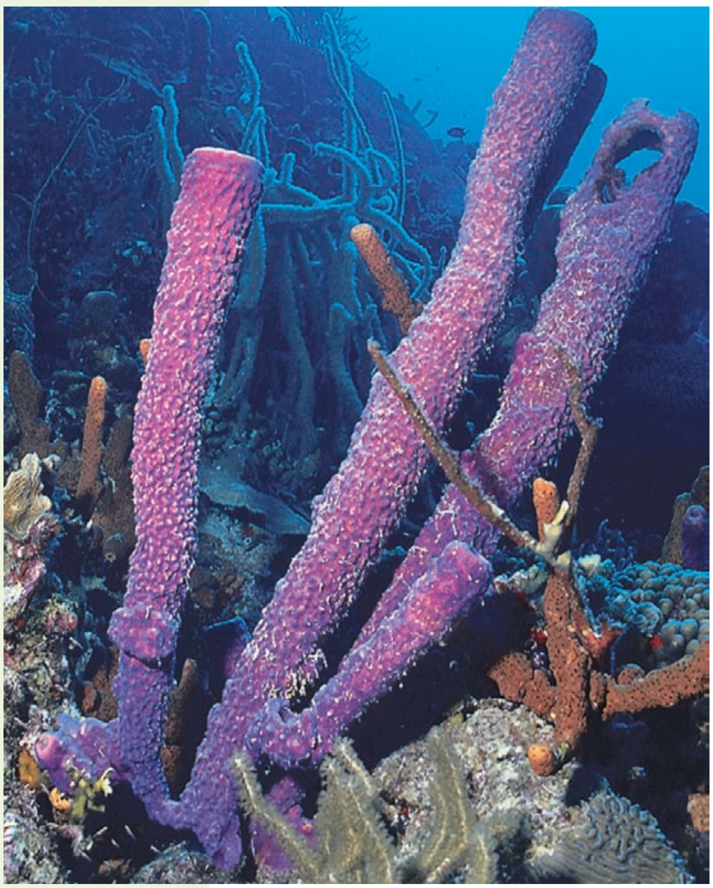
30 An Introduction to Animal Diversity



Charles V. Angelo/Photo Researchers, Inc.

The tube sponge (*Callyspongia vaginalis*). This animal, sometimes mistaken for a plant, ranges in color from purple to blue to gray. It is common on coral reefs in the Caribbean, from Florida to Mexico.

KEY CONCEPTS

30.1 Although they are a diverse group, animals share many characters. They are multicellular, eukaryotic heterotrophs composed of cells specialized to perform specific functions. Most animals are diploid organisms that reproduce sexually, and most have a nervous and muscular system.

30.2 Animals evolved in marine environments, and members of most animal phyla still inhabit marine environments. However, many animals are adapted to life in fresh water and others to terrestrial habitats.

30.3 The common ancestors of animals are choanoflagellates; choanoflagellates, fungi, and animals are a monophyletic group known as opisthokonts.

30.4 Biologists classify animals based on many characteristics, including their morphology, features of their early development, and on molecular data; they generally agree that bilateral animals split into at least three major clades.

Although members of most animal species are readily recognizable as animals, the identity of some others is less obvious. Early naturalists thought sponges were plants because they did not move from place to place. Some people still mistake certain marine animals, such as sponges and corals, for plants (see photograph). Locomotion is not a requirement for being classified as an animal.

Animal phylogeny is an exciting and rapidly changing field of study. Biologists have described and named more than 1.5 million species of animals, and 15,000 to 20,000 new species are named each year. Millions more probably remain to be discovered and classified. Interestingly, an estimated 99% of all animal species that ever inhabited our planet are extinct. Taxonomists have assigned the extant (living) animals to about 35 phyla. Molecular studies have confirmed that many of these groups are **monophyletic,** that is they consist of *all* of the descendants and *only* the descendants of a common ancestor. (Recall from Chapter 23 that a monophyletic group is called a **clade.**)

Animal groups that are not monophyletic have been split or reorganized, with some members of the groups being reassigned to other taxa. It is important to remember that the classification of animals and the relative positions of animal groups are a work in progress. As they consider new data, systematists redraw the tree of animal life.

In this chapter we discuss the characters of animals and their habitats. We then explore animal origins and some of the criteria biologists use to determine evolutionary relationships and to classify animals. In Chapter 31 we describe three phyla traditionally viewed as diverging early in the evolutionary history of animals. Then we discuss one of the major clades of animals: the protostomes. (In Chapter 32 we focus on the deuterostomes, which include the echinoderms and chordates—the clade to which we belong.) Many hypotheses are presented in these chapters, and we will discuss many examples of how systematists revise the relationships of the branches of the animal phylogenetic tree in response to new data.

30.1 ANIMAL CHARACTERS

LEARNING OBJECTIVE

1 Describe several characteristics common to most animals.

Animals are so diverse that for almost any definition we can find exceptions. We can best describe animals by the characteristics they share:

1. Animals are multicellular eukaryotes. In contrast to plants, algae, and fungi, their cells lack cell walls. Instead, structural support depends on collagen and other structural proteins. Collagen is an important *shared derived character* in animals (see Chapter 23).
2. Animals are **heterotrophs.** As consumers, they depend on producers for their raw materials and energy. In contrast to the fungi, most animals ingest their food first and then digest it inside the body, usually within a digestive system.
3. Cells that make up the animal body are specialized to perform specific functions. In all but the simplest animals, cells are organized to form tissues, and tissues are organized to form organs. In small animals with simple body plans, life processes such as gas exchange, circulation of materials, and waste disposal can take place by diffusion of gases and other substances directly to and from the environment. Specialized organ systems perform these functions in large animals.
4. Animals have diverse body plans. The term **body plan** refers to the basic structure and functional design of the body. An animal's body plan and lifestyle are adapted to its methods of obtaining food and reproducing.
5. Most animals are capable of locomotion at some time during their life cycle. Some animals (such as sponges and corals) move about as larvae (immature forms) but are **sessile** (firmly attached to the ground or some other surface) as adults (see chapter opening photograph).
6. Most animals have nervous systems and muscle systems that enable them to respond rapidly to stimuli in their environment.
7. Most animals are diploid organisms that reproduce sexually, with large, nonmotile eggs and small, flagellate sperm. A haploid sperm unites with a haploid egg, forming a diploid **zygote** (fertilized egg).
8. Animals go through a period of embryonic development. The zygote undergoes **cleavage,** a series of mitotic cell divisions. During cleavage the zygote develops into a hollow ball of cells called a **blastula.** Although some animals develop directly into adults, the majority first develop into a **larva,** a sexually immature form that may look very different from the adult (**FIG. 30-1**). The larva differs from the adult in many ways, including where it lives (its habitat), how it moves, and what it eats. Larvae typically go through **metamorphosis,** a developmental process that converts the immature animal into a juvenile form that can then grow into an adult.

Review

- For centuries, scientists classified sponges as plants, but now they are classified as animals. What criteria do biologists use to classify them as animals?

30.2 ADAPTATIONS TO OCEAN, FRESHWATER, AND TERRESTRIAL HABITATS

LEARNING OBJECTIVE

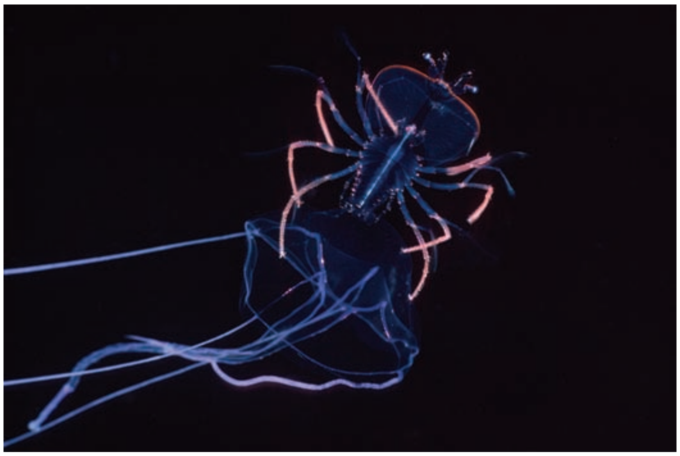
2 Compare the advantages and disadvantages of life in the ocean, in fresh water, and on land.

Fossil evidence suggests that animals evolved in shallow, marine environments during the Proterozoic eon, at least 600 million years ago (mya; see Chapter 21). Although animals are now distributed in virtually every environment, at least some members of most animal phyla still inhabit marine environments.

Marine habitats offer many advantages

The buoyancy of sea water provides support, and its large volume keeps the water temperature relatively stable. The body fluids of most invertebrates have about the same osmotic concentration as sea water, so fluid and salt balance are more easily maintained than in fresh water. **Plankton,** which consists of the mainly microscopic animals and protists that are suspended in water and float with its movement, provides a ready source of food for many aquatic animals.

Life in the ocean also presents some challenges. Although the continuous motion of water brings nutrients to animals and washes their wastes away, animals must be able to cope with the water's movements and the currents that could sweep them away. Squids, fishes, and marine mammals have evolved as strong swimmers, usually able to direct their movements and maintain their location. However, most invertebrates and young



Doug Perrine/SeaPics.com

(a) Spiny lobster larva. This larva is hitching a ride on a jellyfish. Over a period of months, the larva passes through several stages before becoming an adult. Photographed in open ocean at night, Hawaii.

Dr. Magnus Kjaergaard

(b) Adult spiny lobster. The adult has two long antennae used to sense movement. Spiny lobsters lack large claws. The spines on their back help protect them. In this image you can see the two large spines above the animal's eyes. Spiny lobsters leave their hiding places at night to hunt.

FIGURE 30-1 **Larva and adult spiny lobster (*Panulirus* sp.)**

Most animals go through a larva stage before developing into an adult. The larva usually differs from the adult in size, appearance, and in lifestyle.

vertebrates cannot swim strongly, and they have adapted in various ways to the tides and currents.

Some sessile animals attach permanently to a stable structure such as a rock. Others burrow in the sand and silt that cover the sea bottom. Many invertebrates have adapted by maintaining a small body size and becoming part of the plankton. As they are tossed about, their food supply continues to surround them.

Some animals are adapted to freshwater habitats

Far fewer kinds of animals make their homes in fresh water than in the ocean because living in this habitat is more difficult. Fresh water is hypotonic to the tissue fluids of animals, so water tends to move into the animal by osmosis. To survive in this habitat, freshwater species must have mechanisms for removing excess water while retaining salts. This *osmoregulation* requires an expenditure of energy.

Fresh water offers a much less constant environment than sea water. Animals that inhabit fresh water must have adaptations for surviving variations in oxygen content, temperature, turbidity (because of sediments suspended in the water), and even water volume. In addition, fresh water generally contains less food than the sea.

Terrestrial living requires major adaptations

Living on land is even more difficult than living in fresh water, and the evolution of terrestrial animals involved major adaptations. Analyzing the fossil record, many biologists hypothesize that the first air-breathing terrestrial animals were scorpion-like arthropods that came ashore in the Silurian period about 444 mya. The first vertebrates to inhabit terrestrial environments, the amphibians, did not appear until the Devonian period, about 30 million years later.

The chief problem facing all terrestrial organisms is desiccation (drying out). Water is constantly lost by evaporation and is often difficult to replace. A body covering adapted to minimize fluid loss helps solve this problem in many terrestrial animals (**FIG. 30-2**). Location of the respiratory surface deep within the animal also helps prevent fluid loss. Thus, the gills of aquatic animals are typically located externally, but lungs and tracheal tubes of terrestrial animals are typically found deep within the body.

Reproduction on land also poses challenges to protect gametes and the developing offspring from desiccation. Aquatic animals typically shed their gametes in the water, where fertilization occurs. The surrounding water also serves as an effective shock absorber that protects the delicate embryos as they develop. Some land animals, including most amphibians, return to the water for reproduction, and their larval forms develop in the water.

The evolution of internal fertilization has permitted many terrestrial animals, including earthworms, land snails, insects, reptiles, birds, and mammals, to meet the desiccation challenge. Because these terrestrial animals transfer sperm from the body of the male directly into the body of the female by copulation, a watery medium continuously surrounds the sperm. Another important adaptation to reproduction on land is the tough, protective shell that surrounds the eggs of many species (see Fig. 30-2). Secreted by the female, this shell protects the developing embryo from drying out.

E. R. Degginger/Photo Researchers, Inc.

FIGURE 30-2 **Adaptations to terrestrial life**
The tough, horny skin of the green iguana (*Iguana iguana*) has scales and is water resistant. Leathery eggs protect the embryos from drying out.

An alternative adaptation for terrestrial reproduction is development of the embryo within the moist body of the mother.

Water has buoyancy that helps support animals that inhabit this environment. Air is less dense than water, and to inhabit the land, animals must have structures, such as a skeletal system and muscles, that support the body. The temperature extremes of terrestrial habitats also present challenges. In later chapters we discuss behavioral and physiological adaptations for maintaining body temperature.

Review

- What are some advantages of marine environments over freshwater and terrestrial habitats?
- What are some animal adaptations to the terrestrial environment?

30.3 ANIMAL EVOLUTION

LEARNING OBJECTIVE

3 Use current hypotheses to trace the early evolution of animals.

Biologists generally agree that animals share a common ancestor with a group of protists known as *choanoflagellates* (see Fig. 26-21). The cells of these colonial flagellates became specialized to perform specific functions, such as movement, feeding, or reproduction. As this division of labor evolved, a colony of flagellates reached the level of cooperation and coordination that qualified it to be considered a single organism—the first animal. The choanoflagellates, fungi, and animals are a monophyletic group known as **opisthokonts.** Recall from Chapter 26 that opisthokonts are characterized by a posterior flagellum on motile cells.

Historically, biologists depended on fossils, on similarities in body plan, and on patterns of development to determine evolutionary relationships among various groups of animals. **Molecular systematics,** the science that focuses on molecular structure to clarify evolutionary relationships, has provided additional data that are critical in answering questions about phylogeny. In many cases, molecular data have confirmed hypotheses that were based on morphology.

Complex genomes were apparently present early during animal evolution. Molecular studies suggest that the ancestor of animals had more than 1500 genes not found in other eukaryotes. Some of these genes may be traced to horizontal gene transfer from other domains, followed by modification of the genes. Complex genomes have been described in the sea anemone and in other animals that are relatively simple morphologically.

Molecular analyses indicate that the structure of genes that control development, RNA molecules, and many other molecules are very similar among all animal groups that have been studied. According to the *principle of parsimony,* such complex molecules are unlikely to have evolved multiple times (see Chapter 23). Thus, these data support the hypothesis that animals evolved only once. Animals are a monophyletic group.

Molecular systematics helps biologists interpret the fossil record

The evolutionary history of animals has been vigorously debated, because early animals were soft-bodied forms that left few fossils. The scarcity of fossils has made it difficult to determine the age, rate of divergence, and number of branches of animal groups. In 2009, a research team found fossil traces in an oil field on the Arabian Peninsula that are thought to date back more than 635 million years. The fossil traces are steroids found only in the skeletal structures of certain sponges (demosponges). Before this discovery, the earliest known animal fossils were the **Ediacaran biota** from the Ediacaran period (600 mya to 542 mya). These fossils of small, simple animals suggest that sponges, jellyfish, and comb jellies were present during this period (see Fig. 21-9).

Paleontologists have discovered many large, complex animal fossils in Chengjiang, an Early Cambrian (542 mya to 520 mya) fossil site in China, and in the Burgess Shale in British Columbia, a Middle Cambrian fossil site (520 mya to 515 mya). Fossils of most extant phyla (and also many extinct animals) have been found at these sites. The rapid appearance of an amazing variety of body plans during this time is known as the **Cambrian radiation,** or less formally as the **Cambrian explosion** (see Fig. 21-10). According to the Cambrian radiation hypothesis, which is based on the fossil record, major modifications in body plan that occurred during this time account for many branches of the animal tree.

Studies of large molecular data sets suggest that most animal clades actually diverged over a very long period during the Proterozoic eon (2.5 bya to 542 mya). Thus, the animal phyla that first left fossils during the Cambrian radiation may have evolved several hundred million years *before* they appear in the fossil record. Biologists estimate that certain groups are about twice as old as the oldest fossils found to date. According to this view, the Cambrian radiation was a rapid evolution of new animal body plans among clades that already existed. Perhaps fossils of these early animals remain to be discovered in Proterozoic rocks. Another hypothesis