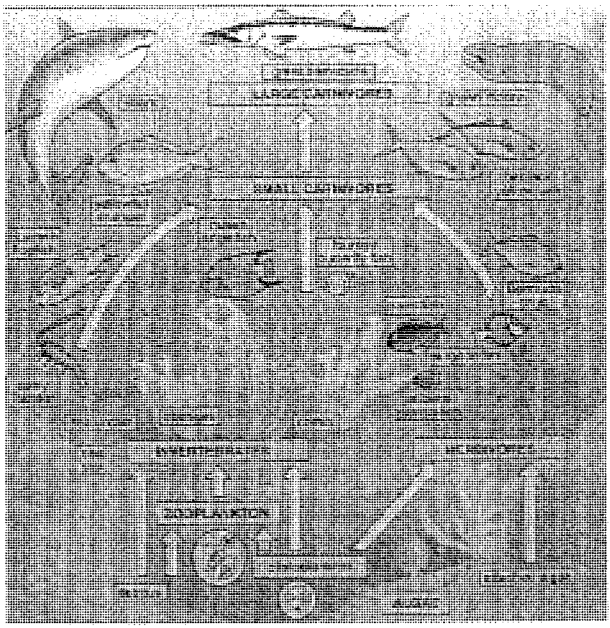


نظام بيئي مائي

1

A View of Life

At a height of nearly 3 m (10 ft), the titan arum slowly unfurls its enormous flower, which heats up, turns red, and emits an overpowering stench reminiscent of rotting meat. Its home is the forests of Sumatra, and the smell attracts the beetles and flies that ordinarily pollinate the flower. Now the plant is cultivated in botanical gardens around the world to the delight of curious onlookers.

The Earth hosts a wide variety of ecosystems, from which spring a mind-boggling diversity of life, including the titan arum. Even so, all Earth's organisms, regardless of form, are united by a number of common characteristics, such as the need to acquire nutrients, the ability to respond to a changing environment, and to reproduce their own kind. Incredibly, even organisms as diverse as the titan arum and a human being share similar characteristics, including a common chemistry and genetic code. As you read this chapter, reflect on the staggering diversity of life on Earth and on the many ties that bind even the most diverse organisms, from bacteria to the titan arum to humans. It is through these ties that our fates are linked together in the web of life.

The titan arum (*Amorphophallus titanum*).

1.1 HOW TO DEFINE LIFE

- The living organisms on Earth share many common characteristics: they are organized, acquire materials and energy, respond to the environment, and reproduce and develop. 2–5
- Still, living things are diverse because they are adapted to their different environments. 5

1.2 EVOLUTION, THE UNIFYING CONCEPT OF BIOLOGY

- The theory of evolution states that all types of living organisms share a common ancestor and change over time. Therefore, evolution explains both the unity and diversity on Earth. 6–8

1.3 HOW THE BIOSPHERE IS ORGANIZED

- Living things interact with each other and with the physical environment to form ecosystems. 9–10
- Due to human activities, many diverse ecosystems are currently endangered. Biologists are concerned about the current rate of extinctions, and believe that we should take steps to preserve biodiversity. 10

1.4 THE PROCESS OF SCIENCE

- The scientific process is used by biologists to gather information and come to conclusions about the natural world before reporting it to other scientists and to the public. 11
- The process includes observation, proposing a hypothesis, performing an experiment, analyzing the results, and making conclusions. Conclusions usually lead to a new hypothesis. 11–16

1.1 How to Define Life

Life on Earth takes on a staggering variety of forms, often functioning and behaving in ways strange to humans. For example, gastric-brooding frogs swallow their embryos and give birth to them later by throwing them up! Some species of puffballs, a type of fungus, are capable of producing trillions of spores when they reproduce. Fetal sand sharks kill and eat their siblings while still inside their mother. Some *Ophrys* orchids look so much like female bees that male bees try to mate with them. Octopuses and squid have remarkable problem-solving abilities despite a small brain. Some bacteria live their entire life in 15 minutes, while bristlecone pine trees outlive ten generations of humans. Simply put, from the deepest oceanic trenches to the upper reaches of the atmosphere, life is plentiful and diverse.

Figure 1.1 illustrates the major groups of living things, also called organisms. From left to right, bacteria are widely distributed, tiny, microscopic organisms with a very simple structure. A *Paramecium* is an example of a microscopic protist. Protists are larger in size and more complex than bacteria. The other organisms in Figure 1.1 are easily seen with the naked eye. They can be distinguished by how they get their food. A morel is a fungus that digests its food externally. A sunflower is a photosynthetic plant that makes its own food, and a snow goose is an animal that ingests its food.

Because life is so diverse, it seems reasonable that it cannot be defined in a straightforward manner. Instead, life is best defined by several basic characteristics shared by all organisms. Like nonliving things, organisms are composed of chemical elements. Also, organisms obey the same laws of chemistry and physics that govern everything within the universe. The characteristics of life, however, will provide great insight into the unique nature of organisms and will help us distinguish living things from nonliving things.

Living Things Are Organized

The levels of organization depicted in Figure 1.2 begin with atoms, which are the basic units of matter. Atoms combine with other atoms of the same or different elements to form molecules. The cell, which is composed of a variety of molecules working together, is the basic unit of structure and function of all living things. Some cells, such as unicellular paramecia, live independently. Other cells, for example, the colonial alga *Volvox*, cluster together in microscopic colonies.

Many living things are multicellular, meaning they contain more than one cell. In multicellular organisms, similar cells combine to form a tissue; nerve tissue is a common tissue in animals. Tissues make up organs, as when various tissues combine to form the brain. Organs work together in systems; for example, the brain works with the spinal cord and a network of nerves to form the nervous system. Organ systems are joined together to form a complete living thing, or organism, such as an elephant.

The levels of biological organization extend beyond the individual organism. All the members of one species in a particular area belong to a population. A nearby forest may have a population of gray squirrels and a population of white oaks, for example. The populations of various animals and plants in the forest make up a community. The community of populations interacts with the physical environment and forms an ecosystem. Finally, all the Earth's ecosystems make up the biosphere.

Emergent Properties

Each level of biological organization builds upon the previous level, and is more complex. Moving up the hierarchy, each level acquires new emergent properties that are determined by the interactions between the individual parts. When cells are broken down into bits of membrane and liquids, these parts themselves cannot carry out the business of living. For example, you can take apart a lump of coal, rearrange the pieces in any order, and still have a lump of coal with the same function as the original one. But, if you slice apart a living plant and rearrange the pieces, the plant is no longer functional as a complete plant, because it depends on the exact order of those pieces.

In the living world, the whole is indeed more than the sum of its parts. The emergent properties created by the interactions between levels of biological organization are new, unique characteristics. These properties are governed by the laws of chemistry and physics.

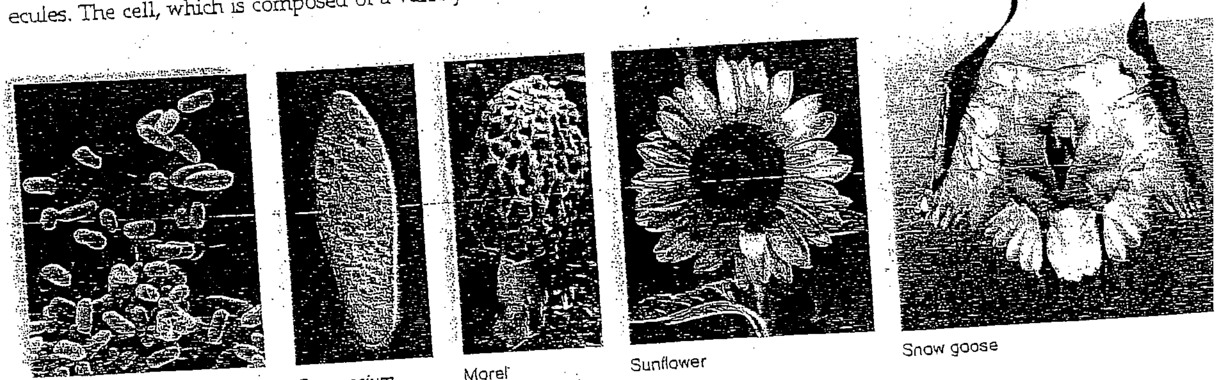


FIGURE 1.1 Diversity of life. Biology is the scientific study of life. Many diverse forms of life are found on planet Earth.

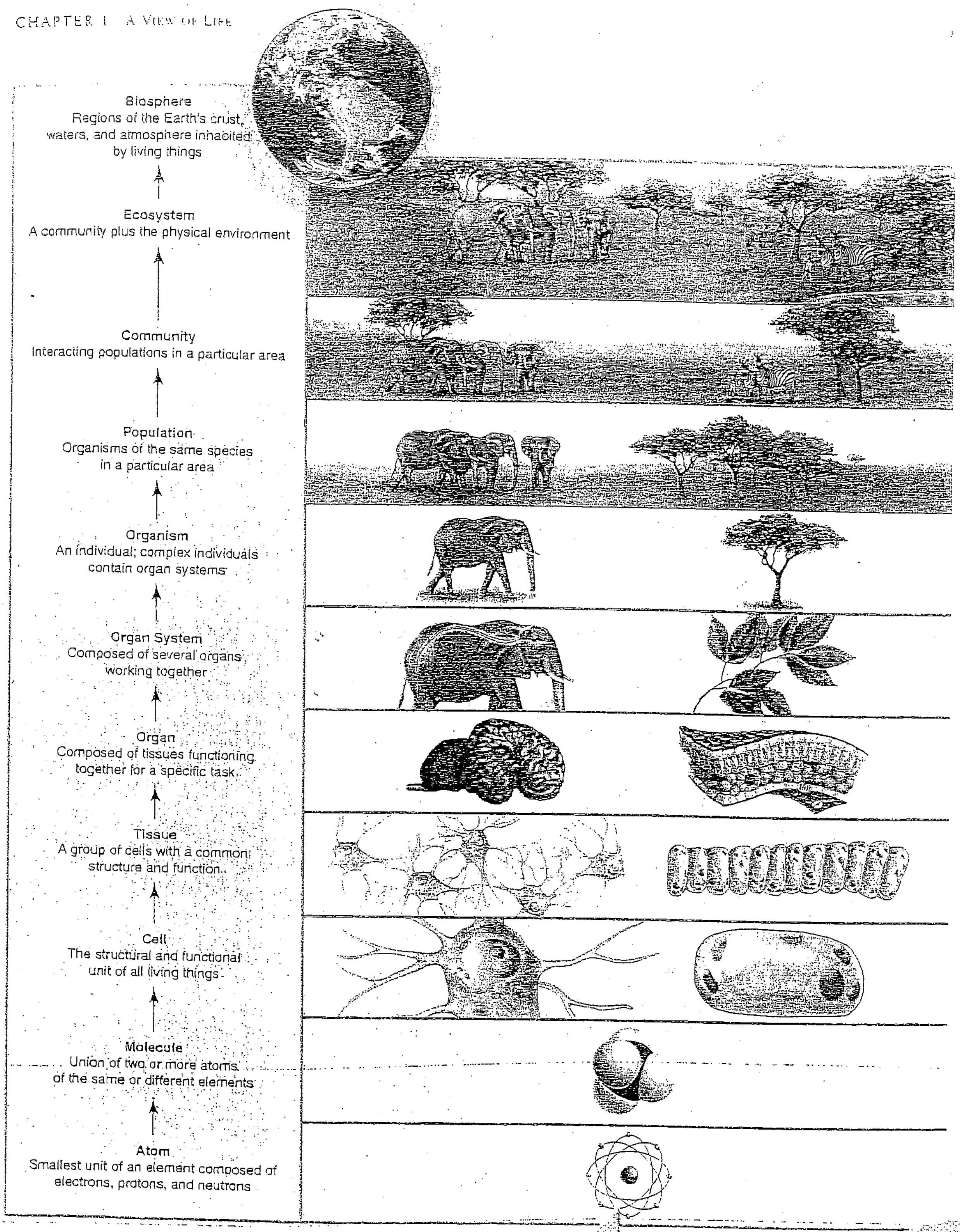


FIGURE 1.2 Levels of biological organization.

Living Things Acquire Materials and Energy

Living things cannot maintain their organization or carry on life's activities without an outside source of nutrients and energy (Fig. 1.3). Food provides nutrients, which are used as building blocks or for energy. Energy is the capacity to do work, and it takes work to maintain the organization of the cell and the organism. When cells use nutrient molecules to make their parts and products, they carry out a sequence of chemical reactions. The term metabolism [Gk. *meta*, change] encompasses all the chemical reactions that occur in a cell.

The ultimate source of energy for nearly all life on Earth is the sun. Plants and certain other organisms are able to capture solar energy and carry on photosynthesis, a process that transforms solar energy into the chemical energy of organic nutrient molecules. All life on Earth acquires energy by metabolizing nutrient molecules made by photosynthesizers. This applies even to plants.

Remaining Homeostatic

To survive, it is imperative that an organism maintain a state of biological balance or homeostasis [Gk. *homoios*, like, and *stasis*, the same]. For life to continue, temperature, moisture level, acidity, and other physiological factors must remain within the tolerance range of the organism. Homeostasis is maintained by systems that monitor internal conditions and make routine and necessary adjustments.

Organisms have intricate feedback and control mechanisms that do not require any conscious activity. These mechanisms may be controlled by one or more tissues themselves, or by the nervous system. When a student is so engrossed in her textbook that she forgets to eat lunch, her liver releases stored sugar to keep blood sugar levels within normal limits. Many organisms depend on behavior to regulate their internal environment. These behaviors are controlled by the nervous system, and are usually not consciously controlled. The same student may realize that she is hungry and decide to visit the local diner. A lizard may raise its internal temperature by basking in the sun or cool down by moving into the shade.

Living Things Respond

Living things interact with the environment as well as with other living things. Even unicellular organisms can respond to their environment. In some, the beating of microscopic hairs or, in others, the snapping of whiplike tails moves them toward or away from light or chemicals. Multicellular organisms can manage more complex responses. A vulture can detect a carcass a kilometer away and soar toward dinner. A

FIGURE 1.3 **Acquiring nutrients and energy.**

a. An eagle ingesting fish. b. A human eating an apple. c. A cypress tree capturing sunlight. d. An amoeba engulfing food. e. A fungus feeding on a tree. f. A bison eating grass.

monarch butterfly can sense the approach of fall and begin its flight south where resources are still abundant.

The ability to respond often results in movement: the leaves of a land plant turn toward the sun, and animals dart toward safety. Appropriate responses help ensure survival of the organism and allow it to carry on its daily activities. All together, these activities are termed the behavior of the organism. Organisms display a variety of behaviors as they maintain homeostasis and search and compete for energy, nutrients, shelter, and mates. Many organisms display complex communication, hunting, and defense behaviors.

Living Things Reproduce and Develop

Life comes only from life. Every type of living thing can reproduce, or make another organism like itself (Fig. 1.4). Bacteria, protists, and other unicellular organisms simply split in two. In most multicellular organisms, the reproductive process begins with the pairing of a sperm from one partner and an egg from the other partner. The union of sperm and egg, followed by many cell divisions, results in an immature stage, which grows and develops through various stages to become the adult.

An embryo develops into a humpback whale or a purple iris because of a blueprint inherited from its parents. The instructions, or blueprint, for an organism's metabolism and organization are encoded in genes. The genes, which contain specific information for how the organism is to be ordered, are made of long molecules of DNA (deoxyribonucleic acid). DNA has a shape resembling a spiral staircase with millions of steps. Housed within this spiral staircase is the genetic code that is shared by all living things.

When living things reproduce, their genes are passed on to the next generation. Random combinations of sperm and egg, each of which contains a unique collection of genes, ensure that the new individual has new and different characteristics. The DNA of organisms, over time, also undergoes mutations (changes) that may be passed on to the next generation. These events help to create a staggering diversity of life, even within a group of otherwise identical organisms. Sometimes, organisms inherit characteristics that allow them to be more suited to their way of life.

Living Things Have Adaptations

Adaptations [L. *ad*, toward, and *aptus*, suitable] are modifications that make organisms better able to function in a particular environment. For example, penguins are adapted to an aquatic existence in the Antarctic. An extra layer of downy feathers is covered by short, thick feathers that form a waterproof coat. Layers of blubber also keep the birds warm in cold water. Most birds have forelimbs proportioned for flying, but penguins have stubby, flattened wings suitable for swimming. Their feet and tails serve as rudders in the water, but the flat feet also allow them to walk on land. Rockhopper penguins have a bill adapted to eating small shellfish.

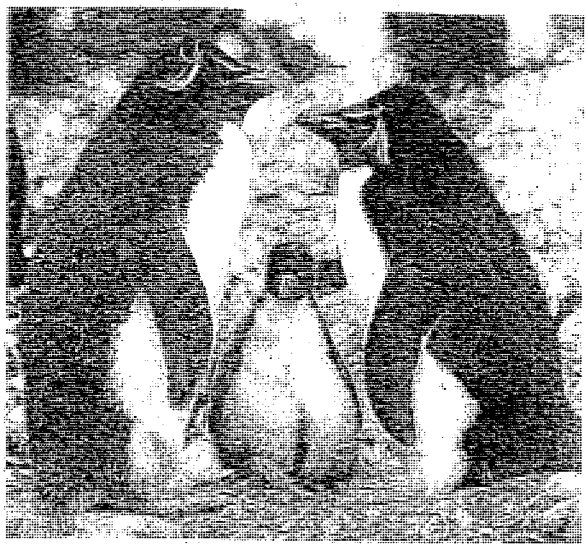


FIGURE 1.4 Rockhopper penguins with their offspring.
Rockhopper penguins, which are named for their skill in leaping from rock to rock, produce one or two offspring at a time. Both male and female have a brood patch, a feather-free area of skin containing many blood vessels, which keeps the egg(s) warm when either parent sits on the nest.

Penguins also have many behavioral adaptations to living in the Antarctic. Penguins often slide on their bellies across the snow in order to conserve energy when moving quickly. Their eggs—one or at most two—are carried on the feet, where they are protected by a pouch of skin. This also allows the birds to huddle together for warmth while standing erect and incubating eggs.

From penguins to fire ants, life on Earth is very diverse because over long periods of time, organisms respond to ever-changing environments by developing new adaptations. Evolution [L. *evolutio*, an unrolling] includes the way in which populations of organisms change over the course of many generations to become more suited to their environments. Evolution constantly reshapes the species, providing a way for organisms to persist, despite a changing environment.

Check Your Progress 1.1

1. What are common characteristics of living organisms?
2. In what ways do viruses (p. 356) not specifically meet all of the above characteristics?
3. What adaptations would suit an organism, such as a cactus, to life in a desert?

1.2 Evolution, the Unifying Concept of Biology

Despite diversity in form, function, and lifestyle, organisms share the same basic characteristics. As mentioned, they are all composed of cells organized in a similar manner. Their genes are composed of DNA, and they carry out the same metabolic reactions to acquire energy and maintain their organization. The unity of living things suggests that they are descended from a common ancestor—the first cell or cells.

An evolutionary tree is like a family tree (Fig. 1.5). Just as a family tree shows how a group of people have descended from one couple, an evolutionary tree traces the ancestry of life on Earth to a common ancestor. One couple can have diverse children, and likewise a population can be a common ancestor to several other groups, each adapted to a particular set of environmental conditions. In this way, over time, diverse life-forms have arisen. Evolution may be considered the unifying concept of biology because it explains so many aspects of biology, including how living organisms arose from a single ancestor.

Organizing Diversity

Because life is so diverse, it is helpful to group organisms into categories. Taxonomy [Gk. *tasso*, arrange, and *nomos*, usage] is the discipline of identifying and grouping organisms according to certain rules. Taxonomy makes sense out of the bewildering variety of life on Earth and is meant to provide valuable insight into evolution. As more is learned about living things, including the evolutionary relationships between species, taxonomy changes. DNA technology is now being used to revise current information and to discover previously unknown relationships between organisms.

Several of the basic classification categories, or *taxa*, going from least inclusive to most inclusive, are species, genus, family, order, class, phylum, kingdom, and domain (Table 1.1). The least inclusive category, species [L. *species*, model, kind], is defined as a group of interbreeding individuals. Each successive classification category above species contains more types of organisms than the preceding one. Species placed within one genus share many specific characteristics and are the most closely related, while species placed in the same kingdom share only general characteristics with one another. For example, all species in the genus *Pisum* look pretty much the same—that is, like pea plants—but species in the plant kingdom can be quite varied, as is evident when we compare grasses to trees. Species placed in different domains are the most distantly related.

TABLE 1.1

Levels of Classification

Category	Human	Corn
Domain	Eukarya	Eukarya
Kingdom	Animalia	Plantae
Phylum	Chordata	Anthophyta
Class	Mammalia	Monocotyledones
Order	Primates	Commelinales
Family	Hominidae	Poaceae
Genus	*Homo*	*Zea*
Species[a]	*H. sapiens*	*Z. mays*

[a] To specify an organism, you must use the full binomial name, such as *Homo sapiens*.

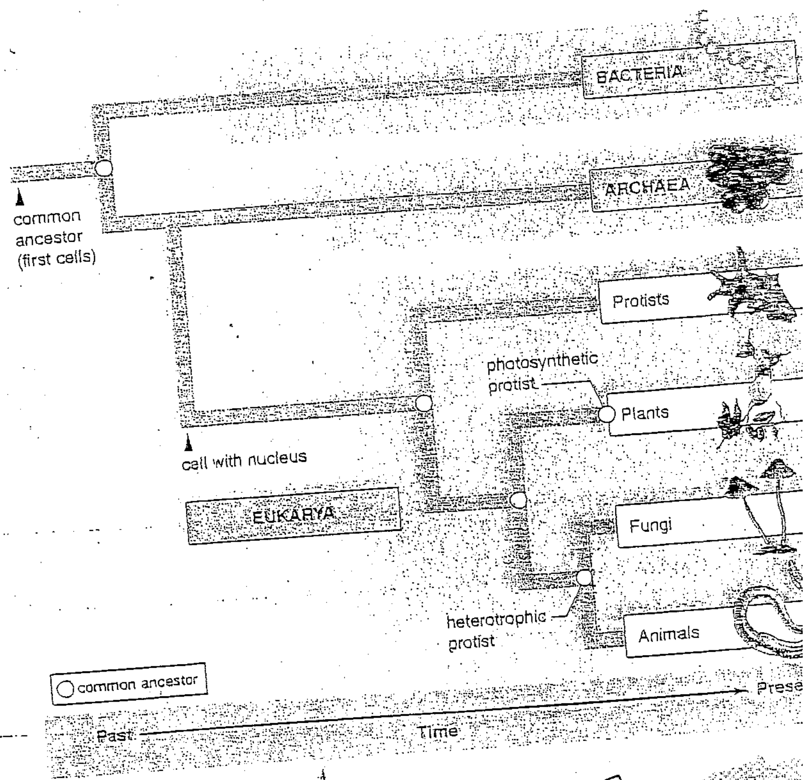


FIGURE 1.5 Evolutionary tree of life.

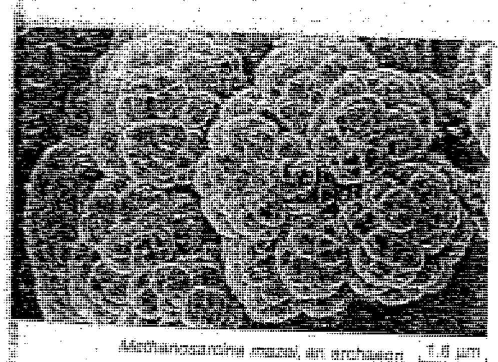
As existing organisms change over time, they give rise to new species. Evolutionary studies show that all living organisms arose from a common ancestor about 4 billion years ago. Domain Archaea includes prokaryotes capable of surviving in extreme environments, such as those with high salinity and temperature and low pH. Domain Bacteria includes metabolically diverse prokaryotes widely distributed in various environments. The domain Eukarya includes both unicellular and multicellular organisms that possess a membrane-bounded nucleus.

Domains العوالم

Biochemical evidence suggests that there are only three domains: domain Bacteria, domain Archaea, and domain Eukarya. Figure 1.5 shows how the domains are believed to be related. Both domain Bacteria and domain Archaea may have evolved from the first common ancestor soon after life began. These two domains contain the prokaryotes, which lack the membrane-bounded nucleus found in the eukaryotes of domain Eukarya. However, archaea organize their DNA differently than bacteria, and their cell walls and membranes are chemically more similar to eukaryotes than to bacteria. So, the conclusion is that eukarya split off from the archaeal line of descent.

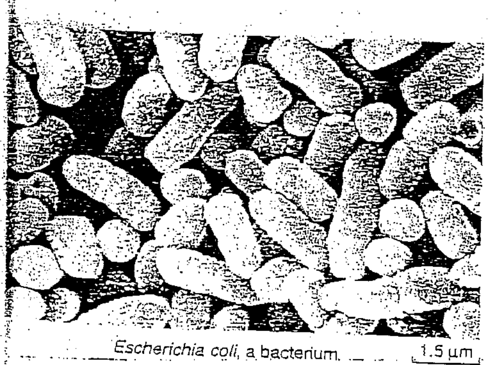
Prokaryotes are structurally simple but metabolically complex. Archaea (Fig. 1.6) can live in aquatic environments that lack oxygen or are too salty, too hot, or too acidic for most other organisms. Perhaps these environments are similar to those of the primitive Earth, and archaea (Gk. *archae*, ancient) are the least evolved forms of life, as their name implies. Bacteria (Fig. 1.7) are variously adapted to living almost anywhere—in the water, soil, and atmosphere, as well as on our skin and in our mouths and large intestines.

Taxonomists are in the process of deciding how to categorize archaea and bacteria into kingdoms. Domain Eukarya, on the other hand, contains four major groups of organisms (Fig. 1.8). Protists, which now comprise a number of kingdoms, range from unicellular forms to a few multicellular ones. Some are photosynthesizers, and some must acquire their food. Common protists include algae, the protozoans, and the water molds. Figure 1.5 shows that plants, fungi, and animals most likely evolved from protists. Plants (kingdom Plantae) are multicellular photosynthetic organisms. Example plants include azaleas, zinnias, and pines. Among the fungi



Methanosarcina mazei, an archaean

FIGURE 1.6 Domain Archaea.



Escherichia coli, a bacterium

FIGURE 1.7 Domain Bacteria.

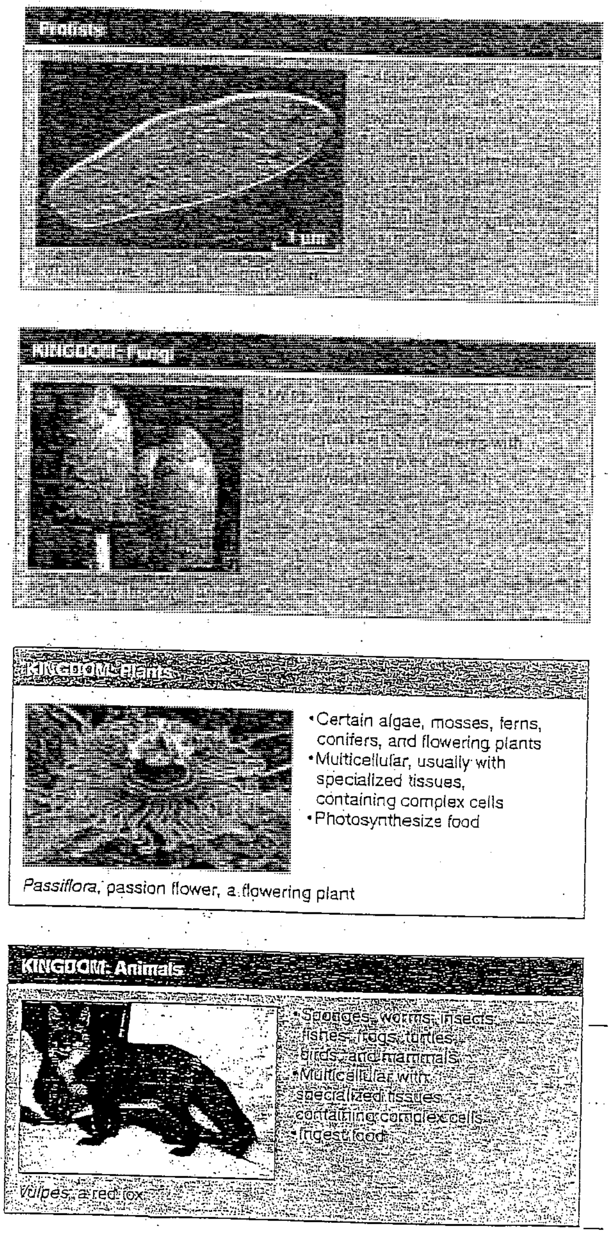


FIGURE 1.8 Domain Eukarya.

(kingdom Fungi) are the familiar molds and mushrooms that, along with bacteria, help decompose dead organisms. Animals (kingdom Animalia) are multicellular organisms that must ingest and process their food. Aardvarks, jellyfish, and zebras are representative animals.

Scientific Name

Biologists use binomial nomenclature [L. *bi*, two, and *nomen*, name] to assign each living thing a two-part name called a scientific name. For example, the scientific name for mistletoe is *Phoradendron tomentosum*. The first word is the genus, and the second word is the specific epithet of a species within a genus. The genus may be abbreviated (e.g., *P. tomentosum*) and the species may simply be indicated if it is unknown (e.g., *Phoradendron* sp.). Scientific names are universally used by biologists to avoid confusion. Common names tend to overlap and often are in the language of a particular country. But scientific names are based on Latin, a universal language that not too long ago was well known by most scholars.

Evolution Is Common Descent with Modification

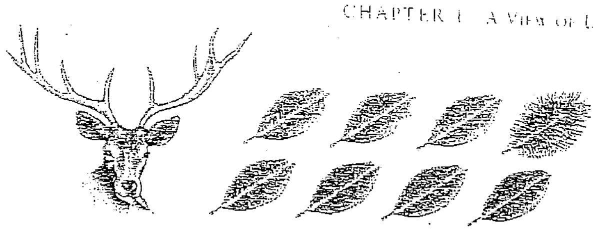
The phrase "common descent with modification" sums up the process of evolution because it means that, as descent occurs from common ancestors, so do modifications that cause organisms to be adapted to the environment. Through many observations and experiments, Charles Darwin came to the conclusion that natural selection was the process that made modification—that is, adaptation—possible.

Natural Selection

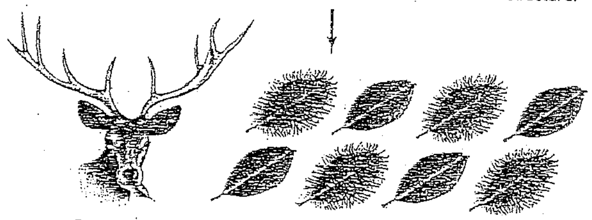
During the process of natural selection, some aspect of the environment selects which traits are more apt to be passed on to the next generation. The selective agent can be an abiotic agent (part of the physical environment, such as altitude) or it can be a biotic agent (part of the living environment, such as a deer). Figure 1.9 shows how the dietary habits of deer might eventually affect the characteristics of the leaves of a particular land plant.

Mutations fuel natural selection because mutation introduces variations among the members of a population. In Figure 1.9, a plant species generally produces smooth leaves, but a mutation occurs that causes one plant to have leaves that are covered with small extensions or "hairs." The plant with hairy leaves has an advantage because the deer (the selective agent) prefer to eat smooth leaves and not hairy leaves. Therefore, the plant with hairy leaves survives best and produces more seeds than most of its neighbors. As a result, generations later most plants of this species produce hairy leaves.

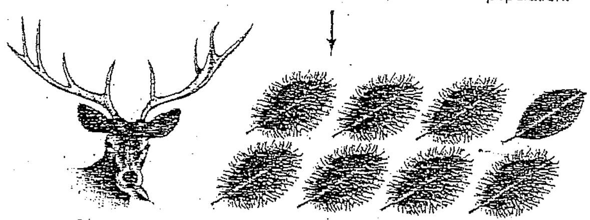
As with this example, Darwin realized that although all individuals within a population have the ability to reproduce, not all do so with the same success. Prevention of reproduction can run the gamut from an inability to capture resources, as when long-neck, but not short-neck, giraffes can reach their food source, to an inability to escape being eaten



Some plants within a population exhibit variation in leaf structure.



Deer prefer a diet of smooth leaves over hairy leaves. Plants with hairy leaves reproduce more than other plants in the population.



Generations later, most plants within the population have hairy leaves, as smooth leaves are selected against.

FIGURE 1.9 Natural selection.

Natural selection selects for or against new traits introduced into a population by mutations. Over many generations, selective forces such as competition, predation, and the physical environment alter the makeup of a population to more suit its environment and lifestyle.

because long legs but not short legs can carry an animal to safety. Whatever the example, it can be seen that living things with advantageous traits can produce more offspring than those that lack them. In this way, living things change over time, and these changes are passed on from one generation to the next. Over long periods of time, the introduction of newer, more advantageous traits into a population may drastically reshape a species. Natural selection tends to sculpt a species to fit its environment and lifestyle and can create new species from existing ones. The end result is the diversity of life classified into the three domains of life (see Fig. 1.5).

Check Your Progress 1.2

1. List the levels of taxonomic classification from most inclusive to least inclusive.
2. What differences might be used to distinguish the various kingdoms of domain Eukarya?
3. Explain how natural selection results in new adaptations within a species.

1.3 How the Biosphere Is Organized

The organization of life extends beyond the individual organism to the biosphere, the zone of air, land, and water at the surface of the Earth where organisms exist (see Fig. 1.2). Individual organisms belong to a population, which is all the members of a species within a particular area. The populations of a community interact among themselves and with the physical environment (e.g., soil, atmosphere, and chemicals), thereby forming an ecosystem.

Figure 1.10 depicts a grassland inhabited by populations of rabbits, mice, snakes, hawks, and various types of land plants. These populations exchange gases with and give off heat to the atmosphere. They also take in water from and give off water to the physical environment. In addition, populations interact by forming food chains in which one population feeds on another. Mice feed on plants and seeds, snakes feed on mice, and hawks feed on rabbits and snakes, for example. Interactions between the various food chains make up a food web.

Ecosystems are characterized by chemical cycling and energy flow, both of which begin when photosynthetic plants, aquatic algae, and some bacteria take in solar energy and inorganic nutrients to produce food in the form of organic nutrients. The gray arrows in Figure 1.10 represent chemical cycling—chemicals move from one population to another in a food chain, until with death and decomposition, inorganic nutrients are returned to living plants once again. The yellow to red arrows represent energy flow. Energy flows from the sun through plants and other members of the food chain as one population feeds on another. With each transfer some energy is lost as heat. Eventually, all the energy taken in by photosynthesizers has dissipated into the atmosphere. Because energy flows and does not cycle, ecosystems could not stay in existence without a constant input of solar energy and the ability of photosynthesizers to absorb it.

The Human Population

Humans possess the unique ability to modify existing ecosystems, which can greatly upset their natural nutrient cycles. When an ecosystem's natural energy flow has been disrupted by eliminating food sources for other animal populations even the human population can eventually suffer harm. Humans clear forests or grasslands to grow crops; later, they build houses on what was once farmland; and finally, they convert small towns into cities. Coastal ecosystems are most vulnerable. As they are developed, humans send sediments, sewage, and other pollutants into the sea. Human activities destroy valuable coastal wetlands, which serve as protection against storms and as nurseries for a myriad of invertebrates and vertebrates.

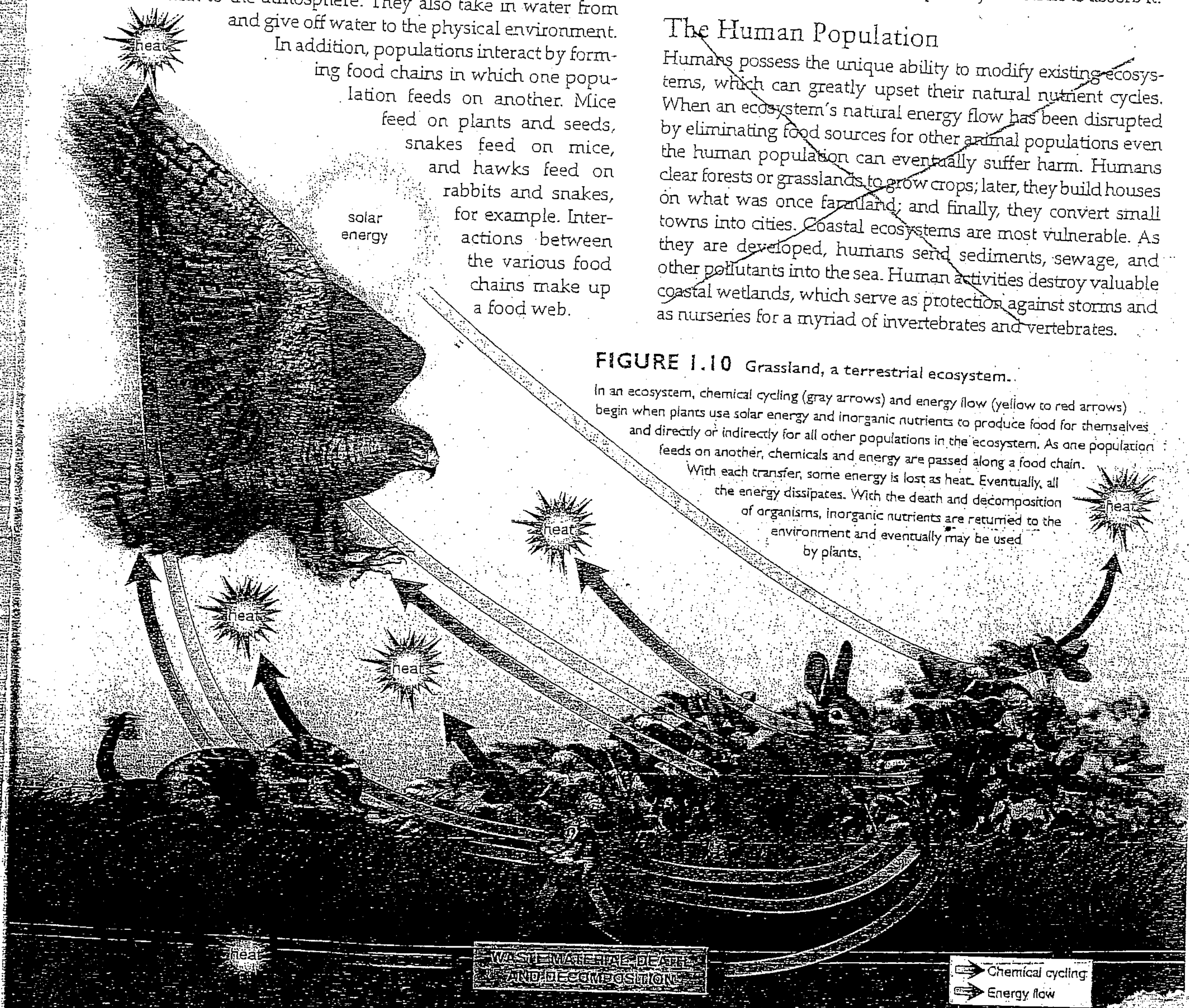


FIGURE 1.10 Grassland, a terrestrial ecosystem.

In an ecosystem, chemical cycling (gray arrows) and energy flow (yellow to red arrows) begin when plants use solar energy and inorganic nutrients to produce food for themselves and directly or indirectly for all other populations in the ecosystem. As one population feeds on another, chemicals and energy are passed along a food chain. With each transfer, some energy is lost as heat. Eventually, all the energy dissipates. With the death and decomposition of organisms, inorganic nutrients are returned to the environment and eventually may be used by plants.