

## THE VERTEBRATES

**Chordates (phylum Chordata)** are deuterostome coelomates whose nearest relatives in the animal kingdom are the echinoderms, the only other deuterostomes. However, unlike echinoderms, chordates are characterized by a notochord, jointed appendages, and segmentation.

Four features characterize the chordates and have played an important role in the evolution of the phylum:

1. **A single, hollow nerve cord** runs just beneath the dorsal surface of the animal. In vertebrates, the dorsal nerve cord differentiates into the brain and spinal cord.
2. **A flexible rod**, the notochord, forms on the dorsal side of the primitive gut in the early embryo and is present at some developmental stage in all chordates. The notochord is located just below the nerve cord. The notochord may persist throughout the life cycle of some chordates or be displaced during embryonic development, as in most vertebrates, by the vertebral column that forms around the nerve cord.
3. **Pharyngeal slits** connect the pharynx, a muscular tube that links the mouth cavity and the esophagus, with the outside. In terrestrial vertebrates, the slits do not actually connect to the outside and are better termed pharyngeal pouches. Pharyngeal pouches are present in the embryos of all vertebrates. They become slits, open to the outside in animals with gills, but disappear in those lacking gills. The presence of these structures in all vertebrate embryos provides evidence of their aquatic ancestry.
4. Chordates have a **postanal tail** that extends beyond the anus, at least during their embryonic development. Nearly all other animals have a terminal anus.

### **The Nonvertebrate Chordates**

Nonvertebrate chordates have a notochord but no backbone.

*The tunicates (subphylum Urochordata)* are a group of about 1250 species of marine animals. Most of them are sessile as adults, with only the larvae having a notochord and nerve cord. As adults, they exhibit neither a major body cavity nor visible signs of segmentation. Most species occur in shallow waters, but some are found at great depths.

*Lancelets are scaleless*, fishlike marine chordates a few centimeters long that occur widely in shallow water throughout the oceans of the world. Lancelets (subphylum Cephalochordata) were given their English name because they resemble a lancet—a small, two-edged surgical knife. There are about 23 species of this subphylum. Most of them belong to the genus *Branchiostoma*, formerly called *Amphioxus*, a name still used widely. In lancelets, the notochord runs the entire length of the dorsal nerve cord and persists throughout the animal's life.

### **Characteristics of Vertebrates**

The evolution of vertebrates involved invasions of sea, land, and air.

Vertebrates (subphylum Vertebrata) are chordates with a spinal column. The name vertebrate comes from the individual bony or cartilaginous segments called vertebrae that make up the spine. Vertebrates differ from the tunicates and lancelets in two important respects:

1. **Vertebral column.** In all vertebrates except the earliest fishes, the notochord is replaced during the course of embryonic development by a vertebral column (figure 34.8). The column is a series of bony or cartilaginous vertebrae that enclose and protect the dorsal nerve cord like a sleeve.

2. **Head.** Vertebrates have a distinct and well differentiated head; the brain is fully encased within a protective box, the skull or cranium, made of bone or cartilage. For this reason, the vertebrates are sometimes called the craniate chordates.

In addition to these two key characteristics, vertebrates differ from other chordates in other important respects:

1. **Neural crest.** A unique group of embryonic cells called the neural crest contributes to the development of many vertebrate structures. These cells develop on the crest of the neural tube as it forms by invagination and pinching together of the neural plate. Neural crest cells then migrate to various locations in the developing embryo, where they participate in the development of a variety of structures.

2. **Internal organs.** Internal organs characteristic of vertebrates include a liver, kidneys, and endocrine glands. The ductless endocrine glands secrete hormones that help regulate many of the body's functions. All vertebrates have a heart and a closed circulatory system. In both their circulatory and their excretory functions, vertebrates differ markedly from other animals.

3. **Endoskeleton.** The endoskeleton of most vertebrates is made of cartilage or bone. Cartilage and bone are specialized tissue containing fibers of the protein collagen compacted together. Bone also contains crystals of a calcium phosphate salt. Bone forms in two stages. First, collagen is laid down in a matrix of fibers along stress lines to provide flexibility, and then calcium minerals infiltrate the fibers, providing rigidity. The great advantage of bone over chitin as a structural material is that bone is strong without being brittle. The vertebrate endoskeleton makes possible the great size and extraordinary powers of movement that characterize this group.

### **Overview of the Evolution of Vertebrates**

The first vertebrates evolved in the oceans about 470 million years ago. They were jawless fishes with a single caudal fin. Many of them looked like a flat hot dog, with a hole at one end and a fin at the other. The appearance of a hinged jaw was a major advancement, opening up new food options, and jawed fishes became the dominant creatures in the sea.

### **MAMMALS (CLASS MAMMALIA)**

There are about 4500 living species of mammals (class Mammalia), the smallest number of species in any of the five classes of vertebrates. Most large, land-dwelling vertebrates are mammals (figure 34.38), and they tend to dominate terrestrial communities, as did the dinosaurs they replaced.

### **Major Orders of Mammals**

Order || Typical Examples || Key Characteristics || Approximate Number of Living Species

*Rodentia* || Beavers, mice, porcupines, rats. || Small plant-eaters. Chisel-like incisor teeth || 1814

*Chiroptera* || Bats Flying mammals. || Primarily fruit- or insect-eaters; elongated fingers; thin wing membrane; nocturnal; navigate by sonar || 986

*Insectivora* || Moles, shrews || Small, burrowing mammals Insect-eaters; the most primitive placental mammals; spend most of their time underground ||390

*Marsupialia* || Kangaroos, koalas || Pouched mammals. Young develop in abdominal pouch || 280

*Carnivora* || Bears, cats, raccoons, weasels, dogs || Carnivorous predators. Teeth adapted for shearing flesh; no native families in Australia || 240

*Primates* || Apes, humans, lemurs, monkeys || Tree-dwellers. Large brain size; binocular vision; opposable thumb; group that evolved from a line that branched off early from other mammals || 233

*Artiodactyla* ||Cattle, deer, giraffes, pigs || Hoofed mammals. With two or four toes; mostly herbivores || 211

*Cetacea* || Dolphins, porpoises, whales || Fully marine mammals. Streamlined bodies; front limbs modified into flippers; no hind limbs; blowholes on top of head; no hair except on muzzle || 79

*Lagomorpha* || Rabbits, hares, pika || Rodent-like jumpers. Four upper incisors (rather than the two seen in rodents); hind legs often longer than forelegs, an adaptation for jumping || 69

*Pinnipedia* || Sea lions, seals, walruses || Marine carnivores. Feed mainly on fish; limbs modified for swimming || 34

*Edentata* || Anteaters, armadillos, sloths || Toothless insect-eaters. Many are toothless, but some have degenerate, peg like teeth || 30

*Perissodactyla* || Horses, rhinoceroses, zebras || Hoofed mammals with one or three toes Herbivorous teeth adapted for chewing || 17

*Proboscidea* || Elephants || Long-trunked herbivores. Two upper incisors elongated as tusks; largest living land animal || 2

### **Key Mammalian Characteristics**

Mammals are distinguished from all other classes of vertebrates by two fundamental characteristics - hair and mammary glands-and are marked by several other notable features:

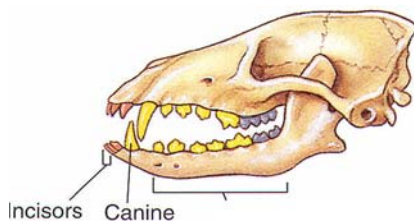
**Hair.** All mammals have hair. Even apparently naked whales and dolphins grow sensitive bristles on their snouts. The evolution of fur and the ability to regulate body temperature enabled mammals to invade colder climates that ectothermic reptiles

could not inhabit, and the insulation fur provided may have ensured the survival of mammals when the dinosaurs perished.

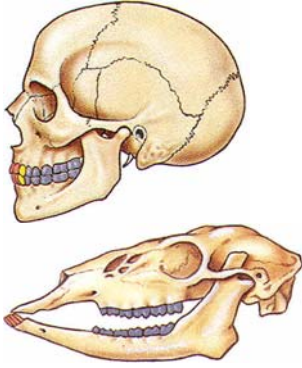
**Mammary glands.** All female mammals possess mammary glands that secrete milk. Newborn mammals, born without teeth, suckle this milk. Even baby whales are nursed by their mother's milk. Milk is a fluid rich in fat, sugar, and protein. A liter of human milk contains 11 grams of protein, 49 grams of fat, 70 grams of carbohydrate (chiefly the sugar lactose), and 2 grams of minerals critical to early growth, such as calcium. About 95% of the volume is water, critical to avoid dehydration. Milk is a very high calorie food (human milk has 750 kcal per liter), important because of the high energy needs of a rapidly growing.

**Endothermy.** As stated previously, mammals are endothermic, a crucial adaptation that has allowed them to be active at any time of the day or night and to colonize severe environments, from deserts to ice fields. Many characteristics, including hair that provides insulation, played important roles in making endothermy possible. **Placenta.** In most mammal species, females carry their young in a uterus during development, nourishing them through a placenta, and give birth to live young. The placenta is a specialized organ within the uterus of the pregnant mother that brings the bloodstream of the fetus into close contact with the bloodstream of the mother. **Teeth.** Reptiles have homodont dentition, meaning that their teeth are all the same. However, mammals have heterodont dentition, with different types of teeth that are highly specialized to match particular eating habits (figure 34.40). It is usually possible to determine a mammal's diet simply by examining its teeth. Compare the skull of a dog (a carnivore) and a deer (an herbivore). The dog's long canine teeth are well suited for biting and holding prey, and some of its premolar and molar teeth are triangular and sharp for ripping off chunks of flesh. In contrast, canine teeth are absent in deer; instead, the deer clips off mouthfuls of plants with flat, chisel-like incisors on its lower jaw. The deer's molars are large and covered with ridges to effectively grind and break up tough plant tissues. Rodents, such as beavers, are gnawers and have long incisors for chewing through branches or stems. These incisors are ever-growing; that is, the ends wear down, but new incisor growth maintains the length.

Mammals have different types of specialized teeth. While reptiles have all the same kind of teeth, mammals have different types of teeth specialized for different feeding habits.



**Carnivores**, such as dogs, have canine teeth that are able to rip food; some of the premolars and molars in dogs are also ripping teeth.



**Herbivores**, such as deer, have incisors to chisel off vegetation and molars designed to grind up the plant material. In the beaver, the chiseling incisors dominate. In the elephant, the incisors have become specialized weapons, and molars grind up vegetation.

Humans are **omnivores**; we have ripping, chiseling, and grinding teeth.

**Digestion of plants.** Most mammals are herbivores, eating mostly or only plants. Cellulose, the major component of plant cell walls, forms the bulk of a plant's body and is a major source of food for mammalian herbivores.

**Hooves and horns.** Keratin, the protein of hair, is also the structural building material in claws, fingernails, and hooves. Hooves are specialized keratin pads on the toes of horses, cows, sheep, antelopes, and other running mammals. The horns of cattle, sheep, and antelope are composed of a core of bone surrounded by a sheath of keratin. The bony core is attached to the skull, and the horn is not shed.

**Flight.** Bats are the only mammals capable of powered flight (figure 34.41). Like the wings of birds, bat wings are modified forelimbs. The bat wing is a leathery membrane of skin and muscle stretched over the bones of four fingers.