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GRADE 8

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Spectrum®
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Lesson 1.1 Scientific Reasoning

reasoning: the process of forming conclusions, judgments, or inferences based on facts or other evidence

deduction: reasoning from the general to the specific, in which a conclusion must be true because it's based on true statements

induction: reasoning that uses specific events or facts to draw more general conclusions

evidence: something that helps either prove or disprove a conclusion

theory: statement that explains a group of facts or phenomena; most accepted theories have been repeatedly tested and can be used to make predictions about nature

law: a scientific statement that describes a fact about or an event in the universe that has never been observed to occur differently

The example of deductive reasoning that's probably more famous than any other is: Socrates is a man. All men are mortal. Therefore, Socrates is mortal.

What's the difference between deductive and inductive reasoning?

Science is about discovering the reasons why things happen in the universe, so it shouldn't be a surprise to learn that scientific knowledge is gained through **reasoning**. There's more than a single way to reason, though, and one plays a much bigger role in science than any other.

Deduction is a form of reasoning that uses broad, generalized facts to draw conclusions about specific questions or events. For example, let's say you go to bed one night, wake up at dawn, and the ground is covered in a layer of fresh snow. You also see a line of tiny footprints imprinted on the snow. Using deductive reasoning, you know an animal walked there during the night. You reach this conclusion because, **a**: animals leave footprints when they walk through snow; and **b**: the snow fell during the night; therefore, **c**: an animal walked across the snow during the night. If **a** and **b** are true, then **c** must be true.

Deduction doesn't really lead to new knowledge, though. When a more general truth is already known, deduction simply proves that more specific instances are true as well. You know that gravity causes objects to fall when they're dropped, and an apple is an object, so concluding that an apple will fall when it's dropped isn't particularly informative.

Science is mainly based on **induction**, which, in a way, is the opposite of deduction. Inductive reasoning uses specific examples to draw more general conclusions. Going back to the tracks in the snow, induction might lead you to conclude that a possum walked across the yard at night. In five years, you've never observed any animals but possums during the night. The tracks also appear to have been made by a small, four-legged animal. Therefore, it was most likely a possum that crossed the yard. Inductive reasoning leads to most likely conclusions, but there's always a chance, no matter how small, that something else is the answer.

Scientific knowledge is gained through inductive reasoning. Scientists observe specific events—whether they occur in nature or in controlled experiments. Then, based on the accumulated **evidence** from many specific observations, they draw conclusions about the world. A hypothesis that's been tested many, many times and never proven wrong will eventually become a **theory**. The theory that's never proven wrong might become a **law**. Even so, scientists understand that science is based on induction, and that even the strongest theories and laws have to be adjusted if new evidence appears.

NAME _____

Read the following examples of reasoning. Then, write **deductive** or **inductive** on the line to indicate which type of reasoning was used.

1. _____ A biologist studying chimpanzees in the wild knows that young chimps have light brown faces and older chimps have dark gray faces. Chimp 1435 has a light brown face, so the biologist reasons that it's a young chimp.

2. _____ A truck traveling from Detroit to Chicago takes the most direct route. The most direct route from Detroit to Chicago runs through Michigan City, Indiana. Before arriving in Chicago, the truck will pass through Michigan City, Indiana.

3. _____ Most nights you look outside and see light from a street lamp illuminating the sidewalk. Then, one night you look outside and the street is dark. You reason that the bulb must have burned out in the lamp.

4. _____ In the 1920s, Edwin Hubble and other astronomers made the observation that galaxies are expanding away from each other at a steady rate. Other scientists calculated the galaxies' speeds and directions of movement, and then worked backward. They reasoned that all the galaxies and the matter in them must have once been combined into a single point of matter that exploded and began the observed, expanding motion.

5. _____ Each year, Alfonse has observed the leaves on trees near his home changing colors and falling to the ground during autumn. Then, in spring, the leaves reemerge. Alfonse reasons that the same thing will happen this year as well.

Write your answers on the lines below.

6. Write your own example of deductive reasoning.

_____

_____

7. Write your own example of inductive reasoning.

_____

_____

Lesson 1.2 Reconstructing the Past

paleontologists: scientists who study life from past geological periods

physiology: the study of the structure and makeup of organisms and how they function

In some labs, CT scans—like the kind hospitals use to do brain scans—are used on dinosaur skulls. Then, researchers use computers to create 3-D models of the insides of the skulls. This helps them figure out the size of the dinosaur's brain and can even give them information about the animal's sight or sense of smell.

An elephant's trunk is muscle and its large, floppy ears are made of cartilage, a relatively soft material. This means that the skeleton of an elephant would give no indication of two of its most recognizable features.

How do scientists figure out what dinosaurs looked like?

Do you know what dinosaurs look like? You've probably seen their images hundreds of times. Although most people could easily describe one, the truth is that no one really knows what dinosaurs looked like. The creatures that the word *dinosaur* bring to mind are actually the joint creations of **paleontologists** and artists. While they do their best to be scientifically accurate, a lot of educated guesswork is involved.

Fossils are the source of most of what is known about dinosaurs. As paleontologists unearth dinosaur bones, they must note the location of the bones in relation to one another. This information can be useful when they assemble a skeleton. It's very rare to find all the bones of an individual dinosaur. Many are washed away by water, moved by scavengers, or damaged by bacteria or the effects of weathering. Scientists look for other dinosaurs of the same species so that they can assemble a complete skeleton.

An in-depth knowledge of animal **physiology** is necessary because it can give paleontologists clues about how dinosaur bones fit together. The study of other dinosaur skeletons can also provide information, though there is no guarantee that all other dinosaur skeletons have been put together correctly.

Once a complete skeleton has been created, the next step is to determine how the muscles and tendons would have filled out the body of the dinosaur. Soft-tissue generally isn't preserved because it decays too quickly. However, soft tissues often leave microscopic marks on bones. The places where muscles were attached also leave marks. By comparing these marks to the marks on the bones of modern-day animals, paleontologists and artists can make more accurate predictions about the outward appearance of dinosaurs.

It's impossible to know what colors the dinosaurs were, but they are usually drawn in shades of brown and green, because these colors would have provided camouflage. Making this assumption requires researching the environments where dinosaurs lived. By choosing this sort of coloration, scientists also assume that dinosaurs could see in color—otherwise color camouflage wouldn't have protected them from one another.

Although there are new ways of learning about the appearance of dinosaurs, it's likely that some elements of what they looked like will always remain a mystery. Filling in the details will be left to the paleontologists who study them and the imaginations of the artists who portray them.

NAME _____

Write **true** or **false** next to each statement below.

1. _____ Complete dinosaur skeletons are rarely found.

2. _____ The images most people have of dinosaurs were created totally from the imaginations of artists.

3. _____ Imprints of soft tissues are found near most fossilized dinosaur bones.

4. _____ Dinosaur skeletons in museums are usually made from the bones of more than one dinosaur of the same species.

5. _____ There is no sure way to know what colors dinosaurs were.

Write your answers on the lines below.

6. After reading the sidebar text, you know that it isn't obvious from looking at an elephant's skeleton that it has a trunk and huge ears. What does this tell you in terms of the appearance of dinosaurs?

_____

7. How can modern technology help scientists figure out what dinosaurs looked like?

_____

8. Explain why the environment in which a dinosaur lived can give paleontologists a clue about its coloring.

_____

_____

9. If it turned out that dinosaurs were colorblind, how would this affect some assumptions scientists have made about them?

_____

_____

10. What information can paleontologists gain by doing comparative studies of the bones of dinosaurs and the bones of modern-day animals?

_____

_____

Lesson 1.3 The Evolution of Ideas

How does new knowledge change the way scientists look at old discoveries?

Around 1909, Charles Doolittle Walcott received a bit of interesting news. Canadian railroad workers were collecting "stone bugs" that they had found while cutting a path through the Rocky Mountains. Walcott was the head of the Smithsonian Institute, and a respected paleontologist, so he rushed to see what kinds of fossils had been found.

From 1910 to 1917, Walcott collected more than 65,000 specimens from the area—a massive **fossil bed** he named the *Burgess Shale*. After Walcott returned to Washington, D.C. with his fossils, he began the task of categorizing them. He didn't recognize many of the creatures, so he classified them as odd examples of organisms already known to have existed in Earth's prehistoric past. Eventually, the fossils ended up in drawers at the Smithsonian, and there they sat, mostly forgotten, for almost 50 years.

In the 1960s, Canadian scientists decided to take another look at the Burgess Shale. They discovered even more fossils, and a new study, led by Harry Whittington began. He traveled to D.C. and reexamined Walcott's forgotten fossils. Many years had passed since their discovery. A lot of new information was known about Earth's earliest life-forms and how they had evolved into the **diverse** organisms of today. Whittington and the other scientists were shocked to discover such a huge collection of creatures that looked like no other organisms they'd ever seen before.

Most fossils have an **evolutionary line** that can be traced to other creatures in the fossil record, or even to organisms that exist today. Many of the creatures in the Burgess Shale fossils, though, seemed to have appeared at just this one time in history. They didn't slowly evolve over time into other known organisms. Instead, something seemed to have happened that caused them to become extinct soon after this one appearance in the fossil record.

In his popular book, *Wonderful Life*, **evolutionary biologist** Stephen Jay Gould argued that this characteristic helped prove his idea that luck plays as much, if not more, of a role in evolution than natural selection does. Gould's book angered the scientists who were still studying the fossils. They felt that Gould was **misinterpreting** their data to support his hypothesis.

By the 1990s, paleontologists Derek Briggs and Richard Fortey had reclassified most of the unusual Burgess Shale organisms as **arthropods**. The fossilized creatures were ancient relatives of insects—not completely unique life forms that had never evolved.

fossil bed: an area of land that contains fossils

diverse: of different kinds, forms, or types

evolutionary line: the sequence of organisms that descend from one particular organism

evolutionary biologist: a scientist who studies the origins and evolution of living organisms

misinterpreting: understanding or explaining incorrectly

arthropods: the largest phylum in the Animal kingdom, it includes insects, spiders, and crustaceans

Trilobite fossils found at the Burgess Shale helped scientists date the other creatures found there to the Cambrian period, which lasted from 530 to 520 million years ago. This period in Earth's history saw a phenomenal increase in the diversity and abundance of Earth's life forms within a relatively short time.

Another of Stephen Jay Gould's debated hypotheses was that evolutionary change occurs in sudden bursts, followed by long periods of stability.

NAME _____

Circle the letter of the best answer to each question below.

1. The creatures preserved in the Burgess Shale fossils are most closely related to modern

a. reptiles.

b. mammals.

c. fish.

d. insects.

2. The Cambrian period occurred

a. thousands of years ago.

b. a few million years ago.

c. hundreds of millions of years ago.

d. billions of years ago.

Write your answers on the lines below.

3. Further research into the Burgess Shale fossils showed that the data did not support Gould's hypothesis. Do you think this information proved that Gould was wrong? Why or why not?

_____

_____

4. Major museums such as the Smithsonian Institute have thousands, if not millions, of artifacts that are stored away, but not displayed. Based on what you read in this selection, why is it important for museums and other institutions to hold on to artifacts, even if they are no longer currently being studied?

_____

_____

5. The biggest criticisms of Gould's book didn't focus on his hypothesis; they focused on his methods. Why do you think scientists' methods of investigation need to be carefully examined by other scientists?

_____

_____

Lesson 1.4 Dating 101

relative dating: ordering events or objects in time without assigning actual ages or dates

absolute dating: determining an actual age for an object or a date of occurrence for an event

radiometric dating: a method of absolute dating in which the amount of a radioactive element that remains in a material after it has begun to decay is measured

Using radiometric dating, Earth has been dated at 4.5 billion years old. The planet's oldest rocks were formed about 3.8 billion years ago, but meteorites in our solar system have been dated at 4.5 billion years old. Earth and the meteorites would have formed at the same time—with the formation of our solar system—so they should be approximately the same age.

Dendrochronology is the use of a tree's growth rings to determine the age of a tree and what the environmental conditions were like during its lifetime.

How can scientists determine the age of objects and events from Earth's past?

Antiques dealers can use style, workmanship, and materials as clues to date a piece of furniture or a vase. It's quite a bit more complex for scientists to assign an age to a fossil, a piece of rock, a tree limb, or even a geological event. Like an expert in antiques, a paleontologist or geologist will gather clues about an object. Then, he or she will use the information to determine the object's age. Over the years, methods of dating have improved and allow most materials to be dated with accuracy.

Relative dating was used before a reliable method of **absolute dating** was discovered. It allowed scientists to determine the order of events or tell whether one object was older than another. For example, using the law of superposition—one of the principles of relative dating—a geologist knows that the oldest beds of rock form the bottom layers in a series, while the most recent are on top.

When methods of absolute dating became possible, scientists could assign an actual age to objects and events, instead of just ordering them in time. **Radiometric dating**, developed after radioactivity was discovered in 1896, is one of the best-known methods. It's based on the theory that radioactive elements decay at predictable rates.

Carbon dating is frequently used to date organic remains. It's based on the fact that there is always a specific percentage of all carbon that exists as the isotope carbon-14. Those unstable carbon-14 isotopes steadily break down and turn into nitrogen-14. Other processes ensure there is always the same percentage of carbon-14. However, when the organism dies, the percentage will not stay at its stable amount. Over a period of 5,730 years, half the carbon in a dead plant, for example, will have changed to nitrogen. This is called the *half-life* of carbon-14. In another 5,730 years, half the remaining carbon will have changed to nitrogen. By measuring how much carbon-14 there is in the organic material, scientists can tell how old it is.

One problem with using carbon dating is that it's useful only to date things that are less than about 40,000 years old because carbon's half-life isn't very long. Other radioactive elements can be used for some types of dating, but like carbon, they also have limits.

One type of dating isn't superior to another. In fact, scientists generally use more than one method when possible. This allows them to double-check their conclusions and be sure that they are as accurate as possible.

NAME _____

Write your answers on the lines below.

1. How could a natural event, like an earthquake, make it difficult to use the law of superposition?

_____

2. Sam is the oldest in his group of friends. Amira is five years younger than Sam, Lea is between Sam and Amira in age, and Marcus is the youngest. Arrange the names of the friends in order from youngest to oldest.

_____ _____ _____ _____

3. Explain whether you used absolute or relative dating in the previous item and why you were able to use one method but not the other.

_____

_____

4. Why would a radioactive element need to have a known rate of decay in order for it to be useful as a dating tool?

_____

_____

5. Why is the use of carbon-14 dating limited?

_____

6. Describe a scenario in which a scientist might use both relative and absolute methods of dating.

_____

_____

_____

Unifying Concepts and Processes

When paleontologists dated the Burgess shale fossils to the Cambrian period because trilobites were found among them, were they using relative dating or absolute dating?

_____

Lesson 1.5 The Cicadas of Summer

nymphs: insects that haven't reached full maturity; nymphs look like adults, but they are smaller, don't have fully-developed wings, and can't reproduce

molt: to shed an outer skin or covering in order to allow growth

brood: a group of young that hatch at one time

Cicada is a Latin word that means "tree cricket."

Cicadas are harmless; they don't sting or bite.

When millions of cicadas are buzzing at once, the sound can reach 90 decibels. That's loud enough to damage your hearing if you're exposed to it for too long.

Cicadas are a common treat in parts of Asia. Although they are edible, and trying a few won't hurt you, the cicadas in the U.S. may contain trace amounts of pesticides, so it's not recommended that you eat too many of them.

If cicadas emerge only once every 13 or 17 years, why do you hear them every summer?

Each summer in July and August, the steady buzz of cicadas fills the air across much of the United States. Male cicadas produce this noise in order to attract mates. When dozens of cicadas buzz at once, the sound can be loud, but when millions of them are calling out at once, the sound can be nearly deafening.

Although there are thousands of different species of cicadas, they're all members of the Cicadidae family of insects. The most common cicadas in America are in the genus *Tibicen*. They emerge from the ground as **nymphs** in July and climb into nearby trees to **molt**. The adult cicada leaves behind its old exoskeleton as it flies off to find a mate, and the empty shells remain clinging to tree trunks and branches.

For a few short weeks, the male cicada's song can be heard echoing through the trees, but soon after mating, the male cicadas die. The adult females survive a bit longer in order to lay eggs in tiny slits they've cut into tree limbs, but then they die as well. Several weeks later, the eggs hatch and the larvae that emerge fall to the ground. They burrow deep into the soil, where they'll live for the next few years by feeding on juices from tree roots. About three years later, they reemerge as nymphs, and the cycle continues.

Although *Tibicen* cicadas are more common, the *Magicicada* genus is the one that makes the news. They emerge in the millions—and sometimes even in the billions—every 13 or 17 years, depending on the **brood**. In some wooded areas, the swarms are so thick that you can quickly end up with a dozen cicadas clinging to your body. The sound can be so overwhelming that it can be difficult to hold a conversation.

Entomologists believe there are a total of 15 *Magicicada* broods that emerge in different years and in different areas scattered across the eastern U.S. In 2004, Brood X emerged after its normal 17-year absence. Covering an area from Illinois to New York, and south to Georgia, Brood X is the largest of all the broods. Red-eyed cicadas filled the air. Because *Magicicadas* emerge a little earlier than *Tibicens*, most of them had mated and died by mid-July. The forest floor was littered with millions of rotting cicada carcasses, but chemicals released by the decomposing bodies provided important nutritional elements to the soil.

NAME _____

Write your answers on the lines below.

1. What's the difference between *Tibicen* and *Magicicada* cicadas?

_____

2. Explain the life cycle of a cicada.

_____

_____

_____

3. How does the emergence of millions of cicadas at once benefit the environment?

_____

4. How might the emergence of millions of cicadas at once benefit the cicadas?

_____

5. In 2007, Brood XIII reemerged in Illinois. After weeks of news reports about the cicadas' return, people in some of the suburban areas surrounding Chicago were disappointed when no cicadas appeared in their neighborhoods. In areas like state parks, though, the air was absolutely swarming with bugs. Use the following clues to explain why you think the cicadas may have disappeared from these suburban areas.

   - Cicadas don't migrate. The adults rarely travel more than a quarter of a mile from where they first emerged as nymphs.
   - These *Magicicada* nymphs spend 17 years living several feet underground.
   - Nymphs molt in trees, and the adults lay eggs in tree branches.

_____

_____

_____

What's Next?

Scientific classification is an important tool for describing and categorizing Earth's many millions of living organisms. Look in the library or online to find a list of the eight major categories, and then choose an animal to discover how it's classified scientifically.