Chapter 1: Invitation to Biology Chapter Contents
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Chapter 1

Invitation to Biology

Chapter 1: Invitation to Biology Chapter Introduction
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Chapter Introduction

Near a tent serving as a makeshift laboratory, herpetologist Paul Oliver records the call of a frog on an expedition to New Guinea's Foja Mountains cloud forest.

Photograph by Tim Laman/National Geographic Creative.

Links to Earlier Concepts

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.

Key Concepts

The Science of Nature

We can understand life by studying it at many levels, starting with atoms that are components of all matter, and extending to interactions of organisms with their environment.

Life's Unity

All living things require ongoing inputs of energy and raw materials; all sense and respond to change; and all have DNA that guides their functioning.

Life's Diversity

Observable characteristics vary tremendously among organisms. Various classification systems help us keep track of the differences.

The Nature of Science

Carefully designing experiments helps researchers unravel cause-and-effect relationships in complex natural systems.

Limitations of Science

Science addresses only testable ideas about observable events and processes. It does not address anything untestable, such as beliefs and opinions.

Chapter 1: Invitation to Biology: 1.1 How Do Living Things Differ From Nonliving Things?
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.1 How Do Living Things Differ From Nonliving Things?

Life Is More Than the Sum of Its Parts

Biology (The scientific study of life.) is the study of life, past and present. What, exactly, is the property we call "life"? We may never actually 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.

Complex properties, including life, often emerge from the interactions of much simpler parts. To understand why, take a look at this drawing:

© Cengage Learning 2015

The property of "roundness" emerges when the parts are organized one way, but not other ways. Characteristics of a system that do not appear in any of the system's components are called **emergent properties** (A characteristic of a system that does not appear in any of the system's component parts.) . The idea that structures with emergent properties can be assembled from the same basic building blocks is a recurring theme in our world, and also in biology.

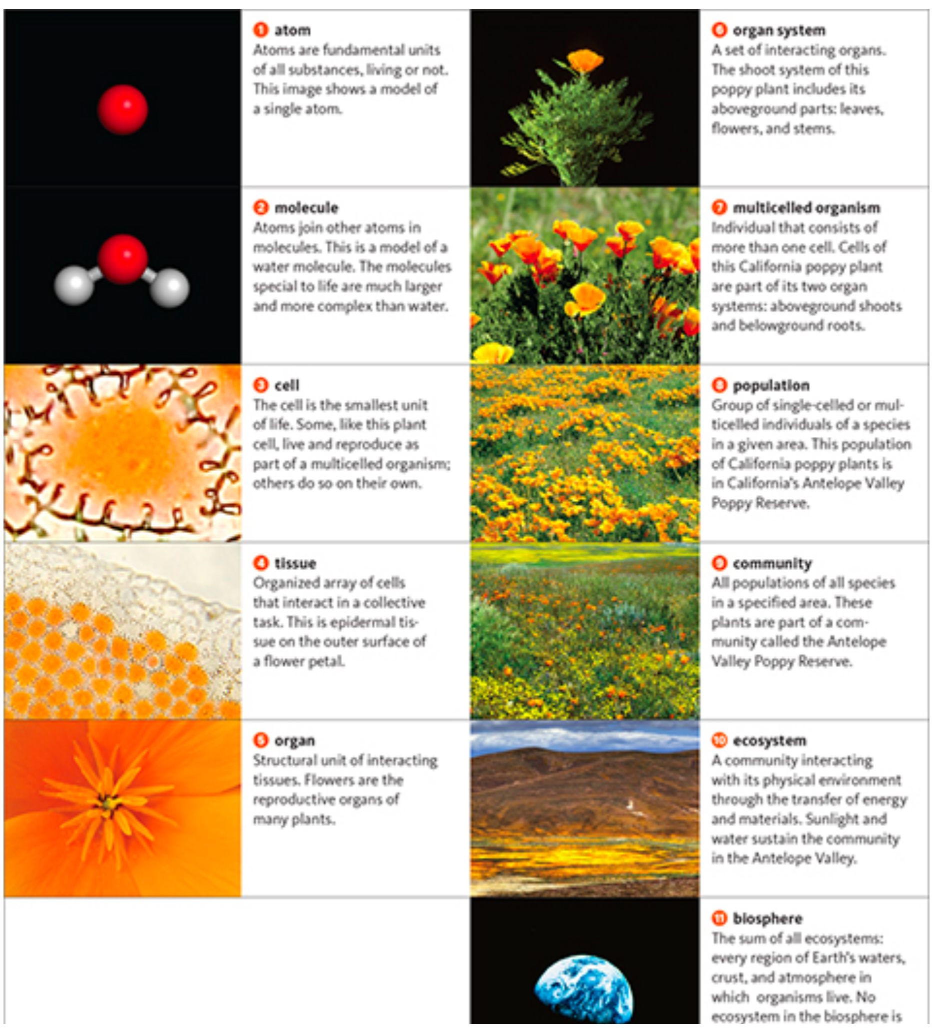
Chapter 1: Invitation to Biology Life's Organization
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Life's Organization

Through the work of biologists, we are beginning to understand an overall pattern in the way life is organized. We can look at life in successive levels of organization, with new emergent properties appearing at each level (Figure 1.1).

Figure 1.1

An overall pattern in the way life is organized. New emergent properties appear at each successive level.



1, 2: © Cengage Learning; 3, 4: © Umberto Salvagnin, www.flickr.com/photos/kaibara.; 5: California Poppy, © 2009, Christine M. Welter./ 6: Lady Bird Johnson Wildflower Center; 7: Michael Szoenyi/Science Source; 8: Photographers Choice RF/SuperStock; 9: © Sergei Krupnov, www.flickr.com/photos/7969319@N03; 10: © Mark Koberg Photography; 11: NASA.

Life's organization starts with interactions between atoms. **Atoms** (Fundamental building block of all matter.) are fundamental building blocks of all substances 1. Atoms join as **molecules** (An association of two or more atoms.) 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 emergent property of "life" appears at the next level, when many molecules of life become organized as a cell 3. A **cell** (Smallest unit of life.) is the smallest unit of life. Cells survive and reproduce themselves using energy, raw materials, and information in their DNA.

Some cells live and reproduce independently. Others do so as part of a multicelled organism. An **organism** (Individual that consists of one or more cells.) is an individual that consists of one or more cells. A poppy plant is an example of a multicelled organism 7.

In most multicelled organisms, cells are organized as tissues 4. A **tissue** (In multicelled organisms, specialized cells organized in a pattern that allows them to perform a collective function.) consists of specific types of cells organized in a particular pattern. The arrangement allows the cells to collectively perform a special function such as protection from injury (dermal tissue), movement (muscle tissue), and so on.

An **organ** (In multicelled organisms, a grouping of tissues engaged in a collective task.) is an organized array of tissues that collectively carry out a particular task or set of tasks 5. For example, a flower is an organ of reproduction in plants; a heart, an organ that pumps blood in animals. An **organ system** (In multicelled organisms, set of organs engaged in a collective task that keeps the body functioning properly.) is a set of organs and tissues that interact to keep the individual's body working properly 6. Examples of organ systems include the aboveground parts of a plant (the shoot system), and the heart and blood vessels of an animal (the circulatory system).

A **population** (Group of interbreeding individuals of the same species that live in a given area.) is a group of individuals of the same type, or species, living in a given area 8. An example would be all of the California poppies that are living in California's Antelope Valley Poppy Reserve. At the next level, a **community** (All populations of all species in a given area.) consists of all populations of all species in a given area. The Antelope Valley Reserve community includes California poppies and all other organisms—plants, animals, microorganisms, and so on—living in the reserve 9. Communities may be large or small, depending on the area defined.

The next level of organization is the **ecosystem** (A community interacting with its environment.), which is a community interacting with its environment 10. The most inclusive level, the **biosphere** (All regions of Earth where organisms live.), encompasses all regions of Earth's crust, waters, and atmosphere in which organisms live 11.

Take-Home Message 1.1

- Biologists study life by thinking about it at different levels of organization, with new emergent properties appearing at each successive level.
- 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.

Chapter 1: Invitation to Biology: 1.2 How Are All Living Things Alike?
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.2 How Are All Living Things Alike?

Even though we cannot precisely define "life," we can intuitively understand what it means because all living things share a set of key features. All require ongoing inputs of energy and raw materials; all sense and respond to change; and all pass DNA to offspring (Table 1.1).

Table 1.1

Three Key Features of Living Things

Requirement for energy and nutrients	Ongoing inputs of energy and nutrients sustain life.
Homeostasis	Each living thing has the capacity to sense and respond to change.
Use of DNA as hereditary material	DNA is passed to offspring during reproduction.

Chapter 1: Invitation to Biology Organisms Require Energy and Nutrients
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

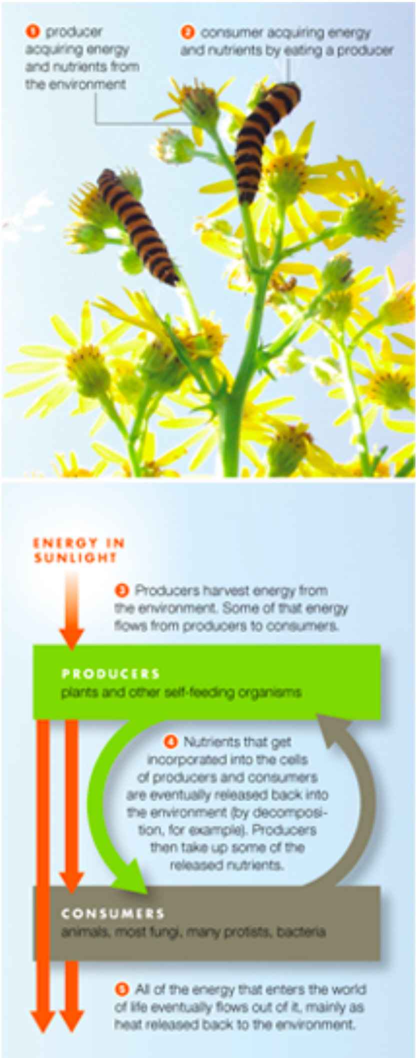
Organisms Require Energy and Nutrients

Not all living things eat, but all require energy and nutrients on an ongoing basis. Both are essential to maintain the functioning of individual organisms and the organization of life. A **nutrient** (Substance that an organism needs for growth and survival but cannot make for itself.) 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 (Figure 1.2). However, the source of energy and the type of nutrients required differ among organisms. These differences allow us to classify all living things into two categories: producers and consumers. **Producers** (Organism that makes its own food using energy and nonbiological raw materials from the environment.) make their own food using energy and simple raw materials they get from nonbiological sources 1. 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** (Process by which producers use light energy to make sugars from carbon dioxide and water.) . By contrast, **consumers** (Organism that gets energy and nutrients by feeding on tissues, wastes, or remains of other organisms.) cannot make their own food. They get energy and nutrients by feeding on other organisms 2. Animals are consumers. So are decomposers, which feed on the wastes or remains of other organisms. The leftovers from consumers' meals end up in the environment, where they serve as nutrients for producers. Said another way, nutrients cycle between producers and consumers.

Figure 1.2

The one-way flow of energy and cycling of materials through the world of life.



top, © Victoria Pinder, www.flickr.com/photos/vixstarplus; bottom, © Cengage Learning 2015

Unlike nutrients, energy is not cycled. It flows through the world of life in one direction: from the environment 3, through organisms 4, and back to the environment 5. 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 (we return to this topic in Chapter 5).

Chapter 1: Invitation to Biology Organisms Sense and Respond to Change
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Organisms Sense and Respond to Change

An organism cannot survive for very long in a changing environment unless it adapts to the changes. Thus, every living thing has the ability to sense and respond to change both inside and outside of itself (Figure 1.3). For 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.

Figure 1.3

Living things sense and respond to their environment. 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.

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 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** (Process in which an organism keeps its internal conditions within tolerable ranges by sensing and responding to change.) is the name for this process, and it is one of the defining features of life.

Chapter 1: Invitation to Biology Organisms Use DNA
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Organisms Use DNA

With little variation, the same types of molecules perform the same basic functions in every organism. For example, information in an organism's **DNA** (Deoxyribonucleic acid; carries hereditary information that guides development and other activities.) (deoxyribonucleic acid) guides ongoing functions that sustain the individual through its lifetime. Such functions include **development** (Multistep process by which the first cell of a new multicelled organism gives rise to an adult.) : the process by which the first cell of a new individual gives rise to a multicelled adult; **growth** (In multicelled species, an increase in the number, size, and volume of cells.) : increases in cell number, size, and volume; and **reproduction** (Processes by which parents produce offspring.) : 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, which differs from caterpillar DNA in the information it carries. **Inheritance** (Transmission of DNA to offspring.) refers to the transmission of DNA to offspring. All organisms inherit their DNA from one or two 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 1.2

- Continual inputs of energy and the cycling of materials maintain life's complex organization.
- Organisms sense and respond to change 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.
- All organisms use information in the DNA they inherited from their parent or parents to develop, grow, and reproduce. DNA is the basis of similarities and differences in form and function among organisms.

1.3 How Are Living Things Different?

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

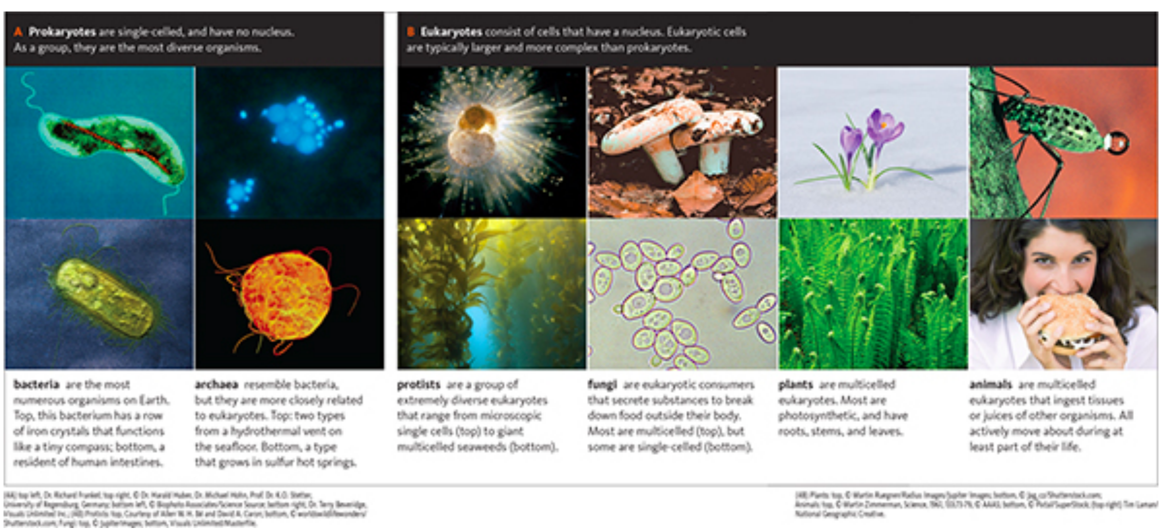
For example, organisms can be grouped on the basis of whether they have a **nucleus** (Sac that encloses a cell's DNA; has two membranes.) , which is a sac with two membranes that encloses and protects a cell's DNA. **Bacteria** (The most diverse and well-known group of single-celled organisms that lack a nucleus.) (singular, bacterium) and **archaea** (Group of single-celled organisms that lack a nucleus but are more closely related to eukaryotes than to bacteria.) (singular, archaeon) are organisms whose DNA is *not* contained within a nucleus. All bacteria and archaea are single-celled, which means each organism consists of one cell (Figure 1.4A). Collectively, these organisms are the most diverse representatives of life. Different kinds are producers or consumers in nearly all regions of Earth. 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.

Figure 1.4

A few representatives of life's diversity:

A some prokaryotes;

B some eukaryotes.



(4A) top left, Dr. Richard Frankel; top right, © Dr. Harald Huber, Dr. Michael Hohn, Prof. Dr. K.O. Stetter, University of Regensburg, Germany; bottom left, © Biophoto Associates/Science Source; bottom right, Dr. Terry Beveridge, Visuals Unlimited Inc.; (4B) Protists: top, Courtesy of Allen W. H. Bé and David A. Caron; bottom, © worldswildlifewonders/Shutterstock.com; Fungi: top, © JupiterImages; bottom, Visuals Unlimited/Masterfile./ (4B) Plants: top, © Martin Ruegner/Radius Images/Jupiter Images; bottom, © Jag_cz/ Shutterstock.com; Animals: top, © Martin Zimmerman, Science, 1961, 133:73–79, © AAAS; bottom, © Pixtal/SuperStock

Traditionally, organisms without a nucleus have been called **prokaryotes** (Single-celled organism without a nucleus.) , but this designation is now used only informally. This is because, despite the similar appearance of bacteria and archaea, the two types of cells are less related to one another than we once thought. Archaea turned out to be more closely related to **eukaryotes** (Organism whose cells characteristically have a nucleus.) , which are organisms whose DNA is contained within a nucleus. Some eukaryotes live as individual cells; others are multicelled (Figure 1.4B). Eukaryotic cells are typically larger and more complex than bacteria or archaea.

Structurally, **protists** (Member of a diverse group of simple eukaryotes.) are the simplest eukaryotes, but as a group they vary dramatically, from single-celled consumers to giant, multicelled producers.

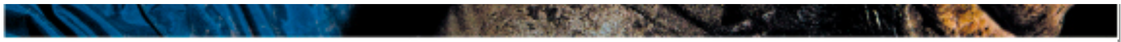
Fungi (Single-celled or multicelled eukaryotic consumer that breaks down material outside itself, then absorbs nutrients released from the breakdown.) (singular, fungus) are eukaryotic consumers that secrete substances to break down food externally, then absorb nutrients released by this process. Many fungi are decomposers. Most fungi, including those that form mushrooms, are multicellular. Fungi that live as single cells are called yeasts.

Plants (A multicelled, typically photosynthetic producer.) are multicelled eukaryotes; the majority are photosynthetic producers that live on land. Besides feeding themselves, plants also serve as food for most other land-based organisms.

Animals (Multicelled consumer that develops through a series of stages and moves about during part or all of its life.) are multicelled consumers that consume tissues or juices of other organisms. Unlike fungi, animals break down food inside their body. They also develop through a series of stages that lead to the adult form. All kinds actively move about during at least part of their lives.

People Matter

National Geographic Explorer Kristofer Helgen



Tim Laman/National Geographic Creative.

Kristofer Helgen discovers new animals. Deep in a New Guinea rain forest. High on an Andean mountainside. Resting in a museum's specimen drawer. "Conventional wisdom would have it that we know all the mammals of the world," he notes. "In fact, we know so little. Unique species, profoundly different from anything ever discovered, are out there waiting to be found." His own efforts prove this. Helgen himself has discovered approximately 100 new species of mammals previously unknown to science. "Since I was three years old, I've been transfixed by animals," he recalls. "Even then, my excitement revolved around figuring out how many different kinds there were."

Helgen's search plunges him into the wild on almost every continent. Yet about three times as many new finds are made within the walls of museums. "An expert can go into any large natural history museum and identify kinds of animals no one knew existed," he explains. When only a few specimens of a species exist, and reside in museums scattered across the globe, sheer logistics often prevent researchers from connecting the dots and pinpointing a new find. "Collections build up over centuries," he says, "It's virtually impossible to fully interpret that wealth of material. Every day brings surprises." As Curator of Mammals for the Smithsonian Institution's National Museum of Natural History, he oversees not only the collection's use as an invaluable research resource, but also its continued expansion through exploration.

Take-Home Message 1.3

- 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.

Chapter 1: Invitation to Biology: 1.4 What Is a Species?
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.4 What Is a Species?

Each time we discover a new **species** (Unique type of organism.) , or unique kind of organism, we name it. **Taxonomy** (The science of naming and classifying species.) , 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 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** (A group of species that share a unique set of traits.) (plural, genera), a group of species that share a unique set of features. The second part is the **specific epithet** (Second part of a species name.) . 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.

Chapter 1: Invitation to Biology A Rose by Any Other Name...
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

A Rose by Any Other Name...

The individuals of a species share a unique set of inherited characteristics, or **traits** (An observable characteristic of an organism or species.) . For example, giraffes normally have very long necks, brown spots on white coats, and so on. These are morphological traits (*morpho-* means form). Individuals of a species also share biochemical traits (they make and 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 shared sets of traits. Each rank, or **taxon** (Group of organisms that share a unique set of traits.) (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 1.5). Using this system, we can sort all life into a few categories (Figure 1.6 and Table 1.2).

Figure 1.5

Linnaean 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.

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

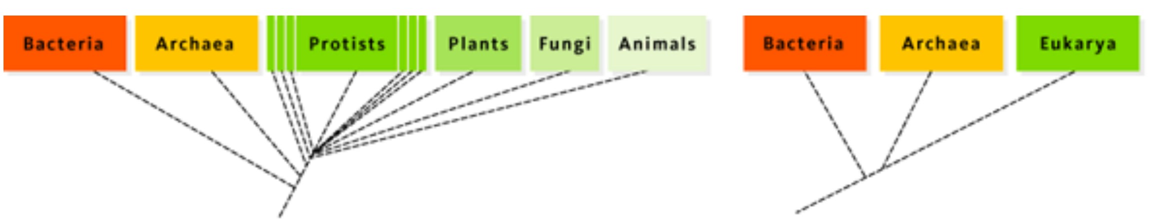
(5) from left, © xania.g, www.flickr.com/photos/52287712@N00; © kymkemp.com; Nigel Cattlin/Visuals Unlimited, Inc.; Courtesy of Melissa S. Green, www.flickr.com/photos/henkimaa; © Grodana Sarkotic.

Figure It Out:

Which of the plants shown here are in the same order?

Figure 1.6

Two ways to see the big picture of life. The lines in such diagrams indicate evolutionary connections.



A **Six-kingdom classification system.** The protist kingdom includes the most ancient multicelled and all single-celled eukaryotes.

B **Three-domain classification system.** The Eukarya domain includes protists, plants, fungi, and animals.

Table 1.2

All of Life in Three Domains

Bacteria	Single cells, no nucleus.

	Most ancient lineage.
Archaea	Single cells, no nucleus. Evolutionarily closer to eukaryotes than bacteria.
Eukarya	Eukaryotic cells (with a nucleus). Single-celled and multicelled species of protists, plants, fungi, and animals.

It is easy to tell that orangutans and caterpillars are different species because they appear very different. Distinguishing species that are more closely related may be much more challenging (Figure 1.7). 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 to that question 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.

Figure 1.7

Four butterflies, two species: Which are which?

The top row shows two forms of the species *Heliconius melpomene*; the bottom row, two forms of *H. 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

The discovery of new information sometimes changes the way we distinguish a particular species or how we group it with others. 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 17, but for now it is important to remember that a "species" is a convenient but artificial construct of the human mind.

Take-Home Message 1.4

- Each type of organism, or species, is given a unique, two-part scientific name.
- Classification systems group species on the basis of shared, inherited traits.

Chapter 1: Invitation to Biology: 1.5 How Does Science Work?
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.5 How Does Science Work?

Most of us assume that we do our own thinking, but do we, really? You might be surprised to find out how often we let others think for us. Consider how a school's job (which is to impart as much information to students as quickly as possible) meshes perfectly with a student's job (which is to acquire as much knowledge as quickly as possible). In this rapid-fire exchange of information, it is sometimes easy to forget about the quality of what is being exchanged. Anytime you accept information without questioning it, you let someone else think for you.

Chapter 1: Invitation to Biology Thinking About Thinking
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Thinking About Thinking

Critical thinking (Judging information before accepting it.) is the deliberate process of judging the quality of information before accepting it. “Critical” comes from the Greek *kriticos* (discerning judgment). When you use critical thinking, you move beyond the content of new information to consider supporting evidence, bias, and alternative interpretations. How does the busy student manage this? 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?

Such questions are a way of being conscious about learning. They can help you decide whether to allow new information to guide your beliefs and actions.

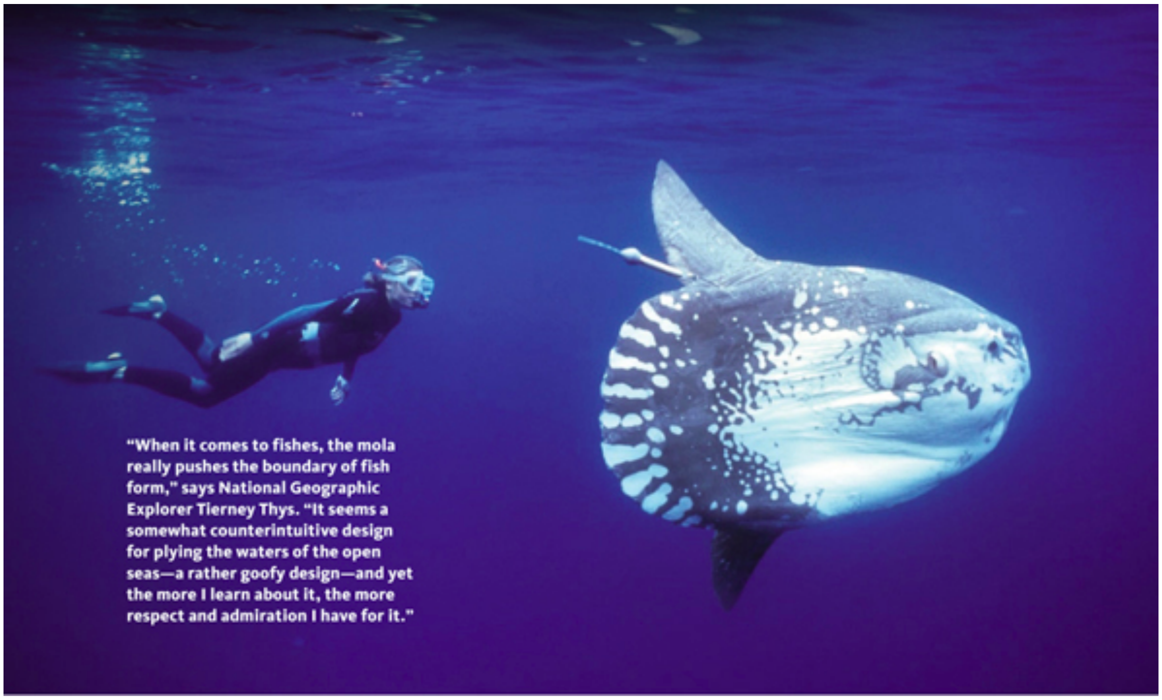
Chapter 1: Invitation to Biology The Scientific Method
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

The Scientific Method

Critical thinking is a big part of **science** (Systematic study of the observable world.) , the systematic study of the observable world and how it works (Figure 1.8). A scientific line of inquiry usually begins with curiosity about something observable, such as, say, a decrease in the number of birds in a particular area. Typically, a scientist will read about what others have discovered before making a **hypothesis** (Testable explanation of a natural phenomenon.) , a testable explanation for a natural phenomenon. An example of a hypothesis would be, “The number of birds is decreasing because the number of cats is increasing.” Making a hypothesis this way is an example of **inductive reasoning** (Drawing a conclusion based on observation.) , which means arriving at a conclusion based on one’s observations. Inductive reasoning is the way we come up with new ideas about groups of objects or events.

Figure 1.8

Tierney Thys travels the world's oceans to study the giant sunfish (mola). This mola is carrying a satellite tracking device.



A **prediction** (Statement, based on a hypothesis, about a condition that should exist if the hypothesis is correct.) , 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. Using a hypothesis to make a prediction is a form of **deductive reasoning** (Using a general idea to make a conclusion about a specific case.) , the logical process of using a general premise to draw a conclusion about a specific case.

Next, a scientist will devise ways to test a prediction. Tests may be performed on a **model** (Analogous system used for testing hypotheses.) , 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** (A test designed to support or falsify a prediction.) : tests designed to support or falsify a prediction. A typical experiment explores a cause-and-effect relationship.

Researchers often investigate causal relationships by changing and observing **variables** (In an experiment, a characteristic or event that differs among individuals or over time.) , characteristics or events that can differ among individuals or over time. An **independent variable** (variable that is controlled by an experimenter in order to explore its relationship to a dependent variable.) is defined or controlled by the person doing the experiment. A **dependent variable** (In an experiment, a variable that is presumably affected by an independent variable being tested.) is an observed result that is supposed to be influenced by the independent variable. For example, an independent variable in an investigation of our observed decrease in the number of birds may be the removal of cats in the area. The dependent variable in this experiment would be the number of birds.

Biological systems are complex, with many interacting variables. It can be difficult to study one variable separately from the rest. Thus, biology researchers often test two groups of individuals simultaneously. An **experimental group** (In an experiment, a group of individuals who have a certain characteristic or receive a certain treatment.) 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** (Group of individuals identical to an experimental group except for the independent variable under investigation.) , which is identical to the experimental group except for one independent variable: the characteristic or the treatment being tested. Any differences in experimental results between the two groups is likely to be an effect of changing the variable.

Test results—**data** (Experimental results.) —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 and evaluating the hypothesis, are collectively called the **scientific method** (Making, testing, and evaluating hypotheses.) (Table 1.3).

Table 1.3

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 experiment, data, and conclusion to the scientific community.

Take-Home Message 1.5

- Judging the quality of information before accepting it is called critical thinking.
- The scientific method consists of making, testing, and evaluating hypotheses. It is a way of critical thinking.
- Experiments measure how changing an independent variable affects a dependent variable.

Chapter 1: Invitation to Biology: 1.6 Why Do Biologists Perform Experiments?
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.6 Why Do Biologists Perform Experiments?

There are many different ways to do research, particularly in biology. Some biologists make surveys; they observe without making hypotheses. Some make hypotheses and leave experimentation to others. Despite a broad range of approaches, however, researchers typically try to design experiments in a consistent way. They change one independent variable at a time, and carefully measure the effects of the change on a dependent variable.

To give you a sense of how biology experiments work, we summarize two published studies here.

Chapter 1: Invitation to Biology Potato Chips and Stomachaches
Book Title: Biology

Potato Chips and Stomachaches

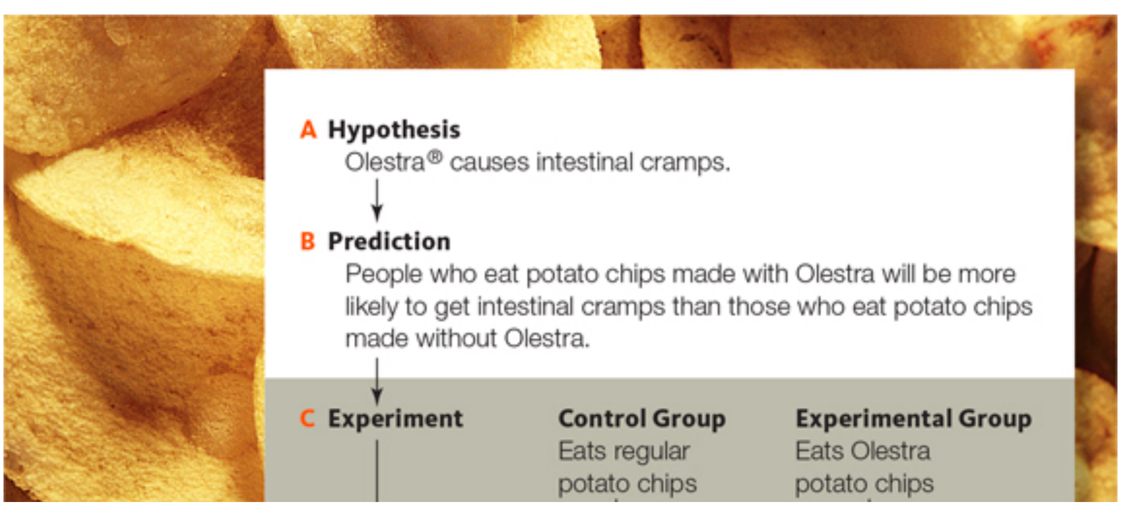
In 1996 the U.S. Food and Drug Administration (the FDA) approved Olestra® (a fat replacement manufactured from sugar and vegetable oil) for use as a food additive. Potato chips were the first Olestra-containing food product on the market in the United States. Controversy soon raged. Many people complained of intestinal problems after eating the chips and thought that the Olestra was at fault.

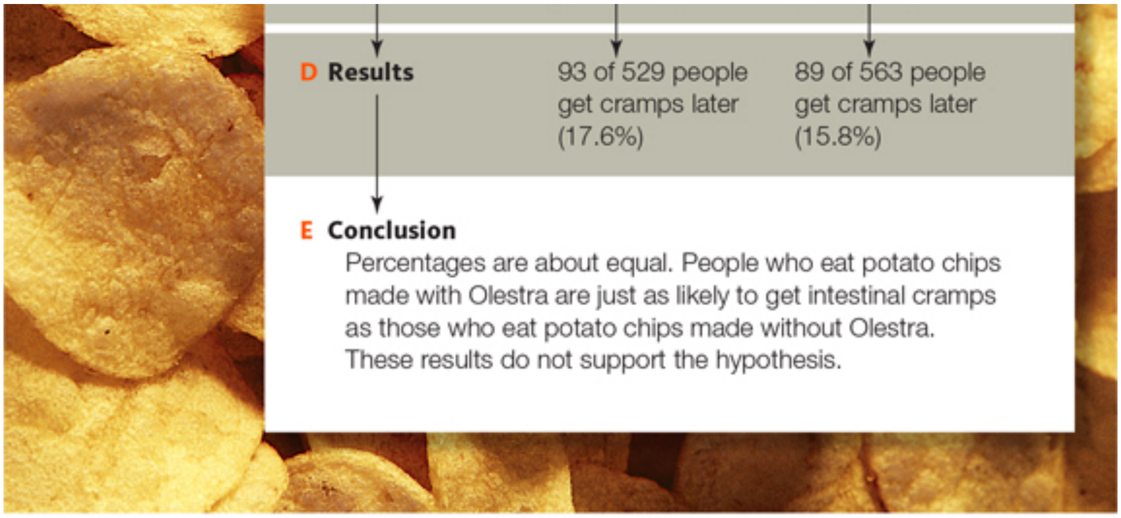
Two years later, researchers at Johns Hopkins University School of Medicine designed an experiment to test the hypothesis that this food additive causes cramps. The researchers predicted *if* Olestra causes cramps, *then* people who eat Olestra will be more likely to get cramps than people who do not. To test their prediction, they used a Chicago theater as a "laboratory," and asked 1,100 people between the ages of thirteen and thirty-eight to eat potato chips while watching a movie. 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 independent variable was the presence or absence of Olestra in the chips.

A few days after the experiment was finished, the researchers contacted everyone and collected reports of any post-movie cramps (the dependent variable). Of the 563 people in the experimental (Olestra-eating) 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 1.9).

Figure 1.9

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 1998.





(9) photo, © Superstock; artwork, © Cengage Learning 2015.

photo, © Superstock; artwork, © Cengage Learning 2015.

Figure It Out:

What was the dependent variable in this experiment?

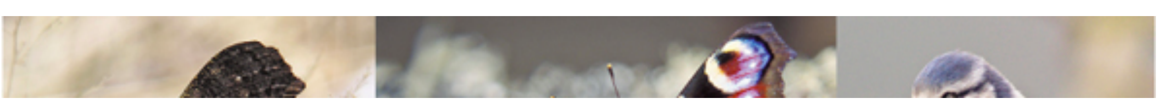
Butterflies and Birds

A 2005 experiment investigated whether certain peacock butterfly behaviors defend these insects from predatory 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 1.10A). 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 1.10B).

Figure 1.10

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, listed below in Table 1.4, support the hypotheses that peacock butterfly spots and sounds can deter predatory birds.



A With wings folded, a resting peacock butterfly resembles 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 It Out:

What was the dependent variable in this series of experiments?

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.
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 wings were painted and cut. The researchers then put each butterfly into a large cage with a hungry blue tit (Figure 1.10C) and watched the pair for thirty minutes.

Table 1.4 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.

Table 1.4

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%)

Take-Home Message 1.6

- Natural processes are often influenced by many interacting variables.
- Researchers unravel cause-and-effect relationships in complex natural processes by performing experiments in which they change one variable at a time.

Chapter 1: Invitation to Biology: 1.7 What Are Some Potential Pitfalls In Scientific Inquiry?
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.7 What Are Some Potential Pitfalls In Scientific Inquiry?

Sampling Error

When researchers cannot directly observe all individuals of a population, all instances of an event, or some other aspect of nature, they may test or survey a subset. Results from the subset are then used to make generalizations about the whole. For example, a survey team may catalog the number of beetles in a given area of a very large forest. If that given area is one-thousandth of the forest, then an estimate of the number of beetles in the entire forest would be one thousand times their result. However, this type of generalization is risky because the subset may not be representative of the whole. In our beetle survey, for example, if the only nest of beetles in the entire forest happened to be located in the area that was surveyed, then the generalized result would be in error. **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.) is a difference between results obtained from a subset, and results from the whole (Figure 1.11A).

Figure 1.11

Demonstration of sampling error, and the effect of sample size on it.

Sampling error may be unavoidable, but 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 repeat their experiments (Figure 1.11B). To understand why these practices reduce the risk of sampling error, think about flipping a coin. There are two possible outcomes of each flip: 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, however, the overall proportion of times the coin lands heads up is much more likely to approach 50 percent.

In cases such as flipping a coin, it is possible to calculate **probability** (The chance that a particular outcome of an event will occur; depends on the total number of outcomes possible.) , which 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, if 10 million people enter a drawing, each has the same probability of winning: 1 in 10 million, or (an extremely improbable) 0.00001 percent.

Analysis of experimental data often includes probability calculations. If a result is very unlikely to have occurred by chance alone, it is said to be **statistically significant** (Refers to a result that is statistically unlikely to have occurred by chance.) . In this context, the word "significant" does not refer to the result's importance. It means that the result has been subjected to a rigorous statistical analysis that shows it has a very low probability (usually 5 percent or less) of being skewed by sampling error.

Variation in data is often shown as error bars on a graph (Figure 1.12). Depending on the graph, error bars may indicate variation around an average for one sample set, or the difference between two sample sets.

Figure 1.12

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.

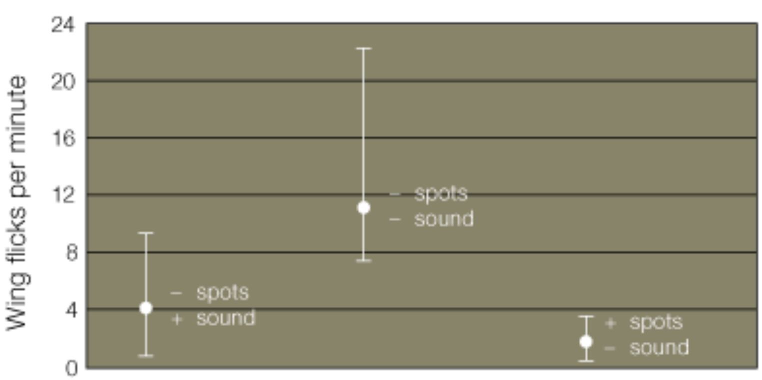


Figure It Out:

What was the fastest rate at which a butterfly with no spots or sound flicked its wings?

Chapter 1: Invitation to Biology Bias In Interpreting Results
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Bias In Interpreting Results

Particularly when studying humans, changing a single variable apart from all others is not often possible. For example, remember that the people who participated in the Olestra experiment were chosen randomly. That means the study was not controlled for gender, age, weight, medications taken, and so on. Such variables may have influenced the results.

Human beings are by nature subjective, and scientists are no exception. Experimenters risk interpreting their results in terms of what they want to find out. That is why they often design experiments to yield quantitative results, which are counts or some other data that can be measured or gathered objectively. Such 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 their 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. Their collective efforts make science a self-correcting endeavor.

Chapter 1: Invitation to Biology The Limits of Science
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

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 all 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 may 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 can be 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.

Take-Home Message 1.7

- Checks and balances inherent in the scientific process help researchers to be objective about their observations.
- Researchers minimize sampling error by using large sample sizes and by repeating their experiments.
- Probability calculations can show whether a result is likely to have occurred by chance alone.
- Science is a self-correcting process because it is carried out by an aggregate community of people systematically checking one another's ideas.

Chapter 1: Invitation to Biology: 1.8 What Is a "Theory"?
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.8 What Is a "Theory"?

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** (Hypothesis that has not been disproven after many years of rigorous testing.) (Table 1.5). 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.

Table 1.5

Examples of Scientific Theories

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.

Scientific theories are our best objective descriptions of the natural world, but 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 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 one 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 be revised until no one could prove it to be incorrect. This potentially falsifiable nature of scientific theories is part of science's built-in system of checks and balances. 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 differs because it 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** (Generalization that describes a consistent natural phenomenon for which there is incomplete scientific explanation.) , 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. As you will see in Chapter 5, we understand *how* energy behaves, but not exactly *why* it behaves the way it does.

Take-Home Message 1.8

- 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.

Chapter 1: Invitation to Biology: 1.9 Application: The Secret Life of Earth
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

1.9 Application: The Secret Life of Earth

Exploration

Researcher Paul Oliver discovered this tiny tree frog perched on a sack of rice during a particularly rainy campsite lunch in New Guinea's Foja Mountains. 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 Creative.

In This ERA of Detailed Cell Phone GPS , could there possibly be any places left on Earth that humans have not yet explored? Actually, there are plenty. For example, a 2-million-acre cloud forest in New Guinea was only recently penetrated by explorers. How did the explorers know they had landed in uncharted territory? For one thing, the forest was filled with plants and animals unknown even to native peoples that have long inhabited other parts of the region. Team member Bruce Beehler remarked, "I was shouting. This trip was a once-in-a-lifetime series of shouting experiences." 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.

Each new species is a reminder that we do not yet know all of the organisms that share our planet. We don't even know how many to look for. Why does that matter? Understanding the scope of life on Earth gives us perspective on where we fit into it. For example, the current rate of extinctions is about 1,000 times faster than ever recorded, and we now know that human activities are responsible for the acceleration. At this rate, we will never know about most of the species that are alive today. Is that important? 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 upon which to base your own opinions about the human connection—your connection—with all life on Earth.

Chapter Review

Summary

Section 1.1 **Biology** is the scientific study of life. Biologists think about life at different levels of organization, with **emergent properties** appearing at successive levels. All matter consists of **atoms**, which combine as **molecules**. **Organisms** are individuals that consist of one or more **cells**, the level at which life emerges. Cells of larger multicelled organisms are organized as **tissues**, **organs**, and **organ systems (#)** . A **population** is a group of interbreeding 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 1.2 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, their wastes, or remains. Organisms keep the conditions in their internal environment within ranges that their cells tolerate—a process called **homeostasis**. **DNA** contains information that guides an organism's **growth**, **development**, and **reproduction**. The passage of DNA from parents to offspring is called **inheritance**.

Section 1.3 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 both **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 1.4 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 1.5 **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, uses **inductive reasoning** to form a **hypothesis** (testable explanation) for it, then uses **deductive**

reasoning to make a **testable prediction** about what might occur if the hypothesis is correct. **Experiments** with **variables** may be performed on an **experimental group** as compared with a **control group**, and sometimes on **models**. A researcher changes an **independent variable**, then observes the effects of the change on a **dependent variable**. Conclusions are drawn from the resulting **data**. The **scientific method** consists of making, testing, and evaluating hypotheses, and sharing results.

Section 1.6 Biological systems are usually influenced by many interacting variables. Research approaches differ, but experiments are typically designed in a consistent way, in order to study a single cause-and-effect relationship in a complex natural system.

Section 1.7 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. Science is ideally a self-correcting process because scientists check and test one another's ideas. Science helps us be objective about our observations because it is only concerned with testable ideas about observable aspects of nature. Opinion and belief have value in human culture, but they are not addressed by science.

Section 1.8 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 has an incomplete scientific explanation.

Section 1.9 We know about only a fraction of the organisms that live on Earth, in part because we have explored only a fraction of its inhabited regions.

Chapter 1: Invitation to Biology Self-Quiz
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Chapter Review

Self-Quiz

1. ____ are fundamental building blocks of all matter.

    a. Atoms

    b. Molecules

    c. Cells

d. Organisms

2. The smallest unit of life is the ____ .

a. atom

b. molecule

c. cell

d. organism

3. Organisms require ____ and ____ to maintain themselves, grow, and reproduce.

4. By sensing and responding to change, organisms keep conditions in the internal environment within ranges that cells can tolerate. This process is called ____ .

5. DNA ____ .

a. guides form and function

b. is the basis of traits

c. is transmitted from parents to offspring

d. all of the above

6. A process by which an organism produces offspring is called ____ .

7. ____ is the transmission of DNA to offspring.

a. Reproduction

b. Development

c. Homeostasis

d. Inheritance

8. A butterfly is a(n) ____ (choose all that apply).

a. organism

b. domain

c. species

d. eukaryote

e. consumer

f. producer

g. prokaryote

h. trait

9. ____ move around for at least part of their life.

10. A bacterium is ____ (choose all that apply).

a. an organism

b. single-celled

c. an animal

d. a eukaryote

11. Bacteria, Archaea, and Eukarya are three ____ .

12. A control group is ____ .

a. a set of individuals that have a certain characteristic or receive a certain treatment

b. the standard against which an experimental group is compared

c. the experiment that gives conclusive results

13. 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

b. sampling error

c. a subjective opinion

d. experimental bias

14. Science only addresses that which is ____ .

a. alive

b. observable

c. variable

d. indisputable

15. Match the terms with the most suitable description.

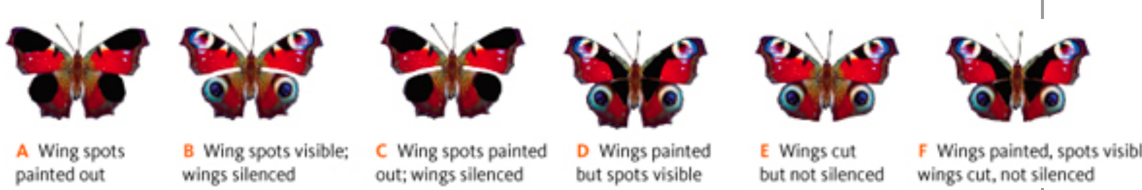
life	a. if-then statement
probability	b. unique type of organism
species	c. emerges with cells
hypothesis	d. testable explanation
prediction	e. measure of chance
producer	f. makes its own food

Chapter 1: Invitation to Biology Data Analysis Activities
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Chapter Review

Data Analysis Activities

Peacock Butterfly Predator Defenses The photographs below represent experimental and control groups used in the peacock butterfly experiment discussed in Section 1.6. 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).



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.

Chapter 1: Invitation to Biology Critical Thinking
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)

Chapter Review

Critical Thinking

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

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

3. Why would you think twice about ordering from a restaurant menu that lists the specific epithet but not the genus name of its offerings? *Hint:* Look up *Homarus americanus, Ursus americanus, Ceanothus americanus, Bufo 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 this 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 "theories 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?

Chapter 1: Invitation to Biology Critical Thinking
Book Title: Biology
Printed By: Eric Daney (edaney@dasd.org)