**Chapter 17**

# The Evolution of Animals

## Biology and Society: The Discovery of the Hobbit People

- In 2003, anthropologists discovered bones on the Indonesian island of Flores, dating back about 18,000 years, of people just over three feet tall, and with heads one-third the size of modern humans.
- Since the initial discovery, researchers have unearthed the bones of a dozen or so more of these miniature humans.

Figure 17.0

- Some scientists think that these bones represent a previously unknown human species, named *Homo floresiensis*.
- Other scientists suggest that the bones are from diseased *Homo sapiens*.

## THE ORIGINS OF ANIMAL DIVERSITY

- Animal life began in Precambrian seas with the evolution of multicellular creatures that ate other organisms.

### What Is an Animal?

- **Animals** are
  - eukaryotic,
  - multicellular,
  - heterotrophic organisms that obtain nutrients by ingestion, and
  - able to digest their food within their bodies.

Figure 17.1

- Animal cells lack the cell walls that provide strong support in the bodies of plants and fungi.
- Most animals have
  - muscle cells and
  - nerve cells that control the muscles.
- Most animals
  - are diploid,
  - reproduce sexually, and
  - proceed through a series of typically similar developmental stages.

Figure 17.2
Figure 17.2a-1
Figure 17.2a-2
Figure 17.2a-3
Figure 17.2a-4
Figure 17.2b-1
Figure 17.2b-2
Figure 17.2b-3
Figure 17.2b-4

### Early Animals and the Cambrian Explosion

- Scientists hypothesize that animals evolved from a colonial flagellated protist.
- The oldest animal fossils found are 550–575 million years old.
- The molecular data suggest a much earlier origin for animals.

Figure 17.3
Figure 17.4
Figure 17.4a
Figure 17.4b

- Animal diversification appears to have accelerated rapidly from 525-535 million years ago, during the Cambrian period.
- Because so many animal body plans and new phyla appear in the fossils from such an evolutionarily short time span, biologists call this episode the Cambrian explosion.
- The Cambrian explosion may have been ignited by
  - increasingly complex predator-prey relationships and/or
  - an increase in atmospheric oxygen.
- The genetic framework for complex bodies, a set of “master control” genes, was already in place.

Figure 17.5
Figure 17.5a
Figure 17.5b

### Animal Phylogeny

- Biologists categorize animals by
  - “body plan,” general features of body structure and,
  - more recently, genetic data.
- One major branch point distinguishes sponges from all other animals because, unlike more complex animals, sponges lack true tissues.

Figure 17.6

- A second major evolutionary split is based on body symmetry.
  - **Radial symmetry** refers to animals that are identical all around a central axis.

- **Bilateral symmetry** exists where there is only one way to split the animal into equal halves.

Figure 17.7

- Animals also vary according to the presence and type of **body cavity**, a fluid-filled space separating the digestive tract from the outer body wall.
- There are differences in how the body cavity develops.
  - If the body cavity is not completely lined by tissue derived from mesoderm, it is called a **pseudocoelom**.
  - A true **coelom** is completely lined by tissue derived from mesoderm.

Figure 17.8
Figure 17.8a
Figure 17.8b
Figure 17.8c

**MAJOR INVERTEBRATE PHYLA**

- **Invertebrates**
  - are animals without backbones and
  - represent 95% of the animal kingdom.

**Sponges**

- **Sponges** represent multiple phyla.
- Sponges
  - are stationary animals,
  - lack true tissues, and
  - probably evolved very early from colonial protists.
- The body of a sponge resembles a sac perforated with holes.
- Choanocyte cells draw water through the walls of the sponge where food is collected.

Figure 17.9
Figure 17.9a
Figure 17.9b

**Cnidarians**

- **Cnidarians** (phylum Cnidaria) are characterized by
  - the presence of body tissues,
  - radial symmetry, and
  - tentacles with stinging cells.
- The basic body plan of a cnidarian is a sac with a **gastrovascular cavity**, a central digestive compartment with only one opening.
- The body plan has two variations:
  - the stationary **polyp** and
  - the floating **medusa.**

Figure 17.10
Figure 17.10a
Figure 17.10aa
Figure 17.10ab
Figure 17.10ac
Figure 17.10ad
Figure 17.10b
Figure 17.10ba
Figure 17.10bb

- Cnidarians are carnivores that use tentacles, armed with cnidocytes (“stinging cells”),
  - for defense and
  - to capture prey.

Figure 17.11-1
Figure 17.11-2
Figure 17.11-3

**Molluscs**

- **Molluscs** (phylum Mollusca) are
  - represented by soft-bodied animals and
  - usually protected by a hard shell.
- Many molluscs feed by using a file-like organ called a **radula** to scrape up food.
- The body of a mollusc has three main parts:
  - a muscular foot used for movement,
  - a visceral mass containing most of the internal organs, and
  - a **mantle**, a fold of tissue that secretes the shell if present.

Figure 17.12
Figure 17.12a
Figure 17.12b

- There are three major groups of molluscs.
  - **Gastropods**
    - include snails, which

- are protected by a single, spiraled shell, or
- have no shell at all, as with slugs and sea slugs.

Figure 17.13
Figure 17.13a
Figure 17.13aa
Figure 17.13ab
Figure 17.13ac
Figure 17.13b
Figure 17.13ba
Figure 17.13bb

**Flatworms**

- **Flatworms** (phylum Platyhelminthes) are the simplest bilateral animals.
- Flatworms include forms that are
  - parasites or
  - free-living in marine, freshwater, or damp habitats.

**Flatworms**

- The **gastrovascular cavity** of flatworms
  - is highly branched and
  - provides an extensive surface area for absorption of nutrients.

Figure 17.14
Figure 17.14a
Figure 17.14b
Figure 17.14ba
Figure 17.14bb
Figure 17.14c

**Annelids**

- **Annelids** (phylum Annelida) have **body segmentation**, a subdivision of the body along its length into a series of repeated parts.

**Annelids**

- The three main groups of annelids are
  - **earthworms**, which eat their way through soil,
  - **polychaetes**, marine worms with segmental appendages for movement and gas exchange, and
  - **leeches,** typically free-living carnivores but with some bloodsucking forms.

Figure 17.15
Figure 17.15a
Figure 17.15b
Figure 17.15c

- The body of annelids includes
  - a **coelom** and
  - a **complete digestive tract** with
    - two openings, a mouth and anus, and
    - one-way movement of food.

Figure 17.16
Figure 17.15c

**Roundworms**

- **Roundworms** (phylum Nematoda) are
  - cylindrical in shape, tapered at both ends, and
  - the most numerous and widespread of all animals.
- Roundworms (also called **nematodes**) are
  - important decomposers and
  - dangerous parasites in plants, humans, and other animals.

Figure 17.17
Figure 17.17a
Figure 17.17b
Figure 17.17c

**Arthropods**

- **Arthropods** (phylum Arthropoda) are named for their jointed appendages.
- There are over 1 million arthropod species identified, mostly insects.
- Arthropods are a very diverse and successful group, occurring in nearly all habitats in the biosphere.
- There are four main groups of arthropods:
  - arachnids,
  - crustaceans,
  - millipedes and centipedes, and
  - insects.

Figure 17.18

***General Characteristics of Arthropods***

- Arthropods are segmented animals with
  - specialized segments and
  - appendages for an efficient division of labor among body regions.

***General Characteristics of Arthropods***

- The body of arthropods is completely covered by an **exoskeleton**, an external skeleton that provides
  - protection and
  - points of attachment for the muscles that move appendages.

Figure 17.19

***Arachnids***

- **Arachnids**
  - usually live on land,
  - usually have four pairs of walking legs and a specialized pair of feeding appendages, and
  - include spiders, scorpions, ticks, and mites.

Figure 17.20
Figure 17.20a
Figure 17.20b
Figure 17.20c
Figure 17.20d
Figure 17.20e

***Crustaceans***

- **Crustaceans**
  - are nearly all aquatic,
  - have multiple pairs of specialized appendages, and
  - include crabs, lobsters, crayfish, shrimp, and barnacles.

Figure 17.21
Figure 17.21a
Figure 17.21b
Figure 17.21c
Figure 17.21d
Figure 17.21e
Figure 17.21f

***Millipedes and Centipedes***

- Millipedes and centipedes have similar segments over most of the body.
- **Millipedes**
  - eat decaying plant matter and
  - have two pairs of short legs per body segment.
- **Centipedes**
  - are terrestrial carnivores with poison claws and
  - have one pair of short legs per body segment.

Figure 17.22
Figure 17.22a
Figure 17.22b

***Insect Anatomy***

- **Insects** typically have a three-part body consisting of
  - head,
  - thorax, and
  - abdomen.
- The insect head usually bears
  - a pair of sensory antennae and
  - a pair of eyes.
- The mouthparts are adapted for particular kinds of eating.
- Flight is one key to the great success of insects.

Figure 17.23

***Insect Diversity***

- Insects outnumber all other forms of life combined.
- Insects live in
  - almost every terrestrial habitat,
  - fresh water, and
  - the air.

Figure 17.24
Figure 17.24a
Figure 17.24aa
Figure 17.24ab
Figure 17.24ac
Figure 17.24ad
Figure 17.24b
Figure 17.24ba
Figure 17.24bb
Figure 17.24bc
Figure 17.24bd

- Many insects undergo **metamorphosis** in their development.
- Young insects may
  - appear to be smaller forms of the adult or
  - change from a larval form to something much different as an adult.

Figure 17.25
Figure 17.25a
Figure 17.25b
Figure 17.25c

**Echinoderms**

- **Echinoderms** (phylum Echinodermata)
  - lack body segments,
  - typically show radial symmetry as adults but bilateral symmetry as larvae,
  - have an **endoskeleton**, and
  - have a **water vascular system** that facilitates movement and gas exchange.

**Echinoderms**

- Echinoderms are a very diverse group.

Figure 17.26
Figure 17.26a
Figure 17.26aa
Figure 17.26ab
Figure 17.26ac
Figure 17.26b
Figure 17.26c
Figure 17.26d

**VERTEBRATE EVOLUTION AND DIVERSITY**

- **Vertebrates** have unique endoskeletons composed of
  - a cranium (skull) and
  - a backbone made of a series of bones called vertebrae.

Figure 17.27

**Characteristics of Chordates**

- **Chordates** (phylum Chordata) all share four key features that appear in the embryo and sometimes the adult:
  - a **dorsal, hollow nerve cord**,
  - a **notochord**,
  - **pharyngeal slits**, and
  - a **post-anal tail**.

Figure 17.28

- Another chordate characteristic is body segmentation, apparent in the
  - backbone of vertebrates and
  - segmental muscles of all chordates.
- Chordates consists of three groups of invertebrates:
  - **lancelets** are bladelike animals without a cranium,
  - **tunicates**, or sea squirts, also lack a cranium, and
  - hagfishes are eel-like forms that have a cranium.
- All other chordates are vertebrates.

Figure 17.29
Figure 17.29a
Figure 17.29b

- An overview of chordate and vertebrate evolution

Figure 17.30

**Fishes**

- The first vertebrates were aquatic and probably evolved during the early Cambrian period, about 542 million years ago. They
  - lacked jaws and
  - are represented today by lampreys.

**Fishes**

- Hagfish
  - also lack jaws,
  - have a cranium, but
  - are not vertebrates.

Figure 17.31
Figure 17.31a
Figure 17.31ba
Figure 17.31bb

- The two major groups of living fishes are the
  - **cartilaginous fishes** (sharks and rays), with a flexible skeleton made of cartilage, and
  - **bony fishes,** with a skeleton reinforced by hard calcium salts.
- Bony fishes include
  - **ray-finned fishes** and
  - **lobe-finned fishes**.

Figure 17.31c
Figure 17.31d

**Amphibians**

- **Amphibians**
  - exhibit a mixture of aquatic and terrestrial adaptations,

- usually need water to reproduce, and
- typically undergo metamorphosis from an aquatic **larva** to a terrestrial adult.

Figure 17.32
Figure 17.32a
Figure 17.32b
Figure 17.32c
Figure 17.32d

- Amphibians
  - were the first vertebrates to colonize land and
  - descended from fishes that had
    - lungs,
    - fins with muscles, and
    - skeletal supports strong enough to enable some movement on land.

Figure 17.33

**Reptiles**

- Reptiles (including birds) and mammals are **amniotes**, which produce **amniotic eggs**, which
  - are fluid-filled,
  - have waterproof shells, and
  - enclose the developing embryo.
- Reptiles include
  - snakes,
  - lizards,
  - turtles,
  - crocodiles,
  - alligators, and
  - birds.
- Reptile adaptations to living on land include
  - an amniotic egg and
  - scaled waterproof skin.

Figure 17.34
Figure 17.34a
Figure 17.34aa
Figure 17.34ab
Figure 17.34ac
Figure 17.34b
Figure 17.34ba
Figure 17.34bb
Figure 17.34bc

***Nonbird Reptiles***

- Nonbird reptiles are **ectotherms**, sometimes referred to as "cold-blooded," which means that they obtain body heat from the environment.
- A nonbird reptile can survive on less than 10% of the calories required by a bird or mammal of equivalent size.
- Reptiles diversified extensively during the Mesozoic era.
- Dinosaurs were
  - the most diverse reptile group and
  - the largest animals ever to live on land.

***Birds***

- Recent genetic and fossil evidence shows that during the great reptilian radiation of the Mesozoic era, **birds** evolved from a lineage of small, two-legged dinosaurs called theropods.
- Birds have many adaptations that make them lighter in flight:
  - honeycombed bones,
  - one instead of two ovaries, and
  - a beak instead of teeth.
- Unlike other reptiles, birds are **endotherms**, maintaining a warmer and steady body temperature.
- Bird wings adapted for flight are airfoils, powered by breast muscles anchored to a keel-like breastbone.

Figure 17.35

**Mammals**

- The first **mammals**
  - arose about 200 million years ago and
  - were probably small, nocturnal insect-eaters.
- Most mammals are terrestrial, although dolphins, porpoises, and whales are totally aquatic.

- Mammals have two unique characteristics:
  - hair and
  - mammary glands that produce milk, which nourishes the young.
- There are three major groups of mammals:
  - **monotremes**, egg-laying mammals,
  - **marsupials**, pouched mammals with a **placenta,** and
  - **eutherians**, also called **placental mammals**.

Figure 17.36
Figure 17.36a
Figure 17.36b
Figure 17.36c

**THE HUMAN ANCESTRY**

- Humans are **primates**, the mammalian group that also includes
  - lorises,
  - pottos,
  - lemurs,
  - tarsiers,
  - monkeys, and
  - apes.

**The Evolution of Primates**

- **Primates** evolved from insect-eating mammals during the late Cretaceous period, about 65 million years ago.
- Primates are distinguished by characteristics that were shaped by the demands of living in trees. These characteristics include
  - limber shoulder joints,
  - eyes in front of the face,
  - excellent eye-hand coordination, and
  - extensive parental care.
- Taxonomists divide the primates into three main groups.

Figure 17.37

- The first group of primates includes
  - lorises,
  - pottos, and
  - lemurs.
- Tarsiers form the second group.

Figure 17.38
Figure 17.38a
Figure 17.38aa
Figure 17.38ab

- The third group, **anthropoids**, includes
  - monkeys,

Figure 17.38ac
Figure 17.38ad

  - apes, the ape relatives of humans,

Figure 17.38b
Figure 17.38ae
Figure 17.38ba
Figure 17.38bb
Figure 17.38bc

  - and humans.

Figure 17.38bd

**The Emergence of Humankind**

- Humans and chimpanzees have shared a common African ancestry for all but the last 5–7 million years.

***Some Common Misconceptions***

- Chimpanzees and humans represent two divergent branches of the anthropoid tree that each evolved from a common, less specialized ancestor.
- Our ancestors were not chimpanzees or any other modern apes.
- Human evolution is not a ladder with a series of steps leading directly from an ancestral anthropoid to *Homo sapiens*.
  - This is often illustrated as a parade of fossil **hominins** (members of the human family) becoming progressively more modern as they march across the page.
  - Instead, human evolution is more like a multibranched bush than a ladder.

- At times in hominin history, several different human species coexisted.

Figure 17.39
Figure 17.39a
Figure 17.39b

- Different human features evolved at different rates.
- At separate times during human evolution, upright posture and an enlarged brain evolved.

***Australopithecus and the Antiquity of Bipedalism***

- Present-day humans and chimpanzees clearly differ in two major physical features. Humans
  - are bipedal and
  - have much larger brains.

***Australopithecus and the Antiquity of Bipedalism***

- Bipedalism evolved first.
  - Before there was the genus *Homo*, several hominin species of the genus *Australopithecus* walked the African savanna.
  - Scientists are now certain that bipedalism is a very old trait.

Figure 17.40
Figure 17.40a
Figure 17.40b
Figure 17.40c

***Homo habilis and the Evolution of Inventive Minds***

- *Homo habilis*, "handy-man,"
  - had a larger brain, intermediate in size between *Australopithecus* and modern humans,
  - walked upright, and
  - made stone tools that enhanced hunting, gathering, and scavenging on the African savanna.
- *Homo erectus* was the first species to extend humanity's range from Africa to other continents.
- The global dispersal began about 1.8 million years ago.
- *Homo erectus*
  - was taller than *H. habilis* and
  - had a larger brain.

**The Process of Science:**
**Who Were the Hobbit People?**

- **Observation**: The hominin fossils on the island of Flores did not belong to any known species.
- **Question**: Where does this hominin fit in our evolutionary history?
- **Hypothesis:** The hobbits evolved from an isolated population of *Homo erectus*.
- **Prediction**: Key traits of the new species, such as its skull characteristics and body proportions, would resemble those of a miniature *Homo erectus*.
- **Experiment**: Detailed measurements and other observations of the new fossils were compared with data from *Homo erectus* fossils.
- **Results**: The initial results supported the hypothesis.
- Other analyses including additional specimens suggest alternate hypotheses:
  - *Homo floresiensis* is most closely related to *Homo habilis* or
  - the hobbits are not a species at all, but *Homo sapiens* with a disorder that caused bone malformations.

Figure 17.41

***Homo neanderthalensis***

- *Homo erectus* gave rise to
  - regionally diverse descendents in Europe and Asia and
  - *Homo neanderthalensis*, commonly called Neanderthals.
- Neanderthals
  - and modern humans last shared a common ancestor about 500,000 years ago and
  - may have interbred with some *Homo sapiens*.

Figure 17.42

***The Origin and Dispersal of Homo sapiens***

- The oldest known fossils of our own species, *Homo sapiens*,
  - were discovered in Ethiopia and
  - date from 160,000 to 195,000 years ago.

Figure 17.43

- DNA studies strongly suggest that all living humans can

trace their ancestry back to a single African *Homo sapiens* lineage that began 160,000 to 200,000 years ago.

- Fossil evidence suggests that our species emerged from Africa in one or more waves.
- The oldest fossils of *H. sapiens* outside of Africa are 50,000 years old.
- The oldest fossils of humans in the New World are uncertain, but are at least 15,000 years old.
- Certain uniquely human traits have allowed for the development of human societies.
  - The primate brain continues to grow after birth and the period of growth is longer for a human than for any other primate.
  - The extended period of human development lengthens the time for parents to care for their offspring and pass along culture.
- **Culture** is the social transmission of accumulated knowledge, customs, beliefs, and art over generations.
- Culture is primarily transmitted by language.

Figure 17.44

**Evolution Connection: Are We Still Evolving?**

- The human body has not changed much in the past 100,000 years.
- But as humans wandered far from their site of origin and settled in diverse environments, populations encountered different selective forces.
  - Certain populations evolved sickle hemoglobin as an adaptation to the deadly disease malaria.

**Evolution Connection: Are We Still Evolving?**

  - The loss of skin pigmentation in humans who migrated north from Africa is thought to be an adaptation to low levels of ultraviolet light in northern latitudes.
  - Tibetans living at altitudes up to 14,000 feet have evolved changes in response to this challenging environment.
  - Despite evolutionary tweaks such as these, we remain a single species.

Figure 17.45
Figure 17.46
Figure 17.UN01
Figure 17.UN02
Figure 17.UN03
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Figure 17.UN21