Biological Diversity [part 2]

IF3211 Domain Specific Computation

School of Electrical Engineering and Informatics ITB

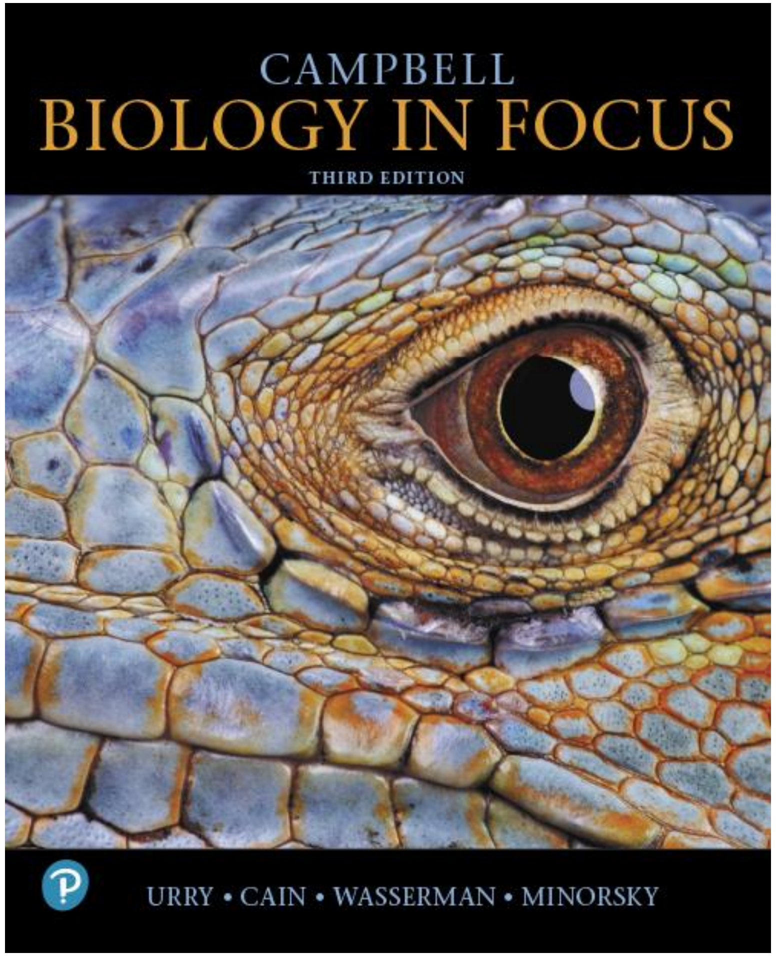
Content

- The Colonization of Land
- The Rise of Animal Diversity
- Computing Tools

The Colonization of Land

Campbell Biology in Focus

Third Edition



Chapter 26

The Colonization of Land

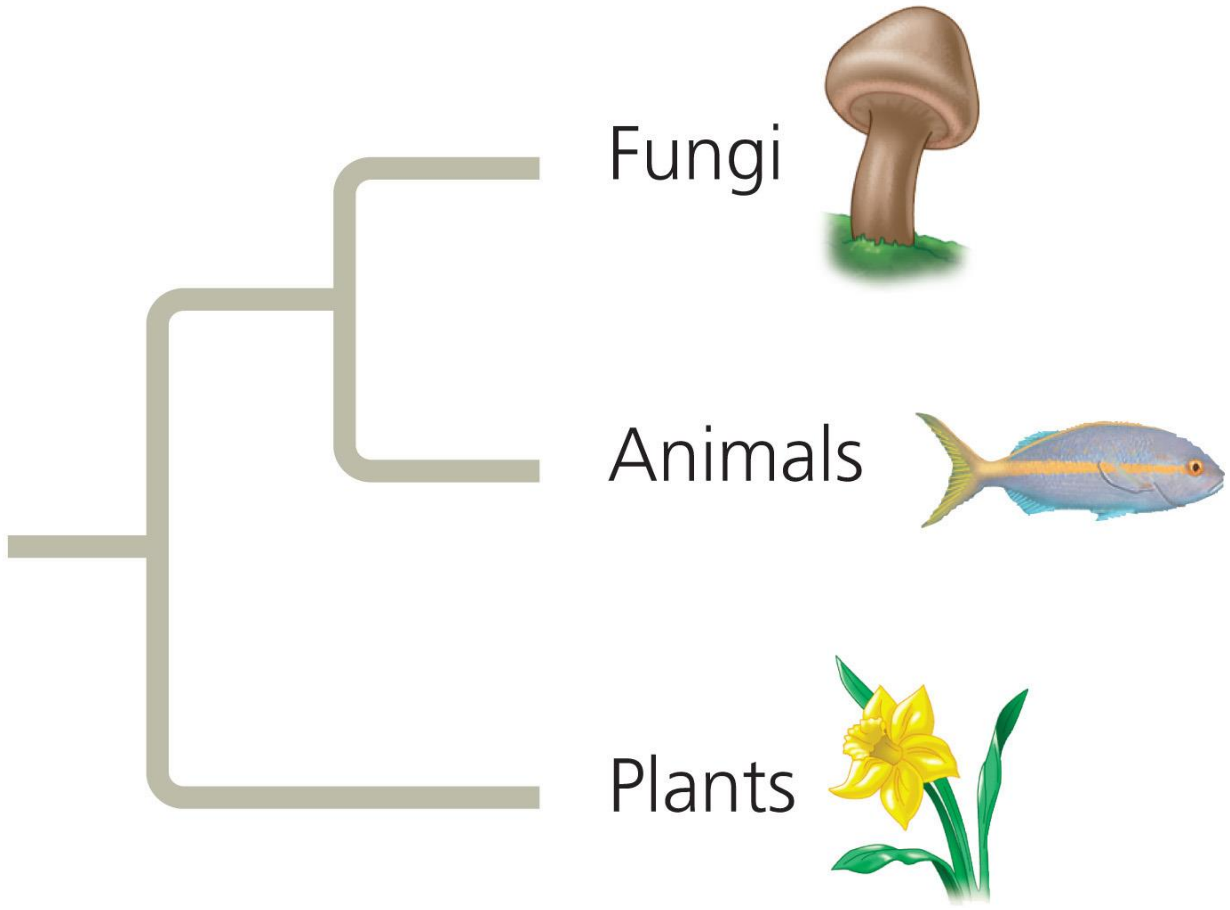
Lecture Presentations by
Kathleen Fitzpatrick and Nicole Tunbridge,
Simon Fraser University

Overview: The Greening of Earth (2 of 2)

- Although fungi are more closely related to animals, they colonized the land as partners with plants
- Plants supply oxygen and are the ultimate source of most food eaten by land animals
- Fungi break down organic material and make chemical nutrients available to plants
- Animals moved onto land after plants and fungi

Figure 26.2

26.2 Fungi and Plants Are Not Closely Related

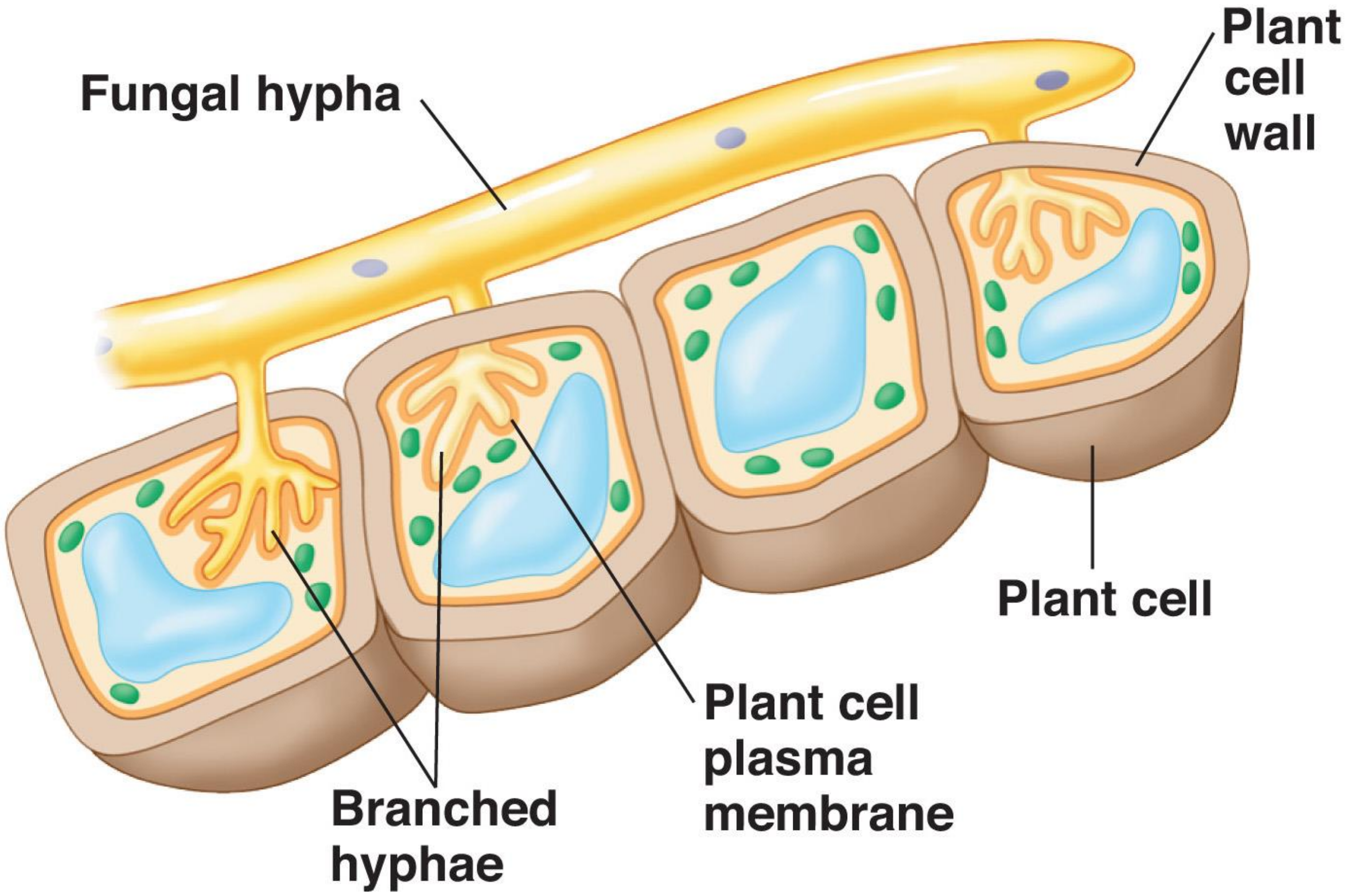


Concept 26.2: Though Not Closely Related to Plants, Fungi Played a Key Role in the Colonization of Land (2 of 3)

- Fungi are heterotrophs that absorb nutrients from outside of their body
- The morphology of multicellular fungi enhances their ability to absorb nutrients
- Fungi consist of networks of branched **hyphae**, filaments adapted for absorption

Figure 26.11

Mycorrhizae: Plant-Fungal Symbioses



The Origin of Fungi

- Fungi and animals are more closely related to each other than they are to plants or other eukaryotes
- Fungi are more closely related to unicellular protists called **nucleariids** than they are to animals
- Animals are more closely related to different group of protists called choanoflagellates
- Multicellularity likely evolved independently in the different ancestors to fungi and animals

Diversification of Fungi (1 of 9)

- Molecular analyses have helped clarify evolutionary relationships among fungal groups, although areas of uncertainty remain
- There are about 100,000 known species of fungi, but there are estimated to be as many as 1.5 million species

Figure 26.16

Exploring Fungal Diversity

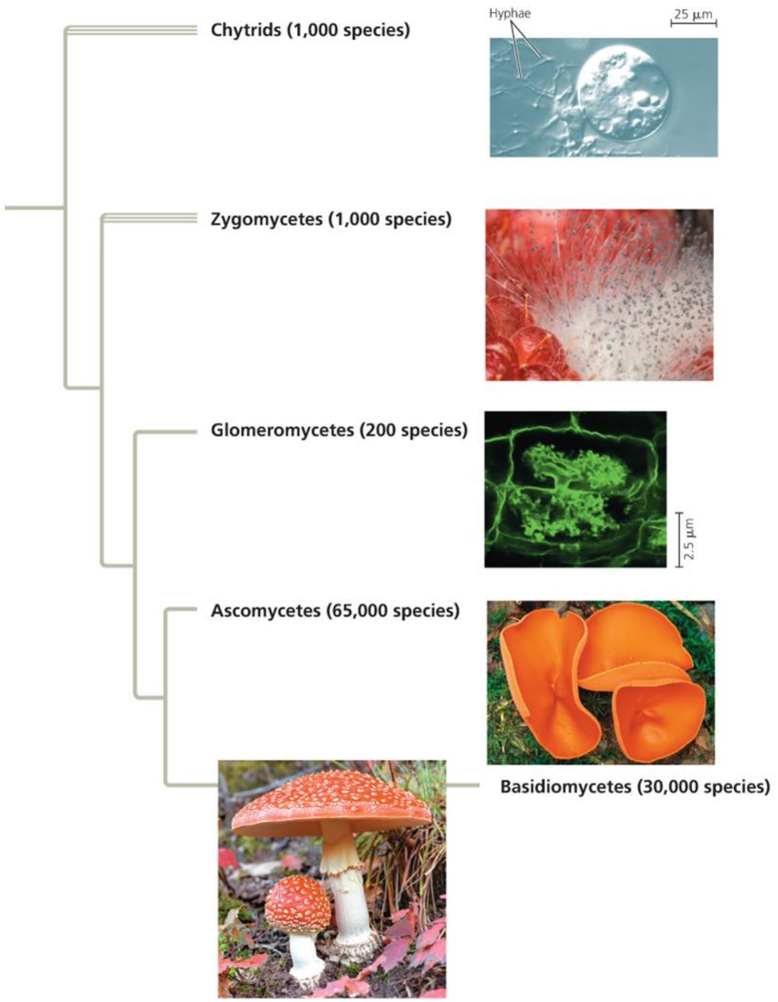
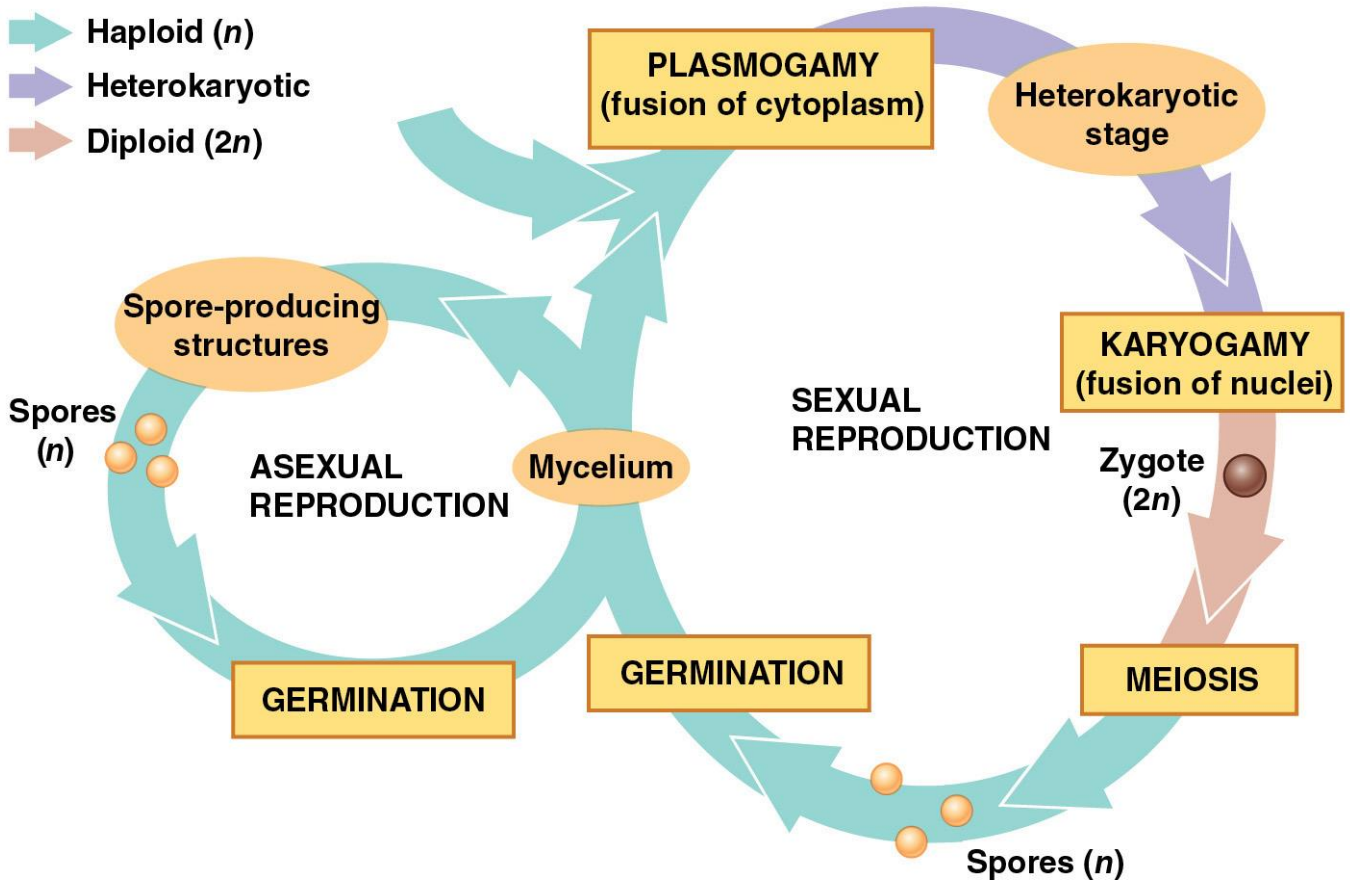


Figure 26.17

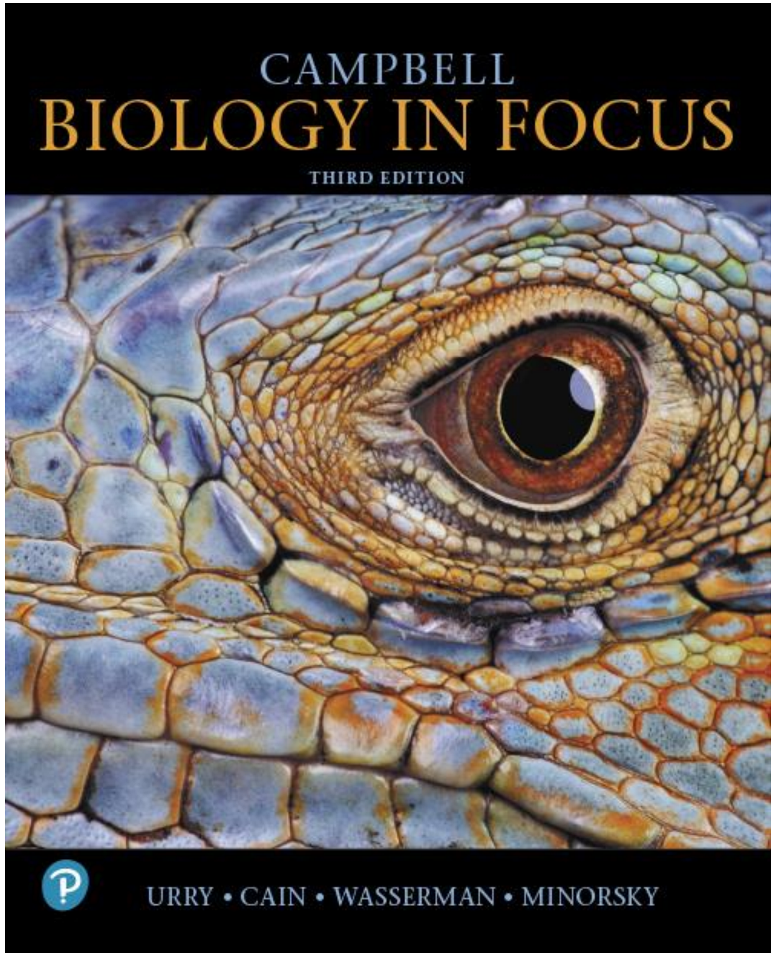
Generalized Life Cycle of Fungi



The Rise of Animal Diversity

Campbell Biology in Focus

Third Edition



Chapter 27

The Rise of Animal Diversity

Lecture Presentations by
Kathleen Fitzpatrick and Nicole Tunbridge,
Simon Fraser University

Overview: Life Becomes Dangerous

- Most animals are mobile and use traits such as strength, speed, toxins, or camouflage to detect, capture, and eat other organisms
  - For example, the banded archerfish (*Toxotes jaculatrix*) spits a stream of water to knock insect prey off of overhanging branches up to 3 m away

Concept 27.1: Animals Originated More Than 700 Million Years Ago

- Animals likely evolved from single-celled eukaryotes similar to present-day choanoflagellates
- More than 1.3 million animal species have been named to date; the actual number of species is estimated to be nearly 8 million

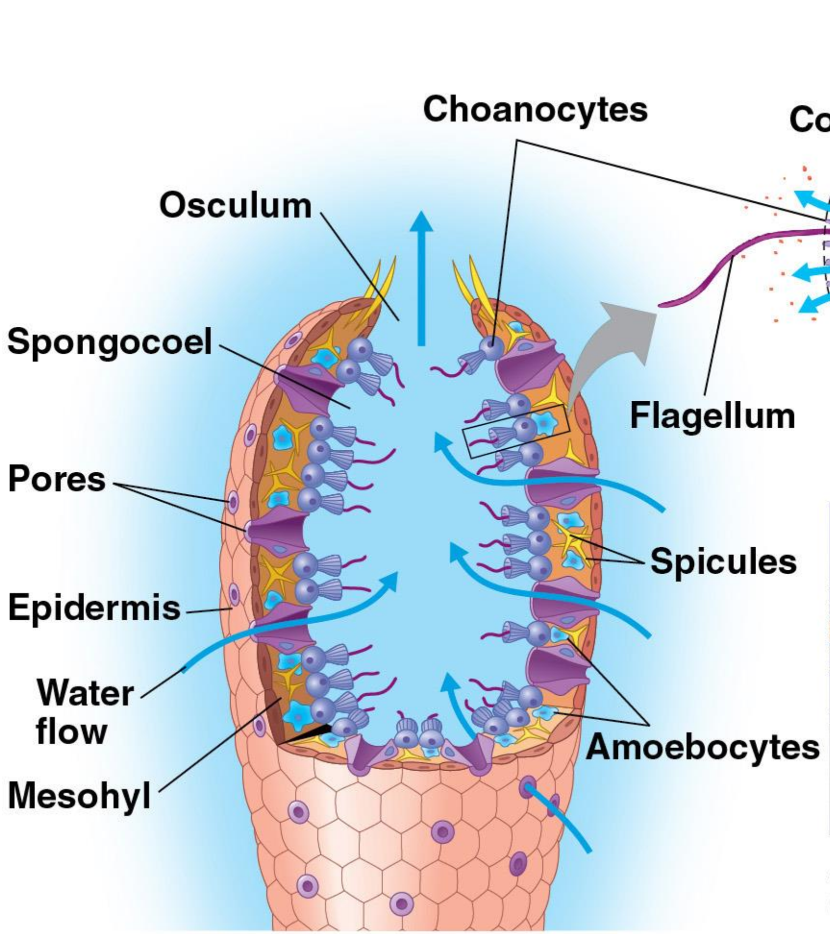
Figure: Simple Phylogenetic Tree Highlighting Sponge and Cnidarian Branches

Sponges

- Sponges are animals in the phylum Porifera
- As **filter feeders**, they capture small food particles suspended in water
- Water is drawn through body pores into a central cavity and flows out through an opening at the top
- Sponges lack true **tissues**, groups of cells that function as a unit

Figure 27.3

Anatomy of a Sponge



Azure vase sponge (*Callyspongia plicifera*)

Cnidarians

- Cnidaria and all other animals except sponges and a few other groups are eumetazoans (“true animals”) that have tissues
- The basic morphology of a cnidarian is a sac with a central digestive cavity, the **gastrovascular cavity**
- A single opening functions as mouth and anus
- Cnidarians are carnivores that use tentacles arranged in a ring around the mouth to capture prey
- Cnidarians lack a brain and muscles, and nerves occur in their simplest forms

Figure 27.4

Major Groups of Cnidarians

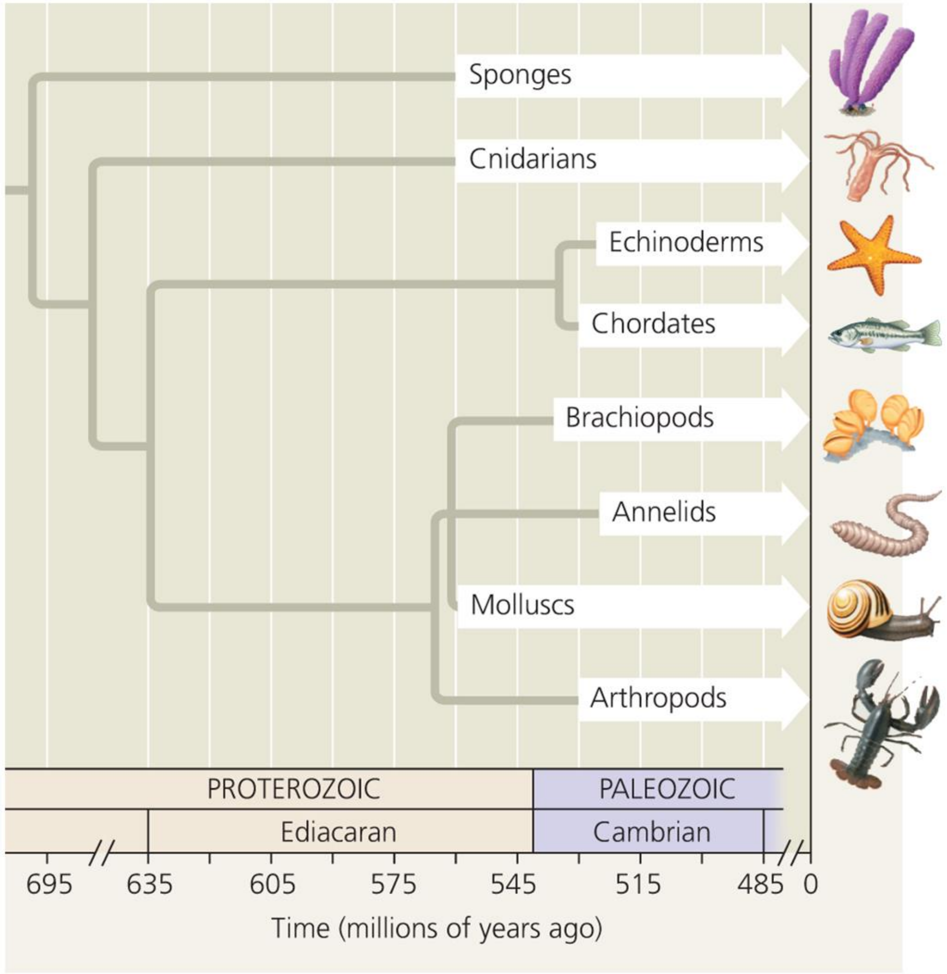
(a) Hydrozoa.

(b) Scyphozoa.

(c) Anthozoa.

Figure 27.5

Appearance of Selected Animal Groups

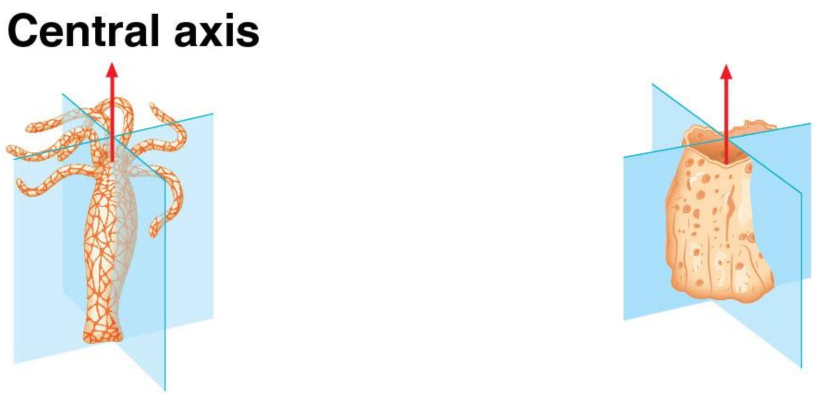


Symmetry (1 of 2)

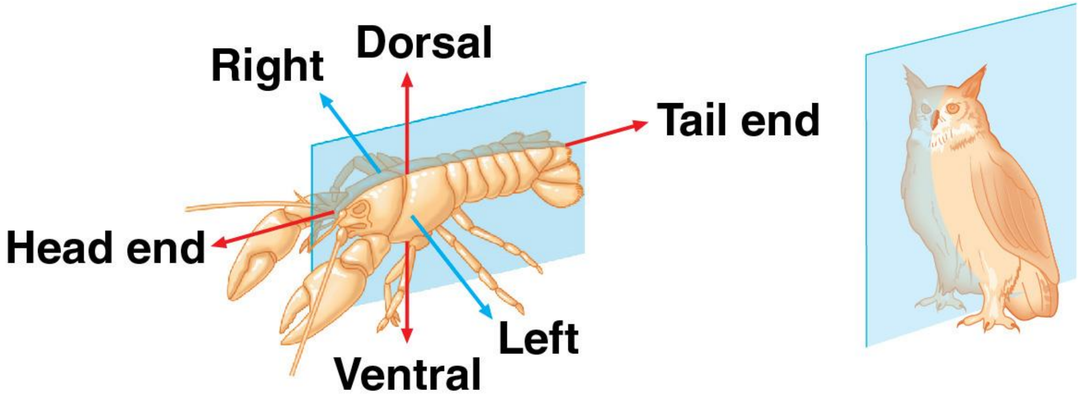
- Animals can be categorized according to body symmetry—or absence of symmetry
- Two common types of symmetry are radial symmetry and bilateral symmetry

Figure 27.8

Visualizing Animal Body Symmetry and Axes



(a) Radial Symmetry



(b) Bilateral Symmetry and Body Axes

Symmetry (2 of 2)

Radial Symmetry

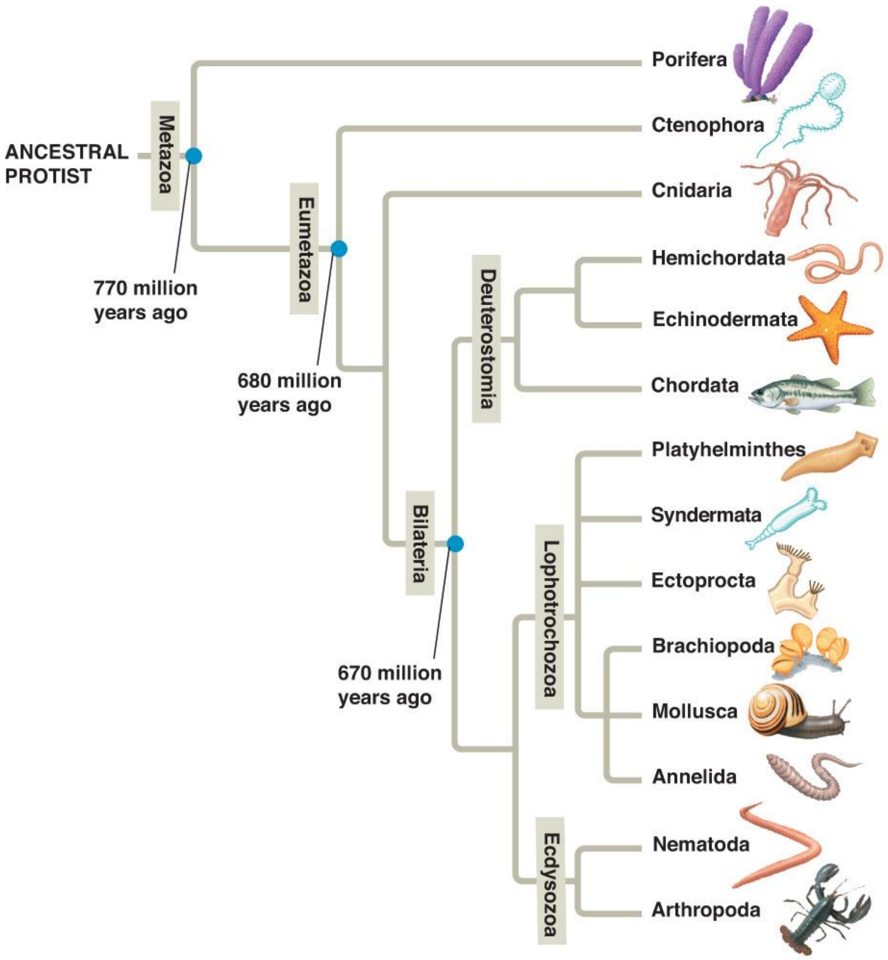
- Animals are arranged around a single, central axis
- Any imaginary slice through the central axis divides the animal into mirror images

Bilateral Symmetry and Body Axes

- Animals are arranged around two axes of orientation, the head-tail axis and the dorsal-ventral axis
- Only one imaginary slice divides the animal into two mirror-image halves

Figure 27.10

A Current Hypothesis of Animal Phylogeny



The Diversification of Animals (2 of 2)

The following points are reflected in the animal phylogeny:

1. **All animals share a common ancestor**
2. **Sponges are the sister group to all other animals**
3. **Eumetazoa is a clade of animals (eumetazoans) with tissues**
4. **Most animal phyla belong to the clade Bilateria**
5. **Most animals are invertebrates**, animals without a backbone; Chordata is the only phylum that includes **vertebrates**, animals with a backbone

Bilaterian Radiation I : Diverse Invertebrates

- Bilaterians have diversified into three major clades: Lophotrochozoa, Ecdysozoa, and Deuterostomia

Figure 27.11

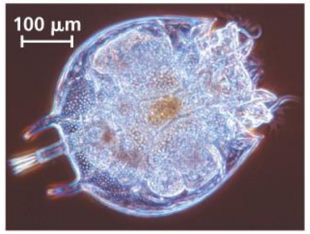
Exploring the Diversity of Invertebrate Bilaterians

Lophotrochozoa

Ectoprocta (4,500 species)

Ectoprocts

Syndermata (2,900 species)



A rotifer (LM)

Annelida (16,500 species)

A fireworm, a marine annelid

Ecdysozoa

Nematoda (25,000 species)

A roundworm

Arthropoda (1,000,000 species)

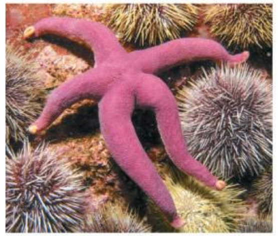
A web-building spider (an arachnid)

Deuterostomia

Hemichordata (85 species)

An acorn worm

Echinodermata (7,000 species)



Sea urchins and a sea star

Bilaterian Radiation II : Aquatic Vertebrates

- Vertebrates are members of phylum Chordata
- **Chordates** are bilaterian animals that belong to the animal clade Deuterostomia
- The four key characters of chordates include
  - **Notochord**, a flexible rod that provides support
  - Dorsal, hollow nerve cord, that develops into the brain and spinal cord
  - **Pharyngeal slits** (or **pharyngeal clefts**) that function in suspension feeding, as gills, or as parts of the head
  - Muscular tail that extends posterior to the anus

Figure 27.17

Key Derived Characters of Chordates

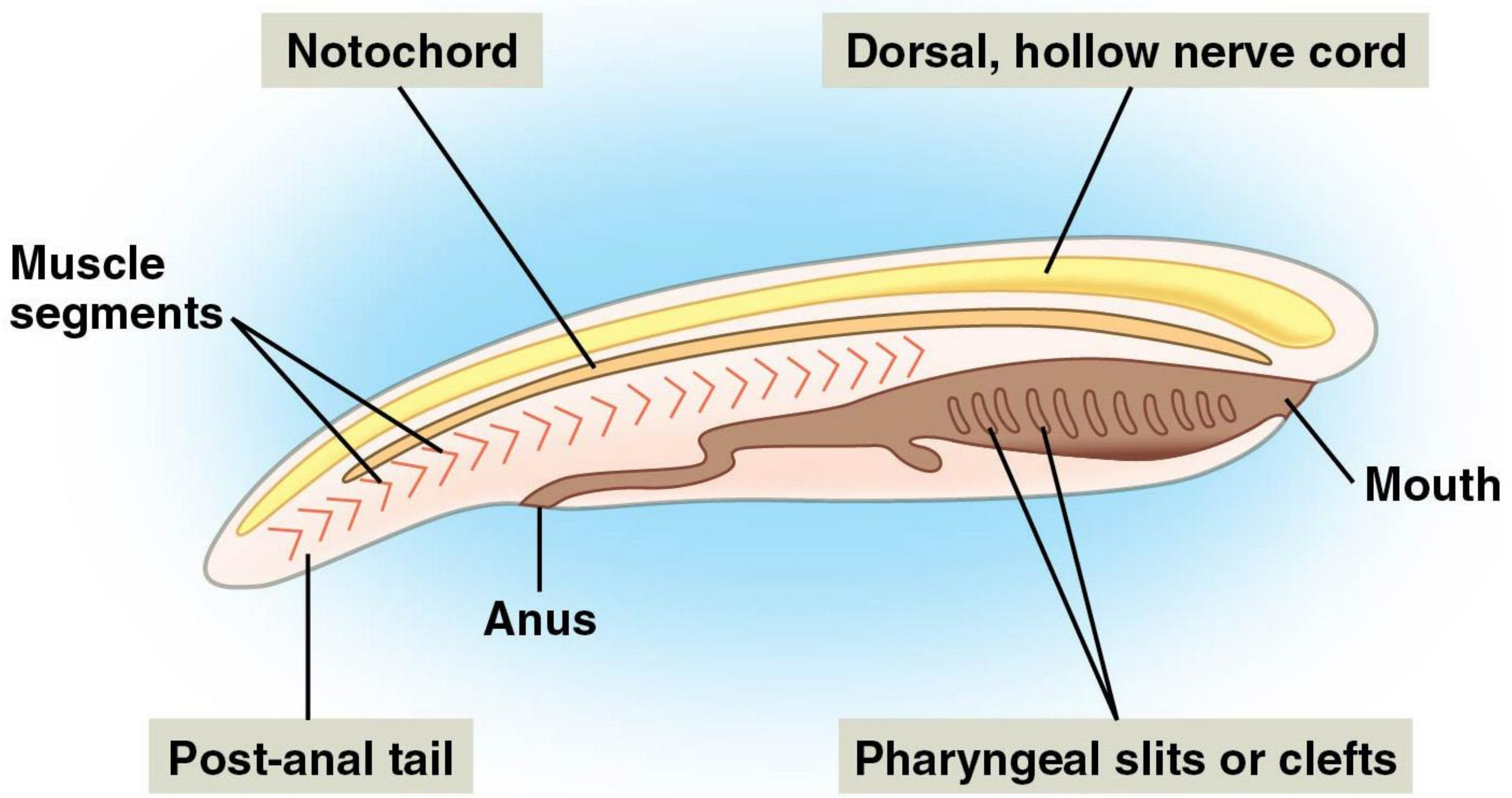


Figure 27.19

Exploring Vertebrate Diversity

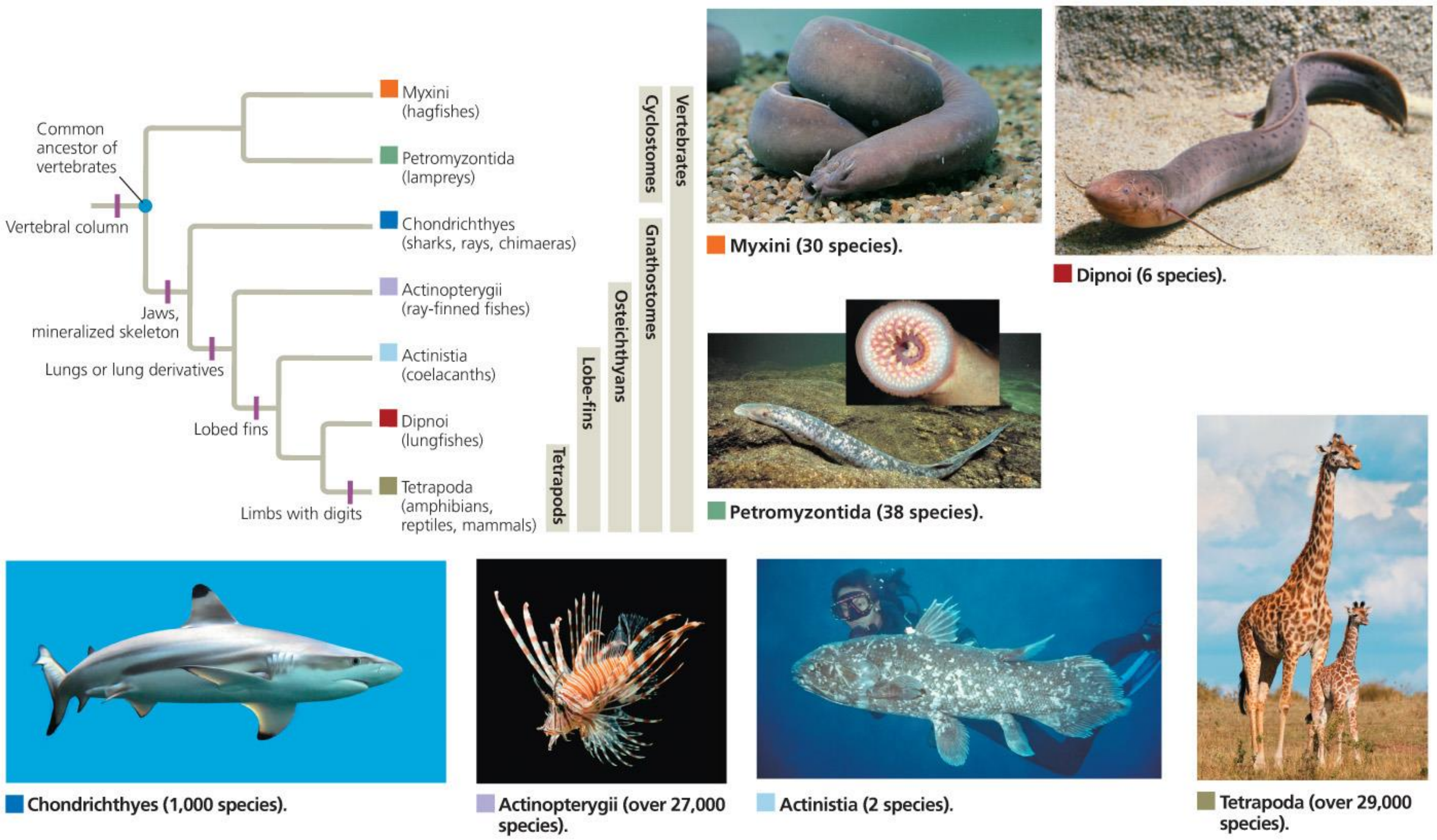
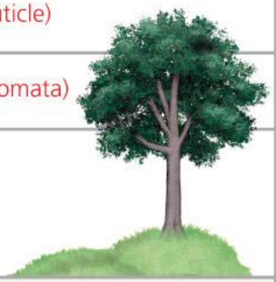
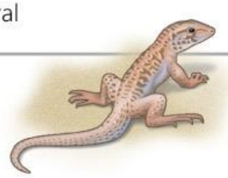


Figure 27.21

Descent with Modification During the Colonization of Land

CLOSE AQUATIC RELATIVE		GREEN ALGA	MARINE CRUSTACEAN	AQUATIC LOBE-FIN
				
CHARACTER	**Anchoring structure**	Derived (roots)	N/A	N/A
	Support structure	Derived (lignin/stems)	Ancestral	Ancestral (skeletal system) Derived (limbs)
	Internal transport	Derived (vascular system)	Ancestral	Ancestral
	Muscle/nerve cells	N/A	Ancestral	Ancestral
	Protection against desiccation	Derived (cuticle)	Ancestral	Derived (amniotic egg/scales)
	Gas exchange	Derived (stomata)	Derived (tracheal system)	Ancestral
TERRESTRIAL ORGANISM				
		PLANTS	INSECTS	TERRESTRIAL VERTEBRATES

Colonization of Land by Arthropods

- Terrestrial lineages have arisen in several different arthropod groups, including millipedes, spiders, crabs, and insects

Figure 27.22

External Anatomy of an Arthropod

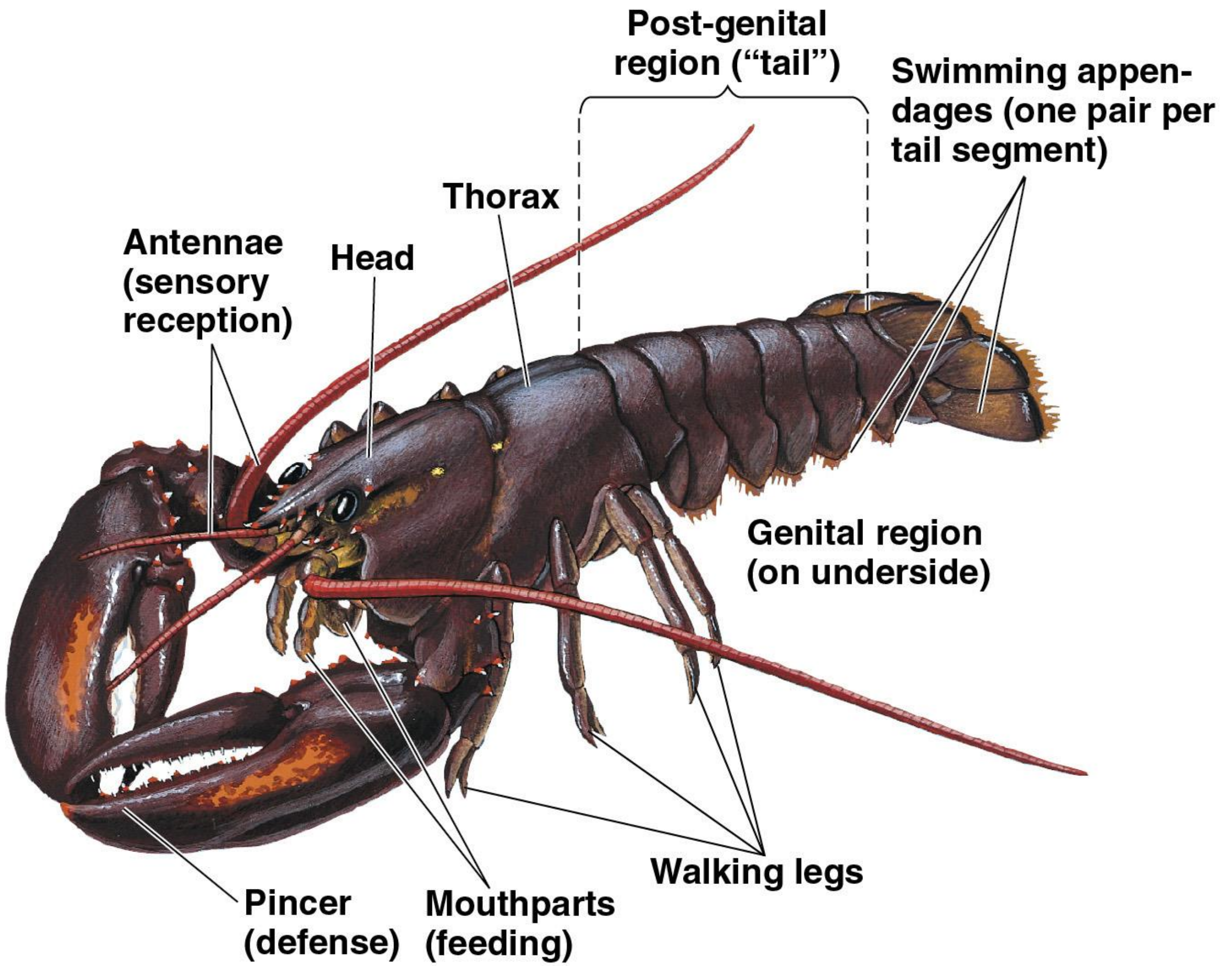
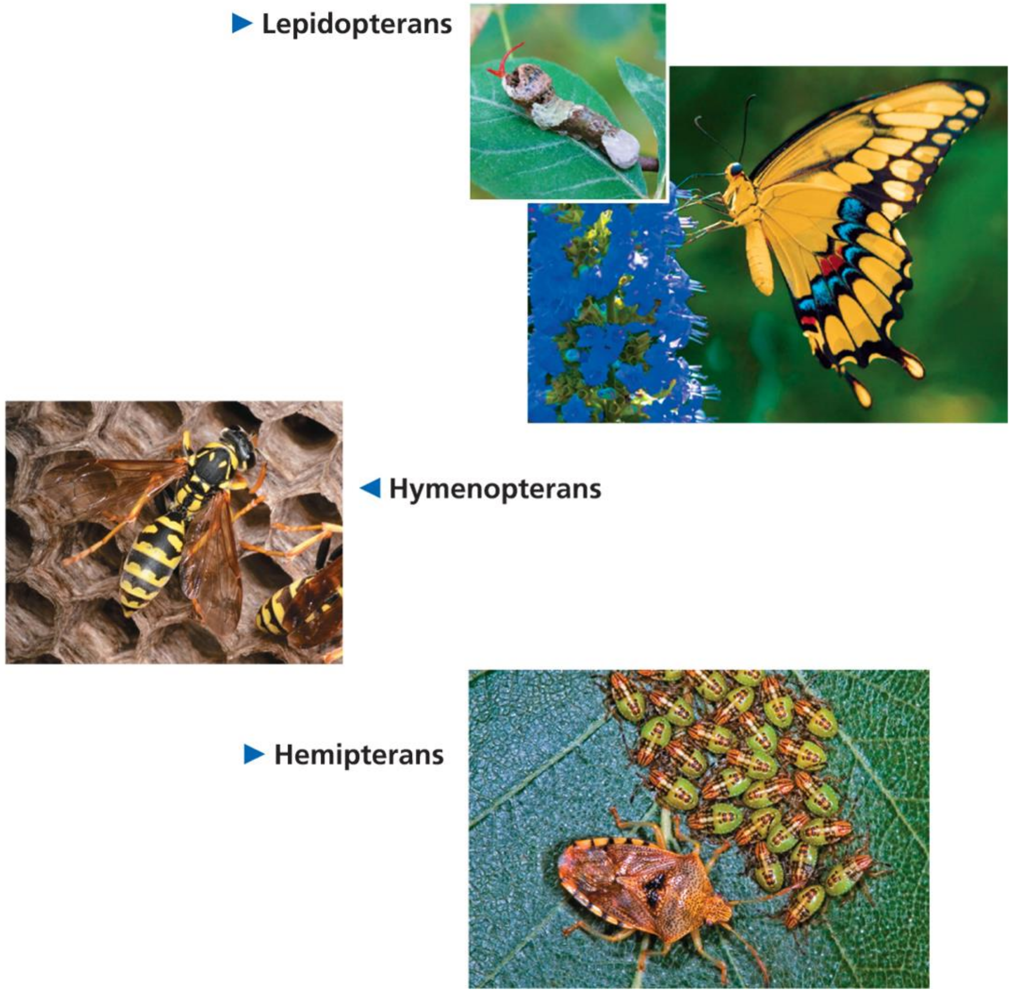


Figure 27.23

Insect Diversity



The Origin of Tetrapods (2 of 2)

- *Tiktaalik* could likely prop itself up on its fins in water but not walk on land
- Tiktaalik predates the oldest tetrapod, making its traits ancestral to the tetrapod lineage
- Fins became progressively more limb-like over evolutionary time, leading to the first appearance of tetrapods 365 million years ago

Figure 27.26

Steps in the Origin of Limbs with Digits

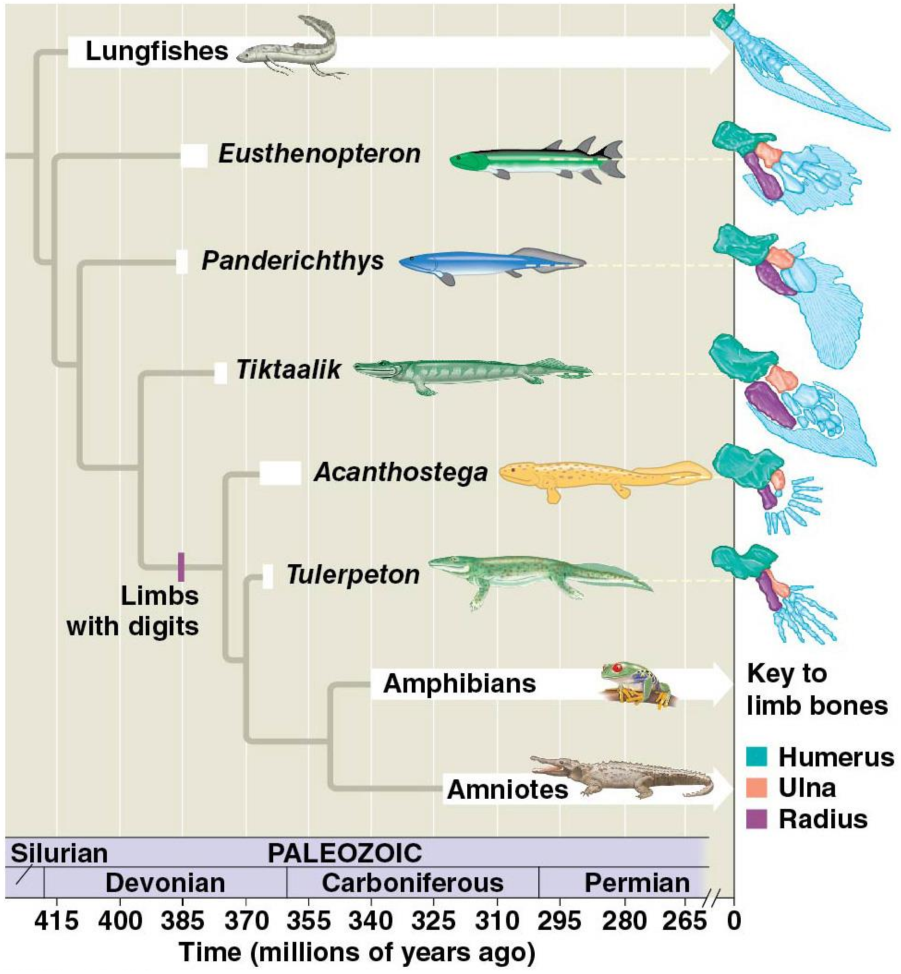


Figure: Simple Phylogenetic Tree of Tetrapods Highlighting Amphibian Branch

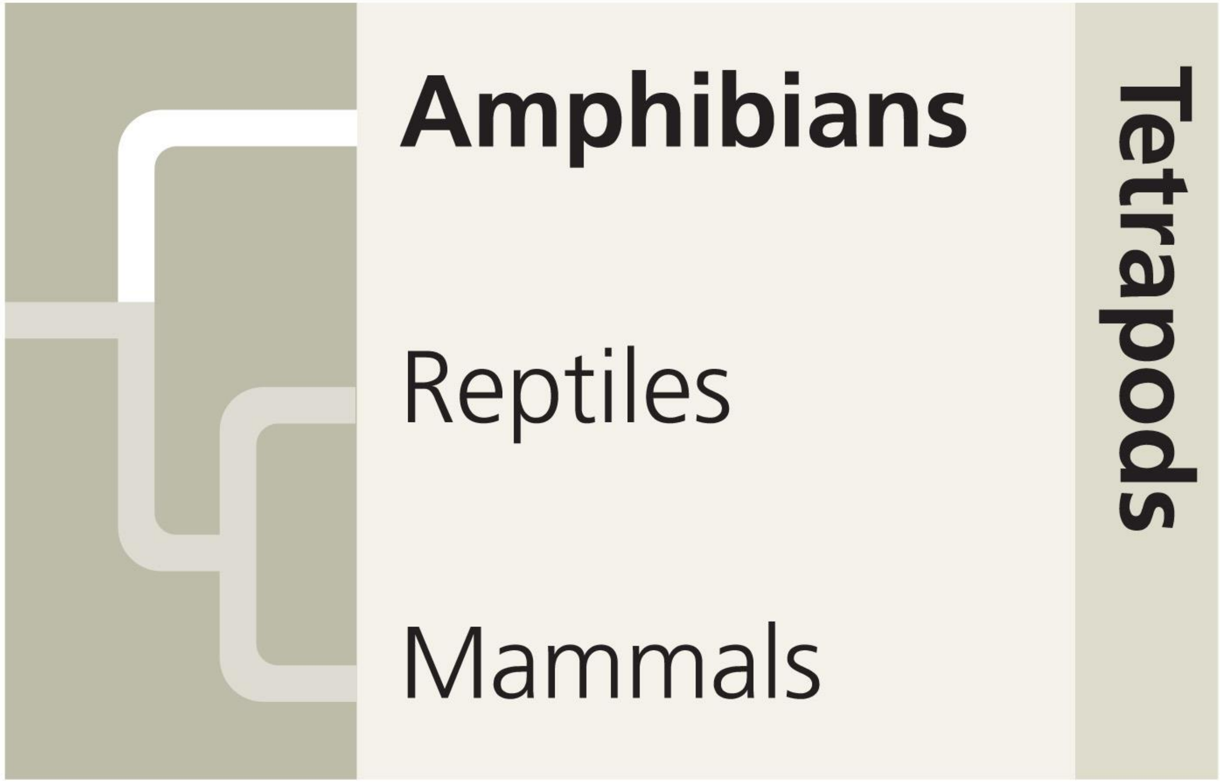
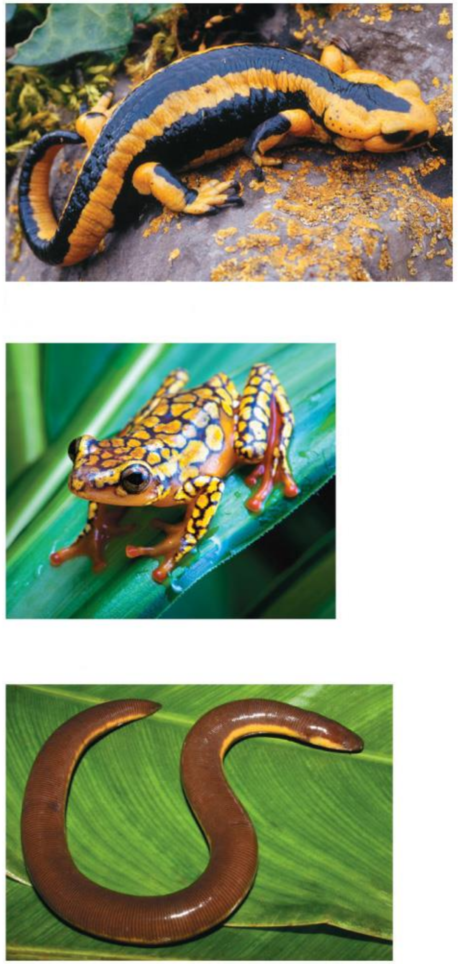


Figure 27.27

Amphibian Diversity



(a) Salamanders

b) Frogs and toads

(c) Caecilians

Amphibians (4 of 4)

- Amphibian populations have declined rapidly over the past 30 years due to a disease-causing chytrid fungus, habitat loss, climate change, and pollution
- At least nine extinctions have occurred in the past 40 years; more than 100 others are possible

Figure: Simple Phylogenetic Tree of Tetrapods Highlighting Reptile and Mammal Branches

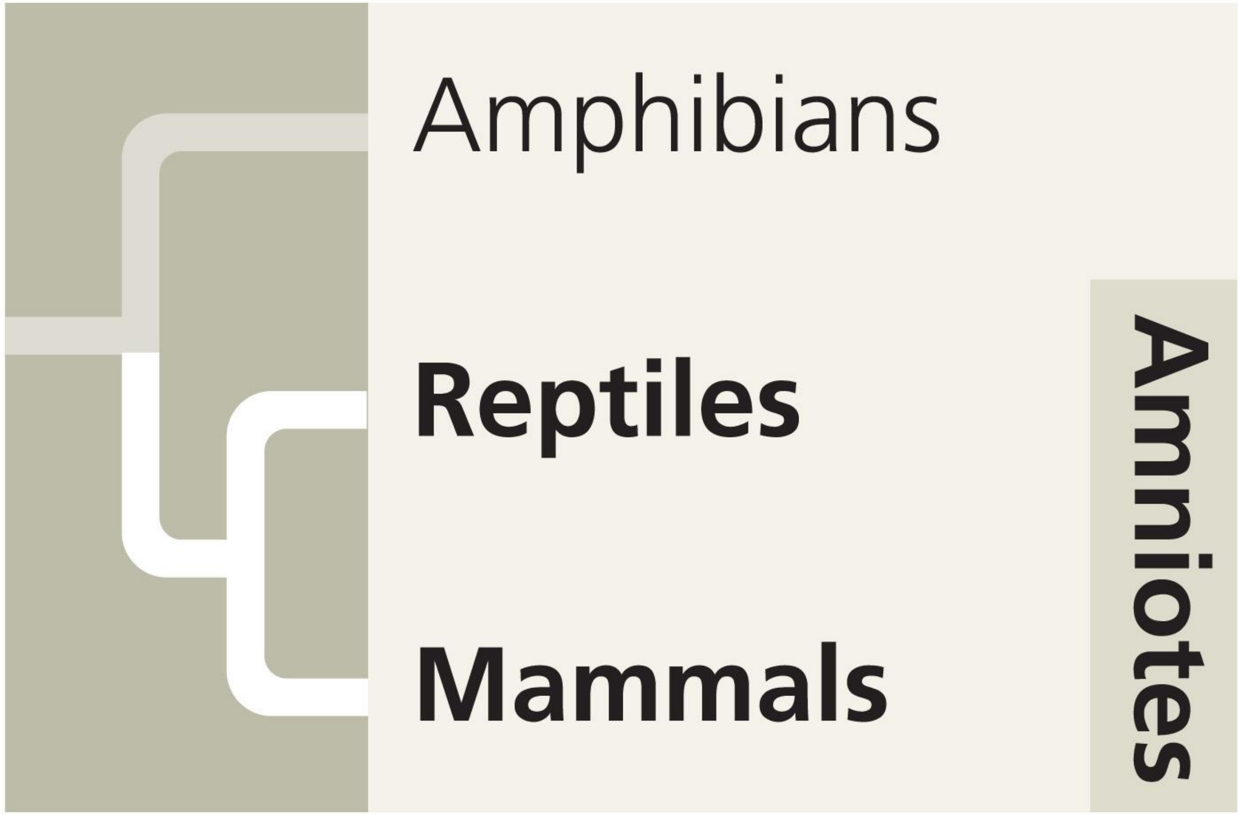
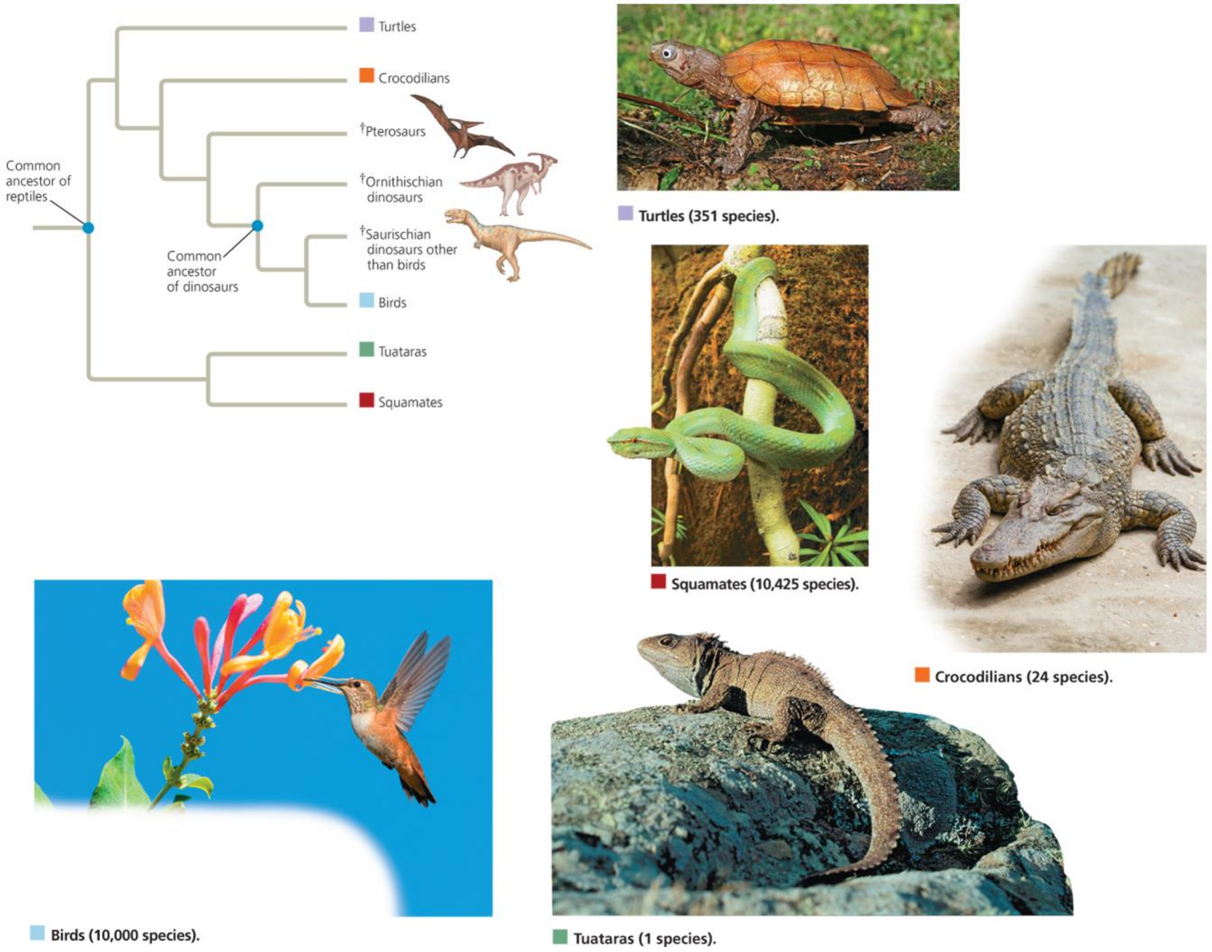


Figure 27.29

Exploring Reptilian Diversity



Mammals (1 of 6)

- **Mammals** are named for their distinctive mammary glands, which produce milk for offspring
- Adaptations for life on land include
  - Hair and an insulating fat layer under the skin
  - Kidneys that conserve water during waste removal
  - Rapid metabolism associated with endothermy
  - A relatively large brain with learning capacity
  - Teeth modified for chewing many kinds of foods

Figure 27.31

Adaptations of the Kangaroo Rat to Its Extremely Dry Habitat

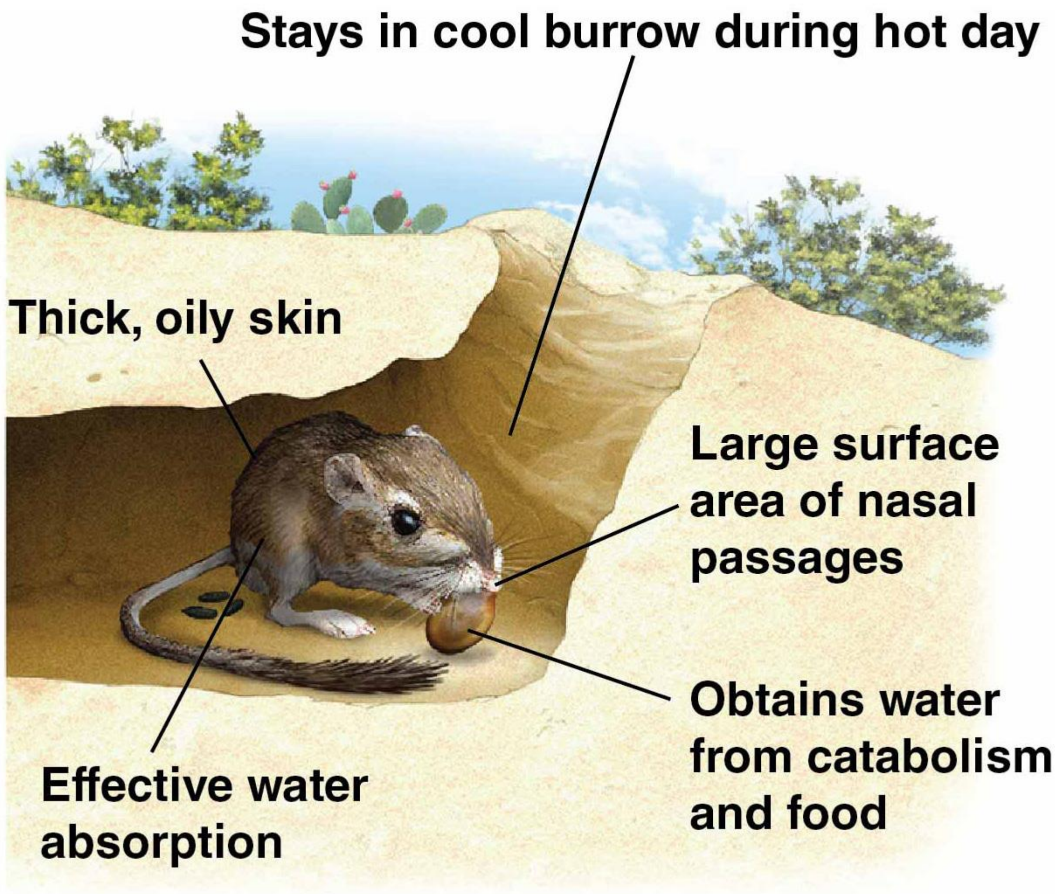


Figure 27.32

The Major Mammalian Lineages

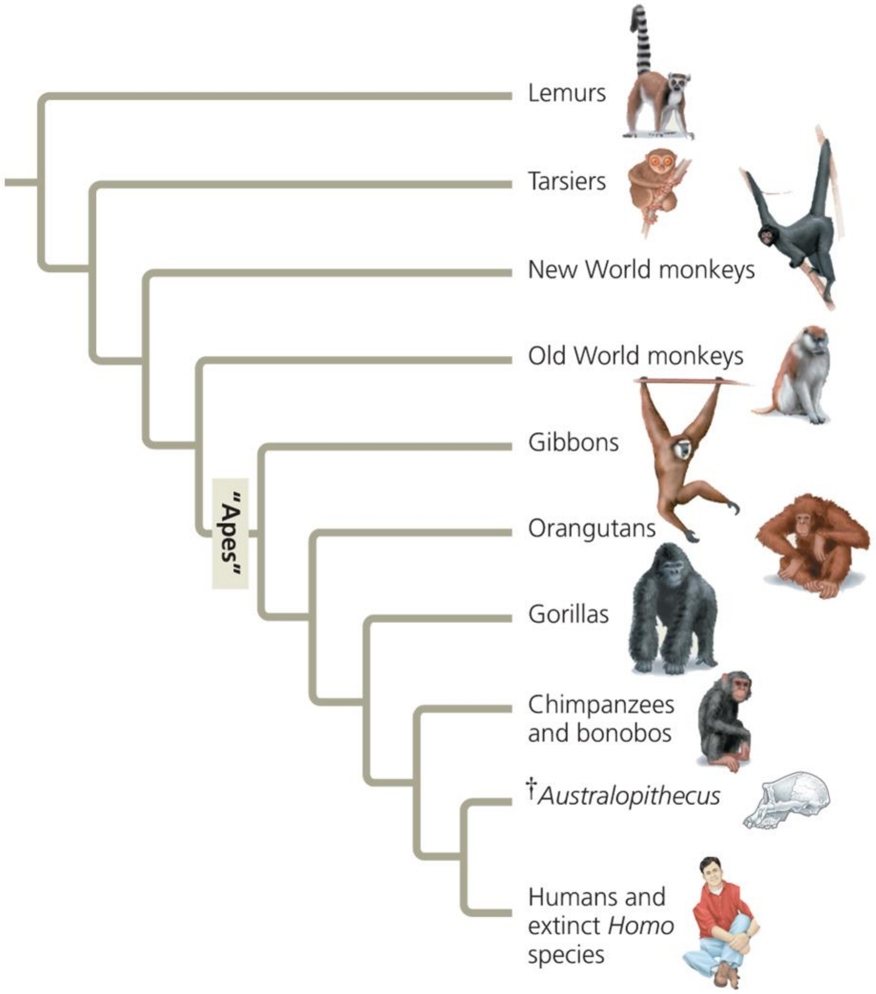
Monotremes

Marsupials

Eutherians

Figure 27.33

The Primate Evolutionary Tree



Human Evolution

- Humans (*Homo sapiens*) are primates, nested within the group informally called apes
- A number of characters distinguish humans from other apes
  - Upright posture and bipedal locomotion
  - Larger brains capable of language, symbolic thought, artistic expression, and the use of complex tools

Early Human Ancestors (1 of 5)

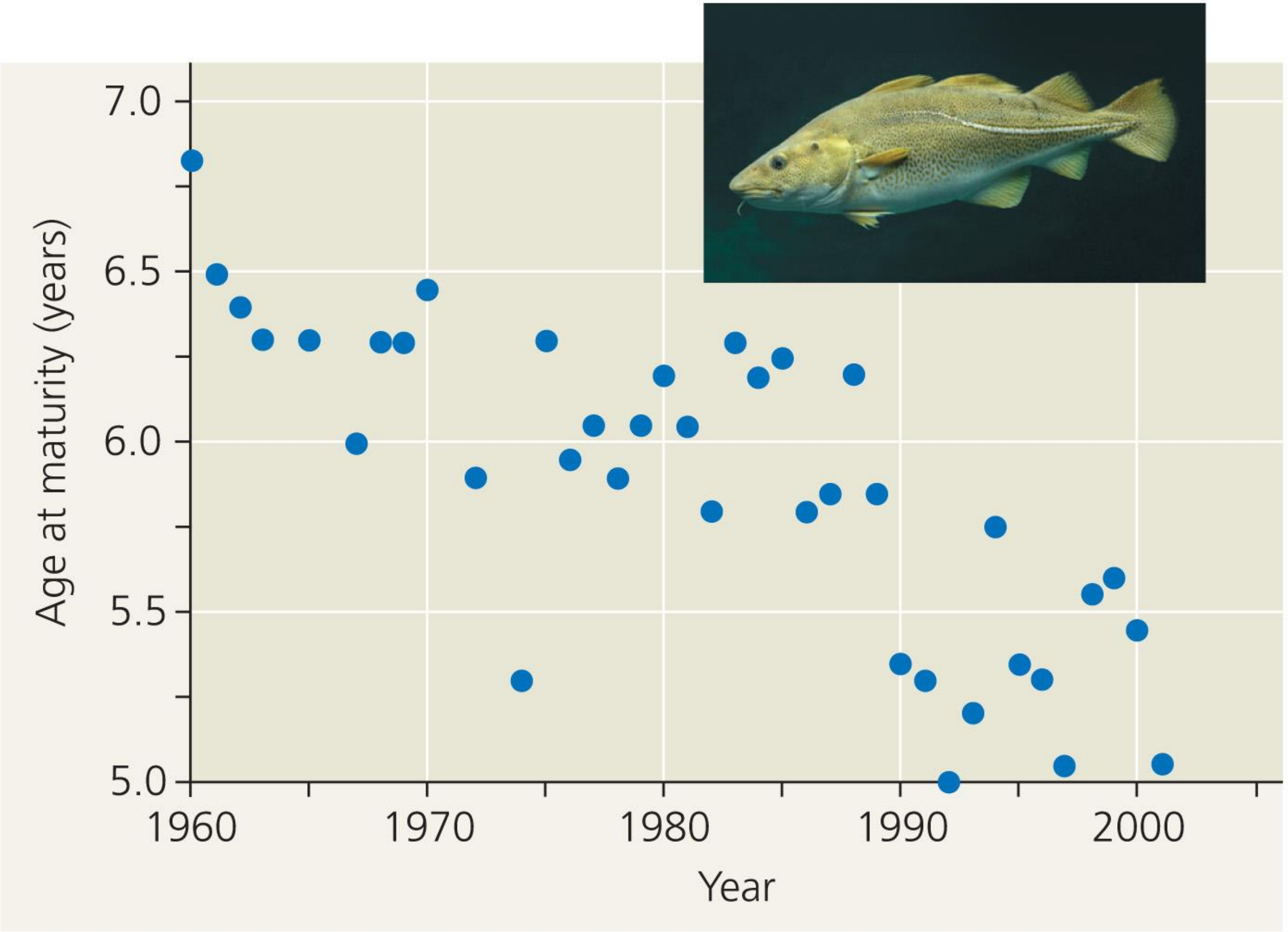
- Chimpanzees and humans are each other's closest relatives; their genomes are 99% identical
- The lineage leading to humans diverged from chimpanzees and other apes 7-8 million years ago
- **Hominins** include humans and the extinct species more closely related to them than chimpanzees

Human Impacts on Evolution (1 of 4)

- Humans have changed the global environment, altering the selective pressures on many species
  - For example, human targeting of large fish for harvesting has led to the reduction in age and size at which individuals reach sexual maturity

Figure 27.41

Reproducing at a Younger Age

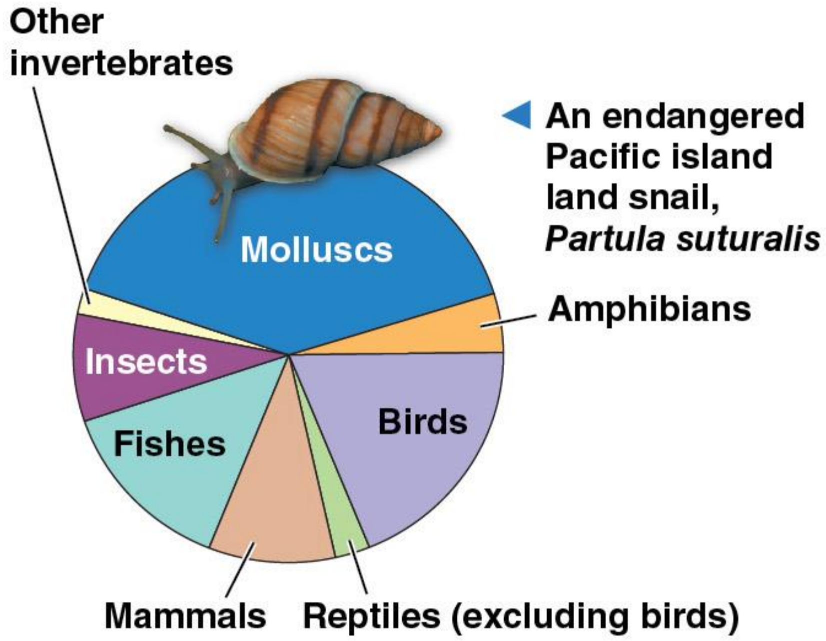


Human Impacts on Evolution (2 of 4)

- Rapid species declines over the past 400 years indicate that human activities may be driving a sixth mass extinction
- Molluscs have experienced the largest number of documented extinctions
  - For example, pearl mussels are among the worlds most endangered animals, due in part to overharvesting

Figure 27.42

The Silent Extinction



▲ Recorded extinctions of animal species

▲ Workers on a mound of pearl mussels killed to make buttons (ca. 1919)

Human Impacts on Evolution (3 of 4)

- The major threats imposed on species by human activities include habitat loss, pollution, competition or predation by non-native species, and overharvesting

Human Impacts on Evolution (4 of 4)

- The evolution of life does not consist of a ladder leading from microorganisms to humanity
- Biological diversity is the product of branching phylogeny, not ladderlike “progress”
- Even relatively simple organisms, like prokaryotes, keep up with the times through adaptive evolution

Copyright

Computing Tools

Several Computing Tasks

- Transcriptomics
- Machine Learning: Species Distribution Analysis, Species Diversity Analysis, Species Classification, Prediction of Enviromental Impacts on Biodiversity
- 3D Morphological Modeling

Transcriptomics

- Transcriptomics is the study of all the RNA (transcripts) expressed in a cell or tissue at any given time.
- In the context of animal diversity, it is used to:
  - Understand how genes are expressed during embryonic development and the evolution of body shape.
  - Compare gene expression between species to see evolutionary changes.
  - Relate gene expression to phenotypes, such as body structure, nervous system, or reproductive strategy.

Genetic Linkage Map for the cichlid fish Metriaclima zebra

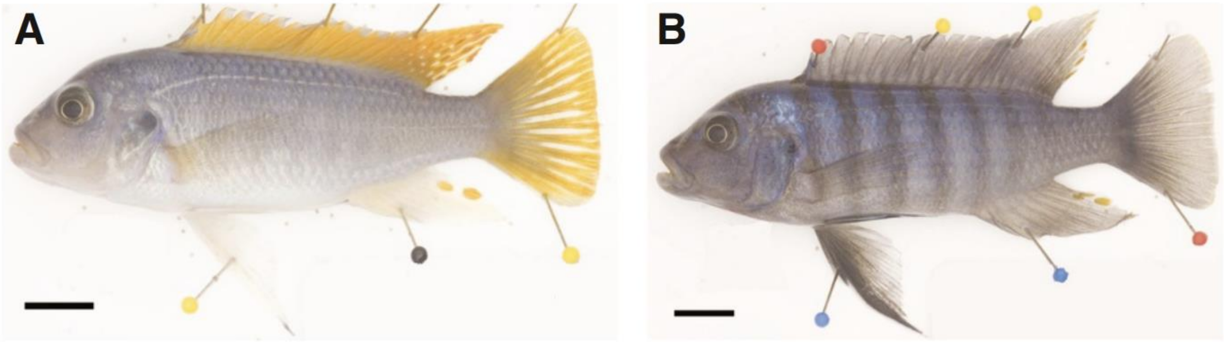
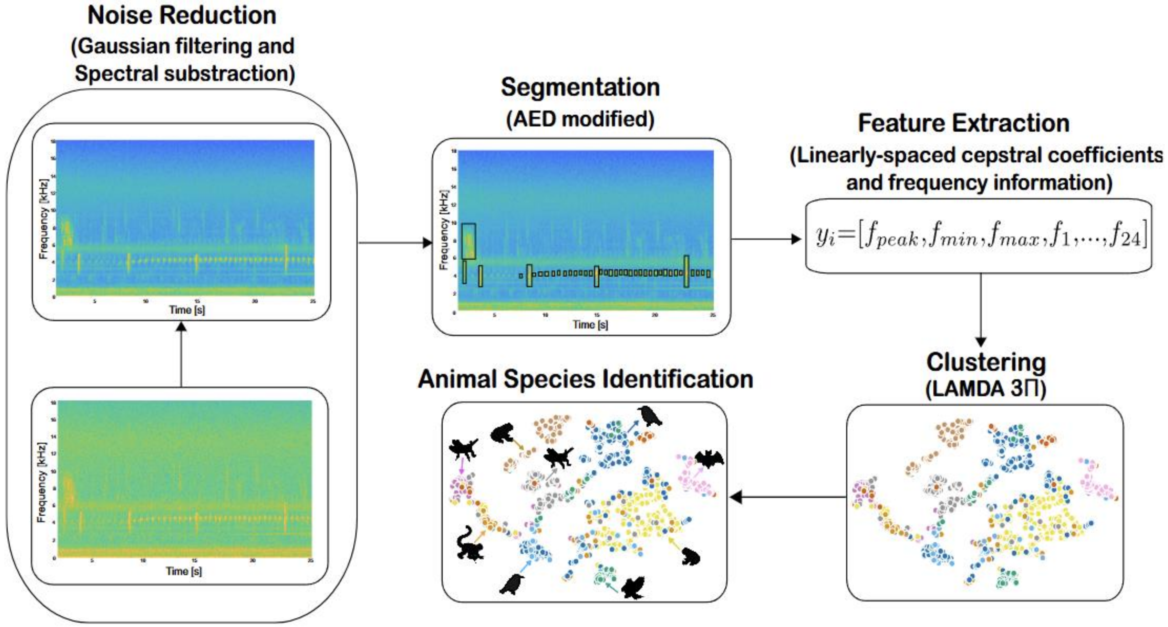


Figure 1 F_0 parents of the hybrid cross. A) *M. mbenjii* male. Note the orange dorsal and caudal fins, plain blue body, and white pelvic fin. **B**) *M. zebra* male. Note the blue dorsal and caudal fins, barred body, and black pelvic fin.

- A genetic linkage map for the cichlid fish by genotyping 798 SNPs across 160 F_2 male individuals
- They identified quantitative trait loci (QTL) associated with pigmentation traits: one QTL on linkage group 12 influencing xanthophore (yellow pigment cell) presence in the dorsal and caudal fins, and another on linkage group 11 affecting melanophore (black pigment cell) presence in the pelvic fin.
- These findings suggest that natural variation in fish pigmentation may involve genetic factors distinct from those previously identified through mutagenesis studies in other species.

https://bmcgenomics.biomedcentral.com/articles/10.1186/1471-2164-14-287

Acoustic Animal Identification using Unsupervised Learning



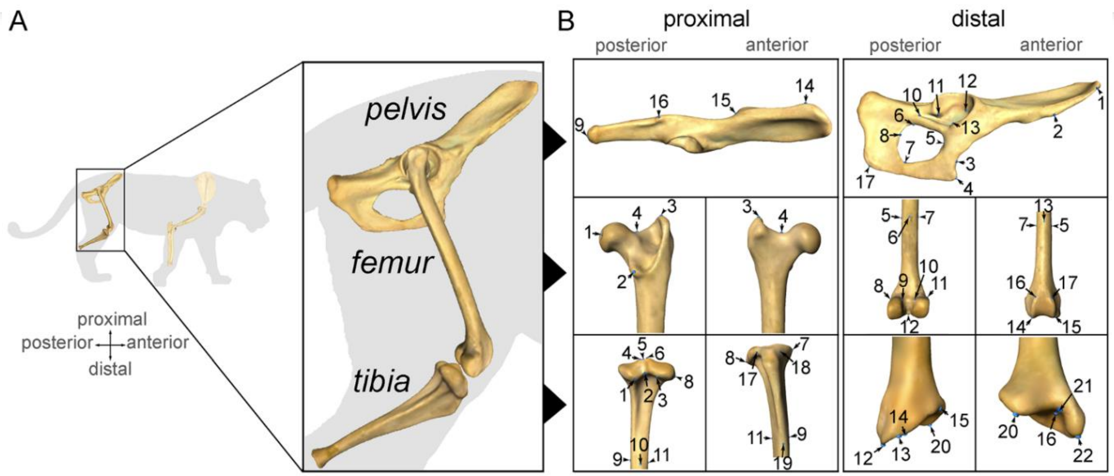
https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1111/2041-210X.14103

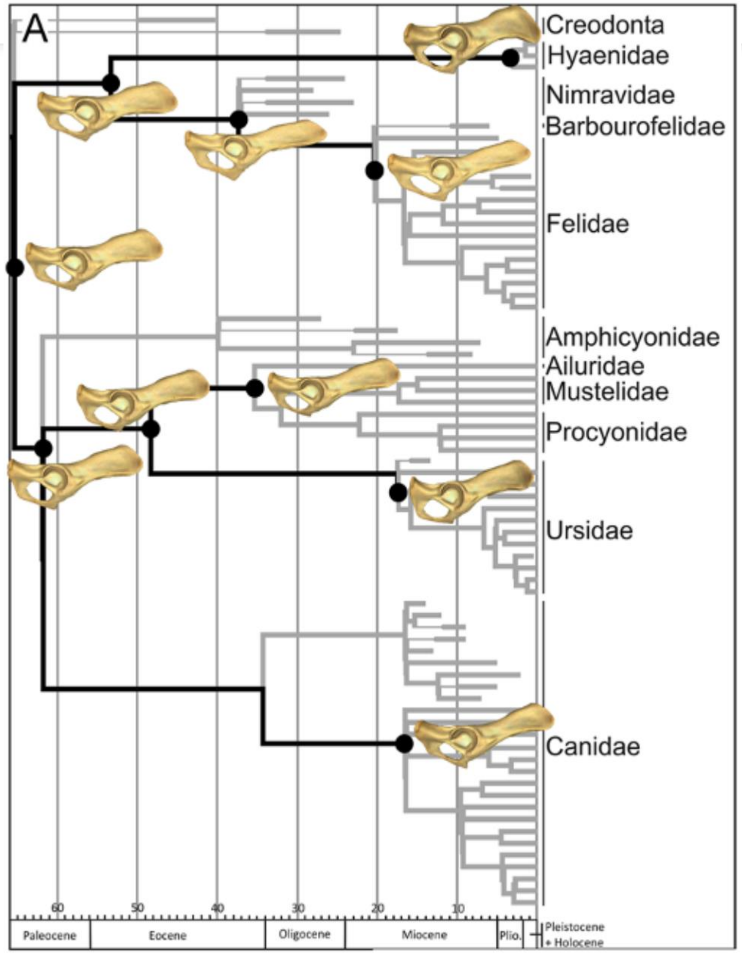
- Use audio from tropical rainforests (e.g. bird, insect, amphibian sounds).
- Unsupervised learning models (clustering + dimensionality reduction such as t-SNE) to group sound patterns into biodiversity indicators.
- Can map spatial diversity differences without manual identification of each species.

3D Morphological Modeling

- 3D Morphological Modeling is a technique for reconstructing and analyzing the physical form of organisms (or parts of their bodies) in three dimensions, often using biological data such as microscope images, CT scans, or even genetic expression.
- In the context of biological diversity, these models help:
  - Explain the evolution of body shape from fossils to modern species.
  - Test hypotheses of morphological adaptation.
  - Map gene-to-shape relationships.

3D Geometric Morphometric Analysis of the Hind Limb Bones





- a comprehensive 3D geometric morphometric analysis of the hind limb bones–specifically the femur, tibia, and pelvic girdle–of both extant and extinct terrestrial carnivorans to assess the impacts of body size, phylogeny, and locomotor behavior on bone morphology.
- This study underscores the evolutionary constraints on appendicular skeleton morphology imposed by terrestrial locomotion, contrasting with the greater morphological variability observed in carnivoran skull evolution.

https://bmcecolevol.biomedcentral.com/articles/10.1186/1471-2148-14-129

References

- O'Quin, C.T., Drilea, A.C., Conte, M.A. et al. Mapping of pigmentation QTL on an anchored genome assembly of the cichlid fish, Metriaclima zebra. BMC Genomics 14, 287 (2013). https://doi.org/10.1186/1471-2164-14-287
- Guerrero, M. J., Bedoya, C. L., López, J. D., Daza, J. M., & Isaza, C. (2023). Acoustic animal identification using unsupervised learning. Methods in Ecology and Evolution, 14(6), 1500-1514. https://doi.org/10.1111/2041-210X.14103
- Martín-Serra, A., Figueirido, B. & Palmqvist, P. A three-dimensional analysis of the morphological evolution and locomotor behaviour of the carnivoran hind limb. BMC Evol Biol 14, 129 (2014). https://doi.org/10.1186/1471-2148-14-129

Project Topic Proposal Checking II

Project Objective

Objective

- Students must demonstrate their understanding of biological foundations in developing computation-based solutions.

Assessment Components

- Application of biological foundations in developing computational models.
- Formulation of well-defined research questions based on a thorough review of existing literature.
- Contribution of the proposed solution to the existing body of knowledge (novelty is encouraged but not mandatory).
- Effort and rigor in developing the computational model, including result analysis and interpretation.
- Clarity and effectiveness in presenting computational results and their biological significance.