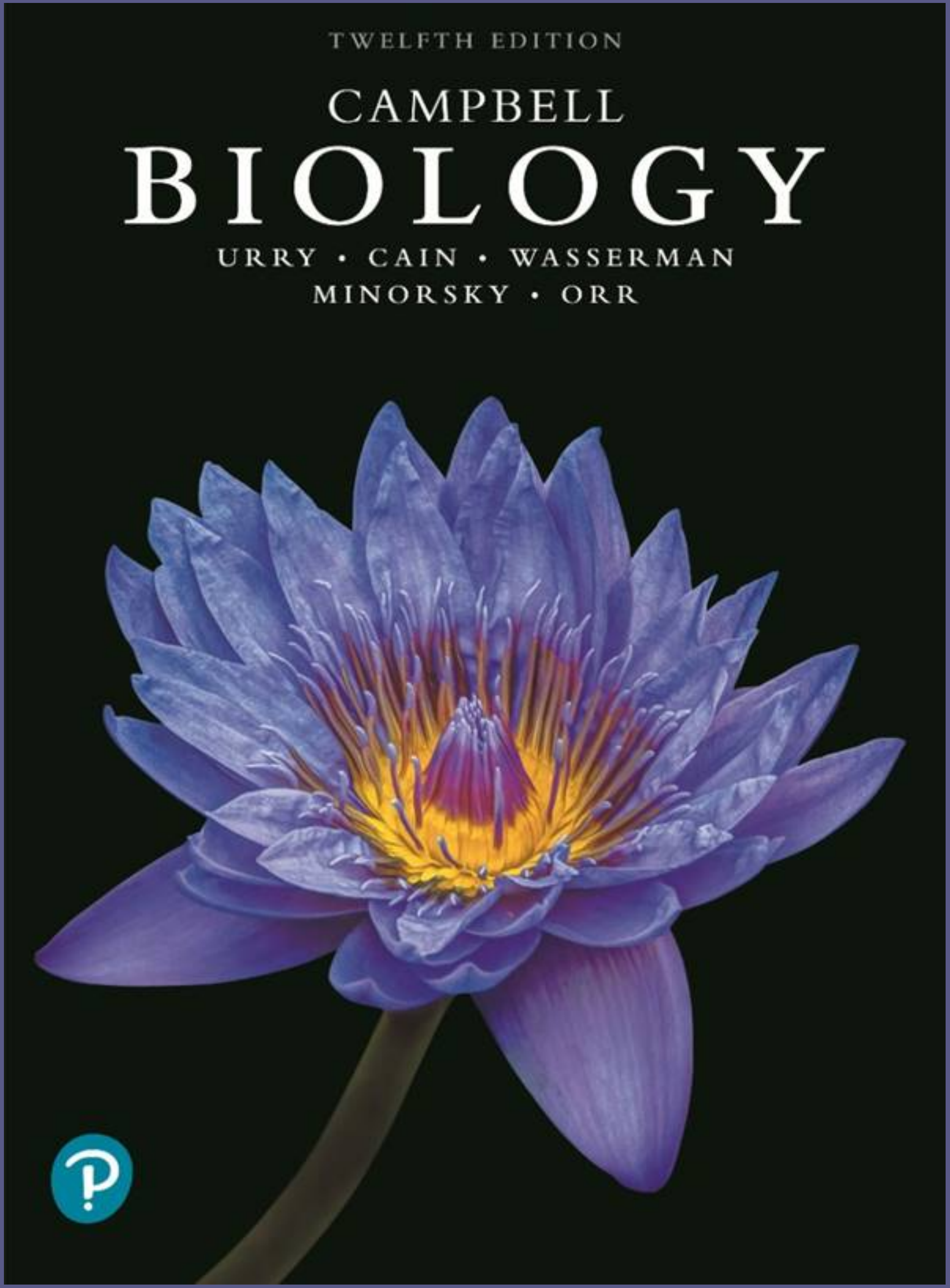


Chapter 32

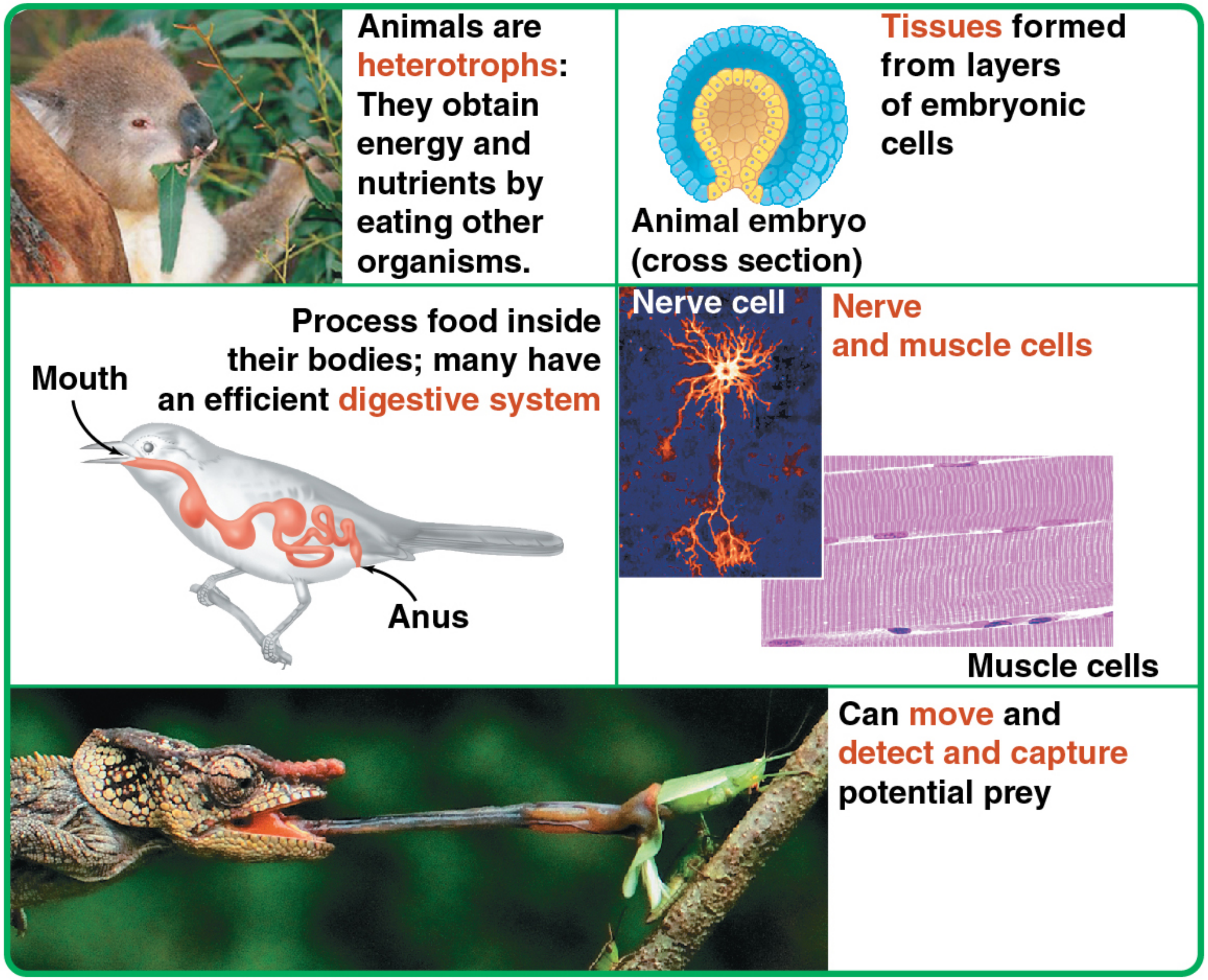
An Overview of Animal Diversity

Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

Figure 32.1a

Figure 32.1b

What key characteristics of animals make them such efficient consumers?



CONCEPT 32.1: Animals are multicellular, heterotrophic eukaryotes with tissues that develop from embryonic layers

- There are exceptions to nearly every criterion for distinguishing animals from other life-forms
- Several characteristics, taken together, sufficiently define the animal kingdom

Nutritional Mode

- Unlike plants, which produce their own organic molecules, animals eat living or nonliving organisms
- Unlike fungi, which digest food externally and then absorb nutrients, animals ingest food and then digest it internally

Cell Structure and Specialization

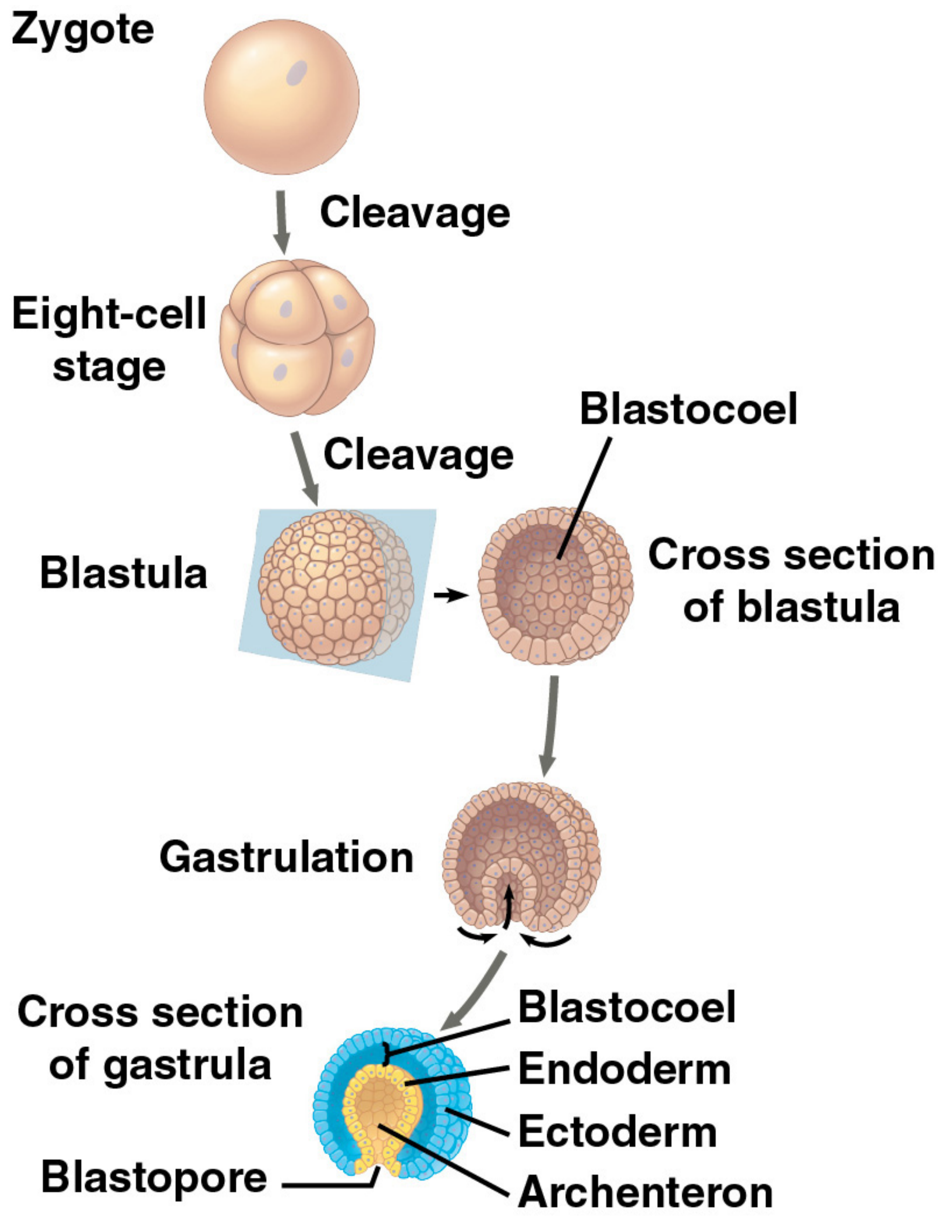
- Animals are multicellular eukaryotes
- Animal cells are supported by structural proteins such as collagen, rather than cell walls
- Nervous tissue and muscle tissue are unique, defining characteristics of animals
- **Tissues** are groups of similar cells that act as a functional unit

Reproduction and Development

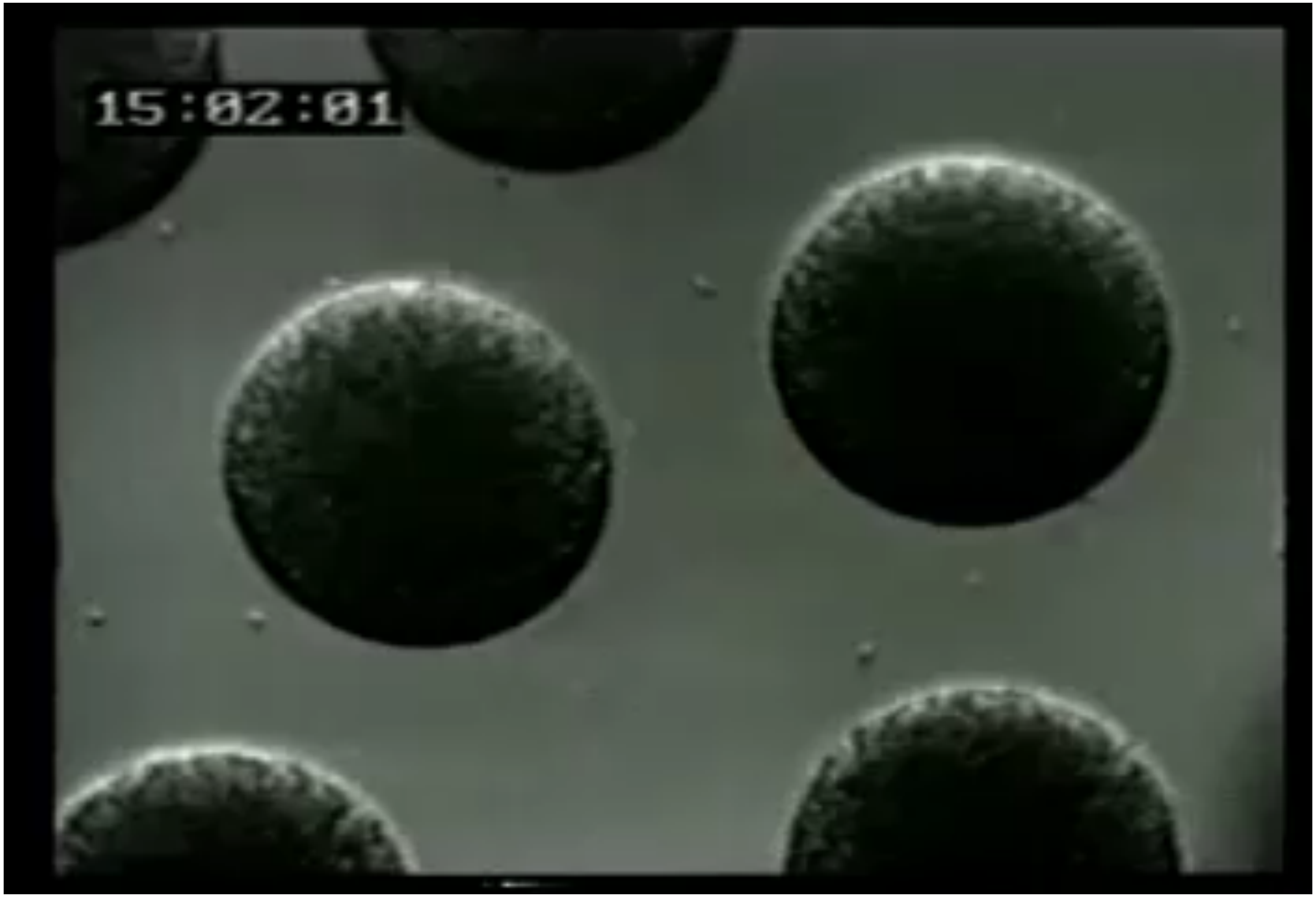
- Most animals reproduce sexually, with the diploid stage usually dominating the life cycle
- Unlike plants and fungi, sperm and egg cells are produced directly by meiotic division in animals

- Animal zygotes undergo **cleavage**, a succession of cell division without growth between divisions
- Cleavage leads to formation of a **blastula**, often in the form of a hollow ball of cells
- The blastula will undergo **gastrulation**, forming a **gastrula** with different layers of embryonic tissues

Figure 32.2


Zygote
Cleavage
Eight-cell stage
Cleavage
Blastocoel
Blastula
Cross section of blastula
Gastrulation
Cross section of gastrula
Blastocoel
Endoderm
Ectoderm
Archenteron
Blastopore

Video: Sea Urchin Embryonic Development (Time Lapse)



- Most animals have at least one larval stage
- The **larva** is sexually immature, and morphologically and behaviorally distinct from the adult stage
- After **metamorphosis**, larvae become juveniles that resemble adults but are sexually immature

- All animals have developmental genes that regulate the expression of other genes
- Most animals share a unique family of regulatory genes called *Hox* genes
- *Hox* genes control the expression of many other genes that influence morphology

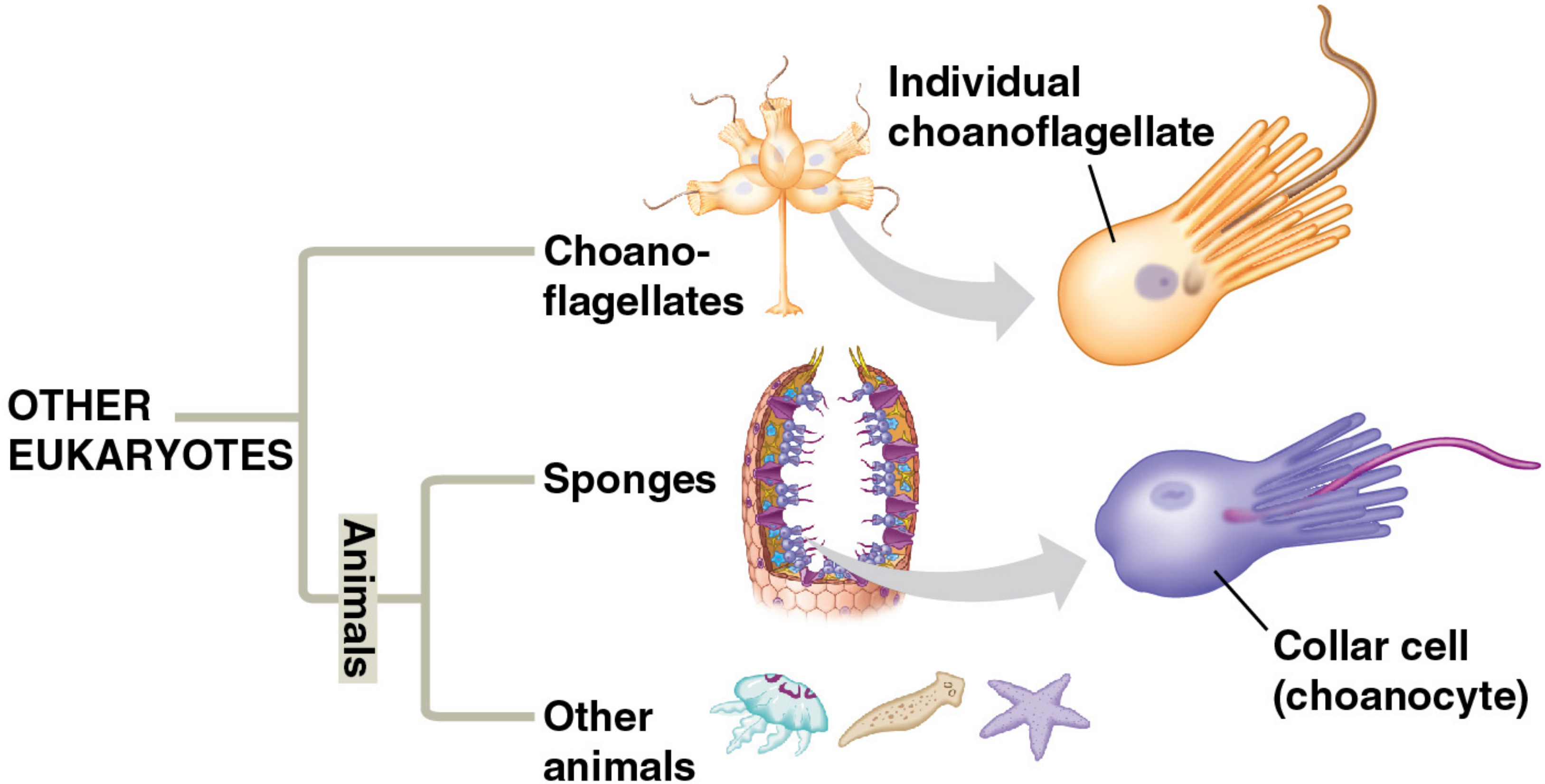
CONCEPT 32.2: The history of animals spans more than half a billion years

- Biologists have identified 1.3 million living animal species to date; far more are estimated to exist
- Chemical evidence of steroids used by sponges has been found in 710-million-year-old sediments
- Molecular analysis suggests the common ancestor animals likely lived about 770 million years ago

Steps in the Origin of Multicellular Animals

- Morphological and molecular evidence indicate that protists called choanoflagellates are the closest living relatives to animals
- The common ancestor may have resembled modern choanoflagellates

Figure 32.3



Individual
choanoflagellate
Choano-
flagellates
OTHER
EUKARYOTES
Sponges
Animals
Collar cell
(choanocyte)
Other
animals

- Multicellularity requires new ways for cells to adhere (attach) and signal (communicate) to each other
- Animal genes involved in adherence and attachment have sequence similarities in choanoflagellates
  - For example, several domains found in the animal cadherin protein are also present in a similar choanoflagellate protein

Figure 32.4


Choano-
flagellate
Hydra
Fruit fly
Mouse
"CCD" domain (only
found in animals)

Interview with Nicole King: Investigating the ancestry of choanoflagellates

Neoproterozoic Era (1 Billion–541 Million Years Ago)

- The first generally accepted macroscopic animal fossils date from about 560 million years ago
- They form the **Ediacaran biota**, for the Ediacara Hills of Australia, where they were first discovered

- Some Ediacaran fossils have been classified as, or closely related to, molluscs, sponges, or cnidarians
- Many do not resemble any living animals or algae
- Microscopic fossils that may be animal embryos have also been found in rocks from this period

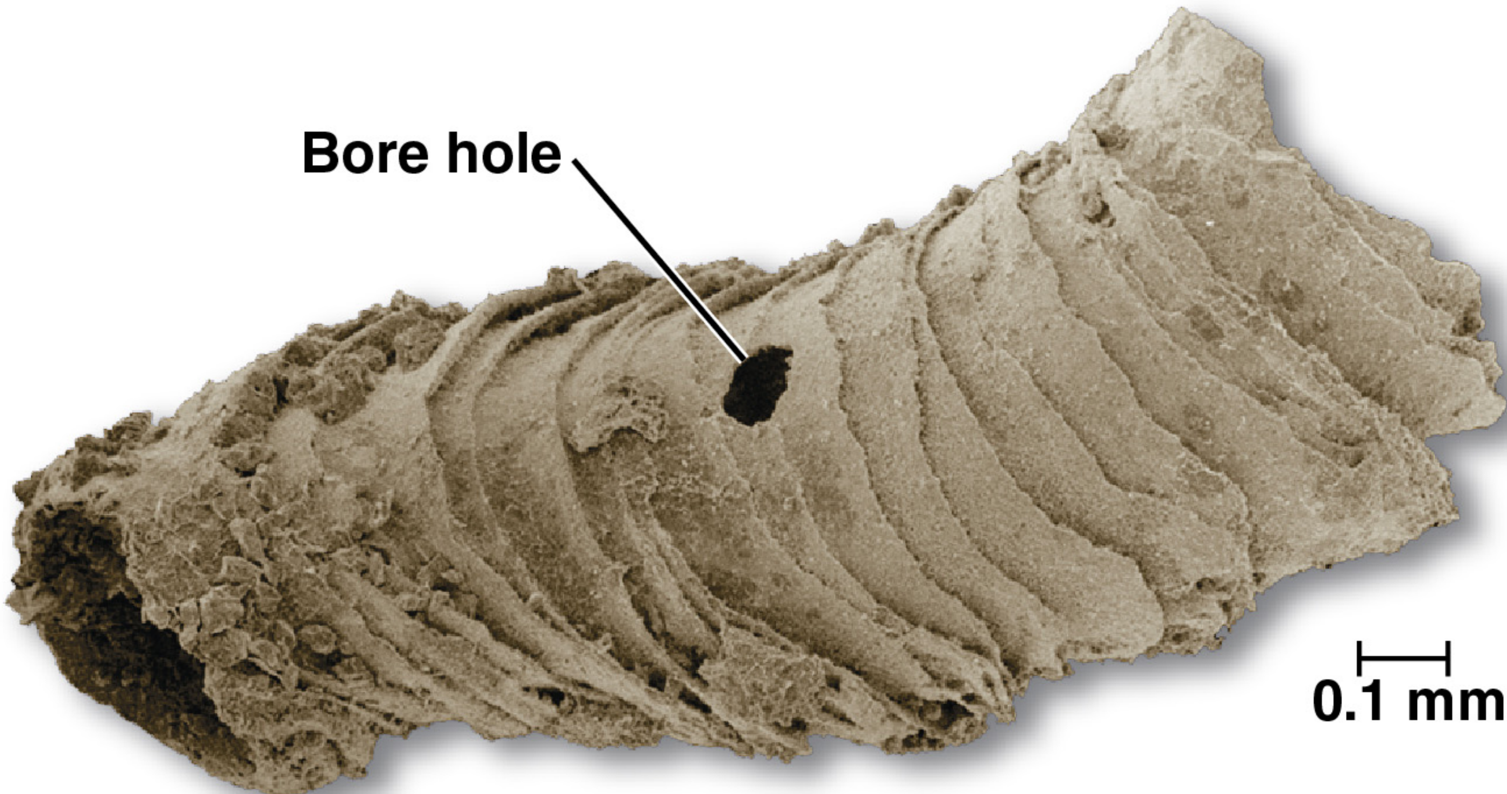
Figure 32.5

(a) ***Dickinsonia costata*** 2.5 cm

(b) ***Kimberella***

- Early evidence of predation is found in fossils of the Ediacaran period (635–541 million years ago)
  - For example, *Cloudina* is a small animal protected by a shell; the shells of some *Cloudina* fossils show signs of predator attack

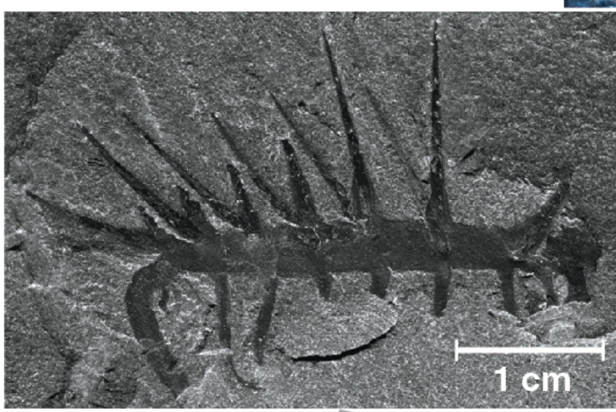
Figure 32.6



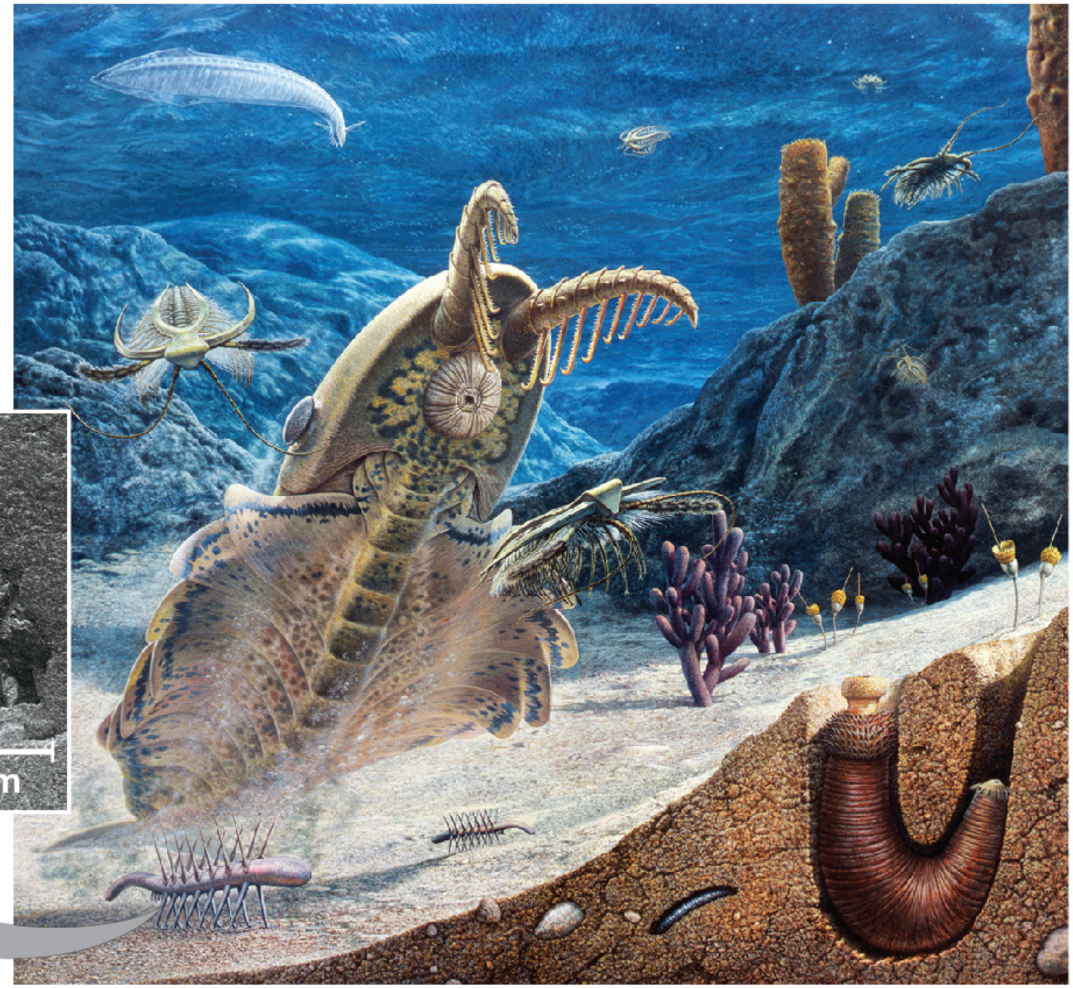
Paleozoic Era (541–252 Million Years Ago)

- The **Cambrian explosion** (535–525 million years ago) marks a period of rapid animal diversification
- The first large animal fossils with hard, mineralized skeletons date back to this time
- The earliest fossils of many extant groups are from this period, but many do not resemble living forms

Figure 32.7



508-million-year-old fossil of *Hallucigenia*



- Most of the fossils from the Cambrian explosion are of **bilaterians**, organisms with the following traits:
  - Bilaterally symmetric form
  - Complete digestive tract
  - Efficient digestive system with a mouth and an anus at opposite ends

- Hypotheses for the rise of Cambrian diversity and concurrent decline of the Ediacaran biota include
  - New predator-prey relationships
  - A rise in atmospheric oxygen
  - The evolution of the *Hox* gene complex and microRNAs (small RNAs involved in gene regulation)

- Animal diversity increased throughout the Paleozoic era, punctuated by mass extinctions
- Animals began to make an impact on land by 450 million years ago
- Arthropods were the first to adapt to life on land, and began influencing plants by 302 million years ago

- Vertebrates colonized land and diversified about 365 million years ago
- Two groups of early land vertebrates survive today: the amphibians and the amniotes

Mesozoic Era (252–66 Million Years Ago)

- During the Mesozoic era, the first coral reefs formed important ecological niches for marine animals
- Some reptiles returned to aquatic habitats; others remained on land and became adapted for flight
- Dinosaurs emerged as predators and herbivores
- Mammals (tiny, nocturnal insect-eaters) appeared
- Flowering plants and insects diversified

Cenozoic Era (66 Million Years Ago to the Present)

- The beginning of the Cenozoic era followed mass extinctions of both terrestrial and marine animals
- Large, flightless dinosaurs and marine reptiles were extinct
- Mammals increased in size and abundance
- The global climate cooled throughout this period
- The primate ancestors to humans moved into open woodlands and savannas

CONCEPT 32.3: Animals can be characterized by body plans

- Animal diversity can be described by a few major **body plans**, sets of morphological and developmental traits
- Some body plans are conserved, while others have changed many times over the course of evolution

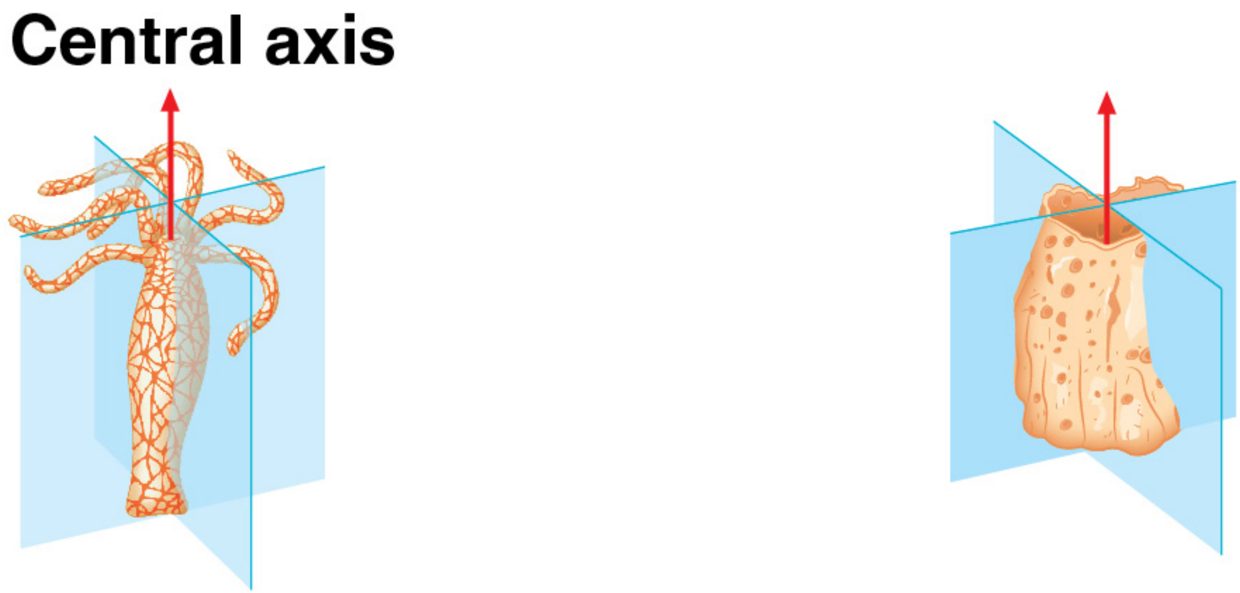
Symmetry

- Animals can be compared based on body symmetry, or lack thereof (many sponges lack symmetry)
- The symmetry of an animal often fits its lifestyle
  - Radially symmetrical animals are often sessile or planktonic (drifting or weakly swimming)
  - Bilateral animals typically move actively and have a central nervous system

Radial Symmetry

- In animals with radial symmetry, body parts are arranged around a single central axis
- Any imaginary slice through the central axis divides the animal into mirror images

Figure 32.8a

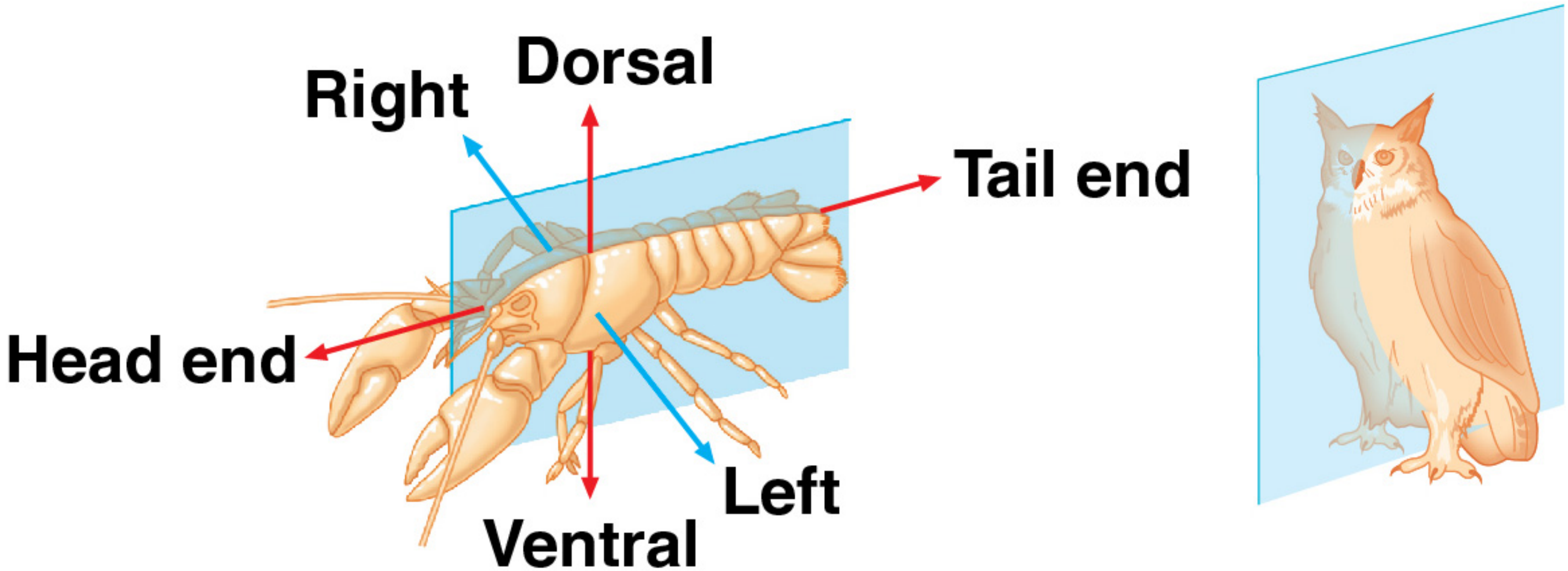


(a) Radial Symmetry

Bilateral Symmetry and Body Axes

- In animals with bilateral symmetry, body parts are arranged around two axes of orientation, the head-tail axis and the dorsal-ventral axis
- Only one imaginary slice divides the animal into mirror-image halves, a right side and a left side

Figure 32.8b



(b) Bilateral Symmetry and Body Axes

- Bilaterally symmetrical animals have
  - A dorsal (top) side and a ventral (bottom) side
  - A right and left side
  - Head end and tail end
- Many also have sensory equipment, such as a brain, concentrated in their anterior end

Tissues

- Animal body plans also vary according to the organization of tissues
- Tissues are collections of specialized cells that act as a functional unit
- Sponges and a few other groups lack tissues

- All other animals have two germ layers that give rise to the tissues and organs of the embryo
  - **Ectoderm** covers the embryo’s surface, and gives rise to the outer covering and central nervous system
  - **Endoderm**, the innermost layer, lines the blind pouch (archenteron) that will form the gut, and gives rise to the lining of the digestive tract and organs

- **Diploblastic** animals, such as cnidarians, have only ectoderm and endoderm
- **Triploblastic** animals, including all bilaterally symmetrical animals, have a third germ layer
  - **Mesoderm** fills the space between ectoderm and endoderm, and gives rise to muscles and most organs

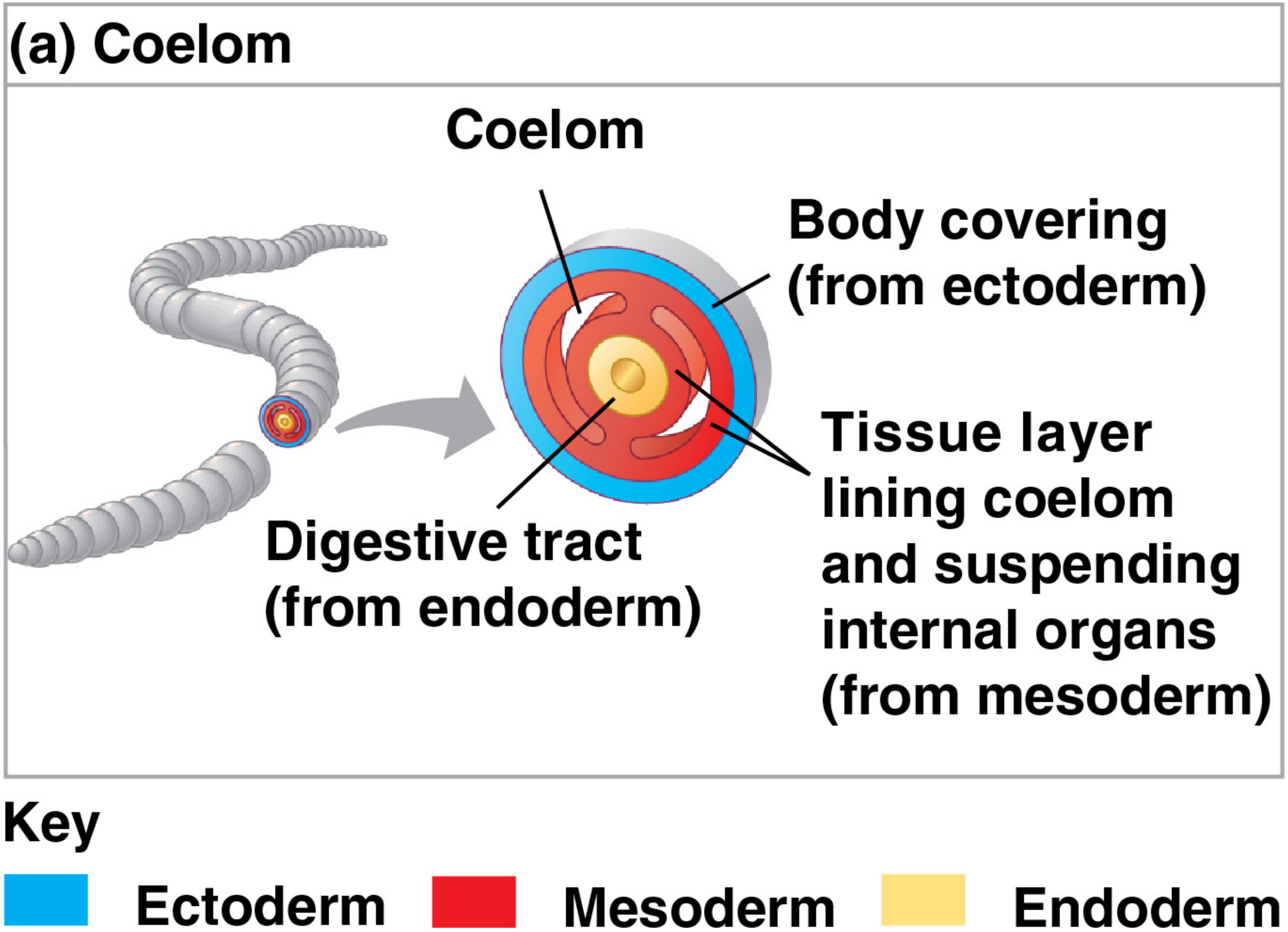
Body Cavities

- Most triploblastic animals have a **body cavity**, a fluid- or air-filled space between the digestive tract and the outer body wall

- Body cavities have many functions
  - The internal fluid cushions the suspended organs
  - The fluid can act like a skeleton against which the muscles of soft-bodied animals can work
  - The cavity enables internal organs to grow and move independently of the outer body wall

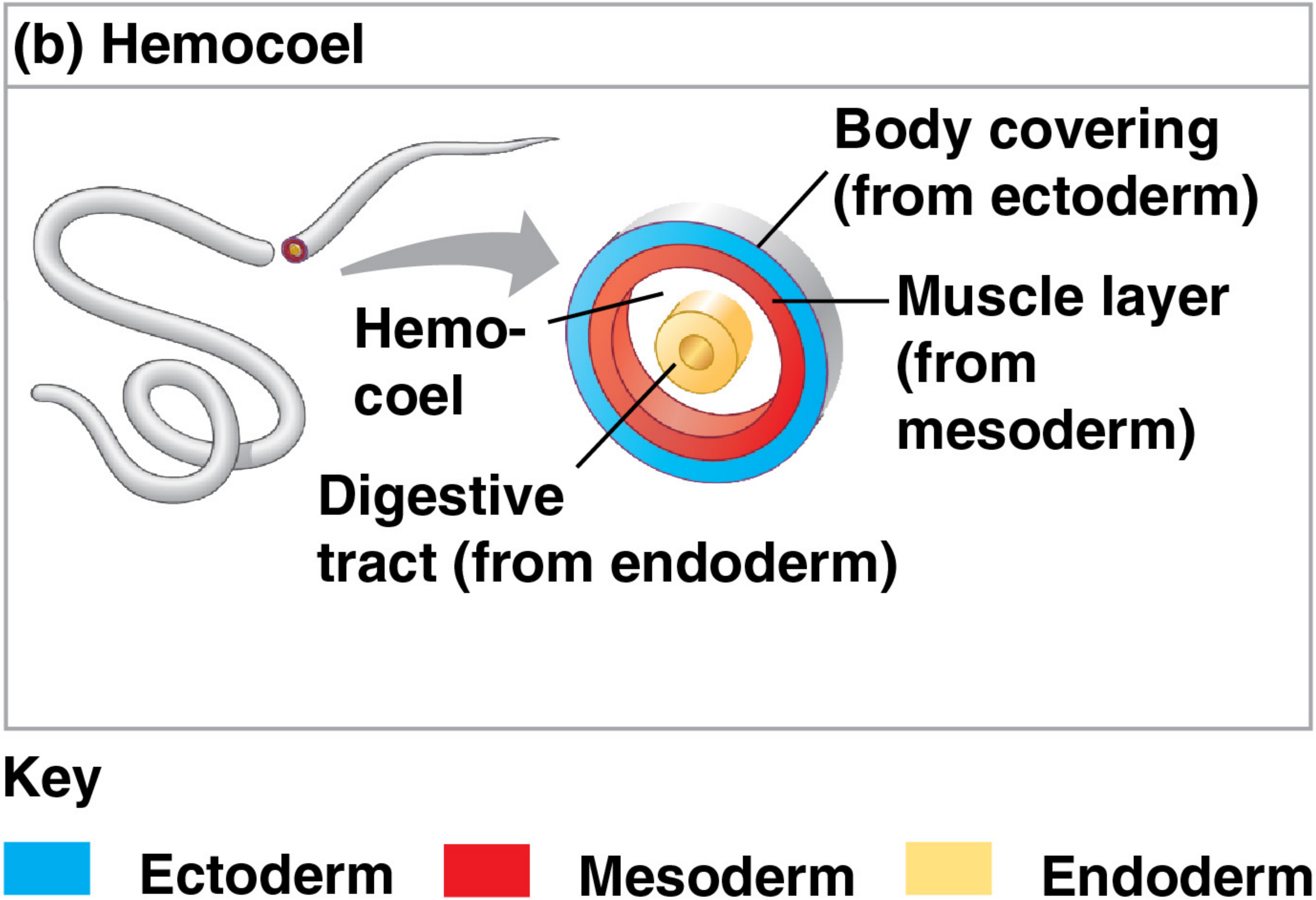
- A **coelom** is a body cavity surrounded by tissues derived from mesoderm
- The mesoderm forms structures that suspend the internal organs

Figure 32.9a


(a) Coelom
Coelom
Body covering (from ectoderm)
Tissue layer lining coelom and suspending internal organs (from mesoderm)
Digestive tract (from endoderm)
Key
Ectoderm
Mesoderm
Endoderm

- A **hemocoel** is a body cavity formed between the mesoderm and endoderm
- It is filled with hemolymph, a fluid that transports nutrients and waste throughout the body cavity

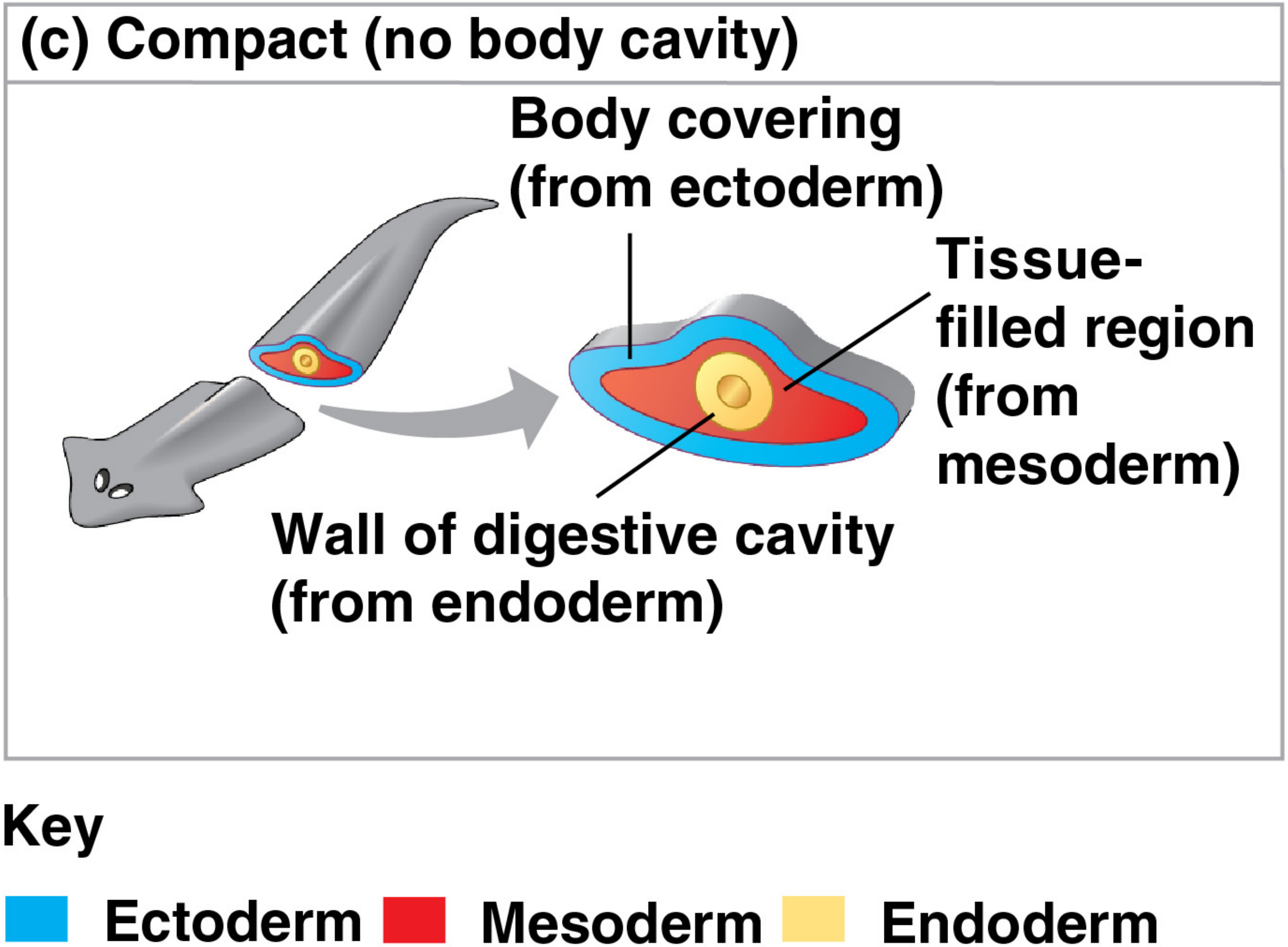
Figure 32.9b


(b) Hemocoel
Body covering (from ectoderm)
Muscle layer (from mesoderm)
Hemo-coel
Digestive tract (from endoderm)
Key
Ectoderm
Mesoderm
Endoderm

- Many animals have a hemocoel and a coelom
  - For example, in molluscs, the hemocoel is the primary body cavity and a reduced coelom surrounds the heart and reproductive structures

- Some triploblastic animals do not have a body cavity
- They tend to be compact animals with thin, flat bodies that exchange nutrients, gases, and wastes across the body surface

Figure 32.9c



(c) Compact (no body cavity)
Body covering
(from ectoderm)
Tissue-
filled region
(from
mesoderm)
Wall of digestive cavity
(from endoderm)
Key
Ectoderm
Mesoderm
Endoderm

Protostome and Deuterostome Development

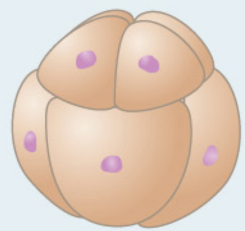
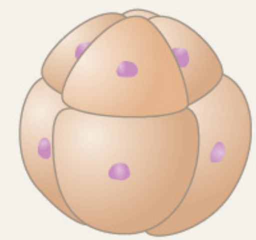
- Many animals can be categorized as having one of two developmental modes: **protostome development** or **deuterostome development**
- These modes differ in cleavage, coelom formation, and fate of the blastopore

Cleavage

- Many animals with protostome development have spiral and determinant cleavage
  - In **spiral cleavage**, the planes of cell division are diagonal to the vertical axis of the embryo
  - **Determinate cleavage** rigidly determines the developmental fate of each embryonic cell very early

- In deuterostome development, cleavage is radial and indeterminate
  - In **radial cleavage**, the planes of division are either parallel or perpendicular to the embryo's vertical axis
  - In **indeterminate cleavage**, each cell produced by early cleavage is able to form a complete embryo

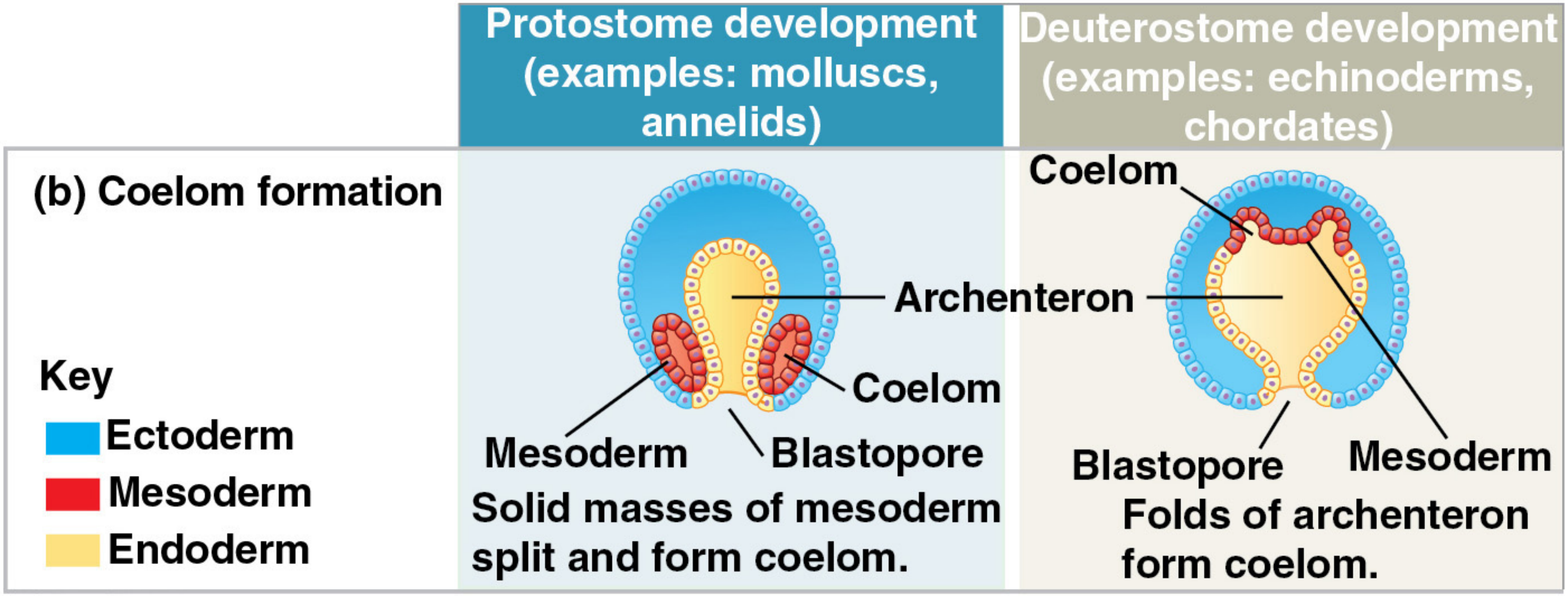
Figure 32.10a

	Protostome development (examples: molluscs, annelids)	Deuterostome development (examples: echinoderms, chordates)
(a) Cleavage **Key** Ectoderm Mesoderm Endoderm	**Eight-cell stage**  **Spiral and determinate**	**Eight-cell stage**  **Radial and indeterminate**

Coelom Formation

- During gastrulation, the embryo forms a blind pouch, the **archenteron** (which becomes the gut)
- The coelom also forms during this stage
  - In protostome development, the splitting of solid masses of mesoderm forms the coelom
  - In deuterostome development, the mesoderm buds from the wall of the archenteron to form the coelom

Figure 32.10b



Fate of the Blastopore

- The **blastopore** is an indentation in the gastrula that leads to the formation of the archenteron
- The blastopore and a second opening at the opposite end will form the mouth and anus
  - In protostome development, the blastopore becomes the mouth
  - In deuterostome development, the blastopore becomes the anus

Figure 32.10c

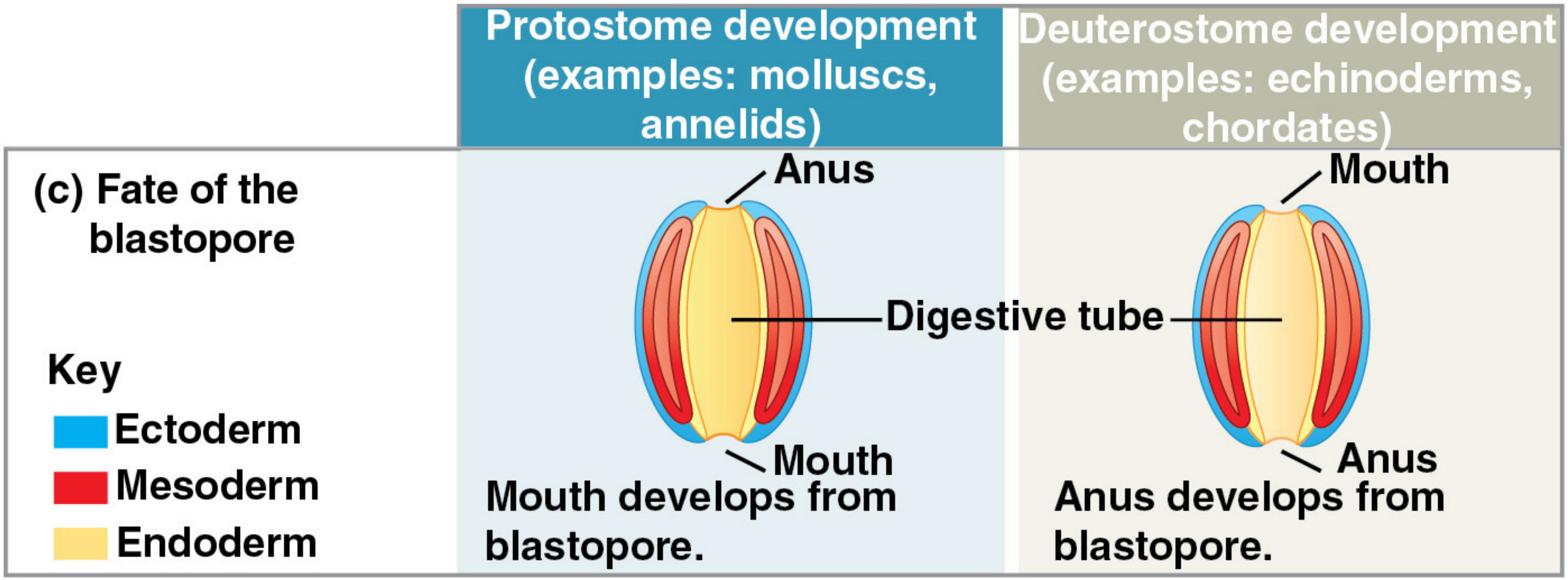
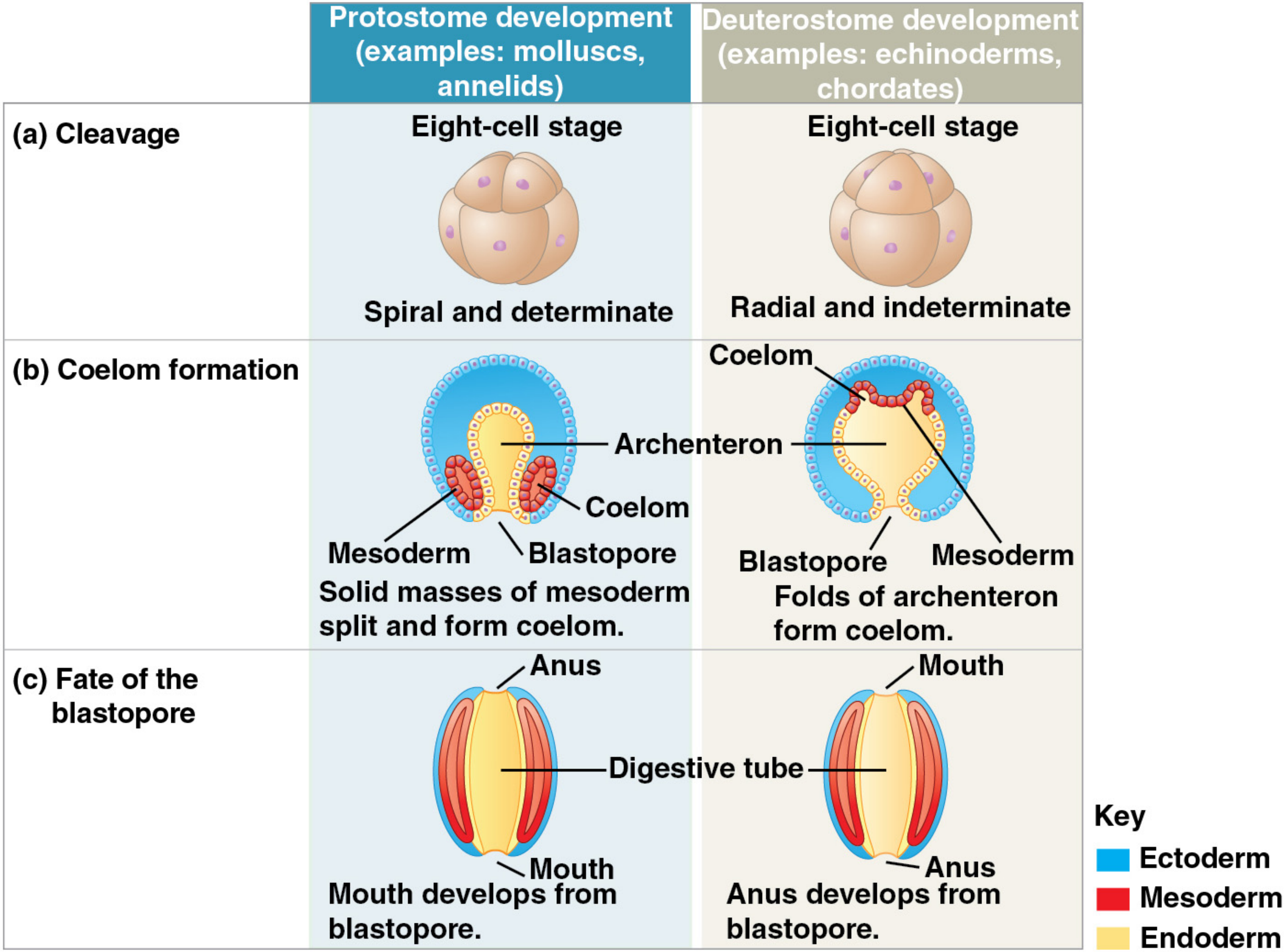


Figure 32.10



Protostome development (examples: molluscs, annelids)
Deuterostome development (examples: echinoderms, chordates)
(a) Cleavage
Eight-cell stage
Eight-cell stage
Spiral and determinate
Radial and indeterminate
(b) Coelom formation
Coelom
Archenteron
Coelom
Mesoderm
Blastopore
Blastopore
Mesoderm
Solid masses of mesoderm split and form coelom.
Folds of archenteron form coelom.
(c) Fate of the blastopore
Anus
Mouth
Digestive tube
Mouth
Anus
Mouth develops from blastopore.
Anus develops from blastopore.
Key
Ectoderm
Mesoderm
Endoderm

CONCEPT 32.4: Views of animal phylogeny continue to be shaped by new molecular and morphological data

- By 500 million years ago, most animal phyla with members alive today were established

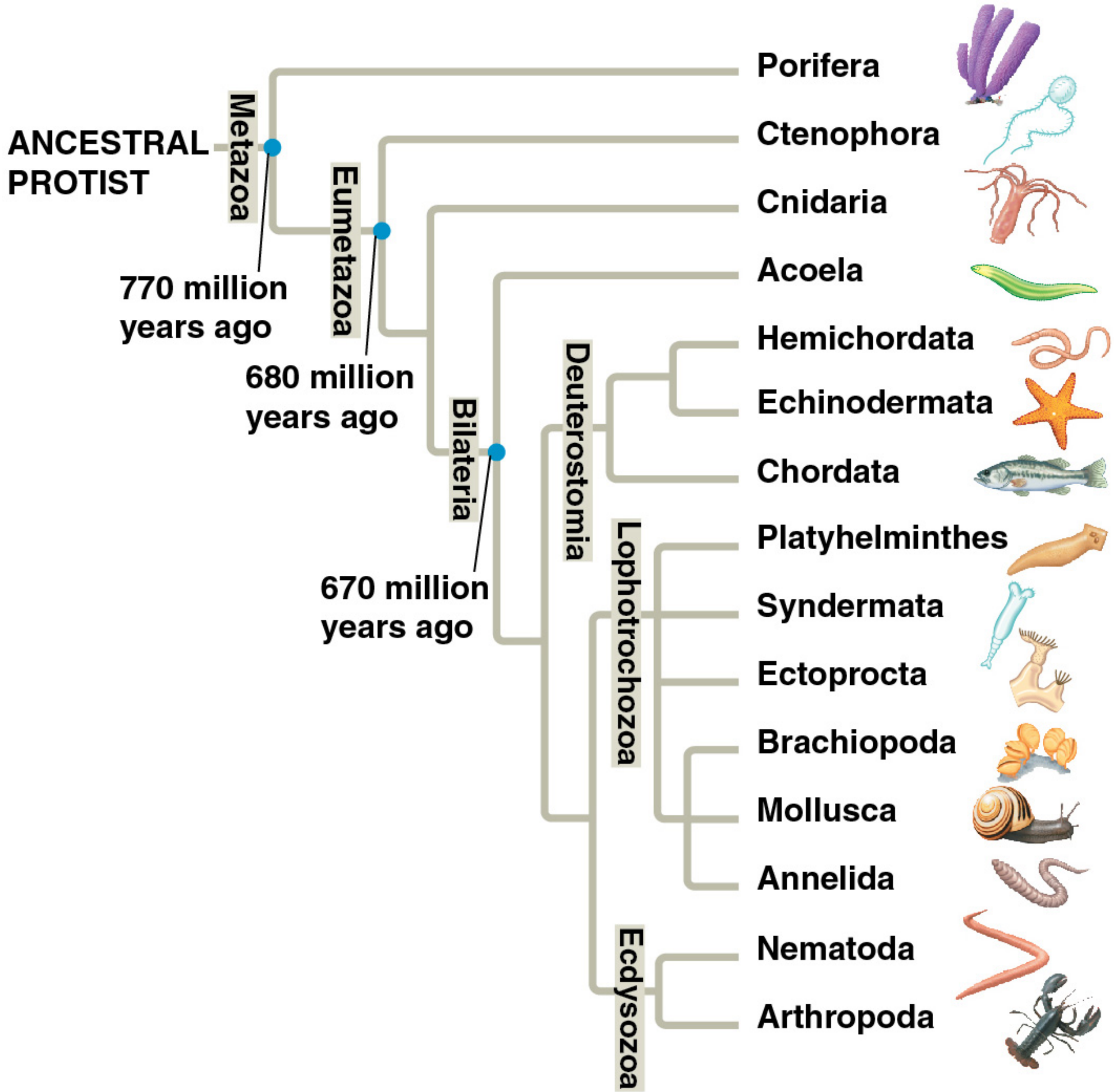
The Diversification of Animals

- Several data sources are used to infer evolutionary relationships among the three dozen extant animal phyla
  - Whole genomes
  - Morphological traits
  - Ribosomal RNA (rRNA) genes
  - *Hox* genes
  - Protein-coding nuclear genes
  - Mitochondrial genes

- Five important points about the relationships among living animals are reflected in their 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 with tissues
     - All animals except for sponges and a few others belong to the **eumetazoans** (“true animals”)

4. Most animal phyla belong to the clade Bilateria
5. There are three major clades of bilaterian animals
   - Most bilaterians are **invertebrates**, animals that lack a backbone
   - Chordata is the only phylum that also includes **vertebrates**, animals with a backbone

Figure 32.11


ANCESTRAL PROTIST
Metazoa
Eumetazoa
770 million years ago
680 million years ago
Bilateria
670 million years ago
Deuterostomia
Lophotrochozoa
Ecdysozoa
Porifera
Ctenophora
Cnidaria
Acoela
Hemichordata
Echinodermata
Chordata
Platyhelminthes
Syndermata
Ectoprocta
Brachiopoda
Mollusca
Annelida
Nematoda
Arthropoda

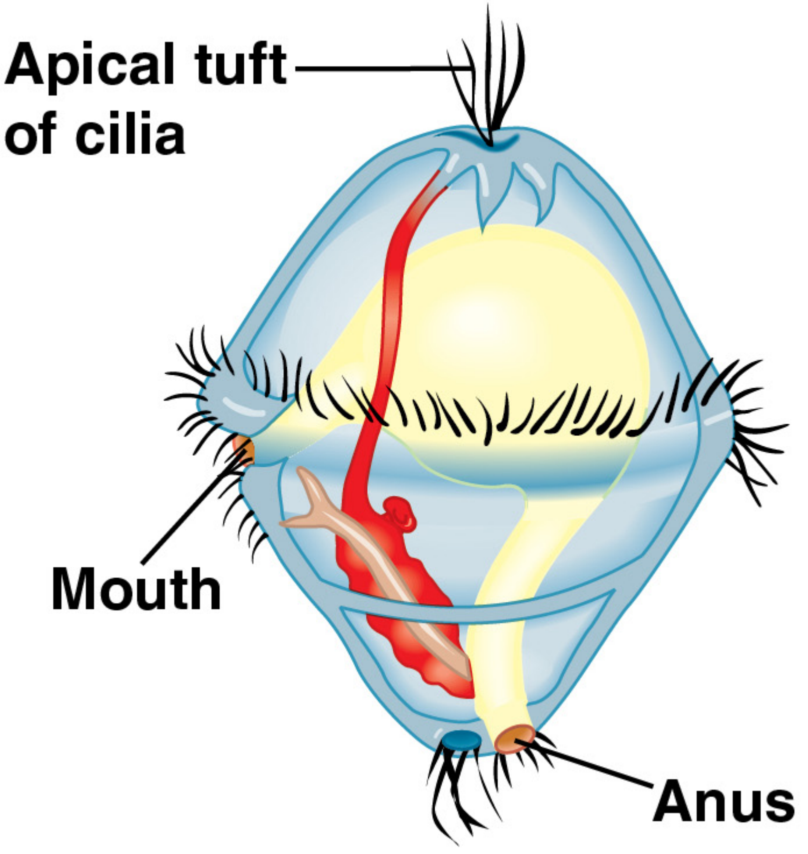
- Bilaterians are divided into three clades: Deuterostomia, Ecdysozoa, and Lophotrochozoa
- Members of **Deuterostomia** may be invertebrates or vertebrates
- Deuterostomia includes hemichordates (acorn worms), echinoderms (sea stars and relatives), and chordates (including vertebrates)

- The ecdysozoans and the lophotrochozoans are all invertebrates
- All members of **Ecdysozoa** secrete an external skeleton (exoskeleton)
- The exoskeleton is shed to allow for growth, a process called ecdysis
- Nematodes and arthropods are ecdysozoans

- The clade **Lophotrochozoa** is named for two different features observed in its members
  - Some, such as ectoprocts, develop a **lophophore**, a crown of ciliated tentacles used for feeding
  - Others, including molluscs and annelids, have a developmental stage called the **trochophore larva**

Figure 32.12

(a) Lophophore feeding structures of an ectoproct



(b) Structure of a trochophore larva

Future Directions in Animal Systematics

- Systematics, like all fields of scientific research, is an ongoing, dynamic process of inquiry
- Two questions are the focus of current research
  1. Are ctenophores basal metazoans?
  2. Are acoelomate flatworms basal bilaterians?

Figure 32.UN01

Data from the Study

Animal Phylum	i	No. of miRNAs (x_i)	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$	No. of Cell Types (y_i)	$(y_i - \bar{y})$	$(y_i - \bar{y})^2$	$(x_i - \bar{x})(y_i - \bar{y})$
Porifera	1	5.8			25			
Platyhelminthes	2	35			30			
Cnidaria	3	2.5			34			
Nematoda	4	26			38			
Echinodermata	5	38.6			45			
Cephalochordata	6	33			68			
Arthropoda	7	59.1			73			
Urochordata	8	25			77			
Mollusca	9	50.8			83			
Annelida	10	58			94			
Vertebrata	11	147.5			172.5			
		$\bar{x}$ = s_x =		Σ =	$\bar{y}$ = s_y =		Σ =	Σ =

Data from B. Deline et al., Evolution of metazoan morphological disparity, *Proceedings of the National Academy of Sciences USA* 115:E8909–E8918 (2018).

Figure 32.UN02

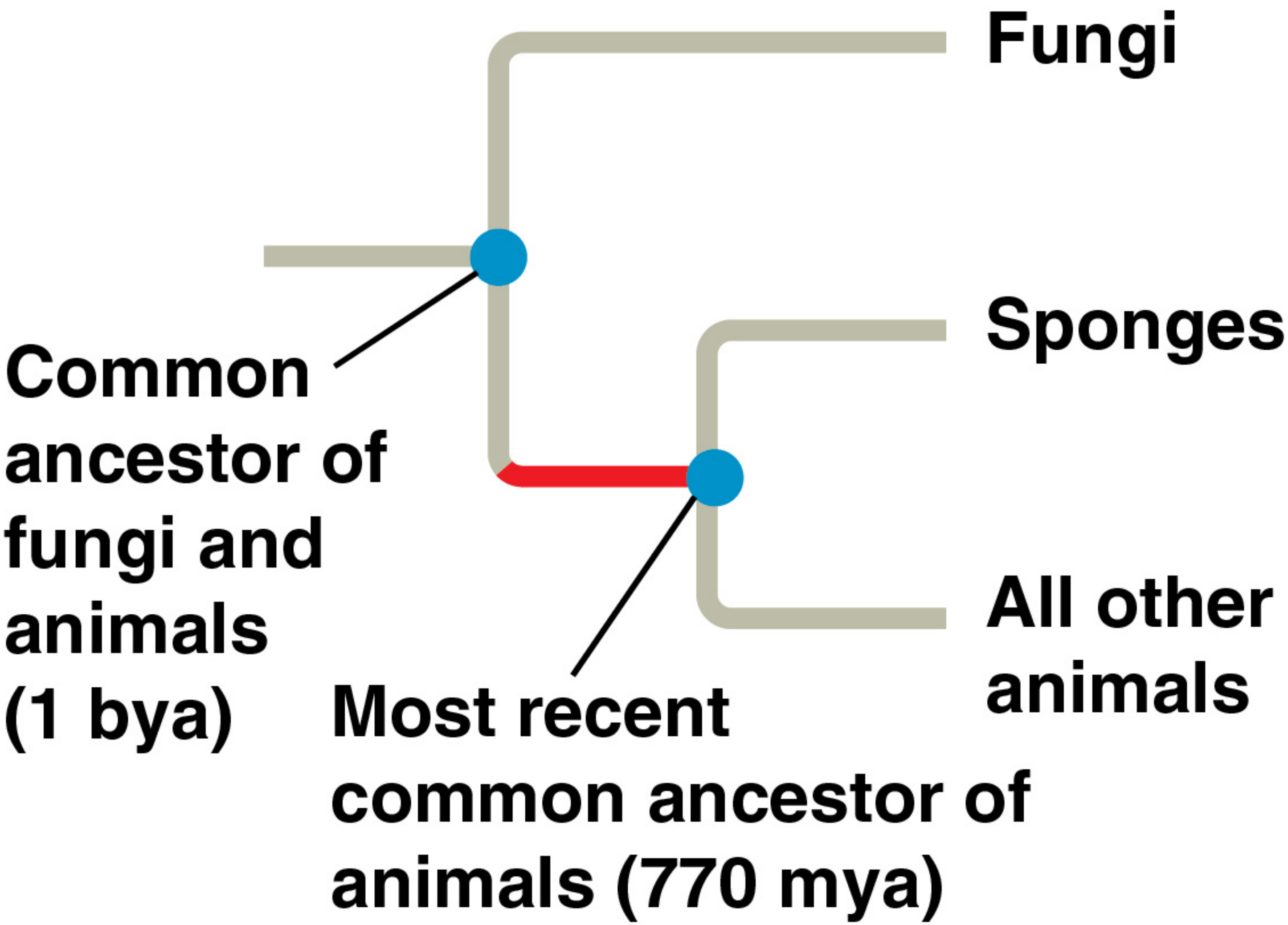


Figure 32.UN03

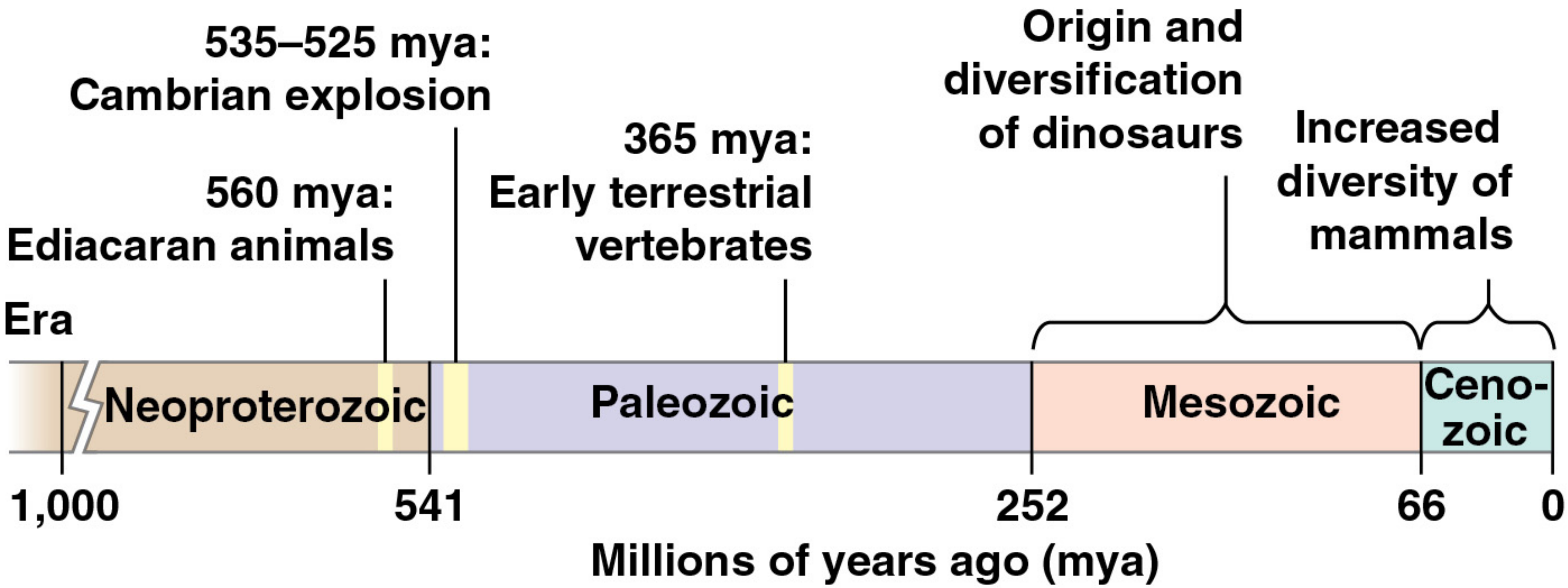


Figure 32.UN04

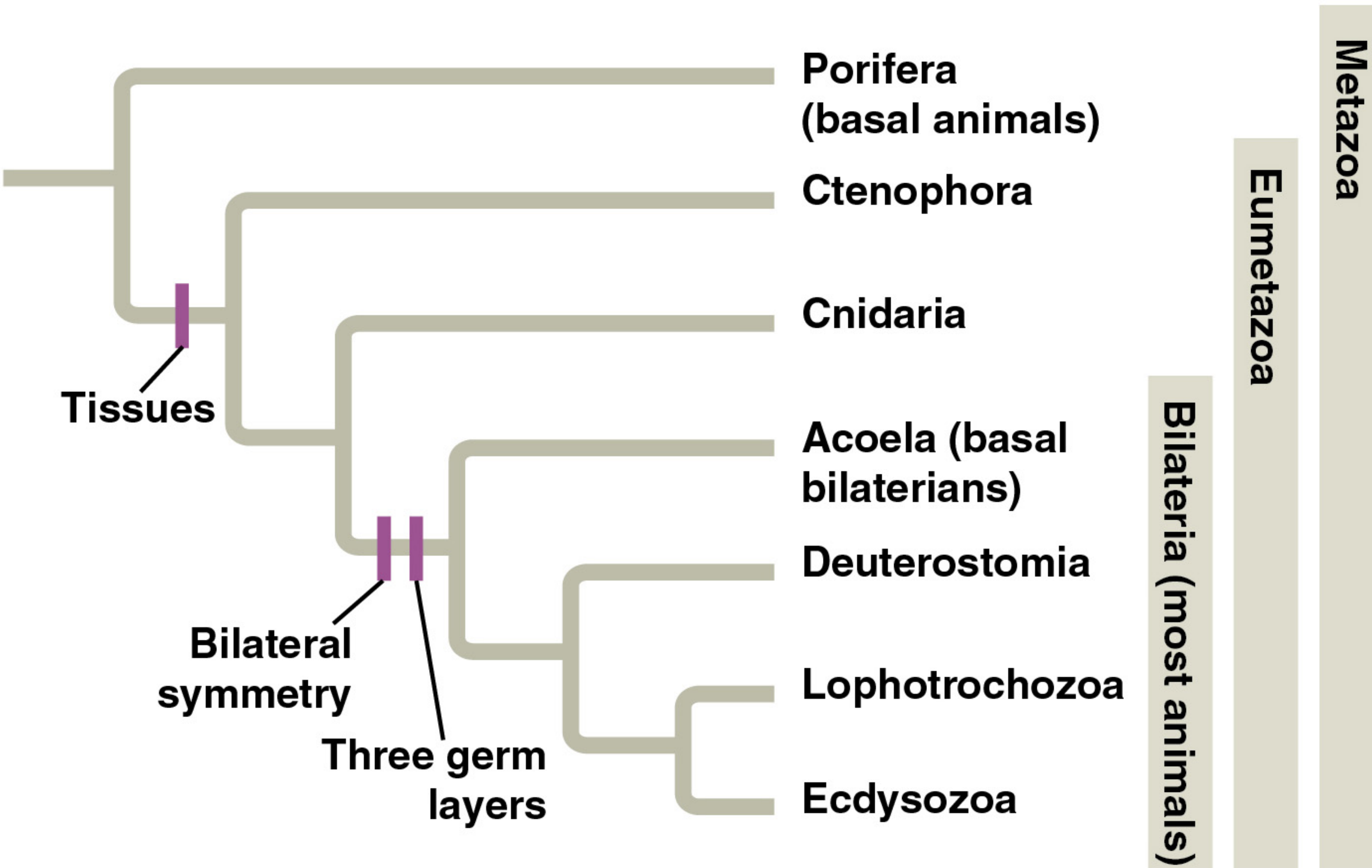


Figure 32.UN05