus, the Son of David, is the true Lion of Judah, the King who has won the victory.

Practice: answers

1. The lionesses. Working together, some circle around the prey while others wait in ambush, so they can catch animals faster or larger than one lion could alone.
2. Samson tore a young lion apart with his hands; David killed a lion (and a bear) to protect his sheep; Daniel was thrown into a lions’ den and God shut the lions’ mouths.
3. 140 pounds heavier; $420 \div 280 = 1.5$, so he is about one and a half times as heavy.
4. In the Gir Forest of western India; about 670 Asiatic lions were counted in 2020.
5. Jesus is the mighty King from the tribe of Judah who has conquered (the Lion), and He conquered by giving His life as a sacrifice (the Lamb). He is both strong and gentle.

1.2 ELEPHANTS

OBJECTIVES

- Tell the three kinds of elephants apart by ears, back and tusks.
- Explain how the trunk, ears and feet are designed for an elephant's life, with numbers.
- Use the “foot rule” to estimate an elephant's height from its footprint.

Warm-up. Hold your nose and upper lip together and imagine they were one long arm with no bones, strong enough to lift a log and gentle enough to pick up a peanut. That is an elephant's trunk. Try picking up a coin from the table using only two fingers held stiff, like the “fingers” on the tip of an African elephant's trunk.

Video slot. Video coming. Elephants using their trunks to drink, feed and greet; a herd led by its matriarch; African and Asian elephants compared. Search approved channels (BBC Earth, National Geographic, Smithsonian's National Zoo, San Diego Zoo Wildlife Alliance); preview first.

KEY TERMS

trunk

An elephant's long nose and upper lip joined together, with thousands of muscles and no bones.

tusk

A very long front tooth (an incisor) made of ivory that keeps growing all the elephant's life.

matriarch

The oldest female who leads an elephant herd.

herbivore

An animal that eats only plants.

infrasound

Sounds too low for people to hear; elephants use them to call to each other over long distances.

CORE IDEAS

The story. In 1637, in the busy Dutch city of Amsterdam, crowds paid to see an elephant named Hansken. She was an Asian elephant who had been brought by ship from Ceylon (now Sri Lanka). Hansken could wave a flag, fire a pistol and bow to her audience. The painter Rembrandt came to watch, and he drew her in black chalk, carefully following every fold and wrinkle of her skin. Hansken toured the cities of Europe for years and died in Florence, Italy, in 1655.

Three kinds. There are three living kinds of elephants. The **African bush elephant** is the largest land animal on earth: a big bull can stand 10 to 13 feet at the shoulder and weigh around 13,000 pounds (about 6 tons). The smaller **African forest elephant** lives in the rainforests of central Africa and has straighter tusks. The **Asian elephant**, like Hansken, has smaller, rounded ears and a humped back, and usually only the males grow large tusks.

A nose like no other. The **trunk** is the elephant's nose and upper lip together. It has no bones, but tens of thousands of small muscle bundles. With it an elephant breathes, smells water from far away, pulls down branches, sprays dust on its back, and sucks up several quarts of water at a time to squirt into its mouth. The **tusks** are long front teeth of ivory, used for digging, peeling bark and lifting. The great ears work like radiators: blood flows through the thin skin, and flapping the ears cools the elephant on hot days.

A life of eating and remembering. An elephant is a **herbivore** and may eat around 300 pounds of grass, leaves, bark and fruit a day, spending 16 hours or more feeding. Herds of mothers, aunts and calves are led by the **matriarch**, the oldest female, who remembers where to find water in a dry year. Elephants call to each other with deep rumbles, some too low for us to hear (**infrasound**), which travel for miles and may even be felt through the ground by sensitive pads in their feet. A mother carries her calf for about 22 months, the longest of any land animal, and the newborn weighs about 200 pounds.

Elephants in history and Scripture. In 218 B.C. the general Hannibal led about 37 war elephants over the Alps to attack Rome. King Solomon's ships brought him "gold, and silver, ivory, and apes, and peacocks" (1 Kings 10:22), and he made "a great throne of ivory" (1 Kings 10:18). Because ivory is so valuable, poachers killed many elephants in the 1970s and 1980s. In 1989 most nations agreed to ban the international ivory trade, and today rangers guard elephants in parks across Africa and Asia. Caring for these great creatures is part of the work God gave people in Genesis 2:15.

PICTURE STUDY



An Elephant (Hansken), Rembrandt van Rijn, 1637 · Black chalk on paper · British Museum, London
Wikimedia Commons · Public domain

Rembrandt is one of the greatest painters of the Dutch Golden Age. He made several drawings of Hansken, and he later put an elephant into one of his prints of Adam and Eve. This drawing shows how hard he worked to see an animal truly.

Look closely

- Look at the ears. Are they large and shaped like Africa, or small and rounded? What kind of elephant is Hansken?
- Find the lines Rembrandt used for wrinkles. Are they long and smooth or short and quick?
- Look at the feet. How did Rembrandt show the elephant's great weight?

Talk about it

1. Rembrandt drew Hansken from life, not from a book. How can you tell?
2. Why might an artist practice by drawing animals, which never hold still?

HANDS-ON: DIAGRAM AND FOOTPRINT: HOW TALL IS THAT ELEPHANT?

Elephant keepers and scientists use a handy rule: twice the distance around an elephant's front foot is about equal to its height at the shoulder. You will draw a labeled diagram and test the rule with a life-size footprint.

You will need

- Sidewalk chalk or a large sheet of paper

- A piece of string about 6 feet long
- A tape measure
- Pencil and colored pencils

Steps

1. **Diagram.** In your notebook, draw an African elephant and an Asian elephant side by side. Label on each: ear, trunk, tusk, back, forehead. Add arrows showing the differences: big ears shaped like Africa vs. small rounded ears; dipped back vs. humped back; two “fingers” on the trunk tip vs. one.
2. **Footprint.** Outside, draw a circle on the pavement about 18 inches across, the size of a big African elephant’s front foot.
3. Lay the string around the edge of the circle and measure it. (It should be about 56 inches, or 4 feet 8 inches.)
4. Multiply by 2. That is the elephant’s height at the shoulder. Stand next to your number on a wall. How many of you would it take to reach that high?

Check your work

- My diagram shows both kinds of elephants with five labels each.
- I measured the footprint and multiplied by two.
- I can explain the foot rule in my own words.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph (5–7 sentences) titled “Ten Jobs for a Trunk.” Name as many uses of the trunk as you can and tell which one you think is most amazing, and why.
2. Copy a few lines of Rembrandt’s wrinkles in your notebook, practicing short, quick chalk or pencil strokes.

Did you know? Elephants cannot jump; at least one foot is always on the ground. They walk on tiptoe: a thick pad of fat and tissue behind the toe bones works like a cushioned heel. An elephant’s molars are as big as bricks, and it grows six sets in its lifetime, each one moving forward as the old one wears out. The famous circus elephant Jumbo, bought from the London Zoo by P. T. Barnum in 1882, gave the English language the word “jumbo.”

Goes deeper in. Life Science, the unit on mammals and their design (coming soon); Geography, the units on Africa and South Asia (coming soon); and History, Hannibal and the Punic Wars (coming soon).

For families. Weights, food and water figures are typical estimates from zoo and wildlife sources and vary widely. Trunk muscle counts in popular sources range from about 40,000 to 150,000 “muscle units”; the stop says “tens of thousands.” The foot-circumference rule is an approximation long used in the field. Hansken’s dates (arrival in

the Netherlands in the 1630s; death in Florence, 1655) follow standard accounts; Rembrandt drew several elephant studies in 1637, held in the British Museum and the Albertina, Vienna. The 1989 CITES ivory listing is stated simply; nations still debate limited sales.

PRACTICE

1. **EASY** Name the three living kinds of elephants. Which is the largest land animal?
2. **EASY** What is a tusk made of, and what kind of tooth is it?
3. **MEDIUM** Why does an elephant flap its ears on a hot day?
4. **MEDIUM** An Asian elephant's front foot measures 50 inches around. Using the foot rule, about how tall is it at the shoulder, in inches and in feet?
5. **CHALLENGE** An elephant eats about 300 pounds of food a day. About how many pounds is that in one week? In a 365-day year, about how many tons (2,000 pounds = 1 ton)?

Make it a game • Matriarch, Lead the Way. The oldest player is the matriarch and holds a “map” only she has seen: where the “water hole” (a cup) is hidden in the yard. The rest of the herd lines up behind her holding the shoulders of the player in front, eyes closed or looking down. The matriarch leads them by rumbling signals only: one low hum means turn left, two means turn right, a long hum means stop. When the herd reaches the water, a new matriarch hides it.

Scripture. “Behold now behemoth, which I made with thee; he eateth grass as an ox.” (Job 40:15, KJV)

God points Job to a huge, strong creature He made. Bible readers have long wondered what behemoth was: an elephant, a hippopotamus, or a great beast now gone. Either way, God made it, and it shows His power.

Practice: answers

1. African bush elephant, African forest elephant and Asian elephant. The African bush elephant is the largest.
2. Ivory; it is a very long front tooth (an incisor).
3. Blood flows through the thin ears; flapping them cools the blood, which helps cool the whole elephant.
4. $50 \times 2 = 100$ inches, which is 8 feet 4 inches (about $8\frac{1}{3}$ feet).
5. $300 \times 7 = 2,100$ pounds a week. $300 \times 365 = 109,500$ pounds a year, which is about 55 tons.

1.3 WHALES, THE “GREAT WHALES” OF GENESIS 1:21

OBJECTIVES

- Give four reasons a whale is a mammal and not a fish.
- Compare baleen whales and toothed whales, with an example of each.
- Make a scale drawing that compares a blue whale with a school bus and a person.

Warm-up. Take a deep breath and hold it as long as you comfortably can while someone times you. A sperm whale can hold its breath for an hour or more on a single dive. What do you think its body must do differently from yours?

Video slot. Video coming. Blue whales feeding, humpback whales breaching and singing, sperm whales diving. Search approved channels (BBC Earth, National Geographic, NOAA Fisheries, Monterey Bay Aquarium); preview first.

KEY TERMS

mammal

A warm-blooded animal that breathes air, has hair at some time in its life and feeds its young on milk.

baleen

Long, fringed plates of keratin (the stuff of fingernails) in some whales’ mouths, used to strain small food from the water.

blowhole

The nostril on top of a whale’s head through which it breathes.

blubber

A thick layer of fat under a whale’s skin that keeps it warm and stores energy.

krill

Small, shrimp-like animals that swim in huge swarms; the main food of many baleen whales.

CORE IDEAS

“Great whales.” On the fifth day of creation, “God created great whales, and every living creature that moveth, which the waters brought forth abundantly, after their kind” (Genesis 1:21). The Hebrew word, *tannin*, means great sea creatures, and the King James translators fittingly chose “whales,” the largest creatures in the sea. God made them on purpose, and He “saw that it was good.”

Mammals of the sea. Whales live in the water, but they are not fish. They are **mammals**. They breathe air through a **blowhole** on top of the head and must come up to breathe. They are warm-blooded and kept warm by **blubber**, which in the Arctic bowhead whale can be

about a foot and a half thick. Mothers give birth to live calves and nurse them with rich milk. Whales even have a few bristly hairs, especially when young. And a whale swims by moving its tail flukes up and down, while a fish swings its tail from side to side.

Two great groups. Baleen whales, like the blue, humpback and gray whales, have no teeth. Instead, hundreds of fringed plates hang from the upper jaw. The whale gulps a huge mouthful of seawater, pushes it out through the baleen with its tongue, and swallows the **krill** and small fish left behind. Toothed whales, like the sperm whale and the orca (and their smaller cousins, the dolphins), catch fish and squid one at a time, finding them with clicks of sound.

The largest animal ever known. The blue whale can grow to about 100 feet (30 meters) long and weigh around 150 tons or more. Its heart weighs about 400 pounds, and a calf may gain about 200 pounds a day on its mother's milk. Other whales amaze in other ways: male humpbacks sing long, repeating songs that can last for hours; gray whales migrate 10,000 miles or more every year between Alaska and Mexico; and sperm whales dive more than a mile deep to hunt squid in the dark.

Whaling and wise care. In the 1700s and 1800s, whale oil lit lamps and oiled machines, and whaling ships sailed from towns like Nantucket and New Bedford, Massachusetts. Herman Melville's novel *Moby-Dick* (1851) grew out of that world. Later, factory ships hunted so many whales that some kinds became very rare. In 1986 most whaling nations agreed to pause commercial whaling. Since then, humpback whales in many oceans have grown back strongly, a good example of careful stewardship of God's creatures.

PICTURE STUDY



The Sperm Whale Stranded at Katwijk on 3 February 1598, Jacob Matham, after a drawing by Hendrick Goltzius, 1598 · Engraving · Staatliche Graphische Sammlung, Munich (impressions also in the Rijksmuseum, Amsterdam, and other collections)
Wikimedia Commons · Public domain

In February 1598 a sperm whale washed up on the Dutch beach at Berckhey, between Katwijk and Scheveningen. Crowds came to see it, including the artist Hendrick Goltzius, who drew it on the spot. His friend Jacob Matham turned the drawing into this engraving so that many copies could be printed.

Look closely

- Find the man measuring the whale. What do you think he was trying to learn?
- Look at the whale's head and lower jaw. Is this a baleen whale or a toothed whale?
- Look at the crowds, horses and carriages. How do you know this was big news?

Talk about it

1. How is an engraving like this one similar to a newspaper photograph today?
2. In 1598 few people had ever seen a whale. Why might they have walked a long way to see this one?

HANDS-ON: SCALE DRAWING: THE BLUE WHALE AND YOU

A scale drawing shrinks something big by the same amount in every direction. You will draw a blue whale, a school bus and a person on the same scale.

You will need

- A long strip of paper at least 12 inches long (tape two sheets together)
- A ruler and a pencil
- Colored pencils
- Optional: a 100-foot tape measure or a long rope for outdoors

Steps

1. Write the scale at the top: **1 inch = 10 feet.**
2. Draw a straight line 10 inches long. That is a 100-foot blue whale. Sketch the whale's long, slim body around the line and label: blowhole, flippers, flukes, baleen, throat pleats.
3. Underneath, draw a school bus 4 inches long (40 feet) and a person about $\frac{1}{2}$ inch tall (5 feet). Label each with its real size.
4. Add a title, "Great Whales: Genesis 1:21," and a key that repeats the scale.
5. Optional outdoors: measure 100 feet with a tape or steps (about 40 grown-up steps) and stand at each end.

Check your work

- My drawing uses one scale for everything and the scale is written on it.
- The whale is about 10 inches, the bus 4 inches and the person $\frac{1}{2}$ inch.
- I labeled five parts of the whale.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph (5–7 sentences): "A Whale Is Not a Fish." Give at least four reasons, and end with one sentence about Genesis 1:21.
2. Draw a small chart with two columns, "Baleen whales" and "Toothed whales," and list at least two whales under each with how they eat.

Did you know? A whale's blow is not a fountain of seawater; it is warm, moist breath that turns to mist in the air, like your breath on a cold day. Whale watchers can name a species by the shape of its blow: a blue whale's is tall and straight, a right whale's is V-shaped. Bowhead whales may live more than 150 years; some old harpoon points from the 1800s have been found in living bowheads.

Map or diagram. On a map of the Pacific coast of North America, draw the gray whale's path from the cold feeding waters of the Bering Sea off Alaska to the warm lagoons of Baja California in Mexico, where calves are born. Label both ends and write "about 5,000 miles each way."

Goes deeper in. Life Science, the unit on mammals and the ocean (coming soon); Literature, for *Moby-Dick* in a later year; and Trail D (Ocean Life) of this track, including Stop D10, "Jonah and Leviathan."

For families. Blue whale sizes are given as commonly reported maximums; weights near 150–190 tons appear in NOAA and museum sources. Bowhead lifespans are estimated from eye-lens chemistry and old harpoon points found in living whales. The 1986 date is when the International Whaling Commission’s moratorium on commercial whaling took effect; a few nations still whale under objections or permits. The 1598 engraving is widely reproduced; impressions are held by the Rijksmuseum and other print rooms. The whale’s identity as a sperm whale follows the museum descriptions. No Commons file name is given; search with the query provided.

PRACTICE

1. **EASY** Give four ways a whale is a mammal and not a fish.
2. **EASY** What is baleen, and what does a whale use it for?
3. **MEDIUM** Is a sperm whale a baleen whale or a toothed whale? How does it find its food in the dark deep sea?
4. **MEDIUM** A blue whale is 100 feet long. A school bus is 40 feet long. How many buses long is the whale?
5. **CHALLENGE** A blue whale calf gains about 200 pounds a day. If it keeps that pace, how much would it gain in a 30-day month? How many tons is that (2,000 pounds = 1 ton)?

Make it a game • Baleen or Teeth?. Scatter dried rice (krill) and a few dried beans (fish) in a shallow pan of water. Player one is a baleen whale: scoop with a cup, then pour the water out through a comb or fork held across the cup and count the rice caught. Player two is a toothed whale: use tweezers to pick up beans one at a time for 30 seconds. Compare how each kind of whale is designed for its food.

Scripture. “And God created great whales, and every living creature that moveth, which the waters brought forth abundantly, after their kind, and every winged fowl after his kind: and God saw that it was good.” (Genesis 1:21, KJV)

The largest animals ever known were made on purpose, on the fifth day, and God called them good. Every whale song and every spout of breath is part of His good creation.

Practice: answers

1. Any four: it breathes air through a blowhole; it is warm-blooded; it gives birth to live young; it feeds its young milk; it has some hair; its tail moves up and down, not side to side.
2. Fringed plates of keratin hanging from the upper jaw; the whale uses them to strain krill and small fish out of seawater.
3. A toothed whale. It finds squid and fish by sending out clicks of sound and listening for echoes.
4. $100 \div 40 = 2.5$ buses.
5. $200 \times 30 = 6,000$ pounds, which is 3 tons.

1.4 BATS

OBJECTIVES

- Explain why a bat is a mammal and how its wing is built like a hand.
- Compare insect-eating bats and fruit bats, with sizes and examples.
- Describe two ways bats help people and one way people are helping bats.

Warm-up. Spread your fingers wide and imagine a thin, stretchy skin joining them all the way to your ankles. Now flap. You have just made a bat wing! The bat's scientific group is called Chiroptera, which means "hand-wing."

Video slot. Video coming. Mexican free-tailed bats leaving the Congress Avenue Bridge in Austin or Bracken Cave; fruit bats and flying foxes; a bat wing in slow motion. Search approved channels (National Geographic, BBC Earth, Bat Conservation International, U.S. Fish and Wildlife Service); preview first.

KEY TERMS

Chiroptera

The scientific name for the bat group; it means "hand-wing."

membrane

A thin, stretchy sheet of skin; a bat's wing membrane stretches between its long finger bones.

nocturnal

Active at night and resting during the day.

echolocation

Finding things by making sounds and listening to the echoes.

pollinate

To carry pollen from one flower to another so the plant can make seeds and fruit.

CORE IDEAS

The story. On a summer evening in Austin, Texas, hundreds of people gather on the Congress Avenue Bridge and along the river below. As the sun sets, a dark ribbon begins to pour out from cracks under the bridge: up to about 1.5 million Mexican free-tailed bats, streaming out to hunt. They will fly high and far through the night, eating moths and other insects over the farm fields. Not far away, at Bracken Cave, an even larger colony of perhaps 15 million or more bats lives in a single cave, the largest bat colony known.

A flying mammal. Bats are **mammals**: they have fur, are warm-blooded and nurse their pups with milk. They are the only mammals that truly fly; "flying" squirrels only glide. A bat's wing is built like a hand. Its arm and four very long finger bones hold up a thin **membrane**

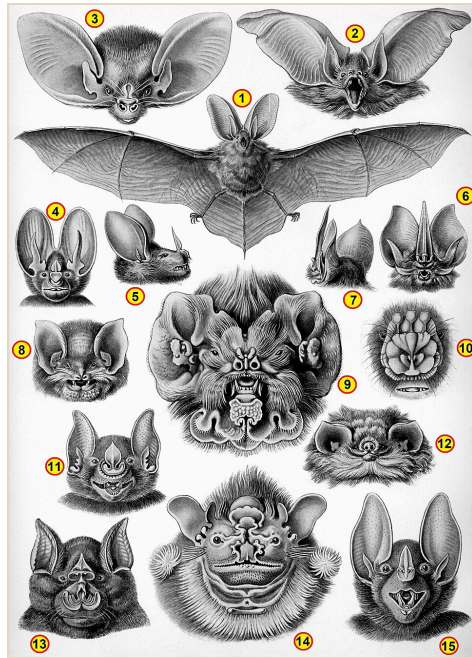
of skin, like the cloth of an umbrella over its ribs. The short thumb, with a hooked claw, stays free for climbing. Because the bat can bend each finger, it can change the shape of its wing in flight and turn more sharply than most birds.

Many kinds. There are more than 1,400 kinds of bats, about one out of every five kinds of mammals. The smallest, the bumblebee bat of Thailand, weighs about 2 grams, less than a penny. The largest, the flying foxes of Asia and the Pacific islands, can have wings that stretch 5 feet or more. Most small bats are **nocturnal** insect eaters that find their prey by **echolocation** (Trail F has a whole stop on it). Most fruit bats have large eyes and a keen sense of smell instead. When a bat rests, it hangs upside down; its weight pulls tendons that lock its toes closed, so it can sleep without effort.

Helpers in the dark. One little brown bat can catch hundreds of insects in an hour. Scientists estimate that bats save American farmers billions of dollars a year by eating crop pests. Fruit bats and nectar bats **pollinate** flowers and spread seeds; the agave plant of Mexico and many rainforest trees depend on them. Only three kinds of bats, all in Latin America, are vampire bats that lap small amounts of blood, mostly from cattle and birds.

Stewardship. In 2006 a cave explorer in New York photographed bats with a strange white fuzz on their noses. It was a fungus, now called white-nose syndrome, and it has killed millions of hibernating bats in North America. People are helping by closing some caves in winter, cleaning their gear between caves and building bat houses. Moses listed the bat among the flying creatures Israel was not to eat (Leviticus 11:19); the Hebrew word for “fowl” there simply means a creature that flies. The Psalmist says of all God’s creatures, “in wisdom hast thou made them all.”

PICTURE STUDY



*Chiroptera (Bats), Plate 67 of Art Forms in Nature, Ernst Haeckel, 1904 · Color lithograph · From the book Kunstformen der Natur (Art Forms in Nature), Leipzig
Wikimedia Commons · Public domain*

Ernst Haeckel was a German scientist and artist who published a famous book of nature plates. On this page he gathered the faces of many bats. Look closely: the strange leaf-shaped noses and huge folded ears are tools that help many bats send and catch sound.

Look closely

- Find a bat with a “nose leaf,” a flap of skin standing up on its nose.
- Compare the ears. Which bat has the biggest ears for the size of its head?
- Find the bat with spread wings. Can you see the long finger bones?

Talk about it

1. Why do you think Haeckel arranged the bats in a pattern, almost like a decoration?
2. If these bats use sound to find food, why might their ears and noses look so different from one another?

HANDS-ON: DIAGRAM: YOUR HAND AND A BAT’S WING

See for yourself how a bat’s wing is made from the same parts as your hand and arm, stretched long.

You will need

- A sheet of paper and a pencil
- A ruler

- Colored pencils

Steps

1. On the left side of the page, trace your hand and draw your forearm. Label: upper arm, forearm, wrist, thumb, fingers 2, 3, 4 and 5.
2. On the right side, draw a bat wing seen from above. Use the same parts, but make the fingers about as long as the whole forearm, and spread them like the ribs of an umbrella. Keep the thumb short, with a claw.
3. Shade the membrane between the fingers, and from the last finger down to the bat's leg.
4. Use the same color for matching bones on both drawings (for example, all thumbs in red).
5. Title the page "Hand-Wing: Chiroptera" and add one sentence explaining why a wing built like a hand can turn so well.

Check your work

- Both drawings have the same labeled parts.
- Matching bones are the same color.
- I wrote a sentence explaining my diagram.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph (5–7 sentences): "Why Farmers Should Thank Bats." Use at least two facts or numbers from the stop.
2. If you live where bats fly, watch the sky for 15 minutes after sunset on a warm evening. Record the date, time, place and how many bats you saw.

Did you know? Many bats live a surprisingly long time for their size: some small brown bats have lived more than 30 years. A mother Mexican free-tailed bat can find her own pup among thousands in a crowded cave by its voice and smell. Bats' legs are turned around at the hip so their knees bend backward, which helps them hang and crawl.

Map or diagram. On a map of Texas, mark Austin (the Congress Avenue Bridge) and San Antonio (Bracken Cave is just north of it). Then draw an arrow south to Mexico, where these bats spend the winter.

Goes deeper in. Life Science, the unit on mammals and flight (coming soon); Gardening & Animals, for pollinators and building a bat house; and Trail F of this track, Stop F1 "Echolocation."

For families. Colony counts are estimates from Bat Conservation International and Texas sources and change from year to year. The farm-value figure comes from a 2011 study in *Science* (Boyles et al.), which gave a wide range; the stop says only "billions." White-nose syndrome was first photographed in New York in 2006 (U.S. Fish and Wildlife Service).

Haeckel was a leading Darwinist of his day whose embryo drawings were criticized even in his lifetime; his plate is used here only for its careful, beautiful drawings. If you build a bat house, an adult should do any cutting, and bats should never be handled bare-handed because a few carry rabies.

PRACTICE

1. **EASY** What does “Chiroptera” mean, and why is it a good name for bats?
2. **EASY** Name two ways bats help people.
3. **MEDIUM** How can a bat sleep hanging upside down without getting tired?
4. **MEDIUM** There are about 1,400 kinds of bats, and they make up about one-fifth of all mammal kinds. About how many kinds of mammals are there?
5. **CHALLENGE** A little brown bat eats about 600 insects in one hour. If it hunts for 3 hours a night for a 30-night month, how many insects is that?

Make it a game • Bat and Moth. One player is the bat and wears a blindfold inside a circle of other players. The bat calls “Bat!” and every moth must answer “Moth!” right away. Listening for the answers, the bat tries to tag a moth. Moths must stay inside the circle. Play on soft grass, with a grown-up watching so the bat stays safe.

Scripture. “O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches.” (Psalm 104:24, KJV)

“Manifold” means many and varied. A furry animal that flies on its hands, hangs by locking toes and plants rainforests by night is one more sign of God’s wisdom.

Practice: answers

1. “Hand-wing.” A bat’s wing is made of its arm and very long finger bones with skin stretched between them.
2. Any two: they eat huge numbers of insect pests; they pollinate flowers such as agave; they spread the seeds of fruit trees.
3. Its own weight pulls on tendons that lock its toes closed, so it holds on without using its muscles.
4. $1,400 \times 5 =$ about 7,000 kinds of mammals.
5. $600 \times 3 = 1,800$ a night; $1,800 \times 30 = 54,000$ insects in a month.

1.5 HORSES

OBJECTIVES

- Label the main points of a horse and measure height in hands.
- Explain three ways a horse is designed for running and watching for danger.
- Tell how horses changed life in the Americas after 1493.

Warm-up. Horses are measured in “hands.” One hand is 4 inches, about the width of a grown man’s hand. Lay your hand flat against a wall, starting at the floor, and count hands up to the top of your shoulder. How many hands tall are you?

Video slot. Video coming. Horse breeds compared (Arabian, Thoroughbred, Clydesdale, Shetland pony); how a horse moves at walk, trot, canter and gallop in slow motion; a farrier at work. Search approved channels (Smithsonian, National Geographic, the Kentucky Horse Park, university equine programs); preview first.

KEY TERMS

hand

A unit for measuring horses: 4 inches. 15.2 hands means 15 hands and 2 inches.

withers

The highest point of a horse’s back, at the base of the neck, where its height is measured.

hoof

The hard, horny covering of a horse’s foot, made of keratin like your fingernails.

breed

A group of animals within one kind, bred by people to share certain looks and abilities.

farrier

A craftsman who trims horses’ hooves and fits horseshoes.

CORE IDEAS

The war horse. When God answered Job out of the whirlwind, He asked, “Hast thou given the horse strength? hast thou clothed his neck with thunder?” (Job 39:19). He described a horse that “paweth in the valley,” “mocketh at fear” and “smelleth the battle afar off.” Job had to admit that only God could design such a creature. For thousands of years horses have carried people, pulled plows and wagons, and gone with soldiers into battle.

Built to run and to watch. A horse stands on a single toe on each leg, capped with a hard **hoof** that keeps growing, so it must be trimmed by a **farrier** every six to eight weeks. Long legs with light lower bones let it run fast. A system of tendons and ligaments called the “stay apparatus” locks its legs, so a horse can doze standing up. Its eyes are the largest of any land mammal and set on the sides of its head, so it can see almost all the way around, with

blind spots only right in front of its nose and directly behind it. A horse can breathe only through its nose, never its mouth.

One kind, many breeds. All horses belong to one kind, and people have bred them into hundreds of **breeds**. The Arabian is small, tough and swift. Every Thoroughbred racehorse traces back to three stallions brought to England around 1700: the Byerley Turk, the Darley Arabian and the Godolphin Arabian. Giant draft horses like the Shire and the Clydesdale can stand 18 hands and weigh over a ton, while Shetland ponies may be under 11 hands. Horses can even be crossed with donkeys to make mules, a sign that they are close relatives.

Horses come to the Americas. When Columbus returned to the New World in 1493, he brought horses, and in 1519 Hernán Cortés landed in Mexico with sixteen. Over the next two centuries, horses spread north. By the 1700s the Comanche, Lakota and other Plains nations had become some of the finest riders in the world, hunting bison on horseback. In 1860–1861 the Pony Express carried mail about 1,900 miles from Missouri to California in about ten days, with riders changing to fresh horses at stations every 10 to 15 miles.

Partners in work. Until tractors and trucks took over in the 1900s, horses and mules did much of America's farm work; there were more than 20 million of them in the country around 1915. A horse is strong, but it is also a prey animal that startles easily, and it trusts people who treat it calmly and kindly. The Bible reminds us where real safety lies: "The horse is prepared against the day of battle: but safety is of the LORD" (Proverbs 21:31).

PICTURE STUDY



The Horse Fair, Rosa Bonheur, 1852–1855 · Oil on canvas · The Metropolitan Museum of Art, New York
Wikimedia Commons · Public domain

Rosa Bonheur was a French painter who studied animals with great care. For about a year and a half she went twice a week to the horse market in Paris, near the Salpêtrière hospital,

to sketch the big Percheron draft horses being shown for sale. The finished painting is huge, about 8 feet tall and more than 16 feet wide, and it made her famous in Europe and America.

Look closely

- Find a horse that is rearing up. How is its handler trying to control it?
- Look at the horses' muscles and legs. Are these racehorses or heavy draft horses?
- Follow the path of the horses around the picture. Which way are they moving?

Talk about it

1. Why do you think Bonheur went back to the market so many times instead of painting from memory?
2. What do the handlers' poses tell you about how strong these horses are?

Safety first. Around real horses, always have an experienced adult with you. Approach a horse from the side where it can see you, speak calmly, and never stand directly behind a horse, where it cannot see you and might kick. Keep your feet back from its hooves, and wear a helmet if you ride.

HANDS-ON: DIAGRAM: THE POINTS OF THE HORSE

Horsemen call the parts of a horse its "points." Learning them helps you read about horses, talk with riders and see a horse the way an artist does.

You will need

- Paper and a pencil
- Colored pencils
- A picture of a horse standing sideways (from a book or online)
- A tape measure

Steps

1. Draw a horse standing sideways, copying the outline from your picture.
2. Label at least ten points: muzzle, forelock, mane, withers, back, croup, tail, hock, fetlock, hoof, knee, shoulder.
3. Draw a straight line from the ground up to the withers and write "height measured here."
4. Add a scale bar beside the horse marked in hands from 0 to 16.
5. Measure a family member's height in inches, divide by 4 and write it in hands, using the horseman's way (for example, 58 inches = 14 hands 2 inches, written 14.2).

Check your work

- My horse has at least ten labeled points.
- I showed where a horse is measured.

- I wrote one person's height correctly in hands.

FIELD NOTEBOOK

1. **Notebook entry.** Read Job 39:19–25. Then write a paragraph (5–7 sentences) describing the war horse in your own words, and tell which phrase you like best and why.
2. Copy one horse from Rosa Bonheur's painting in pencil, paying attention to the curve of its neck.

Did you know? A horse's teeth keep growing through much of its life and wear down as it chews tough grass; a horse dentist (an equine dentist) files sharp edges smooth. Horses cannot vomit, so they must be fed carefully. George Stubbs, an English painter, spent about eighteen months studying horse anatomy before painting his life-size *Whistlejacket* (about 1762), now in the National Gallery, London.

Map or diagram. On a map of the United States, draw the Pony Express route from St. Joseph, Missouri, to Sacramento, California. Mark a few towns along the way (Fort Kearny, Fort Laramie, Salt Lake City, Carson City) and write "about 1,900 miles, about 10 days."

Goes deeper in. Gardening & Animals, the unit on large animals and horse care (coming soon); History, the Spanish in the Americas and the Pony Express (coming soon); and Art, for Rosa Bonheur and George Stubbs.

For families. Columbus brought horses on his second voyage (1493); Bernal Díaz, who marched with Cortés, listed sixteen horses in 1519. The three Thoroughbred foundation sires were imported to England between about 1689 and 1730. The Pony Express ran from April 1860 to October 1861. U.S. horse and mule numbers peaked at roughly 26 million around 1915–1920 (USDA); the stop says "more than 20 million." *The Horse Fair* was given to the Met by Cornelius Vanderbilt in 1887. No Commons file name is given; search with the query provided. Real horse visits need adult supervision; see the safety line.

PRACTICE

1. **EASY** How many inches are in one hand? How tall in inches is a 16-hand horse?
2. **EASY** Where on a horse is its height measured?
3. **MEDIUM** A horse is 15.2 hands. How many inches tall is it? (Careful: .2 means 2 inches, not two-tenths.)
4. **MEDIUM** Name two ways a horse is designed to watch for danger or rest safely.
5. **CHALLENGE** The Pony Express route was about 1,900 miles, and riders changed horses about every 12 miles. About how many horse changes did one letter need? If the trip took 10 days, about how many miles a day did the mail travel?

Make it a game · Walk, Trot, Canter, Gallop. The caller names a gait and players move in that rhythm across the yard: walk (four slow beats), trot (two beats, a bouncy jog), canter (three beats, a rocking skip), gallop (four quick beats, a run). When the caller says “Whoa!”, everyone must stop still. Anyone who moves is out until the next round.

Scripture. “Hast thou given the horse strength? hast thou clothed his neck with thunder?” (Job 39:19, KJV)

God asked Job questions only the Creator could answer. The horse’s power, speed and courage are His gifts, and they remind us to be humble before Him.

Practice: answers

1. 4 inches; $16 \times 4 = 64$ inches.
2. At the withers, the highest point of the back at the base of the neck.
3. $15 \times 4 = 60$, plus 2 = 62 inches.
4. Any two: huge eyes on the sides of its head that see almost all the way around; the stay apparatus that lets it doze standing up, ready to run; long legs built for speed.
5. $1,900 \div 12 \approx 158$ changes (about 160). $1,900 \div 10 = 190$ miles a day.

1.6 WOLVES AND DOGS

OBJECTIVES

- Describe how a wolf pack lives, with at least three facts and numbers.
- Explain how wolves and dogs belong to one created kind, and how people bred many dog breeds.
- Map the return of wolves to Yellowstone in 1995–1996.

Warm-up. Close your eyes while someone holds a slice of orange, a bar of soap and a pencil under your nose one at a time. Can you name each by smell? A dog's nose has roughly 50 times as many smell receptors as yours. What might a dog smell in this room that you cannot?

Video slot. Video coming. Gray wolves in Yellowstone: a pack traveling, howling and raising pups; working dogs herding sheep and guarding flocks; search-and-rescue dogs. Search approved channels (National Park Service / Yellowstone, National Geographic, BBC Earth, Smithsonian); preview first.

KEY TERMS

pack

A family group of wolves, usually a mother and father and their young of the past few years.

domestic

Tamed and bred by people to live and work with them, like dogs, horses and sheep.

kind

The Bible's word for the created groups of living things (Genesis 1); animals of one kind can often breed with one another.

selective breeding

Choosing which animals become parents in order to bring out certain traits in their young.

reintroduction

Bringing an animal back to a place where it once lived but had disappeared.

CORE IDEAS

The story. In January 1995, trucks carrying metal crates drove through the snow into Yellowstone National Park. Inside were gray wolves caught in Alberta, Canada. No wolf pack had lived in Yellowstone for about seventy years; the last ones had been killed by the 1920s. Fourteen wolves came that winter and seventeen more the next. They were kept in large pens for a few weeks to settle, then the gates were opened. Today about a hundred wolves in roughly ten packs live in the park, and visitors with spotting scopes watch them every day.

The wolf pack. The gray wolf is the largest wild member of the dog family. A big male may weigh 100 pounds or more. A **pack** is usually a family: a mother and father with their pups and the young of the past year or two, often five to ten wolves in all. They hunt elk, deer and bison together, travel 20 or 30 miles in a day, and howl to keep in touch across the miles. A hungry wolf can eat 20 pounds of meat at one meal and then go days without eating.

One kind. Dogs, wolves, coyotes and dingoes can all breed with one another, a strong sign that they belong to one created **kind**. People have kept **domestic** dogs as far back as written history goes; Job speaks of “the dogs of my flock” (Job 30:1). By **selective breeding**, choosing which dogs would be parents, people brought out the variety God had placed within the dog kind. The American Kennel Club recognizes about 200 breeds, from the Chihuahua at around 5 pounds to the mastiff at over 150. All of them are still dogs.

Noses and jobs. A dog’s nose may have around 300 million smell receptors, compared with about 6 million in ours, and a large part of its brain works on smells. Bloodhounds can follow a trail that is days old. Border collies herd sheep with a look and a crouch. In 1929 the first American guide-dog school, The Seeing Eye, was founded to train dogs to lead blind people. In the Swiss Alps, a Saint Bernard named Barry, who worked at the Great St. Bernard Hospice from 1800 to 1812, was credited with saving more than 40 travelers lost in the snow.

Shepherds and wolves. In the Bible the wolf is the danger to the flock, and the good shepherd stands between them (John 10:11-12). Ranchers near Yellowstone still lose some cattle and sheep to wolves, and people disagree about how many wolves the land should hold. Many ranchers now use guard dogs, lights and fences to keep wolves away. Isaiah looked ahead to a day when “the wolf also shall dwell with the lamb” (Isaiah 11:6), and every faithful sheepdog lying beside the sheep is a small picture of that peace.

PICTURE STUDY



Dignity and Impudence, Sir Edwin Landseer, 1839 · Oil on canvas · Tate Britain, London
Wikimedia Commons · Public domain

Edwin Landseer was the most famous animal painter in Victorian England, and Queen Victoria herself asked him to paint her dogs. In this picture he shows two very different dogs sharing one kennel: a solemn bloodhound and a lively little West Highland terrier. The title tells you which one is which.

Look closely

- Compare the two dogs' eyes. What feeling does each show?
- Look at the bloodhound's long ears and loose skin. What job was this breed made for?
- Find the chain and the kennel. Where do you think these dogs lived?

Talk about it

1. Which dog is "Dignity" and which is "Impudence"? How did Landseer show it without words?
2. Both are the same kind of animal. What does this painting show about how many breeds people have made from the dog kind?

HANDS-ON: MAP AND CHART: WOLVES COME HOME

Make a map that tells the story of the Yellowstone reintroduction and a chart of the dog kind.

You will need

- An outline map of western Canada and the western United States
- Colored pencils and a ruler

- A second sheet of paper for the chart

Steps

1. **Map.** Title it “Wolves Come Home, 1995–1996.” Mark Alberta (Canada), Montana, Wyoming and Idaho. Draw Yellowstone National Park as a square in the northwest corner of Wyoming.
2. Draw an arrow from Alberta to Yellowstone and write “14 wolves, 1995” and “17 wolves, 1996.” (Central Idaho received wolves at the same time; add an arrow there too.)
3. Add a compass rose, a scale bar and a key.
4. **Chart.** On the second sheet, draw a large circle labeled “The Dog Kind.” Inside, draw smaller circles for gray wolf, coyote, dingo and domestic dog.
5. Around the domestic dog circle, draw seven spokes for the American Kennel Club groups (Sporting, Hound, Working, Terrier, Toy, Non-Sporting, Herding) and write one breed on each.

Check your work

- My map has a title, compass rose, scale bar and arrows with numbers.
- My chart shows four members of the dog kind and seven breed groups.
- I can explain why wolves and dogs are counted as one kind.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph (5–7 sentences): “Why the Good Shepherd Needs to Know About Wolves.” Use John 10:11–12 and at least one fact about real wolves.
2. Sketch a dog you know (or one from Landseer’s painting). Label three features that show what its breed was made to do.

Did you know? Wolf pups are born deaf and blind in a den, usually four to six in a litter, and the whole family helps feed them by bringing back meat. Barry the Saint Bernard can still be seen, preserved, at the Natural History Museum in Bern, Switzerland. Contrary to cartoons, wolves do not howl at the moon; they howl more at dusk and dawn, when they are most active.

Goes deeper in. Life Science, the unit on created kinds and variety within kinds (coming soon); Gardening & Animals, for raising and training a dog and guarding livestock; Geography, the Rocky Mountains (coming soon); and Trail F, Stop F8, for the sled dogs of the 1925 Nome serum run.

For families. The National Park Service reports 14 wolves released in Yellowstone in 1995 and 17 in 1996 (31 total); wolves were released in central Idaho in the same years. Park wolf counts vary year to year, usually near 100. How much wolves changed elk numbers and streamside plants is still debated among scientists, so the stop does not make strong claims. Smell-receptor numbers are commonly cited estimates. Barry’s years

of service are usually given as 1800–1812 (he died in 1814); the “40 lives” figure is traditional. AKC breed counts change as breeds are added; about 200 is current. The “dogs of my flock” are Job’s sheepdogs. Wolf management is a public debate; the stop presents it as a stewardship question without taking sides.

PRACTICE

1. **EASY** Who usually makes up a wolf pack?
2. **EASY** Name three working jobs dogs do for people.
3. **MEDIUM** What evidence suggests wolves and dogs are one created kind?
4. **MEDIUM** A dog has about 300 million smell receptors and a person about 6 million. How many times as many does the dog have?
5. **CHALLENGE** In 1995 and 1996, 31 wolves were released in Yellowstone. Years later the park had about 100 wolves. About how many times larger was the population? Name two things the wolves needed for the number to grow.

Make it a game • Sheepdog and Wolf. Set up a “pen” with two cones. Several players are sheep, one is the sheepdog and one is the wolf. The sheepdog must steer the sheep into the pen without touching them, only by moving and crouching. The wolf tries to tag a sheep that wanders from the flock. Sheep inside the pen are safe. Swap roles after each round.

Scripture. “The wolf also shall dwell with the lamb, and the leopard shall lie down with the kid; and the calf and the young lion and the fatling together; and a little child shall lead them.” (Isaiah 11:6, KJV)

Today wolves hunt sheep and shepherds must guard their flocks. Isaiah promises a day when Christ’s kingdom brings full peace, even between the wolf and the lamb.

Practice: answers

1. A family: a mother and father wolf with their pups and young wolves from the past year or two.
2. Any three: herding sheep, guarding flocks, tracking by scent, guiding blind people, search and rescue, pulling sleds, hunting, sniffing for dangerous things.
3. They (along with coyotes and dingoes) can breed with one another, and they share the same basic design.
4. $300,000,000 \div 6,000,000 = 50$ times as many.
5. $100 \div 31 \approx 3.2$, a little more than three times as many. Any two: enough prey (elk, deer, bison); safe places for dens; room to form new packs; protection from being killed.

1.7 BEARS

OBJECTIVES

- Name the eight kinds of bears and find where each lives on a world map.
- Explain how a bear is designed for digging, climbing, smelling and its long winter sleep.
- Tell the true story behind the teddy bear and Smokey Bear.

Warm-up. Hug your favorite stuffed animal, or picture one. Teddy bears are named after a real man, an American president, and a real bear in Mississippi. Before you read, guess: did he shoot the bear or not?

Video slot. Video coming. Brown bears catching salmon at Brooks Falls (Katmai National Park bear cams); black bear cubs; polar bears on sea ice; giant pandas eating bamboo. Search approved channels (National Park Service, explore.org bear cams, BBC Earth, Smithsonian's National Zoo); preview first.

KEY TERMS

omnivore

An animal that eats both plants and animals.

plantigrade

Walking on the whole sole of the foot, heel included, as bears and people do.

den

A sheltered resting place, such as a cave, hollow log or dug-out hole, where a bear spends the winter.

hibernation

A long winter rest in which an animal's body slows down to save energy.

species

A group of very similar animals that breed with one another; there are eight species of bears.

CORE IDEAS

The story. In November 1902, President Theodore Roosevelt went bear hunting in Mississippi. After days without success, his guides chased down an old black bear, tied it to a tree and invited the president to shoot it. Roosevelt refused; it would not be fair or sportsmanlike. A cartoonist, Clifford Berryman, drew the scene for *The Washington Post*. In Brooklyn, a shopkeeper named Morris Michtom saw it, and he and his wife sewed a stuffed bear and put it in their window as "Teddy's bear." Soon the whole country wanted one.

Eight kinds. There are eight **species** of bears. The American black bear and the brown bear (which includes the grizzly and the giant Kodiak) live in North America; brown bears also live across Europe and Asia. The polar bear lives on Arctic sea ice. The Asiatic black bear, the sloth bear and the sun bear live in Asia; the spectacled bear lives in the Andes Mountains of South America; and the giant panda lives in the bamboo forests of China. A big male polar bear may weigh 900 to 1,300 pounds or more, while a sun bear may weigh under 100.

Designed to dig, climb and smell. Most bears are **omnivores**, eating berries, nuts, roots, insects, fish and meat. They are **plantigrade**, walking flat-footed like you, which lets them stand up to look and sniff. A grizzly's shoulder hump is a mass of muscle for digging, and its front claws can be 4 inches long. Black bears have short, curved claws and climb trees easily. A bear's nose is one of the keenest in the animal world; it may smell food more than a mile away. And though bears look slow, they can run 30 miles per hour or more.

The long winter sleep. In the north, black bears may stay in their **dens** for five months or more without eating, drinking or passing waste. Their heartbeat slows from about 40-50 beats a minute to sometimes fewer than 10, yet their body temperature drops only a few degrees, so they can wake if disturbed. Amazingly, their bones and muscles stay strong all winter, and scientists study them for ideas to help bedridden patients and astronauts. In January or February, mother bears give birth in the den to cubs that weigh less than a pound and nurse them until spring.

Bears and people. David the shepherd boy killed both a lion and a bear to protect his father's sheep (1 Samuel 17:34-36), and Proverbs warns that a mother bear robbed of her cubs is dangerous (Proverbs 17:12). In 1950 firefighters in the Capitan Mountains of New Mexico rescued a burned black bear cub clinging to a tree. He was named Smokey and lived the rest of his life at the National Zoo in Washington, D.C., as the living symbol of the forest-fire prevention campaign begun in 1944. Wise stewardship means giving bears room, never feeding them, and storing food carefully in bear country.

PICTURE STUDY



American Black Bear, from The Viviparous Quadrupeds of North America, John James Audubon (with his son John Woodhouse Audubon), 1840s (published 1845–1848) · Hand-colored lithograph · From The Viviparous Quadrupeds of North America; copies in many libraries
Wikimedia Commons · CC BY 2.0

After finishing his great book of birds, Audubon set out with his sons and his friend, the Lutheran pastor John Bachman, to picture every four-footed mammal of North America. “Viviparous” means giving birth to live young. Audubon’s sons painted many of the large animals as his eyesight failed.

Look closely

- Look at the bear’s feet. Can you see that it stands flat-footed (plantigrade)?
- Find the bear’s muzzle. What color is it compared with the body?
- Look at the claws. Are they long and straight, like a grizzly’s, or short and curved for climbing?

Talk about it

1. Why might an artist paint an animal standing still and sideways for a science book?
2. How is this careful, real-looking bear different from a teddy bear? Why do we like both?

Safety first. In bear country, travel with an adult and stay in a group, make noise on the trail, keep food and trash locked away, and never approach, feed or run from a bear. Follow park rangers’ instructions; some parks ask families to carry bear spray, which only an adult should handle.

HANDS-ON: WORLD MAP: THE EIGHT BEARS

Make a world map that shows where each of the eight kinds of bears lives.

You will need

- An outline map of the world
- Eight colored pencils
- An atlas or online range maps

Steps

1. Title your map “The Eight Bears of the World.”
2. Give each bear a color and shade its range: American black bear (forests of North America); brown bear (Alaska, western Canada, a few Rocky Mountain states, northern Europe and Asia); polar bear (around the Arctic Ocean); Asiatic black bear (southern and eastern Asia); sloth bear (India and Sri Lanka); sun bear (Southeast Asia); spectacled bear (Andes of South America); giant panda (mountains of central China).
3. Make a key with all eight colors and add one fact beside each name, for example its weight or its favorite food.
4. Label the Arctic Ocean, the Andes Mountains, the Himalayas and the Rocky Mountains.
5. Answer under your map: Which continent has the most kinds of bears? Which continents have none?

Check your work

- All eight bears are on my map with a key.
- I labeled four mountain ranges or oceans.
- I answered the two questions under the map.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph (5–7 sentences): “How a Black Bear Gets Through the Winter.” Include at least three numbers from the stop.
2. Draw a bear’s front paw print and a human footprint side by side. Label the heel, toes and claws, and write “plantigrade” underneath.

Did you know? Polar bears have black skin under their fur, and each hair is clear and hollow, not white; it looks white because it scatters light. A giant panda has an extra “thumb,” a long wrist bone covered by a pad, for gripping bamboo. Each summer, people around the world watch brown bears catching salmon at Brooks Falls in Alaska on live park cameras.

Goes deeper in. Life Science, the unit on mammals and their habitats (coming soon); Geography, the Arctic and the Rocky Mountains (coming soon); History, Theodore Roosevelt and the national parks (coming soon); and Trail F, Stop F3, “Hibernation.”

For families. The 1902 hunt took place near Onward, Mississippi; the bear was injured, and Roosevelt asked that it be put down quickly rather than shoot it himself, a detail left out of the story for younger readers. Berryman's cartoon "Drawing the Line in Mississippi" ran in November 1902; Morris and Rose Michtom founded the Ideal Novelty and Toy Company; the German firm Steiff made toy bears at about the same time. Heart-rate and weight figures vary widely by study and region and are given as approximate. Smokey was rescued in 1950 and lived at the National Zoo until 1976. Whether bears are true hibernators is a matter of definition; the stop uses the common term. The Audubon plate is part of a work credited to J. J. Audubon and John Bachman; the bear plates were largely painted by John Woodhouse Audubon, so the credit says "with his son."

PRACTICE

1. **EASY** Why did Theodore Roosevelt refuse to shoot the bear in 1902, and what toy was named after him?
2. **EASY** Name four of the eight kinds of bears.
3. **MEDIUM** What does "plantigrade" mean, and how does it help a bear?
4. **MEDIUM** A black bear's heart beats 45 times a minute in summer and 9 times a minute in its winter den. How many times slower is the winter heartbeat? How many fewer beats is that in one hour?
5. **CHALLENGE** Proverbs 17:12 says it is better to meet a mother bear robbed of her cubs than "a fool in his folly." What is the proverb teaching?

Make it a game • Bear in the Den. One player is the bear "hibernating" under a blanket in the den. The others tiptoe close, trying to touch the den without making noise. If the bear hears a sound, it may "wake," call out the name of the noisy player, and that player becomes the next bear. A quiet player who touches the den wins the round.

Scripture. "Let a bear robbed of her whelps meet a man, rather than a fool in his folly." (Proverbs 17:12, KJV)

People in Bible times knew how fierce a mother bear is when guarding her cubs. Solomon says foolishness is even more dangerous, so we should seek wisdom.

Practice: answers

1. The bear had been tied to a tree, and shooting it would not be fair or sportsmanlike. The teddy bear ("Teddy's bear") was named after him.
2. Any four: American black bear, brown bear (grizzly, Kodiak), polar bear, Asiatic black bear, sloth bear, sun bear, spectacled bear, giant panda.
3. Walking on the whole sole of the foot, heel included. It gives the bear a steady base so it can stand up on its hind legs to look and smell.
4. $45 \div 9 = 5$ times slower. $(45 - 9) \times 60 = 36 \times 60 = 2,160$ fewer beats an hour.

5. A mother bear is very dangerous, but a foolish person carrying out his foolishness can do even more harm. We should avoid foolish company and not act foolishly ourselves.

1.8 CHEETAHS, THE FASTEST RUNNER

OBJECTIVES

- Explain five features that make the cheetah the fastest land animal.
- Compare running speeds in a bar graph and do speed arithmetic.
- Tell how farmers and guard dogs are helping cheetahs survive.

Warm-up. With an adult, measure 100 meters (about 110 yards) in a park or field and time yourself running it. In 2012 a cheetah named Sarah ran the same distance in 5.95 seconds. How many of your seconds is that?

Video slot. Video coming. Cheetah running in slow motion (Sarah at the Cincinnati Zoo, National Geographic); cheetah mothers and cubs; Anatolian shepherd guard dogs of the Cheetah Conservation Fund. Search approved channels (National Geographic, BBC Earth, Smithsonian's National Zoo, Cheetah Conservation Fund); preview first.

KEY TERMS

sprint

To run at top speed for a short distance.

stride

The distance covered in one full cycle of running steps.

semi-retractable claws

Claws that can only partly pull back, so they always grip the ground like the cleats on a shoe.

acceleration

How quickly something speeds up.

livestock guarding dog

A large, brave dog raised with goats or sheep to protect them from predators.

CORE IDEAS

The story. On a June morning in 2012, a film crew set up high-speed cameras along a 100-meter track at the Cincinnati Zoo. An eleven-year-old cheetah named Sarah crouched at the start. When the keeper pulled a lure, a fluffy toy on a fast-moving rope, Sarah exploded down the track and finished in 5.95 seconds. The fastest man in the world, Usain Bolt, holds the human record at 9.58 seconds. Sarah's top speed that day was about 61 miles per hour.

Built for speed. A cheetah is light for a big cat, usually 75 to 140 pounds, with long legs and a small head. Its spine is very flexible: it bends like a spring as the back feet reach forward past the front, then stretches out flat, so one **stride** can cover 20 feet or more. Twice in every stride, all four feet are off the ground. Large nostrils, lungs and heart pump

oxygen fast. Its **semi-retractable claws** grip like a sprinter's cleats, and hard paw pads help it turn. The long tail works like a rudder, swinging to balance the body in sharp turns. Cheetahs are often said to reach 60 miles per hour in about three seconds, faster **acceleration** than most sports cars.

The cost of speed. A cheetah can only **sprint** for about 20 to 30 seconds, a few hundred yards, before it overheats and tires. After a chase it must pant and rest, sometimes for half an hour, before it can eat. Lions and hyenas often steal its catch, and many cubs are lost to them. To avoid these bigger hunters, cheetahs usually hunt by day, when lions are resting. They cannot roar; instead they chirp like birds, purr and hiss.

Cheetahs and kings. For centuries, rulers in Egypt, Persia and India kept tame cheetahs for hunting, and the Mughal emperor Akbar of India was said to keep about a thousand. The name comes from a Hindi word meaning "spotted one." In 1764 a hunting cheetah was sent from India to King George III of England, and the painter George Stubbs pictured it with its Indian keepers. When the cheetah was tested on a stag in Windsor Great Park, the stag stood its ground and drove the cheetah away.

Help from farmers and dogs. Only about 7,000 adult cheetahs live in the wild today, mostly in southern and eastern Africa, and the largest number live in Namibia, many on farmland. Farmers used to shoot cheetahs to protect their goats and calves. In 1990 an American scientist, Laurie Marker, started the Cheetah Conservation Fund in Namibia. Beginning in 1994, it gave farmers big Anatolian shepherd and Kangal **livestock guarding dogs**. The dogs bark and stand their ground, the cheetahs go elsewhere, and both the goats and the cheetahs are safer.

PICTURE STUDY



A Cheetah and a Stag with Two Indians, George Stubbs, about 1765 · Oil on canvas · Manchester Art Gallery, Manchester, England
Wikimedia Commons · Public domain

George Stubbs was the great English painter of animals; he studied their bodies so carefully that his horses and wild animals look ready to move. This painting shows the hunting cheetah sent from India to King George III, with the two keepers who came with it. One keeper is lifting the hood from the cheetah's eyes so it can see the stag.

Look closely

- Find the cheetah's hood and belt. Why would a hunting cheetah be kept hooded until the right moment?
- Look at the cheetah's legs and body. How did Stubbs show that it is long and lean?
- Find the stag. Does it look frightened or ready to defend itself?

Talk about it

1. Knowing how the real hunt turned out, what do you notice about the stag in this picture?
2. How is this painting a record of history as well as a picture of animals?

HANDS-ON: BAR GRAPH AND DIAGRAM: HOW FAST IS FAST?

Make a bar graph of top running speeds and a two-part diagram of a cheetah's stride.

You will need

- Graph paper or plain paper with a ruler

- Colored pencils
- Pencil

Steps

1. **Bar graph.** Title it “Top Running Speeds (miles per hour).” Draw the left side (vertical axis) from 0 to 70, counting by 10s.
2. Draw a bar for each runner: cheetah 65; pronghorn 55; lion 50; Thoroughbred racehorse 44; greyhound 43; grizzly bear 35; fastest man (Usain Bolt) 28. Label each bar at the bottom.
3. **Stride diagram.** Below the graph, draw two cheetahs from the side. In the first, the spine is curled and all four feet are bunched together under the belly (“gathered”). In the second, the spine is stretched flat and the legs reach far forward and back (“extended”).
4. Label on your diagram: flexible spine, semi-retractable claws, long tail (rudder), large nostrils, long legs.
5. Under the diagram write one sentence explaining how the bending spine makes each stride longer.

Check your work

- My bar graph has a title, a numbered axis and seven labeled bars.
- My stride diagram shows the gathered and extended positions with five labels.
- I explained the spine in one sentence.

FIELD NOTEBOOK

1. **Notebook entry.** Read Ecclesiastes 9:11. Write a paragraph (5–7 sentences): Even though the cheetah is the fastest runner, it often loses its meal. What does Ecclesiastes say about the swift, and what should we trust instead of our own strength or speed?

Did you know? The black “tear marks” running from a cheetah’s eyes to its mouth may help cut the glare of the bright African sun, like the black grease some football players wear. Cheetah cubs have a thick, silvery mane down their backs for their first months, which may make them look like the fierce honey badger and keep enemies away. A cheetah’s claws are blunt from always touching the ground, unlike a lion’s sharp, hidden claws.

Map or diagram. On a map of Africa, color Namibia, Botswana, South Africa, Kenya and Tanzania, the main cheetah countries today. Then find Iran in Asia, where a few dozen Asiatic cheetahs still survive.

Goes deeper in. Life Science, the unit on motion and the body (coming soon); Arithmetic, for speed, distance and time; Gardening & Animals, for livestock guarding dogs; and Art, for George Stubbs.

For families. Sarah's 2012 run was filmed by National Geographic at the Cincinnati Zoo; her 5.95-second 100-meter time and roughly 61 mph top speed were widely reported. Top-speed claims for wild cheetahs range from about 58 to 70 mph; the bar graph uses 65 as a round middle figure, and the other speeds are typical published maximums. "0 to 60 in three seconds" is a popular estimate, hedged in the story. Wild population figures (about 7,000 adults) come from the Cheetah Conservation Fund and IUCN. The account of the 1764 cheetah, given by Sir George Pigot, and the Windsor trial hunt follow Manchester Art Gallery's description. Akbar's thousand cheetahs come from accounts of his court and may be rounded.

PRACTICE

1. **EASY** Name three body features that help a cheetah run fast.
2. **EASY** Why do cheetahs usually hunt in the daytime?
3. **MEDIUM** Sarah ran 100 meters in 5.95 seconds; Usain Bolt's record is 9.58 seconds. How many seconds faster was Sarah?
4. **MEDIUM** How did guard dogs help both farmers and cheetahs in Namibia?
5. **CHALLENGE** A cheetah running 60 miles per hour covers 1 mile in a minute. At that speed, how many feet does it travel in one second? (1 mile = 5,280 feet.)

Make it a game • Sprint and Rest. Mark a start and a finish about 30 yards apart. The cheetah sprints to catch a "gazelle" who starts 5 yards ahead and zigzags. But the cheetah may only sprint for 10 seconds (a timer counts out loud); if time runs out, the cheetah must sit and "pant" for 30 seconds while the gazelle walks to safety. Take turns and talk about why a short burst of speed needs a clever plan.

Scripture. "I returned, and saw under the sun, that the race is not to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favour to men of skill; but time and chance happeneth to them all." (Ecclesiastes 9:11, KJV)

The cheetah is the swiftest of all land animals, yet it misses many chases and often loses its meal. Solomon teaches that speed, strength and skill are good gifts, but our lives rest in God's hands, not in our own power.

Practice: answers

1. Any three: a flexible, spring-like spine; long legs; semi-retractable claws that grip like cleats; a long tail for balance; large nostrils, lungs and heart; a light body.
2. To avoid lions and hyenas, which are more active at night and may steal their food or kill their cubs.
3. $9.58 - 5.95 = 3.63$ seconds faster.
4. The dogs protected goats and calves by barking and standing their ground, so cheetahs went elsewhere; farmers lost fewer animals and no longer needed to shoot cheetahs.

5. $5,280 \div 60 = 88$ feet per second.

1.9 KANGAROOS

OBJECTIVES

- Explain what a marsupial is and describe a joey's growth from birth to leaving the pouch.
- Describe how a kangaroo's legs, tendons and tail are designed for hopping.
- Map Captain Cook's 1770 voyage along the east coast of Australia and where kangaroos live.

Warm-up. Stand with your feet together and jump forward as far as you can. Measure it. A big red kangaroo can cover about 25 feet in a single bound, and some reports give even more. How many of your jumps would it take to match one kangaroo hop?

Video slot. Video coming. Red and grey kangaroos hopping in slow motion; a joey in its mother's pouch; a newborn joey crawling to the pouch. Search approved channels (BBC Earth, National Geographic, Australian Museum, San Diego Zoo Wildlife Alliance); preview first.

KEY TERMS

marsupial

A mammal whose tiny newborn young grow in a pouch on the mother's belly, such as a kangaroo, koala or opossum.

joey

A baby kangaroo (or other baby marsupial).

macropod

"Big foot": the family name of kangaroos and wallabies.

tendon

A tough, stretchy cord that joins muscle to bone; a kangaroo's leg tendons store energy like springs.

mob

A group of kangaroos.

CORE IDEAS

The story. In June 1770, Captain James Cook's ship *Endeavour* struck the Great Barrier Reef and had to be pulled onto a riverbank in what is now Queensland, Australia, for seven weeks of repairs. While they worked, the sailors saw a strange grey animal, about the size of a greyhound, that bounded along on its hind legs. The naturalist Joseph Banks wrote about it in his journal, and the local Guugu Yimithirr people gave it a name that the English wrote down as "kangaroo." Banks carried a skin and skull home to London, and in 1772 he asked George Stubbs to paint the animal.

A pouch for a nursery. Kangaroos are **marsupials**. A red kangaroo carries her baby inside her body for only about 33 days. The newborn **joey** is about the size of a jellybean, less than an inch long and blind, with no hair. Using its strong little front legs, it climbs through its mother's fur into her pouch and latches onto a teat. There it stays and grows for about seven or eight months before it first hops out, and it keeps diving back into the pouch until it is too big to fit.

A clever mother. A mother kangaroo can have three young at once: a joey at her side, a smaller joey in her pouch, and a tiny embryo waiting, paused in its growth, until the pouch is free. She can even make two different kinds of milk at the same time from two teats, one for the tiny pouch joey and a richer one for the older joey.

Built to hop. Kangaroos and wallabies are called **macropods**, "big feet." The long **tendons** in their back legs stretch when they land and snap back when they push off, like a pogo stick, so hopping fast uses surprisingly little extra energy. A red kangaroo can reach around 35 miles per hour for short bursts and cruise much farther at a slower pace. When moving slowly, a kangaroo leans on its thick tail as a fifth leg. It can also balance on its tail to kick with both hind feet when it fights.

Many kangaroos. The red kangaroo is the largest marsupial: a big male can stand about 6 feet tall and weigh around 200 pounds. Eastern and western grey kangaroos live in the wetter forests and grasslands; the reds live in the dry center. There are also smaller wallabies, rock wallabies, and tree kangaroos that climb in the rainforests of New Guinea and northern Queensland. Australia has tens of millions of kangaroos; their numbers rise in wet years and fall in droughts. Farmers, ranchers and wildlife officers count them and set limits so the land can feed both kangaroos and sheep, a real-life lesson in stewardship.

PICTURE STUDY



The Kongouro from New Holland, George Stubbs, 1772 · Oil on panel · National Maritime Museum, Greenwich, London
Wikimedia Commons · Public domain

This was the first painting of a kangaroo ever seen in Europe. Stubbs never saw a live kangaroo: he worked from the skin and skull Banks had brought back, perhaps from a skin stuffed or blown up to show its shape, and from the sketches and descriptions of the men who had seen it. “New Holland” was the old European name for Australia.

Look closely

- Find the long hind feet and thick tail. How is the kangaroo sitting?
- Look at the front legs. How big are they compared with the back legs?
- Look at the face and ears. What is the kangaroo doing with its head?

Talk about it

1. Stubbs had only a skin and a description. What parts do you think he got right? Does anything look a little odd?
2. Why would a picture like this have amazed people in London in 1773?

HANDS-ON: MAP: COOK’S VOYAGE AND THE LAND OF THE KANGAROO

Make a map of Australia that shows where Cook sailed in 1770 and where the big kangaroos live.

You will need

- An outline map of Australia

- Three colored pencils
- A ruler and pencil

Steps

1. Title your map “The Land of the Kangaroo.”
2. Draw Cook’s route as a dotted line up the east coast. Mark and label Botany Bay (April 1770), the Great Barrier Reef, and the Endeavour River (June–August 1770), where the first kangaroo was described.
3. Shade where red kangaroos live (the dry middle of the continent) in one color, and where eastern grey kangaroos live (the eastern side) in another.
4. Label the Pacific Ocean, the Indian Ocean, Sydney and New Guinea (where tree kangaroos live).
5. Add a key, a compass rose and a scale bar.

Check your work

- My map shows Cook’s route with three labeled places.
- Red and grey kangaroo areas are shaded in two colors with a key.
- My map has a compass rose and a scale bar.

FIELD NOTEBOOK

1. **Diagram.** Draw a timeline for a red kangaroo joey: day 0 (born, jellybean size), day 1 (in the pouch), about 6 months (first peeks out), about 8 months (first hops out), about 12 months (leaves the pouch for good).
2. **Notebook entry.** Write a paragraph (5–7 sentences): “What Would I Write in My Journal?” Pretend you are Joseph Banks in 1770 seeing a kangaroo for the first time. Describe it carefully for people in England who have never seen one.

Did you know? Kangaroos rarely move backward; their big feet and heavy tail make it awkward. That is one reason the kangaroo and the emu (which also rarely walks backward) were chosen for Australia’s coat of arms, as a sign of a nation moving forward. A kangaroo can swim and uses its back legs to kick in the water. Kangaroos can go a long time without drinking, getting much of their water from plants.

Goes deeper in. Life Science, the unit on mammals and marsupials (coming soon); Geography, the unit on Australia and Oceania (coming soon); History, Captain Cook’s voyages (coming soon); and Art, for George Stubbs.

For families. Cook’s *Endeavour* was repaired at the Endeavour River (now Cooktown) from June to August 1770; the Guugu Yimithirr word is usually written *gangurru*. Stubbs’s painting was exhibited in 1773 and bought by the National Maritime Museum in 2013. Pregnancy and pouch times are for the red kangaroo and are approximate. Top speed and bound length vary by report (speeds of 35–44 mph and leaps of 25–30 feet appear in published sources); the stop uses conservative figures. The “never backward”

coat-of-arms explanation is popular tradition, so it is hedged. Kangaroo numbers and harvest quotas are set by Australian state and federal agencies.

PRACTICE

1. **EASY** What is a marsupial? Name one besides the kangaroo.
2. **EASY** How does a newborn joey get into the pouch?
3. **MEDIUM** How do a kangaroo's tendons help it hop without getting tired?
4. **MEDIUM** A red kangaroo is born after 33 days and stays in the pouch about 235 more days before first hopping out. About how many days old is it when it first hops out, counting from the start of its life before birth? About how many months is that?
5. **CHALLENGE** A kangaroo covers 25 feet in one hop. How many hops does it need to cross a football field of 300 feet? If it makes 2 hops a second, how long does that take?

Make it a game • Kangaroo Relay. Teams line up. Each runner must hop (feet together, no running) to a cone and back while carrying a small stuffed animal, the "joey," tucked in a pocket or shirt front. If the joey falls out, the runner must stop, put it back and hop on. The first team to finish wins. Then try it again "on a tail": each runner holds a broomstick behind as a third leg to lean on between hops.

Scripture. "But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee:" (Job 12:7, KJV)

Joseph Banks had never seen an animal like the kangaroo, and he wrote down everything he could learn from it. Job says the animals themselves teach us; the next verses tell what they teach: that "the hand of the LORD hath wrought this" (Job 12:9).

Practice: answers

1. A mammal whose tiny newborn grows in a pouch on the mother's belly. Examples: koala, wombat, wallaby, opossum.
2. It climbs through its mother's fur with its strong front legs and crawls into the pouch, where it latches onto a teat.
3. They stretch when the kangaroo lands and spring back when it pushes off, like a pogo stick, so much of the energy is reused.
4. $33 + 235 = 268$ days; about 9 months ($268 \div 30 \approx 8.9$).
5. $300 \div 25 = 12$ hops; $12 \div 2 = 6$ seconds.

1.10 THE AMERICAN BISON'S COMEBACK

OBJECTIVES

- Describe how the bison is designed for life on the Great Plains, with numbers.
- Explain plainly why the bison nearly vanished in the 1800s.
- Name the people and places that brought the bison back, and map them.

Warm-up. Look at a U.S. nickel minted between 1913 and 1938, or find a picture of the “Buffalo nickel” online. Then think: in 1889, there were fewer American bison left than there are students in many large schools. How did an animal that once filled the plains come so close to disappearing?

Video slot. Video coming. American bison in Yellowstone and on the prairie; the bison herd at Wichita Mountains Wildlife Refuge; the history of the bison’s near loss and recovery. Search approved channels (National Park Service, U.S. Fish and Wildlife Service, Smithsonian, Ken Burns’ The American Buffalo clips via PBS); preview first.

KEY TERMS

bison

A large, shaggy wild ox of North America and Europe; Americans often call it “buffalo.”

herd

A large group of grazing animals that live and travel together.

graze

To eat grass and low plants growing in a field or prairie.

refuge

Land set aside to protect wild animals.

stewardship

Taking good care of something that belongs to someone else; in the Bible, caring for God’s creation (Genesis 2:15).

CORE IDEAS

The story. In October 1907, fifteen bison were loaded into wooden crates at the New York Zoological Park, now the Bronx Zoo. They rode a train more than 1,800 miles west to Oklahoma, then went by wagon to the new Wichita Mountains Wildlife Refuge. When they arrived, crowds came out to see them, among them elderly Comanche who had not seen a bison on those plains for many years. The herd there now numbers several hundred.

Built for the plains. The **bison** is the largest land animal in North America. A bull can weigh up to about 2,000 pounds and stand 6 feet tall at the shoulder. Its great hump is muscle that lets it swing its massive head from side to side like a snowplow to uncover grass

in winter. Its winter coat is so thick that snow can lie on its back without melting. Bison **graze** most of the day, roll in dust wallows to keep off insects, and, though heavy, can run about 35 miles per hour and jump a 6-foot fence.

From millions to hundreds. In 1800, tens of millions of bison roamed from Canada to Mexico; estimates range from 30 to 60 million. The Plains nations depended on them for food, robes, tools and shelter. Then, in about 1871, tanners found a way to make strong leather from bison hides, which factories wanted for machine belts. With railroads to carry hides east and powerful rifles, hide hunters killed bison by the millions in the 1870s, often taking only the skin and leaving the meat to rot. Some army officers and officials welcomed the slaughter because it forced the Plains tribes onto reservations. It was greed and great waste. In 1889, the naturalist William Hornaday counted only about a thousand bison left in North America, and by 1902 only about two dozen wild bison survived in Yellowstone.

The comeback. A few people saw the danger in time. In the 1870s Samuel Walking Coyote of the Pend d'Oreille people led a few orphan calves over the mountains to the Flathead Reservation in Montana; ranchers Michel Pablo and Charles Allard grew them into a large herd. In the Texas Panhandle, Mary Ann Goodnight urged her husband Charles to save orphaned calves, and they began a herd in 1878. In 1894 Congress made it a crime to kill wildlife in Yellowstone. In 1905 Hornaday and others founded the American Bison Society, with Theodore Roosevelt as honorary president. Its **refuges** at Wichita Mountains (1907) and the National Bison Range in Montana (1908) gave bison safe homes.

Today. There are now roughly 400,000 bison in North America. Most live on private ranches; about 20,000 or more live in public and tribal conservation **herds**, including several thousand in Yellowstone, the only place bison have lived wild without a break since prehistoric times. In 2016 Congress named the bison the national mammal of the United States. The bison's story shows both the harm of greed and the good that patient **stewardship** can do.

PICTURE STUDY



Buffalo Hunt under the Wolf-skin Mask, George Catlin, 1832–1833 · Oil on canvas · Smithsonian American Art Museum, Washington, D.C.
Wikimedia Commons · Public domain

George Catlin traveled up the Missouri River in 1832 and painted the Plains nations and the bison herds before the great slaughter. Here two hunters wear wolf skins to sneak close to a herd. Bison feared wolves less when they were together in a big herd, so a “wolf” could creep near.

Look closely

- Find the two hunters. What are they hiding under?
- Look at the bison herd. Are they running or calm?
- Look at the open prairie. How far can you see? What plants grow there?

Talk about it

1. Why was hunting with a bow and a disguise very different from the hide hunters with rifles forty years later?
2. Catlin wrote that he was afraid the bison and the Plains peoples’ way of life might disappear. Why do you think he painted so many pictures of them?

HANDS-ON: MAP: THE BISON COMEBACK

Make a map that shows how far the bison once roamed and where the herds that saved it began again.

You will need

- An outline map of North America (Canada, the United States and Mexico)
- Two colored pencils and a black pen
- A ruler

Steps

1. Title your map “The Bison Comeback.”
2. Lightly shade the bison’s range around 1800: from Alberta and Saskatchewan in Canada south through the Great Plains to northern Mexico, and east as far as the Appalachian Mountains.
3. With a black pen, mark these places with dots and labels: Yellowstone (Wyoming); Bronx Zoo (New York City); Wichita Mountains Wildlife Refuge (Oklahoma); National Bison Range (Montana); Goodnight Ranch (Texas Panhandle); Custer State Park (South Dakota).
4. Draw an arrow from New York to Oklahoma and write “15 bison, 1907.”
5. Add a key, a compass rose and a scale bar. Under the map, write one sentence comparing the shaded range of 1800 with the dots of 1900.

Check your work

- My map shows the old range in color and at least six labeled places.
- I drew and labeled the 1907 arrow.
- My map has a key, a compass rose, a scale bar and a sentence.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph (5–7 sentences): “What Went Wrong, and What Went Right.” Name one wrong that nearly destroyed the bison and two good choices that brought them back. End with Genesis 2:15.
2. Draw a bison from the side and label: hump, horns, beard, winter coat, hooves, tail.

Did you know? Strictly speaking, the American “buffalo” is a bison; true buffalo are the water buffalo of Asia and the Cape buffalo of Africa. Watch a bison’s tail: when it hangs down and swishes, the animal is calm, but when it sticks straight up, it may be about to charge. Yellowstone visitors are told to stay at least 25 yards (75 feet) from bison, which injure more park visitors than any other animal there.

Goes deeper in. History, the American West and the Plains nations (coming soon); Geography, the Great Plains (coming soon); Gardening & Animals, for raising cattle and bison; and Small Business & Economics, for how the hide trade and the railroads worked.

For families. Historic population estimates vary widely (often 30–60 million); Hornaday’s 1889 report, *The Extinction of the American Bison*, counted roughly 1,000 animals in North America including captives. The Yellowstone “about two dozen” figure for 1902 is from National Park Service histories. The Lacey Act of 1894 protected Yellowstone wildlife. The 1907 Wichita shipment of 15 bison from the Bronx Zoo is documented by the

U.S. Fish and Wildlife Service and the Wildlife Conservation Society; accounts note Comanche onlookers, including Quanah Parker. The National Bison Range was transferred to the Confederated Salish and Kootenai Tribes in 2020. The National Bison Legacy Act was signed in 2016. Current numbers (about 400,000 total; roughly 20,000–30,000 in conservation herds) are approximate. The army’s role is stated plainly as historians describe it, without modern slogans. In the field, families should obey the 25-yard rule.

PRACTICE

1. **EASY** What is the bison’s hump made of, and how does it help in winter?
2. **EASY** Name two people who helped save the bison.
3. **MEDIUM** Give two reasons bison were killed in such huge numbers in the 1870s.
4. **MEDIUM** In 1889 there were about 1,000 bison; today there are about 400,000. How many times as many is that?
5. **CHALLENGE** Genesis 2:15 says God put man in the garden “to dress it and to keep it.” Using the bison story, explain what it looks like to break that command and to keep it.

Make it a game • Grow the Herd. Start with 15 beans in a cup (the 1907 herd). Each “year,” roll a die: on 1, lose 1 bison to a hard winter; on 2–6, add that many calves. Every five years, move 10 bison to a new cup (a new refuge). Play 20 years and count how many bison and refuges you have. Talk about why spreading herds to several places keeps them safer.

Scripture. “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.” (Genesis 2:15, KJV)

God gave people the work of using and guarding His creation. The bison nearly disappeared through greed, and it came back through people who chose to keep and care for what God had made.

Practice: answers

1. Muscle. It lets the bison swing its heavy head from side to side like a snowplow to clear snow off the grass.
2. Any two: Samuel Walking Coyote; Michel Pablo; Charles Allard; Mary Ann and Charles Goodnight; William Hornaday; Theodore Roosevelt; James “Scotty” Philip.
3. Any two: a new tanning method made hides valuable for leather machine belts; railroads carried hides east; powerful rifles let hunters kill many quickly; some officials wanted to force the Plains tribes onto reservations; greed and waste.
4. $400,000 \div 1,000 = 400$ times as many.
5. Breaking it: killing millions of bison for hides and leaving the meat to waste, out of greed. Keeping it: protecting the last herds, raising calves, setting aside refuges and ranching bison wisely, so the land and its creatures are cared for and used well.

TRAIL 1 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing or aloud, then checks with a parent. Four right out of five earns each badge. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1-5)

1. Why is Jesus called “the Lion of the tribe of Juda” (Revelation 5:5)?
2. Give two ways to tell an African elephant from an Asian elephant.
3. What is the difference between a baleen whale and a toothed whale? Give an example of each.
4. How is a bat’s wing like your hand?
5. A horse is 14.3 hands tall. How many inches is that?

Badge quiz 2 (Stops 6-10)

6. Why are wolves and dogs counted as one created kind, and how did people get so many dog breeds?
7. Name two things a black bear’s body does during its long winter sleep.
8. Name three features that make the cheetah fast, and one reason it often loses its meal.
9. Describe a red kangaroo joey at birth and how it reaches the pouch.
10. About how many bison were left in 1889, and name one place where the comeback began.

TRAIL CERTIFICATE: MY MAMMAL FIELD NOTEBOOK AND TRAIL A CERTIFICATE

Gather your Field Notebook pages from this trail into one booklet with a cover: “My Mammal Field Notebook,” your name and the dates you started and finished.

Include at least five maps or diagrams from the trail (for example, the lion range map, the blue whale scale drawing, the bat-wing diagram, the cheetah bar graph and the bison comeback map) and all ten notebook paragraphs.

Add a final page: “My Favorite Mammal,” a paragraph telling which animal on this trail shows God’s design most clearly to you and why, with one verse of Scripture.

When the booklet is done, a parent reviews it and signs the Trail A certificate.

- **Ten stops:** A page for each stop with a title, a date and a one-paragraph notebook entry.
- **Maps and diagrams:** At least five maps or diagrams, each with a title, labels and (for maps) a key, compass rose and scale.
- **Facts and Scripture:** Entries use accurate facts and numbers from the stops and connect each animal to Scripture.
- **Care:** Writing is in complete sentences, spelled carefully, and drawings are neat and labeled.

Answer key

1. He came from the tribe of Judah, which Jacob called a lion's whelp, and from King David's line; He is the mighty King who has won the victory.
2. Any two: African elephants have much larger ears (shaped a bit like Africa), a dipped back and two "fingers" on the trunk tip; Asian elephants have smaller rounded ears, a humped back and one "finger," and usually only males have large tusks.
3. A baleen whale strains krill and small fish through fringed baleen plates (blue, humpback, gray); a toothed whale catches prey with teeth and finds it by sound (sperm whale, orca).
4. It is made of the same arm and finger bones, with very long fingers and a thin skin membrane stretched between them; the short thumb stays free.
5. $14 \times 4 = 56$, plus 3 = 59 inches.
6. They can breed with one another and share the same design; people used selective breeding, choosing which dogs would be parents, to bring out the variety within the kind.
7. Any two: its heartbeat slows greatly; it does not eat, drink or pass waste for months; its body temperature drops only a little; its bones and muscles stay strong; mothers give birth to tiny cubs in the den.
8. Any three: flexible spine, long legs, gripping semi-retractable claws, long tail for balance, big nostrils, lungs and heart, light body. It loses its meal because it tires after a short sprint and lions or hyenas steal its catch.
9. It is born after about 33 days, the size of a jellybean, blind and hairless; it climbs through its mother's fur with its front legs into the pouch and latches onto a teat.
10. About a thousand. Any one: Yellowstone; the Bronx Zoo and Wichita Mountains Wildlife Refuge (1907); the National Bison Range (1908); the Goodnight ranch in Texas; the Pablo-Allard herd on the Flathead Reservation.

ANIMALS TRAIL B: BIRDS

The second trail of the Animals track studies the birds God made to fill “the open firmament of heaven” (Genesis 1:20): the soaring eagle of Isaiah 40:31, the silent owl, the hovering hummingbird, the penguin that flies under the sea, the ostrich of Job 39, clever parrots, the great journeys of migration, nests of every shape, John James Audubon and his life-size *Birds of America*, and a real backyard bird count. Each stop has a story full of facts and numbers, a picture study from fine art or historic photography, a hands-on project, a Field Notebook entry, practice questions, a game and a verse of Scripture (KJV).

This is the  **Ranger** level, written for ages 10 to 13. The student reads each stop alone in about 25 to 35 minutes and writes a short paragraph in the Field Notebook. Every stop includes a map or diagram to draw with labels: a thermal, an owl’s ears, a hummingbird’s figure-eight, a penguin map, flyways, nest types, Audubon’s travels and a yard map. Every stop stands alone, and the practice questions run from easy to challenge with full answers for checking. The  Scout stops cover the same birds more simply for younger brothers and sisters, so a family can study the trail together.

Five stops earn the **Bird Ranger badge, part 1**, and ten stops earn part 2 and the **Trail B certificate**. The two badge quizzes at the end of the trail are optional; badges are earned by doing the stops and keeping the notebook, not by test scores.

BEFORE YOU BEGIN

- Read a page of nonfiction alone and write a paragraph about it in your own words.
- Find the continents, the oceans, the equator and the Tropics of Cancer and Capricorn on a world map, and use a ruler to draw a simple labeled diagram.

MASTERY CHECKLIST

- ☐ I can explain how an eagle soars, how an owl hunts in the dark and how a hummingbird hovers, using the right terms.
- ☐ I can describe how penguins and ostriches are designed for swimming and running instead of flying, with at least two numbers for each.
- ☐ I can tell why birds migrate, name three ways they find their way, and draw the four North American flyways.
- ☐ I can name six kinds of nests and a bird that builds each, and tell the life of John James Audubon with key dates.
- ☐ I can do a 15-minute bird count using the “highest number at one time” rule and keep a bird list of at least ten species.

OPTIONAL BOOKS AND RESOURCES

- **Cornell Lab of Ornithology: All About Birds and the Merlin app**
(<https://www.allaboutbirds.org>): Free bird guide with photos, range maps and recorded songs; the free Merlin app helps identify birds by photo or sound.
- **Great Backyard Bird Count** (<https://www.birdcount.org>): The free four-day February count used in Stop B10, with instructions and tally sheets.
- **National Audubon Society: The Birds of America online**
(<https://www.audubon.org/birds-of-america>): All 435 of Audubon's plates, free to view and print for Stop B9.
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Old bird books, including Edward Lear's parrot plates (Stop B6), free to view and copy.
- **BirdCast** (<https://birdcast.info>): Free nightly migration forecasts and radar maps for Stop B7.

2.1 EAGLES: “MOUNT UP WITH WINGS”

OBJECTIVES

- Explain how thermals, broad wings and slotted “finger” feathers let an eagle soar for hours with little flapping.
- Describe the eagle’s hunting tools (eyes, talons and hooked beak) and compare its eyesight with ours.
- Tell the story of the bald eagle’s decline and recovery in numbers, and read Isaiah 40:31 in light of how eagles fly.

Warm-up. Hold a sheet of paper flat at shoulder height and drop it. Now crumple a second sheet into a ball and drop both together. Which falls more slowly? A wide, flat surface catches more air. Keep that in mind as you read about the eagle’s great wings.

Video slot. Video coming. Bald eagles and golden eagles soaring on thermals; slow-motion eagle catching a fish; an eagle nest camera. Search approved channels (U.S. Fish and Wildlife Service, National Park Service, Cornell Lab of Ornithology Bird Cams); preview first.

KEY TERMS

raptor

A bird of prey: a bird that hunts with sharp talons and a hooked beak, such as an eagle, hawk, falcon or owl.

thermal

A rising column of air warmed by sun-heated ground. Soaring birds circle inside thermals to gain height without flapping.

wingspan

The distance from one wing tip to the other when the wings are spread wide.

primary feathers

The long flight feathers at the outer end of the wing. On an eagle they spread apart like fingers when it soars.

fovea

A small spot on the back of the eye packed with light-sensing cells, where sight is sharpest. An eagle has two in each eye; we have one.

CORE IDEAS

There are about sixty kinds of eagles in the world, and they live on every continent except Antarctica. They are among the largest **raptors**. A female bald eagle, larger than the male as in most birds of prey, may weigh about 13 pounds and have a **wingspan** of 7 feet or more.

Yet her hollow, braced bones are so light that her feathers weigh more than her whole skeleton.

An eagle is built to soar. On a sunny morning, the ground warms and heats the air above it, which rises in invisible columns called **thermals**. The eagle finds one, spreads its long, broad wings and circles inside it, climbing hundreds or even thousands of feet without a single wingbeat. At the top it glides off in a long, gentle slope to the next thermal. Look closely at a soaring eagle and you will see its **primary feathers** spread apart at the wing tips like the fingers of a hand. These slots smooth the swirling air at the tips and let the bird fly slowly without stalling. Golden eagles in a steep dive, called a stoop, have been clocked at well over 150 miles per hour.

The eagle's eyes are perhaps four to eight times sharper than ours. Each eye has not one **fovea**, as ours does, but two: one for looking straight ahead and one for looking off to the side. An eagle can pick out a rabbit from a mile or more away. When it strikes, it swings its feet forward and closes its **talons**, which lock tight. A bald eagle's toes have rough, spiky pads that grip a slippery fish, and its hooked beak tears food into bites.

The bald eagle lives only in North America. Congress placed it on the Great Seal of the United States in 1782. By 1963, however, only about 417 nesting pairs were left in the lower 48 states. Hunting, poisoning and the pesticide DDT, which made eggshells so thin that they broke under the sitting parent, had nearly wiped them out. Laws protected the eagles (1940), DDT was banned in the United States (1972), and people guarded nest sites. The eagles came back so well that they were taken off the endangered species list in 2007, and by 2019 the U.S. Fish and Wildlife Service estimated more than 71,000 nesting pairs. That is good stewardship of God's creatures (Genesis 2:15).

The prophet Isaiah wrote to tired, discouraged people around 700 years before Christ. He reminded them that God "fainteth not, neither is weary" (Isaiah 40:28) and promised that those who wait upon the LORD "shall mount up with wings as eagles" (40:31). The picture fits what we have learned: a soaring eagle does not rise by beating its wings harder but by spreading them and resting on the rising air that God supplies. Strength for the Christian comes the same way, by trusting rather than straining.

PICTURE STUDY



Fukagawa Susaki and Jūmantsubo, No. 107 from One Hundred Famous Views of Edo, Utagawa Hiroshige, 1857 · Color woodblock print · Brooklyn Museum, New York (one of several impressions in museums)
Wikimedia Commons · Public domain

Utagawa Hiroshige (1797–1858) was one of the great printmakers of Japan. Near the end of his life he made a series of one hundred views of Edo, the city we now call Tokyo. In this winter scene, he puts us up in the sky beside a golden eagle (some say a sea eagle) as it looks down over the frozen marshes of Edo Bay. Prints were made by carving each color on a separate wooden block and pressing them one after another onto the paper.

Look closely

- Find the eagle's primary feathers. Are they closed together or spread apart like fingers?
- Look at the talons. What is the eagle getting ready to do?
- Find the small bucket floating in the water and the tiny water birds. How does their size show how high the eagle is?

Talk about it

1. Why do you think Hiroshige made the eagle so large and the land so small?
2. How does this picture help you understand the words "mount up with wings as eagles"?

HANDS-ON: THE WINGSPAN WALL

Mark real bird wingspans on a wall or floor so you can see how big an eagle really is, then draw a labeled diagram of a soaring eagle riding a thermal.

You will need

- Painter's tape or masking tape and a marker
- A tape measure or yardstick
- A long hallway, wall or driveway (chalk works outside)
- A notebook page and colored pencils

Steps

1. Tape a starting line on the wall or floor. From it, measure and mark these wingspans with labels: ruby-throated hummingbird, about 4 inches; American robin, about 15 inches; red-tailed hawk, about 4 feet; bald eagle, about 7 feet; wandering albatross, about 11 feet.
2. Stand against the wall with your arms spread wide and have someone mark your own "wingspan." Which bird are you closest to?
3. Make a short table in your notebook: bird, wingspan in feet, wingspan in inches.
4. **Diagram.** Draw sun-warmed ground at the bottom of a page, with wavy arrows rising up from it to show a thermal. Draw an eagle circling upward inside the thermal, and a second eagle gliding off to the side. Label: *sun, warm ground, thermal (rising air), circling climb, glide, primary feathers ("fingers")* and *talons*.

Check your work

- My wall shows five bird wingspans, measured correctly, and my own.
- My table lists each wingspan in both feet and inches.
- My thermal diagram has at least six labels and arrows that show which way the air moves.

FIELD NOTEBOOK

1. **Notebook entry: How an eagle soars.** Write one paragraph explaining how an eagle can stay in the air for hours. Use the words *thermal*, *wingspan* and *primary feathers*, and end with one sentence about Isaiah 40:31.
2. Copy Isaiah 40:31 under your thermal diagram.

Did you know? The largest bald eagle nest on record, near St. Petersburg, Florida, was about 9½ feet wide and 20 feet deep and was estimated to weigh more than two tons. Some of the most powerful eagles in the world, such as the harpy eagle of South America, have rear talons longer than a grizzly bear's claws. In December 2024 the bald eagle was made the official national bird of the United States by law.

Map or diagram. A good thermal diagram reads from the bottom up: sun and warm ground, then rising arrows, then the circling eagle near the top. Use one color for air and another for the bird, and keep labels outside the drawing with straight leader lines.

Goes deeper in. Life Science, “Birds” (coming soon); Earth Science, “Weather and Air” for how thermals form; and Gardening & Animals, for raptors.

For families. Numbers are from the U.S. Fish and Wildlife Service (417 nesting pairs in 1963; delisted in 2007; about 71,400 pairs in the lower 48 estimated for 2019). The Bald Eagle Protection Act was passed in 1940 (golden eagles added in 1962); DDT was banned for most uses in the U.S. in 1972. Eyesight comparisons vary by source, so the stop says “perhaps four to eight times.” Dive speeds for golden eagles are commonly reported at 150 mph or more. The Hebrew word *nesher* in Isaiah 40:31 may include the griffon vulture as well as eagles; the KJV reads “eagles.” Hiroshige’s bird is usually described as an eagle; museums differ on the exact kind.

PRACTICE

1. **EASY** What is a thermal, and how does an eagle use it?
2. **EASY** Why are a soaring eagle’s primary feathers spread apart like fingers?
3. **MEDIUM** How is an eagle’s eye different from yours?
4. **MEDIUM** Name two things that nearly wiped out bald eagles in the lower 48 states, and two things people did to help them recover.
5. **CHALLENGE** In 1963 there were about 417 nesting pairs of bald eagles in the lower 48 states; by 2019 there were about 71,400. About how many times more pairs is that? How many individual nesting birds were there in 1963?

Make it a game • Thermal Tag. Outdoors, mark three “thermals” with hoops or chalk circles. Players are eagles and must keep their arms spread wide. An eagle standing inside a thermal and turning slowly in a circle is “soaring” and cannot be tagged. One player is the tagger. An eagle may stay in a thermal only for a count of five before gliding to another. Switch taggers after each catch.

Scripture. “But they that wait upon the LORD shall renew their strength; they shall mount up with wings as eagles; they shall run, and not be weary; and they shall walk, and not faint.” (Isaiah 40:31, KJV)

Isaiah’s words fit the way eagles really fly: they rise not by beating harder but by spreading their wings on the air God sends. To “wait upon the LORD” is to trust Him, and He renews our strength.

Practice: answers

1. A thermal is a rising column of warm air over sun-heated ground. The eagle spreads its wings and circles inside it, rising without flapping.
2. The slots smooth out the swirling air at the wing tips, so the eagle can fly slowly and steadily without stalling.
3. It is several times sharper, and each eye has two foveas (sharp-sight spots), one for looking ahead and one for looking to the side. We have one.

4. Causes (any two): hunting and shooting, poisoning, DDT thinning the eggshells. Helps (any two): protection laws (1940), the DDT ban (1972), guarding nest sites, the endangered species listing.
5. $71,400 \div 417$ is about 171, so roughly 170 times more pairs. In 1963, $417 \text{ pairs} \times 2 = 834$ nesting birds.

2.2 OWLS: HUNTERS OF THE NIGHT

OBJECTIVES

- Explain how an owl's feathers, facial disc and uneven ears let it find and catch prey in darkness.
- Describe why an owl turns its head instead of its eyes, and how far it can turn.
- Dissect (or study pictures of) an owl pellet and identify what the owl ate.

Warm-up. Close your eyes and have someone jingle keys somewhere in the room. Point to where you think the sound is. Now cover one ear and try again. Is it harder? An owl is so good at this game that it can catch a mouse in total darkness.

Video slot. Video coming. Barn owl silent flight in slow motion; how owls hunt by sound; owl pellet dissection for students. Search approved channels (Cornell Lab of Ornithology, National Audubon Society, a state wildlife agency, a university extension program); preview first.

KEY TERMS

nocturnal

Active at night and resting by day. Most owls are nocturnal, though some, like the snowy owl, also hunt by day.

facial disc

The round, dish-shaped ring of stiff feathers on an owl's face that gathers sound and funnels it toward the ears.

asymmetrical

Not the same on both sides. In many owls, one ear opening sits higher on the head than the other.

pellet

A tight bundle of fur, bones, teeth and feathers that an owl cannot digest and coughs back up through its mouth.

vertebrae

The small bones that make up the backbone and neck. An owl has 14 in its neck; you have 7.

CORE IDEAS

There are about 250 kinds of owls, from the elf owl of the Arizona desert, about the weight of a golf ball, to the Eurasian eagle-owl, with a wingspan of more than 6 feet. Most are **nocturnal**. They hunt mice, voles, insects, fish and even skunks, and farmers have long welcomed them: a single family of barn owls may eat a few thousand rodents in one nesting season.

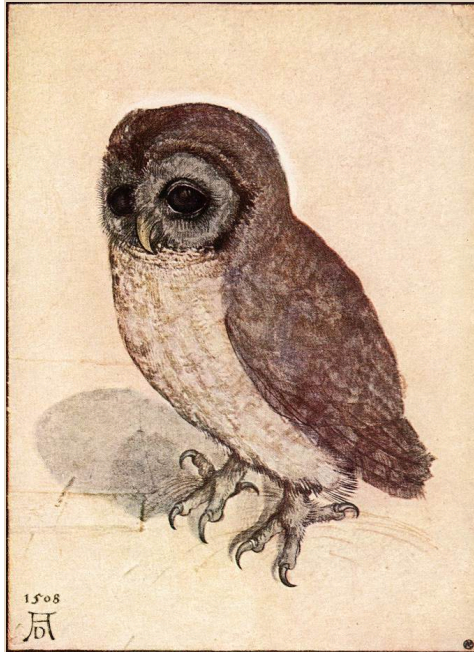
The first secret of the owl is silence. Most birds make a whooshing sound when they flap. An owl's flight feathers are different in three ways. The front edge of the outer feathers has a stiff comb of tiny hooks that breaks the air into small, quiet swirls. The top surface is soft as velvet, so feathers do not rustle against each other. The back edge is a loose fringe that softens the air leaving the wing. Large wings for its weight also let the owl glide slowly. The mouse never hears it coming, and engineers have studied owl feathers to make quieter fans and wind turbines.

The second secret is hearing. An owl's round **facial disc** works like a satellite dish, catching faint sounds and steering them to ear openings hidden under the feathers at its edges. In barn owls and some others, the ear openings are **asymmetrical**: one is higher than the other. A squeak from below reaches the lower ear a tiny bit sooner and louder. The owl's brain compares the two ears and works out not only left and right, but up and down. In the 1970s, scientists at the California Institute of Technology showed that tame barn owls could catch mice in a completely dark room by sound alone.

The third secret is the eyes. An owl's eyes are huge for its head and shaped like tubes, not balls, so they cannot turn in their sockets. To look around, the owl turns its whole head, as far as 270 degrees, three-quarters of a full circle. Its neck has 14 **vertebrae**, twice as many as ours, and special blood vessels with extra room so the blood keeps flowing to its brain while it twists. Owl eyes have many rod cells for dim light, and in the dark an owl sees far better than we do.

Owls swallow small prey whole. What they cannot digest, such as fur, bones and teeth, is squeezed in the gizzard into a **pellet**, which the owl coughs up hours later. Pellets pile up under roosts, and scientists study them to learn what lives nearby. The Bible lists owls among the unclean birds in Leviticus 11 and uses the owl in lonely places as a picture of sorrow: "I am like an owl of the desert" (Psalm 102:6). Yet the same Creator who made the owl for the night made it with wonderful care.

PICTURE STUDY



The Little Owl, Albrecht Dürer, 1506 · Watercolor and gouache on paper · Albertina, Vienna
Wikimedia Commons · Public domain

Albrecht Dürer (1471–1528) of Nuremberg, Germany, was one of the first European artists to paint animals for their own sake, carefully, as if they were sitting for a portrait. His little owl is a real species that lives in farmland across Europe and the Middle East. Notice how he painted each feather with a fine brush so it looks soft enough to touch.

Look closely

- Find the facial disc. Is it as round as a barn owl's, or smaller?
- Look at the eyes. Both face forward. What does that help the owl do?
- Find the feathers on the legs. Why might a bird of cold nights need them?

Talk about it

1. Dürer painted his owl looking straight at us. How does that make you feel?
2. What three things on this owl help it hunt at night? Point to each.

Safety first. Use only owl pellets from a science supplier that have been heat-sterilized. Work on newspaper, wear disposable gloves if you have them, do not touch your face, and wash your hands and the table with soap afterward. Never pick up a pellet, feather or dead bird you find outdoors without an adult.

HANDS-ON: OWL PELLET DETECTIVE

Take apart an owl pellet and find out exactly what one owl ate. If you cannot get a pellet, use a free online virtual pellet dissection and work along on paper.

You will need

- One heat-sterilized owl pellet (from a science supplier)
- Toothpicks or wooden skewers, and tweezers
- A paper plate, newspaper and a magnifying glass
- A printed bone-sorting chart (free from many supplier and extension websites)
- White glue and a sheet of dark construction paper

Steps

1. Measure the pellet's length and weigh it if you have a kitchen scale. Write both in your notebook.
2. Gently pull the pellet apart with the toothpicks. Separate fur from bones. Go slowly; the smallest bones are tiny.
3. Sort the bones into groups: skulls, jaws, leg bones, ribs, hip bones, vertebrae. Count the skulls. Each skull is one animal.
4. Use the chart to decide whether each skull belonged to a mouse, vole, shrew or small bird. Look at the teeth.
5. **Diagram.** Glue the bones of one animal on dark paper in the shape of its skeleton. Label *skull, jaw, vertebrae, ribs, hip (pelvis), front leg* and *back leg*.

Check your work

- I recorded my pellet's size and how many animals were in it.
- I identified at least one animal by its skull and teeth.
- My skeleton diagram has at least six labels.

FIELD NOTEBOOK

1. **Notebook entry: Three secrets of the owl.** Write a paragraph explaining how an owl catches a mouse in the dark. Name its three secrets (silent feathers, hearing, eyes) and use the words *facial disc* and *asymmetrical*.
2. Draw an owl's face from the front. Mark where the hidden ear openings are, one a little higher than the other, and draw arrows to show sound being gathered by the facial disc.

Did you know? The tufts on a great horned owl's head are not ears at all; they are just feathers. The snowy owl of the Arctic hunts in daylight during the long summer days. The burrowing owl of the American West nests underground in old prairie-dog and ground-squirrel holes, and its chicks can make a hiss that sounds like a rattlesnake.

Map or diagram. For the owl-face diagram, draw a large circle for the facial disc. Put the eyes near the middle and the beak below. Mark the ear openings at the edge of the disc, one higher than the other, and add arrows from a "squeak" below to each ear. Label *facial disc, left ear, right ear, eyes* and *beak*.

Goes deeper in. Life Science, “Birds” and “Food Chains” (coming soon); and Gardening & Animals, for owls on the farm and putting up a barn owl box.

For families. Species counts vary (about 230–250 owl species, depending on the list). The barn owl studies are by Masakazu Konishi and colleagues at Caltech in the 1970s. The 270-degree figure and the neck-artery work are from Johns Hopkins researchers (published 2013). Estimates of how many rodents a barn owl family eats vary widely, so the stop says “a few thousand.” KJV owl passages include Leviticus 11:16–17, Psalm 102:6 and Isaiah 34:11–15; the exact birds behind the Hebrew words are uncertain. Pellet dissection kits are sold by science suppliers; check that pellets are heat-treated.

PRACTICE

1. **EASY** What is an owl pellet?
2. **EASY** Why can’t an owl roll its eyes to look to the side?
3. **MEDIUM** Name the three features of an owl’s flight feathers that make it nearly silent.
4. **MEDIUM** How do uneven (asymmetrical) ears help a barn owl find a mouse?
5. **CHALLENGE** An owl turns its head 270 degrees. What fraction of a full circle is that? If a person can turn their head about 90 degrees, how many times farther can the owl turn?

Make it a game • Owl and Mouse. One player is the owl and sits blindfolded in the middle of a quiet room. Another player is the mouse and holds a small bell or a crinkly paper bag. The mouse moves slowly and makes one small sound every few seconds. The owl points to where the sound came from. If the owl points right three times, it catches the mouse and the players switch. Play once with the owl covering one ear to see how much harder it is.

Scripture. “I am like a pelican of the wilderness: I am like an owl of the desert.” (Psalm 102:6, KJV)

The psalmist feels alone and sorrowful, like an owl calling in an empty place. The psalm goes on to trust that God will hear “the prayer of the destitute” (102:17). Even in our loneliest nights, God sees and hears.

Practice: answers

1. A bundle of fur, bones and teeth the owl could not digest, which it coughs back up through its mouth.
2. Its eyes are tube-shaped and fixed in their sockets, so it must turn its whole head instead.
3. A comb of stiff hooks on the front edge, a soft velvety surface, and a loose fringe on the back edge.
4. Sound from below or above reaches one ear a tiny bit sooner and louder than the other. The owl’s brain compares the two and works out whether the mouse is up or down as well as left or right.

5. $270 \div 360 = 3/4$ of a full circle. $270 \div 90 = 3$, so the owl can turn three times as far.

2.3 HUMMINGBIRDS: TINY HELICOPTERS

OBJECTIVES

- Explain how a hummingbird hovers by beating its wings in a figure-eight.
- Use numbers (wingbeats, heartbeats, weight) to describe how fast a hummingbird lives, and explain torpor.
- Mix safe nectar for a hummingbird feeder and keep a short feeding log.

Warm-up. Hold a penny in your palm. It weighs about 2½ grams. A ruby-throated hummingbird weighs only a little more than that, about 3 grams, yet some fly 500 miles across the Gulf of Mexico without stopping. How could something so small do something so hard?

Video slot. Video coming. Hummingbird hovering in slow motion; hummingbird tongue drinking nectar; ruby-throated hummingbird at a feeder. Search approved channels (Cornell Lab of Ornithology, National Audubon Society, Smithsonian’s National Zoo and Conservation Biology Institute); preview first.

KEY TERMS

hover

To stay in one place in the air. Hummingbirds can hover, fly backward and even fly briefly upside down.

nectar

The sweet, sugary liquid made by flowers that hummingbirds and many insects drink.

metabolism

All the work a body does to turn food into energy. Hummingbirds have one of the fastest metabolisms of any animal.

torpor

A deep, short rest, like a one-night hibernation, in which the body cools and the heart slows to save energy.

pollinate

To carry pollen from one flower to another so the plant can make seeds.

CORE IDEAS

Hummingbirds live only in the Americas, from Alaska to the tip of South America, and there are about 360 kinds. Most live in the tropics near the equator, especially in the mountains of Ecuador and Colombia. The smallest is the bee hummingbird of Cuba, about 2¼ inches long and lighter than a dime: it is the smallest bird in the world. In most of the eastern United States, only one kind nests: the ruby-throated hummingbird.

A hummingbird flies like no other bird. Most birds get their lift on the downstroke and simply raise their wings again. A hummingbird's shoulder joint swivels so that its wing turns over on the backstroke, and the wing tip traces a sideways figure-eight. It gets lift on both strokes, so it can **hover** in front of a flower, fly backward and dart sideways like a tiny helicopter. A ruby-throat beats its wings about 50 times a second, which makes the hum that gives the bird its name. Its flight muscles make up about a quarter to a third of its whole weight.

Living that fast takes enormous fuel. A hummingbird's **metabolism** is among the fastest of any animal. Its heart can beat more than 1,000 times a minute in flight, and it breathes about 250 times a minute at rest. It drinks **nectar** with a long forked tongue whose edges curl into tubes and spring open again, licking many times a second. It also eats small insects and spiders for protein. Each day it may visit hundreds of flowers and take in about as much sugar as half or more of its body weight.

How does such a bird survive the night, when it cannot eat? It goes into **torpor**. Its body temperature drops from about 105 °F to as low as about 50-70 °F, and its heart slows to a few dozen beats a minute. In the morning it shivers itself warm and goes back to feeding. In late summer, ruby-throats eat and eat until they nearly double their weight with fat, then many fly nonstop across the Gulf of Mexico to Central America, a flight of about 18 to 22 hours.

Hummingbirds and flowers fit together. Many red, tube-shaped flowers, like trumpet honeysuckle, columbine and cardinal flower, hold their nectar deep where bees struggle to reach, but where a hummingbird's long bill slides right in. As the bird drinks, pollen dusts its forehead, and it carries that pollen to the next flower and **pollinates** it. Jesus told His disciples to "behold the fowls of the air," for "your heavenly Father feedeth them" (Matthew 6:26). The hummingbird, which must eat all day, depends on that daily provision as much as any creature on earth.

PICTURE STUDY



Cattleya Orchid and Three Hummingbirds, Martin Johnson Heade, 1871 · Oil on wood (mahogany panel) ·
National Gallery of Art, Washington, D.C.
Wikimedia Commons · Public domain

Martin Johnson Heade (1819–1904) was an American painter who traveled to Brazil in 1863 to paint its hummingbirds. He planned a fine book of them called *The Gems of Brazil*. The book was never finished, but for the rest of his life he kept painting hummingbirds, often with orchids, against misty rain forests. This painting is less than 18 inches wide.

Look closely

- Count the hummingbirds. Find the tiny nest. Why might it be so small?
- Look at the colors on the birds' throats and backs. How did Heade make them shine?
- Find the orchid. Is the background sharp and clear or soft and hazy? Why?

Talk about it

1. Heade put the orchid very close and the forest far away. How does that change how big the hummingbirds seem?
2. Why do you think Heade called hummingbirds “gems”?

Safety first. Kitchen safety: an adult handles the boiling water and the hot pan. Let the nectar cool completely before filling the feeder. Use only white table sugar: no honey, brown sugar, artificial sweetener or red dye, which can harm the birds.

HANDS-ON: HUMMINGBIRD FEEDER AND FEEDING LOG

Mix nectar the way bird scientists recommend, hang a feeder, and keep a log of visits. If hummingbirds are not in your area this season, plant or find red tubular flowers and log insect visitors instead.

You will need

- A hummingbird feeder (or a clean small bottle with a feeding port)
- White table sugar, water, a measuring cup and a pan
- A notebook, a pencil and a watch or clock

Steps

1. With an adult, measure 1 cup of water and $\frac{1}{4}$ cup of sugar: 1 part sugar to 4 parts water, about the same sweetness as flower nectar. Heat the water, stir in the sugar until it dissolves, and let it cool.
2. Fill the feeder and hang it in partial shade where you can watch it. Place it either within 3 feet of a window or more than 30 feet away, so a startled bird cannot hit the glass at full speed.
3. Change the nectar every two to three days in hot weather (before it turns cloudy) and wash the feeder with hot water.
4. Keep a log for at least five days: date, time, weather, number of visits, and whether the bird was a male (red throat, for ruby-throats) or a female or young bird (white throat).
5. **Diagram.** Draw a hummingbird hovering seen from the side. Trace the path of one wing tip with a dotted figure-eight. Label *downstroke*, *backstroke* (*wing turned over*), *shoulder joint*, *long bill*, *forked tongue* and *gorget* (*throat patch*).

Check your work

- I mixed nectar at 1 part sugar to 4 parts water, with no dye.
- My log has at least five days of entries with times and weather.
- My diagram shows the figure-eight path and at least five labels.

FIELD NOTEBOOK

1. **Notebook entry: Living fast.** Write a paragraph about how a hummingbird uses energy and saves it. Use at least three numbers from the story, and the words *metabolism* and *torpor*.
2. Draw a red tubular flower and a hummingbird bill side by side. Show where the nectar is and where the pollen touches the bird.

Did you know? A hummingbird nest is about the size of half a walnut shell. The mother binds it with spider silk, which stretches as the chicks grow. Hummingbirds have tiny feet and can perch but cannot walk or hop. The rufous hummingbird, at about 3 inches long, travels from Mexico to as far as Alaska, one of the longest journeys for its size of any bird.

Map or diagram. Your figure-eight diagram is a “side view.” Draw the body small and the wing path large and dotted. Use arrows along the path to show the direction the wing travels, and a different color for the downstroke and backstroke.

Goes deeper in. Life Science, “Birds” and “Plants and Pollinators” (coming soon); and Gardening & Animals, for planting a hummingbird garden.

For families. Numbers vary by species and source; the stop uses commonly cited figures for the ruby-throated hummingbird (Cornell Lab of Ornithology, National Audubon Society): about 3 grams, about 50 wingbeats a second, heart rates over 1,000 per minute in flight. Studies of hovering hummingbirds found most lift (roughly three-quarters) comes on the downstroke and the rest on the backstroke. Not every ruby-throat crosses the Gulf; some follow the coast. The 1:4 nectar ratio and the no-dye rule are recommended by the National Audubon Society. Heade’s painting is in the National Gallery of Art (acquired 1982).

PRACTICE

1. **EASY** Where in the world do hummingbirds live?
2. **EASY** What is torpor, and why does a hummingbird need it?
3. **MEDIUM** How is a hummingbird’s wingbeat different from a robin’s, and what does that let it do?
4. **MEDIUM** How does a hummingbird help a flower while it drinks?
5. **CHALLENGE** A ruby-throat beats its wings about 50 times a second. How many times is that in one minute? If it flies for 20 hours across the Gulf, about how many wingbeats is that?

Make it a game • Nectar Dash. Scatter ten paper “flowers” around a yard, each with a cup and one spoonful of water. Each player has a straw (the hummingbird’s tongue) and a small cup (its tummy). On “Go,” hummingbirds fly from flower to flower drinking with their straws and spitting into their own cups. After one minute, whoever has the most “nectar” wins. Play again with the rule that hummingbirds must buzz the whole time.

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

A hummingbird has almost no reserve: it must find food every few minutes all day long. Yet God provides for it. Jesus says we are worth far more, so we need not worry.

Practice: answers

1. Only in the Americas (North, Central and South America and the Caribbean), most of them in the tropics.

2. A deep nightly rest in which the body cools and the heart slows. It saves energy so the bird does not starve during the night when it cannot eat.
3. Its wing swivels and turns over, tracing a figure-eight and making lift on both the downstroke and the backstroke. That lets it hover and fly backward.
4. Pollen rubs onto its head and bill, and it carries the pollen to the next flower, pollinating it so the plant can make seeds.
5. $50 \times 60 = 3,000$ per minute. $3,000 \times 60 = 180,000$ per hour, and $180,000 \times 20 = 3,600,000$, about 3.6 million wingbeats.

2.4 PENGUINS: FLYING UNDER THE SEA

OBJECTIVES

- Explain how a penguin's wings, bones, feathers and fat are designed for swimming in cold water.
- Describe how emperor penguins raise a chick through the Antarctic winter.
- Map where penguins live and test how fat keeps a body warm.

Warm-up. Put your hand in a bowl of ice water and count how many seconds you can keep it there comfortably (stop as soon as it hurts). Emperor penguins stand on the ice through the Antarctic winter at 40 degrees below zero. What would you need to stay warm?

Video slot. Video coming. Emperor penguin huddle in winter; penguins swimming underwater; Galápagos penguin. Search approved channels (Smithsonian Channel, BBC Earth, Monterey Bay Aquarium, British Antarctic Survey); preview first.

KEY TERMS

flipper

A penguin's stiff, flat wing, used to "fly" through water instead of air.

blubber

A thick layer of fat under the skin that keeps sea animals warm and stores energy.

countershading

Coloring that is dark on top and light underneath, so an animal is hard to see from above and from below.

brood pouch

A warm fold of bare skin and feathers above an emperor or king penguin's feet that covers the egg or small chick.

colony

A large group of the same kind of animal living and nesting together.

CORE IDEAS

There are about 18 kinds of penguins, and every one lives in the Southern Hemisphere, south of the equator, with one small exception: the Galápagos penguin, whose islands straddle the equator. Only a few kinds nest on Antarctica itself. Others live on cold islands, the coasts of South America, southern Africa, Australia and New Zealand. The smallest is the little (or fairy) penguin, about 13 inches tall and 2 to 3 pounds. The largest is the emperor, nearly 4 feet tall and up to about 80 pounds.

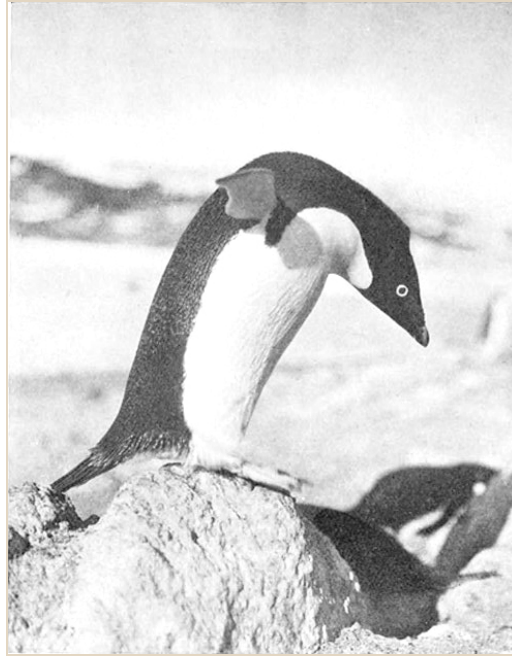
Penguins cannot fly in the air, but they fly under the sea. Their wings are stiff, flat **flippers**. Their bones are solid and heavy, not hollow, which helps them dive. Their bodies are shaped like torpedoes, and their short, stiff feathers overlap like roof tiles to make a waterproof coat. Under the skin lies a layer of **blubber**. Their **countershading** hides them: a leopard seal looking up sees a white belly against the bright surface, and a hunter looking down from above sees a black back against the dark depths. Gentoo penguins can swim about 22 miles an hour, and emperors have been recorded diving more than 1,800 feet deep and staying under for over 25 minutes. Glands above their eyes even remove extra salt from the seawater they swallow.

The emperor penguin has the hardest childhood of any bird. In the Antarctic autumn, about April, emperors walk as far as 50 to 70 miles over the sea ice to their **colony**. The female lays one egg in May or June, passes it carefully to the male's feet, and walks back to the sea to feed. All winter, in total darkness and winds up to 100 miles an hour, the males stand with the egg in their **brood pouch** for about two months, eating nothing. They huddle by the thousands, slowly shuffling so that each takes a turn on the cold outside edge. By the time the chick hatches, a male may have fasted about four months and lost more than a third of his weight. If the mother is late, he feeds the chick a milky curd from his throat until she returns with a stomach full of fish.

In 1911, three men from Robert Falcon Scott's British expedition, Edward Wilson, Henry Bowers and Apsley Cherry-Garrard, sledged for five weeks in the winter darkness to reach an emperor colony at Cape Crozier. They wanted eggs to study how penguin chicks form. The thermometer fell to about 77 degrees below zero (Fahrenheit), and a blizzard tore away their tent; they found it again by a near miracle. They brought back three eggs. Cherry-Garrard later carried them to the Natural History Museum in London and wrote the story in a famous book, *The Worst Journey in the World* (1922).

The book of Job asks, "Hast thou entered into the treasures of the snow?" (Job 38:22). The penguin was made for a world that would freeze us in minutes. It is a living answer to the Lord's questions to Job: He alone knows the cold places of the earth and fills them with life.

PICTURE STUDY



Adélie penguins, photographed on the British Antarctic (Terra Nova) Expedition, Herbert George Ponting, 1910–1913 · Photograph (glass-plate negative) · Scott Polar Research Institute, Cambridge, and the Royal Geographical Society hold Ponting's prints
Wikimedia Commons · Public domain

Herbert Ponting (1870–1935) was the photographer of Captain Scott's expedition, the first professional photographer to work in Antarctica. He carried heavy cameras and glass plates across the ice and developed his pictures in a tiny darkroom inside the expedition hut. His penguin photographs and films showed people around the world what these birds were really like. Adélie penguins, about 2 feet tall, nest on Antarctica's rocky coasts in summer.

Look closely

- Find the white ring around each penguin's eye: the mark of the Adélie.
- Look at the posture of the birds. How do they hold their flippers when they walk?
- Find the dark backs and white bellies. Which way would each side face when the penguin swims?

Talk about it

1. Ponting worked in temperatures far below freezing. What problems would cold cause for a camera and a photographer?
2. What can a photograph show that a painting cannot? What can a painting show that this photograph cannot?

HANDS-ON: THE BLUBBER GLOVE AND A PENGUIN MAP

Test how a layer of fat keeps a body warm in icy water, then map where the world's penguins live.

You will need

- Four zip-top sandwich bags and a tub of vegetable shortening
- A large bowl of ice water
- A watch or timer
- A world map outline (or a globe and blank paper) and colored pencils

Steps

1. Spoon about a cup of shortening into one bag. Turn a second bag inside out, put it inside the first, and zip the two together at the top so the shortening is trapped between them. This is your blubber glove.
2. Put a plain bag on one hand and the blubber glove on the other. Dip both hands into the ice water at the same time. Count how many seconds each hand stays comfortable. Repeat twice and record the times.
3. **Map.** On a world map, draw the equator in red. Shade and label where penguins live: Antarctica (emperor, Adélie), the tip of South America and the Falkland Islands (Magellanic, gentoo, king), southern Africa (African penguin), southern Australia and New Zealand (little penguin), and the Galápagos Islands (Galápagos penguin). Mark Cape Crozier on Antarctica with a star.
4. Add a title, a compass rose and a key, and write a sentence below the map: "All penguins live in the _____ Hemisphere."

Check your work

- I timed both hands at least twice and recorded the results.
- I can explain why the blubber hand stayed warm longer.
- My map has the equator, at least six labeled penguin areas, a key and a compass rose.

FIELD NOTEBOOK

1. **Notebook entry: The emperor's winter.** Write a paragraph telling the story of an emperor penguin egg from the day it is laid to the day the mother returns. Use the words *colony*, *brood pouch* and *huddle*, and include at least two numbers.
2. Record your blubber glove results in a small table: trial, plain bag (seconds), blubber glove (seconds).

Did you know? Penguins molt all their feathers at once each year. For two to three weeks they cannot go into the sea, so they must fatten up beforehand and fast while the new coat grows. Penguins drink seawater safely because glands above their eyes pull out the salt, which drips off the tip of the bill.

Map or diagram. On the penguin map, use one color for all penguin areas and write the kind of penguin beside each. The Galápagos Islands sit right on the equator off Ecuador, so your red line should run through them.

Goes deeper in. Geography, “Antarctica and the Southern Ocean” (coming soon); Life Science, “Birds”; and History, for the Scott and Amundsen expeditions to the South Pole.

For families. Species counts vary from 17 to 20 depending on the list; 18 is common. Emperor dive records over 500 m (about 1,850 ft) and dives over 25 minutes are reported in scientific studies. The Cape Crozier winter journey ran from late June to the start of August 1911; the coldest temperature Cherry-Garrard recorded was about -77°F . Wilson hoped the embryos would answer questions about how birds develop, a view of his day; we have kept the reason simple. Wilson and Bowers died with Scott in 1912 on the return from the Pole; the stop states this only in this note. *The Worst Journey in the World* is summarized, not quoted. The Ponting photograph is identified generally; choose any of his Adélie photographs on Wikimedia Commons.

PRACTICE

1. **EASY** Which hemisphere do penguins live in, and which kind lives right at the equator?
2. **EASY** Why are a penguin’s bones solid instead of hollow like most birds’?
3. **MEDIUM** Explain how countershading protects a swimming penguin from both a seal below it and a bird above it.
4. **MEDIUM** Why do emperor penguins in a huddle keep shuffling?
5. **CHALLENGE** A male emperor weighs about 80 pounds when he arrives at the colony and fasts until he has lost about 40 percent of his weight. How much does he lose, and how much does he weigh at the end?

Make it a game • The Huddle. All players stand close together in a tight group with their arms in like flippers. The players on the outside edge are “cold.” Every time the leader calls “Wind!”, the group slowly shuffles so that the outside players work their way inward and inside players move out. No pushing. Then try “Egg Huddle”: each player balances a beanbag on their feet and must shuffle without dropping it.

Scripture. “Out of the south cometh the whirlwind: and cold out of the north. By the breath of God frost is given: and the breadth of the waters is straitened.” (Job 37:9-10, KJV)

Elihu tells Job that frost and the freezing of the waters come from God. The penguins’ icy world is not a mistake or an accident; God governs the cold and designed creatures to live in it.

Practice: answers

1. The Southern Hemisphere. The Galápagos penguin lives on islands on the equator.
2. Heavy, solid bones help it dive and stay underwater instead of floating.
3. From below, its white belly blends with the bright water surface. From above, its dark back blends with the dark deep water.

4. So that each bird takes a turn on the cold outside edge and then moves to the warm middle; no one freezes.
5. 40% of 80 is $0.4 \times 80 = 32$ pounds lost. $80 - 32 = 48$ pounds left.

2.5 OSTRICHES: SHE SCORNETH THE HORSE (JOB 39:13–18)

OBJECTIVES

- Describe the ostrich with numbers: height, weight, speed, egg size and eye size.
- Explain how the ostrich is built for running instead of flying.
- Read Job 39:13–18 carefully, compare it with how ostriches really nest, and explain what God is teaching Job.

Warm-up. Measure 9 feet up a wall or door frame and mark it with tape. That is how tall a big male ostrich can stand with its head up. Now stand next to the mark. Could you see over a crowd if you were that tall?

Video slot. Video coming. Ostriches running on the African savanna; ostrich nest and eggs; ostrich chicks. Search approved channels (San Diego Zoo Wildlife Alliance, Smithsonian’s National Zoo, BBC Earth); preview first.

KEY TERMS

ratite

A flightless bird with a flat breastbone and no keel for flight muscles, such as the ostrich, emu, rhea, cassowary and kiwi.

keel

A tall ridge on the breastbone of flying birds where the big flight muscles attach. Ostriches do not have one.

stride

The distance covered in one running step. A sprinting ostrich’s stride can be 10 to 16 feet.

clutch

All the eggs laid in one nest at one time.

scorn

To look down on something as not worth fearing. Job 39:18 says the running ostrich “scorneth the horse and his rider.”

CORE IDEAS

The ostrich is the largest living bird. A male may stand 9 feet tall and weigh about 300 pounds. It lives on the dry plains and deserts of Africa, and wild ostriches once lived in the lands of the Bible too, in Arabia, Syria and Israel, until they were hunted out in the 1900s. Like the emu of Australia and the rhea of South America, it is a **ratite**: its breastbone is flat, with no **keel** for flight muscles. Its wings are used for balance, for turning sharply while running, for shading chicks and for showing off.

What the ostrich has instead is legs. Its thighs are thick with muscle, its long lower legs are thin and springy, and each foot has only two toes, the larger one with a thick claw like a hoof. A sprinting ostrich can reach about 43 miles an hour with a **stride** of 10 to 16 feet, and it can hold about 30 miles an hour for many minutes. The fastest racehorses run about 40 to 44 miles an hour, but only for short distances, and they carry riders. A kick from an ostrich is powerful enough to kill a lion, so wise people keep their distance.

The ostrich's eyes are about 2 inches across, the largest of any land animal and bigger than its own brain. From its great height it watches for danger across the open plain. The old saying that ostriches bury their heads in the sand is not true. The idea goes back at least to the Roman writer Pliny the Elder. What ostriches really do is lie flat with their necks stretched along the ground to hide, and they put their heads into their nest scrape to turn the eggs, which from far away may look like a buried head.

An ostrich egg is about 6 inches long and weighs about 3 pounds, the size of about two dozen chicken eggs. Yet compared with the mother's size, it is the smallest egg of any bird. A male scrapes a shallow pit in the sand. His chief hen lays her eggs there, and several other hens may add theirs, until the **clutch** holds twenty or more. The chief hen sits by day and the male, with his black feathers, sits by night. Extra eggs that will not fit are pushed to the edge and left, where jackals and vultures may break them. Eggs left uncovered in the hot sun warm themselves for a time, "in dust" as Job says.

In Job 39, God asks Job about creatures Job cannot control. He describes the ostrich honestly as a bird that seems careless with its eggs, that has not been given wisdom (39:17), and yet that "scorneth the horse and his rider" when it runs (39:18). The lesson is that God gives each creature its own gifts. The ostrich is not wise, but it is fast, and God cares for it anyway. God does not need to explain everything to Job; His works show that He is wiser than we are.

PICTURE STUDY



Ostrich being loaded onto a ship, detail of the Great Hunt mosaic, Unknown Roman mosaic makers, Early 4th century A.D. · Floor mosaic of small stone and glass pieces · Villa Romana del Casale, Piazza Armerina, Sicily, Italy

Wikimedia Commons · Public domain

About 1,700 years ago, a rich Roman built a country house in Sicily and covered its floors with mosaics. One corridor is about 200 feet long and shows the “Great Hunt”: men capturing wild animals in Africa and the East and loading them onto ships to be taken to Rome for shows in the arena. Among the leopards, antelopes and elephants is an ostrich being carried aboard. The house is now a World Heritage Site.

Look closely

- Find the ostrich. Count its toes if you can see them.
- How are the men handling the bird? Does it look easy or hard?
- Look at the tiny pieces (called tesserae). How did the makers show feathers with stones?

Talk about it

1. Why would Romans bring ostriches across the sea? What does that tell you about how unusual the bird seemed to them?
2. If you were the man carrying the ostrich, what would you be most afraid of?

HANDS-ON: THE GIANT EGG: MEASURING AND COMPARING

Use real chicken eggs, a paper model and some arithmetic to see just how big an ostrich egg is, then draw a scale diagram of an ostrich beside a horse and rider.

You will need

- One chicken egg, a ruler and a kitchen scale
- Stiff paper, a pencil, scissors and string
- A measuring cup and water (optional)
- Graph paper for the scale diagram

Steps

1. Measure the length of a chicken egg and weigh it. Most large chicken eggs are about $2\frac{1}{4}$ inches long and weigh about 2 ounces.
2. Draw an oval 6 inches long and 5 inches wide on stiff paper and cut it out: the outline of an ostrich egg. Lay your chicken egg on it.
3. An ostrich egg weighs about 3 pounds (48 ounces). Divide 48 by the weight of your chicken egg. How many chicken eggs equal one ostrich egg?
4. **Diagram.** On graph paper, let one square stand for 1 foot. Draw side by side: a person 5 feet tall, a horse 5 feet at the withers with a rider on top (about 8 feet to the rider’s head), and an ostrich 9 feet tall. Label *ostrich (9 ft)*, *horse and rider*, *person*, *two-toed foot*, *wing (for balance)* and *eye (2 in)*, and write the scale under the drawing.

Check your work

- I measured and weighed a chicken egg and recorded both.

- I worked out how many chicken eggs equal one ostrich egg and showed my math.
- My scale diagram uses 1 square = 1 foot and has at least five labels.

FIELD NOTEBOOK

1. **Notebook entry: What Job saw.** Copy Job 39:18. Then write a paragraph comparing two things Job 39 says about the ostrich with what scientists have observed. End with one sentence about what God was teaching Job.
2. Draw an ostrich foot. Label the large toe with its claw and the small outer toe.

Did you know? Around 1900, ostrich feathers were so fashionable on hats that ostrich farming made some farmers in the town of Oudtshoorn, South Africa, very rich; they built grand “feather palaces.” By 1913 ostrich feathers were among South Africa’s most valuable exports. Then fashions changed, and around 1914 the market collapsed almost overnight. Many farmers were ruined.

Map or diagram. In your scale diagram, keep every figure standing on the same ground line, and measure heights by counting squares. A scale drawing is honest only when every part uses the same scale.

Goes deeper in. Literature, “The Book of Job” (coming soon); Life Science, “Birds”; and Small Business & Economics, for the ostrich-feather boom and bust.

For families. Sizes are typical figures from zoo and museum sources (San Diego Zoo, Smithsonian): males up to about 9 ft and 300–320 lb; top speed about 43 mph (70 km/h); eggs about 3 lb. The Arabian ostrich, a subspecies, is generally said to have died out in the mid-1900s. In Job 39:13 the Hebrew word KJV renders “peacocks” is usually taken today to mean ostriches as well; scholars differ. The stop reads Job 39 as poetry describing what an ostrich appears to do; real ostriches do guard the main clutch, while the outer eggs are left exposed. The Great Hunt mosaic dates to the early 300s A.D. The arena shows it served are mentioned without detail.

PRACTICE

1. **EASY** Why can’t an ostrich fly?
2. **EASY** Is it true that ostriches bury their heads in the sand?
3. **MEDIUM** What does Job 39:18 mean when it says the ostrich “scorneth the horse and his rider”?
4. **MEDIUM** In an ostrich nest, who sits on the eggs by day and who by night? Why does that make sense?
5. **CHALLENGE** An ostrich runs at 30 miles an hour for 20 minutes. How far does it go? At 43 miles an hour, how many feet does it cover in one second? (1 mile = 5,280 feet.)

Make it a game • Ostrich Relay. Mark a start and a finish line about 30 steps apart. Each runner must keep their “wings” (arms) out to the side for balance and take the

longest strides they can. Count each runner's strides from start to finish. Fewest strides wins, not fastest time. Then talk about it: why does a longer stride help an animal run fast?

Scripture. "Gavest thou the goodly wings unto the peacocks? or wings and feathers unto the ostrich? Which leaveth her eggs in the earth, and warmeth them in dust, And forgetteth that the foot may crush them, or that the wild beast may break them. She is hardened against her young ones, as though they were not hers: her labour is in vain without fear; Because God hath deprived her of wisdom, neither hath he imparted to her understanding. What time she lifteth up herself on high, she scorneth the horse and his rider." (Job 39:13-18, KJV)

God shows Job a bird that is not wise and yet is wonderfully fast. God gives each creature its own gifts and does not need Job's advice to run the world. When we do not understand His ways, we can trust His wisdom.

Practice: answers

1. It is too heavy, its wings are small, and its breastbone has no keel for big flight muscles. It is built for running.
2. No. They lie flat with their necks along the ground to hide, and they put their heads into the nest to turn the eggs.
3. When it runs, the ostrich is fast enough that it does not fear a horse and rider chasing it; it can outrun them, especially over a long distance.
4. The brown chief hen sits by day and the black male by night. Her dull feathers blend with the sand in daylight, and his dark feathers are hard to see at night.
5. 20 minutes is $\frac{1}{3}$ of an hour, so $30 \times \frac{1}{3} = 10$ miles. $43 \times 5,280 = 227,040$ feet per hour; $\div 3,600$ seconds ≈ 63 feet per second.

2.6 PARROTS: CLEVER CLIMBERS AND TALKERS

OBJECTIVES

- Describe the parrot's hooked beak and two-forward, two-back (zygodactyl) feet, and how it uses them.
- Explain how parrots imitate speech and what the African grey parrot Alex showed about parrot learning.
- Tell the stories of the lost Carolina parakeet and the rescued kakapo as lessons in stewardship.

Warm-up. Try to pick up a pencil and turn it around using only your thumb and one finger held together on one side and your other three fingers on the other. Now hold two fingers on each side. Which grip is stronger? Parrots grip with two toes in front and two behind.

Video slot. Video coming. Parrot feet and beak climbing; African grey parrot learning words; kakapo recovery in New Zealand. Search approved channels (Smithsonian's National Zoo, San Diego Zoo Wildlife Alliance, New Zealand Department of Conservation); preview first.

KEY TERMS

zygodactyl

Having two toes pointing forward and two pointing backward, like parrots, woodpeckers and owls (part of the time). Say "zy-go-DAK-til."

mimic

To copy sounds or actions. Many parrots mimic human words, other birds and household noises.

syrinx

A bird's voice box, found where the windpipe divides deep in the chest. Birds have no vocal cords like ours.

extinct

No longer living anywhere on earth. The Carolina parakeet became extinct in the early 1900s.

flock

A group of birds that live, feed or travel together.

CORE IDEAS

There are about 400 kinds of parrots, including macaws, cockatoos, lovebirds, budgerigars and parakeets. Most live in the warm belt of the earth around the tropics, in Central and South America, Africa, southern Asia and Australia. The largest by length is the hyacinth

macaw of Brazil, about 3 feet from head to tail; the heaviest is the kakapo of New Zealand, which can weigh up to about 9 pounds; the smallest are the pygmy parrots of New Guinea, about 3 inches long.

A parrot's beak is a tool kit. The upper half is hinged to the skull, so it can move up and down as well as the lower half, giving a strong crushing bite. The hooked tip tears fruit, the sharp edge husks seeds, and a hyacinth macaw can crack palm nuts that a person would need a hammer to open. When climbing, a parrot uses its beak as a third foot, hooking a branch and pulling itself up. Its feet are **zygodactyl**: two toes forward and two back, which makes a strong grip for climbing and lets many parrots hold food up to their mouths like a hand. Many parrots are "left-footed" or "right-footed," just as people favor one hand.

Parrots are famous for talking. A bird has no vocal cords; instead it makes sound with the **syrinx**, deep in its chest, and shapes it with a thick, muscular tongue. In the wild, parrots **mimic** the calls of their own **flock**, so that they belong; in a home, the family becomes the flock. Starting in 1977, the scientist Irene Pepperberg worked for thirty years with an African grey parrot named Alex. Alex learned about 100 words and could name colors, shapes and materials, count small groups of objects up to six, and answer "What's different?" about two objects. Scientists still debate how much he understood, but he showed that a "bird brain" can learn far more than people expected.

Parrots need care. The Carolina parakeet, green with a yellow and orange head, was the only parrot native to the eastern United States, living in flocks from Florida to the Ohio Valley. Farmers shot it because it ate fruit and grain, its feathers were sold for hats, and its forests were cut. The last known bird, named Incas, died at the Cincinnati Zoo in 1918. Today the kakapo of New Zealand tells a happier story. A flightless parrot that climbs trees at night and freezes when danger comes, it fell to only 51 birds in 1995. Rangers moved every kakapo to safe islands free of rats and stoats, watched over each nest, and by recent counts there are about 250.

Parrots also live long. A large macaw or cockatoo may live fifty years or more, and a cockatoo named Cookie at a zoo near Chicago reached 83. Anyone who keeps a parrot takes on a long promise. God gave Adam dominion over "the fowl of the air" (Genesis 1:28), and good dominion means care, not carelessness.

PICTURE STUDY



Hyacinthine Maccaw (Plate 9 of *Illustrations of the Family of Psittacidae, or Parrots*), Edward Lear, 1832 · Hand-colored lithograph, printed by Charles Hullmandel · From Lear's book of parrots, London; copies in many libraries, including the University of Wisconsin and the Biodiversity Heritage Library online · Wikimedia Commons · Public domain

Edward Lear (1812–1888) began this book in 1830, when he was just 18 years old. He drew live parrots at the London Zoo and in private collections, measuring them so he could draw them life-size, and drew straight onto the printing stones himself. He called this bird a “Hyacinthine Maccaw,” but more than a hundred years later scientists decided it was really a different, smaller blue macaw. They named it Lear’s macaw in his honor. Later Lear became famous for something else: funny poems like “The Owl and the Pussy-cat.”

Look closely

- Find the yellow ring around the eye and the yellow patch by the beak. What do they do to the blue of the feathers?
- Look at the feet. Can you see two toes forward and two back?
- Look at the shape of the beak. Which part would crack a nut?

Talk about it

1. Lear drew from live birds, not stuffed ones. What can you see in this picture that shows the bird was alive?
2. Lear’s picture was so careful that scientists could later tell it showed a different kind of macaw. Why is careful drawing important to science?

HANDS-ON: TOE TEST AND FOOT DIAGRAM

Find out why two-forward, two-back toes are good for climbing and holding, then draw and label two kinds of bird feet.

You will need

- Masking tape
- A broom handle or a thick dowel held level between two chairs
- A few peanuts in the shell, a grape and a pencil
- A notebook page and a pencil

Steps

1. Tape your fingers into a “songbird foot”: three fingers taped together pointing forward, thumb behind. Try to pick up a peanut and lift it to your mouth, then roll a pencil in your “foot.”
2. Now tape into a “parrot foot”: index and middle finger taped together, ring and little finger taped together, so you have two “toes” on each side. Try the same tasks. Which foot is better for holding food? Which is better for grasping the broom handle?
3. Record your results in a table: task, songbird foot, parrot foot.
4. **Diagram.** Draw two bird feet side by side as if seen from above. On the left, a perching songbird foot (three toes forward, one back). On the right, a parrot foot (two forward, two back). Number the toes 1 to 4 on each, and label *anisodactyl* (3 forward, 1 back), *zygodactyl* (2 forward, 2 back), *claw* and *scales*.
5. **Map (optional).** On a world map, draw the Tropic of Cancer and the Tropic of Capricorn and shade the belt between them lightly. Mark the homes of the hyacinth macaw (Brazil), African grey (central Africa), kakapo (New Zealand) and the old range of the Carolina parakeet (eastern United States).

Check your work

- I tried at least two tasks with each kind of foot and recorded the results.
- My diagram shows both feet with toes numbered and both labeled correctly.
- I can explain which foot is better for climbing and holding food, and why.

FIELD NOTEBOOK

1. **Notebook entry: Lost and saved.** Write a paragraph comparing the Carolina parakeet and the kakapo. Tell what happened to each and what people did or did not do. Use the words *extinct* and *stewardship*.
2. Sketch a parrot head from Lear’s plate. Label the upper bill, lower bill, hook and eye ring.

Did you know? The kea, a big green parrot of New Zealand’s mountains, is so curious that it pulls rubber strips off parked cars and works out how to open trash cans.

Budgerigars (“budgies”) of Australia fly in flocks of thousands across the dry outback looking for seeds and water. Woodpeckers, cuckoos and roadrunners have zygodactyl feet too.

Map or diagram. On the foot diagram, draw both feet at the same size and from the same view so they can be fairly compared. Use straight leader lines for labels and put the names underneath each foot.

Goes deeper in. Life Science, “Birds” (coming soon); Art, for Edward Lear’s bird plates; Literature, for Lear’s nonsense poems; and Gardening & Animals, for caring for pet birds.

For families. Species counts are about 390–400. Alex the parrot: Irene Pepperberg, studies from 1977 until Alex died in 2007; word counts and abilities are as she reported, and scientists debate how to interpret them. Carolina parakeet: the last known captive bird, Incas, died February 21, 1918, at the Cincinnati Zoo; the species was declared extinct later. Kakapo: 51 known birds in 1995 (New Zealand Department of Conservation); the population has been around 250 in recent counts and changes year to year. Cookie, a Major Mitchell’s cockatoo at Brookfield Zoo, died in 2016 at about 83. Lear’s plate dates are given as 1830–1832, since the book came out in parts.

PRACTICE

1. **EASY** What does zygodactyl mean, and what does it help a parrot do?
2. **EASY** How does a parrot use its beak when it climbs?
3. **MEDIUM** Why do wild parrots imitate sounds, and why do pet parrots imitate people?
4. **MEDIUM** Give two reasons the Carolina parakeet disappeared, and two things rangers did to save the kakapo.
5. **CHALLENGE** The kakapo grew from 51 birds in 1995 to about 250. How many birds were added? By what percent did the population grow?

Make it a game • Parrot, Copy Me! One player is the flock leader and makes a short sound pattern: a whistle, a clap, a word and a click. The next player (the young parrot) copies it exactly, then adds one more sound. Keep going around the group. A parrot who misses a sound drops out, and the last parrot still copying wins.

Scripture. “For every kind of beasts, and of birds, and of serpents, and of things in the sea, is tamed, and hath been tamed of mankind: But the tongue can no man tame; it is an unruly evil, full of deadly poison.” (James 3:7–8, KJV)

People can tame birds and even teach a parrot to talk. James says our own tongues are harder to tame. A parrot repeats whatever it hears; let the words we speak be ones worth repeating.

Practice: answers

1. Two toes forward and two back. It gives a strong grip for climbing and lets the parrot hold food like a hand.
2. It hooks the beak over a branch and pulls itself up, using it like a third foot.
3. In the wild they copy their flock's calls so they belong to the group. In a home, the family becomes the parrot's flock, so it copies the family's words.
4. Parakeet (any two): farmers shot it, its feathers were sold for hats, its forests were cut down.
Kakapo (any two): moved the birds to islands without rats and stoats, guarded each nest, counted and watched every bird.
5. $250 - 51 = 199$ birds added. $199 \div 51 \approx 3.9$, so it grew by about 390 percent (nearly five times as many birds).

2.7 MIGRATION: THE STORK KNOWETH HER APPOINTED TIMES

OBJECTIVES

- Explain why many birds migrate, and tell how people discovered that birds travel instead of hiding for the winter.
- Describe at least three ways birds find their way, including the star experiments with indigo buntings.
- Draw a map of the four North American flyways and the record journeys of the Arctic tern and bar-tailed godwit.

Warm-up. Look at a calendar. What month do the first robins, swallows or geese usually arrive where you live, and when do they leave? Ask a grandparent if they remember. Birds keep a calendar too, and they keep it remarkably well.

Video slot. Video coming. Bird migration explained; Arctic tern migration route; sandhill cranes on the Platte River in spring; radar images of migrating birds at night. Search approved channels (Cornell Lab of Ornithology, U.S. Fish and Wildlife Service, National Park Service, Smithsonian Migratory Bird Center); preview first.

KEY TERMS

migration

A regular journey, usually each spring and fall, between a breeding home and a wintering home.

flyway

A broad route that many migrating birds follow, often along coasts, rivers or mountain ranges.

navigation

Finding one's way from one place to another, using clues such as the sun, stars, landmarks or a compass.

stopover

A place where migrating birds rest and feed for a few days before flying on.

Zugunruhe

A German word meaning “migration restlessness”: the hopping and fluttering of caged birds at migration time, facing the way they would fly. Say “TSOOK-oon-roo-uh.”

CORE IDEAS

About 4,000 of the world's roughly 11,000 kinds of birds make regular **migrations**. In North America, more than half of the breeding birds fly south in the fall. They go because food runs

out. An insect-eating warbler cannot find caterpillars in a snowy Canadian forest, so it winters in Central or South America. In spring the long northern days bring a flood of insects and plenty of room to nest, so it flies back. Most songbirds travel at night, when the air is cooler and calmer and hawks are asleep, and rest and feed by day at **stopovers**.

For centuries, people were not sure where birds went. The Greek thinker Aristotle wrote that some birds hid in holes for the winter or changed into other kinds of birds. As late as the 1700s, some writers thought swallows slept in the mud at the bottom of ponds. Then, in 1822, a hunter near the village of Klütz in northern Germany shot a white stork with a long wooden arrow stuck right through its neck. The arrow came from central Africa. The bird had been wounded there and still flew thousands of miles home. This “arrow stork” (in German, *Pfeilstorch*) is still kept in a museum at the University of Rostock, and it helped prove that storks really do fly to Africa and back.

How do birds find the way? Scientists have found several kinds of **navigation**. Birds use the sun, correcting for its movement across the sky through the day. Night migrants use the stars: in the 1960s, the scientist Stephen Emlen put young indigo buntings in a planetarium. When the star pattern was turned, the birds turned too, facing the direction they “should” fly under the new sky. They had learned the star at the center of the turning night sky, the North Star. Birds also sense the earth’s magnetic field, follow coastlines, rivers and mountains, and some may even use smell. Caged birds become restless at migration time and hop toward the right direction, a behavior scientists call **Zugunruhe**.

Some journeys are almost beyond belief. The Arctic tern, a bird of about 4 ounces, nests near the Arctic and spends the northern winter off Antarctica. One tagged in Britain in 2016 flew about 59,000 miles in a single year, and over a lifetime of thirty years an Arctic tern may fly as far as to the moon and back three times. In October 2022, a young bar-tailed godwit tagged in Alaska flew nonstop to Tasmania, about 8,400 miles in 11 days, without eating, drinking or landing. In North America, birds funnel along four great **flyways**: the Atlantic, Mississippi, Central and Pacific. The United States and Great Britain (for Canada) signed a treaty in 1916 to protect migratory birds that cross borders, and the Migratory Bird Treaty Act of 1918 still protects most of them.

Long before scientists, the prophet Jeremiah noticed: “the stork in the heaven knoweth her appointed times” (Jeremiah 8:7). He was making a point. The birds keep the times God set for them, but God’s own people had forgotten His ways. A stork does not need a calendar; God built the knowledge into it. People have God’s Word, and they should know their appointed duties at least as well as a stork.

PICTURE STUDY



Wild Geese Flying Across the Moon, Utagawa Hiroshige, c. 1832–1835 · Color woodblock print · Impressions in several museums, including the Metropolitan Museum of Art, New York, and the RISD Museum, Providence
Wikimedia Commons · Public domain

In Japan, the cry of wild geese arriving in autumn was a sign of the changing season, and poets wrote about it for a thousand years. Hiroshige (1797–1858) made this print about twenty-five years before his famous eagle print in Stop B1. It is a tall, narrow print made to hang like a scroll. Notice how few lines he uses: a few birds, a moon and a short poem are enough to tell the season.

Look closely

- Count the geese. Which way are they flying: up, down or across?
- Look at their necks and wings. How does Hiroshige show that they are moving fast?
- Find the poem at the top. Why might an artist put words and a picture together?

Talk about it

1. Many geese and songbirds migrate at night. What does a moonlit sky help a bird do?
2. This print shows a season without showing any trees or flowers. How?

HANDS-ON: MAP OF THE FLYWAYS

Draw a map of North America's four flyways and two world-record journeys, then track real migration this week online.

You will need

- An outline map of North and South America, and a world outline map (free to print from many map sites)
- Four colored pencils or markers and a ruler
- A computer or tablet with an adult, for BirdCast (birdcast.info), optional

Steps

1. **Flyways map.** On the Americas map, draw four broad colored bands running north to south: the *Pacific Flyway* along the west coast, the *Central Flyway* over the Great Plains along the Rocky Mountains, the *Mississippi Flyway* down the Mississippi River valley, and the *Atlantic Flyway* along the east coast. Label each band.
2. Mark and label: the Gulf of Mexico (where many songbirds cross), the Platte River in Nebraska (where hundreds of thousands of sandhill cranes stop each March), and your own home with a star. Which flyway are you in?
3. **World map.** Draw the Arctic tern's route as a long dotted line from Greenland or Britain, down the coast of Africa or South America, to the edge of Antarctica. Draw the bar-tailed godwit's route as a solid line from western Alaska straight across the Pacific to Tasmania. Label each with its distance.
4. Add a title, a key for your colors, and a compass rose to each map.
5. With an adult, visit BirdCast and look at the migration forecast for your state tonight. Write down what you find.

Check your work

- My flyways map shows all four flyways in different colors, with labels and a key.
- My world map shows both record routes with distances.
- I marked my home and can name the flyway I live in.

FIELD NOTEBOOK

1. **Notebook entry: How birds find the way.** Write a paragraph explaining at least three ways birds navigate. Describe Stephen Emlen's planetarium experiment in your own words.
2. Draw the arrow stork of 1822 with the arrow through its neck, and write one sentence about what it proved.

Did you know? On busy spring nights, weather radar picks up so many migrating birds that they show up as huge rings and clouds on the screen. Scientists now use radar to forecast migration the way meteorologists forecast rain. Some cities turn off their bright lights at night during migration seasons, because lights can confuse night-flying birds.

Map or diagram. Flyways are wide bands, not thin lines; birds spread out across them. Draw each band about a finger wide, and let the bands narrow where they squeeze through places like the Isthmus of Panama.

Goes deeper in. Geography, “North America” and “Map Skills” (coming soon); Life Science, “Birds”; and Earth Science, for the earth’s magnetic field.

For families. Sources: Cornell Lab of Ornithology and the Smithsonian Migratory Bird Center. The Pfeilstorch was shot in 1822 near Klütz, Mecklenburg, and is held by the University of Rostock zoological collection. Emlen’s indigo bunting studies were published in the 1960s and 1970s. The Arctic tern figure (about 96,000 km in one year) is from a 2016 tracking study of terns from the Farne Islands, England; earlier studies found about 70,000 km. The godwit record (about 13,560 km in 11 days, October 2022) is from tracking reported by researchers with the Pūkoro Mirānda Shorebird Centre and others. Migratory Bird Treaty: 1916 (U.S. and Great Britain, for Canada); Act: 1918. In Jeremiah 8:7, “the turtle” is the turtledove, also a migrant.

PRACTICE

1. **EASY** What is the main reason most birds migrate?
2. **EASY** Name the four North American flyways.
3. **MEDIUM** What did the arrow stork of 1822 help people learn?
4. **MEDIUM** What did Stephen Emlen’s planetarium experiment show?
5. **CHALLENGE** The godwit flew about 8,400 miles in 11 days without stopping. About how many miles is that per day, and per hour?

Make it a game • Star Compass. Tape a large paper “North Star” high on one wall. Players are night migrants. The leader calls “Fall!” and everyone must turn and face south (away from the star); on “Spring!” everyone faces north. Then the leader moves the star to a new wall without warning. Who notices and turns to follow the new “north” first? Talk about how this is like Emlen’s buntings.

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; but my people know not the judgment of the LORD.” (Jeremiah 8:7, KJV)

Jeremiah watched the migrants arrive on time every year. Through him, God says that the birds keep their appointed seasons, while His people have forgotten His ways. We are called to know God’s Word at least as faithfully as a stork knows its journey.

Practice: answers

1. Food. They leave when food (such as insects) runs out in winter and return when long spring days bring plenty of food and room to nest.
2. The Atlantic, Mississippi, Central and Pacific flyways.
3. The arrow came from central Africa, so it proved that storks fly to Africa for the winter and come back, instead of hiding or sleeping in Europe.
4. Young indigo buntings use the stars to choose their direction. When the planetarium sky was turned, the birds turned to match the new star pattern.

5. $8,400 \div 11 \approx 764$ miles per day. $764 \div 24 \approx 32$ miles per hour, day and night.

2.8 NESTS: BUILDERS WITHOUT HANDS

OBJECTIVES

- Name and describe six kinds of nests (cup, cavity, platform, hanging, mound and scrape) with a bird that builds each.
- Explain how a nest's shape and materials protect the eggs from cold, rain and enemies.
- Try to build a nest with only a "beak," and explain why the law protects wild birds' nests.

Warm-up. Hold a small bowl in your hands and imagine you have to make one just like it from grass and twigs, but you may use only a pair of tweezers. That is what a robin does, again and again, about 180 trips' worth of mud and grass for a single nest.

Video slot. Video coming. Weaver bird weaving its nest; cliff swallows building mud nests; sociable weaver colony nest; a bluebird nest box camera. Search approved channels (Cornell Lab of Ornithology NestWatch and Bird Cams, BBC Earth, National Audubon Society); preview first.

KEY TERMS

incubate

To keep eggs warm, usually by sitting on them, until they hatch.

brood patch

A bare, warm patch of skin on a sitting bird's belly that touches the eggs directly.

cavity nester

A bird that nests inside a hole, such as a hole in a tree, a cliff or a nest box. Woodpeckers, bluebirds and chickadees are cavity nesters.

colony

A group of birds of one kind nesting close together, sometimes sharing one great nest.

clutch

All the eggs a bird lays in one nest at one time.

CORE IDEAS

A nest is not a bird's house. Most birds sleep on branches or in hidden places and use a nest only to hold their eggs and young for a few weeks. A good nest keeps the **clutch** warm and dry, hides it from enemies, and holds it safely while a parent sits. A sitting bird presses its eggs against its **brood patch** to **incubate** them. The shape of each nest fits the bird that builds it, and God gave each kind the knowledge to build its own pattern without ever being taught.

The most common shape is the **cup**. An American robin builds a cup of grass and twigs, plasters the inside with mud, and lines it with soft dry grass. She shapes it by pressing her breast into the middle and turning around and around. **Cavity nesters** such as woodpeckers chisel holes in trees, and bluebirds, chickadees and wrens use old woodpecker holes or nest boxes. A bald eagle builds a **platform** of big sticks high in a tree and adds to it every year. A Baltimore oriole weaves a **hanging** pouch from plant fibers, and the village weavers of Africa tie real knots with their beaks to make hanging nests with the door on the bottom, where snakes find it hard to get in.

Some nests are hardly nests at all. Killdeer and many shorebirds lay their speckled eggs in a **scrape**, a shallow dip on bare gravel, where the eggs look like stones. The white tern of tropical islands lays its single egg on a bare branch, balanced in a little fork. Other nests are amazing works of building. The malleefowl of Australia heaps up a **mound** of sand and rotting leaves about 3 feet high and buries its eggs inside; the rotting leaves give off heat, and the male pokes his bill into the mound to check the temperature and adds or removes sand to keep it just right. The rufous hornero of South America builds an oven-shaped nest of mud and straw that can weigh several pounds. Cliff swallows carry about a thousand mouthfuls of mud to build one gourd-shaped nest under a bridge or cliff.

The greatest bird builders may be the sociable weavers of the Kalahari in southern Africa. Working as a **colony**, they build one huge grass nest in a tree, with a thatched roof and dozens or even more than a hundred separate chambers inside, each with its own entrance underneath. Several hundred birds may live in one. The thick roof keeps them cool by day and warm on freezing desert nights, and some of these nests have been used for a century.

The Bible notices nests too. The psalmist saw sparrows and swallows nesting even around the house of God and longed to be as near to God as they were (Psalm 84:3). The law of Moses taught Israel to let a mother bird go free if they found her nest (Deuteronomy 22:6-7). Today in the United States, the Migratory Bird Treaty Act protects the nests of most wild birds, so we watch nests but do not take them, even after the birds have gone.

PICTURE STUDY



Bird's Nest and Primroses, William Henry Hunt, c. 1855 · Watercolor, bodycolor (opaque watercolor) and gum arabic on paper · Private collection (photographed for Wikimedia Commons)
Wikimedia Commons · CC BY-SA 4.0

William Henry Hunt (1790–1864) of London painted so many nests that people nicknamed him “Bird’s Nest” Hunt. He would not paint anything he could not see in front of him, so he brought real nests, flowers and even banks of mossy earth into his studio and studied them for days. Instead of a plain background, he set his nests on banks of soil covered with moss, grass and leaves, just as a bird might find them.

Look closely

- Count the eggs. Look closely at their color and any spots. Are they all the same?
- Look at the edge of the nest. What materials can you see woven into it?
- Find the primroses. What season of the year does this picture show?

Talk about it

1. Why do you think a bird might build its nest low, near the ground, among flowers and moss?
2. Hunt painted only from real objects. How does that make his picture useful to a scientist as well as to an art lover?

Safety first. Never take or disturb a wild bird’s nest, eggs or chicks; most are protected by law, and parents may abandon a nest that is handled. Watch from a distance and keep visits short. Wash your hands after handling outdoor materials.

HANDS-ON: BEAK-ONLY NEST CHALLENGE AND A NEST CHART

Try to build a cup nest using only a “beak,” then draw a labeled chart of the six kinds of nests.

You will need

- A pair of tweezers or a clothespin (your beak)
- Grass, small twigs, dry leaves, moss and string, gathered from your yard
- A small bowl of damp mud or modeling clay
- A small plastic bowl to build around (optional), a timer, and three marbles or small stones (your eggs)
- A large notebook page and colored pencils

Steps

1. Set the timer for 15 minutes. Using only your tweezers or clothespin, carry materials one at a time and build a nest that will hold three marbles. You may use one hand to hold the “beak,” but no fingers may touch the nest.
2. Count how many trips you made. A robin may make 180 or more.
3. Test your nest: put in the marbles and tip it gently. Pour a spoonful of water over it. Does it hold together?
4. **Diagram: Six Nests.** Divide a page into six boxes. In each, draw one kind of nest and its builder, and label it: *cup (robin)*, *cavity (woodpecker or bluebird)*, *platform (eagle)*, *hanging (oriole or weaver)*, *mound (malleefowl)* and *scrape (killdeer)*. Under each, write the main material and one way it protects the eggs.

Check your work

- I built my nest using only a “beak” and counted my trips.
- I tested my nest with marbles and water and wrote what happened.
- My chart shows all six nest types, each with a builder, a material and a way it protects the eggs.

FIELD NOTEBOOK

1. **Notebook entry: My nest challenge.** Write a paragraph about building your nest. How many trips did it take? What was hardest? What did you learn about the birds that do this with no hands?
2. Draw one real nest you have seen (from a distance) or a nest from a picture. Write the date, the place and the kind of bird if you know it.

Did you know? The tailorbird of Asia sews leaves together, poking holes with its bill and pulling plant fibers or spider silk through, to make a pouch for its nest. The edible-nest swiftlet of Southeast Asia builds its nest almost entirely of its own hardened saliva, and

those nests are gathered for bird's nest soup. Brown-headed cowbirds build no nest at all; they lay their eggs in other birds' nests.

Map or diagram. Your six-nest chart is a classification chart: it sorts things into groups by shape. Keep each box the same size, give each a heading, and draw the builder small beside the nest so the nest is the main thing.

Goes deeper in. Life Science, "Birds" (coming soon); and Gardening & Animals, for building and mounting a nest box and joining the Cornell Lab's NestWatch program.

For families. The "about 180 trips" robin figure is a commonly cited estimate and is offered as approximate. Cliff swallow nests are usually said to need 900 to 1,200 mud pellets. Sociable weaver colonies are described by many sources as housing up to several hundred birds in more than 100 chambers; individual nests may be used for decades or longer. U.S. law (Migratory Bird Treaty Act) makes it illegal to collect most native birds' nests, eggs or feathers without a permit; house sparrows, European starlings and rock pigeons are not protected. The Hunt watercolor title and Tate holding are given as published; the exact date is uncertain, so it is given as "c. 1840s."

PRACTICE

1. **EASY** What is a brood patch, and what is it for?
2. **EASY** Match each nest to its builder: platform, hanging pouch, scrape. Builders: killdeer, bald eagle, Baltimore oriole.
3. **MEDIUM** Why does a village weaver put the door of its hanging nest on the bottom?
4. **MEDIUM** How does a malleefowl keep its eggs warm without sitting on them?
5. **CHALLENGE** A pair of cliff swallows carries about 1,000 mud pellets to build one nest. If they make 40 trips an hour together, how many hours does it take? If they work 8 hours a day, how many days?

Make it a game • Nest Detective. One player secretly chooses a nest type from the six. The others ask yes-or-no questions ("Is it made of mud?" "Is it high in a tree?" "Does the bird sit on the eggs?") until someone guesses the nest and the bird that builds it. The guesser chooses next. Try to guess in ten questions or fewer.

Scripture. "Yea, the sparrow hath found an house, and the swallow a nest for herself, where she may lay her young, even thine altars, O LORD of hosts, my King, and my God." (Psalm 84:3, KJV)

The psalmist saw small birds safely nesting near God's house and wished he could be as close. Like a bird in its nest, the believer finds a safe home near God.

Practice: answers

1. A bare, warm patch of skin on a sitting bird's belly. It touches the eggs directly to keep them warm.
2. Platform: bald eagle. Hanging pouch: Baltimore oriole. Scrape: killdeer.
3. A door underneath, on a nest hanging from a thin branch, is hard for snakes and other enemies to reach, and it keeps rain out.
4. It buries them in a mound of sand and rotting leaves. The rotting leaves make heat, and the male checks the temperature with his bill and adds or removes sand to keep it right.
5. $1,000 \div 40 = 25$ hours. $25 \div 8 = 3\frac{1}{8}$, so a little more than 3 days (part of a fourth day).

2.9 AUDUBON THE BIRD PAINTER

OBJECTIVES

- Tell the life of John James Audubon in order, with key dates and places.
- Explain how Audubon made *The Birds of America* (life-size, posed on wires, engraved and hand-colored) and why it was so hard.
- Copy a bird plate using a grid, and map Audubon’s travels in America and Britain.

Warm-up. Open a large book and measure its page. Audubon’s great book had pages about 39 inches tall and 26 inches wide, about as tall as a first-grader. Tape four sheets of printer paper together to see the size. Why would anyone make a book so big?

Video slot. Video coming. John James Audubon and *The Birds of America*; turning the pages of a double elephant folio; Audubon watercolors at the New-York Historical Society. Search approved channels (National Audubon Society, New-York Historical Society, Smithsonian Libraries, a university special-collections library); preview first.

KEY TERMS

naturalist

A person who studies plants and animals by watching them closely in nature.

engraving

A print made from a metal plate into which lines have been cut or etched; ink in the lines is pressed onto paper.

folio

A very large book. Audubon’s was a “double elephant folio,” one of the largest sizes of paper made.

subscriber

A person who agrees to buy a book in parts as it is published, paying for each part as it arrives.

bankruptcy

Being legally declared unable to pay one’s debts, so that one’s property is sold to pay the people owed.

CORE IDEAS

John James Audubon was born on April 26, 1785, in Les Cayes on the French island colony of Saint-Domingue (today Haiti). His father was a French sea captain and planter; his mother died a few months after his birth. He grew up in France near the city of Nantes, wandering the fields to collect birds’ eggs and nests and drawing what he found. In 1803, at 18, his father sent him to America, partly to keep him out of Napoleon’s army, to live on a family farm called Mill Grove near Philadelphia. There, in 1804, he tied light silver threads around

the legs of young eastern phoebes in a nest and found the same birds returning the next spring, one of the first known cases of bird banding in America.

In 1808 he married Lucy Bakewell, and they moved west to Kentucky, to Louisville and then Henderson on the Ohio River. Audubon ran a store and then a steam mill, but he spent much of his time in the woods with his gun and sketchbook. In Kentucky the household owned several enslaved people, as many families of property there did then; this was a real wrong, and it is part of his honest story. In the hard times of 1819 the mill failed. Audubon went through **bankruptcy** and spent a short time in jail for debt. He was 34 and had almost nothing left but his drawings.

Then he made a bold decision: he would paint every bird in North America, life-size. In 1820 he set off down the Ohio and Mississippi rivers on a flatboat with a 13-year-old student, Joseph Mason, who painted many of the plants in the backgrounds. Lucy worked as a teacher and governess for years to support the family. Audubon shot birds to study them, as every **naturalist** of his day did, and pinned the fresh birds on wires stuck into a board so he could pose them as if alive. He painted in watercolor, pastel and pencil, often in dramatic, twisting poses no one had tried before.

No American printer could produce such a book, so in 1826 he sailed to Britain. In Edinburgh the **engraver** William Lizars began the plates; in London, Robert Havell Jr. finished them. Each copper plate was printed on huge sheets and colored by hand. Audubon sold **subscriptions** in Britain and America to pay for it. *The Birds of America* came out in parts from 1827 to 1838: 435 plates showing more than a thousand birds of almost 500 kinds. With the Scottish naturalist William MacGillivray he also wrote *Ornithological Biography* (1831–1839), five volumes describing the birds' lives.

Audubon died in New York on January 27, 1851. He was not always truthful about himself; he told grand stories about his past and once played a trick on another scientist with invented fish. But his paintings were true to the birds, and they taught a nation to look at its wildlife. The Audubon Society, founded decades later to protect birds, was named for him. "The works of the LORD are great, sought out of all them that have pleasure therein" (Psalm 111:2).

PICTURE STUDY



John James Audubon, John Syme, 1826 · Oil on canvas · The White House, Washington, D.C.
Wikimedia Commons · Public domain

John Syme, a Scottish portrait painter, painted Audubon in Edinburgh in 1826, just as the great book was beginning. Audubon posed as an American woodsman in a wolfskin coat, with a gun across his chest, a picture that appealed to British buyers who imagined the American frontier as wild and exciting. It was partly true and partly showmanship. Audubon himself joked that if the head was not a good likeness, perhaps the coat was.

Look closely

- Look at Audubon's clothes. What do they tell you about the image he wanted to give?
- Look at his face and eyes. Is he looking at us or away? What mood does that create?
- Look at the background. Why might the painter keep it dark and plain?

Talk about it

1. Audubon posed as a frontiersman while selling his book in Britain. Was that honest, dishonest, or something in between? Explain.
2. If you had your portrait painted to show your favorite work, what would you wear and hold?

HANDS-ON: COPY A PLATE BY THE GRID, AND MAP AUDUBON'S TRAVELS

Artists have long used a grid to copy a picture accurately. Copy one Audubon bird plate with a grid, then map the places where Audubon lived and worked.

You will need

- A printout of one Audubon plate from the Audubon Society's free online Birds of America (audubon.org/birds-of-america), such as the American Robin, Blue Jay or Carolina Parrot
- A ruler, a sharp pencil, an eraser and colored pencils or watercolors
- Drawing paper the same size or larger than the printout
- An outline map of the eastern United States and one of Great Britain

Steps

1. **Grid.** With a ruler, draw a grid of 1-inch squares lightly over the printout. Draw the same number of squares on your drawing paper (use 2-inch squares to make it twice as large).
2. Copy the bird one square at a time. Look only at what is in that square: where the lines enter and leave. Start with the outline, then the eye, beak and feet.
3. Erase the grid lines and add color. Copy the plate's colors as closely as you can. Write the bird's name, "after J. J. Audubon," and the date at the bottom.
4. **Map.** On the U.S. map, mark and label: Mill Grove (near Philadelphia), Louisville and Henderson (Kentucky), Cincinnati, and New Orleans. Draw Audubon's 1820 river trip as a dotted line down the Ohio and Mississippi rivers from Cincinnati to New Orleans. On the Britain map, mark Liverpool (where he landed in 1826), Edinburgh and London. Add a title, a key and a compass rose.

Check your work

- My copy used a grid and the bird's shape and proportions match the plate.
- My copy is colored and labeled with the bird's name and "after J. J. Audubon."
- My maps show at least seven labeled places and the 1820 river route.

FIELD NOTEBOOK

1. **Notebook entry: Audubon's life.** Write a paragraph telling Audubon's life in order. Include at least five dates, and finish with one sentence about what you admire and one about what you do not.
2. Make a timeline: 1785, 1803, 1804, 1808, 1819, 1820, 1826, 1827–1838, 1851. Write one event beside each.

Did you know? About 200 sets of *The Birds of America* were made, and about 120 complete sets are known to survive. Audubon's original watercolors were bought from Lucy Audubon by the New-York Historical Society in 1863 and are still there. To fit the tall flamingo and great blue heron on the page life-size, Audubon painted them bending their necks down.

Map or diagram. On the travel map, use a dotted line for a journey and dots for places. Number the places in the order Audubon lived there (1 Mill Grove, 2 Louisville, 3 Henderson ...) so the map tells his story at a glance.

Goes deeper in. Art, “Drawing from Observation” and the grid method (coming soon); History, “The Early Republic and the West”; and Life Science, “Birds.”

For families. Dates are from the National Audubon Society and standard biographies (e.g., Richard Rhodes, *John James Audubon: The Making of an American*, 2004). The phoebe banding is described in Audubon’s own *Ornithological Biography*; it is often called the first in North America. Audubon’s ownership and sale of enslaved people in Kentucky is documented in recent biographies and by the National Audubon Society; we state it plainly without dwelling on it. The prank on Constantine Rafinesque (invented fish species, 1818) is well documented. The plate count (435) is certain; the species count (about 489) varies by how they are counted. The Syme portrait is in the White House collection. Hunting birds to study them was standard practice of the time; parents may want to talk about how bird study is done today with cameras and binoculars.

PRACTICE

1. **EASY** What was Audubon’s great book called, and why were its pages so large?
2. **EASY** Why did Audubon have to go to Britain to make his book?
3. **MEDIUM** How did Audubon pose his birds so they looked alive?
4. **MEDIUM** Put these in order: Audubon’s mill fails; he sails to Britain; he bands phoebes at Mill Grove; he goes down the Mississippi with Joseph Mason; the last plate is published.
5. **CHALLENGE** The *Birds of America* was published from 1827 to 1838 and had 435 plates. About how many plates came out per year? If each part held 5 plates, how many parts were there?

Make it a game • Life-Size Guess. One player names a bird from this trail (hummingbird, robin, owl, bald eagle, parrot, penguin, ostrich). Everyone else holds their hands apart to show how long they think it is, life-size, from beak to tail. Then measure the hand-gap with a ruler and check a bird guide. The closest guess scores a point. Audubon had to know these sizes by heart.

Scripture. “The works of the LORD are great, sought out of all them that have pleasure therein.” (Psalm 111:2, KJV)

Audubon spent his life seeking out and drawing the birds. Studying God’s works carefully, with eyes and pencil, is a delight and a way to honor the Maker.

Practice: answers

1. *The Birds of America*. The pages were huge (double elephant folio) so that every bird could be shown life-size.
2. No printer in America could produce such large, fine engravings; skilled engravers in Edinburgh and London could.

3. He pinned freshly collected birds on wires stuck into a board, arranging them in natural, lifelike poses while he painted.
4. Bands phoebes (1804); mill fails (1819); down the Mississippi (1820); sails to Britain (1826); last plate (1838).
5. $1838 - 1827 = 11$ years; $435 \div 11 \approx 40$ plates a year. $435 \div 5 = 87$ parts.

2.10 THE BACKYARD BIRD COUNT

OBJECTIVES

- Tell how the Christmas Bird Count (1900) and the Great Backyard Bird Count (1998) began, and what citizen science is.
- Identify birds by field marks, size, shape, behavior and sound, and count them the way real counters do.
- Carry out a 15-minute bird count, map where each bird was seen, and keep a bird list.

Warm-up. Look out a window for one full minute and count every bird you see. Now do it again. Did you count any bird twice? How could you be sure? Real bird counters have a simple rule that solves this problem. You will learn it today.

Video slot. Video coming. How to take part in the Great Backyard Bird Count; how to identify common feeder birds; using binoculars. Search approved channels (Cornell Lab of Ornithology, National Audubon Society, Birds Canada); preview first.

KEY TERMS

citizen science

Science in which ordinary people, not only trained scientists, collect real observations that scientists use.

field marks

The colors, patterns and shapes that help tell one kind of bird from another, such as a wing bar, an eye ring or a crest.

tally

A running count kept with marks, usually in groups of five.

species

One kind of living thing, such as the northern cardinal or the American robin.

data

Facts and numbers collected so they can be studied and compared.

CORE IDEAS

More than 125 years ago, many hunters in America kept a Christmas tradition called the “side hunt.” They chose teams and shot as many birds as they could, and the side with the bigger pile won. Frank M. Chapman, a bird scientist at the American Museum of Natural History, proposed something better. On Christmas Day, 1900, he invited people to go out and *count* birds instead. Twenty-seven people took part in 25 places, from Toronto to California. That was the first Christmas Bird Count. It has been held every winter since, and today tens of thousands of people take part across the Americas, making it one of the oldest examples of **citizen science**.

In 1998, the Cornell Lab of Ornithology and the National Audubon Society started a newer count that anyone could do at home: the Great Backyard Bird Count. Birds Canada later joined, and in 2013 it went worldwide. It is held over four days each February. A family may count for as little as 15 minutes, in a backyard, a park or a school field, and report what they saw online. Hundreds of thousands of people in more than a hundred countries now take part. Their **data** help scientists see where birds are spending the winter, which birds are increasing or declining, and how birds move from year to year.

Counting birds well takes skill. First, you must know what you are looking at. Look at size and shape first: is it sparrow-sized, robin-sized or crow-sized? Is the bill thick for cracking seeds, or thin for catching insects? Then look for **field marks**: the cardinal's crest, the white outer tail feathers a junco flashes as it flies, the black cap of a chickadee. Watch what it does: a nuthatch creeps headfirst down a tree trunk; a mourning dove walks on the ground. Listen too, since many birds are easier to hear than see.

Second, you must count honestly. Here is the counters' rule: for each **species**, write down only the *largest number you see at one time*. If you see three chickadees, then two, then four, your count is four, not nine, because some of them may be the same birds coming back. Keep a **tally** sheet, note the time, the place and the weather, and never guess a bird you are not sure of. Write "sparrow, unknown kind" instead. Good data are honest data.

Jesus said, "Are not two sparrows sold for a farthing? and one of them shall not fall on the ground without your Father" (Matthew 10:29). God knows every bird, even the common ones no one notices. When we count the birds carefully, we are noticing what God has always noticed. And Jesus' next words are for us: "ye are of more value than many sparrows."

PICTURE STUDY



The Goldfinch, Carel Fabritius, 1654 · Oil on panel · Mauritshuis, The Hague, Netherlands
Wikimedia Commons · Public domain

Carel Fabritius (1622–1654) was a Dutch painter who studied with Rembrandt and worked in the city of Delft. This little painting, only about 13 inches tall, shows a European goldfinch, a pet bird of that time, on its feeding box. Fabritius died young the same year, in 1654, when a gunpowder store exploded in Delft. Only about a dozen of his paintings survive, and this is the most famous. Notice how he painted it with quick, sure brushstrokes so the bird seems to sit right on the wall.

Look closely

- Find the field marks: the red face, the black and white head and the yellow patch on the wing.
- Look at the bird's feet and the chain. Where is it perched?
- Look at the shadow on the wall. Where is the light coming from?

Talk about it

1. If you saw this bird in your yard, which two field marks would help you name it fastest?
2. Why do you think Fabritius painted such a common little bird so carefully?

Safety first. If you make the pinecone feeder, check first for peanut allergies in your family and use vegetable shortening instead of peanut butter if needed. Stay indoors or on your own property during the count unless an adult is with you, and never look at the sun through binoculars.

HANDS-ON: A 15-MINUTE BIRD COUNT AND YARD MAP

Do a real bird count the way scientists ask, map where you saw each bird, and start a bird list. You may report your count to the Great Backyard Bird Count in February or to eBird any time of year, with a parent.

You will need

- A tally sheet: a page with columns for species, tally marks and highest number at one time
- A pencil, a watch or timer, and binoculars if you have them
- A free bird guide or app (the Cornell Lab's Merlin app or allaboutbirds.org)
- For a feeder (optional): a pinecone, string, peanut butter or vegetable shortening, and birdseed

Steps

1. **Feeder (optional, a day or two before).** Tie a string to a pinecone, spread it with peanut butter or shortening, roll it in birdseed and hang it where you can see it from a window.
2. At the top of your tally sheet, write the date, start time, place and weather (temperature, wind, sun or clouds).

3. Sit still and watch for 15 minutes. Each time you see a bird, identify it and make a tally. Next to each species, keep updating the *highest number seen at one time*.
4. At the end, write your final count for each species and the total number of species.
5. **Map.** Draw a bird's-eye map of your yard or park: house, trees, bushes, feeder, fence, any water. Add a compass rose and a key. Mark each bird you saw with a small symbol or letter where you saw it (C = cardinal, R = robin ...). Which spot drew the most birds?
6. Start your **bird list** in the back of your Field Notebook: each new species, the date and the place you first saw it.

Check your work

- My tally sheet has the date, time, place and weather.
- I used the “highest number at one time” rule for every species.
- My yard map has a key, a compass rose and every bird I counted marked where I saw it.
- My bird list has at least three species with dates and places.

FIELD NOTEBOOK

1. **Notebook entry: My first count.** Write a paragraph about your bird count. Tell how many species and birds you counted, which bird was hardest to identify and why, and what you would do differently next time.
2. Choose one bird you counted. Draw it and label at least three field marks.

Did you know? In the 1990s, people taking part in Project FeederWatch, another citizen-science count, noticed house finches with swollen, crusty eyes. Their reports helped scientists track a new bird disease as it spread across North America year by year, something no small team of scientists could have done alone. Bird counters have also helped show which birds are increasing, such as the bald eagle (Stop B1).

Map or diagram. A bird's-eye map is drawn as if you were a bird looking straight down. Trees become circles, the house becomes a rectangle, and the feeder a small square. Keep the symbols simple and explain each one in the key.

Goes deeper in. Arithmetic, “Data and Graphs” (make a bar graph of your count) (coming soon); Life Science, “Birds”; and Gardening & Animals, for feeders and bird-friendly gardens.

For families. Christmas Bird Count history is from the National Audubon Society (first count December 25, 1900; 27 observers; 25 counts). The Great Backyard Bird Count began in 1998 (Cornell Lab of Ornithology and National Audubon Society), was joined by Birds Canada, and went global in 2013; it runs four days in mid-February at birdcount.org. Participation numbers change every year, so they are given in round terms. Reporting online requires a free account; a parent should create it. The house finch eye

disease (mycoplasmal conjunctivitis) was first noticed in 1994. The Fabritius goldfinch is chained to its perch, as pet goldfinches often were in the 1600s.

PRACTICE

1. **EASY** What is citizen science?
2. **EASY** Who started the Christmas Bird Count, and what did it replace?
3. **MEDIUM** In 15 minutes you see 2 blue jays, then 5, then 3. What number do you report, and why?
4. **MEDIUM** Name four kinds of clues that help you identify a bird.
5. **CHALLENGE** The first Christmas Bird Count was held in 1900. How many years ago was that from 2026? If 27 people took part then and about 80,000 take part now, how many times more people is that?

Make it a game • Field Mark Flash. Make ten cards, each with a picture of a common bird from a free guide on one side and its name on the other. Hold up a card for just three seconds, then hide it. Players call out the name and one field mark that gave it away. A correct name plus a correct field mark scores two points. When everyone knows the cards, shorten the time to two seconds.

Scripture. “Are not two sparrows sold for a farthing? and one of them shall not fall on the ground without your Father. But the very hairs of your head are all numbered. Fear ye not therefore, ye are of more value than many sparrows.” (Matthew 10:29-31, KJV)

We count birds for a few minutes and miss some; God knows every sparrow and even numbers the hairs on our heads. If He watches over common birds, He surely watches over His children.

Practice: answers

1. Science in which ordinary people collect real observations, such as bird counts, that scientists then use.
2. Frank M. Chapman, in 1900. It replaced the Christmas “side hunt,” in which teams competed to shoot the most birds.
3. 5, the highest number seen at one time. Adding them (10) would likely count some of the same birds more than once.
4. Any four: size, shape (including the bill), field marks (colors and patterns), behavior (how it moves or feeds), song or call, and where it is (habitat).
5. $2026 - 1900 = 126$ years. $80,000 \div 27 \approx 2,963$, so nearly 3,000 times as many people.

TRAIL 2 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in complete sentences where a sentence is needed, without looking back at the stops; a parent checks with the answers given. Four right out of five on each quiz earns that part of the Bird Ranger badge. Badges and the certificate are earned by doing the stops and keeping the notebook, not by scores.

Badge quiz 1 (Stops 1–5)

1. Explain how an eagle uses a thermal, and what its spread primary feathers do.
2. Name two features that let a barn owl catch a mouse in total darkness.
3. What is torpor, and why does a hummingbird need it?
4. Describe how an emperor penguin egg is kept warm through the winter.
5. Give two facts about the ostrich with numbers, and explain what Job 39:18 says about it.

Badge quiz 2 (Stops 6–10)

6. What does zygodactyl mean, and why is the kakapo a stewardship success story?
7. Name three ways migrating birds find their way, and the four North American flyways.
8. Match each nest to its builder: cup, cavity, mound, scrape. Builders: killdeer, robin, malleefowl, bluebird.
9. What was special about Audubon's *The Birds of America*, and where was it engraved?
10. During a count you see 4 cardinals, then 1, then 3. What do you report, and why?

TRAIL CERTIFICATE: MY BIRD RANGER FIELD NOTEBOOK AND TRAIL B CERTIFICATE

Gather your Field Notebook pages from this trail into one booklet with a cover: "My Bird Ranger Field Notebook," your name and the dates you started and finished.

Include your ten notebook paragraphs, your maps and diagrams from each stop, and your grid copy of an Audubon plate from Stop B9.

Put your bird list at the back: every species you have seen yourself, with the date and place. Aim for at least ten by the end of the trail, and keep adding to it.

When the booklet is done, a parent reviews it with the rubric and signs the Trail B certificate.

- **Ten entries:** A dated notebook paragraph for each stop that uses the stop's key terms correctly and includes facts or numbers from the story.
- **Maps and diagrams:** At least eight labeled maps or diagrams, each with a title and, for maps, a key and a compass rose.
- **Observation:** A completed bird count with a tally sheet and yard map, and a bird list of at least ten species with dates and places.

- **Care and accuracy:** Work is neat, spelling of bird names is correct, and facts match the stops.

Answer key

1. A thermal is rising warm air over sun-heated ground; the eagle circles inside it to climb without flapping. The spread primary feathers (“fingers”) smooth the air at the wing tips so the eagle can fly slowly without stalling.
2. Any two: silent flight feathers (comb, velvet surface, fringe); a facial disc that gathers sound; asymmetrical ears that tell up from down and left from right.
3. A deep nightly rest in which the body cools and the heart slows. A hummingbird’s metabolism is so fast that without torpor it could run out of energy overnight, when it cannot eat.
4. The female passes the egg to the male, who holds it on his feet under his brood pouch for about two months, fasting, while the males huddle together and take turns on the cold outside edge.
5. Any two: up to about 9 ft tall; about 300 lb; runs about 43 mph; eggs about 3 lb; eyes about 2 in across. Job 39:18 says that when it runs it “scorneth the horse and his rider”: it can outrun them.
6. Two toes forward and two back. The kakapo fell to 51 birds in 1995; rangers moved them to predator-free islands and guarded every nest, and the number has grown to about 250.
7. Any three: the sun, the stars, the earth’s magnetic field, landmarks such as coasts and rivers, smell. Flyways: Atlantic, Mississippi, Central and Pacific.
8. Cup: robin. Cavity: bluebird. Mound: malleefowl. Scrape: killdeer.
9. It showed the birds life-size on huge pages (435 plates, 1827–1838), in lifelike poses, hand-colored. It was engraved in Britain, first in Edinburgh by William Lizars and then in London by Robert Havell Jr.
10. 4, the highest number seen at one time, because adding them would count some of the same birds more than once.

ANIMALS TRAIL C: REPTILES AND AMPHIBIANS

The third trail of the Animals track visits the scaly and the slimy: the crocodile with the strongest bite ever measured, the Komodo dragon, snakes that move without legs, sea turtles that cross oceans and come home, chameleons with turret eyes, the giant tortoises of the Galápagos, frogs and their great change from tadpole to adult, salamanders that breathe through their skin, poison dart frogs and the Gila monster, whose venom led to a modern medicine. Each stop pairs a true story with facts and numbers, a picture study, a map or diagram, a notebook entry, practice questions, a game and a verse of Scripture.

This is the  **Ranger** level, written for ages 10 to 13. The student reads each stop alone in about 25 to 35 minutes, draws the map or diagram, and writes a short paragraph in the Field Notebook. Every stop stands by itself, so the stops may be done in any order. Animals are presented as God's handiwork, each made "after his kind" (Genesis 1:24-25), with attention to their design, the variety God placed within each kind, and the good stewardship He gave to people (Genesis 2:15). A parent may check the practice answers and talk through the Scripture.

Five stops earn the **Reptile and Amphibian Ranger badge, part 1**, and ten stops earn part 2 and the **Trail C certificate**. The two badge quizzes at the end are optional.

BEFORE YOU BEGIN

- Read a page of nonfiction alone and write a paragraph about it.
- Use an atlas to find continents, oceans, countries and U.S. states, and draw a simple map with a title, key and compass rose.

MASTERY CHECKLIST

- ☐ I can tell the difference between reptiles and amphibians and give two examples of each.
- ☐ I can explain one design God gave each animal on this trail and how it helps that animal live where it does.
- ☐ I can draw and label a frog's life cycle and maps of the Galápagos, the Komodo islands and the Gila monster's range.
- ☐ I can tell a story of good stewardship from this trail, such as the Kemp's ridley sea turtle or the tortoises of Española.
- ☐ I can tell the difference between an old legend or guess and what careful observers found, using the salamander or the Komodo's bite.

OPTIONAL BOOKS AND RESOURCES

- **Smithsonian's National Zoo: Reptiles and Amphibians**
(<https://nationalzoo.si.edu/animals/reptiles-amphibians>): Free fact pages and photos for

Komodo dragons, Gila monsters, poison frogs, hellbenders and more.

- **AmphibiaWeb** (<https://amphibiaweb.org>): A free university database of the world's frogs and salamanders, with photos and range maps for checking facts.
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free old natural-history books, including Seba's snakes, Günther's giant tortoises and the Boundary Survey reptiles used in the picture studies.

3.1 CROCODILES: THE ARMORED HUNTERS OF THE RIVER

OBJECTIVES

- Explain how a crocodile's eyes, nostrils, ears and throat valve let it hunt while almost hidden in water.
- Tell the difference between crocodiles, alligators, caimans and gharials.
- Read Job 41 and explain why many readers think of the crocodile when they read about leviathan.

Warm-up. Fill a sink or bowl with water and float a toy (or a cork) so that only its top shows. From across the room, can you see it? Now picture an animal as long as a car hiding the same way, with only its eyes and nose above the water. That is how a crocodile waits.

Video slot. Video coming. Saltwater and Nile crocodiles hunting, a mother crocodile carrying hatchlings in her mouth, and the difference between alligators and crocodiles. Search approved channels (Smithsonian's National Zoo, BBC Earth, National Geographic Kids, San Diego Zoo Wildlife Alliance); preview first, since some hunting clips are graphic.

KEY TERMS

reptile

A cold-blooded animal with dry, scaly skin that breathes air with lungs, such as a crocodile, lizard, snake or turtle. Most lay eggs on land.

crocodilian

The group that includes crocodiles, alligators, caimans and gharials: about two dozen kinds in all.

ectotherm

An animal whose body heat comes mostly from its surroundings (“cold-blooded”). A crocodile basks in the sun to warm up and slips into water or shade to cool down.

palatal valve

A flap at the back of a crocodilian's mouth that seals off its throat, so it can open its jaws underwater without drowning.

nictitating membrane

A clear third eyelid that slides across the eye to protect it underwater, like built-in swimming goggles.

CORE IDEAS

The story. On a hot afternoon in northern Australia, a wallaby creeps down to the edge of a muddy river to drink. Nothing seems to be there but a floating log. Then the “log” explodes

from the water. A saltwater crocodile, longer than a minivan, has been waiting for hours with only its eyes, ears and nostrils above the surface. In less than a second its jaws have closed. Crocodiles are patient hunters. They may eat only once a week or less, and a large one can go months without a meal.

Built for ambush. God gave the crocodile a head built for hiding. Its eyes, ears and nostrils sit in a straight line along the top of the head, so the rest of its body can stay underwater. A clear third eyelid, the **nictitating membrane**, covers its eyes when it dives. Flaps close over its ears and nostrils, and a **palatal valve** seals its throat, so it can grab prey underwater with its mouth open and not swallow the river. Thousands of tiny dark dots on its jaws are pressure sensors so sensitive that a crocodile can feel a single drop of water ripple the surface in a dark pool.

The strongest bite. In 2012 a team of scientists led by Gregory Erickson measured the bite of every living kind of crocodilian. The winner was the saltwater crocodile, at about 3,700 pounds of force: the strongest bite ever measured in a living animal. (A strong man's back teeth bite with about 150 to 200 pounds.) Yet the muscles that *open* the jaws are weak. A rubber band or a strip of tape can hold a crocodile's mouth shut, which is how wildlife workers move them safely. A crocodilian may grow and replace each of its teeth dozens of times in its life.

Four cousins. There are about two dozen kinds of **crocodilians**. *Alligators* (in the southeastern United States and China) have wide, U-shaped snouts, and their lower teeth hide when the mouth is shut. *Crocodiles* have narrower, V-shaped snouts, and the big fourth tooth of the lower jaw shows outside the upper lip in a toothy grin. *Caimans* live in Central and South America, and the *gharial* of India has a long, thin snout for catching fish. The largest of all is the saltwater crocodile. A male named Lolong, caught in the Philippines in 2011, measured 20 feet 3 inches, the longest crocodile ever measured in captivity.

A careful mother. For all its fierceness, a crocodile mother is gentle with her young. A Nile crocodile digs a nest in sandy ground near the water and lays about 40 to 60 eggs. She guards it for about three months. When the babies are ready to hatch, they chirp from inside their eggs. She digs them out, carries them to the water in her mouth, and watches over them for weeks. Even the temperature of the nest matters: it decides whether each baby grows up male or female.

The terrible jaws of Job. In the book of Job, God asks Job whether he can catch *leviathan* with a hook, and describes a creature with scales “shut up together as with a close seal” and teeth that are “terrible round about” (Job 41). Many Bible readers since the Middle Ages have thought of the crocodile, the most fearsome animal of the Nile. Whatever leviathan was exactly, the point is the same: if no man can stand before a creature God made, who can stand before God Himself (Job 41:10)?

PICTURE STUDY



The Nile Mosaic of Palestrina, Unknown Hellenistic mosaic makers, c. 100 B.C. · Floor mosaic of small colored stones · National Archaeological Museum, Palestrina, Italy
Wikimedia Commons · Public domain

More than two thousand years ago, mosaic makers laid thousands of tiny stones on the floor of a building in the Italian town of Praeneste (now Palestrina) to make a bird's-eye view of the Nile in flood, from the wild lands of the south to the cities of Egypt. It is one of the oldest pictures that tries to show the real animals of Egypt, and crocodiles are among them. People across the Roman world were fascinated by the crocodiles of the Nile.

Look closely

- Find the crocodiles. Where are they: in the water, on the bank, or both?
- Find a hippopotamus and some boats. What are the people in the boats doing?
- Look at the top and the bottom of the mosaic. How are the wild lands different from the towns?

Talk about it

1. The artists may never have seen a crocodile themselves. Which parts of the crocodiles look right, and which look less certain?
2. Why might people far from Egypt want a picture full of Nile animals on their floor?

Safety first. Crocodiles and alligators are dangerous. Never approach, feed or swim near one in the wild, and obey all warning signs near rivers, lakes and swamps where they live.

HANDS-ON: DIAGRAM: THE CROCODILE AT THE WATERLINE

Draw a crocodile's head from the side as it floats, and show how its design lets it see, hear and breathe while almost hidden.

You will need

- A Field Notebook page
- Pencil, eraser and colored pencils (blue for water)
- A ruler

Steps

1. Use the ruler to draw a straight, level line across the middle of the page. This is the waterline. Color everything below it light blue.
2. Draw the side view of a crocodile's head and the front of its body, with most of it below the line. Only the top of the head should rise above the water.
3. Label these parts and draw an arrow to each: *nostrils* (at the tip of the snout, above water), *eye* (above water), *ear* (just behind the eye, above water), *nictitating membrane*, *palatal valve* (at the back of the mouth, drawn as a dotted flap), *fourth lower tooth* and *pressure sensors* (dots along the jaw).
4. Beside the drawing, draw a small U-shaped snout and a small V-shaped snout from above. Label them "alligator" and "crocodile."
5. Give your diagram a title: "How a Crocodile Hides."

Check your work

- My nostrils, eye and ear are all above the waterline.
- I labeled at least seven parts.
- I drew and labeled the U-shaped and V-shaped snouts.
- I can explain why the palatal valve matters.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph of five to seven sentences: "Why a crocodile is a master of ambush." Use at least three key terms from this stop and one number (bite force, length or number of eggs).
2. Add your waterline diagram from the project.

Did you know? Crocodiles do not cry real tears of sorrow, but they do make tears to keep their eyes wet, and sometimes tears flow while they eat. That is where the old saying "crocodile tears" comes from: pretending to be sad. In ancient Egypt, people kept crocodiles at temples, and thousands of crocodile mummies have been found. The American alligator was listed as endangered in 1967. Hunting rules and protected land helped it recover so well that it was declared fully recovered in 1987.

Map or diagram. On a world map, shade where crocodilians live: the warm rivers, swamps and coasts of the Americas, Africa, southern Asia and northern Australia. Mark the American alligator (southeastern U.S.), the Nile crocodile (Africa), the gharial (India and Nepal) and the saltwater crocodile (from India to northern Australia).

Goes deeper in. Life Science, “Reptiles and Amphibians” (coming soon); Geography, for the Nile and northern Australia; and History, for ancient Egypt.

For families. Bite-force figures are from Erickson et al., *PLoS ONE* (2012), who measured about 3,690 pounds-force in a large saltwater crocodile. Lolong (Guinness World Records, 2012) died in 2013. Scholars do not agree on what animal leviathan was; the crocodile is a common traditional reading, and the stop says so. Nile crocodile clutch sizes vary widely (roughly 25 to 80 eggs); the stop gives a typical range. Some hunting videos show prey being caught; preview before showing.

PRACTICE

1. **EASY** Name three parts of a crocodile's head that stay above water while it hides.
2. **EASY** How can you tell an alligator from a crocodile by its snout and teeth?
3. **MEDIUM** Why can a crocodile open its mouth underwater without drowning?
4. **MEDIUM** A saltwater crocodile bites with about 3,700 pounds of force. A strong man's back teeth bite with about 185 pounds. About how many times stronger is the crocodile's bite?
5. **CHALLENGE** Wildlife workers can hold a crocodile's mouth shut with tape. Using what you learned about its muscles, explain why this works even though its bite is the strongest ever measured.

Make it a game • Log or Croc?. One player is the crocodile and lies still on the floor like a log with eyes open. The others tiptoe past as “animals coming to drink.” The crocodile may not move until someone steps inside an agreed zone (a rug or a taped square). Then the croc may tag with one hand without getting up. Anyone tagged becomes the next croc. The best crocodiles are the stillest.

Scripture. “Who can open the doors of his face? his teeth are terrible round about.” (Job 41:14, KJV)

God shows Job a creature so strong that no man can master it. The lesson is humility: God made the crocodile, and God is greater still.

Practice: answers

1. Any three: eyes, nostrils, ears (and the top of the head).
2. An alligator has a wide, U-shaped snout and its lower teeth hide when its mouth is shut. A crocodile has a narrower, V-shaped snout and its fourth lower tooth shows when its mouth is shut.

3. Its palatal valve seals off its throat, and flaps close its nostrils and ears.
4. About 20 times stronger ($3,700 \div 185 = 20$).
5. The muscles that close the jaws are huge and strong, but the muscles that open them are weak. A little tape is enough to hold the mouth closed against the weak opening muscles.

3.2 KOMODO DRAGONS: THE REAL DRAGONS OF INDONESIA

OBJECTIVES

- Locate Komodo and its neighboring islands on a map of Indonesia.
- Describe how a Komodo dragon finds, hunts and eats its prey.
- Explain how scientists changed their minds about why a Komodo's bite is so dangerous.

Warm-up. Lie down on the floor and stretch out as long as you can. Have someone measure you. A big Komodo dragon can be about 10 feet long from nose to tail tip. How many of you would it take, laid end to end, to make one Komodo?

Video slot. Video coming. Komodo dragons in Komodo National Park and at the zoo: tongue-flicking, walking, hatchlings climbing trees. Search approved channels (Smithsonian's National Zoo, BBC Earth, San Diego Zoo Wildlife Alliance, National Geographic Kids); preview first, since some feeding clips are graphic.

KEY TERMS

monitor lizard

A family of large, long-necked lizards with forked tongues. The Komodo dragon is the largest of them.

Jacobson's organ

A smelling organ in the roof of a lizard's or snake's mouth. The forked tongue gathers scent and touches it there.

venom

A harmful substance an animal makes in its body and delivers by a bite or sting.

carrion

The flesh of dead animals. Komodo dragons eat both live prey and carrion.

national park

Land set aside by a government to protect its animals, plants and scenery. Komodo National Park was founded in 1980.

CORE IDEAS

The story. For centuries, fishermen in the Lesser Sunda Islands of Indonesia told of a *buaya darat*, a “land crocodile,” that walked the dry hills of Komodo. In 1910 a Dutch officer, Lieutenant van Steyn van Hensbroek, went to see for himself. He shot one, and sent its photograph and skin to Peter Ouwens, the director of the zoological museum at Buitenzorg (now Bogor) on Java. In 1912 Ouwens published the first scientific description. The world now knew that a real “dragon” was alive: *Varanus komodoensis*, the Komodo dragon.

The biggest lizard. The Komodo dragon is a **monitor lizard** and the largest lizard on earth. Big males reach about 10 feet long and often weigh around 150 to 200 pounds. It lives only on a handful of islands: Komodo, Rinca, Flores, Gili Motang and Gili Dasami. Komodo National Park was founded in 1980 to protect them, and it was named a World Heritage Site in 1991. Today only a few thousand Komodo dragons live in the wild.

A nose on its tongue. A Komodo flicks its long, yellow, forked tongue in and out. Each flick picks up tiny bits of scent from the air and carries them to the **Jacobson's organ** in the roof of its mouth. Because the tongue is forked, the lizard can tell whether a smell is stronger on the left or on the right, and turn toward it. A Komodo can smell **carrion** from miles away. It also hunts live prey such as deer, wild pigs and water buffalo, lying in wait beside a trail and lunging out at surprising speed.

Science corrects itself. For many years, books said that a Komodo's mouth was so full of germs that a bitten animal soon died of infection. In 2009 a team led by Bryan Fry studied a Komodo's head with an MRI scanner and found **venom** glands in its lower jaw. The venom keeps blood from clotting and lowers blood pressure, so a wounded deer grows weak. Its curved, saw-edged teeth, about 60 of them, slice deeply, and the venom does the rest. The old "dirty mouth" idea was not dishonest; it was simply a guess that better evidence replaced. That is how good science works.

Feast and famine. A Komodo dragon can eat up to about 80 percent of its own body weight in one meal, then go weeks without eating. Its jaws are loosely hinged and its stomach stretches. Young Komodos hatch in about seven to eight months and spend their first years living in trees, eating insects, geckos and eggs, because the ground is dangerous: adult Komodos will eat smaller ones. In 2006, zoos in England were amazed when female Komodos with no mates laid eggs that hatched. Scientists confirmed that a female can sometimes produce young alone.

Dragons in Scripture. The King James Bible uses the word "dragon" many times. The Hebrew words behind it can mean a great sea creature, a serpent or a wild desert animal, and readers do not always agree which. The Komodo was not known to the translators of 1611, but it is a good reminder that the world God made holds more wonders than any storybook. Psalm 148 calls even the "dragons" to praise the Lord.

PICTURE STUDY



Saint George and the Dragon, Paolo Uccello, c. 1470 · Oil on canvas · The National Gallery, London
Wikimedia Commons · Public domain

Long before anyone outside Indonesia had seen a Komodo, European artists painted dragons from old stories. In this famous painting, the Italian artist Paolo Uccello shows the legend of Saint George, a Christian soldier, rescuing a princess from a dragon. Compare this imagined dragon with the real lizard you have read about.

Look closely

- Find the dragon's wings, legs and tail. How many legs does it have?
- Look at the swirling cloud in the sky above the knight. What might it mean?
- Look at the dragon's skin and colors. Are they like a lizard's, a bird's or a bat's?

Talk about it

1. Name two ways Uccello's dragon is like a Komodo dragon and two ways it is different.
2. Why do you think people who first heard about the Komodo called it a “dragon”?

HANDS-ON: MAP: THE ISLANDS OF THE DRAGON

Draw a map of the small corner of the world where Komodo dragons live.

You will need

- A Field Notebook page
- Pencil and colored pencils
- An atlas or online map of Indonesia

Steps

1. Find Indonesia in an atlas. Look east of Java and Bali for a chain of islands called the Lesser Sunda Islands.
2. Draw the outlines of Bali, Lombok, Sumbawa and Flores from west to east, with the sea colored blue around them.
3. Between Sumbawa and Flores, draw the small islands of Komodo and Rinca. Shade them, and the western end of Flores, in green, and label them “Komodo dragons live here.”
4. Draw a dotted line around Komodo, Rinca and the small islands near them and label it “Komodo National Park (1980).”
5. Add a compass rose, a title (“Where the Dragons Live”) and a small arrow pointing toward Australia to the southeast.

Check your work

- My map shows at least five islands, labeled.
- Komodo, Rinca and western Flores are shaded.
- My map has a title and a compass rose.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: “How scientists changed their minds about the Komodo's bite.” Tell what people used to think, what Bryan Fry's team found in 2009, and why changing your mind with new evidence is a good thing.
2. Draw a forked tongue and show with two arrows how it tells left from right.

Did you know? Komodo dragons can run in short bursts at about 12 miles per hour and are good swimmers, crossing from island to island. In 1926 the American explorer W. Douglas Burden led an expedition to Komodo for the American Museum of Natural History and brought back specimens; his story helped make the “dragon” famous in America. A Komodo's skin is armored with tiny bones called osteoderms, like chain mail under its scales.

Goes deeper in. Geography, for Indonesia and the islands of Southeast Asia; and Life Science, “Reptiles and Amphibians” (coming soon).

For families. Discovery details follow Ouwens' 1912 paper in the *Bulletin du Jardin botanique de Buitenzorg*. The venom study is Fry et al., *PNAS* (2009); a few scientists still debate how much the venom matters in the wild, so the stop says the venom and the slicing teeth work together. The 2006 zoo hatchings (Chester and London) were reported in *Nature*. The IUCN listed the Komodo dragon as Endangered in 2021. Hebrew *tannin* and *tan*, translated “dragon” in the KJV, are understood differently by different scholars; the stop does not claim the Bible means the Komodo. Uccello's painting shows a lance striking the dragon; it is not gory.

PRACTICE

1. **EASY** On which islands do Komodo dragons live in the wild? Name at least two.
2. **EASY** Why does a Komodo dragon flick its forked tongue?
3. **MEDIUM** Why do young Komodo dragons live in trees?
4. **MEDIUM** A 150-pound Komodo eats 80 percent of its body weight in one meal. How many pounds of food is that?
5. **CHALLENGE** Komodo dragons were first described by science in 1912, and Bryan Fry's venom study came in 2009. How many years passed? What does this show about how science learns?

Make it a game • Follow the Scent. One player dabs a cotton ball with vanilla or peppermint extract and hides it in a room. The “Komodo” enters with eyes closed (or blindfolded, with a helper beside them for safety) and must find it only by sniffing, turning toward where the smell is stronger. Time each player. Who has the best Komodo nose?

Scripture. “Praise the LORD from the earth, ye dragons, and all deeps:” (Psalm 148:7, KJV)

The psalmist calls every creature, even the fiercest, to praise God. The real dragon of Komodo praises its Maker just by being what He made it to be.

Practice: answers

1. Any two: Komodo, Rinca, Flores, Gili Motang, Gili Dasami (in Indonesia).
2. To pick up scent from the air and carry it to the Jacobson's organ in the roof of its mouth; the fork helps it tell which direction a smell comes from.
3. To stay safe from adult Komodos, which may eat them, and to hunt insects, geckos and eggs.
4. 120 pounds ($150 \times 0.8 = 120$).
5. 97 years. Scientists can study an animal for a long time and still find new things; better tools (like MRI scans) can correct older ideas.

3.3 SNAKES: MOVING WITHOUT LEGS

OBJECTIVES

- Describe four ways snakes move without legs, and draw a diagram of each.
- Explain how a snake smells, senses heat and swallows prey larger than its head.
- Tell the story of the bronze serpent (Numbers 21) and why Jesus pointed to it (John 3:14).

Warm-up. Lie on your stomach on a smooth floor with your arms at your sides. Try to move forward without using your hands or feet. Hard, isn't it? Snakes do it every day, and they climb trees, swim and even “fly” from branch to branch.

Video slot. Video coming. How snakes move (slithering, concertina, sidewinding, rectilinear) and how a snake sheds its skin. Search approved channels (Smithsonian's National Zoo, BBC Earth, National Geographic Kids, San Diego Zoo Wildlife Alliance); preview first.

KEY TERMS

vertebra

One of the small bones that make up a backbone (plural: vertebrae). A snake may have 200 to more than 400 of them.

scute

A wide, overlapping scale on a snake's belly that grips the ground.

shed (molt)

To slip off the old outer layer of skin, often in one piece, as the snake grows.

pit organ

A small hollow on the face of pit vipers, pythons and boas that senses heat, letting the snake “see” warm animals in the dark.

constrictor

A snake that kills its prey by wrapping around it and squeezing, such as a python or boa.

CORE IDEAS

The story. On a sand dune in the Mojave Desert, the morning sun has already made the ground too hot to touch. A small rattlesnake called a sidewinder throws its head sideways, then lifts a loop of its body and sets it down a little farther along. Only two short bits of its body touch the burning sand at any moment. It leaves a trail of J-shaped marks, like a row of hooks, and glides away sideways faster than you would think.

Four ways to go. A snake's body is mostly backbone: 200 to more than 400 **vertebrae**, most with a pair of ribs, all moved by many muscles. With them snakes move in four main ways. In

lateral undulation, the common S-shaped “slither,” the body pushes sideways against rocks and stems. In *concertina* movement, used in tunnels and on branches, the snake bunches up like an accordion, anchors its back half, and stretches the front forward. *Sidewinding* works on loose, hot sand. In *rectilinear* movement, used by heavy snakes like pythons, the wide belly **scutes** grip the ground and the snake creeps forward in a straight line like a caterpillar.

Senses God gave the snake. Snakes have no eyelids. A clear scale covers each eye like a contact lens. They have no outer ears, but they feel vibrations in the ground through their jawbones. Like the Komodo, a snake smells with its forked tongue and the Jacobson's organ. Rattlesnakes and other pit vipers have a **pit organ** between eye and nostril that senses the heat of a mouse in total darkness. Pythons and boas have heat-sensing pits along their lips.

Swallowing whole. Snakes cannot chew. The two halves of the lower jaw are joined by a stretchy band, not fused like ours, and the jaw bones hinge loosely to the skull. The snake “walks” its jaws over its prey, one side and then the other, and its backward-curving teeth keep the food from slipping out. A small tube under its tongue stays open so it can breathe while it swallows. **Constrictors** such as pythons squeeze their prey until its heart stops. Venomous snakes, such as cobras and rattlesnakes, inject venom through hollow or grooved fangs.

Big and small. There are about 4,000 kinds of snakes. The longest is the reticulated python of Southeast Asia, which can pass 20 feet. The heaviest is the green anaconda of South America, which can weigh more than 200 pounds. The smallest known, the Barbados threadsnake described in 2008, is about 4 inches long, small enough to curl up on a quarter. Fewer than one in five kinds of snakes is dangerously venomous. In the United States, about 7,000 to 8,000 people are bitten by venomous snakes each year, but only about 5 die, thanks to quick medical care and antivenom.

The serpent lifted up. The serpent in Eden (Genesis 3) made snakes a picture of evil to many people. But the Bible also tells of a serpent that saved lives. When fiery serpents bit the Israelites in the wilderness, God told Moses to make a serpent of brass and set it on a pole; everyone who looked at it lived (Numbers 21:8-9). Jesus said that He must be “lifted up” in the same way (John 3:14), on the cross, so that whoever believes in Him would have eternal life.

PICTURE STUDY



Snakes, Plate 62 from the Thesaurus of Albertus Seba, Albertus Seba (collector) and Amsterdam engravers, 1734-1735 · Engraving · From *Locupletissimi rerum naturalium thesauri*, Volumes 1-2 (Amsterdam); copies in many libraries, viewable at the Biodiversity Heritage Library
Wikimedia Commons · Public domain

Albertus Seba was a Dutch druggist in Amsterdam who collected animals from sailors returning from all over the world. He paid artists to draw his collection, and between 1734 and 1765 the drawings were published in four huge volumes. Snakes fill many of the pages, coiled in graceful, decorative patterns, like the ones on this plate.

Look closely

- Count the snakes on the plate. How many different patterns can you find?
- Look at the heads. Can you see eyes, nostrils and scales?
- Find a snake whose belly scutes show. How are they different from the back scales?

Talk about it

1. Why do you think the artist curled the snakes into neat loops instead of drawing them stretched out?
2. Old collections like Seba's sometimes mixed up where animals came from. Why is it important for a scientist to write down where each animal was found?

Safety first. Never pick up or tease a wild snake, even one you think is harmless. Back away slowly and give it room. If someone is bitten, keep them calm and still and call 911 or go to a hospital at once.

HANDS-ON: DIAGRAM: FOUR WAYS TO MOVE WITHOUT LEGS

Make a four-part diagram of how snakes move, then test one way with a piece of string or a jump rope.

You will need

- A Field Notebook page divided into four boxes
- Pencil and colored pencils
- A piece of string or yarn about 2 feet long

Steps

1. Title the page “Four Ways to Move Without Legs.” Label the four boxes: *lateral undulation*, *concertina*, *sidewinding*, *rectilinear*.
2. In each box, draw a snake seen from above. Use small arrows to show which way the snake pushes and a big arrow to show which way it travels.
3. In the sidewinding box, draw the J-shaped tracks left in the sand. In the concertina box, draw the snake inside a narrow tunnel.
4. Under each drawing, write one sentence telling where a snake would use that way of moving (grass, tunnel, hot sand, or creeping up on prey).
5. Lay the string on a table in an S shape and push on its curves with your fingers, as rocks and stems push on a slithering snake. Write what you notice.

Check your work

- All four boxes are labeled and have arrows.
- Each box has a sentence about where that movement is used.
- I can explain which way works best on loose, hot sand and why.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: “Five ways a snake is designed for life without legs.” Include its backbone, senses, jaws and at least one number from this stop.
2. Add your four-part movement diagram.

Did you know? A snake sheds its whole skin, even the clear scales over its eyes, often turning it inside out like a sock. A rattlesnake adds a new segment to its rattle each time it sheds, so you cannot tell its age just by counting rattles. The “flying” snakes of Southeast Asia flatten their bodies and glide from tree to tree.

Map or diagram. Draw the head of a rattlesnake from the side and label the nostril, the heat pit, the eye with its clear scale, the forked tongue and the fangs.

Goes deeper in. Life Science, “Reptiles and Amphibians” (coming soon); and Gardening & Animals, for snakes in the garden and on the farm (many eat mice and rats).

For families. Species counts follow the Reptile Database (about 4,000 snakes). U.S. bite figures are from the CDC (NIOSH). The Barbados threadsnake was described by S. Blair Hedges in 2008. Snakes are a common fear; this stop treats them as part of God's good creation while being clear about safety and about the serpent of Genesis 3. Some videos show snakes swallowing prey; preview first.

PRACTICE

1. **EASY** Which way of moving does a snake use on loose, hot sand?
2. **EASY** How does a snake hear without outer ears?
3. **MEDIUM** Name two parts of a snake that let it swallow an animal wider than its own head.
4. **MEDIUM** About 7,500 people a year are bitten by venomous snakes in the United States, and about 5 die. About what fraction survive? What helps them?
5. **CHALLENGE** Read Numbers 21:8-9 and John 3:14-15. What did the Israelites have to do to be healed, and how does Jesus use this story?

Make it a game · Concertina Race. Players line up on their stomachs or knees in a hallway “tunnel.” To move, each must bunch up (knees to chest), anchor the back half, then stretch the front half forward, like a concertina snake. No crawling on hands and knees allowed. First to the end of the tunnel wins.

Scripture. “And as Moses lifted up the serpent in the wilderness, even so must the Son of man be lifted up:” (John 3:14, KJV)

A bronze serpent on a pole brought healing to all who looked at it (Numbers 21). Jesus was lifted up on the cross, and all who look to Him in faith are saved.

Practice: answers

1. Sidewinding.
2. It feels vibrations from the ground through its jawbones.
3. Any two: lower jaw halves joined by a stretchy band; loosely hinged jaw bones; backward-curving teeth that “walk” over the prey; a breathing tube that stays open while it swallows.
4. Almost all: about 7,495 of 7,500 (more than 99.9 percent). Quick medical care and antivenom.
5. They had to look at the brass serpent on the pole. Jesus says He will be lifted up the same way (on the cross), and whoever believes in Him (looks to Him in faith) will not perish but have eternal life.

3.4 SEA TURTLES: OCEAN TRAVELERS THAT COME HOME

OBJECTIVES

- Name the seven kinds of sea turtles and describe the leatherback, the largest.
- Trace a loggerhead's ocean journey on a map of the North Atlantic.
- Explain how careful people helped the Kemp's ridley sea turtle come back.

Warm-up. Find a compass, or a compass app on a phone. Turn around in a circle with your eyes closed, then point to where you think north is. Check. Were you right? A baby sea turtle can find its way across an ocean, partly by sensing the earth's magnetic field, the same force that moves a compass needle.

Video slot. Video coming. Sea turtle hatchlings racing to the sea; a leatherback nesting at night; Kemp's ridley arribada. Search approved channels (NOAA Fisheries, U.S. Fish and Wildlife Service, National Park Service at Padre Island, Smithsonian, BBC Earth); preview first.

KEY TERMS

carapace

The top part of a turtle's shell. The bottom part is the plastron.

hatchling

A baby animal that has just come out of its egg.

natal homing

Returning as an adult to the place where you were born. Female sea turtles come back to nest near the beach where they hatched.

magnetic field

The invisible force around the earth that points a compass needle north. Sea turtles can sense it and use it like a map.

arribada

Spanish for “arrival”: a mass nesting in which thousands of ridley sea turtles come ashore together.

CORE IDEAS

The story. On a summer night on a Florida beach, the sand begins to stir. One by one, then by the dozen, baby loggerhead turtles no bigger than a cookie dig their way out of a nest. Without a pause they turn toward the brightest horizon, the starlit sea, and scramble across the sand. In the surf they swim hard for about a day and a night, out to the Gulf Stream. They will ride the great ocean currents around the North Atlantic, past the Azores and Africa, for years. A female who survives will come back, perhaps 25 or 30 years later, to lay her own eggs on the same stretch of coast.

Seven kinds. There are seven kinds of sea turtles: the leatherback, green, loggerhead, hawksbill, Kemp's ridley, olive ridley and flatback. Unlike land turtles, they cannot pull their heads and flippers into their shells. Their front legs are long flippers, and they “fly” through the water. The **leatherback** is the giant: up to about 6 or 7 feet long and often more than 1,000 pounds. Its **carapace** is not hard plates but leathery skin over small bones. It dives more than 3,000 feet deep, eats mostly jellyfish, and has backward-pointing spines in its throat so the slippery jellies cannot escape.

A map in the mind. How does a hatchling cross an ocean and come home? Scientists such as Kenneth Lohmann of the University of North Carolina have shown that sea turtles can sense the earth's **magnetic field**. Its strength and angle are a little different at every place on earth, so a turtle can tell roughly where it is, like reading an invisible map. This is how, after decades at sea, a female can find her way back toward her birthplace: **natal homing**.

The nest. A mother sea turtle crawls up the beach at night, digs a hole with her back flippers, and lays about 100 eggs the size of ping-pong balls. She covers them and returns to the sea; she never sees her young. The sand keeps the eggs warm for about two months. Sea turtles drink sea water and get rid of the extra salt through glands near their eyes, so on the beach a turtle can look as if it is crying.

A rescue that worked. In 1947 a Mexican engineer, Andrés Herrera, filmed an **arribada** of Kemp's ridley turtles at Rancho Nuevo, Mexico: about 40,000 females nesting on one beach in a single day. Later, people dug up nearly every nest for eggs, and by 1985 only about 700 nests were counted. Mexico and the United States began guarding the beach, moving eggs to safe pens, and in the 1980s the U.S. began requiring shrimp boats to use “turtle excluder devices,” trapdoors that let turtles escape from nets. Today thousands of nests are laid each year. Good stewardship (Genesis 2:15) made the difference.

Turtles in Scripture. When the King James Bible says “the voice of the turtle is heard in our land” (Song of Solomon 2:12), it means the turtledove, a bird. But the Psalms do speak of the creatures of the sea, “things creeping innumerable, both small and great beasts” (Psalm 104:25). The sea turtle is one of them.

PICTURE STUDY



The Turtle Pound, Winslow Homer, 1898 · Watercolor over graphite on paper · Brooklyn Museum, New York
Wikimedia Commons · Public domain

The American painter Winslow Homer spent winters painting in the Bahamas and Florida. In this watercolor, two Bahamian fishermen are at a turtle pound, a pen built in the sea where captured turtles were kept alive until they were sold or cooked. In Homer's day, turtle meat and soup were a common food, and sailors had eaten sea turtles for centuries.

Look closely

- Find the turtle. Which part of it is the man holding?
- Look at the water. How many different colors did Homer use to paint it?
- Look at the wooden posts of the pound. Why would fishermen build a pen in the water?

Talk about it

1. How do you think the turtle got into the pound?
2. People in 1898 saw sea turtles mainly as food. Why do many countries protect them today, and how is that a kind of stewardship?

HANDS-ON: MAP: THE LOGGERHEAD'S LONG LOOP

Trace the ocean journey of a young loggerhead from Florida around the North Atlantic and back.

You will need

- A Field Notebook page or a printed outline map of the Atlantic Ocean
- Pencil, blue and red colored pencils

- An atlas or online map

Steps

1. Draw or trace the outlines of North America, Europe and Africa around the North Atlantic Ocean.
2. Mark and label: Florida, the Gulf Stream (a blue arrow running north along the U.S. coast and then east), the Azores Islands, the Canary Islands, and the Sargasso Sea in the middle of the loop.
3. In red, draw the turtle's path: from a Florida beach, out into the Gulf Stream, east toward the Azores, south past the Canary Islands and Africa, then west across the ocean and back to Florida.
4. Add a small turtle drawing at the start labeled "hatchling" and one at the end labeled "adult returns to nest."
5. Give your map a title and a compass rose. Write "journey: many years" beside the red loop.

Check your work

- My map shows three continents and the North Atlantic.
- The Gulf Stream, Azores and Sargasso Sea are labeled.
- The red loop starts and ends in Florida.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: "How the Kemp's ridley came back." Use the numbers 1947, 40,000 and 700, and name two things people did to help.
2. Draw a leatherback and a green turtle side by side and label the carapace, flippers and head of each.

Did you know? The green sea turtle is named not for its shell but for the greenish color of its fat, from eating sea grass. Hatchlings head toward the brightest horizon, which on a natural beach is the sea. Bright lights from houses and roads can lead them the wrong way, so many beach towns in Florida ask people to turn off outdoor lights during nesting season. The University of Florida biologist Archie Carr spent his life studying sea turtles, and a wildlife refuge on Florida's east coast is named for him.

Goes deeper in. Geography, for ocean currents and the Atlantic; Life Science, "Reptiles and Amphibians" (coming soon); and Art, for Winslow Homer's watercolors.

For families. The 1947 Herrera film was rediscovered by Henry Hildebrand in 1961; the figure of about 40,000 nesters is an estimate from the film. Nest counts follow NOAA Fisheries and U.S. Fish and Wildlife Service recovery reports; numbers rise and fall by year. Turtle excluder devices were required in U.S. shrimp trawls in stages from the late 1980s. Leatherback weights vary; the largest on record (Wales, 1988) was about 2,000

pounds. Homer's painting shows turtles being caught for food, as was normal in 1898; the stop describes this plainly.

PRACTICE

1. **EASY** Name three of the seven kinds of sea turtles.
2. **EASY** What does a leatherback mostly eat, and how does its throat help?
3. **MEDIUM** Why do many beach towns ask people to turn off outdoor lights in nesting season?
4. **MEDIUM** In 1947 about 40,000 Kemp's ridleys nested in one day. By 1985 there were about 700 nests. About how many times smaller was the 1985 number?
5. **CHALLENGE** A mother turtle lays about 100 eggs, and only about 1 hatchling in 1,000 may live to be an adult. About how many nests would it take to produce one adult? What does this tell you about why every nest matters?

Make it a game · Hatchling Dash. In a dark room, one player holds a flashlight low at the far end (the moonlit sea). “Hatchlings” start at the other end on hands and knees and crawl toward the light. Then a second player switches on a “streetlight” flashlight at the side. Which light do the hatchlings follow? Talk about why beach lights confuse real turtles.

Scripture. “So is this great and wide sea, wherein are things creeping innumerable, both small and great beasts.” (Psalm 104:25, KJV)

The sea is wide, but God made creatures that cross it and find their way home. He set a map inside the sea turtle long before anyone drew a chart.

Practice: answers

1. Any three: leatherback, green, loggerhead, hawksbill, Kemp's ridley, olive ridley, flatback.
2. Jellyfish. Backward-pointing spines in its throat keep the slippery jellies from sliding back out.
3. Hatchlings crawl toward the brightest horizon, which should be the sea. Bright lights on land can lead them away from the water.
4. About 57 times smaller ($40,000 \div 700 \approx 57$).
5. About 10 nests ($10 \times 100 = 1,000$ eggs). Because so few survive, protecting each nest and each adult female makes a big difference to the whole population.

3.5 CHAMELEONS: TURRET EYES AND A LIGHTNING TONGUE

OBJECTIVES

- Label a diagram of a chameleon's eyes, tongue, feet and tail and tell what each does.
- Explain how a chameleon changes color and the main reasons it does.
- Find Madagascar on a map and explain why it is called the home of the chameleons.

Warm-up. Close one eye and look around the room. Now try to look at the ceiling with your right eye and the floor with your left at the same time. You can't! A chameleon can point each eye in a different direction, like two security cameras on one head.

Video slot. Video coming. Chameleon tongue strike in slow motion; chameleon eyes moving independently; panther chameleon color change. Search approved channels (BBC Earth, Smithsonian's National Zoo, San Diego Zoo Wildlife Alliance, National Geographic Kids); preview first.

KEY TERMS

turret eye

An eye in a cone of skin that can swivel on its own, like a gun turret. Each chameleon eye moves separately.

prehensile tail

A tail that can curl around and grip things, like a fifth hand.

zygodactyl feet

Feet with toes grouped in two opposing bundles, like tongs, for gripping branches.

iridophore

A skin cell holding tiny crystals that reflect light. Changing the spacing of the crystals changes the color we see.

endemic

Found naturally in only one place in the world. Many chameleons are endemic to Madagascar.

CORE IDEAS

The story. On a twig in a Madagascar forest, a panther chameleon sits so still it looks like a leaf. One eye swivels forward, the other backward. A fly lands on a leaf a foot away. Slowly both eyes swing toward it and lock on. The chameleon sways a little, like a leaf in the breeze. Then, faster than you can blink, its tongue shoots out longer than its body, the sticky tip slaps the fly, and the tongue snaps back. The whole strike takes less than a tenth of a second.

Two eyes, two jobs. A chameleon's eyes sit in cone-shaped **turrets** of scaly skin with only a pinhole to see through. Each eye moves on its own, so a chameleon can look in two

directions at once and see nearly all the way around itself without turning its head. When it spots food, both eyes turn forward together, so it can judge distance exactly before it strikes.

The lightning tongue. The tongue is folded up in the mouth on a bone like an arrow on a bow, with stretchy tissue wrapped around it. When the chameleon fires, the stored energy is released all at once. In 2016 a scientist named Christopher Anderson filmed small chameleons whose tongues sped up from 0 to 60 miles per hour in about one hundredth of a second, faster than almost anything else in the animal world. Many chameleons can shoot the tongue one and a half to two times their body length. The tip is a sticky, sucking cup that holds insects tight.

Made for branches. A chameleon's toes are joined into two bundles on each foot, one facing each way, like tongs; these are **zygodactyl** feet. Its **prehensile tail** curls around twigs as an anchor. A chameleon walks with a slow, rocking step and rarely comes to the ground except to lay eggs.

The truth about color. Many people think chameleons change color mainly to match their background. Scientists now know that chameleons change color mostly to show their mood to other chameleons and to warm up or cool down (darker colors soak up more sunlight). In 2015 a team at the University of Geneva found how it works: skin cells called **iridophores** hold tiny crystals. When the chameleon relaxes or tightens its skin, the crystals move closer together or farther apart, and they reflect different colors of light. A calm panther chameleon may be green; an excited male may blaze with red, orange and yellow.

Madagascar, chameleon island. There are about 200 kinds of chameleons in Africa, southern Europe, the Middle East and southern Asia, and nearly half of them live only on the island of Madagascar, off the east coast of Africa. They are **endemic** there. Madagascar has both the largest chameleons, about two feet long, and some of the smallest reptiles on earth: *Brookesia nana*, described in 2021, could sit on the tip of your finger. The name “chameleon” comes from Greek words meaning “ground lion.” The King James Bible names the chameleon in Leviticus 11:30, among the small creatures Israel was not to eat.

PICTURE STUDY



A Chameleon, Ustad Mansur, c. 1612 · Brush and ink with green bodycolor (opaque watercolor) on paper · Royal Collection Trust, Windsor Castle, United Kingdom (RCIN 912081)
Wikimedia Commons · Public domain

Ustad Mansur was the best animal painter at the court of Jahangir, the Mughal emperor of India, who called him “Wonder of the Age.” Jahangir loved to study animals and had his painters record new ones brought to his court. In 1612 a group of animals arrived from Goa, and this chameleon may have been one of them. Mansur painted it from life with tiny dots of green to show its bumpy skin.

Look closely

- Find the chameleon's feet. Can you see the toes grouped into two bundles?
- Follow the tail. What is it doing?
- Look closely at the eye and what it is looking at. What is the chameleon about to do?

Talk about it

1. This painting is about 400 years old. Which parts are just as accurate as a modern photograph?
2. Why might an emperor want careful pictures of animals instead of imaginary ones?

HANDS-ON: DIAGRAM: THE CHAMELEON'S TOOLKIT

Draw a labeled diagram of a chameleon and the five tools God gave it for life in the trees.

You will need

- A Field Notebook page

- Pencil and colored pencils
- A ruler

Steps

1. Draw a chameleon from the side, gripping a branch. Make it big enough to fill most of the page.
2. Draw its tongue shooting straight out toward an insect. Use the ruler to make the tongue about one and a half times as long as the body (not counting the tail).
3. Label five tools with arrows: *turret eye*, *tongue with sticky tip*, *zygodactyl feet*, *prehensile tail*, *iridophore skin*. Beside each label, write a few words about what it does.
4. In a small box in the corner, draw a tiny outline map of Africa and Madagascar and shade Madagascar.
5. Color your chameleon in calm colors (green) on one half and excited colors (red, orange, yellow) on the other.

Check your work

- My diagram has five labeled tools, each with a short note.
- The tongue is about one and a half times the body length.
- Madagascar is shaded on my small map.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: “Why do chameleons change color?” Explain the old idea, what scientists found in 2015, and the two main reasons chameleons change color.
2. Add your labeled chameleon diagram.

Did you know? Chameleons have no outer ears and hear only low sounds. Some kinds lay eggs that take up to a year to hatch. In 2018 scientists found that the bones on some chameleons' heads glow blue under ultraviolet light, shining through thin skin, which may help them signal to one another in the dim forest.

Goes deeper in. Geography, for Madagascar and Africa; Life Science, “Reptiles and Amphibians” (coming soon); and Art, for Mughal painting.

For families. Tongue-speed figures are from Anderson, *Scientific Reports* (2016). The color-change mechanism is from Teyssier et al., *Nature Communications* (2015). *Brookesia nana* was described by Glaw et al. in 2021. Species counts (about 200–220) vary by source. The Hebrew word in Leviticus 11:30 is uncertain; modern translations render it differently (some say “chameleon,” others another lizard); the stop quotes the KJV. Picture details follow the Royal Collection Trust catalog entry.

PRACTICE

1. **EASY** What is special about a chameleon's eyes?
2. **EASY** On which island do nearly half of all chameleons live?
3. **MEDIUM** Give the two main reasons chameleons change color.
4. **MEDIUM** A chameleon's body is 6 inches long. Its tongue reaches 1.5 times its body length. How far can it reach?
5. **CHALLENGE** The chameleon's tongue works like a bow and arrow. Explain what is stored and what is released when it fires.

Make it a game · Chameleon Eyes. One player is the chameleon and sits in the middle of the room, moving only the eyes, not the head. The others creep in from all sides. If the chameleon names a player it sees moving, that player goes back to the wall. The first to touch the chameleon's shoulder becomes the next chameleon. Then try it with one eye closed. Is it harder?

Scripture. “And the ferret, and the chameleon, and the lizard, and the snail, and the mole.” (Leviticus 11:30, KJV)

God's law to Israel named even the small creeping things. Nothing in creation is too small for God to notice, and He knows each creature by its kind.

Practice: answers

1. Each eye sits in a turret and moves on its own, so it can look two ways at once; both eyes turn forward together to judge distance before a strike.
2. Madagascar.
3. To signal their mood to other chameleons, and to warm up or cool down. (Hiding is a smaller reason.)
4. 9 inches ($6 \times 1.5 = 9$).
5. Stretchy tissue around the tongue bone is stretched and loaded with energy, like a drawn bowstring. When the chameleon fires, the energy is released all at once, launching the tongue much faster than muscle alone could.

3.6 TORTOISES OF THE GALÁPAGOS: GIANTS OF THE ENCHANTED ISLES

OBJECTIVES

- Draw a labeled map of the Galápagos Islands and their place on the equator.
- Explain the difference between domed and saddleback tortoise shells and how each fits its island.
- Tell how Diego and the breeding program saved the tortoises of Española.

Warm-up. Find a book that weighs about 5 pounds and lift it. A large Galápagos tortoise can weigh 100 times as much: more than 500 pounds, as much as three grown men. And it may live more than 100 years.

Video slot. Video coming. Galápagos giant tortoises in the highlands; domed and saddleback shells; the Charles Darwin Research Station tortoise breeding center. Search approved channels (Galápagos Conservancy, Smithsonian's National Zoo, San Diego Zoo Wildlife Alliance, BBC Earth); preview first.

KEY TERMS

tortoise

A turtle that lives on land, with a high shell and stumpy, elephant-like legs.

archipelago

A group of islands. The Galápagos is an archipelago in the Pacific Ocean.

saddleback

A tortoise shell that rises high in front, like a Spanish saddle, so the tortoise can stretch its neck upward.

variety within a kind

Differences among animals of the same created kind, such as the many shell shapes of Galápagos tortoises.

breeding program

A careful plan to raise young animals in safety and return them to the wild to help a rare animal recover.

CORE IDEAS

The story. In March 1535 a ship carrying Tomás de Berlanga, the Bishop of Panama, was becalmed on its way to Peru and drifted for days far out into the Pacific. The crew sighted strange, rocky islands with almost no fresh water. In a letter to King Charles V of Spain, the bishop described giant tortoises so big that a man could ride on them, and birds so tame

they could be caught by hand. Soon the islands were named for the tortoises: *galápagos* was an old Spanish word for a tortoise.

The islands. The Galápagos **archipelago** lies on the equator about 600 miles west of Ecuador, the country it belongs to. It has about 13 large islands and many smaller ones, formed by volcanoes; some volcanoes are still active. Cold ocean currents keep the coasts cooler and drier than you might expect at the equator. Sailors called them “the Enchanted Isles,” partly because strong currents and mists made them hard to find.

Domes and saddles. Galápagos tortoises are the largest tortoises on earth: up to about 5 feet long and more than 500 pounds. On the high, wet islands like Santa Cruz, where grass and low plants grow, tortoises have round, **domed** shells. On low, dry islands like Española, where the best food is up high on tree cactus, tortoises have **saddleback** shells that rise in front, letting them stretch their long necks up. In 1835 the vice-governor of the islands, Nicholas Lawson, told a young English naturalist named Charles Darwin that he could tell which island a tortoise came from just by its shell. These differences are **variety within a kind**: every one is still a Galápagos tortoise, just as God made the animals “after their kind” with room for variety (Genesis 1:25).

Living larders. A tortoise can live for months without food or water. For whalers and buccaneers in the 1700s and 1800s, that made the tortoises perfect “fresh meat” to store alive in a ship's hold. Logbooks show that whaling ships took many thousands; historians estimate that well over 100,000 tortoises were removed in all. Goats, pigs and rats brought by ships ate the tortoises' food and their eggs. Several island kinds vanished. The last Pinta Island tortoise, called Lonesome George, died on June 24, 2012.

Diego and the rescue of Española. By the 1960s only 14 tortoises were left on Española: 12 females and 2 males. Workers at the Charles Darwin Research Station on Santa Cruz brought them into a **breeding program**. In 1976 a third male, Diego, who had been living at the San Diego Zoo, was sent home to help. Over the next 50 years more than 2,000 young Española tortoises were raised and returned to their island, and park rangers removed the goats that had stripped it bare. In 2020 the program ended and Diego, more than 100 years old, was set free on Española. Wise stewardship can help a creature come back.

PICTURE STUDY



Giant Tortoises of the Galápagos Islands, from The Royal Natural History, Gustav Mützel (artist); edited by Richard Lydekker, 1896 · Engraving (printed book illustration) · From The Royal Natural History (London, 1896); copies in many libraries
Wikimedia Commons · Public domain

Gustav Mützel was a German artist who drew animals for many natural history books. This engraving was printed in *The Royal Natural History*, a set of books edited by the English naturalist Richard Lydekker in the 1890s. It shows a group of Galápagos giant tortoises at home on their island. Mützel even added two little finches, another famous animal of the Galápagos.

Look closely

- Look at the shells. Are they low and round like a dome, or high in front like a saddle?
- Find the plates (scutes) on the shells. Do they have rings or ridges?
- Find the two finches. Why might the artist have put them in the picture?

Talk about it

1. How does this picture help you guess what kind of land the tortoises lived on?
2. Most readers in 1896 would never see a living Galápagos tortoise. Why were pictures like this one so important to them?

HANDS-ON: MAP: THE ENCHANTED ISLES

Draw a labeled map of the Galápagos Islands and mark where domed and saddleback tortoises live.

You will need

- A Field Notebook page
- Pencil, colored pencils and a ruler
- An atlas or online map of the Galápagos Islands

Steps

1. Draw a horizontal line across the page with the ruler and label it “Equator (0°).”
2. Draw the islands, using the map as your guide. Label at least these: Isabela (the largest, shaped like a seahorse), Fernandina, Santiago, Santa Cruz, San Cristóbal, Española and Pinta.
3. Draw a small domed shell on Santa Cruz and on Isabela's volcanoes. Draw a small saddleback shell on Española and on Pinta.
4. Mark the Charles Darwin Research Station with a star on Santa Cruz.
5. In one corner, draw an arrow pointing east labeled “Ecuador, about 600 miles.” Add a title and a compass rose.

Check your work

- My map shows the equator and at least seven labeled islands.
- Domed and saddleback shells are drawn on the right islands.
- My map has a title, a compass rose and the arrow to Ecuador.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: “How Diego helped save the tortoises of Española.” Use the numbers 14, 1976, 2,000 and 2020.
2. Draw a domed shell and a saddleback shell side by side and write one sentence under each about where that shell works best.

Did you know? Galápagos tortoises often sleep up to 16 hours a day. Small birds called finches hop in front of them, and the tortoise rises up on its legs and stretches its neck so the birds can pick off ticks. Ecuador made most of the islands a national park in 1959, and the Galápagos was one of the first places named a World Heritage Site, in 1978.

Goes deeper in. Geography, for Ecuador, the equator and island volcanoes; History, for Spanish explorers and the whaling age; and Life Science, “Reptiles and Amphibians” (coming soon).

For families. Berlanga's 1535 letter is preserved in Spanish archives. Lawson's remark is recorded in Darwin's *Journal of Researches* (1839/1845). Darwin later used the islands in arguing for his theory of evolution; this stop presents the shell differences as variety within the created tortoise kind, which all sides agree is observed. Estimates of tortoises taken by ships range from about 100,000 to 200,000 (based partly on C. H. Townsend's 1925 study of whaling logbooks). The Española figures (14 founders; more than 2,000 released) follow the Galápagos National Park Directorate (2020). Experts recognize about

12 to 15 kinds; several are extinct. Günther's book has 55 plates; any Galápagos plate will serve.

PRACTICE

1. **EASY** Where do the Galápagos Islands get their name?
2. **EASY** Who was Diego?
3. **MEDIUM** Why do tortoises on dry islands like Española have saddleback shells?
4. **MEDIUM** Why did sailors carry live tortoises on their ships?
5. **CHALLENGE** The Española breeding program began with 14 tortoises and released more than 2,000 young. About how many young is that for each of the original 15 tortoises (counting Diego)? Why did removing the goats also matter?

Make it a game • Dome or Saddle?. Hang a “cactus” (a paper cutout) high on a wall and set “grass” (green paper) on the floor. Players take turns being a domed tortoise (must keep chin tucked) or a saddleback tortoise (may stretch up on tiptoes). Each turn, a caller says “wet island” or “dry island,” and the tortoise must reach food. Which shell wins on which island?

Scripture. “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.” (Genesis 2:15, KJV)

God gave people the work of keeping His creation. Sailors once nearly emptied the Galápagos of tortoises; patient keepers helped bring them back.

Practice: answers

1. From *galápagos*, an old Spanish word for a tortoise.
2. A male Española tortoise who came home from the San Diego Zoo in 1976 and helped father hundreds of young in the breeding program; he was set free on Española in 2020.
3. Their food (such as tree cactus) is up high. The shell rises in front so they can stretch their necks upward to reach it.
4. Tortoises can live for months without food or water, so they gave sailors fresh meat on long voyages.
5. About 133 each ($2,000 \div 15 \approx 133$). Goats ate the plants the tortoises needed; without removing them, the young tortoises would have had nothing to eat.

3.7 FROGS: A DOUBLE LIFE IN WATER AND ON LAND

OBJECTIVES

- Explain what makes an animal an amphibian and how amphibians differ from reptiles.
- Draw and label the life cycle of a frog from egg to adult.
- Describe two surprising designs: the wood frog that freezes and the Surinam toad that carries its young in its back.

Warm-up. Squat down low, then leap forward as far as you can. Mark where your heels land and measure. A good frog can jump 10 to 20 times its own body length. How far would you have to jump to match that?

Video slot. Video coming. Frog life cycle from egg to tadpole to froglet (time-lapse); spring peepers calling; wood frogs freezing and thawing. Search approved channels (Smithsonian's National Zoo, BBC Earth, National Geographic Kids, U.S. Fish and Wildlife Service); preview first.

KEY TERMS

amphibian

A cold-blooded animal with moist skin and no scales that usually begins life in water and later lives on land, such as a frog, toad or salamander. The word means “double life.”

metamorphosis

A complete change of body form as an animal grows, such as a tadpole becoming a frog.

tadpole

The young water stage of a frog or toad, with gills and a tail but no legs at first.

frogspawn

A mass of frog eggs held together in clear jelly.

vocal sac

A balloon of skin on a male frog's throat that fills with air and makes its call louder.

CORE IDEAS

The story. On a cold March night in Pennsylvania, the snow has only just melted from the edge of a pond. Then a sound begins: *peep, peep, peep*, from one, then dozens, then hundreds of tiny throats, until it rings like sleigh bells. Spring peepers, frogs about an inch long, have woken up. Each male puffs his throat into a shining bubble, his **vocal sac**, to call. On some nights the chorus can be heard from more than half a mile away.

A double life. Frogs are **amphibians**, from Greek words meaning “double life,” because most begin life in water and end it on land. Unlike reptiles, amphibians have no scales; their skin is thin, moist and often slimy. Their eggs have no shells and must stay wet. A frog

breathes with lungs, but it also takes in oxygen through its skin, and it drinks not with its mouth but by soaking up water through a patch of skin on its belly. There are more than 7,000 kinds of frogs and toads, from the Goliath frog of West Africa, about a foot long and over 7 pounds, to a frog from Papua New Guinea about the size of a housefly. Toads are simply frogs with drier, bumpier skin and shorter legs.

The great change. A frog's life is a story of **metamorphosis**. A female lays a clump of **frogspawn**, sometimes thousands of eggs. Out of each comes a **tadpole** with gills, a tail and a mouth for scraping algae. After some weeks, back legs appear, then front legs. Its gills disappear and lungs take over; its tail shrinks as the body absorbs it; its gut changes from a plant-eater's to a meat-eater's. A little froglet climbs out of the water. A small frog may finish in a few weeks; a bullfrog may take two or three years.

Frozen frogs and back-pocket babies. The wood frog of North America can survive being frozen. In winter as much as two-thirds of the water in its body turns to ice, its heart stops and it does not breathe. Its liver fills its cells with sugar, a natural antifreeze that protects them. In spring it thaws and hops away. In South America, the flat Surinam toad has an even stranger design. The female's eggs sink into the skin of her back, and each grows in its own little pocket. After a few months, tiny toads push out of her back and swim away.

Frogs in history. In the 1780s an Italian scientist, Luigi Galvani, noticed that a dead frog's leg twitched when touched with two different metals. His experiments helped begin the study of electricity in the body. And long before that, God sent frogs as the second plague on Egypt, when Pharaoh refused to let Israel go (Exodus 8). The frogs came up from the Nile "and covered the land," filling even the ovens and the beds. The creatures the Egyptians thought of as signs of life and plenty became a sign that the Lord was greater than all their gods.

PICTURE STUDY



*Water Cress, Surinam Toad and Shells, from Metamorphosis of the Insects of Suriname, Maria Sibylla Merian, 1726 edition (first published 1705) · Hand-colored engraving (after Merian's watercolor) · Wellcome Collection, London; from the Latin edition *Dissertatio de generatione et metamorphosis insectorum Surinamensium**
Wikimedia Commons · CC BY 4.0

Maria Sibylla Merian was a German-born artist and naturalist. In 1699, at age 52, she sailed with her daughter to Suriname in South America to study and paint its insects, plants and animals from life. Her book *Metamorphosis of the Insects of Suriname* (1705) made her famous, and it was printed again after her death, as in this 1726 copy. She was among the first Europeans to picture the Surinam toad and its young, at a time when many people still believed frogs sprang up from mud.

Look closely

- Find the young toads. Where are they on the mother's body?
- Look at the shape of the mother toad. How is it different from the frogs you know?
- Look at the plant and the shells. Why might Merian have put them in the same picture?

Talk about it

1. Merian painted animals from life instead of copying older pictures. Why does that matter for science?
2. How does this picture show a stage in an amphibian's life cycle?

HANDS-ON: DIAGRAM: THE FROG LIFE CYCLE WHEEL

Make a circular life-cycle diagram of a frog, then (in spring) look for real frogspawn or tadpoles.

You will need

- A Field Notebook page
- A plate or bowl to trace a circle
- Pencil and colored pencils
- Optional: a clear jar, pond water and a hand lens

Steps

1. Trace a large circle on the page. Divide it into five equal sections like a pie.
2. Label and draw the five stages in order, going clockwise: *eggs (frogspawn)*, *tadpole with gills*, *tadpole with back legs*, *froglet with four legs and a short tail*, *adult frog*.
3. Draw an arrow from each stage to the next, and from the adult frog back to the eggs.
4. Beside each stage, write one change: for example, “gills disappear, lungs take over” or “tail is absorbed.” Draw a wavy blue line across the stages that live in water.
5. Optional (spring): with a parent, look in a pond edge for frogspawn or tadpoles. Scoop a few into a jar of pond water, watch with a hand lens for ten minutes, sketch what you see, and then pour them back where you found them.

Check your work

- My wheel has five stages in the right order with arrows.
- Each stage has a note about what changes.
- I marked which stages live in water.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: “Why a frog is an amphibian and not a reptile.” Name at least three differences (skin, eggs, breathing, life cycle).
2. Add your life-cycle wheel.

Did you know? A frog uses its eyes to help it swallow: it blinks and pulls its eyeballs down into its head to push food down its throat. Mark Twain's funny 1865 story “The Celebrated Jumping Frog of Calaveras County” started a real frog-jumping contest in California that still runs every May.

Map or diagram. Draw a cutaway of a frog's skin and label where it takes in oxygen and water. Add arrows to show air going in through the skin and lungs.

Goes deeper in. Life Science, “Reptiles and Amphibians” and “Life Cycles” (coming soon); History, for Galvani and the study of electricity; Literature, for Mark Twain; and Art, for Maria Sibylla Merian.

For families. Species numbers follow AmphibiaWeb (more than 7,000 frogs and toads). Wood frog freezing follows Storey and Storey and Larson et al. (2014). Galvani published his frog-leg findings in 1791 after experiments in the 1780s. The Merian watercolor is in

the Royal Collection; the engraved version appeared as plate 59 in the enlarged 1719 edition of *Metamorphosis*. Collecting tadpoles may be restricted in some places; check local rules and return animals to the same spot. Wash hands after touching pond water.

PRACTICE

1. **EASY** What does the word “amphibian” mean?
2. **EASY** Put these stages in order: froglet, eggs, adult frog, tadpole with gills, tadpole with back legs.
3. **MEDIUM** Name two ways a frog's body is different from a reptile's.
4. **MEDIUM** A spring peeper is 1 inch long and can jump about 20 times its body length. How far is that in feet and inches?
5. **CHALLENGE** How does a wood frog survive being frozen? Why doesn't the ice destroy its cells?

Make it a game • Frog Jump Measure. Each player does three standing “frog jumps” from a crouch. Measure the best jump in inches and divide by the player's height in inches. Write the answer in your notebook. Then compare: a frog jumps about 10 to 20 times its body length. Who came closest to a frog?

Scripture. “And Aaron stretched out his hand over the waters of Egypt; and the frogs came up, and covered the land of Egypt.” (Exodus 8:6, KJV)

The Egyptians honored the Nile and the frogs that came from it. In the second plague, the Lord showed that He rules the river and every creature in it.

Practice: answers

1. “Double life”: most amphibians live first in water and then on land.
2. Eggs, tadpole with gills, tadpole with back legs, froglet, adult frog.
3. Any two: moist skin with no scales; eggs with no shells that must stay wet; breathes partly through its skin; goes through metamorphosis from a water-living tadpole.
4. 20 inches, which is 1 foot 8 inches.
5. Its heart stops and much of its body water freezes, but its liver fills its cells with sugar (glucose), which acts like antifreeze. The sugar keeps ice from forming inside the cells, where it would damage them; the ice forms outside the cells instead. In spring it thaws and revives.

3.8 SALAMANDERS: SECRET LIVES UNDER LOGS

OBJECTIVES

- Tell how salamanders differ from lizards and from frogs.
- Explain how lungless salamanders breathe and how the axolotl regrows lost parts.
- Separate the old legend of the salamander in the fire from what careful observers actually saw.

Warm-up. Put your hand flat on your chest and feel yourself breathe. Now imagine breathing without lungs at all, only through your skin. More than half of all the salamanders in the world do just that.

Video slot. Video coming. Salamanders of the Great Smoky Mountains; the hellbender; the axolotl regrowing a limb. Search approved channels (National Park Service, Smithsonian's National Zoo, U.S. Fish and Wildlife Service, BBC Earth); preview first.

KEY TERMS

salamander

An amphibian with a long body, a tail, and usually four short legs. It has moist skin without scales.

lungless salamander

A salamander that has no lungs and breathes through its skin and the lining of its mouth.

regeneration

Growing back a lost body part, such as a leg or tail.

axolotl

A Mexican salamander that keeps its feathery gills and lives its whole life in water (say “AX-oh-LOT-ul”).

legend

An old story handed down that may mix some truth with things that are not true.

CORE IDEAS

The story. On a damp morning in the Great Smoky Mountains of Tennessee and North Carolina, a park ranger kneels by a mossy stream and gently rolls over a flat rock. Underneath, glistening in the wet, lies a little red-cheeked salamander, black with bright red patches on its face. It lives nowhere else in the world. The ranger sets the rock back exactly as it was. The Smokies are called the “Salamander Capital of the World”: about 30 kinds live there, more than in almost any other place of its size.

Not a lizard. A salamander looks like a lizard, but it is an **amphibian**, like a frog. Its skin is moist and smooth, with no scales, and it has no claws. It must stay damp, so most

salamanders hide by day under logs, rocks and leaves and come out on rainy nights. There are about 800 kinds of salamanders, most of them in North and Central America. They eat insects, worms and slugs, and in some forests there are so many that their total weight is greater than that of all the birds.

Breathing through skin. The largest family of salamanders, more than half of all kinds, has no lungs at all. These **lungless salamanders** take in oxygen through their thin, wet skin and the lining of their mouths. That is why they need cool, damp places: dry skin cannot breathe. The **hellbender**, North America's biggest salamander, up to about 2 feet long, lives in clear, rocky streams in the eastern United States. It has lungs but breathes mostly through the loose, wrinkly folds of skin along its sides. The largest salamander of all, the Chinese giant salamander, can reach nearly 6 feet.

Growing back. Salamanders are champions of **regeneration**. If a salamander loses a leg, it can grow a whole new one, with bones, muscles and nerves in the right places. The **axolotl** of Mexico can regrow legs, its tail, parts of its heart and eyes, and even parts of its spinal cord and brain. Unlike most salamanders, the axolotl keeps its feathery pink gills and stays in water all its life. Wild axolotls live only in the canals of Xochimilco in Mexico City and are now very rare, though many live in aquariums and laboratories, where scientists study how they heal.

The salamander in the fire. Ancient writers such as Aristotle and the Roman Pliny the Elder said that the salamander could live in fire, or was so cold it could put fire out. Medieval books of animals called **bestiaries** repeated the **legend** and used it as a picture of faithful people who are not harmed by the flames of temptation. What really happened? Salamanders like to hide in rotting logs. When people threw those logs on the fire, the salamanders crawled out to escape. People saw them come out of the flames and drew the wrong conclusion. A good naturalist asks: what did I actually see?

PICTURE STUDY



The Salamander, from the Aberdeen Bestiary, Unknown English illuminator, c. 1200 · Ink, paint and gold leaf on parchment · University of Aberdeen Library, Scotland (MS 24); the whole book can be viewed online
Wikimedia Commons · Public domain

The Aberdeen Bestiary was made in England around the year 1200 and later belonged to the royal library of King Henry VIII. Like other bestiaries, it describes real and imagined animals and draws a Christian lesson from each. Its picture of the salamander follows the old stories rather than a real animal. Find the salamander page in the University of Aberdeen's online copy.

Look closely

- Find the salamander. Does it look like the salamanders in this stop?
- Look for gold leaf on the page. Where did the artist use it?
- Look at what is around the salamander. What part of the legend is the artist showing?

Talk about it

1. Which parts of the picture come from careful looking, and which come from the legend?
2. The bestiary writer used the salamander to teach a lesson about faith. Can a story teach a true lesson even if its natural history is wrong?

HANDS-ON: MAP AND FIELD SEARCH: SALAMANDER COUNTRY

Map the Appalachian Mountains, the salamander capital of the world, and then search your own yard or park for salamander habitat.

You will need

- A Field Notebook page
- Pencil and colored pencils
- An atlas or online map of the eastern United States
- Optional: rubber boots and a flashlight

Steps

1. Draw an outline of the eastern United States from Maine to Georgia. Draw the Appalachian Mountains as a long band of small upside-down V's running from northeast to southwest.
2. Label Great Smoky Mountains National Park on the Tennessee–North Carolina border with a star and the words “about 30 kinds of salamanders.”
3. Shade in blue a few rivers where hellbenders live, such as the Tennessee and Ohio Rivers. Add a title, a compass rose and a key.
4. Then go outside with a parent after a rain. Look for damp places under logs, flat stones and leaf piles. If you lift a log or stone, roll it toward you, look quickly, and put it back exactly as it was. Do not pick up salamanders: the oils and salt on your hands can harm their skin.
5. Write down where you looked, what you found (salamanders, worms, beetles, slugs) and how damp the spot was.

Check your work

- My map shows the Appalachians, the Smokies and at least one hellbender river.
- My map has a title, compass rose and key.
- I recorded at least three places I searched and what I found.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: “The salamander in the fire: legend and truth.” Tell what the old writers said, what probably really happened, and what lesson this teaches a young scientist.
2. Draw an axolotl and label its feathery gills, legs, tail and wide mouth.

Did you know? Some salamanders can drop their tails on purpose when grabbed; the tail keeps wriggling to fool the hunter while the salamander escapes, and it later grows a new one. Hellbenders have funny nicknames: “snot otter” and “mud-devil.” Many salamanders return to the same pond to lay eggs each spring, crossing roads on rainy nights, and some towns close roads or build small tunnels to help them cross.

Goes deeper in. Life Science, “Reptiles and Amphibians” (coming soon); Geography, for the Appalachian Mountains and Mexico; and Literature, for medieval bestiaries.

For families. Species counts follow AmphibiaWeb (about 800 salamanders; Plethodontidae, the lungless salamanders, are more than half). The “Salamander Capital” title and count (about 30–31 species) come from the National Park Service. The fire

legend appears in Aristotle's *History of Animals* and Pliny's *Natural History* (Book 10); the log explanation is a common, likely account. The Aberdeen Bestiary (MS 24) is fully online from the University of Aberdeen; the exact folio of the salamander may be found by searching the online copy. Do not handle wild salamanders; wash hands if you touch pond or stream water.

PRACTICE

1. **EASY** Is a salamander a reptile or an amphibian? Give one reason.
2. **EASY** Why is the Great Smoky Mountains National Park called the “Salamander Capital of the World”?
3. **MEDIUM** How does a lungless salamander breathe, and why must it stay damp?
4. **MEDIUM** A hellbender is 2 feet long. A Chinese giant salamander is about 6 feet long. How many hellbenders laid end to end equal one Chinese giant salamander?
5. **CHALLENGE** People once saw salamanders come out of burning logs and decided salamanders could live in fire. What was their observation, and what was their mistaken conclusion? What should they have asked?

Make it a game • Log Roll Lookout. Hide a few paper salamanders (cut and colored) under books, cushions and boxes around a room. Players search, but each “log” must be lifted gently and put back exactly as it was found. Anyone who leaves a log out of place loses a point. The player who finds the most salamanders and leaves the room tidiest wins.

Scripture. “When thou passest through the waters, I will be with thee; and through the rivers, they shall not overflow thee: when thou walkest through the fire, thou shalt not be burned; neither shall the flame kindle upon thee.” (Isaiah 43:2, KJV)

No salamander can live in fire. But God promises His people that He is with them through every trial, as He was with the three young men in the furnace (Daniel 3).

Practice: answers

1. An amphibian. Reasons: moist skin with no scales, no claws, eggs without shells, many begin life in water.
2. About 30 kinds of salamanders live there, more than in almost any other place of its size.
3. It takes in oxygen through its moist skin and the lining of its mouth. Dry skin cannot take in oxygen, so it must stay in cool, damp places.
4. 3 ($6 \div 2 = 3$).
5. Observation: salamanders came out of a fire. Mistaken conclusion: salamanders can live in fire. They should have asked where the salamanders were before the fire (hiding in the logs) and tested whether a salamander is harmed by flames, instead of jumping to a conclusion.

3.9 POISON DART FROGS: BRIGHT COLORS THAT SAY “STAY AWAY”

OBJECTIVES

- Locate the rainforests of Central and South America where poison dart frogs live, including the Chocó of Colombia.
- Explain warning coloration and where the frogs' poison comes from.
- Describe how poison frog parents care for their young.

Warm-up. Look around your house for things colored bright red, orange or yellow with black. Stop signs, warning labels and wasps often use these colors. What do they all seem to say? Some of the tiniest frogs in the world wear the same colors, and for the same reason.

Video slot. Video coming. Poison dart frogs in the rainforest; strawberry poison frog carrying a tadpole to a bromeliad; golden poison frog. Search approved channels (Smithsonian's National Zoo, BBC Earth, San Diego Zoo Wildlife Alliance, National Geographic Kids); preview first.

KEY TERMS

warning coloration

Bright colors that tell hunters an animal is poisonous or bad-tasting. Scientists call it aposematism.

toxin

A poison made by or stored in a living thing.

alkaloid

A kind of strong natural chemical; poison frogs store alkaloid toxins in their skin.

bromeliad

A rainforest plant (a cousin of the pineapple) whose stiff leaves hold small pools of water, where some frogs raise tadpoles.

mimic

A harmless animal that looks like a dangerous one and so is left alone.

CORE IDEAS

The story. In the wet Chocó rainforest of western Colombia, an Emberá hunter walks quietly along a stream. He spots a small golden-yellow frog on the leaf litter. Without touching it with his bare hands, he holds it down with a leaf and wipes the tip of each blowgun dart along its back. The darts are now deadly enough to bring down a monkey or a bird high in the trees. This is the *golden poison frog*, only about two inches long, and the poison on its

skin is among the strongest made by any animal. Its scientific name, given in 1978, is *Phylllobates terribilis*: “terrible leaf-walker.”

Colors that warn. There are about 200 kinds of poison frogs in the rainforests of Central and South America, from Nicaragua to Bolivia and Brazil. Most are smaller than a paper clip and wear brilliant colors: strawberry red, electric blue, lime green, gold, often with black spots or stripes. Most small frogs hide. Poison frogs hop about in daylight, because their bright colors are a **warning**. A bird or snake that tastes one learns quickly and remembers. Only three kinds, all in Colombia, were used for poison darts, but the name “poison dart frog” stuck to the whole family.

Poison from their food. Here is a surprise. Poison frogs raised in zoos, fed on fruit flies and crickets, are not poisonous at all. In the wild, they get their **toxins** from what they eat: certain ants, mites and beetles that carry **alkaloids**. The frog stores these chemicals in glands in its skin without being harmed. A golden poison frog's skin holds a toxin called batrachotoxin; one wild frog is often said to carry enough to kill ten people. That is why you should never touch a wild one.

Careful parents. Poison frogs lay their eggs on damp leaves on the forest floor, not in water. A parent guards them and keeps them moist. When the tadpoles hatch, they wriggle onto a parent's back, and the parent carries them, sometimes high up a tree, to a tiny pool of water in a **bromeliad** or a tree hole. The mother strawberry poison frog of Costa Rica and Panama puts each tadpole in its own pool, then visits each one every few days and lays an unfertilized egg in the water for it to eat. A tadpole may get dozens of such meals before it becomes a froglet.

From poison to medicine. In the 1970s an American chemist, John Daly of the National Institutes of Health, collected tiny bits of skin chemicals from an Ecuadorian poison frog and found one, epibatidine, that blocked pain about 200 times more strongly than morphine. It was too dangerous to use as a medicine, but it led scientists to search for safer pain-relievers that work the same way. The God who gave the frog its warning colors also built into creation riches for patient people to discover (Proverbs 25:2).

PICTURE STUDY



Batrachia (Frogs), Plate 68 of *Art Forms in Nature*, Ernst Haeckel, with lithographer Adolf Giltisch, 1904 ·
Color lithograph · From *Kunstformen der Natur* (Leipzig, 1899–1904); copies in many libraries
Wikimedia Commons · Public domain

The German scientist Ernst Haeckel published a famous book of nature prints called *Art Forms in Nature*. This plate shows ten kinds of frogs from around the world, arranged like a design. One of them, a small striped frog from South America then called *Hylodes lineatus*, is now known as the painted antfrog. It is harmless, but its bright stripes look much like those of a poison frog that lives in the same forests: it is a **mimic**.

Look closely

- Count the frogs. Which is the most brightly colored?
- Find the striped frog. What colors are its stripes?
- Find a frog that is green or brown. Would it be easy or hard to see on a leaf?

Talk about it

1. Which frogs on this plate do you think hide from hunters, and which might be warning them? Why?
2. Why would a harmless frog be safer if it looked like a poisonous one?

Safety first. Never touch a wild brightly colored frog or any frog in a rainforest. Zoo-raised poison frogs are not toxic, but wild ones can be. Wash your hands after handling any frog or toad.

HANDS-ON: MAP: RAINFOREST JEWELS

Map where poison frogs live and mark where the dart-poison frogs and the strawberry poison frog are found.

You will need

- A Field Notebook page
- Pencil and colored pencils
- An atlas or online map of Central and South America

Steps

1. Draw an outline of Central America and northern South America, from Nicaragua down to Bolivia and Brazil.
2. Shade in green the rainforests where poison frogs live: the Caribbean side of Central America, the Pacific coast of Colombia (the Chocó) and the Amazon basin.
3. Draw and label a small gold frog on the Pacific coast of Colombia: “golden poison frog (used for darts).” Draw a small red frog with blue legs in Costa Rica and Panama: “strawberry poison frog.”
4. Label the Andes Mountains, the Amazon River, the Pacific Ocean and the Caribbean Sea.
5. Make a key for your green shading and frog symbols, and add a title and compass rose.

Check your work

- My map shows Central America and northern South America with rainforests shaded.
- The Chocó, the Amazon and the Andes are labeled.
- My map has two frog symbols, a key, a title and a compass rose.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: “Why a zoo poison frog is not poisonous.” Explain where wild frogs get their toxins and what this teaches about how God designed the rainforest to work together.
2. Draw a bromeliad with a tadpole in its pool and a parent frog nearby. Label the parts.

Did you know? Some birds in New Guinea, the pitohuis, carry the same kind of poison in their feathers and skin as the golden poison frog; they also get it from beetles they eat. Poison frogs are a favorite of zoos and aquariums because, raised on harmless insects, they are safe to keep and beautiful to watch.

Goes deeper in. Geography, for Colombia, Costa Rica and the Amazon; Life Science, “Reptiles and Amphibians” and “Rainforests” (coming soon).

For families. *Phylllobates terribilis* was described by Myers, Daly and Malkin (1978). The “enough to kill ten people” figure is widely cited but is an estimate; the stop says “often said.” Counts of about 200 species refer to the family Dendrobatidae (sources vary). Daly's epibatidine work was published in 1992 from frogs collected in Ecuador in the 1970s. Haeckel's plate does not show a true poison dart frog; it is used here for its striped mimic (now *Lithodytes lineatus*). Haeckel promoted evolution and is known for misleading embryo drawings; his natural-history art is used here only for its frogs. Proverbs 25:2: “It is the glory of God to conceal a thing: but the honour of kings is to search out a matter.”

PRACTICE

1. **EASY** What do a poison frog's bright colors tell a hungry bird?
2. **EASY** Where do wild poison frogs get their poison?
3. **MEDIUM** Why are poison frogs raised in zoos not poisonous?
4. **MEDIUM** A strawberry poison frog mother has 6 tadpoles in 6 bromeliads. She visits each one every 3 days with an egg. How many eggs does she lay for food in 30 days?
5. **CHALLENGE** The painted antfrog is harmless but looks like a poison frog. Explain why this helps it, and what would happen if there were far more mimics than real poison frogs.

Make it a game · Warning Colors. Cut 20 small paper frogs: 15 green or brown and 5 red with black spots. Scatter them on a green blanket or in the grass. One player, the hungry bird, has 15 seconds to pick up as many frogs as possible. Every red frog picked up costs 3 points (a bad taste!) and each green frog earns 1 point. Play again. Does the bird learn to skip the bright ones?

Scripture. “A prudent man foreseeth the evil, and hideth himself; but the simple pass on, and are punished.” (Proverbs 22:3, KJV)

A wise bird heeds the frog's warning colors. A wise person heeds warnings too, above all the warnings of God's Word, and turns away from harm.

Practice: answers

1. “I am poisonous; stay away.” (Warning coloration.)
2. From the ants, mites and beetles they eat.
3. They eat fruit flies and crickets, which do not carry the alkaloid toxins found in the wild frogs' food.
4. 60 eggs (each tadpole gets $30 \div 3 = 10$ eggs; $10 \times 6 = 60$).
5. Hunters that have learned to avoid the poison frog also avoid the look-alike, so it is left alone. If mimics were far more common, hunters would often catch a harmless one, learn the colors are not always dangerous, and start eating both.

3.10 THE GILA MONSTER: A DESERT LIZARD THAT GAVE US MEDICINE

OBJECTIVES

- Map the range of the Gila monster in the Sonoran and Mojave Deserts.
- Describe how a Gila monster survives in the desert by storing fat and staying underground.
- Tell how a discovery in Gila monster venom led to a medicine for diabetes.

Warm-up. How many times did you eat yesterday? Three meals and a snack or two? Count them. A wild Gila monster can live on as few as three or four big meals in a whole year.

Video slot. Video coming. Gila monsters in the Sonoran Desert; a Gila monster raiding a nest; how Gila monster venom led to a diabetes medicine. Search approved channels (Arizona-Sonora Desert Museum, Smithsonian's National Zoo, San Diego Zoo Wildlife Alliance, National Park Service at Saguaro National Park); preview first.

KEY TERMS

Gila monster

A heavy, beaded, black-and-pink or black-and-orange venomous lizard of the southwestern United States and northwestern Mexico (say “HEE-luh”).

osteoderm

A small bone inside the skin. The Gila monster's “beads” have tiny bones in them, like armor.

burrow

A hole or tunnel in the ground where an animal shelters.

fat reserve

Food energy stored in the body for later. A Gila monster stores fat in its thick tail.

hormone

A chemical messenger the body makes to control things like growth and blood sugar.

CORE IDEAS

The story. It is a spring morning in the Sonoran Desert of Arizona, just after sunrise. Among the saguaro cactus, a thick lizard with bead-like scales of black and salmon-pink slowly pushes out of its **burrow**. It waddles along, flicking its forked black tongue, following the scent trail to a quail's nest hidden under a bush. It swallows the eggs one by one, whole. Within an hour it is back underground. A Gila monster may spend 90 percent or more of its life underground, out of the heat.

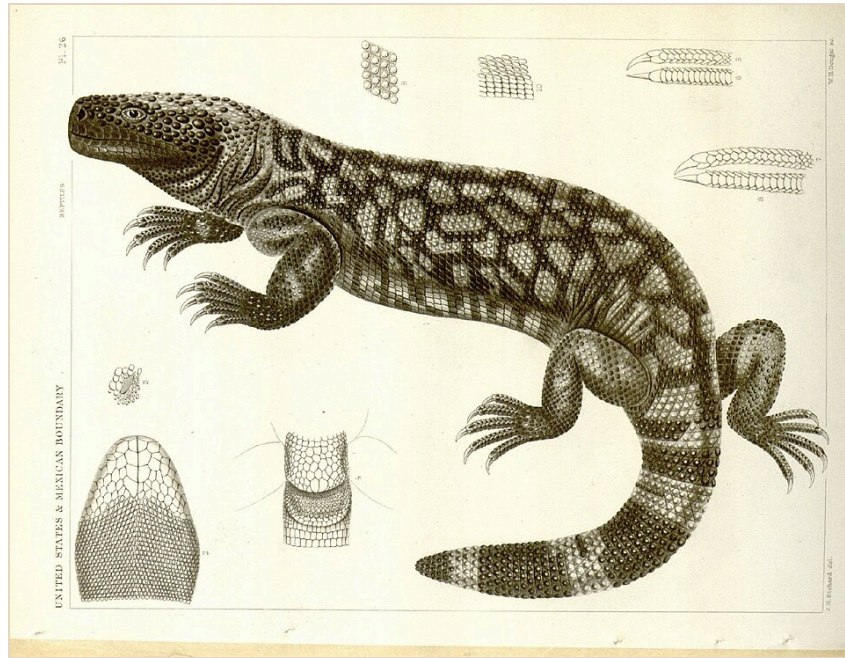
A lizard named for a river. The **Gila monster** is named for the Gila River basin in Arizona. It lives in the deserts of Arizona and parts of New Mexico, Nevada, Utah and California, and south into Sonora and Sinaloa in Mexico. It is the largest native lizard in the United States, up to about 22 inches long and as much as 5 pounds. Its only close cousin is the larger Mexican beaded lizard. In 1869 the scientist Edward Drinker Cope gave it the name *Heloderma suspectum*: “studded skin, suspected,” because he suspected it was venomous. He was right. Its bright pattern is a warning, and its beads are armored with tiny bones called **osteoderms**.

Built for a hard land. The desert offers little food and great heat, and God fitted the Gila monster for both. It eats large meals rarely: a young one can swallow up to about a third of its body weight at once, and three or four big meals of eggs, baby rabbits or nestling birds can carry it through a year. It stores the extra as a **fat reserve** in its fat, sausage-shaped tail, so a plump tail is a sign of a healthy Gila monster. It is slow on land, but it does not need speed to raid nests.

A bite that holds on. The Gila monster's venom comes from glands in its lower jaw. It has no hollow fangs. Instead, when it bites, it holds on tight and chews, and the venom flows along grooves in its teeth into the wound. The bite is very painful, but Gila monsters are shy, slow and bite people only when picked up or bothered. In 1952 Arizona made it illegal to kill or collect them: the first venomous animal protected by law in the United States.

From venom to medicine. In 1992 a doctor named John Eng, working at the Veterans Affairs hospital in the Bronx, New York, was studying the venom of the Gila monster. He found in it a substance, exendin-4, that acts like a **hormone** our own bodies make after eating, one that helps control blood sugar, but it lasts much longer. A lab-made copy, called exenatide, was approved as a medicine for type 2 diabetes in 2005. It also helped open the way to a whole family of newer medicines. A slow desert lizard, made by God and studied by a patient doctor, has helped millions of people. As Job says, “ask now the beasts, and they shall teach thee.”

PICTURE STUDY



The first published picture of a Gila monster, from Reptiles of the Boundary, Spencer Fullerton Baird (author); artists of the U.S. and Mexican Boundary Survey, 1857-1859 · Engraving · From the Report on the United States and Mexican Boundary Survey, Volume 2 (Washington, D.C.); viewable online at the Biodiversity Heritage Library
Wikimedia Commons · CC BY-SA 4.0

After the Mexican War, surveyors and naturalists traveled the new border between the United States and Mexico in the 1850s, mapping the land and collecting its plants and animals. Spencer Baird of the Smithsonian Institution described the reptiles they found, and artists drew them for the official report. This plate shows a Gila monster. It is the first picture of this lizard ever published.

Look closely

- Look at the tail. Is it long and thin like most lizards' tails, or short and fat? Why?
- Find the beaded scales. How did the artist show them?
- Look at the head and feet. What details did the artist take care to show?

Talk about it

1. Why would scientists want a careful picture of an animal no one in the eastern United States had ever seen?
2. How is a careful scientific drawing different from a painting made mainly to be beautiful?

Safety first. Never touch or pick up a Gila monster or any wild lizard you cannot identify. Gila monsters are protected by law, and their bite is very painful. Watch from a distance and give them room. If someone is bitten, call 911.

HANDS-ON: MAP: GILA MONSTER COUNTRY

Map the range of the Gila monster in the deserts of the American Southwest and northwestern Mexico.

You will need

- A Field Notebook page
- Pencil and colored pencils
- An atlas or online map of the southwestern United States and northern Mexico

Steps

1. Draw the outlines of California, Nevada, Utah, Arizona and New Mexico, and the Mexican states of Sonora and Sinaloa below them.
2. Draw and label the Colorado River and the Gila River, which flows west across southern Arizona into the Colorado.
3. Shade the Sonoran Desert (southern Arizona and Sonora) in tan and the Mojave Desert (southern Nevada and southeastern California) in a lighter color. Label both.
4. Using a dotted line, outline the Gila monster's range: most of western and southern Arizona, the southwest corner of Utah, the southern tip of Nevada, edges of California and New Mexico, and south through Sonora into Sinaloa.
5. Add a star for Tucson and one for Phoenix, a key, a title and a compass rose.

Check your work

- My map shows the five U.S. states and two Mexican states, labeled.
- The Gila River and both deserts are labeled.
- The dotted range line, key, title and compass rose are all there.

FIELD NOTEBOOK

1. **Notebook entry.** Write a paragraph: "How a lizard helped make a medicine." Tell who John Eng was, what he found, and what it became. End with a sentence about why God's creatures are worth studying and protecting.
2. Draw a Gila monster from above and label the beaded skin, forked tongue, fat tail and lower jaw where the venom glands are.

Did you know? Old desert tales claimed the Gila monster had poisonous breath or could spit venom. Neither is true. Gila monsters lay their eggs in late summer, but the eggs do not hatch until the following spring, a wait of about 10 months. On a hot day, a Gila monster can lie in a shallow pool or damp burrow to cool off.

Goes deeper in. Geography, for the deserts of the Southwest; History, for the U.S. and Mexican Boundary Survey; and Life Science, "Reptiles and Amphibians" and "The Human Body" (coming soon).

For families. Cope named *Heloderma suspectum* in 1869. Arizona's 1952 protection is reported by the Arizona Game and Fish Department and the Arizona-Sonora Desert Museum. Eng's exendin-4 was published in the *Journal of Biological Chemistry* (1992); exenatide (Byetta) was approved by the U.S. FDA in April 2005. Newer GLP-1 medicines grew from the same line of research; the stop does not name brand drugs or discuss weight-loss uses. Because the Gila monster was named only in 1869, the 1859 Baird plate may label it under an older name, such as *Heloderma horridum* (the Mexican beaded lizard); that makes a good discussion question. Range and size figures follow the Arizona-Sonora Desert Museum.

PRACTICE

1. **EASY** Where does the Gila monster get its name?
2. **EASY** Where does a Gila monster store food energy?
3. **MEDIUM** How does a Gila monster deliver its venom without hollow fangs?
4. **MEDIUM** A young Gila monster weighs 1.5 pounds and eats one-third of its body weight in one meal. How many ounces of food is that? (1 pound = 16 ounces)
5. **CHALLENGE** Arizona protected the Gila monster in 1952. John Eng's discovery came 40 years later. Explain how protecting this animal turned out to help people, and what that teaches about stewardship.

Make it a game • Four Meals a Year. Each player gets 12 counters (beans or coins) to stand for 12 months of energy. Every “month,” the leader calls out a desert event, such as “heat wave: hide underground, lose 1,” “found a quail nest: gain 3,” or “searched all day, found nothing: lose 2.” Players adjust their piles. Whoever's “tail” (pile) lasts the whole year without running out is a healthy Gila monster.

Scripture. “But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee: Or speak to the earth, and it shall teach thee: and the fishes of the sea shall declare unto thee. Who knoweth not in all these that the hand of the LORD hath wrought this?” (Job 12:7-9, KJV)

Every creature on this trail, from the crocodile to the Gila monster, has something to teach. Above all, they teach that the hand of the Lord made them.

Practice: answers

1. From the Gila River basin in Arizona.
2. As fat in its thick tail.
3. It bites, holds on and chews; venom from glands in its lower jaw flows along grooves in its teeth into the wound.
4. 8 ounces ($1.5 \times 16 = 24$ ounces; $24 \div 3 = 8$).
5. $1952 + 40 = 1992$. Because the lizards were protected and studied, Dr. Eng could find exendin-4, which led to a diabetes medicine. Caring for God's creatures (Genesis 2:15) can

bring blessings no one expected; we cannot know in advance what each creature may teach us.

TRAIL 3 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in a sentence or two, without looking back at the stops. Four right out of five on each quiz earns the badge. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1–5)

1. What lets a crocodile open its mouth underwater without drowning?
2. What did Bryan Fry's team discover about the Komodo dragon's bite in 2009, and what older idea did it replace?
3. Name the four main ways snakes move.
4. How does a sea turtle find its way back to the coast where it hatched?
5. Give the two main reasons chameleons change color.

Badge quiz 2 (Stops 6–10)

6. Why do Galápagos tortoises on dry islands have saddleback shells?
7. What is metamorphosis? Give the stages of a frog's life in order.
8. How do lungless salamanders breathe?
9. Why are poison dart frogs raised in zoos not poisonous?
10. How did the Gila monster help people with diabetes?

TRAIL CERTIFICATE: MY REPTILE AND AMPHIBIAN FIELD NOTEBOOK AND TRAIL C CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: “My Reptile and Amphibian Field Notebook,” your name and the dates you started and finished.

Include at least three maps (for example, the Komodo islands, the Galápagos and Gila monster country) and at least three diagrams (for example, the crocodile at the waterline, the four ways snakes move and the frog life cycle).

Add a final page with two columns, “Reptiles” and “Amphibians,” listing the animals of this trail in the right column with one sentence about what makes each group different.

When the booklet is done, a parent signs the Trail C certificate.

- **Ten stops:** A notebook paragraph for each stop, each with a title and a date, written in complete sentences.
- **Maps and diagrams:** At least three maps and three diagrams, each with a title, clear labels, and a key or compass rose where needed.
- **Facts and reasoning:** Paragraphs use correct facts and numbers from the stops and explain how each animal's design fits where it lives.
- **Care:** Pages are neat and complete, and the Reptiles and Amphibians page sorts all ten animals correctly.

Answer key

1. Its palatal valve, a flap that seals off its throat (and flaps that close its nostrils and ears).
2. Komodos have venom glands in the lower jaw. It replaced the idea that germs in their saliva killed their prey.
3. Lateral undulation (slithering), concertina, sidewinding and rectilinear.
4. It senses the earth's magnetic field and uses it like a map (natal homing).
5. To signal their mood to other chameleons, and to warm up or cool down.
6. Their food, such as tree cactus, is high up, and the shell rises in front so they can stretch their necks upward.
7. A complete change of body form as an animal grows. Eggs, tadpole, tadpole with legs, froglet, adult frog.
8. Through their moist skin and the lining of their mouths.
9. Wild frogs get their toxins from the ants, mites and beetles they eat; zoo frogs eat harmless insects.
10. John Eng found exendin-4 in its venom (1992); a lab-made copy, exenatide, became a diabetes medicine in 2005.

ANIMALS TRAIL D: OCEAN LIFE

The fourth trail of the Animals track goes down to the sea: sharks and their electric sense, the three-hearted octopus, coral reefs and Captain Cook's near-wreck in 1770, the giant squid, dolphins and Pelorus Jack, jellyfish and the glowing protein that won a Nobel Prize, the anglerfish and the explorers of the deep, the salmon's journey home, seals and sea lions and the 1911 Fur Seal Treaty, and finally Jonah and leviathan, where Scripture shows God as Lord of the sea. Each stop has a true story, a picture study, a map or diagram, a notebook entry, practice questions, a game and a verse of Scripture.

This is the  **Ranger** level, written for ages 10 to 13. The student reads each stop alone, then does the project and the notebook entry, which is usually a labeled diagram or map and one well-built paragraph. Stops take 25 to 35 minutes and stand by themselves, so they may be done in any order, though D10 makes a fitting end. Parents will find sources and notes on anything uncertain in each stop's "For families" box.

Five stops earn the **Ocean Ranger badge, part 1**, and ten stops earn part 2 and the **Trail D certificate**. The two badge quizzes at the end of the trail are optional; badges are earned by doing the stops.

BEFORE YOU BEGIN

- Read a page of about 500 words on your own and write a paragraph of five to seven sentences about it.
- Find the five oceans, the seven continents, Australia, New Zealand, Alaska and the Mediterranean Sea on a world map or globe.

MASTERY CHECKLIST

- ☐ I can explain how at least five ocean animals are designed for their lives, such as the shark's electric sense, the octopus's three hearts and the salmon's sense of smell.
- ☐ I can tell a fish from a sea mammal and a seal from a sea lion, and give my reasons.
- ☐ I can name the ocean zones from the sunlight zone to the trenches and give their depths.
- ☐ I can tell the true stories of at least four explorers or scientists from this trail, such as Cook, Beebe, Shimomura, Hasler or Elliott, with their dates.
- ☐ I can retell the book of Jonah, find its places on a map and explain what Jesus meant by "the sign of the prophet Jonas."

OPTIONAL BOOKS AND RESOURCES

- **NOAA Ocean Exploration** (<https://oceanexplorer.noaa.gov>): Free videos, deep-sea photos and lessons from U.S. government expeditions; good for Stops D4 and D7.

- **Monterey Bay Aquarium live cams and animal guide** (<https://www.montereybayaquarium.org>): Free live cameras (jellies, kelp forest, sea otters, sharks) and short animal fact pages.
- **Smithsonian Ocean** (<https://ocean.si.edu>): Free articles and photos on sharks, squid, coral reefs and the deep sea from the Smithsonian's National Museum of Natural History.
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Old natural-history books and plates, including Haeckel's *Art Forms in Nature* and Goode and Bean's *Oceanic Ichthyology*, to copy into the Field Notebook.

4.1 SHARKS: BUILT FOR THE SEA

OBJECTIVES

- Explain how a shark's cartilage skeleton, oily liver and gills fit its life in the sea.
- Describe three shark senses, including the ampullae of Lorenzini.
- Draw and label a shark diagram with a size scale comparing the largest and smallest sharks.

Warm-up. Rub a fingertip gently from the front of a sheet of sandpaper to the back, then back again. Shark skin feels smooth one way and rough the other. Guess why before you read.

Video slot. Video coming. Shark senses and body design: ampullae of Lorenzini, dermal denticles, whale sharks feeding. Search approved channels (NOAA Fisheries, Smithsonian Ocean, Monterey Bay Aquarium, Georgia Aquarium); preview first.

KEY TERMS

cartilage

Tough, bendable tissue, like the tip of your nose. A shark's whole skeleton is made of it instead of bone.

dermal denticles

Tiny tooth-shaped scales that cover a shark's skin and point toward the tail.

ampullae of Lorenzini

Jelly-filled pores on a shark's snout that sense the faint electricity made by living animals.

lateral line

A row of sense organs along each side of a fish that feels movements and vibrations in the water.

filter feeder

An animal that strains tiny food, such as plankton, out of the water. The whale shark is one.

CORE IDEAS

The story. In 1678 an Italian doctor named Stefano Lorenzini carefully studied the head of a shark and of a ray, its flat cousin. He found rows of tiny pores on the snout, each leading to a tube of clear jelly. He described them well, but no one knew what they were for. Nearly three hundred years later, in the 1960s and early 1970s, scientists found the answer. The pores, now called the **ampullae of Lorenzini**, sense the faint electricity made by every working muscle and nerve. A shark gliding over the sand can find a flatfish hidden underneath by the tiny electric signal of its heartbeat and breathing.

A skeleton without bones. There are more than 500 kinds of sharks. All of them have skeletons of **cartilage**, which is lighter and more flexible than bone. A shark has no air bladder to help it float, as many fish do. Instead, it has a huge, oily liver, sometimes a quarter of its body weight, that helps keep it from sinking. Sharks breathe through five to seven gill slits on each side. Many, like the great white, must keep swimming so that water flows over their gills. Others, like the nurse shark, can pump water with their mouths and rest on the sea floor.

Skin and teeth. Shark skin is covered with **dermal denticles**, little tooth-shaped scales that point toward the tail. They help water slide past smoothly. Long ago, woodworkers polished furniture with dried shark skin, and sword makers wrapped it around handles for a firm grip. Shark teeth sit in rows like a moving belt. When a front tooth breaks or falls out, the one behind moves forward. One shark may use thousands of teeth in its life.

More senses. Sharks have a keen sense of smell and can notice tiny traces of blood or fish oil in the water. Their **lateral line** feels the splash and wiggle of a struggling fish far away. Their eyes have a mirror-like layer that helps them see in dim water. The largest shark, the whale shark, can grow about 40 feet long, yet it is a gentle **filter feeder** that strains plankton and tiny fish. The dwarf lanternshark is shorter than a pencil and glows in the dark.

Fear and care. Sharks are strong hunters, but bites on people are rare. Around the world, about 70 to 80 unprovoked bites are recorded in a typical year, and only a few are deadly. People catch far more sharks than sharks bite people. Many sharks grow slowly and have few young; scientists estimate the Greenland shark may live for centuries. Wise fishing rules are good stewardship of creatures the psalmist counted among the “great beasts” of the “great and wide sea.”

PICTURE STUDY



The Gulf Stream, Winslow Homer, 1899 · Oil on canvas · The Metropolitan Museum of Art, New York
Wikimedia Commons · Public domain

Winslow Homer, one of America's greatest painters of the sea, sailed to the Bahamas and Key West and watched sharks in the warm waters of the Gulf Stream. In this painting a sailor's small boat has lost its mast in a storm. When people asked what would happen to him, Homer answered in a letter that the sailor would be rescued and live happily ever after.

Look closely

- Count the sharks. Find their dorsal fins and their open mouths.
- Find the waterspout and the ship on the horizon. Which one brings danger, and which brings hope?
- Look at the sailor's face and body. Is he panicking or holding steady?

Talk about it

1. How did Homer make the sea look heavy and dangerous?
2. Homer shows real shark features. Which ones from today's story can you see?

HANDS-ON: SHARK DIAGRAM AND SIZE SCALE

Make a labeled shark diagram, then lay out a life-size size scale outdoors to compare sharks with yourself.

You will need

- Notebook paper, pencil and colored pencils
- A ruler

- A long measuring tape and sidewalk chalk (or four sticks)
- A sheet of fine sandpaper (optional)

Steps

1. **Diagram.** Draw a large side view of a shark. Label: snout, ampullae of Lorenzini (dots on the snout), nostril, eye, mouth with rows of teeth, gill slits, pectoral fin, first dorsal fin, pelvic fin, lateral line (a dashed line along the side) and tail (caudal) fin.
2. Beside the drawing, draw a magnified circle showing a few dermal denticles all pointing toward the tail. Add an arrow labeled “water flows this way.”
3. **Size scale.** Outdoors, chalk a start line. Measure and mark: dwarf lanternshark, 8 inches; you; nurse shark, about 10 feet; great white shark, about 20 feet; whale shark, about 40 feet.
4. Lie down next to the marks or have a family member stand at each one. Then draw the scale in your notebook as a bar chart with labels and lengths.

Check your work

- My shark diagram has at least ten labels.
- My size scale shows five sharks (or me) with lengths.
- I can explain what the ampullae of Lorenzini do.

FIELD NOTEBOOK

1. Glue in or redraw your labeled shark diagram and the size scale bar chart.
2. **Notebook entry.** Write a paragraph of five to seven sentences: “How a shark finds its food.” Name at least three senses, starting far away (smell, lateral line) and ending close up (electric sense).

Did you know? A whale shark’s mouth can be about 5 feet wide, but it feeds on plankton and small fish. Dried shark skin used for polishing and for grips is called *shagreen*. Shark teeth are among the most common fossils found on beaches.

Map or diagram. On a world map, shade the warm seas where whale sharks gather (for example, off Ningaloo Reef in Australia, the Yucatán in Mexico and the Philippines) and the cold North Atlantic and Arctic waters of the Greenland shark.

Goes deeper in. Life Science, the unit on fish and vertebrates (coming soon); and Trail F, Stop F9 “Design copied by engineers,” for swimsuits and ship coatings modeled on shark skin.

For families. Lorenzini described the pores in 1678; their electric sense was shown by R. W. Murray (1960) and Adrianus Kalmijn (experiments published 1971). Species counts (over 500) follow NOAA and the Florida Museum’s International Shark Attack File, whose recent yearly totals of unprovoked bites have mostly run about 60–80. The Greenland shark age estimate (about 270 to 500 years for the oldest animal studied) comes from a

2016 study in *Science* using eye-lens dating; it is an estimate. Homer's remark about the sailor's rescue is from his 1902 letter to the dealer M. Knoedler & Co. Lengths are rounded.

PRACTICE

1. **EASY** What is a shark's skeleton made of?
2. **EASY** What helps a shark keep from sinking, since it has no air bladder?
3. **MEDIUM** How can a shark find a fish hidden under the sand where it cannot see or smell it well?
4. **MEDIUM** Why can a nurse shark rest on the sea floor when a great white must keep swimming?
5. **CHALLENGE** Suppose one tooth position in a shark's jaw gets a new tooth every 10 days. About how many teeth would that one position use in 30 years? (Use 365 days in a year.)

Make it a game • Shark Sense. In a small cleared room, one player is the blindfolded "shark." The others are fish who must stand still, but every few seconds the leader points to one fish, who gives a soft tap on the floor (the "heartbeat"). The shark slowly walks toward the sound and gently tags the fish. Each tagged fish becomes the next shark. Walk only; keep the space clear.

Scripture. "So is this great and wide sea, wherein are things creeping innumerable, both small and great beasts." (Psalm 104:25, KJV)

From the 8-inch lanternshark to the 40-foot whale shark, the sea holds "small and great beasts." Each one was made with exactly the senses and body it needs.

Practice: answers

1. Cartilage, a tough, bendable tissue, not bone.
2. Its large, oily liver (and the lift from its fins as it swims).
3. The ampullae of Lorenzini sense the faint electricity made by the fish's muscles, heart and gills.
4. The nurse shark can pump water over its gills with its mouth; the great white needs to swim so water flows through its mouth and over its gills.
5. $30 \times 365 = 10,950$ days; $10,950 \div 10 =$ about 1,095 teeth for that one position. A jaw has many positions, so a shark can use thousands of teeth in all.

4.2 OCTOPUS: EIGHT ARMS AND THREE HEARTS

OBJECTIVES

- Describe the octopus's body plan: eight arms, a beak, three hearts and blue blood.
- Explain three ways an octopus hides or escapes: color change, ink and jet swimming.
- Draw and label an octopus diagram showing its inside and outside parts.

Warm-up. Hold out your hand and try to squeeze it through a ring made by your other thumb and finger. You cannot: your bones are in the way. An octopus has no bones at all. What could it squeeze through?

Video slot. Video coming. Octopus camouflage, color change and escape behavior; the mimic octopus; a giant Pacific octopus at an aquarium. Search approved channels (Monterey Bay Aquarium, MBARI, Smithsonian Ocean, Seattle Aquarium); preview first.

KEY TERMS

cephalopod

A sea mollusk whose arms grow from its head, such as an octopus, squid or cuttlefish. The word means “head-foot.”

mollusk

A soft-bodied animal without a backbone, such as a snail, clam or octopus.

chromatophore

A tiny sac of colored pigment in the skin that can be stretched open or squeezed shut to change color.

siphon

A tube on an octopus's body that squirts water out to push it along like a jet.

hemocyanin

A blood protein with copper in it that carries oxygen and makes octopus blood blue.

CORE IDEAS

The story. In 2016, keepers at the National Aquarium of New Zealand in Napier told reporters that their common octopus, Inky, had escaped. The lid of his tank had been left slightly open after cleaning. During the night Inky climbed out, slid across the floor, found the opening of a drain pipe about six inches wide and squeezed inside. The pipe led to the sea. The keepers found only a wet trail. Inky was never seen again, and the aquarium said he had gone home.

A boneless body. The octopus is a **cephalopod**, a “head-foot” **mollusk** related to snails and clams. It has no bones and no shell. The only hard part is a parrot-like beak in the middle of its arms, so it can squeeze through any gap a little bigger than that beak. Each of its eight

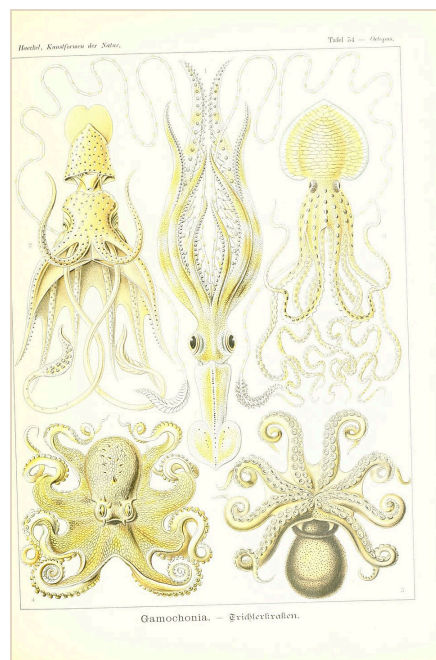
arms is lined with suckers, about 2,000 in all on a giant Pacific octopus. The suckers can grip, and they can also taste what they touch.

Three hearts and blue blood. An octopus has three hearts. Two pump blood through its gills, and the third pumps it through the rest of the body. Its blood uses **hemocyanin**, made with copper instead of iron, so it is blue. A common octopus has around 500 million nerve cells, and about two-thirds of them are in its arms rather than its brain. An arm can reach, feel and grab partly on its own while the octopus is busy with something else.

Masters of disguise. Thousands of **chromatophores** in the skin let an octopus change color in a fraction of a second. It can also raise little bumps to match the texture of rock or seaweed. If a hunter comes close, it squirts a dark cloud of ink and shoots away by forcing water out of its **siphon**. The mimic octopus, first described from Indonesia in 1998, can flatten itself like a flounder or hold its arms like the stripes of a sea snake.

A short life and a faithful mother. There are about 300 kinds of octopus. The giant Pacific octopus is the largest; a big one may weigh over 50 pounds and stretch about 14 feet from arm tip to arm tip. Most octopuses live only one to two years. A mother lays her eggs in a den, then guards, cleans and fans them with fresh water for weeks or months, hardly eating, and dies about the time they hatch. One deep-sea octopus off California was watched guarding her eggs for 53 months, the longest brooding known of any animal.

PICTURE STUDY



Gamochonia (Webbed Octopuses), Plate 54 of Kunstformen der Natur (Art Forms in Nature), Ernst Haeckel, 1904 · Color lithograph (printed plate from Haeckel's drawings) · From the book Kunstformen der Natur, published in Leipzig, 1899–1904; scan from the Biodiversity Heritage Library
Wikimedia Commons · Public domain

Ernst Haeckel was a German zoologist who drew sea creatures under the microscope and in nets for over forty years. His book *Art Forms in Nature* arranged animals in balanced, almost decorative patterns. This plate, which he titled *Gamochonia*, shows several kinds of octopus with webs of skin between their arms.

Look closely

- Count the octopuses. Find the webbing between their arms.
- Find the eyes and siphons. Are they easy to see?
- Notice how the arms curl. How did Haeckel make the page balanced from side to side?

Talk about it

1. This is a scientific drawing and also a design. What makes it each?
2. Which octopus on the plate would hide best on a rocky sea floor? Why?

HANDS-ON: OCTOPUS INSIDE AND OUT

Draw a two-part diagram of an octopus: the outside you can see and the inside parts that make it so unusual.

You will need

- Notebook paper or a large sheet of paper
- Pencil and colored pencils, including blue
- A ruler

Steps

1. **Outside view.** On the left half, draw an octopus from the side. Label: mantle (the baglike body), eye, siphon, arms (number them 1 to 8), suckers and the web between the arms.
2. **Underside view.** Draw a small circle view looking up at the arms from below. Put the beak in the center and label it “the only hard part.”
3. **Inside view.** On the right half, draw the mantle outline again. Inside, draw and label: two gill hearts beside two gills, the main (body) heart, the brain wrapped around the throat, and the ink sac. Color the blood vessels blue.
4. Add a caption: “About two-thirds of an octopus’s nerve cells are in its arms.”

Check your work

- My diagram has an outside view and an inside view.
- I labeled all three hearts and the beak.
- I can explain why octopus blood is blue.

FIELD NOTEBOOK

1. Glue in or redraw your two-part octopus diagram.

2. **Notebook entry.** Imagine you are Inky's keeper the morning after his escape. Write a paragraph explaining how Inky could have done it, using at least three facts about octopus bodies from today's stop.

Did you know? The plural of octopus is "octopuses." The word comes from Greek, not Latin, so "octopi" is not really correct, though many people say it. Octopus ink contains melanin, the same dark pigment in your skin and hair. Some octopuses carry coconut shell halves along the sea floor and hide inside them.

Goes deeper in. Life Science, the unit on animals without backbones (invertebrates) (coming soon); and Trail F, Stop F2 "Camouflage."

For families. Inky's escape was reported by the National Aquarium of New Zealand in April 2016; the details (lid ajar, drain pipe to the sea) come from staff interviews and cannot be verified in every detail. The nerve-cell estimate (~500 million, about two-thirds in the arms) is for the common octopus. The 53-month brooding was a *Graneledone boreopacifica* filmed by MBARI from 2007 to 2011 (published 2014). Sizes for the giant Pacific octopus vary; reports of far larger animals are not well documented. Haeckel was a leading promoter of Darwin's theory, and some of his embryo drawings were later criticized as inaccurate; his animal plates are used here as art.

PRACTICE

1. **EASY** How many hearts does an octopus have, and what does each do?
2. **EASY** What is the only hard part of an octopus's body?
3. **MEDIUM** Name three ways an octopus can hide from or escape a hunter.
4. **MEDIUM** Why is an octopus's blood blue and yours red?
5. **CHALLENGE** A common octopus has about 500 million nerve cells, and about two-thirds are in its arms. About how many are in its arms, and about how many are in each arm if they are shared equally?

Make it a game • Octopus Color Change. Scatter colored paper squares (or pillows and blankets) around a room. The "octopus" holds a stack of colored cards. A "hunter" closes their eyes and counts to ten while the octopus stands next to something and holds up the card that matches it. The hunter opens their eyes and has five seconds to spot the octopus. If the colors match and the hunter misses, the octopus scores a point.

Scripture. "But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee: Or speak to the earth, and it shall teach thee: and the fishes of the sea shall declare unto thee." (Job 12:7-8, KJV)

Job says the creatures themselves teach us about their Maker. The clever octopus, with its three hearts and color-changing skin, "declares" the wisdom of the God who designed it.

1. Three: two pump blood through the gills, and one pumps blood through the rest of the body.
2. Its beak.
3. Any three: changing color with chromatophores, changing skin texture, squirting ink, jetting away with its siphon, squeezing into a tiny crack, mimicking another animal.
4. Octopus blood carries oxygen with hemocyanin, which contains copper; human blood uses hemoglobin, which contains iron and looks red.
5. About 333 million in the arms ($500 \div 3 \times 2 \approx 333$). Divided by 8 arms, that is about 42 million per arm.

4.3 CORAL REEFS: CITIES BUILT BY TINY ANIMALS

OBJECTIVES

- Explain that coral reefs are built by tiny animals called polyps working with algae.
- Tell the story of Captain Cook’s Endeavour on the Great Barrier Reef in 1770.
- Map the Great Barrier Reef and diagram the three kinds of reefs: fringing, barrier and atoll.

Warm-up. Drop a piece of chalk or a seashell into a cup of vinegar and watch closely. The fizzing tells you it is made of limestone (calcium carbonate). Coral skeletons are made of the very same stuff.

Video slot. Video coming. How coral polyps build reefs; coral spawning on the Great Barrier Reef; parrotfish and cleaner fish. Search approved channels (NOAA Ocean Service, Great Barrier Reef Marine Park Authority, Smithsonian Ocean); preview first.

KEY TERMS

polyp

A small, soft animal shaped like a tube with a ring of tentacles around its mouth. Coral polyps build limestone cups under themselves.

zooxanthellae

Tiny algae that live inside coral polyps, make food from sunlight and give corals much of their color (say “zoh-uh-zan-THEL-ee”).

fringing reef

A reef that grows right along the shore.

barrier reef

A reef that grows farther out from shore, with a lagoon between it and the land.

atoll

A ring-shaped coral reef or chain of islands around a lagoon, with no land in the middle.

CORE IDEAS

The story. Late on the night of June 11, 1770, the British ship *Endeavour*, commanded by Lieutenant James Cook, was sailing north along the unknown east coast of Australia. Suddenly the ship struck hard and stuck fast on a hidden reef. Water poured in. The crew threw about fifty tons overboard, including six cannons, and pumped for hours. The next day the rising tide floated the ship free. A young officer, Jonathan Monkhouse, showed them how to “fother” the leak by drawing a sail stuffed with wool and rope fiber under the hull. They limped to a river mouth, now Cooktown, and spent about seven weeks repairing the ship. Cook had found the Great Barrier Reef the hard way.

Who built it? A coral reef looks like rock, but its living surface is made of animals. Each coral **polyp** is a tiny tube with a ring of stinging tentacles, a cousin of the jellyfish. It takes minerals from seawater and builds a cup of limestone underneath itself. Thousands of polyps join in one colony, and colony grows on colony, layer on layer, until the stony city rises toward the light.

Partners in the sun. Inside the polyps live tiny algae called **zooxanthellae**. Using sunlight, they make sugars that feed the coral, often most of its food. In return, the coral gives them a safe home. That is why reef-building corals grow in clear, sunny, shallow water in warm seas. At night the polyps stretch out their tentacles to catch plankton too. When water stays unusually warm, polyps may push out their algae and turn white, which is called bleaching. If conditions improve in time, many corals take in algae again and recover.

Three kinds of reefs. A **fringing reef** hugs the shore. A **barrier reef** lies farther out, beyond a lagoon. An **atoll** is a ring of reef with no island in the middle. In 1842 Charles Darwin suggested that atolls grew on the rims of volcanic islands that slowly sank. In 1952, drillers on Enewetak Atoll in the Pacific bored through about 4,600 feet of coral limestone before reaching volcanic rock. The Great Barrier Reef stretches about 1,400 miles and is made of nearly 3,000 separate reefs. It has been a protected marine park since 1975.

A crowded city. Coral reefs cover less than one percent of the sea floor, yet they shelter roughly a quarter of all known ocean species. Parrotfish crunch dead coral with their beaklike teeth and grind it into fine white sand. Small cleaner fish set up “stations” where large fish wait to have pests picked off their skin. The psalmist’s cry fits a reef well: “O LORD, how manifold are thy works!”

PICTURE STUDY



A View of Endeavour River, on the Coast of New Holland, where the Ship was laid on Shore, in order to repair the Damage which she received on the Rock, Engraved by William Byrne after a drawing by Sydney Parkinson, c. 1773 · Engraving · From John Hawkesworth's account of Cook's first voyage (London, 1773); this impression in the Queensland Art Gallery, Brisbane
Wikimedia Commons · Public domain

Sydney Parkinson was the artist on Cook's first voyage. He drew this scene at the river where the *Endeavour* was hauled ashore in 1770 after striking the reef. Parkinson died of illness on the voyage home in 1771, and engravers in London made prints from his drawings for the official account.

Look closely

- Find the ship. Why is it tipped over on its side?
- Find the tents and the people on shore. What jobs might they be doing?
- Look at the land and the water. Is the river calm or rough?

Talk about it

1. Why would the crew need to lean the ship over to repair it?
2. The engraver never saw Australia. How might that change the picture?

HANDS-ON: MAP THE GREAT BARRIER REEF AND DIAGRAM THREE REEFS

Make a map of Cook's near-disaster and a cross-section diagram of the three kinds of coral reef.

You will need

- An atlas or online map of Australia
- Notebook paper, pencil and colored pencils (blue, green, tan, pink)

- A ruler

Steps

1. **Map.** Draw the northeast coast of Australia from Cape York in the north to the Tropic of Capricorn in the south. Label Queensland, the Coral Sea, Cape York, Cairns and Cooktown.
2. Draw the Great Barrier Reef as a long band of small pink shapes offshore, closer to land in the north and farther out in the south. Add a scale: about 1,400 miles long.
3. Mark Endeavour Reef with an X (southeast of Cooktown) and draw a dotted line for the ship's path north along the coast, ending at Endeavour River. Add the date June 11, 1770.
4. **Diagram.** Draw three side-view slices of the sea: (1) land with reef right at the shore, labeled "fringing reef"; (2) land, then a lagoon, then a reef, labeled "barrier reef" and "lagoon"; (3) a ring of reef around a lagoon with a sunken volcano drawn faintly below, labeled "atoll."

Check your work

- My map has a title, a compass rose and at least six labels.
- My diagram shows all three kinds of reefs, each labeled.
- I can explain how polyps and algae work together.

FIELD NOTEBOOK

1. Glue in your reef map and three-reef diagram.
2. **Notebook entry.** Write a paragraph as if you were a sailor on the *Endeavour* on June 12, 1770. Tell what happened the night before, what you threw overboard and what you hope for next.

Did you know? In 1969 an American expedition found the *Endeavour's* six cannons on the reef where Cook's crew dropped them 199 years earlier. On the Great Barrier Reef, many corals release their eggs and sperm on the same few nights each year, a few days after a full moon in late spring (November or December), so the water looks like an underwater snowstorm.

Goes deeper in. Earth Science, the unit on oceans (coming soon); Geography, Australia and Oceania; and History, the voyages of Captain Cook.

For families. The *Endeavour* struck on the night of June 11, 1770 (ship's date) and reached the Endeavour River on June 17; the fothering was suggested by midshipman Jonathan Monkhouse (Cook's journal). The Enewetak drilling (1952) is reported by the U.S. Geological Survey. Reef figures (about 2,900 reefs, about 2,300 km) are from the Great Barrier Reef Marine Park Authority; the "quarter of ocean species" figure is a common estimate (NOAA). Ages given for reefs on museum signs are interpretations; this stop leaves them out. Bleaching is described as observed, without forecasts.

PRACTICE

1. **EASY** Is coral a plant, an animal or a rock?
2. **EASY** What is the difference between a barrier reef and a fringing reef?
3. **MEDIUM** Why do reef-building corals grow only in clear, shallow water?
4. **MEDIUM** How did Cook's crew get the Endeavour off the reef and keep it afloat?
5. **CHALLENGE** At Enewetak, drillers went through about 4,600 feet of coral limestone. The Empire State Building is about 1,450 feet tall to its tip. About how many Empire State Buildings stacked up would that make?

Make it a game · Cleaning Station. One player is a big grouper who “parks” in a chair with eyes closed. Stick five small sticky notes (the “parasites”) on their sleeves and shoulders. The “cleaner fish” must remove all five in thirty seconds without the grouper feeling them. If the grouper feels a touch, they say “Snap!” and the cleaner loses a turn. Switch roles.

Scripture. “O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches.” (Psalm 104:24, KJV)

“Manifold” means many and varied. A single reef holds thousands of kinds of creatures, all fitted together in wisdom.

Practice: answers

1. Coral polyps are animals. They build rocky limestone skeletons and have algae living inside them.
2. A fringing reef grows right along the shore; a barrier reef grows farther out, with a lagoon between it and the land.
3. The zooxanthellae inside them need sunlight to make food for the coral, and sunlight cannot reach deep or murky water well.
4. They threw about fifty tons overboard (including six cannons), pumped water out, floated free on the high tide, and fothered the leak with a sail stuffed with wool and fiber.
5. $4,600 \div 1,450 \approx 3.2$, so a little more than three Empire State Buildings.

4.4 GIANT SQUID: THE REAL KRAKEN

OBJECTIVES

- Describe the giant squid's body: mantle, eight arms, two long tentacles and huge eyes.
- Tell how people learned about the giant squid, from the Newfoundland fishermen of 1873 to the first photographs of a living one in 2004.
- Chalk a life-size outline of a giant squid and label its parts.

Warm-up. Hold a dinner plate up to your face. A giant squid's eye can be about that wide, about 10 inches across. Why would an animal in the dark deep sea need such huge eyes?

Video slot. Video coming. Giant squid first video in the deep sea (2012); giant squid filmed in the Gulf of Mexico (2019); sperm whales and squid. Search approved channels (NOAA Ocean Exploration, Smithsonian Ocean, Ocean Research and Conservation Association, Schmidt Ocean Institute); preview first.

KEY TERMS

mantle

The muscular, tube-shaped main body of a squid, which holds its organs.

tentacle

One of the two extra-long feeding limbs of a squid, with suckers only near the club-shaped tip.

Architeuthis

The scientific name of the giant squid, meaning "chief squid."

specimen

A real animal or part of one kept so scientists can study it.

kraken

A huge sea monster of old Norwegian sailors' tales, probably inspired by sightings of giant squid.

CORE IDEAS

The story. In late October 1873, a fisherman named Theophilus Piccot, his young son Tom and a companion were rowing in Conception Bay, Newfoundland, when they spotted something large floating in the water. When they poked it, a great beak rose up and long arms wrapped around their small boat. Tom grabbed a hatchet and chopped off an arm and a tentacle. The creature sank away in a cloud of ink. A local minister and naturalist, the Reverend Moses Harvey, bought the tentacle. A few weeks later, fishermen at nearby Logy Bay caught a whole giant squid in a net. Harvey draped it over his bathtub and had it

photographed. The pictures helped convince scientists that the kraken of sailors' tales was a real animal.

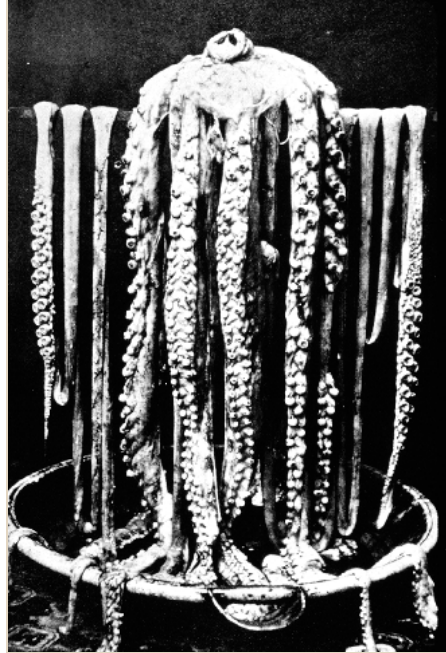
The body. The giant squid, **Architeuthis**, is a cephalopod like the octopus. Its body, the **mantle**, can be six feet or more long. It has eight arms and two much longer **tentacles** for snatching prey. The largest measured animals reached about 40 feet from the fin to the tips of the tentacles, though most of that length is tentacle. Its suckers are ringed with tiny sharp teeth, and its beak can slice prey into bites.

The biggest eyes. The giant squid and its heavier cousin, the colossal squid, have the largest eyes of any known animal, about 10 to 11 inches across. In the dim deep, light comes mostly from glowing animals. Some scientists think such big eyes help a squid notice the faint glow stirred up by a diving sperm whale while it is still far away.

Seen at last. For more than a century, scientists knew the giant squid only from dead **specimens** washed ashore or caught in nets. On September 30, 2004, Japanese scientists Tsunemi Kubodera and Kyoichi Mori lowered a camera and bait about 3,000 feet deep off the Ogasawara Islands. It took over 500 photos of a living giant squid attacking the bait. In 2012, a team including Kubodera and the American scientist Edith Widder filmed one in its home waters for the first time.

Battles of the deep. The giant squid's great enemy is the sperm whale. Whalers found round sucker scars on whales' heads and thousands of squid beaks in their stomachs. The French writer Jules Verne put a fight with giant squid in *Twenty Thousand Leagues Under the Seas* (1870). God asked Job, "Hast thou entered into the springs of the sea?" For thousands of years no man had, and the deep kept its giant secret until our own day.

PICTURE STUDY



The Logy Bay giant squid draped over Moses Harvey's bathtub, Photograph made for the Reverend Moses Harvey, 1873–1874 · Photograph · St. John's, Newfoundland; reproduced in Harvey's articles and in many museum histories

Wikimedia Commons · Public domain

Moses Harvey was a Presbyterian minister who loved natural history. Knowing scientists would doubt a fisherman's tale, he had the squid photographed and sent reports to naturalists in America and Britain. This is one of the earliest photographs of a giant squid, and it shows the first whole specimen scientists could study.

Look closely

- Find the mantle (body) and the arms. Can you see suckers?
- Use the bathtub to guess how long the arms are.
- Look at the background. What does it tell you about where and when this was taken?

Talk about it

1. Why was a photograph more convincing than a drawing in the 1870s?
2. What can a photo of a dead squid not tell us about how it lived?

Safety first. Chalk only where a parent says it is safe, away from cars and traffic.

HANDS-ON: LIFE-SIZE GIANT SQUID

Outline a giant squid at full size on a driveway or sidewalk, then draw a labeled diagram in your notebook.

You will need

- Sidewalk chalk
- A long measuring tape (at least 25 feet; measure twice if it is shorter)
- A dinner plate (for the eye)
- Notebook paper and colored pencils

Steps

1. With a parent, choose a safe driveway, empty lot or long sidewalk away from traffic.
2. Measure and chalk a mantle 7 feet long and about 2 feet wide, with two small fins at one end. Trace the dinner plate on the mantle near the head for the eye.
3. From the head, chalk eight arms about 8 to 10 feet long, then two tentacles reaching out to make the whole squid about 40 feet. Draw a club with suckers at each tentacle tip.
4. Lie down beside it and have someone take a picture. Then draw a small labeled diagram in your notebook: mantle, fins, eye, funnel (siphon), arms, tentacles, tentacle club, suckers and beak. Add a scale line: "1 inch = 4 feet."

Check your work

- My chalk squid is about 40 feet long, with the plate-sized eye.
- My notebook diagram has at least eight labels and a scale.
- I can tell the difference between an arm and a tentacle.

FIELD NOTEBOOK

1. Draw your labeled giant squid diagram with its scale.
2. **Notebook entry.** Write a paragraph telling the 1873 Newfoundland story as Tom Piccot might have told it to a newspaper. Include where, when, what happened and what became of the tentacle.

Did you know? The colossal squid of the Southern Ocean is shorter than the giant squid but much heavier; one caught in 2007 weighed about 1,000 pounds. Its suckers have swiveling hooks. A young colossal squid was filmed alive in its home waters for the first time in 2025.

Map or diagram. On a world map, mark Newfoundland (1873), the Ogasawara Islands south of Tokyo (2004) and the Gulf of Mexico, where a giant squid was filmed in 2019. Giant squid have been found in every ocean.

Goes deeper in. Life Science, the unit on invertebrates (coming soon); Literature, for Jules Verne's *Twenty Thousand Leagues Under the Seas*; and Stop D7, the deep sea.

For families. Accounts of the 1873 encounter differ in details (the date, who was in the boat and which limbs were cut); this stop follows Harvey's reports in outline. The 2004 photographs were published by Kubodera and Mori in *Proceedings of the Royal Society B* (2005). The first video in natural habitat was filmed in 2012 and broadcast in 2013; the

2019 Gulf of Mexico video came from a NOAA-funded expedition using Edith Widder's "Medusa" camera. The colossal squid was filmed by the Schmidt Ocean Institute's expedition in March 2025. Length figures vary; many old claims of 60 feet or more are not trusted.

PRACTICE

1. **EASY** How many arms and how many tentacles does a giant squid have?
2. **EASY** Which animal is the giant squid's main predator?
3. **MEDIUM** What evidence did whalers find that sperm whales eat giant squid?
4. **MEDIUM** Why was the 2004 Japanese discovery so important?
5. **CHALLENGE** A giant squid's eye is about 27 centimeters across. A human eye is about 2.4 centimeters across. About how many times wider is the squid's eye?

Make it a game • Kraken Grab. One player is the giant squid, standing in the middle with a long scarf in each hand (the two tentacles). Other players walk past slowly as "fish." The squid may tag with a scarf tip only, never with hands. A tagged fish becomes an extra arm, holding the squid's shoulder and helping tag. Play until every fish is caught.

Scripture. "Hast thou entered into the springs of the sea? or hast thou walked in the search of the depth?" (Job 38:16, KJV)

God asked Job questions to show how little man knows. Thousands of years later, we have only just begun to photograph creatures of the deep that God has always seen.

Practice: answers

1. Eight arms and two long tentacles.
2. The sperm whale.
3. Round sucker scars on the whales' skin and squid beaks in their stomachs.
4. It gave the first photographs of a living giant squid in its home in the deep sea; before that, scientists had only dead specimens.
5. $27 \div 2.4 \approx 11$, so about 11 times wider.

4.5 DOLPHINS: PELORUS JACK AND THE MAMMALS OF THE SEA

OBJECTIVES

- Explain why a dolphin is a mammal and not a fish, with at least four pieces of evidence.
- Describe how dolphins breathe, sleep and call each other by signature whistles.
- Map Pelorus Jack's waters in New Zealand and diagram a dolphin beside a shark.

Warm-up. Take a deep breath and hold it while you count slowly. How long can you last? A bottlenose dolphin usually comes up every few minutes, but it decides each breath on purpose. It never breathes without thinking, even when it sleeps.

Video slot. Video coming. Bottlenose dolphins: breathing, calves, signature whistles and cooperative fishing; Risso's dolphins. Search approved channels (NOAA Fisheries, Smithsonian Ocean, Sarasota Dolphin Research Program, Monterey Bay Aquarium); preview first.

KEY TERMS

marine mammal

A mammal that lives in or depends on the sea, such as a dolphin, whale, seal or sea otter.

blowhole

The nostril on top of a dolphin's or whale's head, through which it breathes.

blubber

A thick layer of fat under the skin that keeps sea mammals warm and stores energy.

signature whistle

A whistle each bottlenose dolphin makes that is its own, used almost like a name.

pod

A group of dolphins or whales that travel together.

CORE IDEAS

The story. Around 1888, sailors entering French Pass, a narrow and dangerous channel at the north end of New Zealand's South Island, noticed a gray dolphin swimming alongside their ship. It played in the bow wave for about twenty minutes and then turned back. It came again, and again, for nearly twenty-four years, meeting the steamers that ran between Wellington and Nelson. Sailors named it **Pelorus Jack**. It was a Risso's dolphin, a blunt-headed kind rarely seen there. After someone aboard a passing ship fired a gun at it, the people of New Zealand asked for a law, and in 1904 the government made it illegal to harm Risso's dolphins in those waters. Pelorus Jack was last seen in 1912.

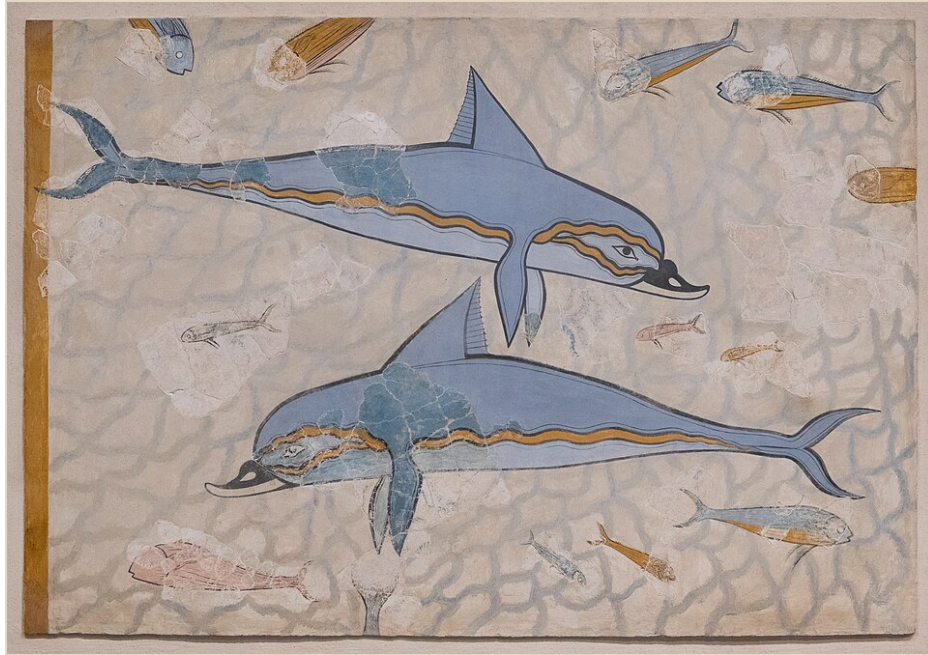
Mammals, not fish. Dolphins look like fish, but they are **marine mammals**. They breathe air through a **blowhole**, are warm-blooded, and stay warm under a layer of **blubber**. A calf is born tail first, and its mother nudges it up for its first breath; then it drinks her milk for a year or more. A dolphin's tail flukes are flat side to side and beat up and down, while a shark's tail stands upright and sweeps side to side. There are about forty kinds of ocean dolphins. The largest is the orca, or killer whale.

Breathing and sleeping. You breathe without thinking, but a dolphin must decide to breathe each time. So how does it sleep? A dolphin rests one half of its brain at a time while the other half stays alert. It often keeps one eye open, swims slowly beside its **pod** and rises to breathe. After a few hours, the two halves switch.

Talking in whistles. Dolphins make clicks to "see" with sound (Trail F, Stop F1) and whistles to keep in touch. In 1965, the scientists Melba and David Caldwell reported that each bottlenose dolphin has a **signature whistle** of its own. Later studies found that dolphins answer when they hear a copy of their own whistle, much as you turn when someone calls your name. A mother and calf whistle to each other often when they are apart.

Teamwork. Bottlenose dolphins cruise at a few miles per hour and can sprint at over 20. They hunt in teams, herding fish into tight balls. In the town of Laguna, Brazil, fishermen have worked with wild dolphins for generations: the dolphins drive mullet toward the shore and give a sudden dive or head-slap, and the men throw their nets. The psalmist said that "they that go down to the sea in ships" see "his wonders in the deep." Pelorus Jack's sailors would agree.

PICTURE STUDY



The Dolphin Fresco, from the Palace of Knossos, Unknown Minoan painter, About 1600–1450 BC (restored in the 20th century) · Fresco (paint on wet plaster), pieced together and restored · Heraklion Archaeological Museum, Crete, Greece (a copy is on the wall at Knossos)
Wikimedia Commons · CC0

The Minoans were a seafaring people on the island of Crete. In a room of the great palace at Knossos, a painter decorated the wall with dolphins and fish. The fresco was found broken into pieces and was carefully restored by the British archaeologist Arthur Evans's team in the early 1900s, so some parts are reconstructions.

Look closely

- Count the dolphins. Find their beaks, fins and tails.
- What smaller creatures swim with them?
- Look at the colors and wavy lines. How did the painter show water?

Talk about it

1. Why might people who lived on an island want dolphins on their walls?
2. Restorers had to guess at missing pieces. How could you find out which parts are original?

HANDS-ON: MAMMAL OR FISH? A COMPARISON DIAGRAM AND A MAP

Show with a diagram why a dolphin is a mammal, and map the waters where Pelorus Jack met the ships.

You will need

- Notebook paper, pencil and colored pencils
- An atlas or online map of New Zealand
- A ruler

Steps

1. **Diagram.** Draw a dolphin and a shark one above the other, both facing left. Label on the dolphin: blowhole, melon (forehead), beak, flipper, dorsal fin, flukes (flat side to side). Label on the shark: gill slits, pectoral fin, dorsal fin, tail fin (upright).
2. Draw arrows by the tails: up and down for the dolphin, side to side for the shark.
3. Below the drawings, make a two-column chart, “Dolphin (mammal)” and “Shark (fish),” comparing: how it breathes, warm or cold-blooded, how babies are born, what babies eat, skeleton (bone or cartilage).
4. **Map.** Draw the two main islands of New Zealand. Label Cook Strait, Wellington, Nelson, Marlborough Sounds and French Pass. Draw a dotted ship route from Wellington to Nelson and a small dolphin at French Pass labeled “Pelorus Jack, 1888–1912.”

Check your work

- My diagram shows at least five differences between a dolphin and a shark.
- My map has a title, a compass rose and six labels.
- I can give four reasons a dolphin is a mammal.

FIELD NOTEBOOK

1. Glue in your comparison diagram and New Zealand map.
2. **Notebook entry.** Write a paragraph explaining how a dolphin sleeps without drowning. Use the words *blowhole*, *pod* and *brain*.

Did you know? Pelorus Jack is often said to be the first individual sea animal protected by its own law. Risso’s dolphins are born dark gray and grow lighter with age, as scratches from other dolphins and from squid beaks leave white scars. The U.S. Navy has trained dolphins since the 1960s to find objects underwater.

Goes deeper in. Life Science, the unit on mammals (coming soon); Geography, New Zealand; and Trail F, Stop F1 “Echolocation.”

For families. Pelorus Jack’s protection came by an Order in Council in September 1904 under the Sea-Fisheries Act (New Zealand government histories, Te Ara). The story that the dolphin was shot at from the steamer *Penguin* and afterward avoided it is a popular tradition that cannot be confirmed. Signature whistles: Caldwell and Caldwell (1965); responses to whistle copies: Janik and colleagues (2006). The Laguna, Brazil, cooperation is documented in scientific studies (e.g., Simões-Lopes 1998; 2023 study in *PNAS*). The Knossos fresco’s date is the usual archaeological range; parts are modern restoration.

PRACTICE

1. **EASY** Name four things that show a dolphin is a mammal.
2. **EASY** What kind of dolphin was Pelorus Jack, and where did he meet ships?
3. **MEDIUM** How does a dolphin sleep without forgetting to breathe?
4. **MEDIUM** How can you tell a dolphin from a shark by watching its tail?
5. **CHALLENGE** Pelorus Jack met ships from about 1888 to 1912. If he met an average of 3 ships a week, about how many ships did he escort? (Use 52 weeks a year.)

Make it a game • Signature Whistle. Each player makes up a short whistle, hum or clap pattern as a “signature” and teaches it to the group. One player is blindfolded. Someone else makes another player’s signature sound; the blindfolded player must name whose it is. Then switch. Try it from across the room or yard.

Scripture. “They that go down to the sea in ships, that do business in great waters; These see the works of the LORD, and his wonders in the deep.” (Psalm 107:23-24, KJV)

For twenty-four years, sailors in New Zealand saw one of God’s “wonders in the deep” ride beside their ships.

Practice: answers

1. Any four: it breathes air with lungs (through a blowhole), is warm-blooded, has live babies, feeds its babies milk, has a few hairs as a newborn, has bones.
2. A Risso’s dolphin; at French Pass, New Zealand, on the route between Wellington and Nelson.
3. It rests one half of its brain at a time while the other half stays awake to swim, watch and come up to breathe.
4. A dolphin’s flukes are flat and move up and down; a shark’s tail stands upright and sweeps side to side.
5. $1912 - 1888 = 24$ years; $24 \times 52 = 1,248$ weeks; $1,248 \times 3 =$ about 3,744 ships.

4.6 JELLYFISH: DRIFTERS WITH STINGERS

OBJECTIVES

- Describe a jellyfish's simple body: bell, tentacles, nerve net and stinging cells.
- Tell how a glowing jellyfish led to a Nobel Prize in 2008.
- Draw and label the jellyfish life cycle from polyp to medusa.

Warm-up. Fill a clear zipper bag with water, seal it and squeeze it gently. Watch it change shape. A jellyfish is about 95 percent water, so its body is almost as soft as your bag.

Video slot. Video coming. Jellyfish life cycle (polyp, ephyra, medusa); crystal jelly and green fluorescent protein; lion's mane jellyfish. Search approved channels (Monterey Bay Aquarium, MBARI, Smithsonian Ocean, NOAA Ocean Service); preview first.

KEY TERMS

medusa

The free-swimming, bell-shaped stage of a jellyfish.

nematocyst

A tiny stinging capsule inside a jellyfish's cells that shoots out a coiled, harpoon-like thread.

nerve net

A web of nerve cells spread through a jellyfish's body instead of a brain.

plankton

Living things that drift with ocean currents instead of swimming against them. The word means "wanderer."

bioluminescence

Light made by a living thing.

CORE IDEAS

The story. In the summer of 1961, a young Japanese scientist named Osamu Shimomura stood on the docks at Friday Harbor, Washington, scooping up crystal jellies with a hand net. Around the rim of each clear bell was a ring of tiny dots that glowed green. Shimomura and his helpers collected about ten thousand jellies that first summer, cut off the glowing rings and squeezed out their juice. In 1962 he reported a protein that gives off blue light and a second one that glows green. That green protein, called GFP, later became one of the most useful tools in biology. Scientists attach it to other proteins to watch them work inside living cells. In 2008, Shimomura shared the Nobel Prize in Chemistry with Martin Chalfie and Roger Tsien.

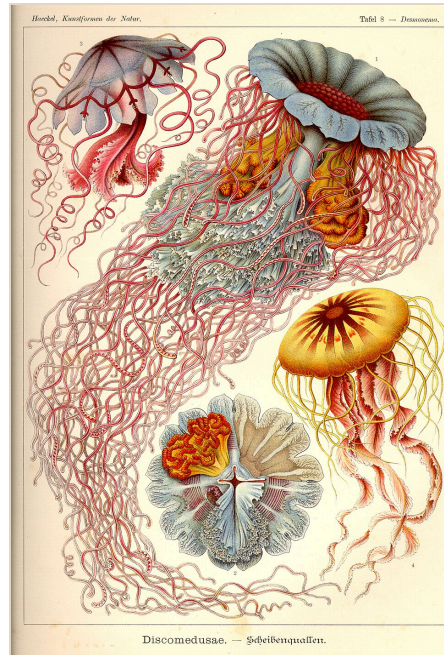
A simple body. A jellyfish has no brain, no heart, no bones and no blood. Its **medusa** body is a soft bell with a mouth underneath, frilly oral arms and a fringe of tentacles. Instead of a brain it has a **nerve net**. It swims by squeezing its bell and relaxing it, pushing out little puffs of water. Some kinds have simple eyespots, and the box jellyfish has twenty-four eyes, a few with lenses.

Stingers. A jellyfish's tentacles are packed with stinging cells. Each holds a **nematocyst**, a capsule with a coiled thread inside. When something brushes it, the thread fires out in less than a millionth of a second, one of the fastest movements in nature, and injects venom. Most stings only sting, but the box jellyfish of northern Australia is among the most venomous animals known. The Portuguese man-of-war is not a true jellyfish but a colony of many small animals living together.

A life in stages. Adult jellies release eggs and sperm into the sea. A tiny larva swims down and fastens to a rock, where it grows into a **polyp**, like a little upside-down jellyfish. The polyp buds more polyps. Then it grows a stack of discs, which pop off one by one as baby jellies called ephyrae. These grow into new medusas. One small jellyfish of the Mediterranean, *Turritopsis dohrnii*, can even turn itself back into a polyp when it is hurt or starving.

Wanderers. Jellyfish are **plankton**: they drift wherever the currents carry them. The largest known, the lion's mane, lives in cold northern seas. One that washed ashore in Massachusetts Bay in 1870 had a bell over seven feet wide and tentacles reported at about 120 feet long. Leatherback sea turtles and some fish eat jellies by the hundreds. Jellyfish truly "passeth through the paths of the seas."

PICTURE STUDY



Discomedusae, Plate 8 of *Kunstformen der Natur* (*Art Forms in Nature*), Ernst Haeckel, 1904 (plate issued 1899) · Color lithograph (printed plate from Haeckel's drawings) · From the book *Kunstformen der Natur*, Leipzig, 1899–1904
Wikimedia Commons · CC BY 2.0

Ernst Haeckel drew jellyfish from life on many trips to the seaside. This is one of the most famous pages in his book. He named the large jellyfish in the center *Desmonema annasethe* in memory of his first wife, Anna Sethe, who died in 1864.

Look closely

- Find the bell, the frilly oral arms and the thin tentacles of the center jellyfish.
- Look at the smaller jellies. Are any shown from above, like a flower?
- Follow the long tentacles with your finger. What shapes do they make?

Talk about it

1. Why do you think Haeckel arranged the tentacles to flow down the page?
2. This plate is both science and art. Which parts help a scientist, and which make it beautiful?

Safety first. Beach safety: never touch a jellyfish, even one that is dead on the sand; its stinging cells can still fire. Swim at guarded beaches, obey posted stinger warnings and tell a lifeguard or grown-up about any sting.

HANDS-ON: THE JELLYFISH LIFE CYCLE WHEEL

Make a circular diagram showing how a jellyfish grows from egg to polyp to medusa.

You will need

- A paper plate or a circle drawn on notebook paper
- Pencil, fine marker and colored pencils
- A ruler

Steps

1. Divide the circle into six sections like a pie. Write the title “Jellyfish Life Cycle” in the center.
2. Draw and label one stage in each section, going clockwise: (1) adult medusa; (2) eggs and sperm; (3) planula (a tiny swimming larva); (4) polyp attached to a rock; (5) strobila (a polyp with a stack of discs); (6) ephyra (a baby jelly, like a little star).
3. Draw arrows from each stage to the next, and an arrow from the ephyra back to the adult medusa.
4. On the back or beside it, draw one large medusa from the side and label: bell, mouth, oral arms, tentacles, nerve net (dotted lines in the bell) and stinging cells (dots on the tentacles).

Check your work

- My life cycle has six labeled stages in the right order with arrows.
- My medusa drawing has at least five labels.
- I can explain how a nematocyst works.

FIELD NOTEBOOK

1. Glue in your life cycle wheel and labeled medusa.
2. **Notebook entry.** Write a paragraph explaining how a jellyfish without a brain can still swim, sting and catch food. Then add one sentence about how a jellyfish helped scientists study living cells.

Did you know? A group of jellyfish can be called a *smack* or a *bloom*. Moon jellies have even been carried into space: in 1991, NASA sent thousands of moon jelly polyps aboard the space shuttle *Columbia* to study how they grew without gravity. The word *medusa* comes from a monster of Greek legend with snakes for hair.

Goes deeper in. Life Science, the unit on invertebrates and the unit on cells (coming soon), where GFP glows in microscope pictures; and Stop D3, for corals, the jellyfish’s cousins.

For families. Shimomura’s work: Shimomura, Johnson and Saiga (1962); Nobel Prize in Chemistry 2008 (nobelprize.org). Collection numbers (about 10,000 the first summer, and hundreds of thousands over many years) follow Shimomura’s Nobel lecture and autobiography. Nematocyst firing speed is from studies on *Hydra* (Nüchter et al., 2006). The 1870 lion’s mane measurements are from Alexander Agassiz’s report and are often

repeated but unverified. Haeckel's naming of *Desmonema annasethe* after his wife is recorded in his own writings. For first aid, follow local lifeguard or medical advice; recommended treatment differs by species and region.

PRACTICE

1. **EASY** Name three body parts a jellyfish does not have.
2. **EASY** What is a nematocyst?
3. **MEDIUM** Put these stages in order: ephyra, polyp, medusa, planula.
4. **MEDIUM** What did Osamu Shimomura discover in the crystal jelly, and why does it matter?
5. **CHALLENGE** The 1870 lion's mane had tentacles about 120 feet long. A blue whale is about 100 feet long. How much longer were the tentacles, and what percent of a blue whale's length is that difference?

Make it a game • Drift and Sting. One player is a jellyfish who may not walk on purpose: a leader calls out "current north!" or "current east!" and the jellyfish takes two steps that way. The jellyfish holds out arms as tentacles. Other players are fish who move freely but must pass within reach at least once each round. Anyone touched by a tentacle tip becomes a jellyfish too.

Scripture. "The fowl of the air, and the fish of the sea, and whatsoever passeth through the paths of the seas." (Psalm 8:8, KJV)

Jellyfish cannot choose their way; they ride the ocean currents, the "paths of the seas." God, who made the paths, also made every drifter that travels them.

Practice: answers

1. Any three: brain, heart, bones, blood (also gills or lungs).
2. A tiny stinging capsule in a jellyfish's cells that shoots out a coiled thread to inject venom.
3. Planula, polyp, ephyra, medusa (then the medusa makes eggs and the cycle begins again).
4. A green fluorescent protein (GFP) and a blue-glowing protein. GFP lets scientists light up and watch proteins inside living cells; it won the 2008 Nobel Prize in Chemistry.
5. $120 - 100 = 20$ feet longer; $20 \div 100 = 0.20$, or 20 percent.

4.7 ANGLERFISH AND THE DEEP SEA

OBJECTIVES

- Name the layers of the ocean from the sunlight zone to the trenches, with their depths.
- Explain how the deep-sea anglerfish hunts with a glowing lure in the dark.
- Tell how the bathysphere (1934) and the Trieste (1960) carried people into the deep.

Warm-up. Turn off the lights in a room with no windows and wait one minute. Can you see anything at all? Below about 3,300 feet, the whole ocean is darker than that room, all day and all night, all year.

Video slot. Video coming. Deep-sea anglerfish filmed alive; bioluminescence in the midnight zone; the bathysphere and the Trieste. Search approved channels (MBARI, NOAA Ocean Exploration, Smithsonian Ocean, Schmidt Ocean Institute); preview first.

KEY TERMS

midnight zone

The ocean layer from about 3,300 to 13,000 feet deep, where no sunlight reaches.

pressure

The pushing force of the water above. In the sea it grows by about 14.7 pounds per square inch for every 33 feet down.

lure

A bait that draws prey close. An anglerfish's lure glows at the tip of a spine on its head.

bathysphere

A hollow steel ball lowered on a cable to carry explorers into the deep sea.

trench

A long, very deep valley in the ocean floor. The deepest is the Mariana Trench.

CORE IDEAS

The story. On August 15, 1934, off the island of Bermuda, two men squeezed into a steel ball less than five feet wide. William Beebe, a naturalist, and Otis Barton, the engineer who designed the **bathysphere**, were lowered by a single cable from a ship. Through thick quartz windows, Beebe watched the blue water fade to black. He described what he saw by telephone to Gloria Hollister on the deck above, who wrote it all down: fish with glowing rows of lights, flashing shrimp, sparks drifting like stars. That day they reached 3,028 feet, deeper than anyone had gone before.

Layers of the sea. Oceanographers divide the sea into zones. The sunlight zone, down to about 660 feet, is where plants and algae can grow. In the twilight zone, to about 3,300 feet, light fades from blue to almost nothing. Below that is the **midnight zone**, then the abyss

below about 13,000 feet, and finally the **trenches**, which plunge to nearly 36,000 feet. Red light vanishes first, so many deep animals are red or black, which makes them invisible.

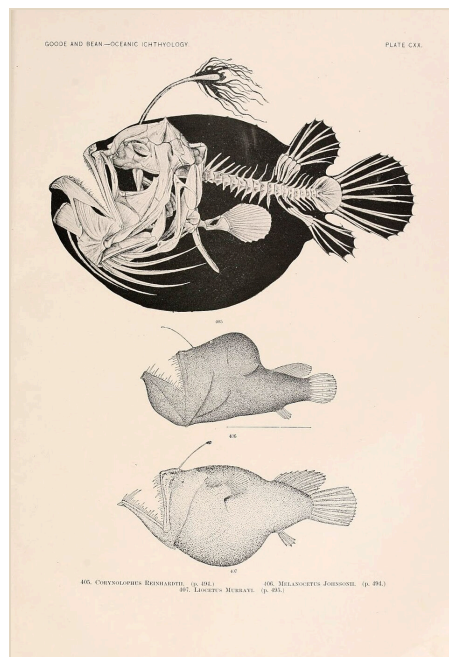
Pressure rises by about one atmosphere, 14.7 pounds per square inch, every 33 feet.

The fisherman fish. The deep-sea anglerfish is mostly the size of a fist or smaller, but it is a fierce hunter. The female has a long spine growing from her head like a fishing rod, tipped with a glowing **lure**. The light comes from glowing bacteria that live in it. Small fish swim toward the light, and the anglerfish snaps them up with a huge mouth of needle teeth. Her stomach can stretch to hold prey nearly as large as herself, which is useful where meals are rare. The males are tiny, and in some kinds a male attaches to a female for life.

Lights in the dark. Most deep-sea animals make their own light. A 2017 study off California found that about three out of four animals seen in the water there could glow. They use light to lure prey, to find mates, to confuse hunters and even to hide their shadows from fish below.

To the bottom. In the 1840s, the naturalist Edward Forbes guessed that little or nothing could live below about 1,800 feet. Then the British ship HMS *Challenger* (1872–1876) dredged up thousands of new kinds of creatures from the deep. On January 23, 1960, Jacques Piccard and U.S. Navy Lieutenant Don Walsh rode the bathyscaphe *Trieste* to the floor of the Challenger Deep in the Mariana Trench, almost seven miles down. David wrote, “the darkness and the light are both alike to thee.”

PICTURE STUDY



Deep-sea anglerfishes, Plate 120 from the atlas of Oceanic Ichthyology, Illustrations for G. Brown Goode and Tarleton H. Bean, 1896 · Printed scientific plate (lithograph from drawings) · Smithsonian Institution, U.S. National Museum (Special Bulletin 2); free online at the Biodiversity Heritage Library
Wikimedia Commons · Public domain

In the 1880s American fishery ships such as the *Blake* and the *Albatross* dragged nets deep in the Atlantic. Two Smithsonian scientists, George Brown Goode and Tarleton Bean, described the strange fish they caught in a huge book, *Oceanic Ichthyology*, with an atlas of drawings. This plate includes the humpback anglerfish. No one had yet seen these fish alive; the artists drew them from specimens in jars.

Look closely

- Find an anglerfish's "fishing rod" and the lure at its tip.
- Look at the mouths and teeth. How big is the mouth compared with the body?
- Find the eyes. Are they large or small?

Talk about it

1. These fish were drawn from dead specimens. What might the drawings miss about the living animals?
2. Why might a black-and-white drawing actually suit animals from the dark?

HANDS-ON: THE OCEAN ZONES COLUMN

Make a tall diagram of the ocean from the surface to the bottom of the Mariana Trench, and mark where explorers and animals live.

You will need

- A long strip of paper about 36 inches long (tape sheets end to end)
- A yardstick or ruler
- Colored pencils or markers: light blue, dark blue, purple, black
- Pencil

Steps

1. Use the scale **1 inch = 1,000 feet**. Mark the top "Sea level, 0 feet" and the bottom, 36 inches down, "Challenger Deep, about 36,000 feet."
2. Draw lines and label the zones: sunlight zone (0-660 ft, about 2/3 inch), twilight zone (to 3,300 ft), midnight zone (to 13,000 ft), abyss (to 20,000 ft) and trench (below 20,000 ft). Shade from light blue at the top to black at the bottom.
3. Mark these: a scuba diver at about 130 feet; the bathysphere at 3,028 feet (1934); a giant squid at about 3,000 feet (Stop D4); an anglerfish at about 5,000 feet; the *Trieste* at the bottom (1960). For comparison, draw Mount Everest, 29,032 feet, beside the column.
4. Along the side, write the water pressure at three depths: 33 ft $\approx$ 2 atmospheres (1 of air + 1 of water); 3,300 ft $\approx$ 101 atmospheres; 36,000 ft $\approx$ 1,090 atmospheres.

Check your work

- My column is drawn to scale with five labeled zones.

- I marked at least five animals, explorers or objects at their depths.
- I can explain why the deep sea is dark and cold, with great pressure.

FIELD NOTEBOOK

1. Draw a deep-sea anglerfish and label: lure (esca), rod (illicium), eye, mouth, teeth and stretchy stomach. Color it dark, with the lure glowing.
2. **Notebook entry.** Pretend you are Gloria Hollister on the deck on August 15, 1934. Write a paragraph telling what William Beebe described to you over the telephone as he sank deeper.

Did you know? The Challenger Deep is deeper than Mount Everest is tall: if Everest were set on the bottom, its peak would still be more than a mile underwater. After 1960, no one went back to the bottom until filmmaker James Cameron dove there alone in 2012.

Goes deeper in. Earth Science, the unit on oceans and ocean floors (coming soon); Life Science, fish; and Arithmetic, for scale drawings.

For families. Beebe and Barton's record dive of 3,028 feet was August 15, 1934 (Beebe, *Half Mile Down*, 1934). The bioluminescence figure (about 76 percent) is from Martini and Haddock, *Scientific Reports* (2017), for animals observed in the water off Monterey. Forbes's "azoic" idea and the *Challenger* results (about 4,700 new species) are standard history of oceanography. Piccard reported seeing a flatfish on the bottom, but many scientists doubt it, so it is left out. The Goode and Bean atlas is on the Biodiversity Heritage Library; plate numbers vary between scanned copies, so pick any anglerfish plate. Zone boundaries are rounded.

PRACTICE

1. **EASY** Name the ocean zones in order from the surface down.
2. **EASY** What makes the anglerfish's lure glow?
3. **MEDIUM** Why are many deep-sea animals red or black?
4. **MEDIUM** Who reached the bottom of the Challenger Deep in 1960, and in what vessel?
5. **CHALLENGE** Water pressure increases by about 14.7 pounds per square inch every 33 feet. About how much water pressure pressed on the bathysphere's window at 3,028 feet?

Make it a game • Follow the Lure. Play in a dim room with a parent. The "anglerfish" sits in one spot holding a small flashlight (the lure) and blinks it now and then. The "fish" crawl slowly toward the light from across the room. When a fish gets within arm's reach, the anglerfish may switch off the light and try to tag it. Then the fish becomes the next anglerfish.

Scripture. "If I say, Surely the darkness shall cover me; even the night shall be light about me. Yea, the darkness hideth not from thee; but the night shineth as the day: the darkness and the light are both alike to thee." (Psalm 139:11-12, KJV)

No sunlight reaches the midnight zone, but nothing there is hidden from God. He made the anglerfish and its glowing lure, and He sees it in the dark as clearly as in the day.

Practice: answers

1. Sunlight zone, twilight zone, midnight zone, abyss, trenches.
2. Glowing (bioluminescent) bacteria living inside it.
3. Red light does not reach the deep and the animals' own lights are mostly blue, so red and black animals look invisible there.
4. Jacques Piccard and Lieutenant Don Walsh, in the bathyscaphe Trieste.
5. $3,028 \div 33 \approx 92$ groups of 33 feet; $92 \times 14.7 \approx 1,350$ pounds per square inch (not counting the air above).

4.8 SALMON: THE JOURNEY HOME

OBJECTIVES

- Describe the salmon life cycle from egg to adult and back to the home stream.
- Explain how Arthur Hasler’s experiments showed that salmon find their home streams by smell.
- Map a salmon’s journey up the Columbia and Snake Rivers to Redfish Lake, Idaho.

Warm-up. Close your eyes while a grown-up holds three things under your nose one at a time: an orange peel, a cinnamon stick and a bar of soap. Can you name them? A salmon remembers the smell of its home stream for years.

Video slot. Video coming. Salmon run: sockeye spawning, salmon leaping waterfalls, fish ladders at Bonneville Dam, bears fishing for salmon. Search approved channels (NOAA Fisheries, U.S. Fish and Wildlife Service, National Park Service, Explore.org Katmai bear cams); preview first.

KEY TERMS

anadromous

Born in fresh water, grows up in the sea, and returns to fresh water to lay eggs. The word means “running upward.”

spawn

To lay and fertilize eggs. Salmon spawn in the gravel of streams.

redd

A nest a female salmon digs in stream gravel with her tail.

smolt

A young, silvery salmon whose body is changing so it can live in salt water.

fish ladder

A series of pools built like steps beside a dam so fish can swim around it.

CORE IDEAS

The story. In 1946, a scientist named Arthur Hasler of the University of Wisconsin was hiking in the mountains of Utah where he grew up. As he came around a cliff, a cool breeze carried the smell of moss and columbine, and suddenly he remembered his boyhood in that very place. He wondered: could salmon remember the smell of their home streams? In the early 1950s his team tested the idea at Issaquah Creek in Washington, where the creek splits into two forks. They caught coho salmon that had returned to each fork and plugged the noses of some. When the fish were released downstream, those with clear noses swam back up their own fork. Those with plugged noses chose a fork almost at random.

Between two waters. Salmon are **anadromous**. A female digs a nest called a **redd** in clean stream gravel and lays thousands of eggs. The hatchlings, called alevins, live in the gravel on their yolk sacs. They become fry, then parr with dark marks on their sides. After months or a few years, they turn silver and become **smolts**, and their bodies change so they can live in salt water. They swim to the sea and feed and grow for one to five years before heading home to **spawn**.

Kinds of salmon. In North America there are five Pacific salmon: chinook (or king), coho (silver), sockeye (red), pink and chum. All five die after they spawn once. The Atlantic salmon can return to the sea and spawn again. The biggest is the chinook; the sport-fishing record, caught on Alaska's Kenai River in 1985, weighed 97 pounds 4 ounces. Sockeye turn bright red with green heads as they swim upriver.

The long climb. Out in the ocean, research suggests salmon use the earth's magnetic field to steer back toward the right coast. Near land, smell guides them up the right river and the right branch. They stop eating and live on stored fat. Some chinook in the Yukon River swim nearly 2,000 miles upstream, and Idaho's Redfish Lake sockeye climb about 900 miles and 6,500 feet. They leap waterfalls several feet high and pass dams by **fish ladders**, such as those built at Bonneville Dam on the Columbia River in 1938.

A gift to the forest. After Pacific salmon spawn and die, their bodies feed bears, eagles, wolves, gulls and insects. Bears often carry salmon into the woods to eat, and scientists have found nitrogen from the sea in the trees along salmon streams. Solomon wrote that the rivers return to "the place from whence the rivers come." So do the salmon.

PICTURE STUDY



Salmon (Sake), Takahashi Yuichi, About 1877 · Oil paint · Tokyo University of the Arts (University Art Museum), Tokyo, Japan

Wikimedia Commons · Public domain

Takahashi Yuichi (1828–1894) was one of the first Japanese artists to paint in oils in the Western style. He painted this salted salmon, hung up for winter the way Japanese families stored it, so exactly that the scales and the rough rope look almost real. It is now a national Important Cultural Property of Japan.

Look closely

- Find the rope and how the fish hangs. Why is the painting so tall and narrow?
- Look closely at the skin. How did the painter show scales and shine?
- Find where part of the fish has been cut away. What does it tell you about the people who owned it?

Talk about it

1. Why might an artist choose an everyday thing like a salted fish as a subject?
2. What does this painting tell you about how important salmon were as food?

HANDS-ON: THE LONG WAY HOME: A SALMON MAP AND LIFE CYCLE

Map the journey of Snake River sockeye from the Pacific Ocean to Redfish Lake, Idaho, and draw the salmon life cycle beside it.

You will need

- An atlas or online map of the Pacific Northwest
- Notebook paper or a larger sheet
- Pencil, colored pencils and a ruler

Steps

1. **Map.** Draw the coast of Oregon and Washington and the state of Idaho. Label the Pacific Ocean, the Columbia River, the Snake River, the Salmon River, Portland and Redfish Lake (in the Sawtooth Mountains of Idaho).
2. Draw small bars across the rivers for dams. Label Bonneville Dam (the first dam fish meet, 1938) and add a little staircase symbol beside it for the fish ladder.
3. Draw a red line with arrows from the ocean up the rivers to Redfish Lake. Write beside it: “about 900 miles; climbing about 6,500 feet.”
4. **Life cycle.** Beside the map, draw a circle with arrows and label six stages: eggs in the redd, alevin, fry, parr, smolt (going to sea), adult (returning to spawn).

Check your work

- My map has a title, a compass rose, six place labels and the route.
- My life cycle shows six stages in the right order.
- I can explain how a salmon finds its home stream.

FIELD NOTEBOOK

1. Glue in your salmon map and life cycle.
2. **Notebook entry.** Write a paragraph describing Hasler's Issaquah Creek experiment: the question, what he did, what happened and what it proved.

Did you know? At the Bonneville Dam visitor center, you can watch salmon swim past an underwater window in the fish ladder, and workers count every fish that goes by. Brown bears at Brooks Falls in Katmai National Park, Alaska, stand at the top of a waterfall and catch leaping salmon in their mouths.

Goes deeper in. Life Science, the unit on fish and life cycles (coming soon); Geography, the Pacific Northwest; and Trail F, Stop F7 "Long journeys."

For families. Hasler told the story of his Utah hike in his writings; the Issaquah Creek experiment was published by Wisby and Hasler (1954). Magnetic navigation is supported by studies such as Putman and colleagues (2013) on Fraser River sockeye; it is presented as research, not settled fact. The Kenai River chinook record (97 lb 4 oz, 1985) is the International Game Fish Association record. Redfish Lake figures are from NOAA and Idaho Fish and Game. The marine-nitrogen-in-trees research is from studies in Alaska and British Columbia (e.g., Reimchen; Helfield and Naiman). The medium of Takahashi's painting is given simply as oil; several versions exist.

PRACTICE

1. **EASY** What does anadromous mean?
2. **EASY** Name the five kinds of Pacific salmon in North America.
3. **MEDIUM** In Hasler's experiment, what happened to the salmon with plugged noses, and what did that show?
4. **MEDIUM** How do dead salmon help a forest?
5. **CHALLENGE** A Redfish Lake sockeye swims about 900 miles upstream in about 75 days. About how many miles a day is that? If it climbs 6,500 feet on the way, about how many feet does it climb per mile?

Make it a game • Smell Your Way Home. Put a cotton ball with a different scent (vanilla, lemon, peppermint, cinnamon) in each of four paper cups and set them in four corners of a room. Each player sniffs one scent: that is their "home stream." Then players close their eyes, are turned around gently and, peeking only at the floor, go cup to cup sniffing until they find home. A grown-up watches that no one bumps into furniture.

Scripture. "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again." (Ecclesiastes 1:7, KJV)

Solomon saw the great cycle of water God made. Salmon follow a cycle too, from river to sea and back to the very place they began.

Practice: answers

1. Born in fresh water, grows up in the sea, and returns to fresh water to spawn.
2. Chinook (king), coho (silver), sockeye (red), pink and chum.
3. They chose a fork of the stream almost at random instead of going home. It showed salmon use smell to find their home stream.
4. Bears and other animals carry and eat them in the woods, and their remains add nutrients (such as nitrogen from the sea) to the soil that trees use.
5. $900 \div 75 = 12$ miles a day; $6,500 \div 900 \approx 7$ feet per mile.

4.9 SEALS AND SEA LIONS: THE FIN-FOOTED

OBJECTIVES

- Tell a true seal from a sea lion by its ears, flippers and way of moving.
- Describe how seals dive deep and stay warm.
- Tell how Henry Wood Elliott and the 1911 Fur Seal Treaty helped save the northern fur seal.

Warm-up. Lie on your stomach with your hands at your sides and try to move across the floor without using hands or feet. That is how a true seal gets around on land. Now try on hands and knees. That is closer to a sea lion.

Video slot. Video coming. Seals versus sea lions: how they move on land and in water; elephant seals diving; Pribilof fur seals; sea lions at Pier 39. Search approved channels (NOAA Fisheries, The Marine Mammal Center, National Park Service, Monterey Bay Aquarium); preview first.

KEY TERMS

pinniped

A seal, sea lion or walrus. The word means “fin-footed.”

true seal

A seal with no ear flaps that swims with its hind flippers and wriggles on land, such as a harbor seal or elephant seal.

eared seal

A sea lion or fur seal, which has small ear flaps and can turn its hind flippers forward to walk.

rookery

A beach or island where seals gather in great numbers to have their pups.

treaty

A written agreement between nations.

CORE IDEAS

The story. In 1872, a young artist and naturalist named Henry Wood Elliott sailed to St. Paul Island, a lonely island in the Bering Sea that the United States had acquired with Alaska five years before. Every summer, millions of northern fur seals crowded its beaches to have their pups. Elliott counted them, studied them and painted them in watercolor. When he returned in 1890, he was shocked: the herd had shrunk badly, mostly because ships were shooting seals at sea, where many sank and were lost and many mothers never returned to their pups. Elliott spent the next twenty years writing, speaking and pleading. In 1911, the United States, Great Britain (for Canada), Japan and Russia signed the North Pacific Fur Seal

Convention, which banned hunting fur seals on the open sea. It was one of the first treaties ever made to protect wildlife, and the herd grew several times over in the following decades.

The fin-footed. Seals, sea lions and walruses are **pinnipeds**. There are about thirty-three kinds in three families: the **true seals**, the **eared seals** (sea lions and fur seals) and the walrus alone in its own family.

How to tell them apart. Look at the head: a sea lion has small ear flaps, while a true seal has only a hole. Watch it on land: a sea lion turns its back flippers forward and walks, even climbs stairs, while a seal humps along on its belly like a caterpillar. Watch it swim: a sea lion rows with its long front flippers, while a seal sweeps its back flippers side to side like a fish tail. Sea lions bark loudly; seals are usually quieter.

Champion divers. Pinnipeds stay warm with thick **blubber**, and fur seals also have very dense fur, hundreds of thousands of hairs in every square inch. Before diving, a seal breathes out. Under water, its heart slows to just a few beats a minute, and its blood and muscles hold extra oxygen. Northern elephant seals regularly dive over 1,000 feet, and a southern elephant seal has been recorded at more than 7,000 feet and some dives last nearly two hours. In Antarctica, Weddell seals keep breathing holes open in the ice by scraping them with their teeth.

Neighbors in the city. In January 1990, a few months after a strong earthquake shook San Francisco, California sea lions began climbing onto the boat docks at Pier 39. The marina moved the boats and gave the docks to the sea lions. In November 2009 more than 1,700 were counted there at once. God placed Adam in the garden “to dress it and to keep it.” Caring for creatures like the fur seals is part of that work.

PICTURE STUDY



The Fur Seal Millions, Henry Wood Elliott, 1872 · Watercolor on paper · Anchorage Museum, Anchorage, Alaska (Elliott painted many versions of these scenes)
Wikimedia Commons · Public domain

Henry Wood Elliott (1846–1930) worked for the Smithsonian and the U.S. Treasury in Alaska. In 1872 he painted the fur seals crowding the beaches of the Pribilof Islands and called this picture *The Fur Seal Millions*. His careful watercolors showed Americans who had never left home what the seal rookeries looked like, and they helped him win support to protect the seals.

Look closely

- Find the big males, the smaller females and the pups. How can you tell them apart?
- Look at how crowded the shore is. Try to count the seals in one small area, then guess the total.
- Find the sea and the sky. What is the weather like?

Talk about it

1. Why would a painting help persuade Congress to protect the seals?
2. Elliott was both an artist and a scientist. How does this painting show both?

HANDS-ON: SEAL OR SEA LION? A DIAGRAM AND A MAP

Draw a side-by-side diagram of a harbor seal and a California sea lion, and map the Pribilof Islands.

You will need

- Notebook paper, pencil and colored pencils
- An atlas or online map of Alaska and the Bering Sea
- A ruler

Steps

1. **Diagram.** Draw a harbor seal lying on a rock and a California sea lion standing up on its flippers beside it.
2. Label on the seal: ear hole (no flap), short front flippers with claws, back flippers pointing backward, spotted coat. Label on the sea lion: ear flap, long front flippers, back flippers turned forward under the body, smooth brown coat.
3. Under each animal, draw a small arrow diagram showing how it swims: “rows with front flippers” for the sea lion and “sweeps back flippers side to side” for the seal.
4. **Map.** Draw Alaska, the Bering Sea and the tip of Russia. Label the Aleutian Islands, the Pribilof Islands (St. Paul and St. George) and the North Pacific Ocean. Add a note: “Fur Seal Treaty, 1911.”

Check your work

- My diagram shows at least four differences between a seal and a sea lion.
- My map has a title, a compass rose and five labels.
- I can explain what the 1911 treaty did.

FIELD NOTEBOOK

1. Glue in your seal and sea lion diagram and your Pribilof map.
2. **Notebook entry.** Write a paragraph explaining how Henry Wood Elliott helped the fur seals. Tell what he saw in 1872, what had changed by 1890 and what the treaty of 1911 did.

Did you know? A male northern elephant seal can weigh around 5,000 pounds and has a big, droopy nose like a short trunk. The walrus uses its long tusks to haul itself out of the water onto ice. The leopard seal of Antarctica hunts penguins.

Goes deeper in. Life Science, the unit on mammals (coming soon); Geography, Alaska; History, the purchase of Alaska (1867); and Gardening & Animals, for stewardship.

For families. Elliott first went to St. Paul Island in 1872 and returned in 1890; his early population estimates were later judged too high. The North Pacific Fur Seal Convention was signed July 7, 1911. The herd grew from a low of a few hundred thousand around 1910 to well over a million by the 1940s (NOAA Fisheries); it has since declined again for reasons still studied, so the stop says only that it grew in the following decades. Dive records: southern elephant seal deeper than 2,300 m (about 7,500–7,800 ft). Pier 39 dates and the 2009 count (1,701) are from Pier 39 and The Marine Mammal Center. The

exact title and holding institution of the Elliott watercolor vary by version; search the Smithsonian collections.

PRACTICE

1. **EASY** What does pinniped mean, and which animals are pinnipeds?
2. **EASY** You see an animal on a dock with small ear flaps, standing up on its front flippers. Is it a true seal or a sea lion?
3. **MEDIUM** Name two ways a seal's body helps it dive deep and stay down a long time.
4. **MEDIUM** What did the 1911 North Pacific Fur Seal Convention do, and which nations signed it?
5. **CHALLENGE** A seal's heart beats about 100 times a minute at the surface and about 10 times a minute on a deep dive. How many fewer beats is that in a 20-minute dive, and what fraction of the surface rate is the diving rate?

Make it a game · Seal, Sea Lion or Walrus?. The leader calls out "Seal!", "Sea lion!" or "Walrus!" On "Seal," players lie on their stomachs and wriggle forward. On "Sea lion," they walk on hands and feet and bark. On "Walrus," they hold two fingers down from their mouths like tusks and pull themselves along on their elbows. The leader switches fast; anyone who does the wrong move sits out one round.

Scripture. "And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it." (Genesis 2:15, KJV)

To "keep" means to guard and care for. When nations agreed to stop wasting the fur seals, they were keeping God's creatures as He intended.

Practice: answers

1. "Fin-footed." Seals, sea lions (and fur seals) and walruses.
2. A sea lion (an eared seal).
3. Any two: it breathes out before diving; its heart slows way down; its blood and muscles store extra oxygen; blubber keeps it warm in cold water.
4. It banned hunting fur seals on the open sea. The United States, Great Britain (for Canada), Japan and Russia signed it.
5. Surface: $100 \times 20 = 2,000$ beats; diving: $10 \times 20 = 200$ beats; 1,800 fewer beats. The diving rate is $1/10$ of the surface rate.

4.10 JONAH AND LEVIATHAN: GOD, LORD OF THE SEA

OBJECTIVES

- Retell the book of Jonah in order and find its places on a map.
- Explain what the Bible says about the “great fish” and about leviathan, and how Christians have understood them.
- Explain why Jesus spoke of “the sign of the prophet Jonas.”

Warm-up. Open a map or globe and put one finger on Israel. Move your other finger east to the Tigris River in Iraq, then all the way west to Spain. God sent Jonah one way. Jonah tried to go the other. Read Jonah chapter 1 before you begin.

Video slot. Video coming. The book of Jonah for older children; Nineveh and the Assyrian palace reliefs at the British Museum. Search approved channels (The Bible Project with discernment, Answers in Genesis kids, the British Museum); preview first.

KEY TERMS

prophet

A person God sends to speak His word to people.

Nineveh

A great capital city of the Assyrian empire on the Tigris River, across from today’s Mosul, Iraq.

Tarshish

A far-off port in the west, perhaps in Spain, where Jonah tried to flee.

leviathan

A great, powerful creature of the waters described in Job 41 and the Psalms, made and ruled by God.

repent

To be sorry for sin and turn away from it, back to God.

CORE IDEAS

The story. Jonah, the son of Amittai, was a prophet from Gath-hepher in Galilee who spoke for God in the days of King Jeroboam II of Israel, in the 700s BC (2 Kings 14:25). God told him to go to **Nineveh**, the great city of Assyria, Israel’s fierce enemy, and cry out against its wickedness. Nineveh lay about 550 miles to the northeast. Instead Jonah went down to the port of Joppa and paid for a ship to **Tarshish**, far to the west, perhaps in Spain. God sent a great storm. The sailors cast lots, and the lot fell on Jonah. He told them to throw him into the sea, and the sea grew calm.

The great fish. “Now the LORD had prepared a great fish to swallow up Jonah” (Jonah 1:17). The Hebrew words simply mean “great fish.” In Matthew 12:40, where Jesus speaks of Jonah, the Greek word means a huge sea creature, and the King James translators wrote “whale.” In older times people often called whales fish. The Bible does not name the kind. Some point out that a sperm whale can swallow a giant squid whole (Stop D4). But the book’s own point is that the LORD “prepared” the fish: it was His work. From inside it Jonah prayed, “Salvation is of the LORD” (Jonah 2:9), and after three days and three nights the fish put him out on dry land.

Nineveh repents. Jonah walked into Nineveh crying, “Yet forty days, and Nineveh shall be overthrown.” The king and all the people fasted, put on sackcloth and turned from their violence, and God spared the city. Jonah was angry. God asked him whether He should not spare a city of “more than sixscore thousand persons,” that is, more than 120,000, “and also much cattle” (Jonah 4:11). God cares for people and even for animals. In the 1840s, Austen Henry Layard and others dug up the ruins of Nineveh. One of its two great mounds is still called Nebi Yunus, “the prophet Jonah.”

Leviathan. God also asked Job, “Canst thou draw out **leviathan** with an hook?” (Job 41:1). Job 41 describes a creature with scales sealed tight, a mighty neck, and a strength no man can tame. Psalm 104:26 says God made leviathan “to play” in the sea. Christians have identified it as the crocodile, a great whale or a huge sea creature no longer living. All agree on the lesson: if no man dares stir up leviathan, “who then is able to stand before me?” (Job 41:10).

The sign of Jonah. Jesus spoke of Jonah as a real man and his three days as a sign: “For as Jonas was three days and three nights in the whale’s belly; so shall the Son of man be three days and three nights in the heart of the earth” (Matthew 12:40). Every creature on this trail, from sharks to salmon, obeys its Maker. Only Jonah ran. Yet God, the Lord of the sea, rescued him.

PICTURE STUDY



Jonah and the Whale, Pieter Lastman, 1621 · Oil on oak panel · Museum Kunstpalast, Düsseldorf, Germany
Wikimedia Commons · Public domain

Pieter Lastman was a Dutch painter of Bible stories in Amsterdam and the teacher of the young Rembrandt. Like many artists of his time, he imagined the great fish as a fearsome sea monster. He chose the moment of Jonah 2:10, when “the LORD spake unto the fish, and it vomited out Jonah upon the dry land.”

Look closely

- Find Jonah. What is he doing with his arms, and what does his face show?
- Look at the great fish. Does it look like any real animal you know from this trail?
- Find the land and the sky. Where is the light coming from?

Talk about it

1. Why do you think Lastman painted the fish as a monster rather than a whale or shark?
2. What do you think Jonah is feeling at this moment? Use Jonah 2 to support your answer.

HANDS-ON: MAP OF JONAH’S JOURNEYS

Map every place in the book of Jonah and trace the way he went and the way he was sent.

You will need

- A Bible atlas or online map of the ancient Near East and the Mediterranean
- Notebook paper, pencil and colored pencils (red, blue, green)
- A ruler

Steps

1. Draw the Mediterranean Sea from Spain in the west to Israel in the east, and the land eastward to the Tigris and Euphrates Rivers. Label the Mediterranean (the “Great Sea”), Spain, Israel, Assyria, the Tigris River and the Euphrates River.
2. Mark and label Gath-hepher (Jonah’s hometown in Galilee), Joppa (the port), Tarshish (with a question mark, in southern Spain) and Nineveh (on the Tigris).
3. Draw a **green** arrow from Gath-hepher to Nineveh labeled “Where God sent him.” Draw a **red** dotted arrow from Joppa west toward Tarshish labeled “Where Jonah fled,” and stop it at a wavy storm symbol in the sea.
4. Draw a **blue** arrow from the sea back to the coast and then a green line to Nineveh labeled “Second time” (Jonah 3:1). Add a distance note: Joppa to Nineveh about 550 miles; Joppa to Spain about 2,200 miles.

Check your work

- My map has a title, a compass rose and at least ten labels.
- I used colors to show where God sent Jonah and where he fled.
- I can retell the four chapters of Jonah in order.

FIELD NOTEBOOK

1. Glue in your map of Jonah’s journeys.
2. **Notebook entry.** Write a paragraph answering: “What does the book of Jonah teach about God’s power over creation and His mercy?” Use at least two verses from Jonah and one from Job 41 or Matthew 12.

Did you know? The book of Jonah has only four chapters, and it is the only book of the prophets that ends with a question from God. Carved stone panels from Nineveh’s palaces, showing Assyrian kings, ships and lion hunts, can be seen today at the British Museum in London.

Goes deeper in. History, the ancient Near East and the Assyrian empire (coming soon); Geography, the Middle East; and Literature, for how artists and writers have retold Jonah.

For families. Jonah’s dates follow 2 Kings 14:25 (Jeroboam II reigned roughly 793–753 BC). Tarshish is often identified with Tartessos in southern Spain, but some scholars suggest other places; the stop hedges. Distances are rough straight-line figures. Layard excavated at Nineveh (Kuyunjik) from 1847; Paul-Émile Botta had dug there briefly in 1842. The KJV “whale” in Matthew 12:40 translates Greek *kētos*. Leviathan has been identified by different Christian commentators as the crocodile, a whale or an extinct sea creature; the stop presents these fairly. Popular stories of modern sailors swallowed by whales (such as “James Bartley”) are not reliably documented and are left out on purpose.

PRACTICE

1. **EASY** Where did God send Jonah, and where did Jonah try to go instead?
2. **EASY** According to Jonah 1:17, who prepared the great fish?
3. **MEDIUM** Why does the King James Version say “whale” in Matthew 12:40 but “great fish” in Jonah 1:17?
4. **MEDIUM** What does God’s question to Job about leviathan teach?
5. **CHALLENGE** Jonah 3:3 calls Nineveh “an exceeding great city of three days’ journey.” If a traveler walks about 20 miles a day, how far is a three days’ journey? Then explain in one sentence why Jesus called Jonah a “sign.”

Make it a game • Jonah in Order. Write these on ten cards and shuffle them: God calls Jonah; Jonah goes to Joppa; the storm; the sailors cast lots; Jonah is thrown into the sea; the great fish; Jonah prays; the fish puts Jonah on land; Nineveh repents; the gourd and God’s question. Race a family member or a timer to lay them in order. Then try it again, saying the verse reference for each card.

Scripture. “Now the LORD had prepared a great fish to swallow up Jonah. And Jonah was in the belly of the fish three days and three nights.” (Jonah 1:17, KJV)

The sea, the storm and the great fish all obeyed God. Jonah’s rescue points to a greater rescue: Jesus, who rose from the dead after three days.

Practice: answers

1. God sent him to Nineveh in Assyria; Jonah tried to sail to Tarshish, far to the west.
2. The LORD.
3. Jonah uses Hebrew words meaning “great fish”; Matthew uses a Greek word for a huge sea creature, which the translators rendered “whale.” The Bible does not name the exact kind, and in older times whales were often called fish.
4. No man can capture or tame leviathan, but God made it and rules it; if we cannot stand before His creature, we cannot stand against God Himself (Job 41:10). It teaches humility and trust.
5. $3 \times 20 = 60$ miles (many think this means the greater Nineveh region or the time needed to go through it). Jesus said that as Jonah was three days and nights in the great fish, He would be three days and nights in the earth and then rise (Matthew 12:40).

TRAIL 4 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in full sentences where possible, then checks with a parent. Four right out of five earns the first badge; five right out of six earns the second. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1–5)

1. What are the ampullae of Lorenzini, and how do they help a shark hunt?
2. Why can an octopus squeeze through a tiny hole, and why is its blood blue?
3. What two living things work together to build a coral reef, and what does each give the other?
4. When and where was a living giant squid first photographed in the deep sea?
5. Give three reasons a dolphin is a mammal and not a fish.

Badge quiz 2 (Stops 6–10)

6. Name the stages of the jellyfish life cycle in order.
7. How does a deep-sea anglerfish catch food in total darkness?
8. Who reached the bottom of the Challenger Deep in 1960, and about how deep is it?
9. How do salmon find their way back to their home stream?
10. Name two ways to tell a sea lion from a true seal, and tell what the 1911 Fur Seal Treaty did.
11. What did Jesus mean by “the sign of the prophet Jonas” (Matthew 12:39–40)?

TRAIL CERTIFICATE: MY OCEAN FIELD NOTEBOOK AND TRAIL D CERTIFICATE

Gather your Field Notebook pages from this trail into one booklet with a cover: “My Ocean Field Notebook,” your name and the dates you started and finished.

Make sure it holds at least five maps or diagrams (for example, the shark size scale, the reef map, the ocean zones column, the salmon route and the map of Jonah’s journeys) and a notebook paragraph for every stop.

Add a final page: a timeline of the ocean discoveries on this trail, from Lorenzini (1678) and Cook (1770) to Beebe (1934), the Trieste (1960) and the first giant squid photographs (2004).

When the booklet is done, a parent reviews it with the rubric and signs the Trail D certificate.

- **Ten stops:** A page for each stop, each with a title, a date and a paragraph of five to seven sentences in the student’s own words.
- **Maps and diagrams:** At least five maps or diagrams with titles, labels and a compass rose or scale where needed.

- **Accurate facts:** Names, dates and numbers match the stops, and the timeline is in the right order.
- **Care and Scripture:** Work is neat and complete, and at least one page explains a verse from the trail in the student's own words.

Answer key

1. Jelly-filled pores on a shark's snout that sense the faint electricity made by living animals; they let a shark find prey hidden in sand or dark water.
2. It has no bones; its only hard part is its beak. Its blood uses hemocyanin, which contains copper and looks blue.
3. Coral polyps and zooxanthellae (algae). The algae make food from sunlight for the polyps; the polyps give the algae a safe home.
4. In 2004 (September 30), off the Ogasawara Islands of Japan, by Tsunemi Kubodera and Kyoichi Mori.
5. Any three: it breathes air through a blowhole; it is warm-blooded; it has live young; it feeds its young milk; its tail moves up and down.
6. Medusa (adult), eggs and sperm, planula (larva), polyp, strobila, ephyra, and back to medusa.
7. It dangles a glowing lure (lit by bacteria) on a spine above its mouth; small fish swim toward the light, and it swallows them with its huge mouth.
8. Jacques Piccard and Don Walsh in the Trieste; nearly 36,000 feet, almost seven miles.
9. At sea they likely steer by the earth's magnetic field; near land they follow the smell of their home stream, as Arthur Hasler's experiments showed.
10. A sea lion has ear flaps, walks on its turned-forward back flippers and swims with its front flippers; a seal has no ear flaps, wriggles on land and swims with its back flippers. The treaty banned hunting fur seals on the open sea.
11. As Jonah was three days and three nights in the great fish, Jesus would be three days and three nights in the earth and then rise again.

ANIMALS TRAIL E: INSECTS AND SMALL CREATURES

The fifth trail of the Animals track gets down on hands and knees with the small creatures: the ant of Proverbs 6, the honeybee and its dance, the migrating monarch, the silk-spinning spider, the beetle in its hundreds of thousands of kinds, the firefly's cold light, the dragonfly, the locusts of the eighth plague in Exodus 10, Jean-Henri Fabre the insect watcher, and a bug hotel built at home. Each stop has a true story, key terms, a picture to study, a hands-on project, a notebook entry, practice questions, a game and a verse of Scripture.

This is the  **Ranger** level, for ages 10 to 13. The student reads each stop alone, in about 25 to 35 minutes. Ranger stops give more facts, numbers and dates than the Scout stops, and every stop asks for a map or labeled diagram and a written paragraph in the Field Notebook. Practice questions run from easy to challenge, and most stops send the student outdoors to watch real creatures, as Solomon said: "Go to the ant ... consider her ways."

Five stops earn the **Insect Ranger badge, part 1**, and ten stops earn part 2 and the **Trail E certificate**. The two badge quizzes at the end of the trail are optional; badges are earned by doing the stops.

BEFORE YOU BEGIN

- Read a page of about 500 words alone and retell it in your own words.
- Use a ruler in centimeters and inches, and find North America, Europe, Africa, Egypt and the Red Sea on a map.

MASTERY CHECKLIST

- ☐ I can tell an insect (six legs, three body parts, antennae) from a spider (eight legs, two body parts, no antennae) and explain complete and incomplete metamorphosis.
- ☐ I can explain how ants, bees and fireflies send messages: scent trails, the waggle dance and flash patterns.
- ☐ I can trace the monarch migration on a map of North America and the winds of the eighth plague on a map of Egypt.
- ☐ I can tell the story of Jean-Henri Fabre and carry out a simple observation and experiment of my own.
- ☐ I can plan, build and care for a bug hotel and explain how it shows good stewardship of creation (Genesis 2:15).

OPTIONAL BOOKS AND RESOURCES

- **BugGuide (Iowa State University)** (<https://bugguide.net>): Free photo guide to insects and spiders of North America; good for identifying what you find in the beetle survey and bug hotel.

- **Monarch Watch (University of Kansas)** (<https://monarchwatch.org>): Free monarch life-cycle and migration information and a fall tagging program families can join (tag kits are sold separately).
- **Project Gutenberg: Jean-Henri Fabre** (<https://www.gutenberg.org>): Fabre's insect books in English, free: *The Life of the Spider*, *The Life of the Caterpillar*, *The Mason-Bees* and more (Stop E9).
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free scans of Maria Sibylla Merian's *Metamorphosis insectorum Surinamensium* (1705) and Moses Harris's *The Aurelian* (1766) to copy in the Field Notebook.

5.1 ANTS: “GO TO THE ANT, THOU SLUGGARD”

OBJECTIVES

- Name the body parts of an ant and tell the jobs of the queen, the workers and the males in a colony.
- Explain how ants use scent trails to find food and lead their nest-mates to it.
- Read Proverbs 6:6–8 and explain what Solomon wanted the lazy person to learn from the ant.

Warm-up. Put one crumb of cookie or a drop of honey on a sidewalk near an ant hill and set a timer. How many minutes until the first ant finds it? How many ants are there after ten more minutes? Write both numbers down; you will use them in the project.

Video slot. Video coming. Ant colonies: harvester ants storing seeds, leafcutter ants farming fungus, ants following scent trails. Search approved channels (BBC Earth, PBS Nature, Smithsonian, National Geographic Kids); preview first.

KEY TERMS

colony

A large family of ants (or bees, wasps or termites) that live and work together in one nest.

queen

The ant that lays the eggs for the colony. She does not give orders; her work is to lay eggs.

worker

A wingless female ant that gathers food, digs, cleans, guards and cares for the young.

pheromone

A scent chemical an animal gives off to send a message to others of its kind, such as “food this way” or “danger.”

petiole

The thin “waist” between an ant’s thorax and its rounded abdomen (also called the gaster).

CORE IDEAS

Solomon’s schoolroom. About three thousand years ago King Solomon wrote a lesson for lazy people, and he did not send them to a teacher. He sent them to an insect: “Go to the ant, thou sluggard; consider her ways, and be wise” (Proverbs 6:6). He added that the ant has “no guide, overseer, or ruler,” yet “provideth her meat in the summer, and gathereth her food in the harvest” (6:7–8). In the land of Israel, harvester ants of the genus *Messor* still carry grass seeds home in long lines and store them in underground rooms called granaries.

Doubters and a careful watcher. For a long time some European naturalists doubted that ants really stored grain. The ants they knew in northern Europe did not. Then in the early 1870s an English naturalist named J. Traherne Moggridge, living near Menton on the coast of southern France, dug into harvester ant nests. He found chambers packed with seeds and watched ants carry them in. His book *Harvesting Ants and Trap-door Spiders* (1873) showed that Solomon had been right all along.

How an ant is made. An ant has three main body parts: the **head**, with jaws called mandibles and bent “elbowed” antennae; the **thorax**, where all six legs attach; and the **abdomen**, joined to the thorax by a narrow waist, the **petiole**. Scientists have named more than 14,000 kinds of ants. Many workers can lift 10 to 50 times their own weight. If you could do that, you could carry a small car.

A family, not a kingdom. A colony may have a few dozen ants or millions. The **queen** lays the eggs, sometimes for many years. Nearly every ant you see is a **worker**, a wingless female. The workers take turns at jobs: younger ones often nurse eggs and young inside the nest, while older ones go out to gather food. Winged males appear only at certain seasons to mate with young queens. Solomon was right again: no ant gives orders. Each worker does the next job in front of it.

Talking with scent. When a scout ant finds food, she hurries home and touches her abdomen to the ground now and then, leaving a trail of **pheromone**. Other workers smell it with their antennae and follow. Each one that finds food adds more scent on the way back, so a good food source quickly gets a busy highway. When the food is gone, no one adds scent, the trail fades, and the ants stop coming. This is why a line of ants on a kitchen counter can appear in a few minutes.

The lesson. Solomon did not praise ants for being strong or clever. He praised them for working ahead. They store food in summer while the weather is good, so they will have enough when it is not. That is the wisdom of the ant: do today’s work today, without someone standing over you.

PICTURE STUDY



The Ant and the Grasshopper, from *The Aesop for Children*, Milo Winter, 1919 · Color illustration for a printed book · From *The Aesop for Children* (Rand McNally, Chicago, 1919); copies at the Library of Congress and online at Project Gutenberg
Wikimedia Commons · Public domain

Aesop's old fable tells of a grasshopper who sang all summer while the ants stored food. When winter came, he went hungry. The American illustrator Milo Winter drew this picture for a children's book of Aesop's fables in 1919. The fable teaches the same lesson as Proverbs 6, though it comes from ancient Greece, not the Bible.

Look closely

- Find the grasshopper. How does he look different from the ants?
- Look at the ants. What are they doing with their bodies and hands?
- Find clues in the picture that tell you how each character spent the summer.

Talk about it

1. Real ants do not wear clothes or talk. Why do you think fable artists draw them like people?
2. How is the lesson of this fable like Proverbs 6:6-8? Is there anything the Bible says that the fable leaves out?

HANDS-ON: MAP AN ANT HIGHWAY

Watch a real ant trail form and make a scale map of it, the way a field scientist would.

You will need

- A small bait: a crumb of cookie, a dab of honey on a bottle cap, or a piece of tuna
- A sidewalk or patio near an ant nest
- Sidewalk chalk
- A tape measure or ruler
- A timer, pencil and graph paper

Steps

1. Find an ant nest entrance (a small hole, often with a ring of loose soil). Mark it with a chalk X.
2. Set the bait about 1 meter (3 feet) from the nest. Start the timer and record the time the first ant arrives.
3. Every 5 minutes for 20 minutes, count the ants on the bait and write the number in a table.
4. When a trail has formed, follow it with chalk dots every 10 centimeters. Is the path straight, or does it bend around cracks and pebbles?
5. Gently rub out a short piece of the trail with your finger or a wet cloth. Watch what the ants do at the gap for two minutes.
6. Draw a map on graph paper: one square = 10 centimeters. Mark the nest, the bait, the trail, the gap you made, and any obstacles. Add a title, a scale and a north arrow.

Check your work

- My table shows ant counts at 0, 5, 10, 15 and 20 minutes.
- My map has a title, a scale, a north arrow, the nest, the bait and the trail.
- I can explain what the ants did at the gap and why (the scent was broken).

FIELD NOTEBOOK

1. **Diagram.** Draw a large worker ant from the side. Label: head, mandibles, antennae, compound eye, thorax, six legs, petiole (waist) and abdomen (gaster).
2. **Notebook entry.** Write a paragraph (5–7 sentences): what you saw at the bait, how fast the trail formed, what happened at the gap, and one way you can “consider her ways” this week.

Did you know? Leafcutter ants of Central and South America do not eat the leaves they carry. They chew them into a mulch and grow a fungus garden on it, and the fungus is their food. A large leafcutter nest can have millions of ants and reach several meters underground. Weaver ants of Asia and Africa sew leaves together into nests using silk from their own larvae, holding the larvae like little glue tubes.

Map or diagram. Draw a cross-section of an ant nest, as if you sliced the ground like a cake: the entrance mound, tunnels, a granary room full of seeds, a nursery room with eggs and larvae, and the queen’s room deepest down. Label each room.

Goes deeper in. Life Science, the unit on insects and social insects (coming soon); and Literature, for Aesop's fables and the Book of Proverbs.

For families. Moggridge's *Harvesting Ants and Trap-door Spiders* was published in London in 1873; earlier writers such as Pierre Huber had doubted that ants store grain because northern European species do not. The count of named ant species (over 14,000) comes from AntWiki and the AntCat catalog and rises every year. Lifting figures (10–50 times body weight) vary by species. Fire ants in the southern United States sting painfully; check the nest is not a fire ant mound before the project, and keep hands off the trail itself.

PRACTICE

1. **EASY** Name the three main body parts of an ant and say which one the legs are attached to.
2. **EASY** Which ants in a colony are the workers, and what is the queen's main job?
3. **MEDIUM** Why does an ant trail to a food source disappear after the food is gone?
4. **MEDIUM** Proverbs 6:7 says the ant has "no guide, overseer, or ruler." Is that true of a real colony? Explain using the word queen.
5. **CHALLENGE** A worker ant weighs 5 milligrams and carries a seed 20 times her weight. How much does the seed weigh? If a 40-kilogram student could do the same, how much could the student carry?

Make it a game • Follow the Scent. One player (the scout) walks a winding path around the yard or house, dropping a small paper scrap every few steps, and ends at a "food" spot with a snack. The other players (workers) start at the "nest" and must follow the trail only by finding scraps. Each worker who reaches the food drops one more scrap on the way back. Then pick up the first few scraps and see whether the later players can still find the way.

Scripture. "Go to the ant, thou sluggard; consider her ways, and be wise:" (Proverbs 6:6, KJV)

"Consider" means to look closely and think. Solomon sends us outdoors to study God's creatures and learn from them. The ant teaches diligence: doing the work in front of us, without being told, while there is still time.

Practice: answers

1. Head, thorax and abdomen. All six legs attach to the thorax.
2. The workers are wingless females. The queen's main job is to lay eggs.
3. Ants only add pheromone on the way back from food they found. When the food is gone, no one renews the scent, it fades, and the ants stop following it.
4. Yes. The queen lays eggs but does not give orders. Each worker responds to what is in front of her (scents, food, young needing care) without a boss directing her.

5. The seed weighs $5 \times 20 = 100$ milligrams. The student could carry $40 \times 20 = 800$ kilograms, about the weight of a small car.

5.2 HONEYBEES: THE DANCE AND THE COMB

OBJECTIVES

- Describe the jobs a worker honeybee does at different ages.
- Explain how the waggle dance tells other bees the direction and distance of flowers.
- Explain why honeycomb cells are six-sided and how bees turn nectar into honey.

Warm-up. Taste a little honey slowly. Now think: a single worker bee makes only about one-twelfth of a teaspoon of honey in her whole life. How many bees worked to fill the spoon you just licked? (About twelve.)

Video slot. Video coming. The honeybee waggle dance, inside an observation hive, building wax comb. Search approved channels (PBS Nature, BBC Earth, Smithsonian, a state university extension beekeeping program); preview first.

KEY TERMS

drone

A male honeybee. Drones do not gather food or sting; their job is to mate with a young queen.

nectar

The sweet liquid flowers make. Bees gather it and turn it into honey.

pollen

The fine powder made by flowers. Bees eat it for protein and carry it from flower to flower, which helps plants make seeds and fruit.

waggle dance

A figure-eight dance a forager bee does on the comb to show other bees which way and how far to fly to find food.

comb

Sheets of six-sided wax cells that bees build to raise young and store honey and pollen.

CORE IDEAS

A city of sisters. In summer a strong honeybee hive may hold 20,000 to 60,000 bees or more. There is one queen, a few hundred male drones, and tens of thousands of female workers. The queen may lay over 1,500 eggs a day at the height of summer. A summer worker lives only about five or six weeks, and in that short life she works through a series of jobs: cleaning cells, feeding young as a nurse bee, making wax and building comb, guarding the entrance, and finally, in her last two or three weeks, flying out to gather nectar and pollen.

Six sides. Workers make wax from glands on the underside of their abdomens and shape it into **comb**. Every cell is a hexagon. Circles would leave wasted gaps between them, and squares or triangles would need more wax for the same space. In 1999 the mathematician Thomas Hales proved what people had long suspected: a hexagon grid divides a flat surface into equal rooms using the least wall. The bees have been building it that way from the beginning.

The dance. How does one bee tell thousands of others where the clover is? The Austrian scientist Karl von Frisch spent years watching bees in glass-walled hives and marking them with dots of paint. He found that a returning forager runs in a straight line on the comb while wagging her body, then circles back and repeats in a figure eight. The **angle** of the straight run, measured from straight up, matches the angle between the sun and the food. The **length** of the waggle tells distance: the longer the waggle, the farther the flowers. Von Frisch shared the Nobel Prize in 1973 for this work.

From nectar to honey. A forager sips **nectar** into her honey stomach and carries it home. House bees pass it mouth to mouth, adding enzymes, and spread it in cells. Then they fan their wings until most of the water evaporates, leaving honey that is only about 17 to 18 percent water. They cap the cell with wax. Honey stored this way keeps for a very long time. To make one pound, bees together may visit around two million flowers.

Bees and people. Honeybees are not native to the Americas; English colonists brought hives to Virginia in the 1620s. In 1852 a Pennsylvania pastor, the Rev. Lorenzo Langstroth, patented a hive with wooden frames that hang a set space apart, about three-eighths of an inch. Bees leave that “bee space” open instead of gluing it shut, so beekeepers can lift out frames without breaking the comb. Most hives today still use his design. And as bees carry **pollen** between blossoms, they help apples, almonds, blueberries and many other crops bear fruit.

PICTURE STUDY



The Beekeepers, Pieter Bruegel the Elder, about 1568 · Pen and brown ink on paper · Kupferstichkabinett, Staatliche Museen zu Berlin
Wikimedia Commons · Public domain

Pieter Bruegel the Elder was a Flemish artist who loved to draw ordinary country work. In this drawing, three beekeepers in heavy clothes and masks woven like baskets tend straw hives called skeps. Old skeps had no frames, so honey was often taken by cutting out the comb.

Look closely

- Find the woven masks. Why do you think the beekeepers covered their faces completely?
- Count the straw hives (skeps). What is each beekeeper doing with one?
- Find the boy in the tree. What might he be watching or looking for?

Talk about it

1. Compare a straw skep with a Langstroth hive. Which would make it easier to check on the bees without harming them, and why?
2. Bruegel did not show any faces. How does that change the feeling of the drawing?

Safety first. Do not go near a beehive or a swarm unless a beekeeper is with you and you are wearing protective gear. Anyone allergic to bee stings must stay away from hives and keep their medicine close. Watch a bee on a flower; do not swat or touch it.

HANDS-ON: READ A WAGGLE DANCE

Use a protractor and a diagram to decode bee dances, then write a dance of your own.

You will need

- A protractor and ruler
- Paper and a pencil
- A compass or a phone compass app
- A sunny window or yard, with a parent

Steps

1. Draw a vertical arrow pointing up the page and label it “Up on the comb = toward the sun.”
2. Dance 1: a bee waggles straight up. Which way should the others fly? (Straight toward the sun.) Draw it.
3. Dance 2: a bee waggles 60° to the right of straight up. Use the protractor to draw that line. Below it, draw the sun and a flower patch 60° to the right of the sun as seen from the hive.
4. Dance 3: a bee waggles straight down. Where are the flowers? (Directly away from the sun.)
5. Outdoors, note where the sun is right now. Pick a real tree or flower bed. Estimate its angle from the sun and draw the waggle dance a bee would do to send her sisters there.
6. Make a key: a short waggle line = near, a long waggle line = far. Add a title and label the sun, the hive and the flowers on each diagram.

Check your work

- I drew and labeled three dance diagrams with angles measured by protractor.
- I designed one dance for a real place near my home.
- I can explain what the angle and the length of the waggle tell the bees.

FIELD NOTEBOOK

1. **Diagram.** Draw a section of honeycomb with seven hexagon cells. Label one cell each: egg, larva, capped brood, pollen, uncapped honey and capped honey. Next to it, draw a worker bee and label head, thorax, abdomen, four wings, pollen basket on the hind leg, and stinger.
2. **Notebook entry.** Write a paragraph about the life of one worker bee, from cleaning cells to flying out as a forager, using at least four facts from the story.

Did you know? A worker honeybee’s stinger has barbs, so if she stings a person, it often stays in the skin and she dies. The queen’s stinger is smooth, and drones have no stinger at all. Bees flap their wings about 200 times a second, which is what makes the buzz.

Honey found sealed in ancient Egyptian tombs was still recognizable as honey when it was opened.

Map or diagram. Make a map of your yard or a park with the “hive” at the center. Mark three flowering plants. Using the sun’s position at noon, draw the waggle dance line for each one.

Goes deeper in. Gardening & Animals, the units on pollinators and keeping bees (coming soon); Life Science, social insects; and Arithmetic, angles and the protractor.

For families. Colony and egg-laying figures vary with season and source; the ranges here follow university extension programs. Von Frisch shared the 1973 Nobel Prize in Physiology or Medicine with Konrad Lorenz and Nikolaas Tinbergen. Hales’ “honeycomb conjecture” proof was published in 2001 after he announced it in 1999. Langstroth’s U.S. patent is dated October 5, 1852. The “two million flowers per pound” figure is a common estimate and should be taught as approximate. Bruegel’s drawing has an inscription in old Dutch about the one who finds a nest and the one who takes it; scholars debate its meaning.

PRACTICE

1. **EASY** Name the three kinds of honeybees in a hive and one job of each.
2. **EASY** Why do bees build six-sided cells instead of round ones?
3. **MEDIUM** A forager’s waggle run points 90° to the left of straight up. Where should the other bees fly?
4. **MEDIUM** What two things do bees do to nectar to turn it into honey?
5. **CHALLENGE** One worker makes about 1/12 teaspoon of honey in her life. A pound of honey is about 96 teaspoons. About how many worker lifetimes does it take to make one pound?

Make it a game • Waggle to the Treasure. Hide a small treat outdoors. The “forager” who hid it may not talk or point. Instead, standing at the “hive,” the forager walks a short straight line in the direction of the treat while wiggling, then loops back and repeats: a longer wiggle for farther away. The other players try to find the treat from the dance alone. Take turns being the forager.

Scripture. “How sweet are thy words unto my taste! yea, sweeter than honey to my mouth!” (Psalm 119:103, KJV)

Honey was the sweetest food the psalmist knew. Bees gather it a drop at a time from countless flowers. In the same way, a person who reads God’s Word day by day stores up something sweeter and more lasting.

1. Queen: lays eggs. Workers (females): clean, nurse young, build comb, guard and gather food. Drones (males): mate with a young queen.
2. Hexagons fit together with no gaps and hold the most honey for the least wax.
3. At a right angle to the left of the sun's direction (90° to the left of the sun, as seen from the hive).
4. They add enzymes as they pass it from bee to bee, and they fan their wings to evaporate most of the water. Then they cap the cell with wax.
5. $96 \times 12 = 1,152$, so roughly 1,150 bees working their whole lives.

5.3 MONARCH BUTTERFLIES: THE LONG WAY SOUTH

OBJECTIVES

- Name and describe the four stages of a monarch's life (complete metamorphosis).
- Explain why monarchs need milkweed and how it protects them from birds.
- Trace the eastern monarch migration on a map and tell how the wintering grounds in Mexico were found.

Warm-up. Hold a paper clip in your hand. A monarch butterfly weighs about half a gram, about the same as a small paper clip. Yet some monarchs fly as far as 3,000 miles each fall. Guess how many miles a day a monarch might travel, and write down your guess.

Video slot. Video coming. Monarch butterfly life cycle (caterpillar to chrysalis to butterfly) and the overwintering colonies in Mexico. Search approved channels (PBS Nature, Smithsonian, U.S. Forest Service, Monarch Watch); preview first.

KEY TERMS

metamorphosis

A complete change of body form as an animal grows. A monarch goes from egg to caterpillar (larva) to chrysalis (pupa) to adult.

larva

The young, worm-like stage of an insect that goes through metamorphosis; a butterfly larva is a caterpillar.

chrysalis

The hard case a butterfly caterpillar forms around itself; inside, its body is rebuilt into a butterfly. Also called the pupa.

host plant

The plant a caterpillar must eat. For the monarch, it is milkweed and nothing else.

migration

A long journey animals make at the same season each year, usually to find food or a better climate.

CORE IDEAS

Four lives in one. A monarch begins as a cream-colored egg about the size of a pinhead, laid on the underside of a milkweed leaf. In about four days a tiny striped caterpillar chews its way out and eats its own eggshell. For the next two weeks it does almost nothing but eat milkweed, shedding its skin four times as it grows through five stages called instars, and ending up about 2,000 times heavier. Then it hangs upside down in a “J,” splits its skin one last time, and becomes a jade-green **chrysalis** dotted with gold. Inside, over about ten days,

the caterpillar's body is broken down and rebuilt into wings, long legs, compound eyes and a coiled drinking tube. This is **complete metamorphosis**.

Poison by design. Milkweed sap contains bitter chemicals called cardenolides that make many animals sick. The monarch caterpillar is not harmed by them. It stores them in its body, and they stay in the adult butterfly. A bird that eats a monarch usually vomits and learns quickly to leave orange-and-black butterflies alone. The bright colors are a warning sign. That is why the female will lay eggs only on milkweed, its one **host plant**.

The great journey. Monarchs born in summer live only two to six weeks. But the generation that comes out of the chrysalis in late summer is different. These butterflies do not lay eggs right away. They fly south, sometimes 25 to 30 miles a day or more, gliding on rising warm air. Eastern monarchs from Canada and the United States funnel through Texas into the mountains of central Mexico. Western monarchs winter along the California coast. The fall migrants can live eight or nine months. In spring they fly north and lay eggs, and it takes three or four generations to get back to Canada. No monarch ever makes the full round trip, yet the great-great-grandchildren find the same mountains.

The secret forest. For decades no scientist knew where the eastern monarchs went. Canadian zoologist Fred Urquhart and his wife Norah began a tagging program, with volunteers sticking tiny labels on monarch wings. In 1973 they asked for helpers in a Mexican newspaper, and Ken Brugger, an American living in Mexico, answered. On January 2, 1975, Brugger and his wife Catalina Aguado climbed a high mountain west of Mexico City and found fir trees covered by millions of monarchs, so thick that branches bent under them. The Urquharts told the world in *National Geographic* in August 1976.

How do they know the way? Monarchs steer by the sun, using an inner clock to correct for its movement across the sky. Scientists found in 2009 that part of this clock is in their antennae. They seem to sense the earth's magnetism too. People can help by planting milkweed and nectar flowers, a simple way to "dress and keep" the garden God gave us.

PICTURE STUDY



*A plate from The Aurelian, or Natural History of English Insects, Moses Harris, 1766 · Hand-colored engraving · From The Aurelian (London, 1766); copies in the Biodiversity Heritage Library
Wikimedia Commons · Public domain*

Moses Harris was an English insect collector and engraver. “Aurelian” was the old English word for a butterfly collector, from the Latin for gold, because some chrysalises shine like gold. Like Maria Sibylla Merian before him, Harris showed each insect’s whole life on its food plant: caterpillar, chrysalis and adult on one page. Monarchs do not live in England, but the plates show the same four-stage life you are studying.

Look closely

- Find every stage you can: egg, caterpillar, chrysalis and adult. Point to each.
- Find the food plant. How did Harris show that the caterpillars were eating it?
- Compare the colors of the caterpillar and the adult. Would you guess they were the same animal?

Talk about it

1. Why is it useful for a scientist to draw an insect on its food plant instead of alone on a blank page?
2. Harris made his engravings by hand before cameras existed. What would he have had to do to draw a chrysalis accurately?

HANDS-ON: MAP THE MONARCH HIGHWAY

Draw a map of the eastern monarch migration and calculate how long the trip takes.

You will need

- A blank outline map of North America (print one free, or trace from an atlas)
- Colored pencils (orange and green especially)
- A ruler and the atlas map scale
- A calculator (optional)

Steps

1. Label Canada, the United States, Mexico, the Great Lakes, the Rocky Mountains, the Gulf of Mexico and the Pacific Ocean.
2. Mark a star in central Mexico for the overwintering forests (the mountains where the states of Michoacán and México meet, west of Mexico City). Mark a second star on the California coast for the western monarchs.
3. With orange arrows, draw the fall route: from southern Ontario and the Great Lakes, southwest across the Great Plains, through Texas, into central Mexico.
4. With green arrows, draw the spring return in three steps, one arrow per generation: Mexico to Texas, Texas to the central states, central states to Canada.
5. Use the map scale to measure the fall route from Toronto to the star in Mexico. Divide by 30 miles a day. How many days would the trip take?
6. Add a title, a key for the orange and green arrows, a north arrow and a scale.

Check your work

- My map shows both routes with a key, a north arrow and a scale.
- I measured the distance and calculated the number of days.
- I can explain why no single monarch makes the round trip.

FIELD NOTEBOOK

1. **Diagram.** Draw the monarch life cycle as a circle with four labeled pictures: egg on a milkweed leaf, caterpillar, chrysalis, adult. Write the number of days for each stage beside it (egg about 4, caterpillar about 14, chrysalis about 10, adult 2–6 weeks or 8–9 months for migrants).
2. **Notebook entry.** Write a paragraph telling the story of the 1975 discovery in your own words, and end with one question you would still like answered about how monarchs find their way.

Did you know? The viceroy butterfly looks so much like a monarch that birds often leave it alone too. Scientists have found that viceroys taste bad to birds as well, so each look-alike protects the other. You can tell a male monarch from a female: the male has a small black spot on a vein of each hind wing, and the female's black veins are thicker.

Goes deeper in. Life Science, insect life cycles and metamorphosis; Geography, North America map skills; and Gardening & Animals, planting for pollinators (coming soon).

For families. The Urquharts' tagging began in the 1940s and grew into the Insect Migration Association; Ken Brugger and Catalina Aguado found the Cerro Pelón colony on January 2, 1975, and Fred Urquhart's article appeared in *National Geographic* in August 1976. The antennal clock finding is Merlin, Gegear and Reppert, *Science* (2009). Distances and daily mileage vary widely by year and individual; Monarch Watch (University of Kansas) runs a fall tagging program families can join. Conservation is presented here as stewardship: planting native milkweed is a practical way to help.

PRACTICE

1. **EASY** List the four stages of a monarch's life in order.
2. **EASY** What is the only plant monarch caterpillars eat?
3. **MEDIUM** How does eating milkweed protect a monarch from birds?
4. **MEDIUM** Who found the monarchs' winter forest in Mexico, and in what year?
5. **CHALLENGE** A monarch flies 2,400 miles from Ontario to Mexico at an average of 30 miles a day. How many days does the trip take? About how many weeks?

Make it a game • Generation Relay. Set four stations across a yard: Mexico, Texas, Kansas and Canada. Player 1 (a monarch) starts at Mexico and runs to Texas, then "lays an egg" by tagging Player 2, who runs to Kansas and tags Player 3, who runs to Canada. Then Player 4, the "super generation," must run the whole way back to Mexico alone. Time each round and try to beat it.

Scripture. "Therefore if any man be in Christ, he is a new creature: old things are passed away; behold, all things are become new." (2 Corinthians 5:17, KJV)

A caterpillar does not just grow bigger; it is made into something new. Christians have long seen in this a picture of what God does in a person who trusts Christ: not a patched-up old life, but a new creation.

Practice: answers

1. Egg, caterpillar (larva), chrysalis (pupa), adult butterfly.
2. Milkweed.
3. Milkweed has bitter poisons (cardenolides). The caterpillar stores them, and they stay in the adult, so a bird that eats one gets sick and learns to avoid orange-and-black butterflies.
4. Ken Brugger and Catalina Aguado, on January 2, 1975, working with Fred and Norah Urquhart's tagging program.
5. $2,400 \div 30 = 80$ days, a little over 11 weeks.

5.4 SPIDERS: SILK SPINNERS

OBJECTIVES

- Explain why a spider is an arachnid and not an insect.
- Describe how an orb weaver builds its web and what different kinds of silk are for.
- Identify the two dangerous spiders of North America and practice safe spider watching.

Warm-up. Go outside early in the morning, or mist a bush lightly with a spray bottle. Look for webs sparkling with drops. How many webs can you find in five minutes? Are they all the same shape?

Video slot. Video coming. An orb weaver spider building its web step by step; jumping spiders; spiderlings ballooning. Search approved channels (BBC Earth, PBS Nature, Smithsonian, a state university extension entomology program); preview first.

KEY TERMS

arachnid

An animal with eight legs, two main body parts and no antennae or wings, such as a spider, scorpion, tick or mite.

cephalothorax

The front body part of a spider, where the head and thorax are joined; the eyes, fangs and all eight legs attach here.

spinneret

A small finger-like nozzle at the tip of a spider's abdomen that pulls out silk.

orb web

A round, wheel-shaped web with spokes and a sticky spiral.

venom

A poison an animal injects with a bite or sting. Spiders use it to stop their prey; only a few kinds can seriously harm people.

CORE IDEAS

Not an insect. A spider is often called a bug, but count its legs: eight, not six. It has two body parts instead of three, the **cephalothorax** and the abdomen. It has no antennae and no wings, and most spiders have eight simple eyes. Spiders belong to the **arachnids**, with scorpions, ticks and mites. Scientists have named about 50,000 kinds. They live on every continent except Antarctica.

Silk factories. At the end of the abdomen are **spinnerets**, fed by silk glands inside. Silk starts as a liquid and hardens as the spider draws it out. A single spider can make several

kinds: a strong dragline it trails behind it like a climber's safety rope, dry silk for frames and spokes, sticky silk for catching, soft silk for egg sacs, and wrapping silk for prey. Dragline silk is, for its weight, stronger than steel and far stretchier, and engineers have tried for years to copy it.

Building an orb. An orb weaver often builds at dusk. It lets out a fine thread that floats on the breeze until it snags a twig, making a bridge. From the bridge it drops a line to form a "Y," then adds frame threads and a set of spokes, all running to a hub in the middle. Next it lays a temporary spiral to walk on. Last it spirals inward laying sticky silk, eating the temporary threads as it goes. The whole web may take less than an hour. Many orb weavers eat the old web each morning and recycle the silk to spin a new one.

Other ways to hunt. Not all spiders spin webs. Jumping spiders have two huge front eyes and can leap many times their body length, tied to a dragline. Wolf spiders run down their prey, and the mother carries her babies on her back. Trapdoor spiders wait under a silk-hinged lid. Spiders eat enormous numbers of flies, mosquitoes and crop pests; one study estimated that the world's spiders eat hundreds of millions of tons of insects a year.

Respect, not fear. Nearly all spiders are harmless to people and bite only if squeezed. In North America two need real care: the **black widow**, shiny black with a red hourglass under its abdomen, and the **brown recluse**, brown with a dark violin shape on its back, found mostly in the south-central states. Watch spiders with your eyes, not your fingers. Baby spiders sometimes travel by "ballooning," lifting into the wind on a silk thread. In 1832 Charles Darwin saw spiders land on the rigging of HMS *Beagle* about sixty miles out at sea.

PICTURE STUDY



Plate 18 of Metamorphosis insectorum Surinamensium: Guava Branch with Ants and Spiders, Maria Sibylla Merian, 1705 · Hand-colored engraving (after Merian's watercolor) · From Metamorphosis insectorum Surinamensium (Amsterdam, 1705); copies in the Royal Collection, the National Museum of Women in the Arts and many libraries
Wikimedia Commons · Public domain

In 1699 the German-born artist Maria Sibylla Merian sailed from Amsterdam to Suriname in South America with her daughter Dorothea to study insects in the wild. She returned in 1701 and published her plates in 1705. This famous plate shows tarantulas, huntsman spiders and army ants on a guava branch. Merian wrote that ants could swarm through a house so that people fled before them.

Look closely

- Count the legs on the large spider. Are there eight?
- Find the ants. What are they doing on the branch?
- Find the hummingbird and its nest. What is happening to it?

Talk about it

1. Large tropical spiders eat insects, frogs and lizards but rarely if ever birds. Merian's picture made people call them "bird-eating spiders." Why should a scientist be careful about drawing a rare event as if it were usual?
2. Merian painted from living animals she watched herself. Why did that make her work better than pictures copied from dried specimens?

Safety first. Do not handle spiders. Look for a red hourglass (black widow) or a violin mark (brown recluse) before getting close, and use a jar or a magnifying glass at arm's

length. Wear gloves when moving woodpiles, boxes or rocks. If someone is bitten and feels ill, see a doctor.

HANDS-ON: COLLECT AND DIAGRAM A WEB

Preserve an empty orb web on paper and make a labeled diagram of how it is built.

You will need

- An abandoned orb web (check carefully that no spider is home, or gently move the spider aside with a stick)
- Black construction paper
- Unscented hairspray or spray starch, used by a parent
- Talcum powder or flour (optional)
- A white pencil and a ruler

Steps

1. With a parent, find an empty web. Lightly dust it with powder so the threads show, if you like.
2. The parent sprays the black paper with hairspray. While it is sticky, bring the paper up behind the web and press gently so the web sticks flat.
3. Snip the frame threads with scissors. Let the paper dry flat.
4. Count the spokes (radii). Count the turns of the sticky spiral along one spoke. Measure the web's width.
5. Using the white pencil, label the parts: bridge thread, frame threads, spokes, hub and sticky spiral. Write the date, place and measurements below.

Check your work

- My web is mounted, labeled and dated.
- I counted the spokes and spiral turns and measured the width.
- I can describe the order in which the spider built each part.

FIELD NOTEBOOK

1. **Diagram.** Draw a spider seen from above and an ant beside it. Label on both: the body parts, the number of legs, and antennae (only the ant has them). Under them, write three differences between an arachnid and an insect.
2. **Notebook entry.** Write a paragraph describing a real spider you found: where it was, what kind of web or hunting style it had, its size and colors, and what you think it was catching.

Did you know? Darwin's bark spider of Madagascar spins the biggest known orb webs, with bridge lines stretching across rivers 25 meters (80 feet) wide. Diving bell spiders in

Europe live underwater, breathing from an air bubble held in a silk net. Some jumping spiders can see in color and turn their heads to watch you.

Map or diagram. Draw an orb web step by step in four small boxes: (1) the bridge thread, (2) the Y and frame, (3) the spokes and hub, (4) the sticky spiral. Number each step.

Goes deeper in. Life Science, arthropods and classifying animals (coming soon); Art, for Maria Sibylla Merian's nature illustration.

For families. Species counts follow the World Spider Catalog (about 52,000 named species as of the mid-2020s). The global prey estimate is Nyffeler and Birkhofer, *The Science of Nature* (2017), 400–800 million tons a year. Darwin's ballooning spiders are described in *The Voyage of the Beagle* (off the coast of Argentina, 1832). Merian's plate 18 helped give the tarantula genus *Avicularia* ("little bird") its name; tarantulas very rarely take birds. The KJV "spider" of Proverbs 30:28 translates a Hebrew word many scholars think means a lizard such as a gecko; the stop quotes the KJV as written.

PRACTICE

1. **EASY** Give three ways a spider is different from an insect.
2. **EASY** Where does a spider's silk come out?
3. **MEDIUM** Why does an orb weaver eat its old web?
4. **MEDIUM** Describe the markings of the two dangerous spiders of North America.
5. **CHALLENGE** A web has 30 spokes and the sticky spiral crosses each spoke 40 times. How many places does the spider attach sticky silk to a spoke? If each attachment takes 1 second, about how many minutes is that?

Make it a game • Web Weaver. Players stand in a circle as the "frame." Toss a ball of yarn across the circle, each player holding a loop of string before tossing it on, to make spokes through a center point. Then wind a spiral from the middle outward, looping once around each spoke. Toss a balled-up sock "fly" into the web: does it stick? Untangle carefully at the end.

Scripture. "The spider taketh hold with her hands, and is in kings' palaces." (Proverbs 30:28, KJV)

Agur lists four small creatures that are "exceeding wise" (Proverbs 30:24). A spider is small and weak, yet it climbs into the king's own house. Wisdom, not size, is what God praises.

Practice: answers

1. Any three: eight legs not six; two body parts not three; no antennae; no wings; usually eight simple eyes instead of compound eyes.
2. From the spinnerets at the tip of its abdomen.

3. Silk is made of protein; eating the old web recycles it so the spider can spin a new one without wasting food.
4. Black widow: shiny black with a red hourglass under the abdomen. Brown recluse: brown with a dark violin shape on the back.
5. $30 \times 40 = 1,200$ attachments; $1,200 \text{ seconds} \div 60 = 20 \text{ minutes}$.

5.5 BEETLES: THE MOST KINDS OF ALL

OBJECTIVES

- Explain what makes a beetle a beetle, especially the hard elytra.
- Describe four beetles with special designs: the bombardier, the dung beetle, the ladybug and the Namib fog-catcher.
- Sort beetles you find by shape and use a simple key.

Warm-up. Turn over a log or a flat stone in the yard (lift the far side toward you, so anything underneath runs away from you, and put it back gently afterward). Count every beetle you see. Did any of them “play dead”?

Video slot. Video coming. Beetles: bombardier beetle spray in slow motion, dung beetles rolling balls, Namib desert fog-basking beetle, ladybugs eating aphids. Search approved channels (BBC Earth, PBS Nature, Smithsonian, Natural History Museum London); preview first.

KEY TERMS

Coleoptera

The scientific name for the beetle order; it means “sheath wings” in Greek.

elytra

A beetle’s hard front wings, which close over its back like a shell and protect the thin flying wings folded beneath (one is an elytron).

pronotum

The shield-like plate on top of a beetle’s first body segment behind the head.

grub

The soft, worm-like larva of a beetle.

biomimicry

Copying a design found in living things to solve a human problem.

CORE IDEAS

An astonishing number. If you lined up every kind of animal scientists have named, about one in four would be a beetle. More than 400,000 kinds of beetles have been described, more than any other group of creatures. They range from featherwing beetles smaller than the period at the end of this sentence to the titan beetle of the Amazon, which can be over 6 inches (16 centimeters) long. The psalmist cried, “O LORD, how manifold are thy works!” (Psalm 104:24). “Manifold” means many and varied, and beetles show it well.

Armor wings. The beetle order is called **Coleoptera**, “sheath wings.” A beetle’s front wings have become hard covers called **elytra**. When it lands, the elytra close neatly down the

middle of its back, making a straight line you can see. Underneath, the thin flying wings are folded up like a map. To fly, a beetle lifts the elytra and unfolds the hind wings. This armor lets beetles crawl under bark, burrow into soil and live in places where a delicate insect would be torn. Beetles go through complete metamorphosis: egg, **grub**, pupa, adult.

The bombardier. When a bombardier beetle is attacked, it mixes two chemicals from separate storage chambers in a tough reaction chamber at the end of its abdomen. They react with a pop and spray out at about the temperature of boiling water, 100°C (212°F). The beetle can aim the spray in almost any direction, and some kinds fire it in rapid pulses, hundreds per second, so the chamber does not burn itself.

Dung beetles and ladybugs. Dung beetles roll balls of animal droppings away to eat or to lay eggs in, cleaning pastures as they go. In 2013 scientists showed that some African dung beetles keep a straight path at night by watching the band of the Milky Way. The ladybug (or lady beetle) is a beetle too. A single ladybug may eat thousands of aphids, the tiny sap-sucking pests, in its life, and gardeners welcome them.

Water from fog. In the Namib Desert of southwest Africa, where it almost never rains, one darkling beetle climbs a sand dune on foggy mornings and tips its head down into the wind. Fog droplets gather on bumps on its back, grow into drops and roll down grooves to its mouth. Engineers have studied its back to design surfaces and nets that collect drinking water from fog. Copying God's designs like this is called **biomimicry**.

PICTURE STUDY



Stag Beetle, Albrecht Dürer, 1505 · Watercolor and gouache on paper · J. Paul Getty Museum, Los Angeles
Wikimedia Commons · Public domain

The German artist Albrecht Dürer painted this stag beetle in 1505, three years after his famous *Young Hare* (1502). Before Dürer, artists usually painted insects small, in the

margins of books. Dürer gave one beetle a whole page, painted from life so carefully that you can see the shine on its shell. The stag beetle's huge "antlers" are its jaws, which males use to wrestle each other.

Look closely

- Find the jaws, the antennae, the six legs and the line down the middle of the elytra.
- Look at the shadow under the beetle. How does it make the beetle seem to stand on the page?
- Look at the legs. Is the beetle standing still or walking?

Talk about it

1. Why might Dürer, a famous painter of saints and kings, spend days painting a beetle?
2. What did Dürer do to make the beetle look alive and not like a dried specimen?

HANDS-ON: BEETLE SURVEY AND SORTING KEY

Find and compare beetles near your home and build a simple key to sort them, the way scientists do.

You will need

- A clear plastic cup or bug jar with air holes
- A hand lens or magnifying glass
- A ruler marked in millimeters
- A tray or white sheet of paper
- Field Notebook and colored pencils

Steps

1. Search for beetles for 20 minutes: under logs and stones (put them back), on flowers, on tree bark and around a porch light at night.
2. For each beetle, gently place it in the cup. Check that it is a beetle: six legs, hard elytra meeting in a straight line down the back.
3. Measure its length in millimeters, note its color and shape, then let it go where you found it.
4. Make a yes/no key: Question 1 "Is it round like a dome?" If yes, it may be a ladybug or leaf beetle. If no, go to Question 2 "Does it have a long snout?" (weevil). Question 3 "Is it shiny black and fast on the ground?" (ground beetle). Add your own questions to separate every beetle you found.
5. Draw a map of your search area with an X for each beetle you found and a number matching your notes.

Check your work

- I found and recorded at least three beetles with measurements.

- My key separates every beetle I found using yes/no questions.
- My map shows where each beetle was found.

FIELD NOTEBOOK

1. **Diagram.** Draw a beetle twice: once from above with elytra closed, and once from above with elytra lifted and hind wings spread. Label head, antennae, pronotum, elytra, hind wings, six legs and the center line.
2. **Notebook entry.** Write a paragraph about the most interesting beetle from your survey or from the story. What design did God give it, and how does that design help it live where it lives?

Did you know? Weevils, beetles with long snouts, are the biggest beetle family, with tens of thousands of kinds. The ancient Egyptians carved the scarab, a dung beetle, on jewelry and seals. Some longhorn beetle grubs live inside wood for years before turning into adults; a few have come out of furniture made from the wood they were in.

Map or diagram. Draw the bombardier beetle's defense as a cut-away diagram: two storage chambers, a valve, the reaction chamber and the nozzle. Use arrows to show the chemicals moving and the hot spray coming out.

Goes deeper in. Life Science, insects and classification keys (coming soon); Art, Albrecht Dürer's nature studies.

For families. The 400,000 figure is the usual round number for described beetle species; estimates of total species are much higher and uncertain. Bombardier beetle pulsing was described by Dean and colleagues in *Science* (1990) and studied further by Arndt and colleagues (2015). The Milky Way navigation study is Dacke and colleagues, *Current Biology* (2013). The Namib beetle (*Onymacris unguicularis* and related species) is often cited in biomimicry; how much the bumps and grooves help is still studied. Ladybug aphid totals vary by species; "thousands in a lifetime" is a fair summary. Do not survey beetles on private land without permission.

PRACTICE

1. **EASY** What does Coleoptera mean, and what are elytra?
2. **EASY** About what fraction of all named animal species are beetles?
3. **MEDIUM** How does the Namib Desert beetle get water?
4. **MEDIUM** Why would a gardener be glad to see ladybugs?
5. **CHALLENGE** If there are about 400,000 kinds of beetles and you learned 10 new kinds every day, how many years would it take to learn them all? (Use 365 days in a year.)

Make it a game • Bombardier Tag. One player is the "frog" and tries to tag the others (beetles). A beetle about to be tagged may call "Pop!" and spin once in place, and the frog

must count to three before tagging that player. Each beetle has only three “pops.” Once out of pops, a tagged beetle becomes a frog too.

Scripture. “O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches.” (Psalm 104:24, KJV)

“Manifold” means many and different. Hundreds of thousands of kinds of beetles, each fitted to its own place, show both how many and how wise are the works of God.

Practice: answers

1. Coleoptera means “sheath wings.” Elytra are a beetle’s hard front wings that cover and protect the flying wings.
2. About one in four (one-quarter).
3. On foggy mornings it tips its head down into the wind; fog droplets collect on bumps on its back and roll down to its mouth.
4. Ladybugs eat aphids, which suck sap and damage plants; one ladybug can eat thousands.
5. $400,000 \div 10 = 40,000$ days; $40,000 \div 365 \approx 110$ years.

5.6 FIREFLIES: LIVING LANTERNS

OBJECTIVES

- Explain how a firefly makes light (bioluminescence) and why it is called “cold light.”
- Describe how male and female fireflies use flash patterns to find each other.
- Record and diagram firefly flash patterns on a summer evening.

Warm-up. Hold your hand near (not on) a light bulb that has been on for a few minutes, and feel the heat; an old-style bulb can burn you. Then think about this: a firefly makes light inside its own body, and its lantern stays cool to the touch. How might that be?

Video slot. Video coming. Firefly flashing at night, synchronous fireflies of the Great Smoky Mountains, firefly larvae glowing. Search approved channels (National Park Service, PBS Nature, Smithsonian, BBC Earth); preview first.

KEY TERMS

bioluminescence

Light made by a living thing through a chemical reaction in its body.

luciferin

The chemical in a firefly’s lantern that gives off light when it reacts with oxygen.

luciferase

The enzyme (a helper protein) that makes the luciferin reaction happen quickly.

lantern

The light organ on the underside of a firefly’s last abdominal segments.

synchronous

Happening at the same time. Synchronous fireflies flash together in waves.

CORE IDEAS

A beetle with a light. Fireflies, or lightning bugs, are neither flies nor bugs in the scientist’s sense. They are soft-bodied beetles, with elytra like their cousins in Stop E5. Scientists have named more than 2,000 kinds around the world, and well over a hundred live in the United States and Canada. Not every kind glows as an adult, but nearly all glow as larvae, which is why the young are sometimes called glowworms.

How the light works. On the underside of the abdomen is the **lantern**. Inside it, a chemical called **luciferin** joins with oxygen, helped by an enzyme called **luciferase** and by ATP, the energy molecule every cell uses. The reaction gives off light, usually yellow-green, with almost no heat. That is why firefly light is called “cold light.” An old-style light bulb turns most of its energy into heat; the firefly wastes very little as heat. The firefly switches its light on and off by controlling the flow of air through tiny breathing tubes into the lantern.

A language of flashes. On a June evening in much of the eastern United States, the common “big dipper” firefly, *Photinus pyralis*, flies low and flashes while swooping upward, drawing a little “J” of light. That is a male. A female waiting in the grass answers with her own flash after a short, exact delay of about two seconds. He flies toward her, they flash back and forth, and he lands beside her. Each kind of firefly has its own pattern of color, length and timing, so they do not mix up their signals. One kind, *Photuris*, has females that copy other kinds’ answers to lure the males in and eat them, a hunter’s trick sometimes called the “femme fatale” firefly.

Flashing together. In the Great Smoky Mountains near Elkmont, Tennessee, for about two weeks between late May and mid-June, thousands of *Photinus carolinus* fireflies flash in step: a burst of five to eight quick flashes all together, then several seconds of darkness, again and again. Visitors come in such numbers that the National Park Service gives out a limited number of passes. In the mangrove swamps of Southeast Asia, whole trees full of fireflies blink together through the night.

Light for medicine. Scientists have learned to make luciferase in the lab. Because it lights up only when ATP is present, it is used in tests to find bacteria on food and hospital surfaces and in research on cells. A small beetle in a summer field has become a tool for keeping people healthy.

PICTURE STUDY



Catching Fireflies, Kitagawa Utamaro, about 1796–1797 · Color woodblock print, triptych (three sheets) ·
Cleveland Museum of Art
Wikimedia Commons · CC0

In Edo-period Japan, families went out on summer evenings to catch fireflies and keep them for a night in little cages before letting them go. Kitagawa Utamaro, one of the great

woodblock artists, made this three-sheet print of the scene. Japanese poets had written about fireflies for many centuries.

Look closely

- Find the fans. How are people using them?
- Find the insect cage. Who is looking at it, and how is it made?
- Find the stream. Who has waded into it?

Talk about it

1. Fireflies are tiny in this picture. How did Utamaro make you feel that they are there anyway?
2. Why do you think fireflies are often found near streams, ponds and wet meadows? (Hint: think about what the larvae eat.)

HANDS-ON: FIREFLY FLASH LOG

Record real firefly flash patterns and turn them into a diagram, like a scientist's chart.

You will need

- A summer evening outdoors (June or July in much of the U.S.), with a parent
- A watch or phone stopwatch
- A small flashlight covered with green or yellow cellophane
- Field Notebook, pencil and a red flashlight or dim light to write by

Steps

1. Go out 30 minutes after sunset. Record the date, time, temperature (if you can) and place.
2. Watch one firefly at a time. Count its flashes in ten seconds and note whether it flies high or low and whether its flash is a dot, a long glow, or a "J" swoop.
3. Watch the grass for answering flashes from females. Use the stopwatch to estimate the delay.
4. Try "talking": point your covered flashlight at the grass and flash about two seconds after a male flashes. Does any firefly come toward you?
5. At home, make a flash diagram: draw a timeline 10 seconds long (1 centimeter = 1 second) and mark each flash as a dot or dash. Make one line for each firefly you watched. Add a title and key.

Check your work

- My log has date, time, place and at least three fireflies recorded.
- My flash diagram shows each pattern on a timeline with a scale and key.
- I can explain why each kind of firefly has its own flash pattern.

FIELD NOTEBOOK

1. **Diagram.** Draw a firefly from below and label head, antennae, six legs, elytra, and the lantern. Next to it, draw the reaction as a simple equation: luciferin + oxygen + ATP (with luciferase) → light.
2. **Notebook entry.** Write a paragraph about your evening of firefly watching: what you saw, what patterns you noticed, and how the evening made you think about Matthew 5:16.

Did you know? Firefly larvae eat snails, slugs and earthworms, injecting them with a substance that softens them. Many fireflies spend one to two years as larvae and only a few weeks as adults. Some adults eat nothing at all. Fireflies taste bitter to birds and spiders, so the glow may also be a warning: “I taste bad.”

Map or diagram. Make a map of your yard or a nearby field at dusk. Mark where you saw the most fireflies, where the grass is long or short, and where there is water or a bright porch light. Do you see a pattern?

Goes deeper in. Life Science, light and energy and insect communication (coming soon); Art, Japanese woodblock prints.

For families. Species counts follow the Xerces Society and firefly researchers (over 2,000 worldwide; more than 150 in the U.S. and Canada by recent counts). The two-second female delay is typical of *Photinus pyralis* and changes with temperature. “Cold light” is accurate in the sense that the reaction makes little heat; popular claims of “100% efficiency” overstate the measured light output. The National Park Service runs a limited-access system for the Elkmont viewing; check its website each spring. If you catch fireflies, keep them in a jar with a damp paper towel and release them the same night.

PRACTICE

1. **EASY** Is a firefly a fly, a bug or a beetle?
2. **EASY** What is bioluminescence?
3. **MEDIUM** Name the chemicals and the enzyme in a firefly’s light reaction.
4. **MEDIUM** Why does each kind of firefly have its own flash pattern?
5. **CHALLENGE** A synchronous firefly group flashes 6 times in a 3-second burst, then is dark for 9 seconds, and repeats. How many flashes will one firefly make in 2 minutes?

Make it a game • Flash and Answer. In a dark room or yard, give each player a small flashlight and a secret pattern card (for example, two short flashes; one long; three quick). Half the players are “males” who walk around flashing their pattern; the others are “females” who sit still and answer only their own pattern after counting two seconds. Pairs with matching patterns find each other without talking.

Scripture. “Let your light so shine before men, that they may see your good works, and glorify your Father which is in heaven.” (Matthew 5:16, KJV)

A firefly cannot help shining; God built the light into it. Jesus tells His followers to let their good works be seen, not to praise themselves, but so that others will give glory to God.

Practice: answers

1. A beetle.
2. Light made by a living thing through a chemical reaction in its body.
3. Luciferin, oxygen and ATP react, helped by the enzyme luciferase.
4. So males and females of the same kind can recognize each other and not answer the wrong kind.
5. Each cycle is $3 + 9 = 12$ seconds. $120 \div 12 = 10$ cycles; $10 \times 6 = 60$ flashes.

5.7 DRAGONFLIES: MASTERS OF THE AIR

OBJECTIVES

- Tell a dragonfly from a damselfly by its wings and eyes.
- Describe the dragonfly's underwater nymph stage and how it turns into a flying adult (incomplete metamorphosis).
- Explain what makes the dragonfly such a successful hunter.

Warm-up. Hold your arms straight out like wings. Now try moving your left arm up while your right arm goes down, then both forward, then one forward and one back. A dragonfly can move each of its four wings separately like this, which lets it hover, dart sideways and even fly backward.

Video slot. Video coming. Dragonfly flight in slow motion, dragonfly nymph catching prey with its lower lip, a dragonfly emerging from its nymph skin. Search approved channels (BBC Earth, PBS Nature, Smithsonian, U.S. Fish and Wildlife Service); preview first.

KEY TERMS

Odonata

The insect order of dragonflies and damselflies; the name means “toothed ones,” for their strong jaws.

nymph

The young stage of an insect with incomplete metamorphosis; a dragonfly nymph lives underwater and has no wings yet. Also called a naiad.

incomplete metamorphosis

Growing from egg to nymph to adult with no pupa (resting) stage; the nymph changes a little with each molt.

compound eye

An eye made of thousands of tiny units, each seeing one small part of the view.

labium

The lower lip of an insect; in a dragonfly nymph it is a hinged “mask” that shoots out to grab prey.

CORE IDEAS

Two cousins. Dragonflies and damselflies make up the insect order **Odonata**, about 6,000 named kinds in all. You can tell them apart at a pond. A resting dragonfly holds its wings out flat, like an airplane; a damselfly folds its wings together over its back. A dragonfly's huge eyes usually touch or nearly touch on top of its head; a damselfly's eyes are set wide apart, like a hammerhead. Dragonflies are also stouter and stronger fliers.

Built to hunt. Each dragonfly **compound eye** may have nearly 30,000 tiny units, giving it a view almost all the way around. Its four wings are each worked by their own muscles, so it can hover, turn on the spot, fly backward and reach speeds of perhaps 30 miles per hour. It catches flies and mosquitoes in the air, using its spiny legs as a basket. In a 2012 study, dragonflies caught their prey in more than nine of every ten tries. Instead of chasing where a fly is, a dragonfly flies to where the fly is going to be, the way an outfielder runs to catch a fly ball.

Life underwater. Most of a dragonfly's life is spent not in the air but in the water. The mother lays eggs in a pond, stream or wet plant stem. The **nymph** that hatches lives on the bottom for months, and in some kinds for several years. It breathes with gills inside the end of its abdomen, and by squirting water out it can jet forward. Folded under its head is a long hinged lower lip, the **labium**, tipped with hooks. When a tadpole or small fish swims close, the labium shoots out in a fraction of a second and snatches it.

Coming out. Dragonflies have **incomplete metamorphosis**: egg, nymph, adult, with no chrysalis. When the nymph is ready, usually at night or early morning, it climbs a reed out of the water. Its skin splits down the back, and the adult slowly pulls itself out, rests, then pumps blood into its crumpled wings until they are full and stiff. The empty nymph skin, called an exuvia, stays clinging to the reed. Look for them in summer.

Ocean crossers. In 2009 a biologist working in the Maldives, islands in the Indian Ocean, showed that the globe skimmer dragonfly crosses the open sea between India and East Africa, riding seasonal winds. Over several generations the round trip may be 14,000 to 18,000 kilometers, among the longest known insect journeys. Museum signs also tell of fossil dragonfly-like insects called *Meganeura* with wings about 70 centimeters across, larger than a crow.

PICTURE STUDY



Bellflower and Dragonfly, from an untitled series known as *Large Flowers*, Katsushika Hokusai (published by Nishimura Yohachi), about 1830–1833 · Color woodblock print · Rijksmuseum, Amsterdam (RP-P-1988-349); other copies in the Art Institute of Chicago and the Museum of Fine Arts, Boston
Wikimedia Commons · CC0

Katsushika Hokusai, the Japanese artist who made *The Great Wave*, also made a set of prints of large flowers when he was in his seventies. In this one, a small dragonfly hovers above Chinese bellflowers. In Japan the dragonfly was a favorite summer and autumn creature and stood for courage and strength.

Look closely

- Find the dragonfly. Are its wings held flat out or folded together? What does that tell you?
- Look at how Hokusai drew the bellflower petals. Which details are sharp and which are simplified?
- Find the open space in the picture. Where did Hokusai leave the background empty?

Talk about it

1. Why do you think Hokusai made the flowers large and the dragonfly small?
2. How would the picture feel different if the dragonfly were missing?

HANDS-ON: POND DIP AND DRAGONFLY DIAGRAM

Look for real dragonfly nymphs at a pond and make a labeled life-cycle diagram.

You will need

- A kitchen strainer or small net on a stick
- A white tub or dishpan with a few inches of pond water
- A hand lens and a ruler
- Rubber boots
- Field Notebook and colored pencils

Steps

1. With a parent, go to the shallow edge of a pond (stay where the water is no deeper than your ankles).
2. Scoop gently through the mud and plants near the bottom. Empty the net into the white tub and wait a minute for the mud to settle.
3. Look for nymphs: dragonfly nymphs are chunky with a stubby abdomen; damselfly nymphs are thin with three leaf-like gills at the tail. Measure one and draw it.
4. Search reed stems above the water for empty nymph skins (exuviae). Count them.
5. Return every creature to the pond.
6. At home, draw the life cycle as a diagram: egg in the water, nymph on the pond bottom with the labium shooting out, nymph climbing a reed, adult splitting out, adult flying. Label each stage and add arrows. Add a side drawing comparing a dragonfly and a damselfly at rest.

Check your work

- I found at least one water creature and identified whether it was a nymph.
- My diagram shows all stages with labels and arrows.
- I can tell a dragonfly from a damselfly two ways.

FIELD NOTEBOOK

1. **Diagram.** Draw a dragonfly from above, wings spread, and label the compound eyes, thorax, four wings, long abdomen and six legs. Draw a side view of a nymph's head with the labium folded and then extended.
2. **Notebook entry.** Write a paragraph comparing the dragonfly's life in the water and its life in the air. Which part of its life is longer? Which design surprised you most?

Did you know? Dragonflies are insects with incomplete metamorphosis, like grasshoppers, not complete metamorphosis like butterflies and beetles. An adult dragonfly may eat hundreds of mosquitoes a day. Some dragonflies patrol a stretch of stream as their territory and chase off rivals.

Map or diagram. On a map of the Indian Ocean, mark India, the Maldives, the Seychelles and East Africa (Kenya and Tanzania). Draw arrows for the globe skimmer's route: southwest toward Africa in autumn with the northeast monsoon winds, and back toward India in spring.

Goes deeper in. Life Science, insect life cycles and pond ecosystems; Geography, the Indian Ocean and monsoon winds; Art, Japanese woodblock prints (coming soon).

For families. Species counts follow the World Odonata List (about 6,400 species). The 2012 hunting study is Combes and colleagues on *Libellula* dragonflies (Harvard), reporting about 95% success. Top speeds are hard to measure; “around 30 mph” is a common estimate. The globe skimmer research is R. Charles Anderson, *Journal of Tropical Ecology* (2009). *Meganeura* sizes are from fossils; the ages on museum signs are interpretations and are not taught here. Pond safety: an adult should supervise any water outing.

PRACTICE

1. **EASY** Give two ways to tell a dragonfly from a damselfly.
2. **EASY** Where does a dragonfly nymph live?
3. **MEDIUM** Why is a dragonfly’s metamorphosis called “incomplete”?
4. **MEDIUM** Explain how a dragonfly is like an outfielder catching a fly ball.
5. **CHALLENGE** A dragonfly catches prey in 95 of every 100 tries. If it makes 60 tries in a day, about how many catches does it make? How many misses?

Make it a game • Intercept!. One player (the fly) walks steadily across a yard in a straight line. The other (the dragonfly) starts off to the side and must tag the fly by running to where the fly will be, not by chasing from behind. Try it both ways: chasing straight at the fly, then cutting ahead. Which is faster?

Scripture. “But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee:” (Job 12:7, KJV)

Job says the creatures themselves teach that “the hand of the LORD hath wrought this” (Job 12:9). A small insect that lives first in the water and then rules the air is a lesson in the wisdom of its Maker.

Practice: answers

1. A resting dragonfly holds its wings flat out, a damselfly folds them over its back; dragonfly eyes touch or nearly touch, damselfly eyes are far apart. (Also: dragonflies are stouter.)
2. Underwater, on the bottom of a pond or stream.
3. It goes from egg to nymph to adult with no pupa (chrysalis) stage.
4. It does not chase where the prey is; it predicts where the prey will be and flies to meet it there.
5. $60 \times 0.95 = 57$ catches and 3 misses.

5.8 LOCUSTS: THE EIGHTH PLAGUE (EXODUS 10)

OBJECTIVES

- Explain how a locust is a grasshopper that changes when crowded and forms swarms.
- Retell the eighth plague of Exodus 10 and map the winds that brought and removed the locusts.
- Use numbers to show how much a locust swarm can eat, with an example from American history.

Warm-up. Weigh a slice of bread on a kitchen scale. A desert locust eats about its own weight in fresh plants every day, about 2 grams. Now imagine 40 million locusts, the number that can be packed into one square kilometer of a swarm. How many slices of bread is that each day?

Video slot. Video coming. Desert locust swarms and how grasshoppers change into swarming locusts. Search approved channels (BBC Earth, PBS Nature, Smithsonian, the Food and Agriculture Organization of the United Nations); preview first.

KEY TERMS

locust

A kind of short-horned grasshopper that can change its color and behavior when crowded and gather in huge traveling swarms.

solitary phase

The form of a locust when few are around: usually green or brown, shy, and living alone like an ordinary grasshopper.

gregarious phase

The crowded form of a locust: brighter colored, restless and drawn to other locusts, ready to march and swarm.

swarm

A huge flying mass of locusts (or bees) moving together.

plague

A great disaster, especially one sent as a judgment; in Exodus, one of the ten signs God sent on Egypt.

CORE IDEAS

The eighth plague. When Pharaoh refused again to let Israel go, Moses warned him that locusts would come and “cover the face of the earth.” Pharaoh’s own servants begged him, “knowest thou not yet that Egypt is destroyed?” (Exodus 10:7). He still refused. Moses stretched out his rod, and “the LORD brought an east wind upon the land all that day, and all that night; and when it was morning, the east wind brought the locusts” (10:13). They

darkened the land and ate “every herb of the land, and all the fruit of the trees which the hail had left” (10:15). When Pharaoh asked for mercy, “the LORD turned a mighty strong west wind” that carried the locusts into the Red Sea (10:19).

A grasshopper that changes. A **locust** is a grasshopper with a strange ability. The desert locust, *Schistocerca gregaria*, usually lives in the **solitary phase**: green or tan, shy, avoiding others. But after rains bring plenty of green plants, many hatch close together. When they are crowded and keep bumping into each other, especially touching the hairs on their hind legs, a chemical in their bodies called serotonin rises. Within hours they begin to seek each other out. Their young grow up yellow and black. This is the **gregarious phase**. The young, wingless “hoppers” march in bands; the winged adults rise as a **swarm**.

Swarm numbers. A single square kilometer of swarm may hold 40 to 80 million locusts. Each eats about 2 grams of fresh plants a day, its own weight. The United Nations Food and Agriculture Organization says a swarm of one square kilometer eats as much in one day as about 35,000 people. Swarms ride the wind and may travel 100 kilometers or more a day. In plague years, desert locusts have spread across parts of some sixty countries, from West Africa to India.

Locusts in America. The Great Plains once had their own: the Rocky Mountain locust. In the 1870s great swarms swept from the Rockies into Kansas, Nebraska, Minnesota and Dakota Territory, eating crops, fence posts, harness leather and the wool off sheep. In 1875 a Nebraska doctor named Albert Child timed the passing swarm and estimated it was about 1,800 miles long and 110 miles wide. Then, strangely, the Rocky Mountain locust disappeared. The last living one was collected in 1902. Many scientists think farmers plowing and watering the river valleys where the locusts laid their eggs destroyed their breeding grounds without knowing it.

More than a bug story. Scripture mentions locusts often. The law allowed Israel to eat them (Leviticus 11:22), and John the Baptist ate “locusts and wild honey” (Matthew 3:4). The prophet Joel saw a locust plague as a call to turn back to God, who promised, “I will restore to you the years that the locust hath eaten” (Joel 2:25). The plague of Exodus showed Egypt that the God of Israel rules even the wind and the smallest creatures.

PICTURE STUDY



The Plague of Locusts, James Jacques Joseph Tissot, about 1896–1902 · Gouache on board · The Jewish Museum, New York
Wikimedia Commons · Public domain

James Tissot was a French painter who, late in his life, traveled to the Holy Land and spent years painting hundreds of scenes from the Bible. He tried to show the lands, buildings and clothing as they really looked. This painting of the eighth plague belongs to his Old Testament series, now at the Jewish Museum in New York.

Look closely

- Look at the sky. How did Tissot paint the swarm: as separate insects or as a cloud?
- Find the people. How big are they compared with the swarm?
- What do the plants and fields look like? Can you tell the locusts have arrived?

Talk about it

1. Exodus 10:15 says “the land was darkened.” How did Tissot show that?
2. Why would a painter visit Egypt and the Holy Land before painting Bible scenes?

HANDS-ON: MAP THE EIGHTH PLAGUE

Draw a map of Egypt and its neighbors and show how the winds of Exodus 10 brought and removed the locusts.

You will need

- A blank map of Egypt, the Sinai Peninsula and Arabia (print one free, or trace from a Bible atlas)

- Colored pencils
- A Bible open to Exodus 10
- A ruler

Steps

1. Label the Nile River, the Nile Delta, the Mediterranean Sea, the Red Sea and its two northern arms (the Gulf of Suez and the Gulf of Aqaba), the Sinai Peninsula and Arabia.
2. Shade the green strip along the Nile and the Delta: this is where Egypt's crops grew, and where the locusts would do the most harm. Mark the land of Goshen in the eastern Delta, where Israel lived.
3. Read Exodus 10:13. Draw a thick arrow from the east, labeled "east wind," bringing a cloud of locusts over Egypt.
4. Read Exodus 10:19. Draw a second arrow from the west, labeled "mighty strong west wind," carrying the cloud into the Red Sea.
5. Add a title, a compass rose and a key. In the margin, write the verse numbers for each arrow.

Check your work

- My map shows the Nile, the Delta, the Red Sea, Sinai and Arabia.
- Both winds are drawn and labeled with verse references.
- I can retell the eighth plague in order using my map.

FIELD NOTEBOOK

1. **Diagram.** Draw two locusts side by side: a green solitary-phase locust and a yellow-and-black gregarious-phase locust. Label head, antennae, wings, the big jumping hind legs and the color difference. Between them draw an arrow labeled "crowding."
2. **Notebook entry.** Write a paragraph explaining how a shy grasshopper becomes part of a swarm, then one or two sentences on what the eighth plague showed Pharaoh about the God of Israel.

Did you know? Grasshoppers "hear" with ears on the sides of their abdomens, just behind the hind legs. A desert locust can fly for many hours at a stretch. Locusts are still eaten in parts of Africa, Arabia and Asia; they are high in protein. Between 2019 and 2021, large desert locust swarms struck East Africa, and some were bigger than any seen there in decades.

Goes deeper in. History, ancient Egypt and the Exodus (coming soon); Geography, the Nile and the Red Sea; Life Science, insect behavior.

For families. Swarm figures (40–80 million per km²; one km² eating as much as about 35,000 people a day) are from the FAO Desert Locust Watch. The leg-touching and serotonin research is Anstey and colleagues, *Science* (2009). Albert Child's 1875 estimate (about 198,000 square miles) is often called "Albert's swarm"; the numbers are his

estimate from timing the swarm and telegraph reports, not a measurement. The extinction explanation follows Jeffrey Lockwood, *Locust* (2004). Families who have read Laura Ingalls Wilder's *On the Banks of Plum Creek* may recognize the Minnesota grasshopper years of the 1870s. The Hebrew phrase in Exodus 10:19 is *yam suph*, which the KJV translates "Red sea."

PRACTICE

1. **EASY** What brought the locusts into Egypt in Exodus 10, and what took them away?
2. **EASY** What is the difference between a locust's solitary phase and gregarious phase?
3. **MEDIUM** What causes a solitary locust to begin changing to the gregarious phase?
4. **MEDIUM** What happened to the Rocky Mountain locust, and what may have caused it?
5. **CHALLENGE** A swarm covers 10 square kilometers with 50 million locusts per square kilometer. Each locust eats 2 grams a day. How many tonnes of plants does the swarm eat in one day? (1 tonne = 1,000,000 grams.)

Make it a game • Solitary or Swarm. Players spread out in a yard as shy "solitary" locusts, walking slowly. Whenever two players bump elbows, both become "gregarious" and must link arms and keep moving together. Groups that bump join into bigger groups. When everyone is in one marching swarm, the leader calls "West wind!" and the swarm must walk together to the far end of the yard (the Red Sea) and sit down.

Scripture. "And the LORD turned a mighty strong west wind, which took away the locusts, and cast them into the Red sea; there remained not one locust in all the coasts of Egypt." (Exodus 10:19, KJV)

No farmer can stop a swarm, but God turned the wind and every locust was gone. The plague showed Egypt that the LORD alone is God, ruler of wind, land and every creature.

Practice: answers

1. An east wind brought them (10:13); a mighty strong west wind carried them into the Red Sea (10:19).
2. Solitary: green or tan, shy, lives alone. Gregarious: brighter yellow and black, seeks other locusts, marches and swarms.
3. Crowding: being touched over and over by other locusts, especially on the hind legs, raises serotonin and changes its behavior.
4. It became extinct; the last living one was collected in 1902. Farmers plowing and irrigating the river valleys where it laid eggs probably destroyed its breeding grounds.
5. $10 \times 50,000,000 = 500,000,000$ locusts; $\times 2 \text{ g} = 1,000,000,000 \text{ g} = 1,000$ tonnes a day.

5.9 JEAN-HENRI FABRE, THE INSECT WATCHER

OBJECTIVES

- Tell the story of Jean-Henri Fabre's life and place it on a map of France.
- Describe two of Fabre's experiments and what each one showed.
- Practice Fabre's method: patient watching, careful notes and a simple test.

Warm-up. Sit still outdoors for five full minutes and watch one small patch of ground, about the size of this page. Do not move or talk. Write down every living thing that moves through it. Fabre sometimes watched a single insect for hours.

Video slot. Video coming. Jean-Henri Fabre and his garden, the Harmas at Sérignan-du-Comtat; pine processionary caterpillars in a line. Search approved channels (Smithsonian, BBC, the Muséum national d'Histoire naturelle); preview first.

KEY TERMS

entomologist

A scientist who studies insects.

instinct

A pattern of behavior an animal is born able to do without learning it, such as a wasp building its nest.

experiment

A careful test, set up to answer one question, in which you change one thing and watch what happens.

Harmas

A Provençal word for a stony, uncultivated field; the name of Fabre's home and insect garden at Sérignan-du-Comtat.

observation

Something seen, measured or noticed with care, written down exactly as it happened.

CORE IDEAS

A poor boy who looked closely. Jean-Henri Fabre was born on December 21, 1823, in Saint-Léons, a village in the hills of southern France. His family was poor, and as a boy he lived for a time with his grandparents on their farm, where he watched beetles, birds and flowers. He worked odd jobs as a teenager but won a place at a teachers' college in Avignon. For many years he taught school in Carpentras, on the island of Corsica, and in Avignon, studying mathematics and natural science on his own and earning his degrees by hard work at night.

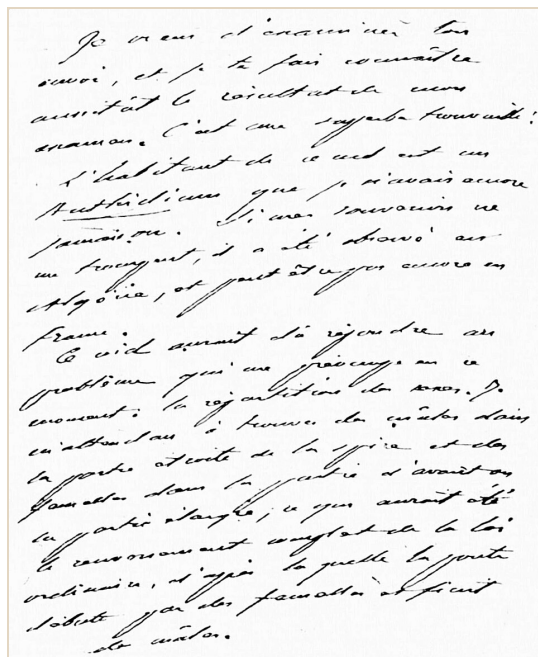
The wasp that does not kill. In 1854 Fabre read a paper by an older naturalist, Léon Dufour, about a wasp called *Cerceris* that stocked its nest with beetles. The beetles stayed fresh for weeks, and Dufour guessed the wasp preserved them with a special fluid. Fabre watched for himself. He found that the wasp stings each beetle exactly in one spot, a bundle of nerves, so that it is paralyzed but alive, fresh food for the wasp's young. He had corrected an expert by patient looking, and he never stopped.

The Harmas. On March 4, 1879, Fabre bought a house with a weedy, stony garden in the village of Sérignan-du-Comtat. He called it the **Harmas** and filled it with plants that insects love. That same year he published the first volume of his *Souvenirs entomologiques* ("Insect Memories"). By 1907 there were ten volumes, written not in dry lists but in lively stories that ordinary readers enjoyed. Charles Darwin, who corresponded with him, called him an "inimitable observer," even though Fabre did not accept Darwin's theory.

Famous experiments. Fabre wanted to know how mason bees find home. He carried them in a closed box kilometers away, sometimes swinging the box around, and released them. Many were back at their nests by evening. He watched great peacock moth males fly to a female in a cage in his study, through an open window, on dark, stormy nights. In January 1896 he watched pine processionary caterpillars, which follow each other nose to tail on a silk thread, crawl around the rim of a palm pot in a closed circle. They kept marching for about seven days before they broke the loop. His conclusion: instinct is wonderful but can be blind when the usual pattern is broken.

Honored at last. For most of his life Fabre was poor and little known. He received the Legion of Honor in the late 1860s, but real fame came only when he was old. In 1910 admirers held a celebration for him at Sérignan, and in 1913 the President of France, Raymond Poincaré, visited him. He died at the Harmas on October 11, 1915, at 91. The Harmas is now a museum, and his books are still read around the world.

PICTURE STUDY



Portrait photograph of Jean-Henri Fabre in old age, Unknown photographer, early 1900s · Black-and-white photograph · Many copies; the Muséum national d'Histoire naturelle keeps Fabre's Harmas and papers
Wikimedia Commons · Public domain

Most photographs of Fabre were taken when he was famous, near the end of his life. He usually wore his black felt hat, even indoors. He once wrote that he studied insects living, in the open air, among the cicadas and flowers, and not dead and pinned in a drawer.

Look closely

- Look at his face and eyes. What words would you use to describe his expression?
- Look at his clothes and hat. Do they look like a rich man's or a country man's?
- Find any objects in the photograph. What might they tell you about him?

Talk about it

1. If you could ask Fabre one question about insects, what would it be?
2. Why might a photographer in 1910 want to take a picture of an old insect watcher?

HANDS-ON: A FABRE EXPERIMENT: DO ANTS FOLLOW THE TRAIL OR THE LANDMARK?

Use Fabre's method: watch first, ask one clear question, change one thing, and record exactly what happens.

You will need

- An ant trail (see Stop E1) or a beetle or pill bug you can watch
- A sheet of paper or index card
- A watch, pencil and Field Notebook

Steps

1. Watch: spend 10 minutes observing your chosen creature and write down everything it does, with times.
2. Ask: write one question, such as “If I slide a card under an ant trail and then turn the card, will the ants follow the scent or the old direction?”
3. Guess: write what you think will happen and why.
4. Test: change only one thing. For the ant trail, let ants walk across a card laid on the trail, then gently turn the card a quarter turn. Watch for five minutes.
5. Record: write exactly what happened, even if it surprised you. Draw a before-and-after diagram with arrows showing the ants’ paths.
6. Conclude: write one sentence answering your question, and one new question it raised.

Check your work

- My notes include the date, time, place, question, guess, test and result.
- My diagram shows the before and after with arrows.
- I changed only one thing in my test.

FIELD NOTEBOOK

1. **Map.** Draw a map of southern France and Corsica. Mark and label Saint-Léons (where Fabre was born), Avignon, Carpentras, Ajaccio on Corsica, Sérignan-du-Comtat (the Harmas), the Rhône River and the Mediterranean Sea. Draw a dotted line connecting the places in the order he lived there.
2. **Notebook entry.** Write a paragraph in Fabre’s style: tell the story of one small creature you watched today as if it were a little adventure, with real details and times.

Did you know? Fabre was nominated several times for the Nobel Prize in Literature for his insect books. He also wrote dozens of science textbooks for schools to support his family. He studied mushrooms and painted hundreds of careful watercolors of them, which are kept at the Harmas.

Map or diagram. Draw the processionary caterpillar circle as a diagram: the round rim of a pot from above, with caterpillars nose to tail all the way around and an arrow showing the direction. Label it “January 1896: about seven days.”

Goes deeper in. History, nineteenth-century France (coming soon); Literature, nature writing; Life Science, insect behavior and how to design an experiment.

For families. Dates follow standard biographies and the Muséum national d’Histoire naturelle: born December 21, 1823, at Saint-Léons (Aveyron); bought the Harmas March 4, 1879; *Souvenirs entomologiques* in ten series, 1879–1907; died October 11, 1915. Sources give 1867 or 1868 for his Legion of Honor, so the stop says “late 1860s.” Darwin and Fabre exchanged letters (Darwin suggested some of the homing tests with bees); the

“inimitable observer” praise is reported by Fabre himself and his biographers, and its exact first printing should be checked before quoting it as Darwin’s published words. Fabre is often quoted as saying, “I can’t say I believe in God; I see Him,” but the source of the quotation is uncertain, so it is not used in the story. His books, translated by Alexander Teixeira de Mattos, are free at Project Gutenberg (for example, *The Life of the Spider* and *The Life of the Caterpillar*).

PRACTICE

1. **EASY** What was the name of Fabre’s home and insect garden, and in what village was it?
2. **EASY** What did Fabre do for a living for most of his life before he became famous?
3. **MEDIUM** What did Fabre discover about the *Cerceris* wasp that Dufour had gotten wrong?
4. **MEDIUM** What did the processionary caterpillar circle teach Fabre about instinct?
5. **CHALLENGE** Fabre was born in 1823 and died in 1915. He bought the Harmas in 1879. How old was he when he bought it, and how many years did he live there?

Make it a game • Follow the Leader in a Circle. Players walk in a line, each holding the shoulders of the one ahead, following the leader around the yard. At a signal, the leader joins the end of the line, making a closed circle. Everyone keeps walking and following. Who notices first that no one is leading? Talk about what Fabre learned from the caterpillars.

Scripture. “It is the glory of God to conceal a thing: but the honour of kings is to search out a matter.” (Proverbs 25:2, KJV)

God has hidden wonders even in a wasp’s nest and a line of caterpillars. Fabre spent his life searching them out. Careful, patient study of creation is an honorable work.

Practice: answers

1. The Harmas, in Sérignan-du-Comtat in southern France.
2. He was a schoolteacher (and wrote textbooks).
3. The beetles were not preserved by a fluid; the wasp stung them in a nerve center so they were paralyzed but still alive, staying fresh for its young.
4. Instinct is wonderful but can be blind: when the usual pattern was broken, the caterpillars kept following each other in a circle for about a week.
5. He was 55 (he turned 56 that December). He lived there about 36 years (1915 – 1879).

5.10 MAKE A BUG HOTEL

OBJECTIVES

- Explain which small creatures use a bug hotel and what each needs: hole size, material and shelter.
- Plan and build a bug hotel from a labeled diagram, using tools safely.
- Keep a season-long record of who moves in, as good stewards of the garden.

Warm-up. Walk around your yard and find three places a small creature could hide for the winter: under bark, inside a hollow stem, under a pile of leaves. Write them down. A bug hotel is simply a tidy, safe collection of places like these.

Video slot. Video coming. Mason bees nesting in tubes, leafcutter bees cutting leaf circles, building a bug hotel or bee house. Search approved channels (a state university extension program, the Royal Horticultural Society, the U.S. Forest Service, the Xerces Society); preview first.

KEY TERMS

solitary bee

A bee that does not live in a hive; each female builds and stocks her own small nest. Most kinds of bees are solitary.

mason bee

A solitary bee that nests in holes and walls off each egg's room with mud. The blue orchard bee is a North American mason bee.

habitat

The place where a creature finds what it needs: food, water, shelter and a place to raise young.

pollinator

A creature that carries pollen from flower to flower, helping plants make fruit and seeds.

overwinter

To survive the winter, often by resting, hidden and still, until spring.

CORE IDEAS

Not all bees live in hives. There are about 20,000 known kinds of bees in the world and around 4,000 in the United States. Most are **solitary bees**. A female mason bee, for example, finds a hole about the width of a pencil in dead wood or a hollow stem. At the back she packs a ball of pollen and nectar, lays one egg on it, and walls off the little room with mud. She builds room after room toward the entrance, then plugs the door. The young grow inside through summer, rest through winter and chew their way out in spring, just as the fruit trees bloom.

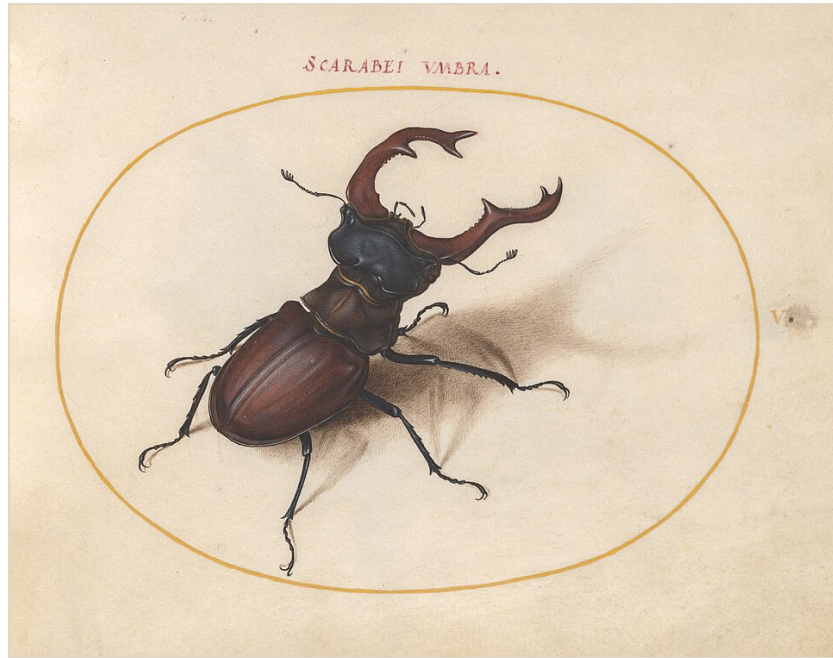
Gentle and useful. Solitary bees have no honey or hive to defend, so they rarely sting. Yet they are excellent **pollinators**. The blue orchard bee, a North American mason bee, carries pollen loosely on the hairs of its belly and drops it freely from blossom to blossom. A few hundred of them can pollinate an acre of apple trees, a job that would take thousands of honeybees. Leafcutter bees cut neat circles from leaves to line their nest rooms; if you see round holes in rose leaves, a leafcutter has been shopping.

Other guests. A bug hotel can shelter more than bees. Ladybugs and lacewings, which eat aphids, **overwinter** in dry crevices and bundles of stems. Beetles and their grubs live in rotting logs at the bottom. Pill bugs and sow bugs, which are not insects at all but small land crustaceans (relatives of crabs and shrimp), like the damp places among bark and leaves. Spiders will move in to hunt. Every room meets a need: food nearby, shelter from rain, and a safe place to raise young.

Building it right. Good bug hotels follow a few rules. Holes for mason bees should be about 8 millimeters (5/16 inch) wide and about 15 centimeters (6 inches) deep, closed at the back; smaller holes of 3 to 6 millimeters suit smaller bees. Drill into untreated wood, never pressure-treated wood. Smooth the entrances so wings are not torn. Give the hotel a roof that sticks out to keep rain off. Hang it firmly, 1 to 2 meters off the ground, facing the morning sun (east or southeast). Plant flowers nearby, and leave a patch of bare mud for mason bees to use.

Keeping it clean. A crowded bug hotel that is never cleaned can collect mites, mold and parasites. Use paper straws or liners you can replace, or reed bundles you can swap out every two years. Good stewardship means not only making a home for creatures but also caring for it, as God placed Adam in the garden “to dress it and to keep it” (Genesis 2:15).

PICTURE STUDY



Animalia Rationalia et Insecta (Ignis), Plate V, a page of insects from The Four Elements, Joris Hoefnagel, about 1575–1580 · Watercolor and gouache, with oval border in gold, on vellum · National Gallery of Art, Washington, D.C.

Wikimedia Commons · CC0

Joris Hoefnagel, an artist from Antwerp, painted four little books called *The Four Elements*. Each page shows animals of one kind: fire (insects, which old writers linked with fire), earth, water and air. The insect volume, *Ignis*, is one of the earliest books devoted to insects painted from life. On this page a big stag beetle shares the stage with smaller insects, each with room around it.

Look closely

- Find the stag beetle. What are its big “antlers” really?
- Count how many different insects you can find. Look for one painted from the side and one from above.
- Look for any writing on the page. What do you think it is for?

Talk about it

1. If Hoefnagel painted the guests in your bug hotel, which ones would you want on the page?
2. Hoefnagel painted his insects about 130 years before Merian’s Surinam book (Stop E4). What do both artists share in the way they looked at insects?

Safety first. A parent must supervise all sawing, drilling and hammering. Wear safety glasses when drilling or cutting, clamp the wood instead of holding it, and keep fingers

away from the bit. Use untreated wood only. Wasps may move in; watch from a short distance, and anyone allergic to stings should not handle the hotel in warm weather.

HANDS-ON: PLAN, BUILD AND LOG A BUG HOTEL

Draw a labeled plan, build a small bug hotel and keep a log of its guests through the season.

You will need

- A short wooden box or frame: a small untreated board box, a wooden crate, or a cut section of a 2×6 board (about 25 cm long)
- A block of untreated wood at least 15 cm deep, for drilling
- A drill with 8 mm (5/16 in) and 5 mm bits (with a parent)
- Hollow plant stems (bamboo, elderberry, teasel or reeds) cut to 15 cm, or paper nesting straws
- Pine cones, bark, dry leaves, small sticks and a short piece of rotting log
- A board or shingle for a roof, nails or screws, a hanging wire
- Graph paper, ruler and pencil

Steps

1. Plan: on graph paper, draw the front of your hotel to scale (1 square = 1 centimeter). Divide it into rooms. Label each room with its material and its guest: drilled block (mason bees), stems (small bees, lacewings), pine cones and sticks (ladybugs), bark and rotting wood at the bottom (beetles, pill bugs). Draw the roof overhang and write the hole sizes.
2. With a parent, drill rows of holes 15 cm deep in the wood block, about 2 cm apart, without drilling all the way through. Sand the entrances smooth.
3. Cut stems just below a joint so the back of each stem is closed. Pack them tightly into one section so they do not wobble.
4. Fill the other sections with cones, bark, sticks and leaves as your plan shows. Put the damp, rotting wood at the bottom.
5. Fix the roof so it sticks out at least 5 cm over the front.
6. Make a yard map: draw your yard from above, mark the hotel's location, a compass arrow, the flowers nearby, and a mud patch. Hang the hotel 1–2 meters high, facing east or southeast, before early spring.
7. Log: once a week, look (do not poke) and record date, weather and what you see: mud plugs, leaf plugs, insects coming and going.

Check your work

- My plan is drawn to scale with every room labeled for material and guest.
- My hotel has smooth holes of the right size, a roof overhang and untreated wood.
- My yard map shows the location, direction and nearby flowers.
- I have at least four weekly log entries.

FIELD NOTEBOOK

1. **Diagram.** Draw a cut-away of one mason bee tunnel: the back wall, a row of rooms each with a pollen ball and an egg, mud walls between them, and the mud plug at the entrance. Label each part and the 15 cm depth.
2. **Notebook entry.** Write a paragraph telling what you built, where you placed it and why, and who you hope will move in. Add a line each month with what you have seen.

Did you know? A mother mason bee usually puts eggs that will become females at the back of the tunnel and males toward the front. The males come out first in spring and wait nearby. Mason bees may make hundreds of trips to gather enough pollen for a single room. In Europe, people have built “insect walls” and bee houses in gardens for many generations.

Map or diagram. Make a “flower calendar” map of your yard: mark every plant that blooms and the month it flowers. Do you have something blooming from early spring to fall? Bees need food the whole season.

Goes deeper in. Gardening & Animals, pollinators and the wildlife garden (coming soon); Life Science, habitats; Arithmetic, scale drawings and measurement.

For families. Bee counts follow the U.S. Department of Agriculture and the Xerces Society (about 20,000 species worldwide; about 4,000 native to the U.S.). Most native bees nest in the ground, so leaving some bare, sunny soil also helps. Hole sizes and depths follow university extension guidance for the blue orchard bee (*Osmia lignaria*); the pollination comparison (a few hundred mason bees per acre of apples versus thousands of honeybees) is an often-cited USDA estimate. Replace liners or tubes every one to two years to prevent mites and disease. A bug hotel is for watching, not selling; nothing in this project is sold.

PRACTICE

1. **EASY** What is a solitary bee?
2. **EASY** Why should you use untreated wood for a bug hotel?
3. **MEDIUM** Name three guests a bug hotel might shelter and the material each one would use.
4. **MEDIUM** Why should the bug hotel face east or southeast and have a roof overhang?
5. **CHALLENGE** Your wood block is 12 cm wide and 9 cm tall. You drill holes in a grid with centers 2 cm apart, starting 1 cm from each edge. How many holes fit? If each tunnel holds 6 rooms, how many mason bee eggs could the block hold?

Make it a game · Who Checks In?. Write guests on cards (mason bee, leafcutter bee, ladybug, lacewing, ground beetle, pill bug, spider) and rooms on others (drilled holes, hollow stems, pine cones, rotting log, damp leaves). The “hotel clerk” draws a guest card

and reads one clue (“I need a hole the width of a pencil, and I bring my own mud”). The first player to point to the right room becomes the next clerk.

Scripture. “And the LORD God took the man, and put him into the garden of Eden to dress it and to keep it.” (Genesis 2:15, KJV)

God gave Adam work to do in the garden: to tend it and guard it. Making a safe home for small creatures and caring for it is one small way to do the same work today.

Practice: answers

1. A bee that does not live in a hive; each female builds and stocks her own nest.
2. Treated wood has chemicals that can harm the insects.
3. Any three: mason bees in drilled holes; small bees or lacewings in hollow stems; ladybugs in pine cones and sticks; beetles in rotting wood; pill bugs in damp bark and leaves; spiders in crevices.
4. The morning sun warms the bees so they can start flying early, and the roof keeps rain out of the tunnels.
5. Across: centers at 1, 3, 5, 7, 9, 11 cm = 6 holes. Down: 1, 3, 5, 7 cm = 4 rows (9 cm would put the next row at the edge). $6 \times 4 = 24$ holes; $24 \times 6 = 144$ eggs.

TRAIL 5 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in full sentences where possible. Four right out of five earns each badge. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1-5)

1. What did Solomon want the “ sluggard ” to learn from the ant (Proverbs 6:6-8), and how does an ant colony work without a ruler?
2. In the waggle dance, what does the angle of the waggle run tell the other bees, and what does its length tell them?
3. Why does no single monarch butterfly make the whole round trip between Canada and Mexico?
4. Is a spider an insect? Give two reasons.
5. What are elytra, and about what fraction of named animal species are beetles?

Badge quiz 2 (Stops 6-10)

6. Why is firefly light called “ cold light ,” and what is it used for?
7. Where does a dragonfly spend most of its life, and how does the young one catch food?
8. What turns a shy grasshopper into a swarming locust, and how did God bring and remove the locusts in Exodus 10?
9. Describe one of Jean-Henri Fabre’s experiments and what he learned.
10. Give three rules for building a good mason bee house.

TRAIL CERTIFICATE: MY INSECT FIELD NOTEBOOK AND TRAIL E CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: “ My Insect Field Notebook ,” your name, and the dates you started and finished.

Include at least one labeled diagram and one written paragraph from every stop, plus the two maps (the monarch migration and the eighth plague) and your bug hotel plan and log.

Add a closing page in Fabre’s style: the true story of one small creature you watched yourself, with dates, times and a drawing.

When the booklet is done, a parent signs the Trail E certificate.

- **Ten stops:** A dated page for each stop with a labeled diagram or map and a paragraph of at least five sentences.
- **Maps and diagrams:** Maps have a title, a key, a north arrow and labels; diagrams name the body parts or stages correctly.
- **Field observation:** At least three entries record real creatures the student watched, with date, time, place and measurements.
- **Care and accuracy:** Facts are correct, Scripture is copied exactly, and the work is neat and complete.

Answer key

1. To be diligent and work ahead, gathering food in summer and harvest. The queen only lays eggs; each worker does the job in front of her, guided by scents, with no one giving orders.
2. The angle from straight up shows the direction of the food compared with the sun; the length of the waggle shows how far away it is.
3. The fall “super generation” flies south and lives eight or nine months, but the return north takes three or four generations, each laying eggs on milkweed along the way.
4. No, it is an arachnid: it has eight legs (not six), two body parts (not three), and no antennae or wings.
5. Elytra are a beetle’s hard front wings that cover the flying wings. About one in four named animal species is a beetle.
6. The chemical reaction (luciferin, oxygen and ATP with luciferase) makes light with almost no heat. Fireflies use their flash patterns to find mates of their own kind.
7. Underwater as a nymph, for months or years. It shoots out its hinged lower lip (the labium) to grab tadpoles, small fish and insects.
8. Crowding: repeated touching, especially of the hind legs, changes its body and behavior. God brought them with an east wind and took them away with a mighty strong west wind into the Red Sea.
9. Any one: the *Cerceris* wasp stings beetles in a nerve center to paralyze, not kill, them; mason bees carried kilometers away found their way home; pine processionary caterpillars circled a pot rim for about seven days, showing instinct can be blind.
10. Any three: holes about 8 mm wide and 15 cm deep, closed at the back; untreated wood; smooth entrances; a roof overhang; hang it 1–2 m high facing east or southeast; flowers and mud nearby; replace tubes or liners every year or two.

ANIMALS TRAIL F: ANIMALS DOING AMAZING THINGS

The sixth and last trail of the Animals track looks at what animals *do*: bats and dolphins that see with sound, creatures that hide in plain sight, woodchucks and wood frogs that sleep through winter, beavers and weaver birds that build, partners like the honeyguide and the clownfish, the sea otter and its rock, record-setting journeys, the sled dogs of the 1925 serum run to Nome, inventions copied from creation and, at the end, Adam naming the animals (Genesis 2:19). Every stop has a story, a picture study, a project, a diagram or map, practice questions, a game and a verse of Scripture.

This is the  **Ranger** level, for ages 10 to 13. The student reads each stop alone, in about 25 to 35 minutes. Ranger stops give more facts, dates and numbers than the Scout level, ask for a labeled map or diagram and a short written paragraph in the Field Notebook, and include five practice questions (easy, medium and challenge) with worked answers. Every stop stands by itself; Stop F10 makes a good close to the whole track.

Five stops earn the **Animal Wonders Ranger badge, part 1**, and ten stops earn part 2 and the **Trail F certificate**. The two badge quizzes at the end of the trail are optional. Badges and the certificate are earned by doing the stops, not by scores.

BEFORE YOU BEGIN

- Read a page of about 500 words on your own and write a paragraph about it.
- Multiply and divide with decimals and find a simple percent (a calculator may be used for larger numbers).

MASTERY CHECKLIST

- ☐ I can explain echolocation, camouflage and hibernation, with one real example and one number for each.
- ☐ I can tell the difference between mutualism, commensalism and parasitism and give an example of each.
- ☐ I can tell the story of the 1925 serum run to Nome with its dates, its distance and the names of Togo and Balto.
- ☐ I can name three inventions copied from living things and the animal or plant behind each.
- ☐ I can draw a labeled diagram or map, read a two-part scientific name and explain what Genesis 2:19 teaches about mankind's care for the animals.

OPTIONAL BOOKS AND RESOURCES

- **Monterey Bay Aquarium: Sea Otter Program and live cams**
(<https://www.montereybayaquarium.org>): Free sea otter and kelp forest pages and live cameras for Stop F6.

- **National Park Service: The Serum Run of 1925** (<https://www.nps.gov>): Search “serum run” for the history, route and mushers used in Stop F8 (Bering Land Bridge and Denali park pages).
- **Biodiversity Heritage Library** (<https://www.biodiversitylibrary.org>): Free old natural history books and plates, including Audubon, Haeckel and Linnaeus’s *Systema Naturae*, for copying into the Field Notebook.
- **Your public library** (<https://www.worldcat.org>): Find books such as Gay and Laney Salisbury’s *The Cruellest Miles* (for a parent) or children’s books on Togo, Balto, beavers and bats near you.

6.1 ECHOLOCATION: SEEING WITH SOUND

OBJECTIVES

- Explain how a bat or a dolphin uses echoes to find its food and its way.
- Tell how Lazzaro Spallanzani (1793) and Donald Griffin (1938) solved the puzzle of how bats fly in the dark.
- Use the speed of sound to work out how far away an object is from the time of its echo.

Warm-up. Shut your eyes and hum steadily while a helper slowly brings a large hardcover book toward your face and then takes it away again. Many people can hear the sound change and tell when the book is close, without seeing it. You have just tried a very weak version of what a bat does hundreds of times a night.

Video slot. Video coming. Bat echolocation with slowed-down ultrasonic calls; dolphin clicks and the melon. Search approved channels (BBC Earth, PBS Nature, Smithsonian Channel, National Geographic Kids, Bat Conservation International); preview first.

KEY TERMS

echolocation

Finding objects by making sounds and listening for the echoes that bounce back. The word was made up by Donald Griffin in 1944.

echo

A sound that has bounced off a surface and come back to the listener.

frequency (hertz)

How many times a sound wave vibrates each second. One hertz (Hz) is one vibration per second; high-pitched sounds have high frequencies.

ultrasound

Sound with a frequency above about 20,000 hertz, too high for human ears to hear.

sonar

A machine that finds things underwater by sending out sound and timing the echoes; short for “sound navigation and ranging.”

CORE IDEAS

A puzzle in the dark. In 1793 an Italian priest and scientist named Lazzaro Spallanzani noticed something strange. His pet owls could not fly in a completely dark room; they bumped into the walls. But bats flew through the same darkness without touching a thing. Spallanzani covered the eyes of some bats and strung silk threads across a room. The bats still dodged the threads. The next year a Swiss surgeon, Louis Jurine, tried plugging bats’ ears with wax instead. Now the bats blundered into everything. Somehow bats “saw” with

their ears, but no one could hear them making any sound, and the puzzle sat unsolved for almost 150 years.

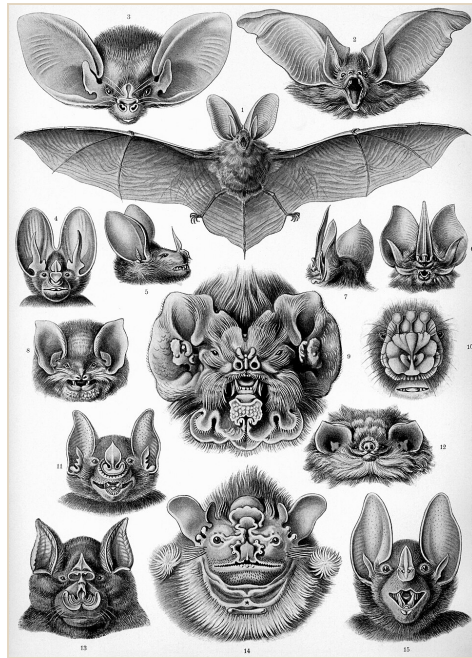
The answer, 1938. A Harvard student named Donald Griffin carried a cage of bats to the laboratory of a physicist, George W. Pierce, who had built a machine that could pick up sounds too high for human ears. When the bats flew, the machine crackled with noise. The bats had been shouting all along! Their calls were **ultrasound**. Human ears hear up to about 20,000 vibrations a second (20,000 hertz); most bat calls are between about 20,000 and 100,000 hertz, and some go higher. In 1944 Griffin named the bats' gift **echolocation**.

How it works. A hunting bat sends out a call through its mouth or nose. The sound spreads out, strikes a moth and bounces back as an **echo**. The time the echo takes to return tells the bat how far away the moth is. The strength of the echo hints at its size, and the tiny difference between what reaches the left ear and the right ear tells its direction. While searching, a bat may call about ten times a second. As it closes in, the calls speed up into a "feeding buzz" of up to about 200 calls a second. Just as it calls, small muscles in its ears tighten so its own loud shout does not deafen it.

Echoes in the sea. Dolphins and other toothed whales echolocate underwater with rapid clicks. The clicks are made in the passages below the blowhole and focused by the **melon**, the rounded, fatty forehead. Returning echoes travel through fat in the lower jaw to the ears. Sound moves about 1,500 meters per second in seawater, more than four times faster than in air (about 343 meters per second). A few birds echolocate too: the oilbirds of South America and some cave swiftlets of Asia make clicks that people can hear. Engineers had already built **sonar** for ships by the end of the First World War, about twenty years before anyone knew that bats had been doing the same thing all along.

"He that planted the ear." The psalmist asks, "He that planted the ear, shall he not hear?" (Psalm 94:9). Spallanzani, Jurine, Pierce and Griffin spent years learning how a small bat hears its way through the night. Every careful discovery about the ear points back to the wisdom of the One who planted it.

PICTURE STUDY



Chiroptera (Bats), Plate 67 from Kunstformen der Natur (Art Forms in Nature), Ernst Haeckel (lithograph by Adolf Giltisch), 1904 · Color lithograph · From Kunstformen der Natur, published in Leipzig, 1899–1904
Wikimedia Commons · Public domain

Ernst Haeckel was a German zoologist who drew animals with great care and arranged them like ornaments. In this plate he gathered the strange faces of many kinds of bats. Look closely: the shapes you see are the bats' sound equipment.

Look closely

- Find the bats with leaf-shaped flaps of skin on their noses. These “nose leaves” help aim calls that some bats send out through the nose.
- Compare the ears. Which bat has the largest ears for its head? Find ridges and folds inside the ears.
- Look at the eyes. Are they large or small next to the ears?

Talk about it

1. Why might a bat that hunts by sound need such big, folded ears?
2. Haeckel arranged real animals into a pattern like a carpet. What does this way of drawing help you notice that a single photograph might not?

Safety first. Do the echo test outdoors with a grown-up, on a playground or open field away from roads and parked cars. Clap; do not shout right next to anyone's ears.

HANDS-ON: ECHO DISTANCE TEST

Measure an echo the way Griffin and Pierce measured bat calls: by timing sound. You will use the echo to find the speed of sound, then draw a labeled diagram of a bat hunting.

You will need

- A large flat wall (a school building, gym or church wall) with open ground in front of it
- A long tape measure or measuring wheel, or a known stride length to pace the distance
- A stopwatch or phone timer
- A helper
- Your Field Notebook, a pencil and a calculator

Steps

1. Stand facing the wall about 50 meters (165 feet) away. Measure or pace the distance and write it down.
2. Clap once, sharply. Listen for the echo. If you cannot hear it, step back farther.
3. Now clap in a steady rhythm so that each new clap falls exactly on the echo of the last one. When the rhythm matches, your helper starts the stopwatch and counts 20 claps.
4. Divide the time by 20. That is about how long the sound takes to go to the wall and back.
5. Work out the speed of sound: $\text{speed} = (2 \times \text{distance}) \div \text{time}$. Compare your answer with the true speed in air, about 343 meters per second.
6. Draw the diagram described in the Field Notebook tasks.

Check your work

- I measured the distance to the wall and wrote it down.
- I timed 20 claps and found the time for one round trip.
- I calculated a speed of sound and compared it with 343 meters per second.
- My bat diagram has all its labels.

FIELD NOTEBOOK

1. **Diagram.** Draw a bat on the left of the page and a moth on the right. Draw curved lines spreading out from the bat's mouth toward the moth and label them "call (ultrasound)." Draw smaller curved lines coming back and label them "echo." Label the bat's mouth or nose leaf, its ears and the distance between bat and moth. Add a note: "time of echo tells distance."
2. **Notebook entry.** Write a paragraph explaining to a younger child how a bat catches a moth in the dark. Use the words call, echo and ultrasound, and tell who first heard the bats' calls and when.

Did you know? Some tiger moths answer bats with their own ultrasonic clicks. Certain kinds warn the bat that they taste bad, and at least one kind seems to jam the bat's sonar

so that it misses. Meanwhile, some bats call so loudly that, if we could hear them, they would be as loud as a smoke alarm held next to your ear.

Map or diagram. Diagram tip: draw the outgoing calls as wide arcs and the echo as smaller arcs, because the echo is weaker. Draw the moth twice, once near and once far, and show that the near echo comes back sooner.

Goes deeper in. Life Science (sound, hearing and mammals) and Arithmetic (distance = speed $\times$ time) (coming soon). Stop A4 “Bats” in Trail A and Stop D5 “Dolphins” in Trail D tell more about these animals.

For families. Spallanzani’s blinded-bat experiments were in 1793; Louis Jurine’s ear-plugging experiments followed in 1794, and the two men corresponded. G. W. Pierce and D. R. Griffin reported bat ultrasound in the *Journal of Mammalogy* (1938); Griffin coined “echolocation” in 1944. Call rates and frequencies vary by species; the numbers given are typical ranges. Ernst Haeckel was a strong promoter of evolutionary theory, and some of his embryo drawings were later shown to be exaggerated; this plate is used only for its careful art. The speed of sound in air (343 m/s) is for about 68°F (20°C).

PRACTICE

1. **EASY** Who showed in 1793 that bats can fly in the dark without using their eyes?
2. **EASY** Why could no one hear bats calling before 1938?
3. **MEDIUM** A bat hears an echo 0.1 second after it calls. Sound travels about 343 meters per second in air. How far away is the moth?
4. **MEDIUM** Why does a bat speed up its calls into a “feeding buzz” as it closes in on a moth?
5. **CHALLENGE** A dolphin hears the echo of its click 0.2 second later. Sound travels about 1,500 meters per second in seawater. How far away is the fish? If a bat heard an echo after the same 0.2 second in air, how far away would its target be? Why are the answers different?

Make it a game • Bat and Moth. Players hold hands in a big circle. One player inside is the bat, blindfolded; two or three are moths. When the bat calls “Bat!” every moth must answer “Moth!” at once. The bat tags moths using only the sound of their answers. Moths may move but must always answer. The circle gently keeps the bat from wandering out.

Scripture. “He that planted the ear, shall he not hear? he that formed the eye, shall he not see?” (Psalm 94:9, KJV)

The bat’s ear, tuned to sounds we cannot hear, was planted by God. If He made ears that can find a moth in the dark, He surely hears His people.

Practice: answers

1. Lazzaro Spallanzani, an Italian priest and scientist.

2. Most bat calls are ultrasound, higher than about 20,000 hertz, which is above the top of human hearing. It took Pierce's special detector to pick them up.
3. In 0.1 second sound travels $343 \times 0.1 = 34.3$ meters. That is the trip there and back, so the moth is about $34.3 \div 2 \approx 17$ meters away.
4. Near echoes come back sooner, so the bat can call again sooner, and quick calls give it fresh information many times a second about where the dodging moth is.
5. Dolphin: $1,500 \times 0.2 = 300$ meters round trip, so the fish is 150 meters away. Bat: $343 \times 0.2 = 68.6$ meters round trip, so about 34 meters away. Sound moves more than four times faster in water than in air, so the same echo time means a much greater distance.

6.2 CAMOUFLAGE: HIDDEN IN PLAIN SIGHT

OBJECTIVES

- Name and give an example of five kinds of camouflage: background matching, countershading, disruptive patterns, masquerade and color change.
- Explain countershading, the discovery of the painter Abbott Thayer.
- Run a camouflage experiment, record the results in a table and draw a bar graph.

Warm-up. Look around the room for one minute. Which objects are hardest to see because they match what is behind them? Which jump out at you? Write down one of each. Then think: if you were a mouse in this room, where would you hide?

Video slot. Video coming. Cuttlefish and octopus changing color; snowshoe hare winter and summer coats; stick and leaf insects. Search approved channels (BBC Earth, PBS Nature, Smithsonian Channel, Monterey Bay Aquarium); preview first.

KEY TERMS

camouflage

Colors, patterns or shapes that help an animal avoid being seen. The word comes from the French *camoufler*, “to disguise.”

countershading

Coloring that is darker on the back and paler on the belly, so that sunlight from above cancels out the animal’s own shadow.

disruptive pattern

Bold spots, stripes or patches that break up an animal’s outline so the eye does not see its true shape.

masquerade

Looking like an object that a hunter is not interested in, such as a twig, a leaf or a bird dropping.

chromatophore

A tiny sac of colored pigment in the skin of animals like octopuses and cuttlefish that can be stretched open or squeezed shut to change color.

CORE IDEAS

A painter who watched animals. Abbott Handerson Thayer (1849–1921) was an American painter who lived in the hills of Dublin, New Hampshire. He spent hours watching birds, rabbits and deer, and he noticed that a great many animals are darker on their backs and paler on their bellies. In 1896 he explained why. Sunlight falls from above, so it brightens an animal’s back and leaves its belly in shadow. Shadows are what make a round body look solid. A dark back and a pale belly cancel the light and the shadow, and the animal looks flat

and fades into the background. Thayer showed it with painted model birds set side by side: the countershaded models almost vanished. Scientists still call this **countershading**, or “Thayer’s law.”

Five ways to hide. Some animals simply match their background, like the flounder on sandy seafloor. Some use countershading, like sharks and deer. Some wear **disruptive patterns**: the spots of a leopard or the bold blotches on a moth break up the outline so a hunter does not see a body shape. Some practice **masquerade**: stick insects look like twigs, leaf insects even have “veins” and chewed-looking edges, and some caterpillars look like bird droppings. And a few change color on the spot.

Changing with the seasons. The snowshoe hare of North America is brown in summer and white in winter. As the days shorten in fall, the hare begins growing white fur, and the change takes about ten weeks. The willow ptarmigan, the Arctic fox and the short-tailed weasel (called an ermine in its white coat) change too. The days’ length, not the snow, sets the timing, so a hare sometimes sits white on bare brown ground in a late autumn.

Color in a flash. Cuttlefish and octopuses change faster than any other animals. Their skin holds thousands of **chromatophores**, each one a tiny elastic bag of yellow, red or brown pigment. Muscles stretch the bags open or let them shrink, and nerves control the muscles, so the whole skin can change pattern in less than a second. A cuttlefish can even raise little bumps to copy the texture of rock or seaweed. Strangely, tests suggest cuttlefish cannot see color the way we do, yet they match their surroundings very well. Scientists are still working out how.

Soldiers learn from animals. In 1915 the French army formed the first unit of camouflage painters, and the word spread. Thayer himself urged armies to use his ideas. Yet he also went too far: he claimed that every color of every animal, even the bright pink of flamingos, was for hiding. Theodore Roosevelt, a keen naturalist, argued that this did not fit what hunters saw in the field. A true idea, stretched to explain everything, becomes a false one. The psalmist simply praises: “O LORD, how manifold are thy works!” (Psalm 104:24).

PICTURE STUDY



Young Hare, Albrecht Dürer, 1502 · Watercolor and gouache on paper · Albertina, Vienna
Wikimedia Commons · Public domain

More than five hundred years ago the German artist Albrecht Dürer painted this hare so carefully that you can almost count the hairs. He signed it with his monogram, a large A with a small D beneath. The brown hare of Europe does not turn white in winter like the snowshoe hare, but its mottled coat is still a fine camouflage.

Look closely

- Look at the fur on the back and on the belly. Is the hare darker on top? Where are the lightest hairs?
- Find the hairs that change direction around the shoulders and haunches. How many shades of brown, gray and gold can you find?
- Look at the hare's eye. Can you see the reflection of a window in it?

Talk about it

1. Imagine this hare crouched still in a dry, plowed field. Which parts of its coat would help it disappear, and what might give it away?
2. Dürer painted on a plain background. Why might that make it easier to study the hare's coloring but harder to judge its camouflage?

HANDS-ON: THE TOOTHPICK HUNT

Test camouflage the way field scientists do: set out “prey” of different colors and see which ones a “predator” finds. Then graph your results.

You will need

- 100 toothpicks: 20 each of green, brown, red, yellow and blue (colored toothpicks, or plain ones colored with markers)
- A patch of lawn about 3 meters (10 feet) square, marked with string or sticks
- A stopwatch
- A helper to be the predator
- Your Field Notebook, a ruler and colored pencils

Steps

1. While the predator looks away, scatter all 100 toothpicks evenly over the square.
2. The predator has 60 seconds to pick up as many toothpicks as possible, one at a time.
3. Count how many of each color were found and write the numbers in a table with five rows.
4. Work out the percent found for each color: $\text{number found} \div 20 \times 100$.
5. Draw a bar graph of your results (see the Field Notebook tasks).
6. If you can, repeat the hunt on bare dirt or a sidewalk. Which color is best hidden now?
7. Pick up every toothpick when you are done.

Check your work

- I recorded the number of each color found in a table.
- I worked out the percent found for each color.
- My bar graph has a title, labeled axes and a bar for each color.
- I can explain which color was best camouflaged and why.

FIELD NOTEBOOK

1. **Bar graph.** Draw a bar graph of the toothpick hunt. Title it "Toothpicks Found in 60 Seconds." Label the bottom axis with the five colors and the side axis "number found" from 0 to 20. Color each bar to match.
2. **Countershading diagram.** Draw two fish side by side with a sun above them. Color the first fish the same gray all over and shade its belly dark, as a shadow. Color the second fish dark on top and pale underneath. Label: "sunlight," "shadow," "countershaded," "looks flat."
3. **Notebook entry.** Write a paragraph explaining what your experiment showed. Which colors hid best on grass, and which kind of camouflage were they using?

Did you know? In the First World War, British ships were painted in wild zigzags of black, white and blue. This "dazzle" paint, suggested by the marine artist Norman Wilkinson in 1917, did not hide the ships. It was meant to make it hard for an enemy to judge which way a ship was heading and how fast. A zebra's stripes may work in a similar way, though scientists still debate what the stripes are for.

Goes deeper in. Life Science (adaptations, light and color) and Art (color and shading) (coming soon). Stop C5 "Chameleons" and Stop D2 "Octopus" tell more about color-

changing animals.

For families. Thayer published on countershading in *The Auk* in 1896. The 1909 book *Concealing-Coloration in the Animal Kingdom* was written by his son Gerald H. Thayer with Abbott Thayer's introduction and ideas. Theodore Roosevelt's critique appeared in 1911 in the *Bulletin of the American Museum of Natural History*. The French army's camouflage section dates to 1915. Cuttlefish have one type of visual pigment and appear colorblind in standard tests; how they match color is still studied. The hare molt length (about ten weeks) varies with region and individual.

PRACTICE

1. **EASY** What is countershading?
2. **EASY** Name two animals that change the color of their coats with the seasons.
3. **MEDIUM** A shark is dark gray on top and white underneath. Explain how this helps it whether a fish looks down at it or up at it.
4. **MEDIUM** In a toothpick hunt, the predator found 4 of 20 green toothpicks and 17 of 20 red ones. What percent of each color was found? Which was better camouflaged on grass?
5. **CHALLENGE** Thayer was right about countershading but claimed that even flamingos' pink was camouflage against the sunset. Why did Roosevelt and others doubt it, and what does this teach about using a good idea?

Make it a game • Camouflage. One player is the hawk and stands on a spot with eyes shut, counting to 20. Everyone else hides, but they must be able to see the hawk's spot from where they are (no hiding fully behind walls). The hawk opens its eyes and, without moving its feet, names and points to everyone it can see. Those players are caught. The hawk then shuts its eyes again for 10 seconds while the rest must move closer. Last one uncaught becomes the next hawk.

Scripture. "O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches." (Psalm 104:24, KJV)

"Manifold" means many and varied. The hare's coat, the cuttlefish's skin and the stick insect's twiggy legs are a few of the many ways God clothed His creatures in wisdom.

Practice: answers

1. Coloring that is dark on the back and pale on the belly, so that light from above cancels the shadow and the animal looks flat and hard to see.
2. Any two: snowshoe hare, willow ptarmigan, Arctic fox, short-tailed weasel (ermine).
3. From above, its dark back matches the dark deep water below. From below, its white belly matches the bright water and sky above.
4. Green: $4 \div 20 \times 100 = 20\%$. Red: $17 \div 20 \times 100 = 85\%$. Green was much better camouflaged.

5. Flamingos are seen in broad daylight in open places, where bright pink stands out, so the claim did not fit what observers actually saw. A true idea must still be tested against each case; stretching it to explain everything makes it false.

6.3 HIBERNATION: THE LONG WINTER SLEEP

OBJECTIVES

- Explain what happens to an animal's body temperature, heartbeat and breathing during hibernation.
- Compare true hibernators (woodchuck, ground squirrel, poorwill) with bears and with frozen wood frogs.
- Run a heat-loss experiment, record temperatures and draw a line graph.

Warm-up. Find your pulse on your wrist or neck and count the beats for 15 seconds. Multiply by 4 to get beats per minute. Write it down. A woodchuck's heart beats about as fast as yours when it is awake. By the end of this stop you will learn how slow it beats in January.

Video slot. Video coming. Hibernating woodchucks, Arctic ground squirrels and bats; a frozen wood frog thawing. Search approved channels (PBS Nature, BBC Earth, Smithsonian Channel, U.S. Fish and Wildlife Service, National Park Service); preview first.

KEY TERMS

hibernation

A long winter rest in which an animal's body temperature, heartbeat and breathing drop far below normal so it can live on stored fat.

torpor

A short period, often a night or a few days, of lowered body temperature and slowed body processes to save energy.

metabolism

All the chemical work the body does to stay alive, which uses up food energy.

dormancy

A resting state in which an animal is inactive and uses little energy; bears are said to be dormant in winter.

brumation

The winter rest of reptiles such as turtles and snakes.

CORE IDEAS

The sleeping one. On December 29, 1946, a desert naturalist named Edmund Jaeger was hiking with two students in the Chuckwalla Mountains of southern California. In a crack in a rock wall he found a small gray-brown bird, a common poorwill, sitting perfectly still. He picked it up and it barely stirred. When he came back and took its temperature, it was only about 65°F, though an awake poorwill runs about 106°F. He could find no heartbeat or

breathing. Jaeger put a band on its leg, and the same bird returned to the same crevice for the next several winters. It was the first bird known to science to hibernate. The Hopi people of Arizona, it turned out, already had a name for the poorwill that meant “the sleeping one.”

More than sleep. Hibernation is not ordinary sleep. A hibernating woodchuck’s heart slows from about 80 beats a minute to about 5. Its body cools from about 99°F to near 40°F, and it may take only a couple of breaths a minute. Its **metabolism**, the body’s work, slows so much that the fat it stored in autumn lasts all winter, though it may lose a third of its weight by spring. Every week or two it warms up for a few hours and then sinks back down; scientists still are not sure why.

The champions. In 1989 a scientist in Alaska, Brian Barnes, measured hibernating Arctic ground squirrels at about 27°F, below the freezing point of water, yet their blood did not freeze. The wood frog goes further. In winter as much as two-thirds of the water in its body turns to ice. Its heart stops and it does not breathe. Sugar flooding its cells works like antifreeze to protect them, and in spring the frog thaws and hops away. Bats hibernate too, hanging in caves and old mines, their heartbeats dropping from hundreds of beats a minute to a handful.

What about bears? Black bears and grizzlies spend up to five to seven months in their dens without eating, drinking or, in most cases, passing waste. Yet their body temperature drops only about 10°F, and they can wake fairly quickly. Mother bears give birth in the den in January or February to cubs that weigh under a pound. Some scientists call this **dormancy** rather than true hibernation; many now count bears as hibernators of a special kind. Reptiles such as turtles and snakes have their own winter rest, called **brumation**.

Seedtime and harvest. After the Flood, God promised that “summer and winter... shall not cease” (Genesis 8:22). Creatures that cannot find food in winter are made to store it up and rest. Not every animal sleeps; a fox and a crow must hunt all winter. But for the woodchuck under the snow, God’s faithful seasons mean that spring will surely come.

PICTURE STUDY



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

Winslow Homer painted this, his largest picture, in his studio at Prouts Neck, Maine, during the winter of 1893. It shows the other side of winter: animals that do not hibernate. The fox and the crows must stay awake and find food in the cold.

Look closely

- Look at the fox's legs. How deep is the snow? How would that make hunting hard?
- Count the crows. What are they doing, and what might they be hoping for?
- Find the small red berries on the snow. What does that tell you about how little food there is?

Talk about it

1. Why would a woodchuck sleeping under this snow be better off than the fox?
2. Homer used only a few colors: white, black, gray, red-brown and a little bright red. How do those colors make the picture feel cold?

Safety first. Use warm tap water only, never boiling water from the stove. A grown-up should help fill and carry the jars, and wipe up spills so no one slips.

HANDS-ON: BUILD A WINTER DEN

A hibernating animal must hold on to its heat. Test whether a den of leaves or cloth keeps a "body" warmer than open air, and graph what you find.

You will need

- Two identical jars with lids (the “animals”)
- Warm tap water
- A kitchen or aquarium thermometer
- A cardboard box filled with dry leaves, straw, crumpled newspaper or an old sweater (the “den”)
- A clock or timer
- Your Field Notebook and colored pencils

Steps

1. Fill both jars with warm tap water of the same temperature. Measure and record it as the temperature at 0 minutes.
2. Bury one jar deep in the den box and close the flaps. Set the other jar beside the box in the open. If it is cold outdoors, do this on a porch or in a garage.
3. Every 10 minutes for 40 minutes, quickly measure each jar’s temperature and close the den again. Record each reading in a table.
4. Work out how many degrees each jar lost from start to finish.
5. Draw the line graph described in the Field Notebook tasks.

Check your work

- I started both jars at the same temperature.
- I recorded five readings for each jar in a table.
- My line graph has two labeled lines, a title and labeled axes.
- I can explain why a den or a burrow helps a hibernating animal.

FIELD NOTEBOOK

1. **Line graph.** Title it “Which Jar Stayed Warm?” Put time (0, 10, 20, 30, 40 minutes) along the bottom and temperature up the side. Draw one line for the den jar and one for the open jar in two colors, with a key.
2. **Diagram.** Draw a cross-section of a woodchuck burrow under snow: the entrance, a long tunnel, the sleeping chamber lined with grass, and the woodchuck curled in a ball. Beside it write two numbers: “heartbeat awake 80 / hibernating 5” and “body 99°F / about 40°F.”
3. **Notebook entry.** Write a paragraph comparing a hibernating woodchuck with a winter bear. Tell one way they are alike and two ways they are different.

Did you know? Bats that are woken in winter burn a great deal of stored fat to warm up, and if it happens too often they can starve before the insects return in spring. That is why many caves where bats hibernate are closed to visitors in winter. Keeping out of them is a simple way to care for God’s creatures (Genesis 2:15).

Goes deeper in. Life Science (body temperature, energy and mammals) and Gardening & Animals (helping backyard animals through winter) (coming soon). Stop A7 “Bears” in Trail A tells more about bears’ dens.

For families. Jaeger’s poorwill was found December 29, 1946, and reported in *The Condor* (1948, 1949); he measured about 18–19.8°C (64–68°F). The Hopi name is reported as *hölchko*. Brian Barnes reported Arctic ground squirrel body temperatures of –2.9°C (26.4°F) in *Science* (1989). Woodchuck heart rate and temperature figures vary among sources; the numbers given are typical. Whether bears are “true” hibernators is a matter of definition among scientists; the stop says so. The painting has been described by some critics in evolutionary terms; the stop uses it simply to show winter hunger.

PRACTICE

1. **EASY** Name two animals that truly hibernate.
2. **EASY** What does a hibernating woodchuck live on all winter?
3. **MEDIUM** A woodchuck’s heart beats about 80 times a minute when awake and about 5 times a minute in hibernation. How many beats is that in one hour for each? How many times fewer?
4. **MEDIUM** Give two ways a bear’s winter rest is different from a woodchuck’s hibernation.
5. **CHALLENGE** In your den experiment, the open jar cooled from 104°F to 84°F in 40 minutes and the den jar cooled from 104°F to 96°F. How many degrees did each lose? Explain what this means for a woodchuck that sleeps in a burrow instead of on the open ground.

Make it a game · Seasons Freeze. The leader calls out seasons in any order. “Summer!” means run and play in place. “Fall!” means gather pretend food as fast as you can. “Winter!” means curl up on the floor and stay perfectly still: a hibernator who moves is out. “Spring!” means stretch and yawn slowly. Make winter last a long time.

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

God promised Noah that the seasons would keep coming. The hibernating woodchuck is a small picture of trust: it rests through the cold because spring is promised.

Practice: answers

1. Any two: woodchuck (groundhog), Arctic ground squirrel, little brown bat or other bats, common poorwill, chipmunk, jumping mouse.
2. The fat it stored up in late summer and fall.
3. Awake: $80 \times 60 = 4,800$ beats. Hibernating: $5 \times 60 = 300$ beats. That is $4,800 \div 300 = 16$ times fewer.
4. Any two: a bear’s temperature drops only about 10°F, not 60°F; a bear can wake fairly quickly; a bear does not wake every week or two to warm up the same way; mother bears give

birth in the den.

5. The open jar lost 20°F; the den jar lost 8°F, less than half as much. A burrow or den slows heat loss, so the animal burns less of its stored fat to stay alive and is more likely to last until spring.

6.4 ANIMAL BUILDERS: BEAVERS AND WEAVER BIRDS

OBJECTIVES

- Describe how a beaver builds a dam and a lodge, and the body parts God gave it for the work.
- Describe how a village weaver ties and weaves its hanging nest.
- Draw and label a cross-section of a beaver lodge and pond.

Warm-up. Tie a simple knot in a piece of string using only one hand and your teeth to hold the other end. (Ask first; use clean string!) It is hard. A weaver bird ties knots in grass using only its beak and feet.

Video slot. Video coming. Beavers building a dam and lodge; a village weaver weaving its nest; sociable weaver colony nests in the Kalahari. Search approved channels (BBC Earth, PBS Nature, Smithsonian Channel, National Geographic Kids, Parks Canada); preview first.

KEY TERMS

dam

A wall built across flowing water to hold it back and make a pond.

lodge

A beaver's home: a dome of sticks and mud with a dry room inside and entrances under the water.

incisors

The sharp front teeth used for cutting and gnawing. A beaver's incisors never stop growing.

rodent

A gnawing mammal with ever-growing front teeth, such as a mouse, squirrel or beaver.

colony

A group of the same kind of animal living closely together, like a weaver colony in one tree.

CORE IDEAS

A dam seen from space. In 2007 a Canadian researcher named Jean Thie was studying satellite pictures of northern Alberta when he spotted a long, curving line across the wetlands of Wood Buffalo National Park. It was a beaver dam about 850 meters (2,790 feet) long, more than half a mile, the longest beaver dam known. Families of beavers had probably been adding to it since the 1970s. It is so far from any road that the first person to hike to it, Rob Mark, did not reach it until 2014.

A builder's tool kit. The beaver is the largest rodent in North America, often 35 to 65 pounds. Its front **incisors** are bright orange because the enamel holds iron, which makes it hard. They never stop growing, so gnawing keeps them sharp and short. A beaver can close its lips behind its teeth to gnaw underwater without swallowing water. Its ears and nose close when it dives, clear eyelids cover its eyes like goggles, and it can stay under for about 15 minutes. Its broad, scaly tail is a rudder in the water, a prop when it sits up to chew a tree, and a warning drum when slapped on the pond.

Dam and lodge. Beavers build a **dam** of sticks, stones and mud to make a deep pond. Deep water keeps the doors of their **lodge** underwater, out of reach of wolves and coyotes, and keeps the pond from freezing to the bottom. Inside the domed lodge is a dry room above the waterline, with a breathing hole in the roof. In fall they push branches into the pond mud beside the lodge to eat all winter under the ice. The sound of running water spurs them to work: in Swedish experiments, beavers piled sticks and mud over a loudspeaker playing the sound of a leak. Beaver ponds become homes for ducks, fish, frogs and moose, though they sometimes flood roads and fields, and people must manage them wisely.

A bird that ties knots. In Africa, the male village weaver builds a hanging nest. He tears long strips from grass or palm leaves, loops them around a twig and ties them with his beak and feet, using real knots. First he makes a ring, then weaves a round chamber on one side, and finally a short tunnel pointing down for the door. Nests usually hang from thin branch tips, often over water, where snakes have trouble reaching them. The female inspects the nest, and if she rejects it, he may tear it down and start again. Young males build clumsy nests at first and get better with practice. The sociable weaver of the Kalahari goes further: whole colonies build one huge thatched "apartment house" in a tree, with chambers for a hundred or more birds.

Who builds the house? "Except the LORD build the house, they labour in vain that build it" (Psalm 127:1). The beaver and the weaver work hard, but the skill in their teeth, beaks and instincts was given by their Maker.

PICTURE STUDY



*American Beaver, Plate 46 from The Viviparous Quadrupeds of North America, John James Audubon (lithograph by J. T. Bowen), c. 1844 · Lithograph, hand-colored · Brooklyn Museum, New York (64.98.42); copies in many libraries and museums
Wikimedia Commons · Public domain*

After his great book of birds, John James Audubon, with his sons and his friend the Reverend John Bachman, set out to picture every four-legged mammal of North America. This plate shows beavers at work at the water's edge.

Look closely

- Find the orange front teeth. What is the beaver holding, and how is it holding it?
- Find the tail. Describe its shape and texture.
- Look at the hind feet. Can you see webbing between the toes?

Talk about it

1. Which tools in the beaver's body can you see in this picture, and which ones (like the clear eyelids) can you not see?
2. Why do you think Audubon showed more than one beaver instead of just one?

Safety first. If you build your dam outdoors in a ditch or stream, a grown-up must be with you near the water at all times, and ask the landowner first. Take your dam apart afterward so you do not flood anyone's path.

HANDS-ON: BUILD A MODEL BEAVER DAM

Build a dam the way a beaver does and test what makes it hold water.

You will need

- A long plastic storage tub or a large baking pan
- Sand or garden soil
- Small sticks and twigs, pebbles, mud, leaves and grass
- A pitcher of water
- A ruler
- Your Field Notebook

Steps

1. Make a sloping “stream bed” of soil or sand in the tub, higher at one end, with a channel down the middle.
2. Build a dam across the channel: lay sticks first, wedge pebbles between them, then pack mud and leaves into the gaps, as beavers do.
3. Slowly pour water in at the high end. Watch for leaks.
4. Find each leak and plug it with more mud and leaves, like a beaver answering the sound of running water.
5. Measure the depth of the pond behind your dam with the ruler. Write it down.
6. Try a dam of sticks only, with no mud. Measure again and compare.

Check your work

- My dam held back a pond I could measure.
- I found and fixed at least one leak.
- I compared a dam with mud and one without.
- I can explain why beavers want deep water.

FIELD NOTEBOOK

1. **Diagram.** Draw a cross-section of a beaver pond in winter, cut through like a slice of cake. Show and label: the dam, the pond, the ice on top, the lodge, the dry den inside above the water, the vent hole in the roof, two underwater entrance tunnels and the food pile of branches stuck in the mud.
2. **Second diagram.** Draw a village weaver’s nest hanging from a branch tip. Label: branch, ring (built first), nest chamber, entrance tunnel facing down.
3. **Notebook entry.** Write a paragraph telling what happened when you built your model dam and what it taught you about how beavers build.

Did you know? For about two hundred years, beaver fur drove the exploration of North America. Felt hats made from beaver fur were the fashion in Europe, and the Hudson’s Bay Company, founded in 1670, traded for beaver pelts across Canada. Today the beaver is one of Canada’s national symbols and appears on the Canadian five-cent coin.

Goes deeper in. Life Science (mammals and birds, habitats) and Geography (wetlands and rivers of North America) (coming soon). Stop B8 “Nests” in Trail B tells more about bird builders.

For families. The Wood Buffalo dam was located by Jean Thie in 2007 using satellite imagery; Rob Mark reached it on foot in 2014. Its length is usually given as about 850 m. The loudspeaker experiments were done by the Swedish naturalist Lars Wilsson in the 1960s. Iron in beaver enamel is well documented. Audubon’s mammal plates were published 1845–1848 (text volumes to 1854) with lithographs by J. T. Bowen; some plates are by his son John Woodhouse Audubon, and the stop names J. J. Audubon as the lead artist. Colony sizes of sociable weavers vary widely; “a hundred or more” is a cautious figure.

PRACTICE

1. **EASY** Why are a beaver’s front teeth orange?
2. **EASY** In village weavers, who builds the nest, and who decides whether it is good enough?
3. **MEDIUM** Give two reasons a beaver builds a dam.
4. **MEDIUM** The Wood Buffalo dam is about 2,790 feet long. A football field is 300 feet from end zone to end zone. About how many football fields long is the dam?
5. **CHALLENGE** Why might a weaver’s nest hang from the thin tip of a branch, with its door pointing down, rather than sit on top of a thick branch?

Make it a game • Beaver Relay. Make two teams. Each team has a pile of “logs” (sticks, pencils or blocks) at one end of the yard. One at a time, players run, carry a single log back and lay it in a line to build a dam. The leader is the lead beaver: when the leader claps loudly (the tail slap!), every player must drop to a crouch and freeze until the second clap. First team to build a dam ten logs long wins.

Scripture. “Except the LORD build the house, they labour in vain that build it: except the LORD keep the city, the watchman waketh but in vain.” (Psalm 127:1, KJV)

Beavers and weavers are tireless builders, but their skill comes from God. Our work, too, is blessed when we build with Him.

Practice: answers

1. The enamel holds iron, which makes the teeth hard and strong.
2. The male builds it; the female inspects it and accepts or rejects it.
3. Any two: to keep the lodge entrances underwater and safe from predators; to keep the pond from freezing to the bottom; to store branches underwater for winter food; to make safe water for swimming to its food trees.
4. $2,790 \div 300 = 9.3$, so about 9 football fields.

5. Snakes, monkeys and other egg-eaters cannot easily climb out onto thin tips or enter a downward tunnel; the downward door also keeps out rain. Hanging over water adds more protection.

6.5 ANIMAL PARTNERS

OBJECTIVES

- Define symbiosis, mutualism, commensalism and parasitism and sort examples into each.
- Tell the true story of the honeyguide bird and the Yao honey hunters of Mozambique.
- Weigh an old story (Herodotus’s crocodile bird) against what has actually been observed.

Warm-up. Think of a job you can do better with a partner than alone: carrying a long table, folding a sheet, playing catch. What does each partner give? What does each one get? Keep that question in mind: animal partners trade too.

Video slot. Video coming. Honeyguide birds leading honey hunters; clownfish and sea anemones; cleaner wrasse cleaning stations; oxpeckers on buffalo and rhinos. Search approved channels (BBC Earth, PBS Nature, Smithsonian Channel, Monterey Bay Aquarium, University of Cambridge); preview first.

KEY TERMS

symbiosis

Two different kinds of living things living closely together. The word means “living together.”

mutualism

A partnership in which both partners are helped.

commensalism

A partnership in which one partner is helped and the other is neither helped nor harmed.

parasitism

A relationship in which one living thing (the parasite) feeds on another (the host) and harms it, like a tick on a deer.

cleaning station

A place on a reef where small fish or shrimp eat parasites and dead skin off larger fish that come to be cleaned.

CORE IDEAS

A bird that leads the way. In the wild woodlands of northern Mozambique, a Yao honey hunter walks along calling a loud trill followed by a grunt: “Brrrr-hm!” Soon a small brownish bird, the greater honeyguide, answers with a chattering call and flies ahead from tree to tree, waiting for the man to follow. At last it stops near a tree where wild bees have built a nest. The hunter calms the bees with smoke, chops open the hive and takes the honey. He leaves the wax behind, and the honeyguide eats it, for this bird can digest beeswax. In

2016 the scientist Claire Spottiswoode and her team played recordings in the forest. When they played the “brrrr-hm” call, honeyguides led them about twice as often as when they played other sounds. The birds really do know the call, and they choose to work with people. Hadza hunters in Tanzania have a different signal: a whistle.

Kinds of partners. Scientists call close living-together **symbiosis**. When both partners gain, it is **mutualism**, like the honeyguide and the hunter. When one gains and the other is not affected, it is **commensalism**: a remora fish hitches a ride on a shark and eats its scraps, and the shark hardly notices. When one feeds on the other and harms it, it is **parasitism**, like a tick on a deer.

Partners in the sea. A clownfish lives among the stinging arms of a sea anemone. A coat of slimy mucus keeps it from being stung, and the anemone protects it from enemies. In return the clownfish chases away butterflyfish that nibble anemones, and its waste feeds the anemone. On coral reefs, small cleaner wrasse set up **cleaning stations**. Big fish such as groupers line up, hold still and even open their mouths while the wrasse eat parasites off their skin and gills. A hungry grouper could swallow its cleaner, but it does not.

Partners on land. In Africa, oxpeckers ride on buffalo, giraffes and rhinos, eating ticks. When danger comes, they hiss and fly up. The Swahili name of one kind means “the rhino’s guard,” and a recent study found rhinos with oxpeckers noticed approaching people more often. Yet oxpeckers also peck at wounds and sip blood, so scientists still argue about how helpful they are. Partnerships in creation are real, but they must be studied honestly.

Checking an old story. Around 440 B.C. the Greek historian Herodotus wrote that a little bird walks into the open mouth of a Nile crocodile to eat leeches, and the crocodile never harms it. The bird is often said to be the Egyptian plover. It is a wonderful tale, but no scientist has ever recorded it happening. A good naturalist asks: “Has anyone actually seen it?” As Solomon wrote, “Two are better than one” (Ecclesiastes 4:9), and good partnerships, like good stories, should be tested and true.

PICTURE STUDY



Ploughing in the Nivernais, Rosa Bonheur, 1849 · Oil on canvas · Musée d'Orsay, Paris
Wikimedia Commons · Public domain

Rosa Bonheur was one of the most famous animal painters of the 1800s. The French government asked her for this painting, and she made it after careful study of real oxen. It shows one of the oldest partnerships between people and animals: oxen pulling the plow while their drivers guide them.

Look closely

- Count the oxen in each team. How many in all?
- Look at the oxen's faces and the drivers' goads (long sticks). How do the people guide the animals?
- Find the fresh, dark soil turned over by the plows. How can you tell it is a sunny day?

Talk about it

1. What does each partner give and get in this picture? Is this partnership more like mutualism or something else?
2. How is the honeyguide's partnership with hunters like this one, and how is it different (think: who is in charge)?

HANDS-ON: PARTNER WATCH

Look for a real partnership in your own yard or park: ants tending aphids. Aphids are tiny soft insects that suck plant juice and give off a sweet liquid called honeydew. Ants guard them from ladybugs and "milk" them for the honeydew.

You will need

- A magnifying glass
- A garden plant with aphids (roses, milkweed, nasturtiums and young shoots of many plants often have them)
- A timer
- Your Field Notebook and colored pencils

Steps

1. Find a stem crowded with tiny aphids. Look for ants walking among them.
2. Watch quietly with the magnifying glass for 10 minutes. Do not disturb them.
3. Count how many ants you see in one minute. Watch for an ant stroking an aphid with its antennae and drinking a drop of honeydew.
4. If a ladybug comes near, watch what the ants do.
5. Record what you saw, with the time, date and weather.
6. If you cannot find aphids, watch a video of a cleaning station or a clownfish instead and record what you see.

Check your work

- I watched for at least 10 minutes and wrote down the date and time.
- I recorded at least three things the ants or aphids did.
- I can say what the ant gets and what the aphid gets.

FIELD NOTEBOOK

1. **Diagram.** Draw a partnership chart with four rows: honeyguide and hunter, clownfish and anemone, cleaner wrasse and grouper, remora and shark. For each, draw two little pictures joined by arrows. On each arrow write what that partner gives (for example, “leads to honey” and “leaves wax”). Label each row mutualism or commensalism.
2. **Notebook entry.** Write a paragraph about your Partner Watch: what you saw, what each partner seemed to gain, and one question you still have.

Did you know? Honeyguides do not raise their own young. Like cuckoos, a mother honeyguide lays her egg in another bird’s nest, and the chick, born with a sharp hook on its beak, gets rid of the other chicks. So the same bird that is a good partner to people is a parasite to other birds.

Goes deeper in. Life Science (ecosystems and food webs) and Geography (Africa and coral reefs) (coming soon). Stop D3 “Coral reefs” in Trail D tells more about reef partnerships.

For families. Spottiswoode, Begg and Begg reported the honeyguide study in *Science* (July 2016): the “brrrr-hm” call raised the chance of being guided from about 33% to 66% and of being shown a bees’ nest from about 17% to 54%. The oxpecker study (Plotz and Linklater) was published in 2020. Herodotus tells the crocodile-bird story in *Histories*

Book 2; there is no confirmed modern observation. Rosa Bonheur's painting was a state commission shown at the Salon of 1849.

PRACTICE

1. **EASY** What is mutualism? Give one example.
2. **EASY** How does a clownfish keep from being stung by its anemone?
3. **MEDIUM** A remora rides on a shark and eats scraps of its food. The shark is neither helped nor harmed. What kind of relationship is this?
4. **MEDIUM** In the 2016 study, honey hunters were shown a bees' nest on about 17% of trips with ordinary sounds and about 54% with the "brrrr-hm" call. Out of 100 trips each, how many more nests would the "brrrr-hm" hunters find? About how many times as many?
5. **CHALLENGE** Herodotus wrote that a little bird cleans the crocodile's teeth. Is that story proven? What kind of evidence would you need before you believed it?

Make it a game • Follow the Honeyguide. Hide a "bees' nest" (a small treat or toy) in the yard. One player, the honeyguide, knows where it is. The hunters must call "Brrrr-hm!" and the honeyguide may answer only by chirping and hopping a few steps toward the nest each time it is called. No pointing or talking. When the hunters find the nest, they must "leave the wax" by giving the honeyguide a share.

Scripture. "Two are better than one; because they have a good reward for their labour. For if they fall, the one will lift up his fellow: but woe to him that is alone when he falleth; for he hath not another to help him up." (Ecclesiastes 4:9-10, KJV)

God made a world full of partnerships, and He made people to help one another too. A good partner gives as well as takes.

Practice: answers

1. A partnership in which both partners are helped. Examples: honeyguide and honey hunter, clownfish and anemone, cleaner wrasse and grouper, ants and aphids.
2. It has a coat of slimy mucus that keeps the anemone's stinging cells from firing.
3. Commensalism: one partner is helped and the other is not affected.
4. $54 - 17 = 37$ more nests. $54 \div 17$ is about 3, so about three times as many.
5. It is not proven; no scientist has recorded it. You would want careful, repeated observations by different people, ideally photographs or video, showing a bird feeding in a crocodile's mouth in the wild.

6.6 ANIMAL TOOLS: THE SEA OTTER'S ROCK

OBJECTIVES

- Describe how a sea otter uses a rock as a tool and how its body is made for cold water.
- Explain how sea otters protect kelp forests by eating sea urchins, and tell how they were nearly lost and then protected.
- Name three other animals that use tools and tell what each tool is for.

Warm-up. Try to open a walnut or a pistachio with your bare hands. Hard? Now think: what tool would you use? An animal that picks up an object and uses it to get a job done is using a tool, just as you would.

Video slot. Video coming. Sea otters cracking shells on rocks; otter mothers with pups; kelp forests; New Caledonian crow bending a hook. Search approved channels (Monterey Bay Aquarium, BBC Earth, PBS Nature, Smithsonian Channel, University of Oxford); preview first.

KEY TERMS

tool

An object an animal or person holds or moves to get a job done, such as a rock used to crack a shell.

anvil

A hard surface on which something is struck. A sea otter uses a rock on its chest as an anvil.

kelp forest

An underwater forest of giant brown seaweed that grows in cool coastal waters and shelters many fish and other animals.

keystone species

An animal that holds its whole community together, so that if it disappears, many other things change.

underfur

The thick, soft fur close to the skin that traps air and keeps an animal warm and dry.

CORE IDEAS

A rock and a clam. Off the coast of central California, a sea otter floats on its back in the kelp. Suddenly it rolls and dives, swimming down to the rocky bottom. A minute later it pops up holding a clam in its paws and a flat stone tucked into a loose pocket of skin under its forearm. It lays the stone on its chest like an **anvil** and bangs the clam against it, again and again, until the shell cracks. Then it licks out the meat, rolls over to rinse off the crumbs and dives again. Some otters keep a favorite rock in their pocket through many dives. Otters also

smash shells against rocks on the shore, and scientists can find the worn, chipped “otter anvils” they leave behind.

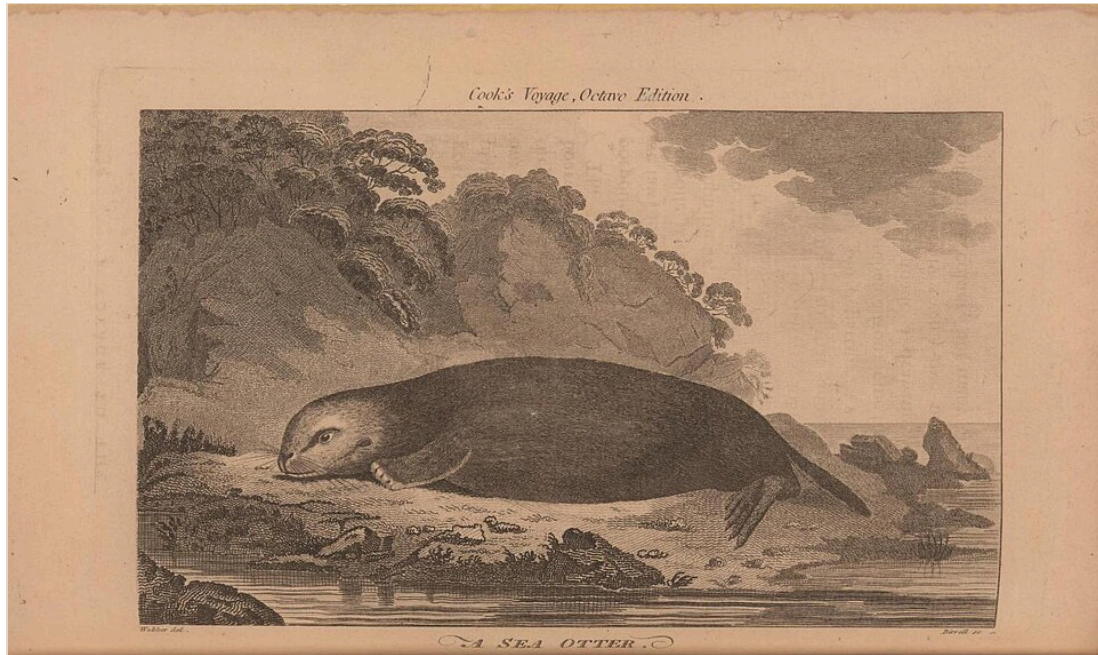
Made for cold water. Whales and seals have thick blubber, but sea otters have none. Instead they have the thickest fur of any animal, up to about a million hairs on a single square inch, roughly ten times as many as on a whole human head. The **underfur** traps a layer of air so the cold water never touches the skin, which is why otters spend hours each day grooming. To stay warm they must eat about a quarter of their body weight every day: clams, crabs, snails and especially sea urchins. When they sleep, they often wrap themselves in kelp so they do not drift away, and a mother floats her pup on her chest.

Guardians of the kelp. Sea urchins are spiny balls that graze on kelp. With no otters to eat them, urchins can multiply and chew whole **kelp forests** down to bare rock, leaving the fish and other creatures that lived there without a home. Where otters live, urchins are kept in check and the kelp stands tall. Because one animal holds so much together, scientists call the sea otter a **keystone species**.

Lost and found. In 1741 the explorer Vitus Bering’s expedition reached Alaska, and its naturalist, Georg Steller, described the sea otter. Fur traders followed. In 1778 sailors on Captain James Cook’s third voyage traded for otter skins on the coast of what is now Canada and later sold them in China for astonishing prices. For more than 150 years otters were hunted for their fur, until perhaps only one or two thousand were left. In 1911 the United States, Great Britain (for Canada), Russia and Japan signed a treaty that ended the hunting. In 1938 a small group of about fifty otters, long thought gone from California, was seen off Big Sur. Protected, they have slowly grown into thousands. God gave mankind the task to “dress” and “keep” His garden (Genesis 2:15); this is stewardship done well.

Other tool users. In 1960 Jane Goodall watched chimpanzees in Tanzania poke grass stems into termite mounds to “fish” for termites. In 2002 a New Caledonian crow named Betty, in a lab at Oxford, bent a straight wire into a hook to lift a little bucket of food out of a tube. Some bottlenose dolphins in Shark Bay, Australia, wear sea sponges on their beaks to protect them while they poke along the sandy bottom, and Egyptian vultures throw stones to crack ostrich eggs.

PICTURE STUDY



A Sea Otter, Plate 43 from A Voyage to the Pacific Ocean (Cook's third voyage), Engraved by Peter Mazell after a drawing by John Webber, 1784 · Engraving · From the official account of Cook's third voyage, London, 1784; this copy at the John Carter Brown Library, and others at Royal Museums Greenwich and many libraries
Wikimedia Commons · Public domain

John Webber was the official artist on Captain Cook's third voyage (1776–1780). At Nootka Sound, on the coast of what is now British Columbia, the crew traded for sea otter skins, and Webber drew the animal. His drawing was engraved for the book of the voyage, which told Europe about the rich fur, and the fur trade quickly grew.

Look closely

- Look at the fur. How did the engraver show that it is thick and soft using only lines?
- Find the hind feet. What shape are they, and what would they be good for?
- Look at the head and whiskers. How big is the head compared with the body?

Talk about it

1. Webber probably drew from a skin or a dead animal. How might a drawing from a living otter floating in the kelp look different?
2. This picture helped start a trade that nearly wiped out the sea otter. How can a picture or a book change what people do?

HANDS-ON: TOOL TEST: THE CROW'S CHALLENGE

Repeat a simple version of the famous Betty the crow test. Can you get a “food bucket” out of a tall jar using only one tool, held in one hand, the way a bird holds it in its beak?

You will need

- A tall, narrow jar or a clear plastic bottle with the top cut off by a grown-up
- A tiny paper cup or a bottle cap with a loop of string or pipe cleaner for a handle (the bucket), with a raisin inside
- Two pipe cleaners
- A timer
- Your Field Notebook

Steps

1. Drop the bucket into the bottom of the jar.
2. Using one hand only, try to lift it out with a straight pipe cleaner. Time yourself for one minute.
3. Now bend the end of the second pipe cleaner into a hook, as Betty did with her wire. Try again and time how long it takes.
4. Record both results in a table.
5. Try with your other hand or with your eyes on a mirror to make it harder, and record again.

Check your work

- I tested a straight tool and a hooked tool.
- I recorded my times in a table.
- I can explain why shaping the tool made the job easier.

FIELD NOTEBOOK

1. **Diagram.** Draw a sea otter floating on its back. Label: rock (anvil) on its chest, clam in its paws, skin pocket under the forearm, thick underfur, webbed hind feet, strand of kelp wrapped around it.
2. **Food chain diagram.** Draw three boxes joined by arrows: kelp → sea urchin → sea otter. Under it draw a second chain with the otter crossed out, and show the urchins multiplying and the kelp gone. Title it “Why the Otter Matters.”
3. **Notebook entry.** Write a paragraph telling how sea otters were nearly lost and how they came back. Include the years 1741, 1911 and 1938.

Did you know? Sea otters are among the few animals that use stones as tools every day. Scientists studying worn rocks along a California slough found that otters chip them in a special pattern, so in the future archaeologists may need to ask whether a chipped stone was used by a person or an otter.

Goes deeper in. Life Science (food chains and ecosystems), Geography (the Pacific coast of North America) and History (Cook’s voyages and the fur trade) (coming soon). Stop D9 “Seals and sea lions” in Trail D meets other marine mammals.

For families. Fur density figures range from about 850,000 to 1,000,000 hairs per square inch (Monterey Bay Aquarium). The 1911 treaty was the North Pacific Fur Seal Convention. The California otters were made known to the public in 1938 near Bixby Creek, Big Sur. Betty's hook-bending was reported by Weir, Chappell and Kacelnik in *Science* (2002). The otter-anvil study was published by Haslam, Fujii and others in *Scientific Reports* (2019). The Webber plate is No. 43, engraved by P. Mazell (1784). Jane Goodall's termite-fishing observation (Gombe, 1960) is well documented. If anyone in the family has a nut allergy, skip the nut in the warm-up and just imagine it.

PRACTICE

1. **EASY** How does a sea otter open a clam?
2. **EASY** Sea otters have no blubber. What keeps them warm?
3. **MEDIUM** A sea otter weighs 60 pounds and eats about a quarter of its weight each day. How many pounds of food does it eat in a day? In a week?
4. **MEDIUM** Why do scientists call the sea otter a keystone species?
5. **CHALLENGE** Put these in order and tell what each did to sea otters: the 1911 treaty, Cook's voyage, the Bering expedition, the 1938 sighting at Big Sur.

Make it a game • Otter, Urchin, Kelp. Play like rock-paper-scissors. Players count "one, two, three" and make a sign: otter (paws on chest), urchin (hands curled into a spiky ball) or kelp (arms waving up). Otter eats urchin, urchin eats kelp, and kelp wraps otter (kelp wins because it holds the otter safe while it sleeps). Best of five.

Scripture. "The eyes of all wait upon thee; and thou givest them their meat in due season. Thou openest thine hand, and satisfiest the desire of every living thing." (Psalm 145:15-16, KJV)

The otter opens its clam, but it is God who opens His hand and feeds every creature. He also gave us the job of caring for the creatures He feeds.

Practice: answers

1. It lays a flat rock on its chest as an anvil and bangs the clam against it until the shell cracks.
2. Very thick fur (up to about a million hairs per square inch) that traps air next to the skin, plus eating a great deal of food.
3. $60 \div 4 = 15$ pounds a day. $15 \times 7 = 105$ pounds a week.
4. Because it eats sea urchins, which would otherwise eat down the kelp forests; so many other creatures depend on the otter being there.
5. Bering expedition (1741): Steller described the otter and the fur trade began. Cook's voyage (1778): sailors sold otter skins in China, which spread the trade. 1911 treaty: hunting was stopped. 1938: the California otters were found still alive, and protection let them grow.

6.7 LONG JOURNEYS: ANIMALS THAT TRAVEL THE WORLD

OBJECTIVES

- Describe the record journeys of the Arctic tern, the bar-tailed godwit and the gray whale, with distances.
- Explain three ways animals find their way: the sun, the stars and the earth's magnetism.
- Draw a world map of three great migrations with a title, labels and a key.

Warm-up. Without looking at a phone or a map, point to the north. How did you decide? By the sun? By a road you know? Animals on long journeys must answer the same question, often over open ocean with no roads at all.

Video slot. Video coming. Arctic tern migration tracking; bar-tailed godwit nonstop flight; gray whale migration along the Pacific coast; caribou herds crossing rivers. Search approved channels (BBC Earth, PBS Nature, Smithsonian Channel, NOAA Fisheries, U.S. Geological Survey); preview first.

KEY TERMS

migration

A regular journey that animals make between two places, often between summer feeding grounds and winter or breeding grounds.

navigation

Finding the way from one place to another.

geolocator

A tiny device fastened to an animal that records light levels, so scientists can work out where the animal was each day.

magnetic field

The invisible force around the earth that makes a compass needle point north; many animals can sense it.

stopover

A place where migrating animals stop to rest and feed partway through their journey.

CORE IDEAS

Following the summer. Each spring, Arctic terns nest on the shores of Greenland, Iceland, Canada and northern Europe. Then, as summer ends, they fly south, all the way to the edge of Antarctica, where it is summer again. In 2007 Danish scientist Carsten Egevang and his team fastened **geolocators**, weighing about as much as a paper clip, to the legs of terns in Greenland and Iceland. When the birds came back the next year, the devices showed that the terns had flown an average of about 44,000 miles (71,000 km) in one round trip. They did not

fly straight. They zigzagged down the Atlantic, stopping for weeks at a **stopover** in the middle of the North Atlantic to feed, and rode the great wind patterns of the ocean. An Arctic tern can live 30 years, so in a lifetime it may fly far enough to go to the moon and back about three times.

Nonstop. The bar-tailed godwit, a long-billed shorebird, holds the record for the longest flight without stopping. In October 2022 a young godwit tracked by satellite flew from Alaska to Tasmania, about 8,400 miles (13,560 km), in about 11 days. It never landed, ate or drank. Before leaving, godwits fatten up so much that fat makes up over half their weight, and some of their stomach and gut shrinks to make the load lighter.

Journeys in the sea and on land. Gray whales swim from their feeding grounds in the cold Bering and Chukchi Seas near Alaska down the Pacific coast to warm, calm lagoons in Baja California, Mexico, where their calves are born. The round trip is about 10,000 to 12,000 miles, one of the longest of any mammal. On land, great herds of caribou in Alaska and northern Canada walk hundreds of miles between winter forests and the open tundra where they give birth, crossing rivers and mountains on the way.

How do they find the way? Scientists have found several “instruments” God built into animals. Many birds use the sun as a compass, adjusting for the time of day. In the 1960s Stephen Emlen raised young indigo buntings and tested them in a planetarium. When he turned the star dome so that a different star sat at the center of the turning sky, the birds turned to the new “north.” They had learned the pattern of stars that circle the pole. Other experiments showed that European robins and many other animals can sense the earth’s **magnetic field**. Sea turtles, salmon and even some insects use it too. Most travelers probably use several of these clues together.

The appointed times. Long ago the prophet Jeremiah noticed that “the stork in the heaven knoweth her appointed times” (Jeremiah 8:7). The stork never misses its season. Jeremiah’s point was that people, who have God’s Word, should know the way back to Him at least as well.

PICTURE STUDY



Arctic Tern, Plate 250 from *The Birds of America*, John James Audubon (engraved by Robert Havell Jr.), c. 1835 · Hand-colored engraving and aquatint (from Audubon's watercolor) · From *The Birds of America* (London, 1827-1838); copies in many libraries and museums
Wikimedia Commons · Public domain

John James Audubon painted the Arctic tern in a sharp, sweeping pose to show its long, narrow wings and forked tail. Those wings carry it from one end of the earth to the other every year.

Look closely

- Find the black cap, the red bill and the forked tail.
- Look at the shape of the wings. Are they long and narrow or short and broad? Which shape do you think is better for long flights?
- Notice how small the bird's body and feet are compared with its wings.

Talk about it

1. Audubon could not know how far this bird flies. What would you write under this picture today to tell people about it?
2. Why might an artist choose to show a bird in motion rather than standing still?

HANDS-ON: MAP THREE GREAT JOURNEYS

Make a world map of three record migrations and measure them.

You will need

- A world map or globe

- A piece of string and a ruler
- A large sheet of paper or a printed outline map of the world
- Colored pencils

Steps

1. On a globe, stretch a string from Greenland to the Weddell Sea off Antarctica, the Arctic tern's route. Mark the length on the string and measure it against the globe's mileage scale (or the equator, which is about 24,900 miles around). That is one way; double it for the round trip.
2. Do the same from western Alaska to Tasmania for the godwit, and from the Bering Sea to Baja California for the gray whale.
3. Compare your straight-line measurements with the real distances in the story. Why are the real ones longer?
4. Draw the map described in the Field Notebook tasks.

Check your work

- I measured three routes on a globe or map.
- My map has a title, a compass rose, a key and three labeled routes.
- I can explain why real migration routes are longer than a straight line.

FIELD NOTEBOOK

1. **Map.** On an outline map of the world, draw three routes in three colors and add a key: (1) the Arctic tern from Greenland and Iceland, zigzagging down the Atlantic to Antarctica, with a dot for the North Atlantic stopover; (2) the bar-tailed godwit from Alaska straight across the Pacific to New Zealand and Tasmania; (3) the gray whale from the Bering Sea down the Pacific coast to Baja California. Label the oceans, the continents, the equator and a compass rose. Title it "Great Journeys."
2. **Notebook entry.** Write a paragraph about the journey that amazes you most. Give its distance and tell one way the animal may find its way.

Did you know? Because Arctic terns spend the northern summer in the Arctic and the southern summer near Antarctica, they probably see more daylight each year than any other creature on earth.

Map or diagram. On your map, draw the tern's southbound route in a solid line and its northbound route in a dashed line. The tracked terns flew north in a great S-shape up the middle of the Atlantic, following the winds.

Goes deeper in. Geography (oceans, continents and the earth's winds) and Earth Science (magnetism and the seasons) (coming soon). Stop B7 "Migration" in Trail B, Stop C4 "Sea turtles" and Stop D8 "Salmon" tell other journey stories.

For families. The tern study is Egevang and others, *PNAS* (2010): tracked in 2007–2008, average round trip about 70,900 km, with longer individual flights. The 2022 godwit flight (Alaska to Tasmania, about 13,560 km in about 11 days) was confirmed by Guinness World Records. Gray whale distances follow NOAA. Emlen’s indigo bunting planetarium studies were published in the 1960s–1970s; the Wiltschkos’ robin compass studies began in the 1960s. Caribou distances vary greatly by herd and year, so the stop says “hundreds of miles.” Jeremiah’s “turtle” is the turtledove. The Audubon plate number follows the Havell edition.

PRACTICE

1. **EASY** Which bird makes the longest yearly migration, and between which two regions does it fly?
2. **EASY** Name two clues animals use to find their way.
3. **MEDIUM** An Arctic tern flies about 44,000 miles a year and lives 30 years. How far does it fly in its life? The moon is about 239,000 miles away. About how many trips to the moon and back is that?
4. **MEDIUM** The godwit flew about 8,400 miles in 11 days. About how many miles is that per day? Per hour?
5. **CHALLENGE** In Emlen’s planetarium, when the sky was turned around a different star, the buntings headed toward a new “north.” What does this show, and why was a planetarium a good way to test it?

Make it a game • Migration Navigator. One player is the migrating bird and stands in the middle of the yard, blindfolded. Another player is the “sun” and stands at the far side, softly humming. The bird must walk toward the sun’s hum, which marks the winter grounds. Partway through, the sun moves, as the real sun does across the sky. Can the bird still arrive? Take turns being the bird and the sun.

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; but my people know not the judgment of the LORD.” (Jeremiah 8:7, KJV)

The “turtle” here is the turtledove. Birds keep the times God set for them. Jeremiah calls God’s people to be just as faithful in returning to Him.

Practice: answers

1. The Arctic tern, between the Arctic (such as Greenland and Iceland) and the seas around Antarctica.
2. Any two: the sun, the stars, the earth’s magnetic field, landmarks such as coastlines and mountains, smells.
3. $44,000 \times 30 = 1,320,000$ miles. A trip to the moon and back is about 478,000 miles. $1,320,000 \div 478,000 \approx 2.8$, so nearly three round trips.
4. $8,400 \div 11 \approx 764$ miles a day. $764 \div 24 \approx 32$ miles an hour, day and night, without stopping.

5. It shows the birds find north from the stars, by learning which part of the sky the other stars turn around, and not from the earth's magnetism (which did not change). A planetarium let Emlen change only the stars while keeping everything else the same, so he knew the stars caused the change.

6.8 ANIMALS THAT HELPED PEOPLE: THE 1925 SERUM RUN TO NOME

OBJECTIVES

- Tell the true story of the 1925 serum run to Nome with its key dates, distances and people.
- Explain why dogs were chosen for the job and what made sled dogs suited to it.
- Draw a labeled map of the serum route across Alaska and calculate the relay's average speed.

Warm-up. Imagine your town is snowed in, the roads are closed, there is no airport you can use, and a medicine that could save the children is 674 miles away. List every way you can think of to get it there. Then read what the people of Alaska did in 1925.

Video slot. Video coming. The 1925 serum run to Nome; Togo and Balto; historic film of Gunnar Kaasen and Balto; the Iditarod Trail. Search approved channels (Smithsonian Channel, National Park Service, Alaska Public Media, The History Guy, Cleveland Museum of Natural History); preview first.

KEY TERMS

diphtheria

A dangerous sickness that blocks the throat and can be deadly, especially for children. Today most children are protected by vaccines.

antitoxin (serum)

A medicine made from blood that fights the poison a disease makes. In 1925 it was the treatment for diphtheria.

musher

A person who drives a team of sled dogs. The word may come from the French *marchez!*, “go!”

relay

A race or journey in which one team hands off to the next, so each can rest while the load keeps moving.

lead dog

The dog at the front of a sled team that follows the musher's commands and finds the trail.

CORE IDEAS

Danger in Nome. In January 1925, Nome, Alaska, was a small gold-rush town on the shore of the Bering Sea, cut off by winter. The sea was frozen, the one railroad ended hundreds of miles away and the few airplanes had open cockpits that could not safely fly in the long,

dark, bitter cold. Then Dr. Curtis Welch, the town's only doctor, found children sick with **diphtheria**. His supply of **antitoxin** was old and nearly gone, and without more, many might die. He sent a telegraph message pleading for help.

The plan. About 300,000 units of serum were found at a hospital in Anchorage. They were packed in a padded metal can and sent north by train to the end of the line at Nenana, about 300 miles. From Nenana to Nome stretched about 674 miles of trail along the Tanana and Yukon Rivers and across the coast. The mail usually took around 25 days to cover it by dog sled. Alaska's governor decided that a **relay** of the best mushers and dogs would be safer than an airplane. At about 11 p.m. on January 27, at around 50 degrees below zero, "Wild Bill" Shannon took the package from the train and set off.

The run. Twenty mushers and about 150 dogs passed the serum from team to team, day and night. At each roadhouse they warmed the can by the fire before going on. The longest and most dangerous run belonged to Leonhard Seppala, a Norwegian-born musher, and his twelve-year-old lead dog, **Togo**. They had already driven out from Nome to meet the relay. Near Shaktoolik they took the serum, turned and raced back across the frozen sea ice of Norton Sound in a rising storm, ice that could break and drift away at any time. In all, Togo's team covered about 260 miles. Seppala handed the serum on at Golovin.

The last leg. At Bluff, Gunnar Kaasen took over with his lead dog, **Balto**. A blizzard was blowing so hard he could not see his own dogs. Balto kept to the trail by feel and smell. At Port Safety the next musher was asleep, not expecting them so soon, so Kaasen pushed on. At about 5:30 a.m. on February 2, 1925, his team stumbled into Nome. The serum had come 674 miles in about five and a half days, a record. Not a vial was broken. Several children had died before it arrived, but the outbreak was stopped.

Honoring the dogs. Newspapers around the world followed the race by telegraph. In December 1925 a bronze statue of Balto was unveiled in Central Park, New York, with Balto himself there. Many mushers said Togo deserved the greater honor. The Iditarod sled dog race, run since 1973, keeps the memory alive. "A righteous man regardeth the life of his beast" (Proverbs 12:10), and these mushers cared for their dogs as faithful partners.

PICTURE STUDY



Gunnar Kaasen with Balto, Unknown photographer, 1925 · Black-and-white photograph · Published in newspapers in 1925; copies in several archives and on Wikimedia Commons
Wikimedia Commons · Public domain

This photograph was taken soon after the serum run, when the whole country wanted to see the dog that brought the medicine into Nome. Pictures like this made Balto the most famous dog in America in 1925.

Look closely

- Look at the musher's clothing. What is it made of, and what parts of his body does it cover?
- Look at Balto's coat, ears and feet. What helps him in deep cold?
- Look at how the man is posed with the dog. What does it tell you about how he felt about Balto?

Talk about it

1. Balto ran the last leg, but Togo ran the longest and most dangerous one. Why do you think the camera found Balto and not Togo?
2. If you could take one more photograph of the serum run, what would you want it to show?

HANDS-ON: MAP THE SERUM RUN

Draw the route of the serum run and use its numbers to work out how fast the relay moved.

You will need

- A map of Alaska (an atlas or a printed outline map)
- A large sheet of paper and colored pencils
- A ruler and a calculator
- Your Field Notebook

Steps

1. Find Anchorage, Nenana, the Yukon River, Norton Sound and Nome on a map of Alaska.
2. Copy the outline of Alaska onto your paper, or use an outline map.
3. Draw the route described in the Field Notebook tasks.
4. Work out the relay's average speed: $674 \text{ miles} \div 127.5 \text{ hours}$.
5. Work out how many days faster the relay was than the usual mail.

Check your work

- My map shows the train line and the sled route in different styles.
- I labeled Nenana, Nome, the Yukon River, Norton Sound and at least four stops along the way.
- I marked where Togo and Balto ran.
- I calculated the average speed.

FIELD NOTEBOOK

1. **Map.** Title it "The Serum Run, January 27 – February 2, 1925." Draw the railroad from Anchorage to Nenana as a dashed line. Draw the sled route as a solid line: Nenana, Tanana, Ruby, Galena, Nulato, Kaltag, Unalakleet, Shaktoolik, then across Norton Sound to Golovin, Bluff and Nome. Label the Yukon River, Norton Sound and the Bering Sea. Color Togo's leg (Shaktoolik to Golovin) and Balto's leg (Bluff to Nome) and add a key and a compass rose.
2. **Notebook entry.** Write a paragraph telling the story of the serum run from the point of view of one musher or one dog. Use at least two real dates or numbers.

Did you know? Dogs are not the only animal heroes. Barry, a St. Bernard at the Great St. Bernard Pass in the Alps, is said to have rescued about forty travelers in the early 1800s; he is preserved in the Natural History Museum in Bern, Switzerland. In 1918 a carrier pigeon named Cher Ami carried a message through gunfire that helped save nearly two hundred trapped American soldiers in France.

Goes deeper in. History (America in the 1920s; Alaska) and Geography (Alaska, the Yukon River and the Bering Sea) (coming soon). Stop A6 "Wolves and dogs" in Trail A tells more about dogs.

For families. Dates, distances and names follow Gay and Laney Salisbury, *The Cruellest Miles* (2003), and the National Park Service: the relay began at Nenana on January 27

and reached Nome at about 5:30 a.m. on February 2, 1925, covering about 674 miles in about 127.5 hours with 20 mushers and about 150 dogs. The usual mail time is given in sources as 25 to 30 days. The number of deaths is uncertain (official counts range from about five to seven, and more may have gone unreported); the stop says “several.” Balto’s statue (sculptor Frederick Roth) was unveiled December 15, 1925. Balto’s mount is at the Cleveland Museum of Natural History; Togo’s is at the Iditarod Trail headquarters in Wasilla, Alaska. Diphtheria is mentioned plainly; children today are protected by routine vaccines.

PRACTICE

1. **EASY** What sickness broke out in Nome in 1925, and what was carried to stop it?
2. **EASY** Which dog ran the longest and most dangerous leg, and which dog led the team into Nome?
3. **MEDIUM** The relay went 674 miles in about 127.5 hours. What was its average speed?
4. **MEDIUM** The mail usually took about 25 days for this route. The relay took about $5\frac{1}{2}$ days. How many days were saved? About how many times faster was the relay?
5. **CHALLENGE** In 1925 some people wanted to fly the serum to Nome. Give two reasons the governor chose dogs instead, and one reason a relay was better than a single team.

Make it a game • Serum Relay. Mark a course around the yard with four handoff stations. Put one player at each station. The “serum” is a small box or a plastic bottle wrapped in a towel. The first runner carries it carefully to the next station and hands it off, and so on to “Nome.” If the serum is dropped, that runner must go back to the last station. Time the run, then try to beat your time without dropping it.

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

The mushers of 1925 asked everything of their dogs, and good mushers cared for them in return: rubbing their feet, feeding them first and resting them. A righteous person cares for the animals in his keeping.

Practice: answers

1. Diphtheria; diphtheria antitoxin (serum) was carried by dog sled relay.
2. Togo, with Leonhard Seppala, ran the longest and most dangerous leg; Balto, with Gunnar Kaasen, led the last leg into Nome.
3. $674 \div 127.5 \approx 5.3$ miles per hour, day and night, including all the handoffs.
4. $25 - 5.5 = 19.5$ days saved. $25 \div 5.5 \approx 4.5$, so about four and a half times faster.
5. Reasons for dogs: airplanes then had open cockpits and could freeze or crash in the extreme cold; there were only a few hours of daylight; few planes or pilots were ready in winter; dog teams and mushers knew the trail. A relay was better because fresh teams could keep the serum moving day and night while tired teams rested.

6.9 DESIGN COPIED BY ENGINEERS

OBJECTIVES

- Tell how burrs led to Velcro, how birds taught the Wright brothers to steer and how a kingfisher reshaped a bullet train.
- Define biomimicry and give three examples with the animal or plant and the invention.
- Test a design idea with an experiment and draw a labeled comparison diagram.

Warm-up. Look closely at the bottom of a sneaker, the zipper on a coat or the handle of a pair of scissors. Can you think of a plant or animal that has a similar shape or does a similar job? Write down one guess. Engineers ask this question all the time.

Video slot. Video coming. The kingfisher and the Shinkansen bullet train; how Velcro was invented; the Wright brothers and wing warping; humpback whale flipper bumps on turbine blades. Search approved channels (Smithsonian National Air and Space Museum, PBS NOVA, BBC Earth, National Park Service Wright Brothers, SciShow Kids); preview first.

KEY TERMS

biomimicry

Solving human design problems by copying ideas from living things. From Greek words meaning “life” and “imitation.”

engineer

A person who uses science and math to design and build machines, structures and tools.

prototype

An early test model of an invention, built to see whether the idea works.

wing warping

The Wright brothers’ method of twisting the ends of an airplane’s wings to balance and turn, copied from birds.

drag

The push of air or water against a moving object that slows it down.

CORE IDEAS

Burrs on a dog. In 1941 a Swiss engineer named George de Mestral came home from a walk in the Jura Mountains with his dog. Both of them were covered in burdock burrs. Instead of just pulling them off, he put one under his microscope. Each burr was covered with hundreds of tiny hooks that caught in the loops of cloth and the dog’s fur. Could he make a fastener that worked the same way? It took him years of trials with weavers in France before he found that nylon, cut just right, made strong hooks. He received a patent in

1955 and named his invention **Velcro**, from the French words *velours* (velvet) and *crochet* (hook).

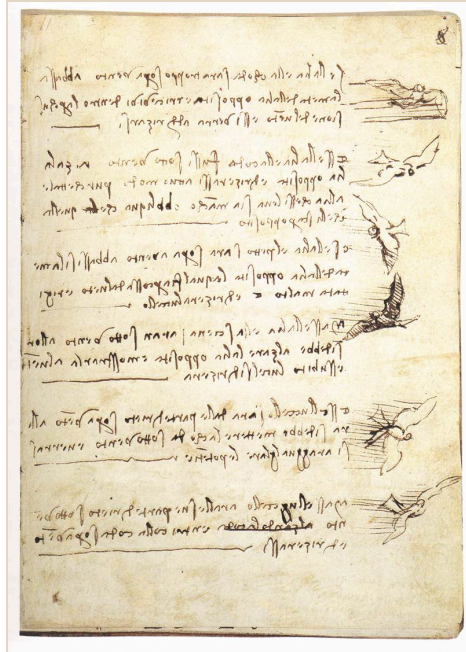
Steering like a bird. For centuries people tried to fly by copying birds. Around 1505 Leonardo da Vinci filled a notebook with drawings of birds in flight. In 1889 the German glider pilot Otto Lilienthal published a book called *Birdflight as the Basis of Aviation*. But flapping wings never lifted a man. In 1899 Wilbur Wright noticed something different: soaring birds keep their balance by twisting the tips of their wings. While twisting an empty cardboard box in his bicycle shop, he saw how to twist an airplane's wings the same way. This **wing warping** let the Wrights steer and balance. On December 17, 1903, at Kitty Hawk, North Carolina, Orville flew 120 feet in 12 seconds: the first controlled, powered airplane flight.

The kingfisher train. In the 1990s Japan's fast trains had a problem. When a bullet train shot into a tunnel, it pushed air ahead like a piston, and when it burst out the other end there was a loud boom that bothered people living nearby. The engineer Eiji Nakatsu was also a birdwatcher. He remembered the kingfisher, which dives from air into water at high speed with hardly a splash, because its long, wedge-shaped beak cuts smoothly from thin air into thick water. His team gave the new 500 Series train a long nose shaped like a kingfisher's beak. When it began running in 1997, it was quieter, about 10 percent faster and used about 15 percent less electricity.

Still learning. The bumps on the front edge of a humpback whale's flippers help it turn sharply; engineers have copied them on fan and turbine blades. Lotus leaves stay clean because water beads up and rolls off, carrying dirt, and scientists have made paints and glass that clean themselves the same way. The tiny hairs on a gecko's toes let it walk up glass, and researchers are trying to copy them in dry, reusable tape. The writer Janine Benyus made the word **biomimicry** popular in 1997.

Ask the beasts. Long ago Job said, "Ask now the beasts, and they shall teach thee" (Job 12:7). Engineers who study creation are learning from a Designer whose work is better than theirs.

PICTURE STUDY



Studies of Birds in Flight, from the Codex on the Flight of Birds, Leonardo da Vinci, c. 1505–1506 · Pen and ink on paper · Biblioteca Reale (Royal Library), Turin, Italy
Wikimedia Commons · Public domain

Leonardo da Vinci, the Italian painter and inventor, wrote this small notebook of about eighteen pages about how birds fly and how a man might fly. He wrote in mirror writing, from right to left. His flying machines never left the ground, but his careful drawings show the same habit as every good engineer: watch first, then design.

Look closely

- Find the small birds. How many different wing positions can you see?
- Look at the handwriting. Hold the picture up to a mirror. What happens?
- Find any arrows, lines or diagrams that look like Leonardo was measuring or explaining the air.

Talk about it

1. Leonardo watched birds but could not build a flying machine. What did the Wright brothers notice that he did not put to use?
2. Why might an inventor keep a notebook of sketches instead of trusting his memory?

HANDS-ON: THE KINGFISHER SPLASH TEST

Test Eiji Nakatsu's idea yourself: does a long, pointed shape enter water with a smaller splash than a blunt one?

You will need

- Modeling clay (enough for three balls the size of a walnut)
- A kitchen scale (if you have one)
- A deep bucket or tub of water, set outdoors or on towels
- A ruler or yardstick taped upright behind the bucket
- A helper, and a phone to film in slow motion if possible
- Your Field Notebook

Steps

1. Make three clay shapes of the same weight: a ball, a flat disc and a long, pointed cone like a kingfisher's beak.
2. Hold each shape at the same height, about 50 centimeters (20 inches) above the water, and drop it. Drop the cone point-first.
3. Your helper watches the ruler (or films) and notes how high the splash rises.
4. Drop each shape three times and record the splash heights in a table.
5. Find the average splash for each shape: add the three heights and divide by 3.
6. Draw the comparison diagram in the Field Notebook tasks.

Check your work

- My three shapes weighed about the same.
- I dropped each shape three times from the same height.
- I recorded the splashes and found the averages.
- I can explain how my results connect to the kingfisher train.

FIELD NOTEBOOK

1. **Diagram.** Draw a kingfisher's head in side view on the left and the nose of the 500 Series bullet train on the right, at the same size. Label on the bird: beak, eye, head; on the train: nose, cab window, wheels. Draw arrows showing air flowing smoothly over both. Title it "Copied from Creation."
2. **Chart.** Make a three-column chart: Living thing / What it does / Invention. Fill in at least four rows from this stop.
3. **Notebook entry.** Write a paragraph telling what your splash test showed and whether it agreed with Nakatsu's idea.

Did you know? Nakatsu's team also copied the owl. An owl flies almost silently because the front edges of its wing feathers have tiny comb-like fringes. The engineers put small saw-tooth notches on the arm that collects electricity from the overhead wire, and it became much quieter.

Goes deeper in. Life Science (structure and function), History (the Wright brothers and the age of invention) and Arithmetic (averages and percents) (coming soon). Stop F1 "Echolocation" tells how sonar and bats work alike.

For families. De Mestral's 1941 walk and his 1955 Swiss patent are documented by Velcro Companies; sources differ on whether he was hunting or walking. Wilbur Wright described watching birds and the twisted-box insight in 1899; the first flight (December 17, 1903) lasted 12 seconds and covered 120 feet. The 500 Series Shinkansen entered service in 1997; the 10 percent and 15 percent figures are Nakatsu's, as reported by JR West and in many interviews. Benyus's book is *Biomimicry: Innovation Inspired by Nature* (1997). The Codex on the Flight of Birds is dated about 1505–1506.

PRACTICE

1. **EASY** What plant gave George de Mestral the idea for Velcro, and what did he see under the microscope?
2. **EASY** What is biomimicry?
3. **MEDIUM** The kingfisher-nosed train used about 15 percent less electricity. If an older train used 1,000 units of electricity on a trip, about how many would the new one use?
4. **MEDIUM** On the first flight, Orville Wright flew 120 feet in 12 seconds. What was his speed over the ground in feet per second?
5. **CHALLENGE** Leonardo and many others copied birds' flapping and failed. The Wrights copied birds and succeeded. What was different about what they copied, and what does that teach about learning from creation?

Make it a game • Inventor's Match. Make two sets of cards. On one set write living things (burr, kingfisher, owl, humpback whale, lotus leaf, gecko, soaring bird). On the other write inventions (Velcro, bullet train nose, quiet train arm, turbine blades, self-cleaning paint, gripping tape, wing warping). Shuffle them face down and play a memory game: turn over two cards; if the living thing matches its invention, keep the pair.

Scripture. "But ask now the beasts, and they shall teach thee; and the fowls of the air, and they shall tell thee: Or speak to the earth, and it shall teach thee: and the fishes of the sea shall declare unto thee." (Job 12:7–8, KJV)

The kingfisher, the burr and the soaring bird have taught engineers lessons they could not find alone. Job adds in the next verse that all these creatures show "that the hand of the LORD hath wrought this."

Practice: answers

1. Burdock burrs; they were covered with tiny hooks that caught in loops of cloth and fur.
2. Solving human design problems by copying ideas from living things.
3. $15\% \text{ of } 1,000 = 150$. $1,000 - 150 = 850$ units.
4. $120 \div 12 = 10$ feet per second (about 7 miles per hour over the ground; the plane was flying into a strong headwind).

5. The Wrights did not copy flapping; they copied how birds balance and steer by twisting their wingtips, and used an engine and propellers for power. Good biomimicry copies the principle that solves the problem, not just the outward look.

6.10 ADAM NAMES THE ANIMALS

OBJECTIVES

- Read Genesis 2:15–20 and explain what Adam’s naming of the animals shows about mankind’s work in creation.
- Tell how Carl Linnaeus gave animals two-part scientific names and read a scientific name.
- Draw a classification ladder for one animal and make a simple key to tell animals apart.

Warm-up. Pick an animal you have never heard named, such as an odd bug in the yard or a bird in a picture. Look at it for one minute and make up a good name that describes it. What did you have to notice first? That is how naming begins.

Video slot. Video coming. Carl Linnaeus and how scientific names work; Linnaeus’s garden and museum at Uppsala; Dürer’s Rhinoceros. Search approved channels (Natural History Museum London, Smithsonian, National Gallery of Art, Uppsala University, SciShow Kids); preview first.

KEY TERMS

kind

In Genesis 1, a group of creatures God made to reproduce “after his kind.” Many Bible scholars think a created kind is often broader than a species.

taxonomy

The science of naming, describing and sorting living things into groups.

binomial name

A two-part scientific name: the genus followed by the species, as in *Castor canadensis*, the American beaver.

genus

A group of closely related species. It is the first, capitalized word of a scientific name.

species

A group of creatures alike enough to breed together. Its name is the second, lowercase word of a scientific name.

CORE IDEAS

The first naturalist. In Genesis 2, before Eve was made, God put Adam in the garden of Eden “to dress it and to keep it” (Genesis 2:15). Then “the LORD God formed every beast of the field, and every fowl of the air; and brought them unto Adam to see what he would call them” (Genesis 2:19). God did not hand Adam a list. He let Adam look, think and choose, and whatever Adam called each creature, “that was the name thereof.” Among all of them, Adam found no one who was a fit companion for himself, and so God made Eve (Genesis 2:20–22).

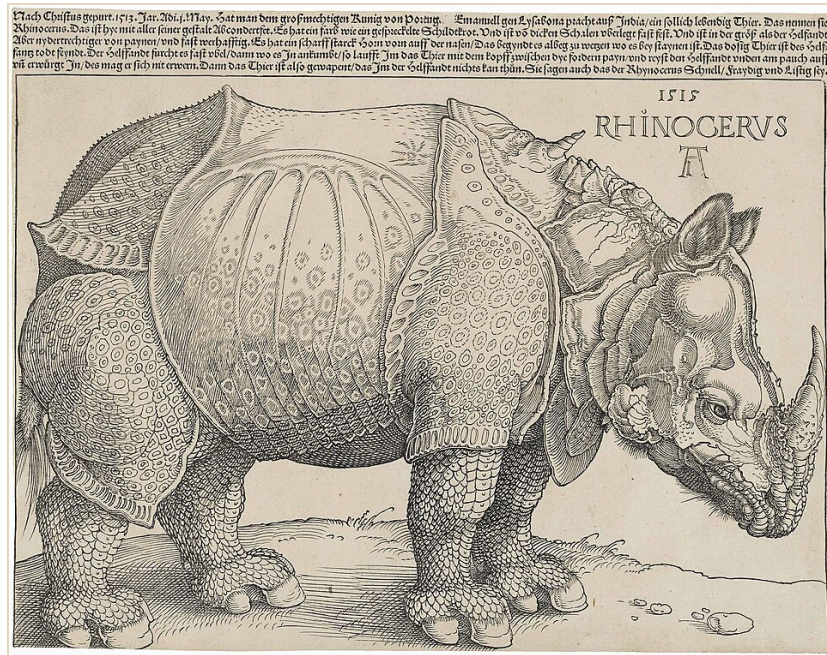
What naming means. In the Bible, giving a name shows understanding and responsibility. A father names his child; God named the stars (Psalm 147:4). By letting Adam name the animals, God showed that people are to rule over the creatures and care for them as His stewards (Genesis 1:28). Naming is also the first step of science. To name a creature well, you must notice how it looks, moves and lives, and how it differs from others. Every stop on this trail, from the bat's echoes to the otter's rock, is part of the same work Adam began.

A second Adam's job. Thousands of years later, a Swedish doctor and botanist named Carl Linnaeus (1707–1778), the son of a Lutheran pastor, set out to bring order to the confusing names scholars used. Some plants had names a dozen words long. In his book *Systema Naturae* he gave each creature just two Latin words: the **genus** and the **species**. The tenth edition, published in 1758, is the official starting point for the scientific names of animals. The gray wolf became *Canis lupus* and the house cat *Felis catus*. Linnaeus sorted creatures into nested groups: kingdom, class, order, genus and species. Scientists later added phylum and family. A saying often linked with him goes, "God created, Linnaeus arranged."

Still naming. Today scientists have named well over a million kinds of animals, most of them insects, and they name thousands of new ones every year. Many names describe the animal: the sea otter, *Enhydra lutris*, means "the otter in the water." Others honor people, such as explorers or the scientists who found them. Every new name still needs what Adam needed: a careful look at a real creature.

Seeing before naming. In 1515 a rhinoceros arrived in Lisbon, the first seen in Europe in over a thousand years. Albrecht Dürer never saw it. Working only from a letter and a rough sketch, he carved a famous woodcut. For more than two hundred years many Europeans believed rhinoceroses looked just like it. Adam named what he had seen with his own eyes; good naming starts with honest looking.

PICTURE STUDY



The Rhinoceros, Albrecht Dürer, 1515 · Woodcut · Many impressions survive; examples are in the National Gallery of Art, Washington, and the British Museum, London
Wikimedia Commons · Public domain

This Indian rhinoceros was a gift to King Manuel I of Portugal and arrived in Lisbon in May 1515. A few months later Dürer, in Nuremberg, made this woodcut from a description and a sketch someone sent him. The words above the picture describe the animal. The real rhinoceros died the next year when the ship carrying it to the Pope sank in a storm.

Look closely

- Find the plates on the rhinoceros's body. Do they look like skin or like armor? Where do they join, like rivets?
- Find the small, twisted horn on its back between the shoulders. Real rhinoceroses do not have one.
- Look at the legs. What did Dürer give them that a real rhinoceros does not have?

Talk about it

1. Dürer got some things right: the folds of skin and the shape of the main horn. What does this show about the description he was given?
2. Why would this picture be believed for so long? What would you need to correct it?

HANDS-ON: MAKE A NAMING KEY

Scientists use a **key** to name an unknown animal by answering a series of yes-or-no questions. Make one for ten animals from this trail.

You will need

- Ten index cards or slips of paper
- A large sheet of paper
- Colored pencils
- Your Field Notebook

Steps

1. Write the name of one animal from this trail on each card: bat, dolphin, snowshoe hare, cuttlefish, woodchuck, wood frog, beaver, village weaver, clownfish, sea otter.
2. Find one yes-or-no question that splits the cards into two piles, such as “Does it have feathers?” or “Does it live in water?”
3. Keep splitting each pile with a new question until every card stands alone.
4. Draw your key on the large sheet as a branching tree: the first question at the top and each animal’s name at the end of a branch.
5. Test your key on a family member: give them an animal in secret and let them follow your questions to its name.

Check your work

- Every question in my key can be answered yes or no.
- Every one of the ten animals ends up at its own branch.
- Someone else used my key and reached the right animal.

FIELD NOTEBOOK

1. **Diagram: a classification ladder.** Draw a ladder with seven rungs. From top to bottom, write: Kingdom Animalia, Phylum Chordata, Class Mammalia, Order Carnivora, Family Mustelidae (the weasel family), Genus *Enhydra*, Species *Enhydra lutris*. Beside the bottom rung draw the sea otter. Beside each rung, write one other animal that shares that group (for example, a robin shares the phylum; a wolf shares the order; a weasel shares the family).
2. **Notebook entry.** Write a paragraph about the creature on this trail you would most like to have named if you had been Adam. Tell what name you would give it and why, using something you learned about how it lives.

Did you know? Linnaeus sent his students, whom he called his “apostles,” all over the world to collect plants and animals. One of them, Daniel Solander, sailed with Captain Cook on his first voyage (1768–1771). Linnaeus also coined *Homo sapiens*, the scientific name for mankind, and in 1959 a scientist named Linnaeus himself as its official “type specimen,” the example that the name belongs to.

Goes deeper in. Life Science (classification of living things), Art (Dürer and the woodcut) and Literature (Genesis 1–2) (coming soon). Stop A1 in Trail A begins the track with the lion of Judah.

For families. Genesis 2:19–20 is quoted from the KJV. The 10th edition of *Systema Naturae* (1758) is the starting point of zoological nomenclature under the International Code. The motto “Deus creavit, Linnaeus disposuit” is traditionally attributed to Linnaeus, though its first source is uncertain. Linnaeus was designated the lectotype of *Homo sapiens* in 1959 (W. T. Stearn). Estimates of named animal species vary (roughly 1.2 to 1.5 million). The view that a biblical “kind” is often broader than a species is common among creation scholars; the stop presents it as a view, not a fixed rule. The rhinoceros arrived in Lisbon on May 20, 1515, and drowned in a shipwreck off Italy in early 1516.

PRACTICE

1. **EASY** According to Genesis 2:19, who brought the animals to Adam, and why?
2. **EASY** Who gave animals two-part scientific names, and what book and year are the starting point for animal names?
3. **MEDIUM** The gray wolf is *Canis lupus*, the coyote is *Canis latrans* and the red fox is *Vulpes vulpes*. Which two are most closely related, and how can you tell from the names?
4. **MEDIUM** Name two mistakes in Dürer’s Rhinoceros and explain why he made them.
5. **CHALLENGE** Genesis says God made creatures “after his kind.” Wolves, coyotes and dogs are different species, but they can breed with one another. What might this suggest about how a created kind compares with a species?

Make it a game · Twenty Questions: Name That Creature. One player secretly chooses any animal from the whole Animals track. The others ask yes-or-no questions, like the questions in a key (“Does it have fur?” “Does it hibernate?”). They have twenty questions to name it. Whoever names it chooses the next creature.

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

God gave Adam the joy of looking closely at His creatures and naming them. Every careful notebook page on this trail continues that same God-given work.

Practice: answers

1. The LORD God brought them to Adam to see what he would call them.
2. Carl Linnaeus; the tenth edition of *Systema Naturae*, 1758.
3. The wolf and the coyote; they share the same genus, *Canis*.
4. Any two: armor-like plates with rivets, a small twisted horn on the back, scaly legs. He never saw the animal and worked only from a letter and a sketch.
5. It suggests a created kind may be broader than a species: wolves, coyotes and dogs may all belong to one original dog kind, with species varying within it. Many creation scholars think kinds are often near the level of the family or genus.

TRAIL 6 BADGE QUIZZES

The badge quizzes are optional. The student answers in writing, in complete sentences, and may look back at the Field Notebook but not at the stops. Four right out of five earns each badge. Badges and the certificate are earned by doing the stops, not by scores.

Badge quiz 1 (Stops 1-5)

1. A bat hears an echo 0.2 second after it calls. Sound travels about 343 meters per second in air. How far away is the moth? Why can't people hear most bat calls?
2. What is countershading, and who explained it in 1896?
3. Describe two changes in a woodchuck's body during hibernation, with numbers.
4. Give two reasons a beaver builds a dam, and tell how a village weaver's nest is protected from snakes.
5. What kind of partnership do the honeyguide and the Yao honey hunters have? What does each partner get?

Badge quiz 2 (Stops 6-10)

6. Why is the sea otter called a keystone species, and what happened in 1911?
7. Which animal makes the longest yearly migration, about how far does it fly, and name one way migrating birds find their way.
8. In the 1925 serum run, about how far did the relay carry the serum, and what did Togo and Balto each do?
9. Name the living thing behind each invention: Velcro; the nose of Japan's 500 Series bullet train; the Wright brothers' wing warping.
10. What did God do in Genesis 2:19, and what is the genus in the scientific name *Castor canadensis*?

TRAIL CERTIFICATE: MY ANIMAL WONDERS FIELD NOTEBOOK AND TRAIL F CERTIFICATE

Gather the Field Notebook pages from this trail into one booklet with a cover: "My Animal Wonders Field Notebook," your name and the dates you started and finished.

Make sure the booklet includes at least three of your labeled diagrams or maps (for example, the bat and moth, the beaver lodge cross-section, the Great Journeys map or the serum run map) and your paragraph entries.

Add a final page: choose one animal from the whole Animals track and write a short "field guide" entry for it, with its common name, its scientific name, a labeled drawing and three amazing facts.

When the booklet is done, a parent signs the Trail F certificate.

- **Ten stops:** At least one page for each stop, with a title, a date and a written paragraph.

- **Maps and diagrams:** At least three maps or diagrams with titles, clear labels and, where needed, a key or scale.
- **Facts and numbers:** Entries use accurate facts, dates and numbers from the stops, and calculations are shown.
- **Care and thought:** Work is neat and complete, and the final field guide entry shows careful observation, as Adam's naming did.

Answer key

1. $343 \times 0.2 = 68.6$ meters there and back, so the moth is about 34 meters away. Most bat calls are ultrasound, above about 20,000 hertz, too high for human ears.
2. Dark coloring on the back and pale coloring on the belly, which cancels the shadow made by light from above so the animal looks flat. The American painter Abbott Thayer explained it.
3. Any two: heartbeat slows from about 80 to about 5 beats a minute; body temperature drops from about 99°F to near 40°F; breathing slows to a couple of breaths a minute; it lives on stored fat and may lose about a third of its weight.
4. Dam: to keep the lodge entrances underwater, to keep the pond from freezing to the bottom, to store winter food underwater. Weaver: the nest hangs from thin branch tips, often over water, with the entrance tunnel facing down.
5. Mutualism: both are helped. The hunters get honey; the honeyguide gets the wax left behind.
6. It eats sea urchins that would otherwise destroy kelp forests, so many other creatures depend on it. In 1911 a treaty ended the hunting of sea otters for their fur.
7. The Arctic tern, about 44,000 miles a year (round trip). Any one: the sun, the stars, the earth's magnetic field, landmarks.
8. About 674 miles, from Nenana to Nome. Togo, with Leonhard Seppala, ran the longest and most dangerous leg, across the ice of Norton Sound; Balto, with Gunnar Kaasen, led the last leg into Nome.
9. Velcro: burdock burrs. Bullet train nose: the kingfisher's beak. Wing warping: soaring birds twisting their wingtips.
10. God formed the beasts and birds and brought them to Adam to see what he would call them, and Adam named them. The genus is *Castor*.