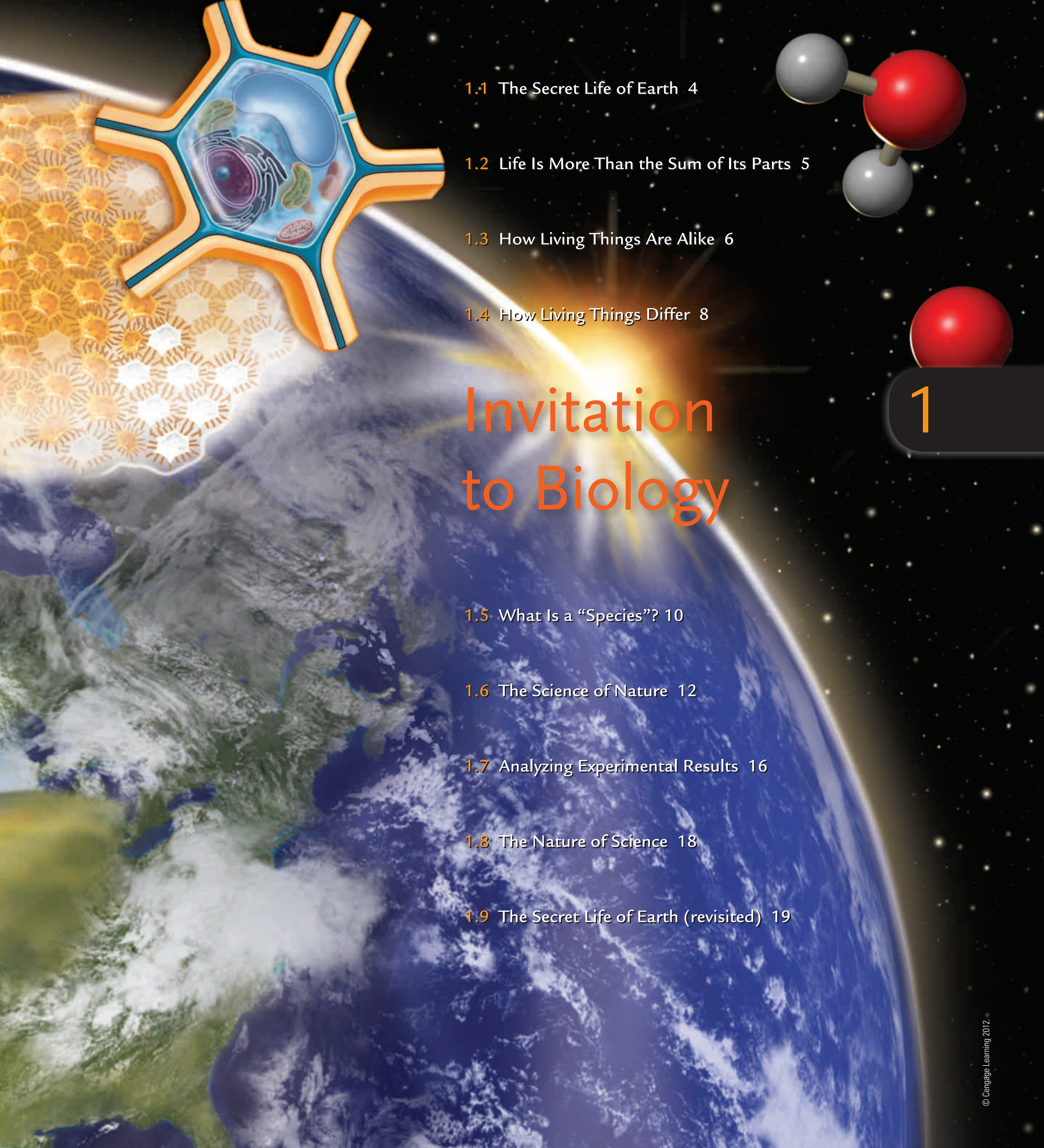


1 Invitation to Biology

. . . Where You Have Been

Whether or not you have studied biology, you already have an intuitive understanding of life on Earth because you are part of it. Every one of your experiences with the natural world—from the warmth of the sun on your skin to the love of your pet—contributes to that understanding.

1.1 The Secret Life of Earth

In this era of detailed satellite imagery and cell phone global positioning systems, could there possibly be any places left on Earth that humans have not yet explored? Actually, there are plenty of them. For example, a team of scientists was recently dropped by helicopter into the middle of a vast and otherwise inaccessible cloud forest on top of New Guinea's Foja Mountains. Within a few minutes, the explorers realized that their landing site, a dripping, moss-covered swamp, had been untouched by humans. Team member Bruce Beehler remarked, "Everywhere we looked, we saw amazing things we had never seen before. I was shouting. This trip was a once-in-a-lifetime series of shouting experiences."

How did the explorers know they had landed in uncharted territory? For one thing, the forest was filled with plants and animals previously unknown even to native peoples that have long inhabited other parts of the region. During the next month, the team members discovered many new species, including a rhododendron plant with flowers the size of plates and a frog the size of a pea. They also came across hundreds of species that are on the brink of extinction in other parts of the world, and some that supposedly had been extinct for decades. The animals had never learned to be afraid of humans, so they could easily be approached. A few were discovered as they casually wandered through camps (Figure 1.1).

FIGURE 1.1 Paul Oliver discovered this tiny tree frog perched on a sack of rice during a particularly rainy campsite lunch. The explorers dubbed the new species "Pinocchio frog" after the Disney character because the male frog's long nose inflates and points upward during times of excitement.
Tim Laman/ National Geographic Stock.

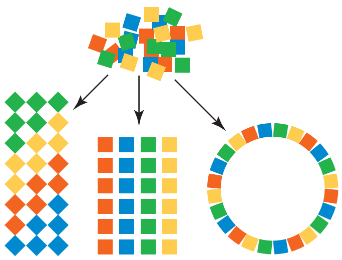
New species are discovered all the time, often in places much more mundane than Indonesian cloud forests. How do we know what species a particular organism belongs to? What is a species, anyway, and why should discovering a new one matter to anyone other than a scientist? You will find the answers to such questions in this book. They are part of the scientific study of life, **biology**, which is one of many ways we humans try to make sense of the world around us.

Trying to understand the immense scope of life on Earth gives us some perspective on where we fit into it. For example, the current rate of extinctions is about 1,000 times faster than normal, and human activities are responsible for the acceleration. At this rate, we will never know about most of the species that are alive on Earth today. Does that matter? Biologists think so. Whether or not we are aware of it, humans are intimately connected with the world around us. Our activities are profoundly changing the entire fabric of life on Earth. The changes are, in turn, affecting us in ways we are only beginning to understand.

Ironically, the more we learn about the natural world, the more we realize we have yet to learn. But don't take our word for it. Find out what biologists know, and what they do not, and you will have a solid foundation on which to base your own opinions about the human connection—your connection—with all life on Earth.

1.2 Life Is More Than the Sum of Its Parts

Biologists study all aspects of life, past and present. What, exactly, is the property we call "life"? We may never come up with a good definition, because living things are too diverse, and they consist of the same basic components as nonliving things. When we try to define life, we end up only identifying properties that differentiate living from nonliving things. Even so, we do understand that life is organized in successive levels, with new properties emerging at each level (Figure 1.2). Complex properties, including life, often emerge from the interactions of much simpler parts. For an example, in the drawings *below*, a property called "roundness" emerges when the parts are organized one way, but not other ways.



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The idea that different structures can be assembled from the same basic building blocks is a common theme in our world, and also in biology. Consider **atoms**, which are fundamental units of matter—the building blocks of all substances 1. Atoms bond together as **molecules** 2. There are no atoms unique to living things, but there are unique molecules. In today's world, only living things make the "molecules of life," which are lipids, proteins, DNA, RNA, and complex carbohydrates. The property of "life" appears at the next level, when many molecules of life become organized as a cell. A **cell** is the smallest unit of life 3. Some cells live and reproduce independently; others do so as part of a multicelled organism. An **organism** is an individual that consists of one or more cells 4. Cells of multicelled organisms are typically organized as tissues, organs, and organ systems that interact to keep the individual's body working properly. A **population** is a group of interbreeding individuals of the same species living in a given area 5. At the next level, a **community** consists of all populations of all species in a given area 6. Communities may be large or small, depending on the area defined. The next level of organization is the **ecosystem**, which is a community interacting with its physical and chemical environment 7. The most inclusive level, the **biosphere**, encompasses all regions of Earth's crust, waters, and atmosphere in which organisms live 8.

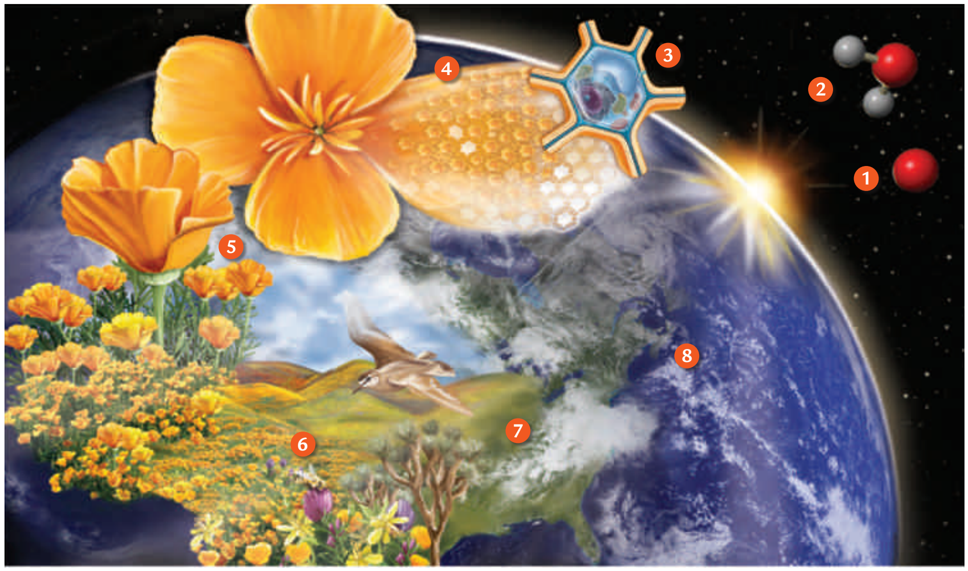

FIGURE 1.2 Animated! Levels of organization in nature, from simpler to more complex.

1 Atoms are fundamental units of matter.

2 Molecules consist of atoms.

3 Cells consist of molecules.

4 Organisms consist of cells.

5 Populations consist of organisms.

6 Communities consist of populations.

7 Ecosystems consist of communities interacting with their environment.

8 The biosphere consists of all ecosystems on Earth.

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Take-Home Message

How do living things differ from nonliving things?

- All things, living or not, consist of the same building blocks: atoms. Atoms join as molecules.
- The unique properties of life emerge as certain kinds of molecules become organized into cells.
- Higher levels of life's organization include multicelled organisms, populations, communities, ecosystems, and the biosphere.

atom Fundamental building block of all matter.
biology The scientific study of life.
biosphere All regions of Earth where organisms live.
cell Smallest unit of life.
community All populations of all species in a given area.
ecosystem A community interacting with its environment.
molecule Two or more atoms bonded together.
organism Individual that consists of one or more cells.
population Group of interbreeding individuals of the same species that live in a given area.

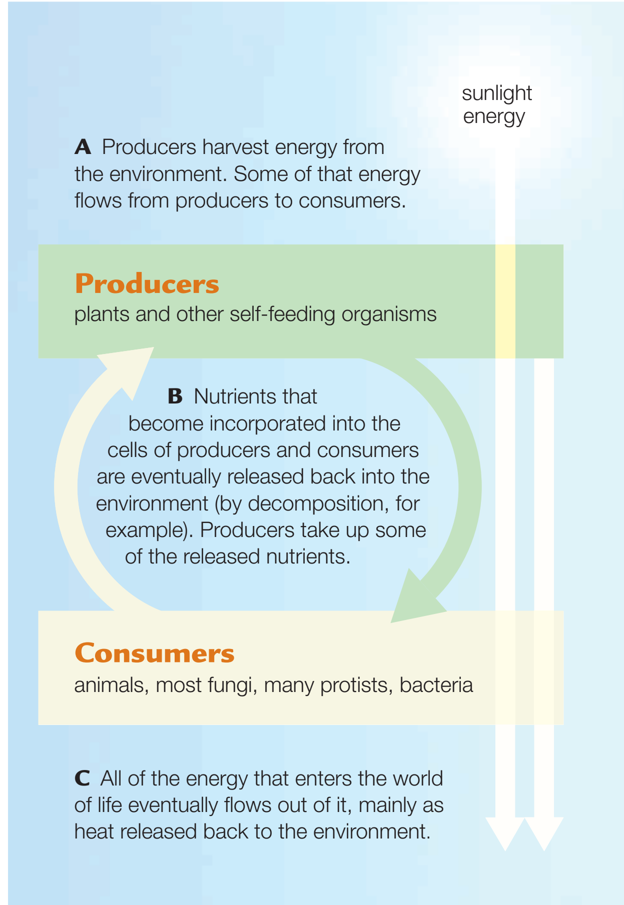


FIGURE 1.3 Animated! The one-way flow of energy and the cycling of materials in the world of life. The photo *above* shows a producer acquiring energy and nutrients from the environment, and consumers acquiring energy and nutrients by eating the producer.

Credits: left, © Victoria Pinder, www.flickr.com/photos/vixstarplus; right, © Cengage Learning.

1.3 How Living Things Are Alike

A set of key features distinguishes living organisms from nonliving things. All living organisms require ongoing inputs of energy and raw materials; all sense and respond to change; and all have DNA that guides their functioning.

› Organisms Require Energy and Nutrients Not all living things eat, but all require energy and nutrients on an ongoing basis. A **nutrient** is a substance that an organism needs for growth and survival but cannot make for itself. Organisms spend a lot of time acquiring energy and nutrients because both are essential to maintain life's organization and functioning. However, what type of energy and nutrients they acquire varies considerably depending on the type of organism. The differences allow us to classify all living things into two categories: producers and consumers. **Producers** make their own food using energy and simple raw materials they get from non-biological sources. Plants are producers that use the energy of sunlight to make sugars from water and carbon dioxide (a gas in air), a process called **photosynthesis**. By contrast, **consumers** cannot make their own food. They get energy and nutrients by feeding on other organisms. Animals are consumers. So are decomposers, which feed on the wastes or remains of other organisms. The wastes and remains of consumers end up in the environment, where they serve as nutrients for producers. Said another way, nutrients cycle between producers and consumers.

FIGURE 1.4 Organisms sense and respond to conditions inside and outside of themselves. This baby orangutan is laughing in response to being tickled. Apes and humans make different sounds when being tickled, but the airflow patterns are so similar that we can say apes really do laugh.

© Dr. Marina Davila Ross, University of Portsmouth.

Energy, however, is not cycled. It flows from the environment, through organisms, and back to the environment. This flow maintains the organization of every living cell and body, and it also influences how individuals interact with one another and their environment. The energy flow is one-way, because with each transfer, some energy escapes as heat, and cells cannot use heat as an energy source. Thus, energy that enters the world of life eventually leaves it (Figure 1.3). We return to this topic in Chapter 5.

Energy flow through the world of life maintains the organization of every living cell and body.

› Organisms Sense and Respond to Change Living things detect and respond to conditions both inside and outside of themselves (Figure 1.4). As an example, after you eat, the sugars from your meal enter your bloodstream. The added sugars set in motion a series of events that causes cells throughout the body to take up sugar faster, so the sugar level in your blood quickly falls. This response keeps your blood sugar level within a certain range, which in turn helps keep your cells alive and your body functioning.

The fluid portion of your blood is a component of your internal environment, which is all of the body fluids outside of cells. Unless that internal environment is kept within certain ranges of composition, temperature, and other conditions, your body cells will die. By sensing and adjusting to change, you and all other organisms keep conditions in the internal environment within a range that favors survival. **Homeostasis** is the name for this process, and it is a defining feature of life.

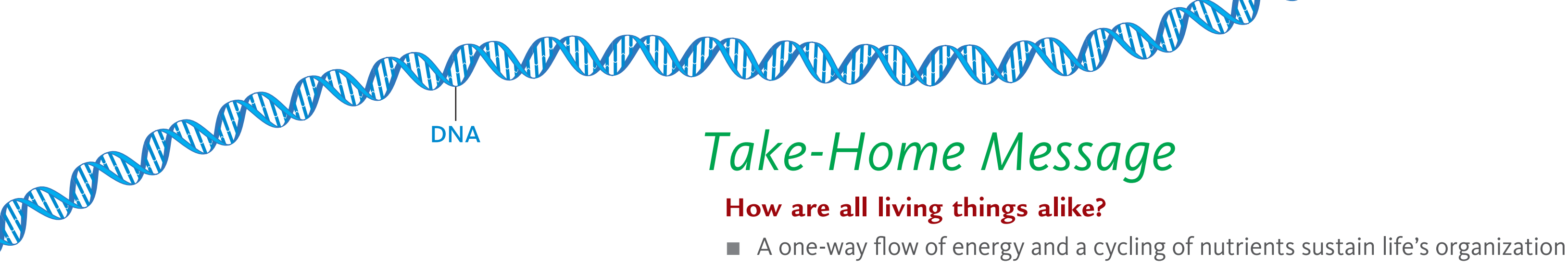
› Organisms Grow and Reproduce With little variation, the same types of molecules perform the same basic functions in every organism. For example, information encoded in an organism's **DNA** (deoxyribonucleic acid) guides the ongoing metabolic activities that sustain the individual through its lifetime. Such activities include **development**: the process by which the first cell of a new individual becomes a multicelled adult; **growth**: increases in cell number, size, and volume; and **reproduction**: processes by which individuals produce offspring.

Individuals of every natural population are alike in certain aspects of their body form and behavior because their DNA is very similar: Orangutans look like orangutans and not like caterpillars because they inherited orangutan DNA,

consumer Organism that gets energy and nutrients by feeding on tissues, wastes, or remains of other organisms.
development Process by which the first cell of a new individual becomes a multicelled adult.
DNA Deoxyribonucleic acid; carries hereditary information that guides development and functioning.
growth In multicelled species, an increase in the number, size, and volume of cells.
homeostasis Process in which an organism keeps its internal conditions within tolerable ranges by sensing and responding to change.
nutrient Substance that an organism needs for growth and survival but cannot make for itself.
photosynthesis Process by which producers use light energy to make sugars from carbon dioxide and water.
producer Organism that makes its own food using energy and nonbiological raw materials from the environment.
reproduction Process by which parents produce offspring.

which differs from caterpillar DNA in the information it carries. **Inheritance** refers to the transmission of DNA to offspring. All organisms receive their DNA from one or more parents.

DNA is the basis of similarities in form and function among organisms. However, the details of DNA molecules differ, and herein lies the source of life's diversity. Small variations in the details of DNA's structure give rise to differences among individuals, and also among types of organisms. As you will see in later chapters, these differences are the raw material of evolutionary processes.



Take-Home Message

How are all living things alike?

- A one-way flow of energy and a cycling of nutrients sustain life's organization.
- Organisms sense and respond to conditions inside and outside themselves. They make adjustments that keep conditions in their internal environment within a range that favors cell survival, a process called homeostasis.
- Organisms develop and function based on information encoded in their DNA, which they inherit from their parents. DNA is the basis of similarities and differences in form and function.

1.4 How Living Things Differ

Living things differ tremendously in their observable characteristics, or traits. Various classification schemes help us organize what we understand about the scope of this variation, which we call Earth's **biodiversity**.

For example, organisms can be grouped on the basis of whether they have a **nucleus**, which is a sac with two membranes that encloses and protects a cell's DNA. **Bacteria** (singular, bacterium) and **archaea** (singular, archaeon) are two types of organisms whose DNA is *not* contained within a nucleus. All bacteria and archaea are single-celled, which means individual organisms consist of one cell (Figure 1.5). Collectively, they are the most diverse representatives of life. Different kinds are producers or consumers in nearly all parts of the biosphere. Some inhabit such extreme environments as frozen desert rocks, boiling sulfurous lakes, and nuclear reactor waste. The first cells on Earth may have faced similarly hostile environments.

Traditionally, organisms without a nucleus have been called **prokaryotes**, but this designation is an informal one. Despite their similar appearance, bacteria and archaea are less related to one another than we had once thought. Archaea are actually more closely related to **eukaryotes**, organisms whose DNA is contained within a nucleus. Some eukaryotes live as individual cells; others are multicelled (Figure 1.6). Eukaryotic cells are typically larger and more complex than bacteria or archaea.

Structurally, **protists** are the simplest eukaryotes. As a group they vary a great deal, from single-celled consumers to giant, multicelled producers.

Fungi (singular, fungus) are eukaryotic consumers that secrete substances to break down food externally. Their cells then absorb nutrients released from the

A **Bacteria** are the most numerous organisms on Earth. *Left*, a bacterium with a row of iron crystals that acts like a tiny compass; *right*, spiral cyanobacteria.

B **Archaea** may resemble bacteria, but they are more closely related to eukaryotes. These are two types of archaea from a hydrothermal vent on the seafloor.

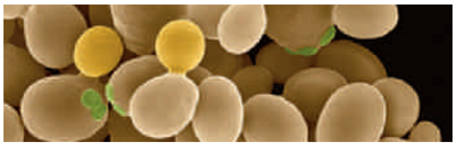
FIGURE 1.5 **Animated!** A few representative bacteria and archaea.

Credits: (a) left, Dr. Richard Frankel; right, © Susan Barnes; (b) © Dr. Harald Huber, Dr. Michael Hohn, Prof. Dr. K.O. Stetter, University of Regensburg, Germany.


Protists are a group of extremely diverse eukaryotes that range from giant multicelled seaweeds to microscopic single cells. Biologists now view "protists" as a collection of major groups, some only distantly related to others.



Animals are multicelled eukaryotes that ingest tissues or juices of other organisms. All actively move about during at least part of their life.

Fungi are eukaryotic consumers that secrete substances to break down food externally. Most are multicelled.


Plants are multicelled eukaryotes, most of which are photosynthetic. Nearly all have roots, stems, and leaves. Plants are the primary producers in land ecosystems.

FIGURE 1.6 Animated! A few representative eukaryotes.

Credits: clockwise from top left, © Lewis Trusty/ Animals Animals; Courtesy of Allen W. H. Bé andDavid A. Caron; © Tom & Pat Leeson, Ardea London Ltd.; © Martin Zimmerman, *Science*, 1961, 133:73-79, © AAAS.; © Pixtal/ SuperStock; Lady Bird Johnson Wildflower Center; © John Lotter Gurling/ Tom Stack & Associates; © Dr. Dennis Kunkel/ Visuals Unlimited; JupiterImages Corporation.

breakdown. Many fungi are decomposers. Individuals of most types, including those that form mushrooms, are multicellular. Yeasts and some other fungi are single-celled.

Plants are multicelled eukaryotes that live mainly on land. Nearly all are photosynthetic producers. Besides feeding themselves, plants and other photosynthesizers serve as food for most of the other organisms in the biosphere.

Animals are multicelled consumers that ingest tissues or juices of other organisms. Herbivores graze, carnivores eat meat, scavengers eat remains of other organisms, parasites withdraw nutrients from the tissues of a host, and so on. Animals develop through a series of stages that lead to the adult form. All kinds actively move about during at least part of their lives.

Take-Home Message

How do living things differ from one another?

- Organisms differ in their details; they show tremendous variation in observable characteristics, or traits.
- We can divide Earth's biodiversity into broad groups based on traits such as having a nucleus or being multicellular.

animal Multicelled eukaryotic consumer that develops through a series of stages and moves about during part or all of its life.

archaeon Member of a group of single-celled organisms that lack a nucleus but are more closely related to eukaryotes than to bacteria.

bacterium Member of the most diverse and well-known group of single-celled organisms that lack a nucleus.

biodiversity Scope of variation among living organisms.

eukaryote Organism whose cells characteristically have a nucleus.

fungus Single-celled or multicelled eukaryotic consumer that breaks down material outside itself, then absorbs nutrients released from the breakdown.

inheritance Transmission of DNA to offspring.

nucleus Double-membraned sac that encloses a cell's DNA.

plant A multicelled, typically photosynthetic eukaryote.

prokaryote Single-celled organism without a nucleus.

protist Member of a diverse group of simple eukaryotes.

domain	Eukarya	Eukarya	Eukarya	Eukarya	Eukarya
kingdom	Plantae	Plantae	Plantae	Plantae	Plantae
phylum	Magnoliophyta	Magnoliophyta	Magnoliophyta	Magnoliophyta	Magnoliophyta
class	Magnoliopsida	Magnoliopsida	Magnoliopsida	Magnoliopsida	Magnoliopsida
order	Apiales	Rosales	Rosales	Rosales	Rosales
family	Apiaceae	Cannabaceae	Rosaceae	Rosaceae	Rosaceae
genus	*Daucus*	*Cannabis*	*Malus*	*Rosa*	*Rosa*
species	*carota*	*sativa*	*domestica*	*acicularis*	*canina*
common name	wild carrot	marijuana	apple	prickly rose	dog rose

FIGURE 1.7 Taxonomic classification of five species that are related at different levels. Each species has been assigned to ever more inclusive groups, or taxa: in this case, from genus to domain.

Figure It Out: Which of the plants shown here are in the same order?

Answer: Marijuana, apple, prickly rose, and dog rose

Credits: © xania.g, www.flickr.com/photos/52287712@N00; © kymkemp.com; Nigel Cattlin/ Visuals Unlimited, Inc.; Courtesy of Melissa S Green, www.flickr.com/photos/henkimaa; © Grodana Sarkotic.

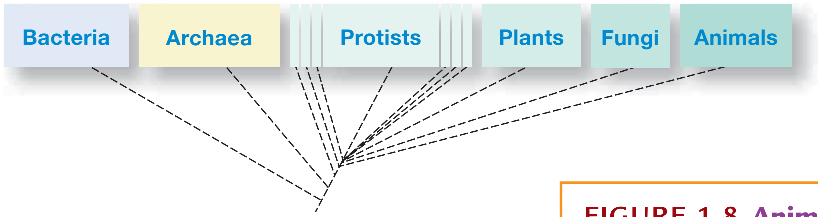
1.5 What Is a "Species"?

Each time we discover a new **species**, or unique kind of organism, we name it. **Taxonomy**, a system of naming and classifying species, began thousands of years ago, but naming species in a consistent way did not become a priority until the eighteenth century. At the time, European explorers who were just discovering the scope of life's diversity started having more and more trouble communicating with one another because species often had multiple names. For example, the dog rose (a plant native to Europe, Africa, and Asia) was alternately known as briar rose, witch's briar, herb patience, sweet briar, wild briar, dog briar, dog berry, briar hip, eglantine gall, hep tree, hip fruit, hip rose, hip tree, hop fruit, and hogseed—and those are only the English names! Species often had multiple scientific names too, in Latin that was descriptive but often cumbersome. The scientific name of the dog rose was *Rosa sylvestris inodora seu canina* (odorless woodland dog rose), and also *Rosa sylvestris alba cum rubore, folio glabro* (pinkish white woodland rose with smooth leaves).

An eighteenth-century naturalist, Carolus Linnaeus, standardized a two-part naming system that we still use. By the Linnaean system, every species is given a unique two-part scientific name. The first part is the name of the **genus** (plural, genera), a group of species that share a unique set of features. The second part is the specific epithet. Together, the genus name and the specific epithet designate one species. Thus, the dog rose now has one official name, *Rosa canina*, that is recognized worldwide.

Genus and species names are always italicized. For example, *Panthera* is a genus of big cats. Lions belong to the species *Panthera leo*. Tigers belong to a different species in the same genus (*Panthera tigris*), and so do leopards (*P. pardus*). Note how the genus name may be abbreviated after it has been spelled out once.

› A Rose by Any Other Name The individuals of a species share a unique set of inherited traits. For example, giraffes normally have very long necks, brown spots on white coats, and so on. These are morphological (structural) traits. Individuals of a species also share biochemical traits (they make and



A six-kingdom classification system in which all eukaryotes have been sorted into one of four kingdoms: protists, plants, fungi, and animals. The protist kingdom includes the most ancient multi-celled and all single-celled eukaryotes.

FIGURE 1.8 Animated! Two ways to see the big picture of life. Lines in such diagrams indicate evolutionary connections.

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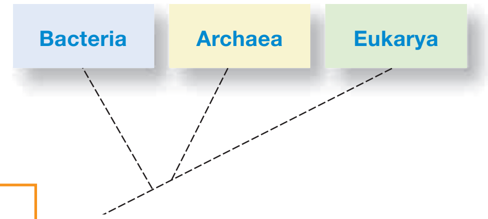

A three-domain system sorts all life into three domains: Bacteria, Archaea, and Eukarya. The Eukarya domain includes all eukaryotes.

use the same molecules) and behavioral traits (they respond the same way to certain stimuli, as when hungry giraffes feed on tree leaves).

We can rank species into ever more inclusive categories based on some subset of traits it shares with other species. Each rank, or **taxon** (plural, taxa), is a group of organisms that share a unique set of traits. Each category above species—genus, family, order, class, phylum (plural, phyla), kingdom, and domain—consists of a group of the next lower taxon (Figure 1.7). Using this system, we can sort all life into a few categories (Figure 1.8).

It is easy to tell that orangutans and tigers are different species because they look very different. Distinguishing species that share a more recent ancestor may be much more challenging (Figure 1.9). In addition, traits shared by members of a species often vary a bit among individuals, such as eye color does among people. How do we decide if similar-looking organisms belong to different species or not? The short answer is that we rely on whatever information we have. Early naturalists studied anatomy and distribution—essentially the only methods available at the time—so species were named and classified according to what they looked like and where they lived. Today's biologists are able to compare traits that the early naturalists did not even know about, including biochemical ones such as DNA sequence. For example, Linnaeus grouped plants by the number and arrangement of reproductive parts, a scheme that resulted in odd pairings such as castor-oil plants with pine trees. Having more information today, we place these plants in separate phyla.

Evolutionary biologist Ernst Mayr defined a species as one or more groups of individuals that potentially can interbreed, produce fertile offspring, and do not interbreed with other groups. This "biological species concept" is useful in many cases, but it is not universally applicable. For example, we may never know whether separate populations could interbreed even if they did get together. As another example, populations often continue to interbreed even as they diverge, so the exact moment at which two populations become two species is often impossible to pinpoint. We return to speciation and how it occurs in Chapter 12, but for now it is important to remember that a "species" is a convenient but artificial construct of the human mind.

FIGURE 1.9 Four butterflies, two species: Which are which?

The top row shows two forms of the species *Heliconius melpomene*; the bottom row, two forms of *Heliconius erato*. *H. melpomene* and *H. erato* never cross-breed. Their alternate but similar patterns of coloration evolved as a shared warning signal to predatory birds that these butterflies taste terrible.

© 2006 Axel Meyer, "Repeating Patterns of Mimicry." *PLoS Biology* Vol. 4, No. 10, e341 doi:10.1371/journal.pbio.0040341. Used with Permission.

Take-Home Message

How do we keep track of all the species we know about?

- Each species has a unique, two-part scientific name.
- Classification systems group species on the basis of shared traits.

genus A group of species that share a unique set of traits.
species Unique type of organism.
taxon Group of organisms that share a unique set of traits.
taxonomy The science of naming and classifying species.

A Improving the efficiency of biofuel production from agricultural wastes.

B Studying benefits of weedy buffer zones on farms.

C Discovering medically active natural products in new species of marine animals.

FIGURE 1.10 Examples of research in the field of biology.

Credits: (a) © Roger W. Winstead, NC State University; (b) Photo by Scott Bauer, USDA/ ARS; (c) Courtesy of Susanna López-Legentil; (d) Volker Steger/ Photo Researchers, Inc.; (e) Cape Verde National Institute of Meteorology and Geophysics and the U.S. Geological Survey; (f) National Cancer Institute.

1.6 The Science of Nature

Most of us assume that we do our own thinking—but do we, really? You might be surprised to find out just how often we let others think for us. Consider how a school's job, which is to impart as much information as possible to students, meshes perfectly with a student's job, which is to acquire as much knowledge as possible. In the resulting rapid-fire transfer of information, it can be easy to forget about the quality of what is being transferred. Any time you accept information without question, you allow someone else to think for you.

How do my own biases affect what I'm learning?

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› Thinking About Thinking **Critical thinking** is the deliberate process of judging the quality of information before accepting it. "Critical" comes from the Greek *kriticos* (discerning judgment). When you think this way, you move beyond the content of information to consider supporting evidence, bias, and alternative interpretations. How does the busy student manage it? Critical thinking does not necessarily require extra time, just a bit of extra awareness. There are many ways to do it. For example, you might ask yourself some of the following questions while you are learning something new:

What message am I being asked to accept?

Is the message based on facts or opinion?

Is there a different way to interpret the facts?

What biases might the presenter have?

How do my own biases affect what I'm learning?

Asking yourself questions like these is a way of being conscious about learning. It can help you decide whether to allow new information to guide your beliefs and actions.

› How Science Works Critical thinking is a big part of **science**, the systematic study of the observable world and how it works. A scientific line of inquiry usually begins with curiosity about something observable, such as a noticeable decrease in the number of birds in a particular area. Typically, a scientist will read about what others have discovered before making a **hypothesis**, which is a testable explanation for a natural phenomenon. An example of a

D Sequencing the human genome.

E Looking for fungi traveling in atmospheric dust.

F Devising a vaccine for cancer.

hypothesis would be, "In my neighborhood, the number of birds is decreasing because the number of cats is increasing." A **prediction**, or statement of some condition that should exist if the hypothesis is correct, comes next. Making predictions is called the if–then process, in which the "if" part is the hypothesis, and the "then" part is the prediction.

Next, a scientist will devise ways to test a prediction. Tests may be performed on a **model**, or analogous system, if working with an object or event directly is not possible. For example, animal diseases are often used as models of similar human diseases. Careful observations are one way to test predictions that flow from a hypothesis. So are **experiments**: tests designed to support or falsify a prediction. A typical experiment explores a cause-and-effect relationship.

Researchers use variables to investigate cause-and-effect relationships. **Variables** are characteristics or events that differ among individuals or over time. Biological systems are complex, which means they involve many variables that are difficult to study separately. Thus, biology researchers often test two groups of individuals simultaneously. An **experimental group** is a set of individuals that have a certain characteristic or receive a certain treatment. This group is tested side by side with a **control group**, which is identical to the experimental group except for one variable: the characteristic or the treatment being tested. Any differences in experimental results between the two groups should be an effect of changing the variable.

Test results—**data**—that are consistent with the prediction are evidence in support of the hypothesis. Data inconsistent with the prediction are evidence that the hypothesis is flawed and should be revised.

A necessary part of science is reporting one's results and conclusions in a standard way, such as in a peer-reviewed journal article. The communication gives other scientists an opportunity to evaluate the information for themselves, both by checking the conclusions drawn and by repeating the experiments.

Forming a hypothesis based on observation, and then systematically testing it, evaluating it, and sharing the results are collectively called the **scientific method** (Table 1.1).

There are many different ways to do research, particularly in biology (Figure 1.10). Some biologists do surveys; they observe without making hypotheses. Some make hypotheses and leave the experimentation to others. However,

Table 1.1 The Scientific Method
1. Observe some aspect of nature.
2. Think of an explanation for your observation (in other words, form a hypothesis).
3. Test the hypothesis. a. Make a prediction based on the hypothesis. b. Test the prediction using experiments or surveys. c. Analyze the results of the tests (data).
4. Decide whether the results of the tests support your hypothesis or not (form a conclusion).
5. Report your results to the scientific community.

control group In an experiment, a group of individuals who are not exposed to the variable being tested.
critical thinking Judging information before accepting it.
data Values or other factual information obtained from experiments or surveys.
experiment A test designed to support or falsify a prediction.
experimental group In an experiment, a group of individuals who are exposed to a variable.
hypothesis Testable explanation of a natural phenomenon.
model Analogous system used for testing hypotheses.
prediction Statement, based on a hypothesis, about a condition that should exist if the hypothesis is correct.
science Systematic study of the observable world.
scientific method Systematically making, testing, and evaluating hypotheses.
variable A characteristic or event that differs among individuals or over time.

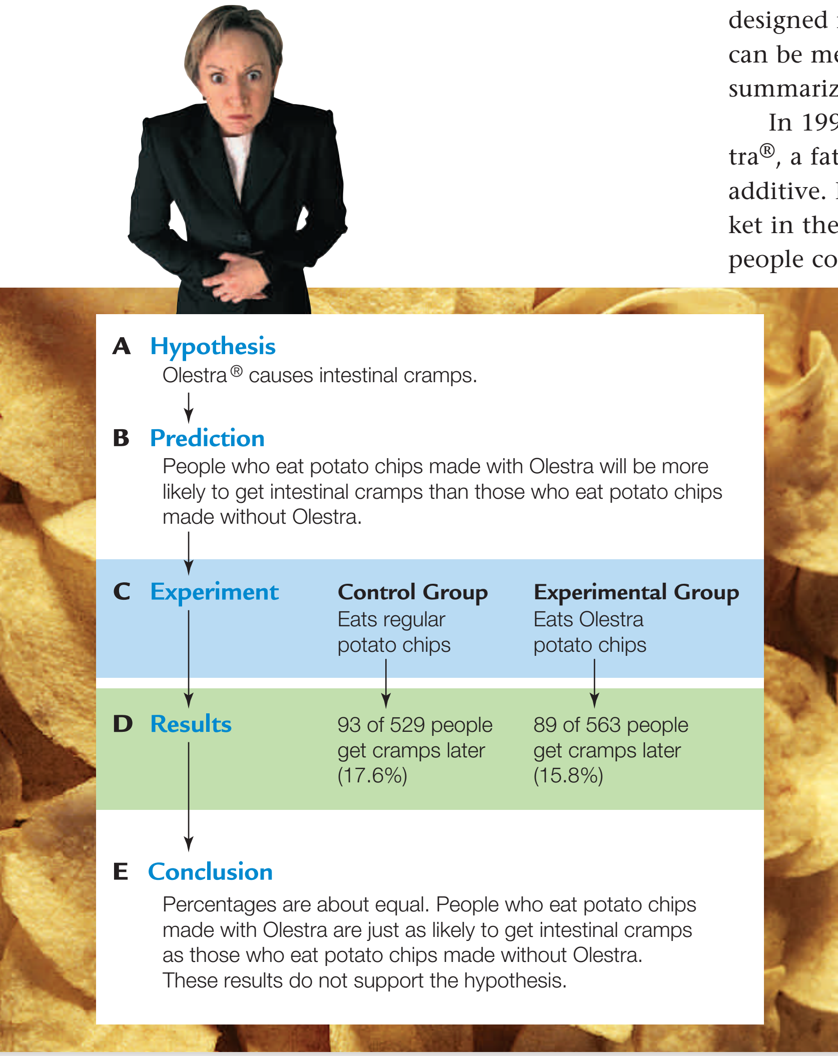


FIGURE 1.11 The steps in a scientific experiment to determine if Olestra causes cramps. A report of this study was published in the *Journal of the American Medical Association* in January of 1998.

Credits: top, © Bob Jacobson/ Corbis; ground, © SuperStock; art, © Cengage Learning.

despite a broad range of subject matter, scientific experiments are typically designed in a consistent way, so the effects of changing one variable at a time can be measured. To give you a sense of how biology experiments work, we summarize two published studies here.

In 1996 the U.S. Food and Drug Administration (the FDA) approved Olestra®, a fat replacement manufactured from sugar and vegetable oil, as a food additive. Potato chips were the first Olestra-containing food product on the market in the United States. Controversy about the food additive soon raged. Many people complained of intestinal problems after eating the chips and thought that the Olestra was at fault. Two years later, researchers at Johns Hopkins University School of Medicine designed an experiment to test the hypothesis that this food additive causes cramps.

The researchers predicted *if* Olestra causes cramps, *then* people who eat Olestra will be more likely to get cramps than people who do not. To test their prediction, they used a Chicago theater as a "laboratory." They asked 1,100 people between the ages of thirteen and thirty-eight to watch a movie and eat potato chips. Each person got an unmarked bag that contained 13 ounces of chips. In this experiment, individuals who ate Olestra-containing potato chips constituted the experimental group, and individuals who ate regular chips were the control group. The variable was the presence or absence of Olestra in the chips.

A few days after the experiment was finished, the researchers contacted all of the people and collected any reports of post-movie gastrointestinal problems. Of 563 people making up the experimental group, 89 (15.8 percent) complained about cramps. However, so did 93 of the 529 people (17.6 percent) making up the control group—who had eaten the regular chips. In this experiment, people were about as likely to get cramps whether or not they ate chips made with Olestra. These results did not support the prediction, so the researchers concluded that eating Olestra does not cause cramps (Figure 1.11).

A different experiment that took place in 2005 investigated whether certain behaviors of peacock butterflies defend these insects from predation by birds. The researchers performing this experiment began with two observations. First, when a peacock butterfly rests, it folds its wings, so only the dark underside shows (Figure 1.12**A**). Second, when a butterfly sees a predator approaching, it repeatedly flicks its wings open, while also moving them in a way that produces a hissing sound and a series of clicks (Figure 1.12**B**).

The researchers were curious about why the peacock butterfly flicks its wings. After they reviewed earlier studies, they came up with two hypotheses that might explain the wing-flicking behavior:

1. Although wing-flicking probably attracts predatory birds, it also exposes brilliant spots that resemble owl eyes. Anything that looks like owl eyes is known to startle small, butterfly-eating birds, so exposing the wing spots might scare off predators.

2. The hissing and clicking sounds produced when the peacock butterfly moves its wings may be an additional defense that deters predatory birds.

The researchers then used their hypotheses to make the following predictions:

1. *If* peacock butterflies startle predatory birds by exposing their brilliant wing spots, *then* individuals with wing spots will be less likely to get eaten by predatory birds than those without wing spots.

A With wings folded, a resting peacock butterfly looks a bit like a dead leaf.

B When a bird approaches, a butterfly repeatedly flicks its wings open. This behavior exposes brilliant spots and also produces hissing and clicking sounds.

C Researchers tested whether peacock butterfly wing flicking and hissing reduce predation by blue tits.

FIGURE 1.12 Testing peacock butterfly defenses. Researchers painted out the spots of some butterflies, cut the sound-making part of the wings on others, and did both to a third group; then exposed each butterfly to a hungry blue tit. Results are listed *right*, in Table 1.2.

Figure It Out: What percentage of butterflies with no spots and no sound survived the test? *Answer: 20 percent*

Credits: (a) © Matt Rowlings, www.eurobutterflies.com; (b) © Adrian Vallin; (c) © Antje Schulte.

Table 1.2 Results of Peacock Butterfly Experiment*

Wing Spots	Wing Sound	Total Number of Butterflies	Number Eaten	Number Survived
Spots	Sound	9	0	9 (100%)
No spots	Sound	10	5	5 (50%)
Spots	No sound	8	0	8 (100%)
No spots	No sound	10	8	2 (20%)

* *Proceedings of the Royal Society of London, Series B* (2005) 272: 1203–1207.

2. *If* peacock butterfly sounds deter predatory birds, *then* sound-producing individuals will be less likely to get eaten by predatory birds than silent individuals.

The next step was the experiment. The researchers used a marker to paint the wing spots of some butterflies black, and scissors to cut off the sound-making part of the wings of others. A third group had both treatments: their wing spots were painted and cut. The researchers then put each butterfly into a large cage with a hungry blue tit (Figure 1.12**C**) and watched the pair for thirty minutes.

Table 1.2 lists the results of the experiment. All of the butterflies with unmodified wing spots survived, regardless of whether they made sounds. By contrast, only half of the butterflies that had spots painted out but could make sounds survived. Most of the silenced butterflies with painted-out spots were eaten quickly. The test results confirmed both predictions, so they support the hypotheses. Predatory birds are indeed deterred by peacock butterfly sounds, and even more so by wing spots.

Take-Home Message

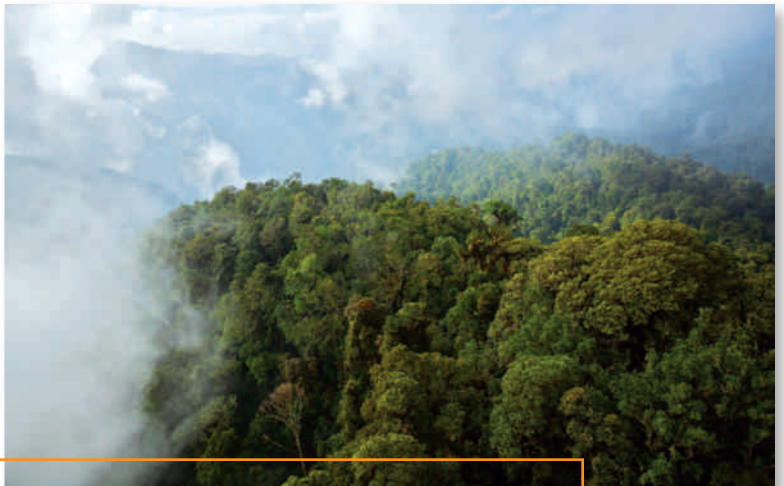
What is science?

- The scientific method consists of making, testing, and evaluating hypotheses, and sharing results. It is a way of critical thinking, or systematically judging the quality of information before allowing it to guide one's beliefs and actions.
- Experiments systematically measure the effect on a natural system of changing a variable.
- Natural processes are often influenced by many interacting variables. Experiments help researchers unravel causes of complex natural processes by focusing on the effects of changing a single variable.

1.7 Analyzing Experimental Results

› Sampling Error Researchers can rarely observe all individuals of a group. For example, the explorers you read about in Section 1.1 did not—and could not—survey every uninhabited part of the Foja Mountains. The cloud forest alone cloaks more than 2 million acres (Figure 1.13**A**), so surveying all of it would take unrealistic amounts of time and effort. Besides, tromping about even in a small area can damage delicate forest ecosystems.

Given such limitations, researchers often look at subsets of an area, a population, or an event. They test or survey the subset, then use the results to make generalizations. However, generalizing from a subset is risky because the subset may not be representative of the whole. Consider the golden-mantled tree kangaroo, an animal that was first discovered in 1993 on a single forested mountaintop in New Guinea. For more than a decade, the species was never seen outside of that habitat, which is getting smaller every year because of human activities. Thus, the golden-mantled tree kangaroo was considered to be one of the most endangered animals on the planet. Then, in 2005, the New Guinea explorers discovered that this kangaroo species is fairly common in the Foja Mountain cloud forest (Figure 1.13**B**). As a result, biologists now believe its future is secure, at least for the time being.



A The cloud forest that covers about 2 million acres of New Guinea's Foja Mountains is extremely remote and difficult to access, even for natives of the region. The first major survey of this forest occurred in 2005.

B Kris Helgen holds a golden-mantled tree kangaroo he found during the 2005 Foja Mountains survey. This kangaroo species is extremely rare in other areas, so it was thought to be critically endangered prior to the expedition.

FIGURE 1.13 Example of how generalizing from a subset can lead to an incorrect conclusion. It is also an example of how science is self-correcting.

Credits: (a) Tim Laman/ National Geographic Stock; (b) © Bruce Beehler/ Conservation International.

Sampling error is a difference between results obtained from testing a subset of a group, and results from testing the whole group. Sampling error may be unavoidable, as illustrated by the example of the golden-mantled tree kangaroo. However, knowing how it can occur helps researchers design their experiments to minimize it. For example, sampling error can be a substantial problem with a small subset, so experimenters try to start with a relatively large sample, and they typically repeat their experiments (Figure 1.14).

To understand why such practices reduce the risk of sampling error, think about what happens each time you flip a coin. There are two possible outcomes: The coin lands heads up, or it lands tails up. Thus, the chance that the coin will land heads up is one in two (1/2), which is a proportion of 50 percent. However, when you flip a coin repeatedly, it often lands heads up, or tails up, several times in a row. With just 3 flips, the proportion of times that heads actually land up may not even be close to 50 percent. With 1,000 flips, the proportion of times that the coin lands heads up is likely to be near 50 percent.

In cases like flipping a coin, it is possible to calculate probability. **Probability** is the measure, expressed as a percentage, of the chance that a particular outcome will occur. That chance depends on the total number of possible outcomes. For instance, imagine that 10 million people enter a random drawing to win a car. There are 10 million possible outcomes, so each person has the same probability of winning the item: 1 in 10 million, or (a very improbable) 0.00001 percent.

Analysis of experimental data often includes calculations of probability. If a result is very unlikely to have occurred by chance alone, it is said to be **statistically significant**. In this context, the word "significant" does not refer to the result's importance. It means that a statistical analysis shows the result has a very low probability (typically, less than a 5 percent chance) of being skewed by sampling error. As you will see in the next section, every scientific result—even a statistically significant one—has a probability of being incorrect.

Variation in a set of data is typically shown as error bars on a graph. Error bars that measure variation around an average indicate precision—the data's closeness in values (Figure 1.15).

A Natalie, blindfolded, randomly plucks a jelly bean from a jar. The jar contains 120 green and 280 black jelly beans, so 30 percent of the jelly beans in the jar are green, and 70 percent are black.

B The jar is hidden from Natalie's view before she removes her blindfold. She sees one green jelly bean in her hand and assumes that the jar must hold only green jelly beans.

C Still blindfolded, Natalie randomly picks out 50 jelly beans from the jar. She ends up picking out 10 green and 40 black ones.

D The larger sample leads Natalie to assume that one-fifth of the jar's jelly beans are green (20 percent) and four-fifths are black (80 percent). This sample more closely approximates the jar's actual green-to-black ratio of 30 percent to 70 percent. The more times Natalie repeats the sampling, the greater the chance she has of guessing the actual ratio.

FIGURE 1.14 How sample size affects sampling error.

© Gary Head.

› Bias in Interpreting Results Experimenting with a single variable apart from all others is not often possible, particularly when studying humans. For example, remember that the people who participated in the Olestra experiment were chosen randomly, which means the study was not controlled for gender, age, weight, medications taken, and so on. Such variables may well have influenced the experiment's results.

Humans are by nature subjective, and scientists are no exception. Researchers risk interpreting their results in terms of what they want to find out. That is why they typically design experiments that will yield quantitative results, which are counts or some other data that can be measured or gathered objectively. Quantitative results minimize the potential for bias, and also give other scientists an opportunity to repeat the experiments and check the conclusions drawn from them. This last point gets us back to the role of critical thinking in science. Scientists expect one another to recognize and put aside bias in order to test hypotheses in ways that may prove them wrong. If a scientist does not, then others will, because exposing errors is just as useful as applauding insights. The scientific community consists of critically thinking people trying to poke holes in one another's ideas. Ideally, their collective efforts make science a self-correcting endeavor.

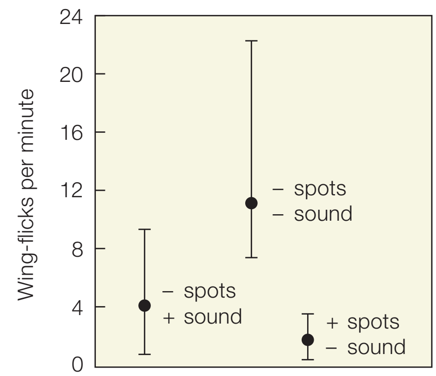


FIGURE 1.15 Example of error bars in a graph. This graph was adapted from the peacock butterfly research described in Section 1.6.
The researchers recorded the number of times each butterfly flicked its wings in response to an attack by a bird. The dots represent average frequency of wing flicking for each sample set of butterflies. The error bars that extend above and below the dots indicate the range of values—the sampling error.
Figure It Out: What was the fastest rate at which a butterfly with no spots or sound flicked its wings?

Answer: 22 times per minute

© Cengage Learning.

Take-Home Message

How do scientists avoid potential pitfalls of sampling error and bias when doing research?

- Researchers minimize sampling error by using large sample sizes and by repeating their experiments.
- A statistical analysis can show the probability that a result has occurred by chance alone.
- Science is a self-correcting process because it is carried out by a community of individuals who continually retest and recheck one another's ideas.

probability The chance that a particular outcome of an event will occur; depends on the total number of outcomes possible.

sampling error Difference between results derived from testing an entire group of events or individuals, and results derived from testing a subset of the group.

statistically significant Refers to a result that is statistically unlikely to have occurred by chance.

Table 1.3	Examples of Scientific Theories
Theory	**Main Premises**
Atomic theory	All substances consist of atoms.
Big bang	The universe originated with an explosion and continues to expand.
Cell theory	All organisms consist of one or more cells, the cell is the basic unit of life, and all cells arise from existing cells.
Evolution	Change occurs in the inherited traits of a population over generations.
Global warming	Human activities are causing Earth's average temperature to increase.
Plate tectonics	Earth's crust is cracked into pieces that move in relation to one another.

© Raymond Gehman/ Corbis.

1.8 The Nature of Science

Suppose a hypothesis stands even after years of tests. It is consistent with all data ever gathered, and it has helped us make successful predictions about other phenomena. When a hypothesis meets these criteria, it is considered to be a **scientific theory** (Table 1.3). To give an example, all observations to date have been consistent with the hypothesis that matter consists of atoms. Scientists no longer spend time testing this hypothesis for the compelling reason that, since we started looking 200 years ago, no one has discovered matter that consists of anything else. Thus, scientists use the hypothesis, now called atomic theory, to make other hypotheses about matter.

Scientific theories are our best objective descriptions of the natural world. However, they can never be proven absolutely, because to do so would necessitate testing under every possible circumstance. For example, in order to prove atomic theory, the atomic composition of all matter in the universe would have to be checked—an impossible task even if someone wanted to try.

Like all hypotheses, a scientific theory can be disproven by a single observation or result that is inconsistent with it. For example, if someone discovers a form of matter that does not consist of atoms, atomic theory would have to be revised. The potentially falsifiable nature of scientific theories means that science has a built-in system of checks and balances. A theory is revised until no one can prove it to be incorrect. The theory of evolution, which states that change occurs in a line of descent over time, still holds after a century of observations and testing. As with all other scientific theories, no one can be absolutely sure that it will hold under all possible conditions, but it has a very high probability of not being wrong. Few other theories have withstood as much scrutiny.

You may hear people apply the word "theory" to a speculative idea, as in the phrase "It's just a theory." This everyday usage of the word differs from the way it is used in science. Speculation is an opinion, belief, or personal conviction that is not necessarily supported by evidence. A scientific theory is different. By definition, a scientific theory is supported by a large body of evidence, and it is consistent with all known facts.

A scientific theory also differs from a **law of nature**, which describes a phenomenon that has been observed to occur in every circumstance without fail, but for which we do not have a complete scientific explanation. The laws of thermodynamics, which describe energy, are examples. We understand *how* energy behaves, but not exactly *why* it behaves the way it does.

law of nature Generalization that describes a consistent natural phenomenon that has an incomplete scientific explanation.

scientific theory Hypothesis that has not been disproven after many years of rigorous testing.

› The Limits of Science Science helps us be objective about our observations in part because of its limitations. For example, science does not address many questions, such as "Why do I exist?" Answers to such questions can only come from within as an integration of the personal experiences and mental connections that shape our consciousness. This is not to say subjective answers have no value, because no human society can function for long unless its individuals share standards for making judgments, even if they are subjective. Moral, aesthetic, and philosophical standards vary from one society to the next, but all help people decide what is important and good. All give meaning to our lives.

Neither does science address the supernatural, or anything that is "beyond nature." Science neither assumes nor denies that supernatural phenomena occur, but scientists often cause controversy when they discover a natural explanation for something that was thought to have none. Such controversy often arises when a society's moral standards are interwoven with its understanding of nature. For example, Nicolaus Copernicus proposed in 1540 that Earth orbits the sun. Today that idea is generally accepted, but the prevailing belief system had Earth as the immovable center of the universe. In 1610, astronomer Galileo Galilei published evidence for the Copernican model of the solar system, an act that resulted in his imprisonment. He was publicly forced to recant his work, spent the rest of his life under house arrest, and was never allowed to publish again.

As Galileo's story illustrates, exploring a traditional view of the natural world from a scientific perspective is often misinterpreted as a violation of morality. As a group, scientists are no less moral than anyone else, but they follow a particular set of rules that do not necessarily apply to others: Their work concerns only the natural world, and their ideas must be testable by other scientists.

Science helps us communicate our experiences without bias. As such, it may be as close as we can get to a universal language. We are fairly sure, for example, that the laws of gravity apply everywhere in the universe. Intelligent beings on a distant planet would likely understand the concept of gravity. We might well use gravity or another scientific concept to communicate with them, or anyone, anywhere. The point of science, however, is not to communicate with aliens. It is to find common ground here on Earth.

Science helps us communicate our experiences without bias.

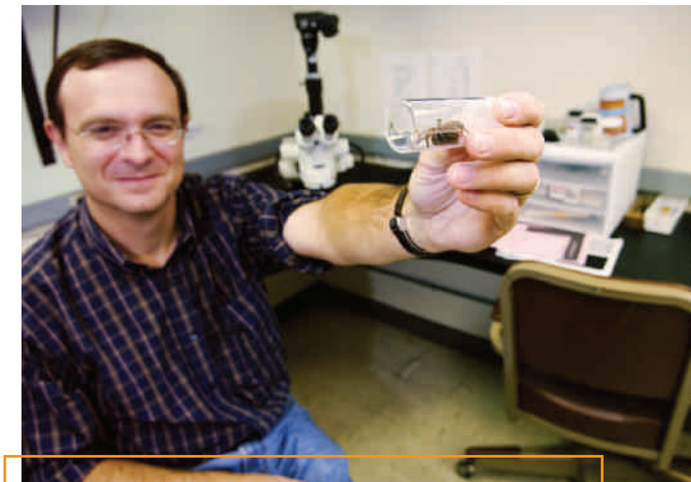


FIGURE 1.16 Dr. Jason Bond holds a new species of trapdoor spider he discovered living in sand dunes along California's central coast. Bond named the spider *Aptostichus stephencolberti*, after TV personality Stephen Colbert.

Courtesy East Carolina University.

Take-Home Message

What is a scientific theory?

- A scientific theory is a time-tested hypothesis that is consistent with all known facts. It is our most objective way of describing the natural world.

1.9 The Secret Life of Earth (revisited)

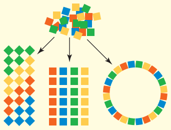
Earth hosts at least 100 million species. That number is only an estimate because we are still discovering them. For example, a mouse-sized opossum and a cat-sized rat turned up on a return trip to the Foja Mountains. Other recently discovered species include a leopard in Borneo; a wolf in Egypt; a dolphin in Australia; spiders in California (Figure 1.16); a giant crayfish in Tennessee; a rat-eating plant in the Philippines; and carnivorous sponges near Antarctica. Each new species discovered is a reminder that we do not yet know all of the organisms living on our own planet. We don't even know how many to look for. You can find information about the 1.8 million species we do know about in the Encyclopedia of Life, an online reference maintained by collaborative effort (www.eol.org).

Where You Are Going . . .

This book parallels nature's levels of organization, from atoms to the biosphere. Learning about the structure and function of atoms and molecules will prime you to understand how living cells work. Learning about processes that keep a single cell alive can help you understand how multicelled organisms survive. Knowing what it takes for organisms to survive can help you see why and how they interact with one another and their environment.

Summary

Section 1.1 **Biology** is the systematic study of life. We have encountered only a fraction of the organisms that live on Earth, in part because we have explored only a fraction of its inhabited regions.



Section 1.2 Biologists think about life at different levels of organization, with different properties emerging at successively higher levels. Life emerges at the level of the **cell**.

All matter consists of **atoms**, which combine as **molecules**. An **organism** consists of one or more cells. A **population** is a group of individuals of a species in a given area; a **community** is all populations of all species in a given area. An **ecosystem** is a community interacting with its environment. The **biosphere** includes all regions of Earth that hold life.

Section 1.3 Life has underlying unity in that all living things have similar characteristics:

(1) All organisms require energy and **nutrients** to sustain themselves. **Producers** harvest energy from the environment to make their own food by processes such as **photosynthesis**; **consumers** eat other organisms, or their wastes and remains.

(2) Organisms keep the conditions in their internal environment within ranges that their cells are able to tolerate—a process called **homeostasis**.

(3) **DNA** contains information that guides an organism's form and function, which include **development**, **growth**, and **reproduction**. The passage of DNA from parents to offspring is called **inheritance**.

Section 1.4 The many types of organisms that currently exist on Earth differ greatly in details of body form and function. **Biodiversity** is the sum of differences among living things. **Bacteria** and **archaea** are **prokaryotes**, single-celled organisms whose DNA is not contained within a **nucleus**. The DNA of single-celled or multicelled **eukaryotes** (**protists**, **plants**, **fungi**, and **animals**) is contained within a nucleus.

Section 1.5 Each **species** has a two-part name. The first part is the **genus** name. When combined with the specific epithet, it designates the particular species. With **taxonomy**, species are ranked into ever more inclusive **taxa** on the basis of shared traits.

Section 1.6 **Critical thinking**, the self-directed act of judging the quality of information as one learns, is an important part of **science**. Generally, a researcher observes something in nature, forms a **hypothesis** (testable explanation) for it, then makes a **prediction** about what might occur if the hypothesis is correct. Predictions are tested with observations, **experiments**, or both. Experiments typically are performed on an **experimental group** as compared with a **control group**, and sometimes on **models**. Conclusions are drawn from experimental results, or **data**. A hypothesis that is not consistent with data is modified or discarded. The **scientific method** consists of making, testing, and evaluating hypotheses, and sharing results.

Biological systems are usually influenced by many interacting **variables**. Research approaches differ, but experiments are typically designed in a consistent way. Experiments test whether and how changing a variable influences a system. A researcher changes a variable, then observes the effects of the change. This practice allows the researcher to study a cause-and-effect relationship in a complex natural system.

Section 1.7 A small sample size increases the potential for **sampling error** in experimental results. In such cases, a subset may be tested that is not representative of the whole. Researchers design experiments carefully to minimize sampling error and bias, and they use **probability** rules to check the **statistical significance** of their results. Scientists check and test one another's work, so science is a self-correcting process.

Section 1.8 Science helps us be objective about our observations because it is concerned only with testable ideas about observable aspects of nature. Opinion and belief have value in human culture, but they are not addressed by science. A **scientific theory** is a long-standing hypothesis that is useful for making predictions about other phenomena. It is our best way of describing reality. A **law of nature** describes something that occurs without fail, but our scientific explanation of why it occurs is incomplete.

Self-Quiz

Answers in Appendix I

1. _______ are fundamental building blocks of all matter.
   a. Cells c. Organisms
   b. Atoms d. Molecules

2. The smallest unit of life is the _______ .
   a. atom c. cell
   b. molecule d. organism

3. _______ is the transmission of DNA to offspring.
   a. Reproduction c. Homeostasis
   b. Development d. Inheritance

4. A process by which an organism produces offspring is called _______ .
   a. reproduction c. development
   b. inheritance d. homeostasis

5. Organisms require _______ and _______ to maintain themselves, grow, and reproduce.
   a. sunlight; energy c. nutrients; energy
   b. cells; raw materials d. DNA; cells

6. ________ move around for at least part of their life.
   a. Organisms c. Animals
   b. Plants d. Prokaryotes

7. By sensing and responding to change, organisms keep conditions in the internal environment within ranges that cells can tolerate. This process is called ________ .
   a. sampling error c. homeostasis
   b. development d. critical thinking

8. DNA ________ .
   a. guides functioning and development c. is transmitted from parents to offspring
   b. is the basis of traits d. all of the above

9. A butterfly is a(n) ________ (choose all that apply).
   a. organism e. consumer
   b. domain f. producer
   c. species g. prokaryote
   d. eukaryote h. trait

10. A bacterium is ________ (choose all that apply).
   a. an organism c. an animal
   b. single-celled d. a eukaryote

11. Bacteria, Archaea, and Eukarya are three ________ .
   a. organisms c. consumers
   b. domains d. producers

12. A control group is ________ .
   a. a set of individuals that have a characteristic under study or receive an experimental treatment
   b. the standard against which an experimental group is compared
   c. the experiment that gives conclusive results

13. Science addresses only that which is ________ .
   a. alive c. variable
   b. observable d. indisputable

14. Fifteen randomly selected students are found to be taller than 6 feet. The researchers concluded that the average height of a student is greater than 6 feet. This is an example of ________ .
   a. experimental error c. a subjective opinion
   b. sampling error d. experimental bias

15. Match the terms with the most suitable description.

_____ life	a. statement of what you expect to see if the hypothesis is correct
_____ probability	b. unique type of organism
_____ species	c. property that emerges at the level of the cell
_____ scientific theory	d. time-tested hypothesis
_____ hypothesis	e. testable explanation
_____ prediction	f. measure of chance
_____ producer	g. makes its own food

Critical Thinking

1. A person is declared to be dead upon the irreversible cessation of spontaneous body functions: brain activity, or blood circulation and respiration. However, only about 1% of a person's cells have to die in order for all of these things to happen. How can someone be dead when 99% of his or her cells are still alive?

2. Explain the difference between a one-celled organism and a single cell of a multicelled organism.

Digging Into Data

Peacock Butterfly Predator Defenses

The photographs *below* represent experimental and control groups used in the peacock butterfly experiment that was discussed in Section 1.7. See if you can identify the experimental groups, and match them up with the relevant control group(s). *Hint:* Identify which variable is being tested in each group (each variable has a control).


A Wing spots painted out


D Wings cut but not silenced


B Wing spots visible; wings silenced


E Wings painted but spots visible; wings cut but not silenced


C Wing spots painted out; wings silenced


F Wings painted but spots visible

Scientific Paper; Adrian Vallin, Sven Jakobsson, Johan Lind and Christer Wiklund, *Proc. R. Soc. B* (2005 272, 1203, 1207). Used with permission of The Royal Society and the author.

3. Why would you think twice about ordering from a restaurant menu that lists only the second part of the species name (not the genus) of its offerings? *Hint:* Look up *Ursus americanus, Ceanothus americanus, Bufo americanus, Homarus americanus, Lepus americanus,* and *Nicrophorus americanus*.

4. Once there was a highly intelligent turkey that had nothing to do but reflect on the world's regularities. Morning always started out with the sky turning light, followed by the master's footsteps, which were always followed by the appearance of food. Other things varied, but food always followed footsteps. The sequence of events was so predictable that it eventually became the basis of the turkey's theory about the goodness of the world. One morning, after more than 100 confirmations of the goodness theory, the turkey listened for the master's footsteps, heard them, and had its head chopped off.

Any scientific theory is modified or discarded upon discovery of contradictory evidence. The absence of absolute certainty has led some people to conclude that "facts are irrelevant because they can change." If that is so, should we stop doing scientific research? Why or why not?

5. In 2005, researcher Woo-suk Hwang reported that he had made immortal stem cells from human patients. His research was hailed as a breakthrough for people affected by degenerative diseases, because stem cells may be used to repair a person's own damaged tissues. Hwang published his results in a peer-reviewed journal. In 2006, the journal retracted his paper after other scientists discovered that Hwang's group had faked their data.

Does the incident show that results of scientific studies cannot be trusted? Or does it confirm the usefulness of a scientific approach, because other scientists discovered and exposed the fraud?