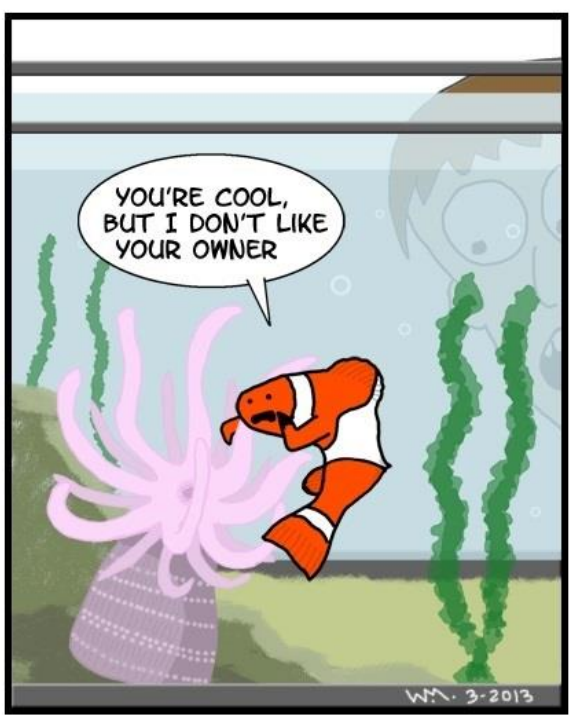
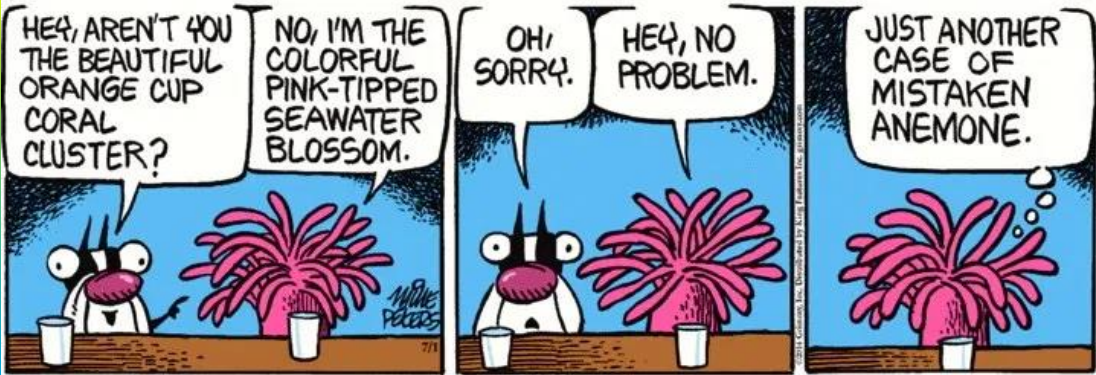
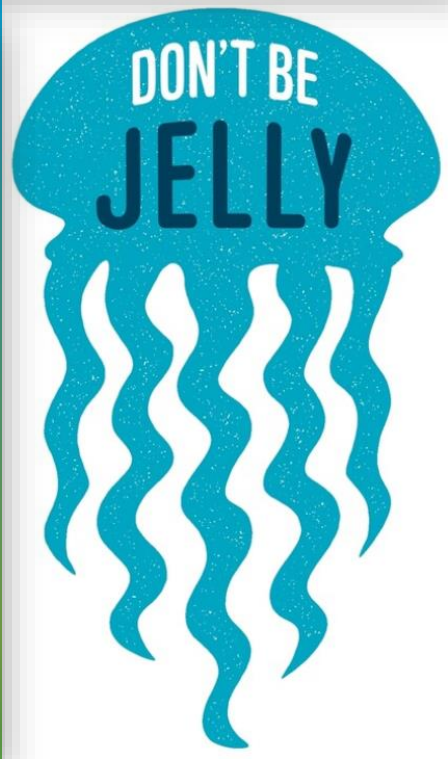


# Chapter 33: Introduction to Invertebrates



ANEMONE OF MY ENEMY IS MY FRIEND

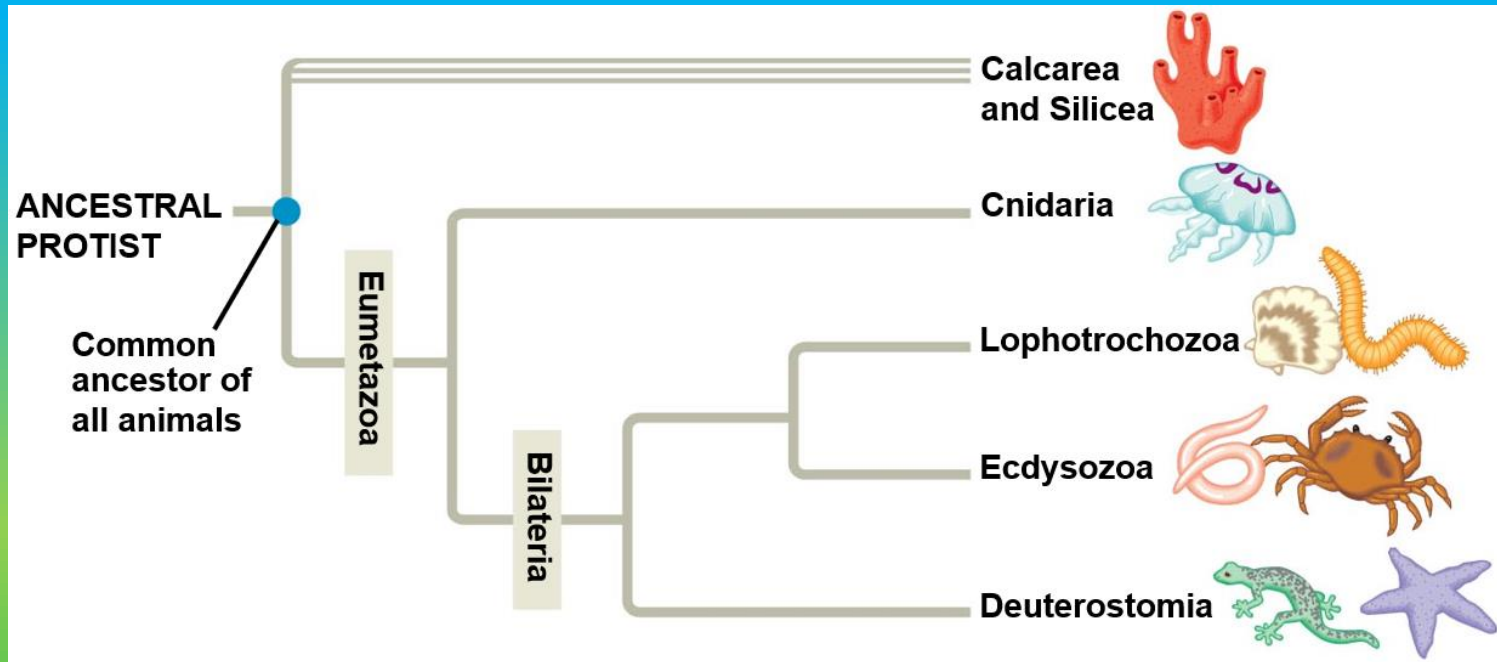


What function do the red whorls of this organism have?



# Overview: Life Without a Backbone

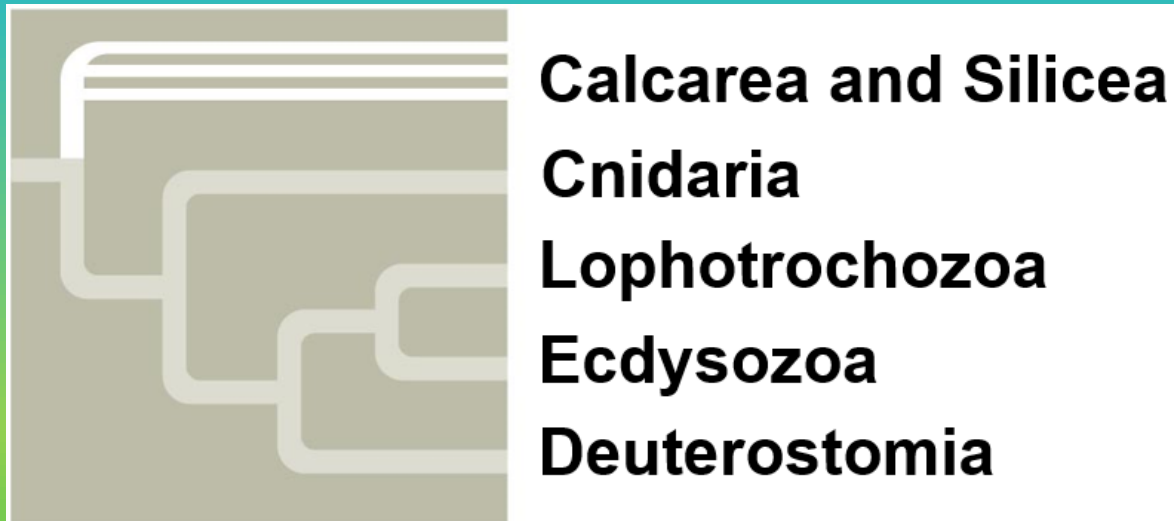
- **Invertebrates** are animals that lack a backbone.
- They account for 95% of known animal species.



# Concept 33.1: Sponges are basal animals that lack true tissues

---

- Sponges are sedentary animals from the Phyla Porifera, Classes Calcarea and Silicea.
- They live in both fresh and marine waters.
- Sponges lack true tissues and organs.



# Phylum Porifera (pore-bearers)

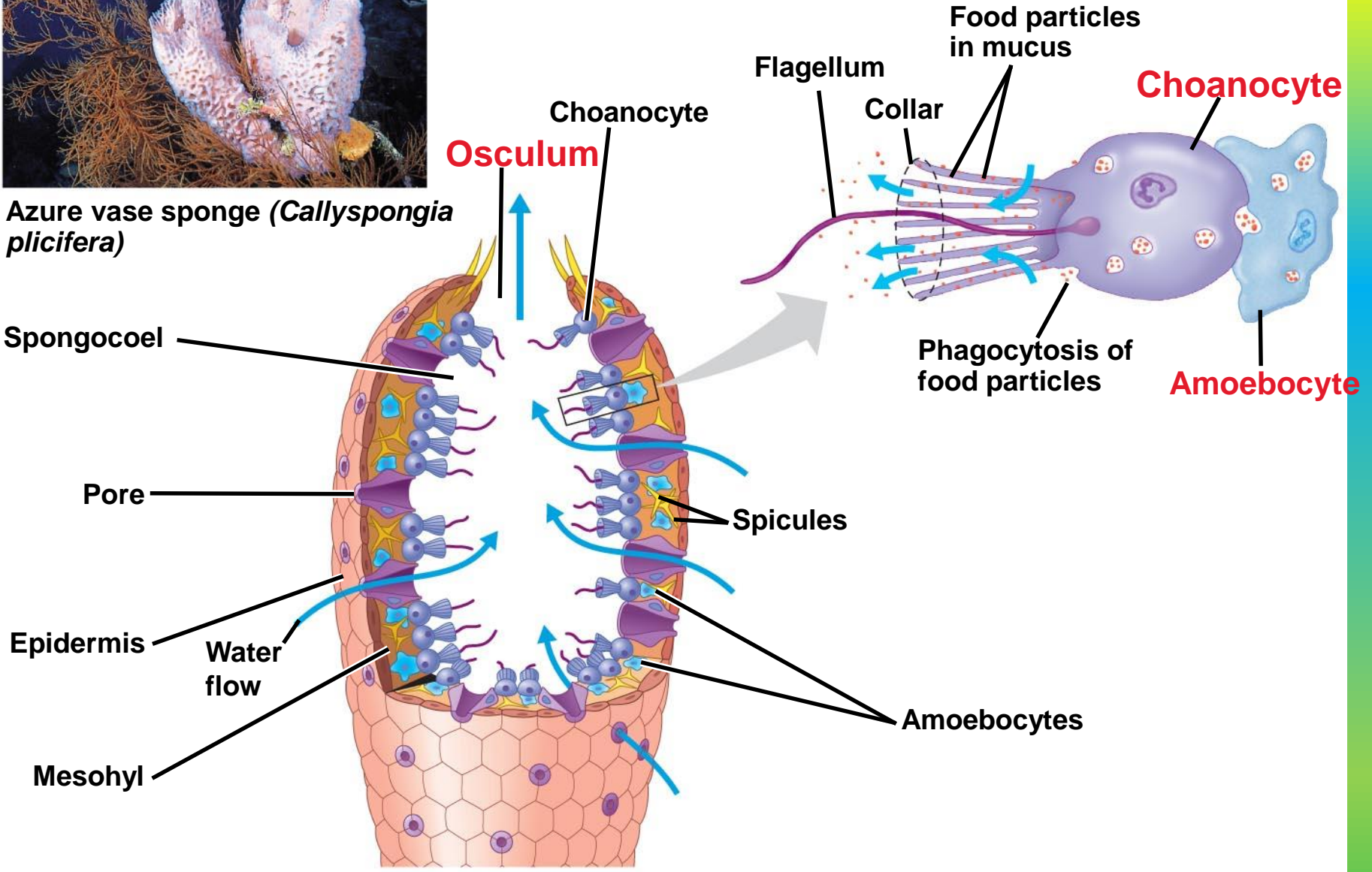
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- Sponges (Phylum Porifera) are **suspension feeders** - *capturing food particles suspended in the water that pass through their body.*
- **Choanocytes**, flagellated collar cells, generate a water current through the sponge and ingest suspended food.
- Water is drawn through pores into a cavity called the **spongocoel**, and out through an opening called the **osculum**.

# Anatomy of a Sponge



Azure vase sponge (*Callyspongia plicifera*)



- Sponges consist of a non-cellular **mesohyl** layer between two cell layers.

- Amoebocytes** are found in the mesohyl and play roles in digestion and structure.

- Most sponges are **hermaphrodites**: *Each individual functions as both male and female.*

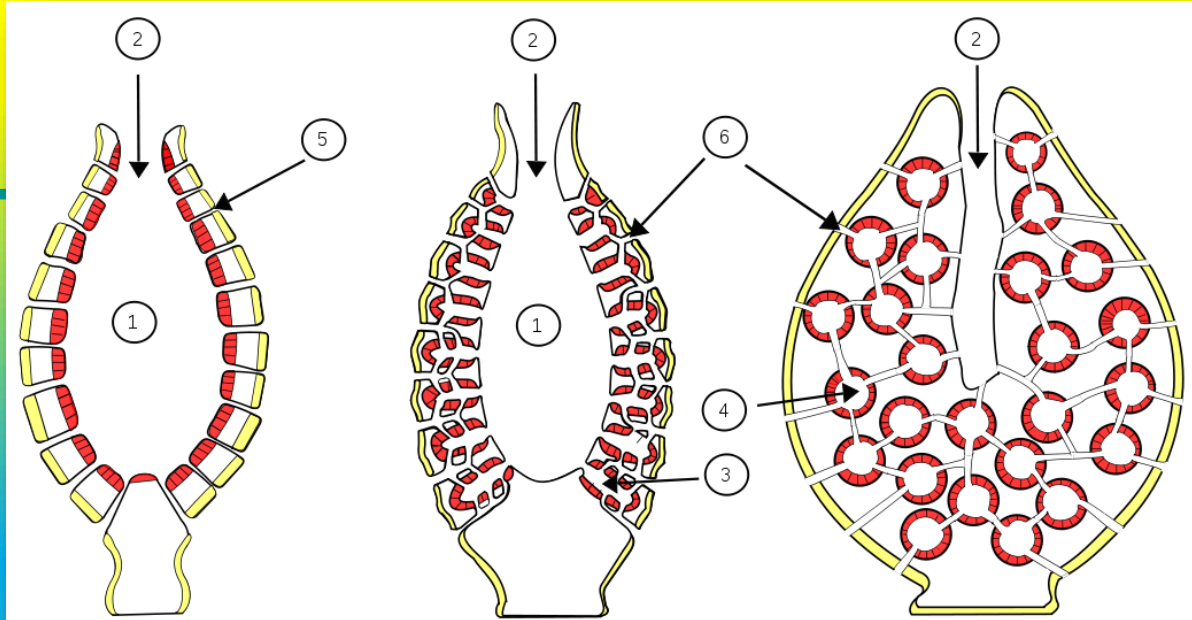
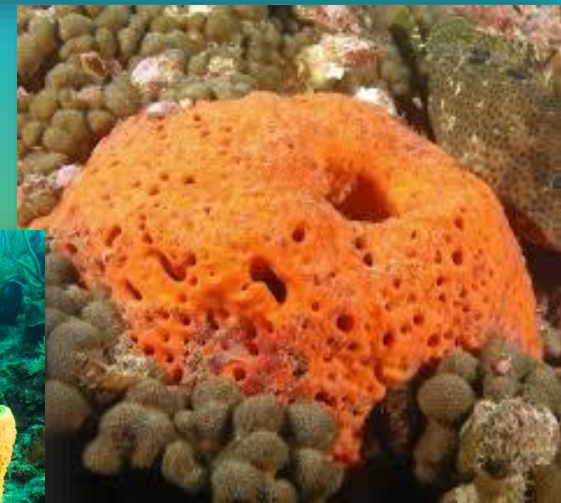


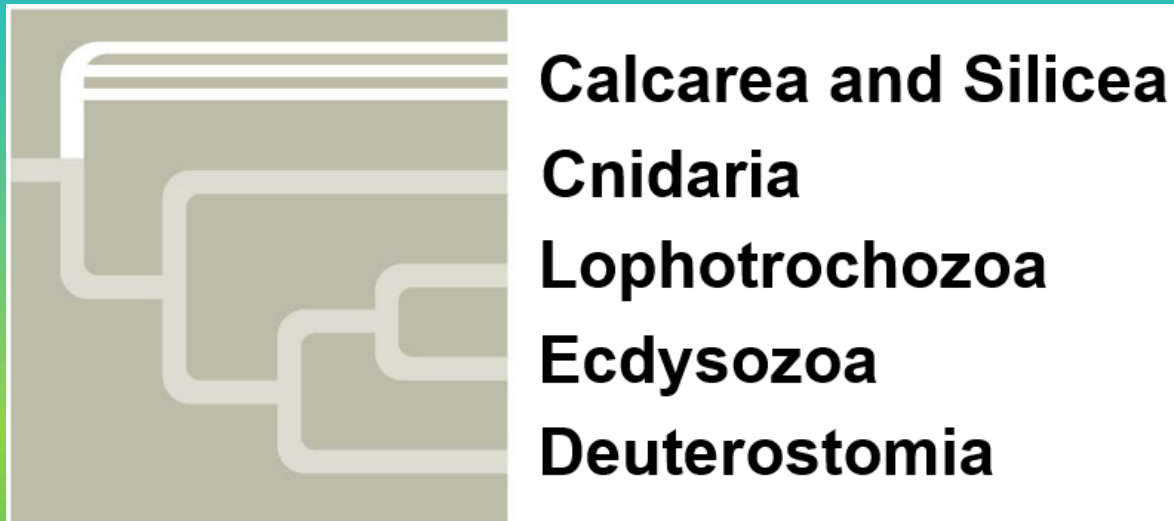
Fig. 3.19. Anatomy of three different simple, vase-like sponges showing (1) spongocoel (2) osculum (3) radial canal (4) flagellated chamber (5) incurrent pore and (6) incurrent channel.



## Concept 33.2: Cnidarians are an ancient phylum of eumetazoans

---

- All animals except sponges and a few other groups belong to the clade Eumetazoa, animals with **true tissues**.
- **Phylum Cnidaria** is one of the oldest groups in this clade.





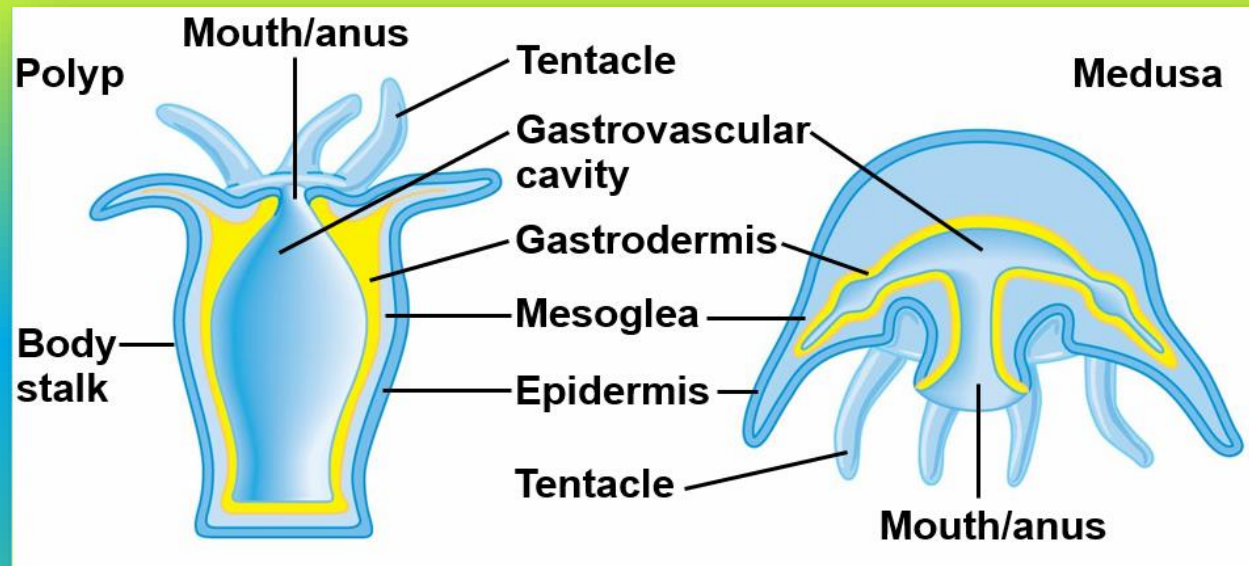
# Phylum Cnidaria

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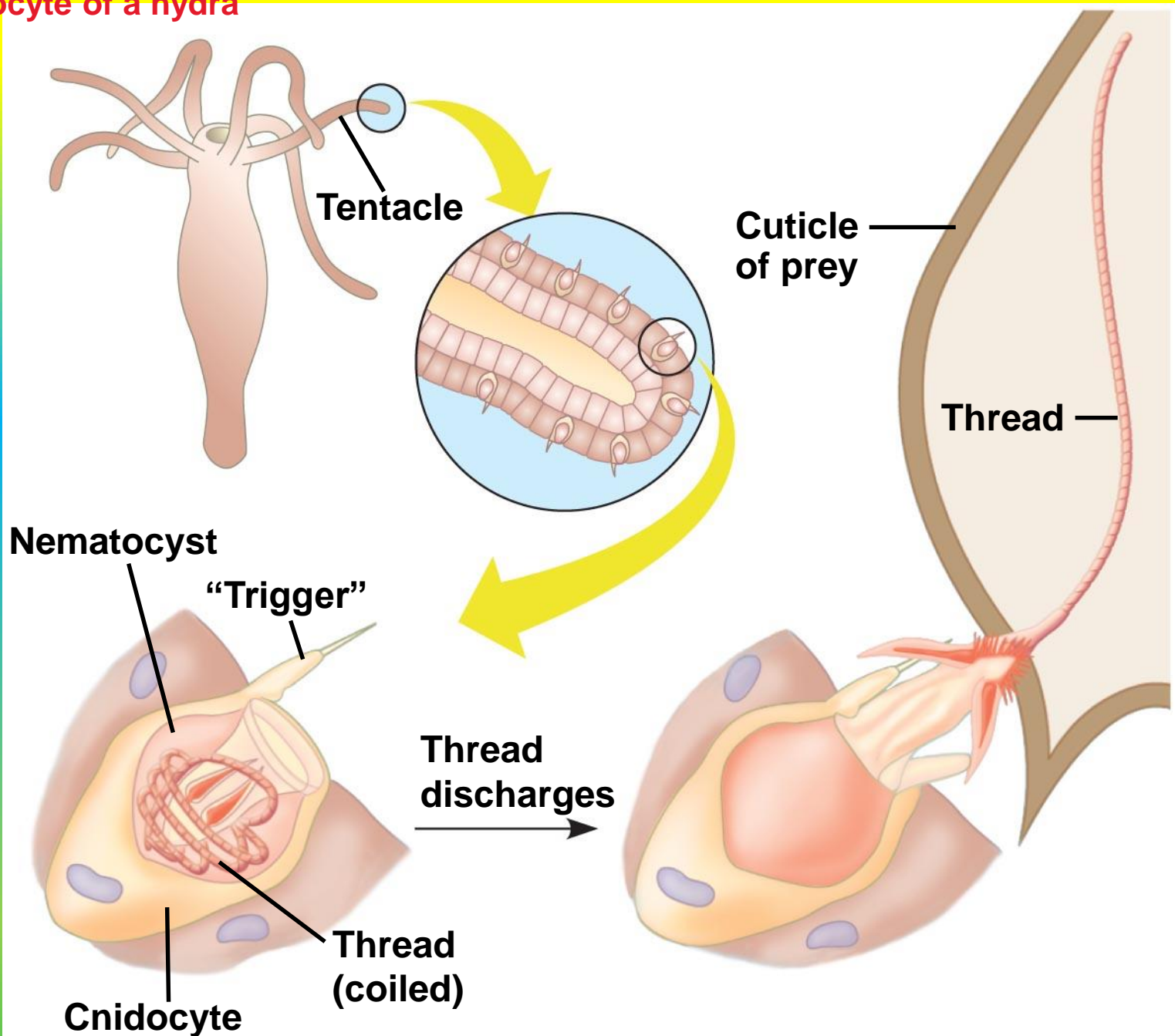
- Cnidarians have diversified into a wide range of both sessile and motile forms including jellies, corals, and hydras.
- The basic body plan of a cnidarian is a sac with a central digestive compartment, the **gastrovascular cavity**.
- A single opening functions as mouth and anus.
- There are two variations on the body plan: the **sessile polyp** and **motile medusa**.
- **Radially symmetrical**

# Polyp and medusa forms of cnidarians

- Cnidarians are carnivores that use tentacles to capture prey.
- The tentacles are armed with **cnidocytes**, unique cells that function in defense and capture of prey.
- **Nematocysts** are specialized organelles within cnidocytes that eject a stinging thread.



# A cnidocyte of a hydra



- Phylum Cnidaria is divided into four major classes:

**Table 33.1 Classes of Phylum Cnidaria**

Class and Examples	Main Characteristics
Hydrozoa (Portuguese man-of-wars, hydras, <i>Obelia</i> , some corals)	Most marine, a few freshwater; both polyp and medusa stages in most species; polyp stage often colonial
Scyphozoa (jellies, sea nettles)	All marine; polyp stage absent or reduced; free-swimming; medusae up to 2 m in diameter
Cubozoa (box jellies, sea wasps)	All marine; box-shaped medusae; complex eyes; potent venom
Anthozoa (sea anemones, most corals, sea fans)	All marine; medusa stage completely absent; most sessile; many colonial



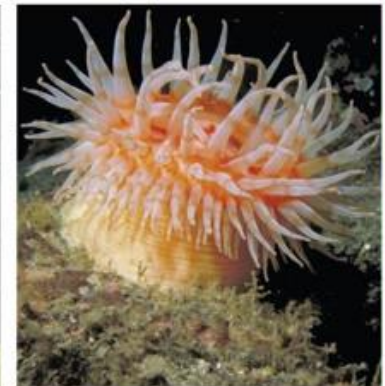
**(a) Colonial polyps (class Hydrozoa)**



**(b) Jellies (class Scyphozoa)**

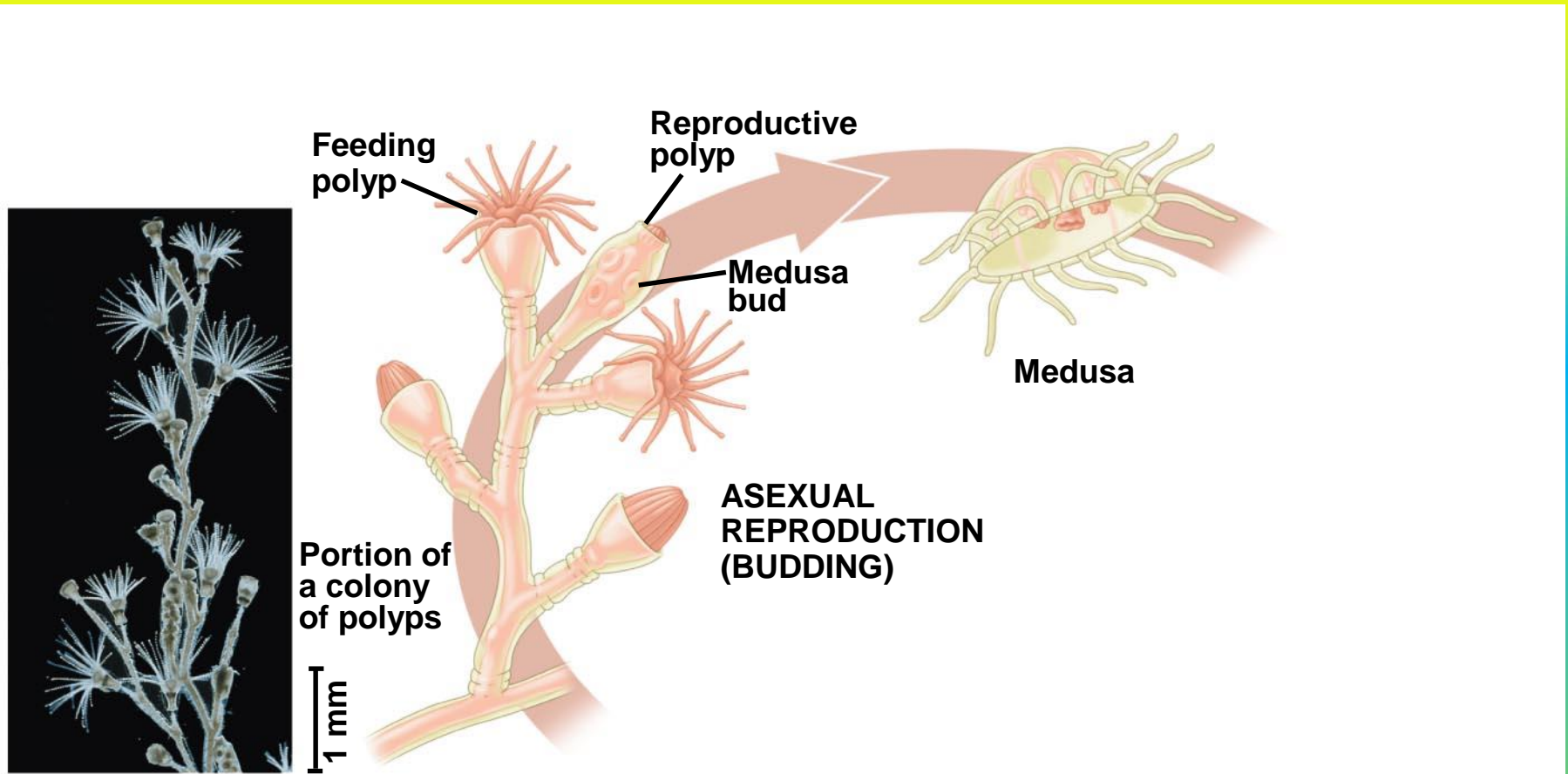


**(c) Sea wasp (class Cubozoa)**



**(d) Sea anemone (class Anthozoa)**

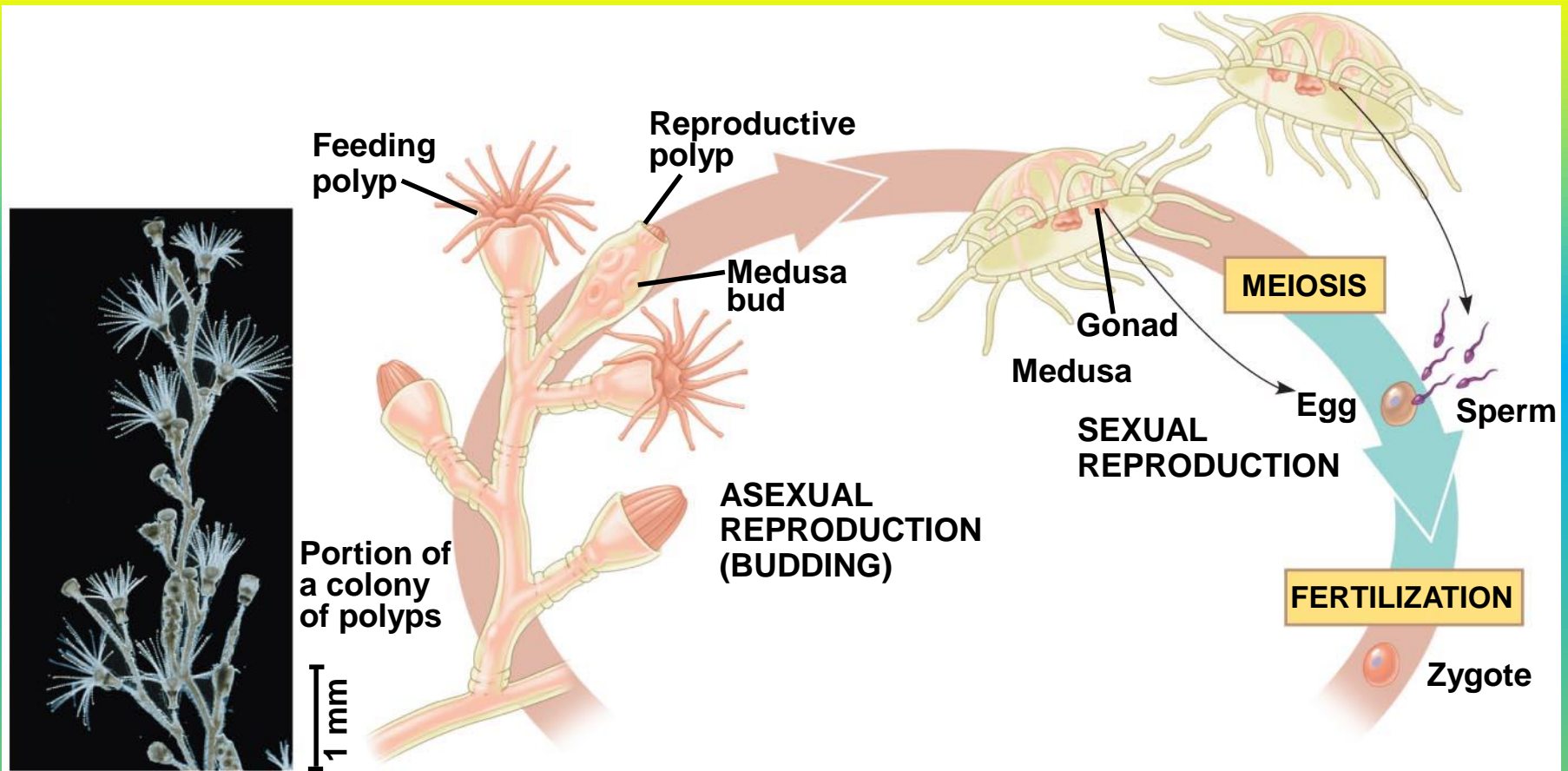
# Most hydrozoans alternate between polyp and medusa forms



## Key

- ➡ Haploid ( $n$ )
- ➡ Diploid ( $2n$ )

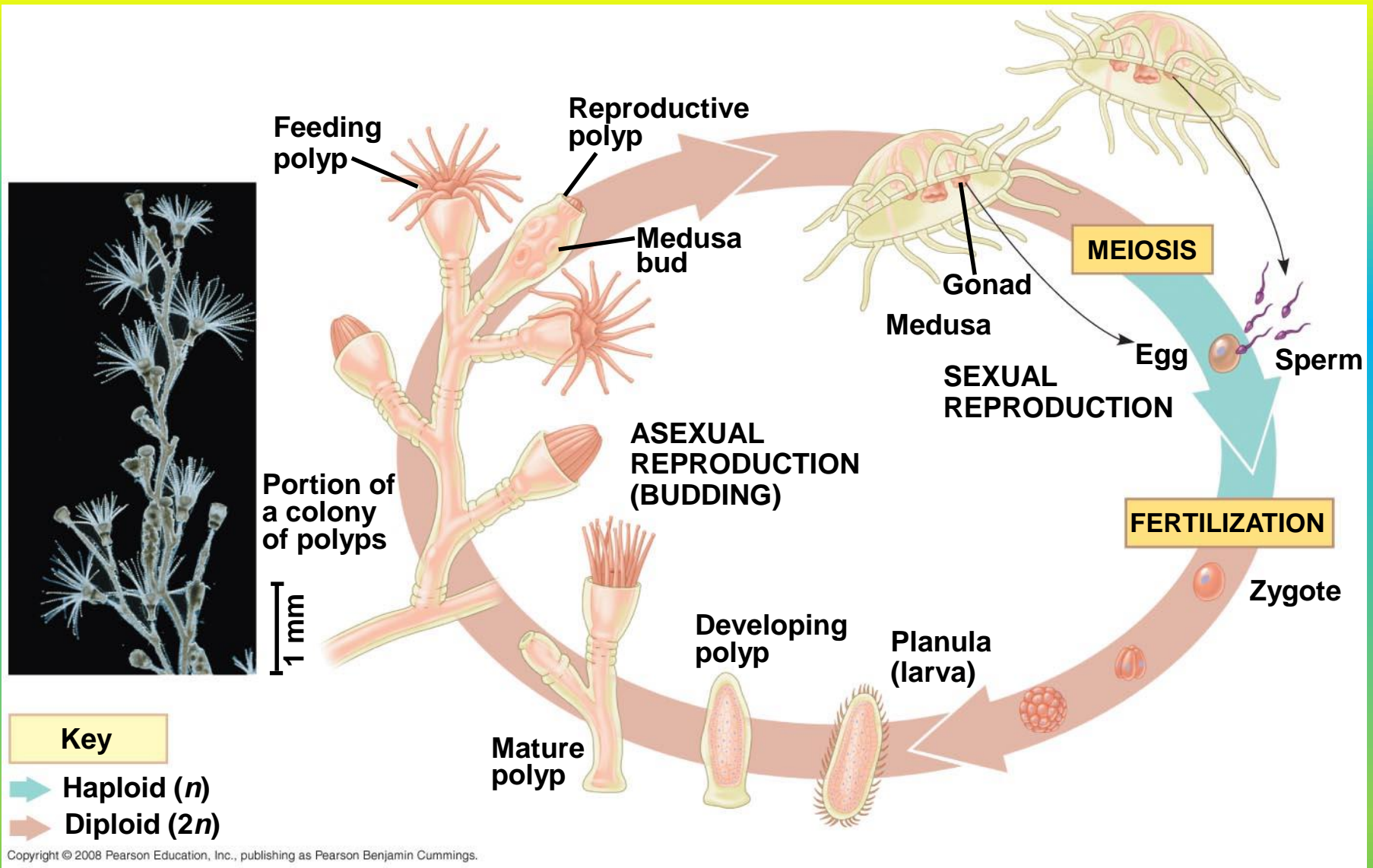
Fig. 33-8-2



**Key**

- ➡ Haploid ( $n$ )
- ➡ Diploid ( $2n$ )

Fig. 33-8-3



# Scyphozoans

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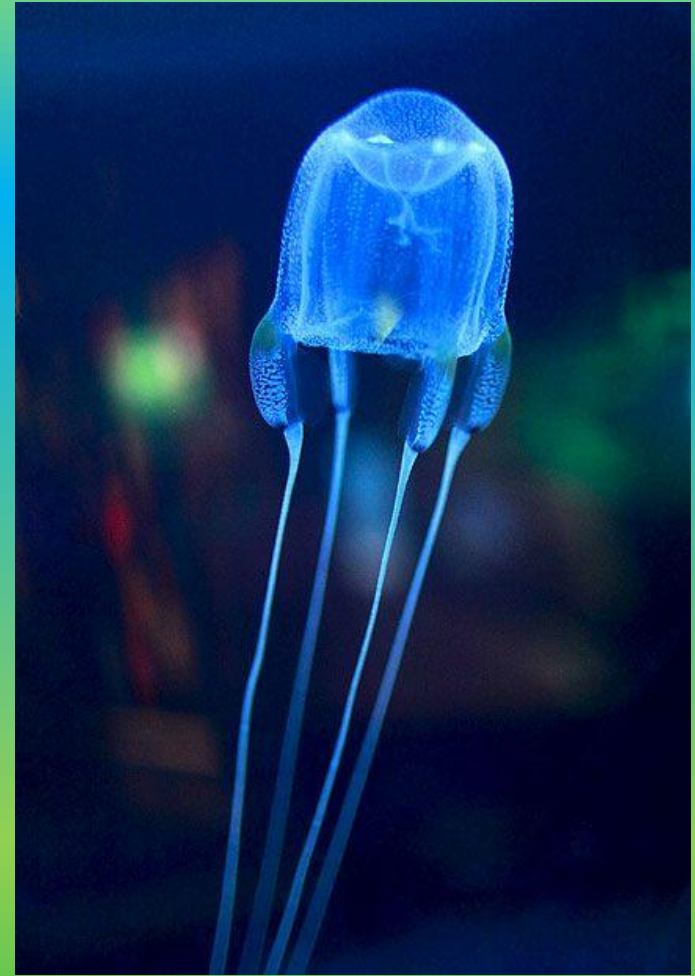
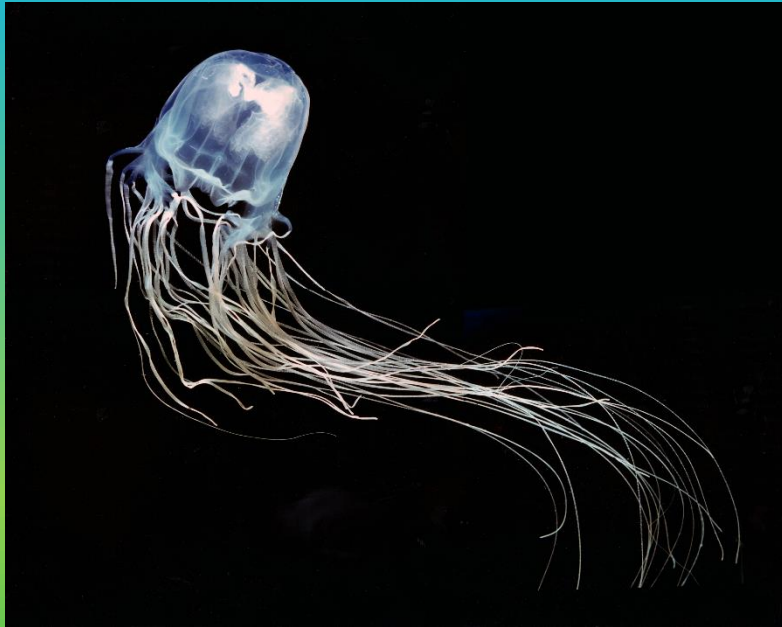
- In the **Class Scyphozoa**, jellies (medusae) are the prevalent form of the life cycle





# Cubozoans

- In the **Class Cubozoa**, which includes box jellies and sea wasps, the medusa is box-shaped and has complex eyes.
- Cubozoans often have highly toxic cnidocytes.



- **Class Anthozoa** includes the corals and sea anemones, which occur only as polyps.

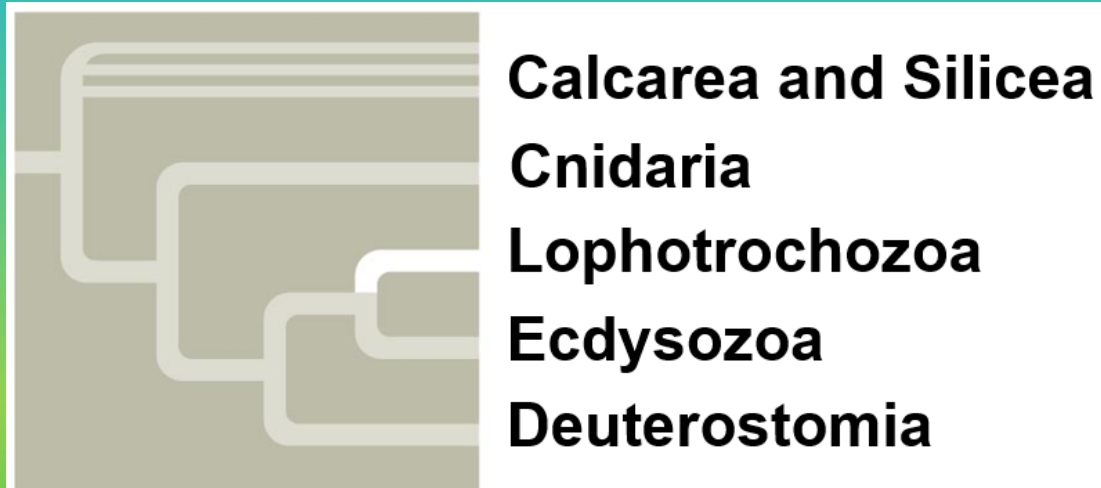


## Concept 33.3: Lophotrochozoans, a clade identified by molecular data, have the widest range of animal body forms

---

- Bilateral animals have bilateral symmetry and triploblastic development.
- The clade Bilateria contains Lophotrochozoa, Ecdysozoa, and Deuterostomia.

**Lophotrochozoa**  
includes the flatworms,  
rotifers, ectoprocts,  
brachiopods, molluscs,  
and annelids



# Flatworms

---

- Members of **Phylum Platyhelminthes** live in marine, freshwater, and damp terrestrial habitats.
- Although flatworms undergo triploblastic development, they are acoelomates.
- They are flattened dorsoventrally and have a gastrovascular cavity.
- Gas exchange takes place across the surface, and **protonephridia** regulate the osmotic balance.

- 
- Flatworms are divided into **four classes**:
    - **Turbellaria** (mostly free-living flatworms)
    - **Monogenea** (monogeneans, rotifers)
    - **Trematoda** (trematodes, or flukes)
    - **Cestoda** (tapeworms)

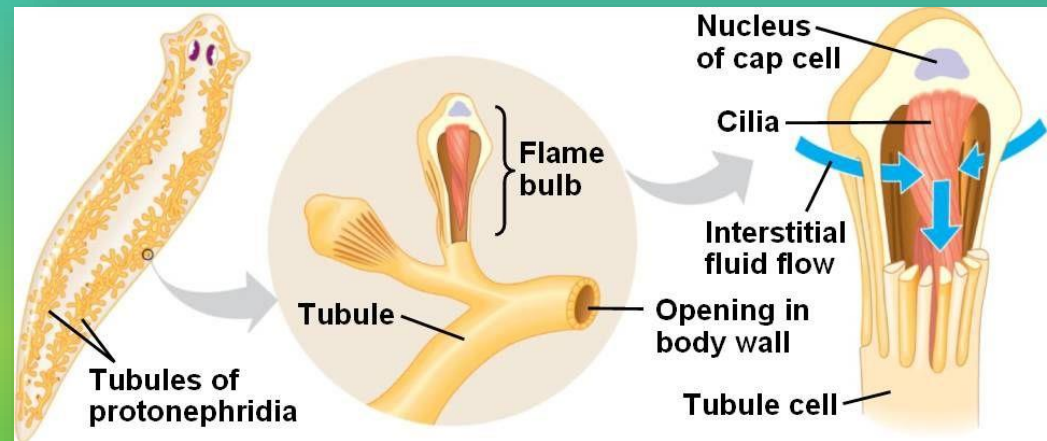
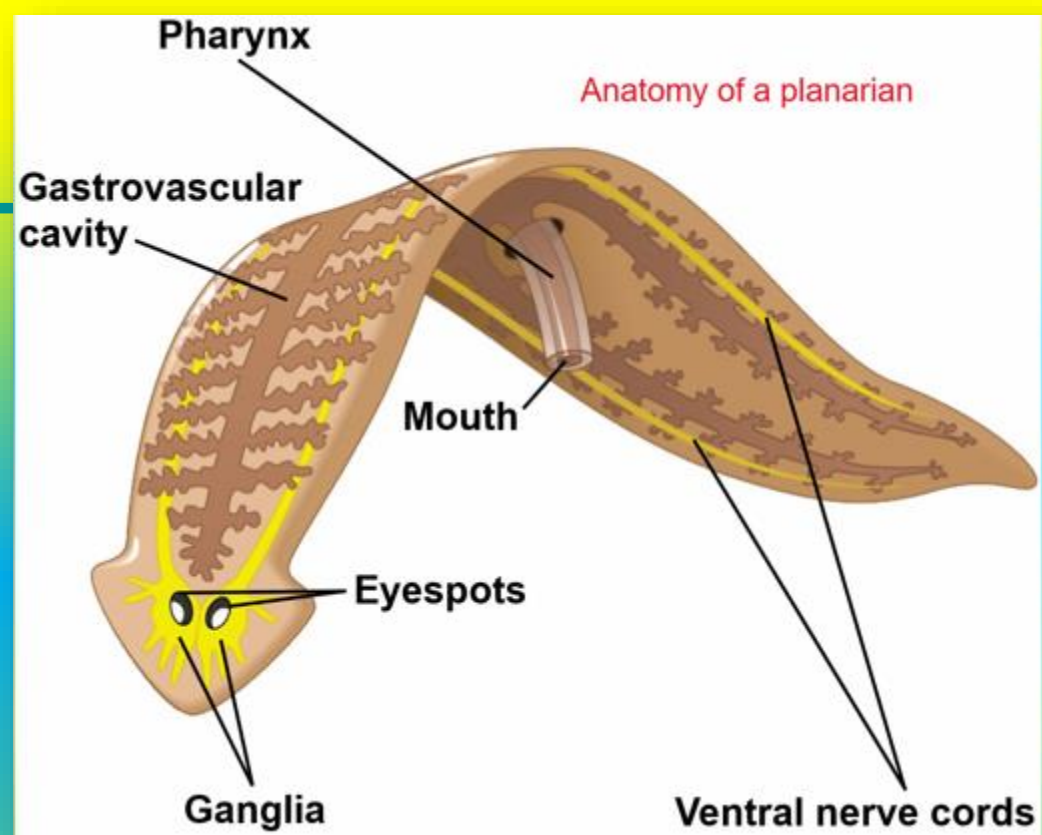
# *Turbellarians*

- Turbellarians are nearly all free-living and mostly marine.
- The best-known turbellarians are commonly called **planarians**.

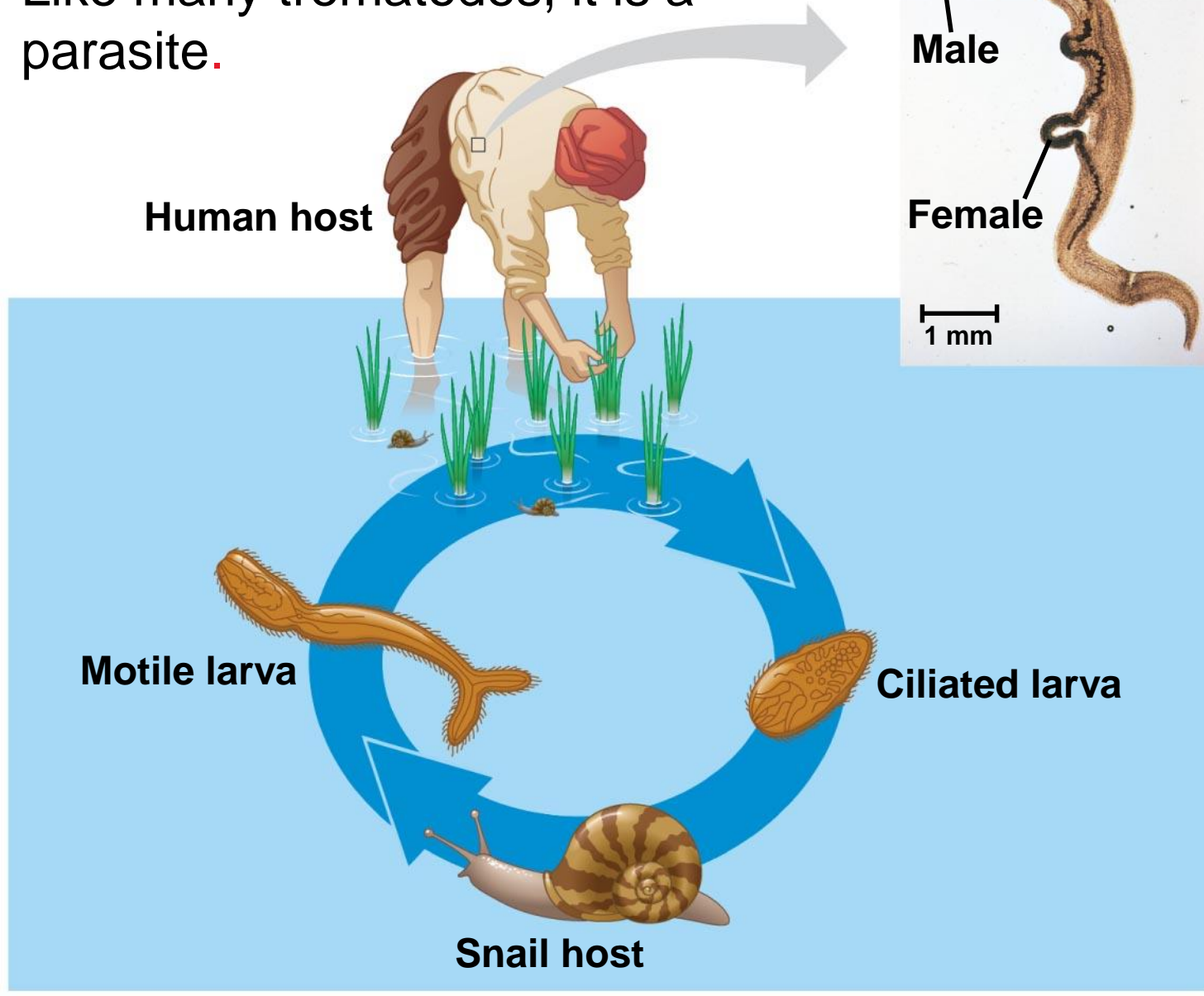


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- Planarians have light-sensitive eyespots and centralized nerve nets.
- The planarian nervous system is more complex and centralized than the nerve nets of cnidarians.
- Planarians are **hermaphrodites** - possess both male and female gonads / sex organs. Planarians can reproduce sexually, or asexually through fission.



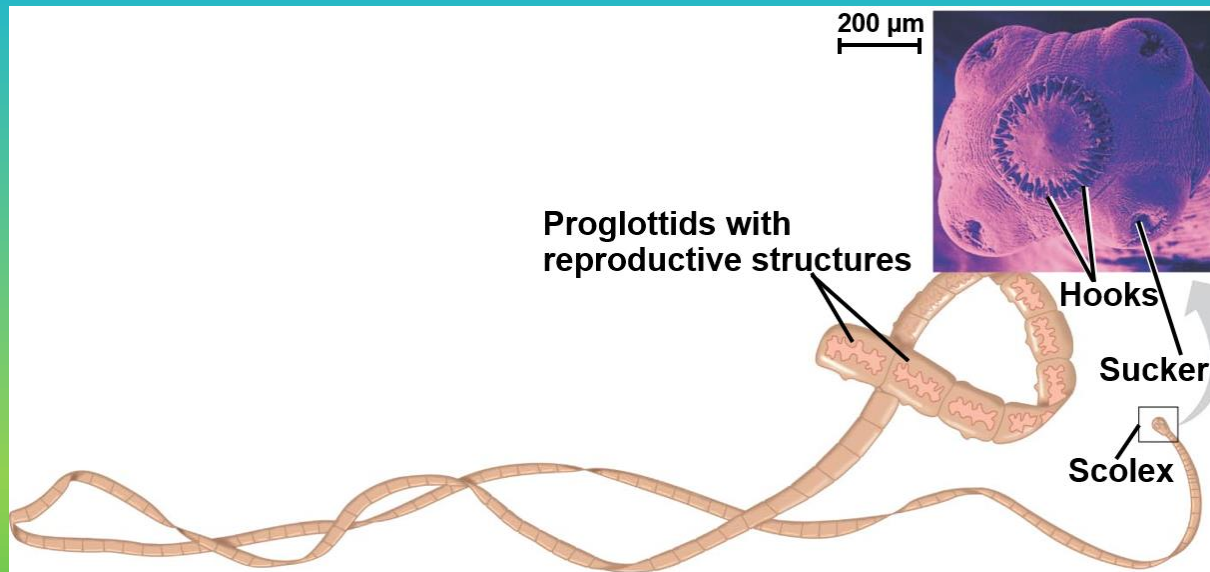
The life cycle of a blood fluke.  
Like many trematodes, it is a parasite.





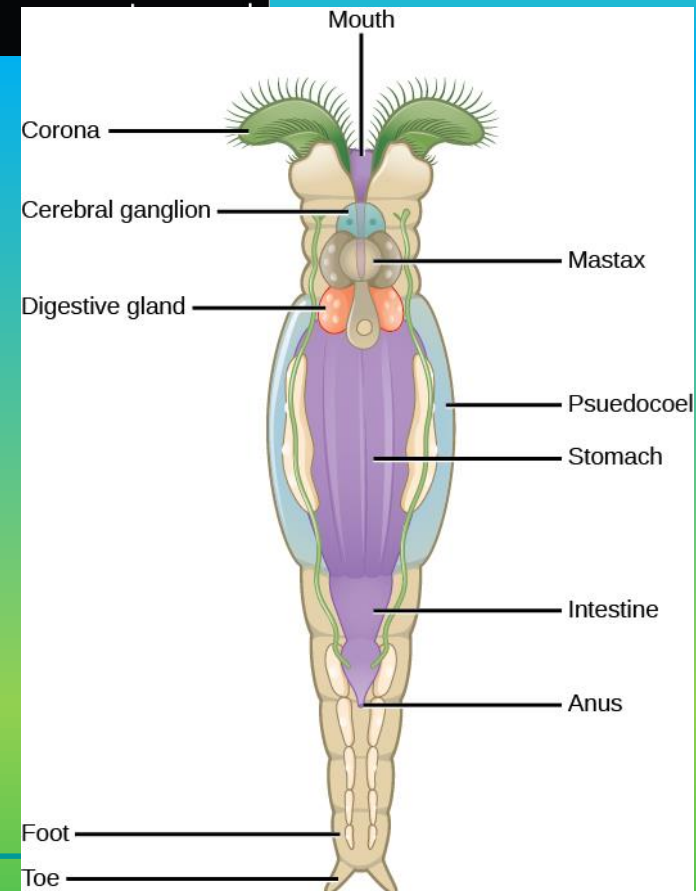
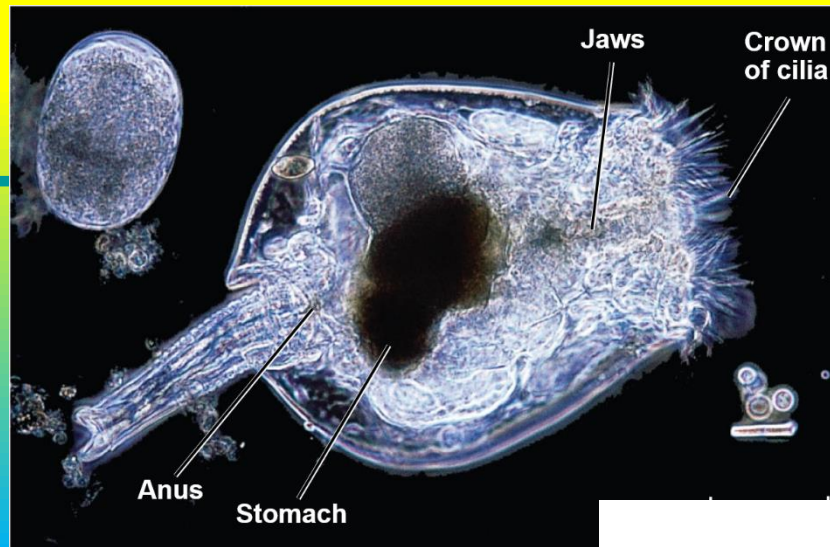
# Tapeworms

- Tapeworms are parasites of vertebrates and lack a digestive system.
- Tapeworms absorb nutrients from the host's intestine.
- Fertilized eggs, produced by sexual reproduction, leave the host's body in feces.



# Rotifers

- Rotifers are tiny animals that inhabit fresh water, the ocean, and damp soil.
- Rotifers are smaller than many protists but are truly multicellular and have specialized organ systems.

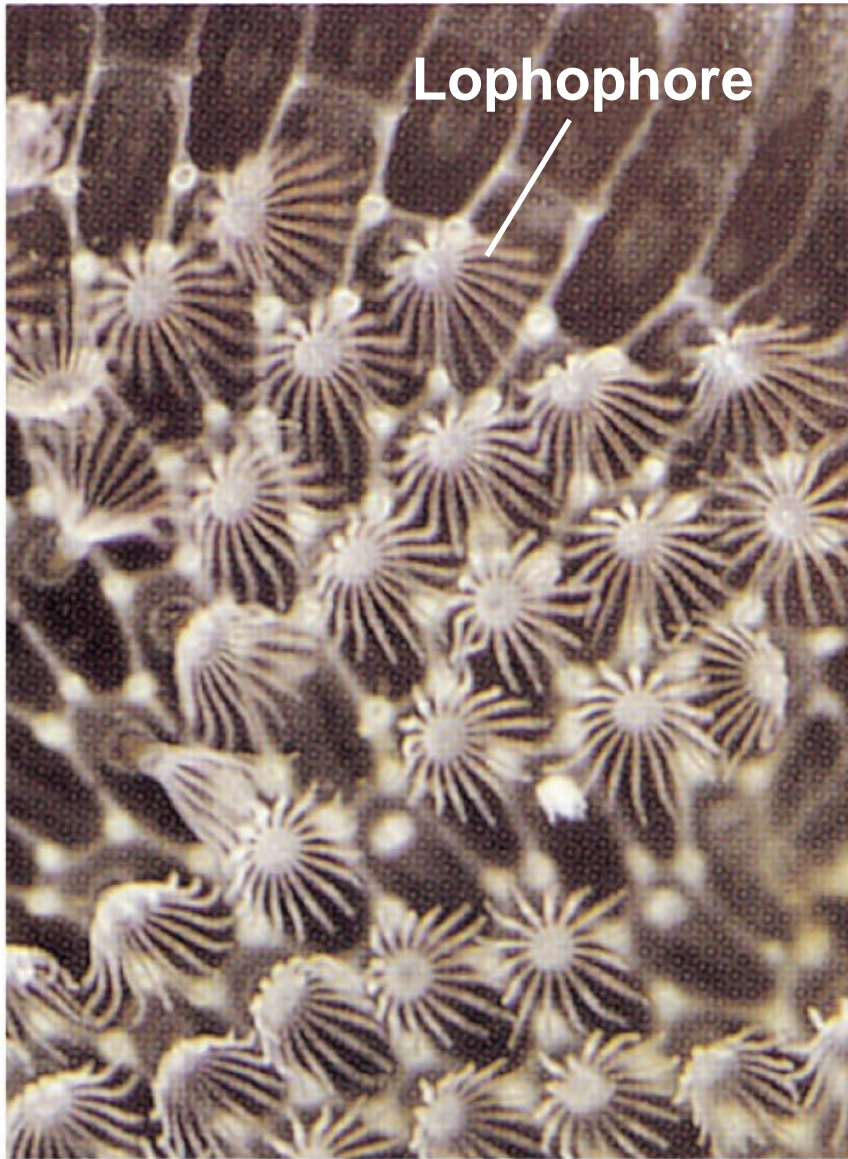


- 
- Rotifers have an **alimentary canal**, a digestive tube with a separate mouth and anus that lies within a fluid-filled pseudocoelom
  - Rotifers reproduce by **parthenogenesis**, in which *females produce offspring from unfertilized eggs*.
  - Some species are unusual in that they lack males entirely

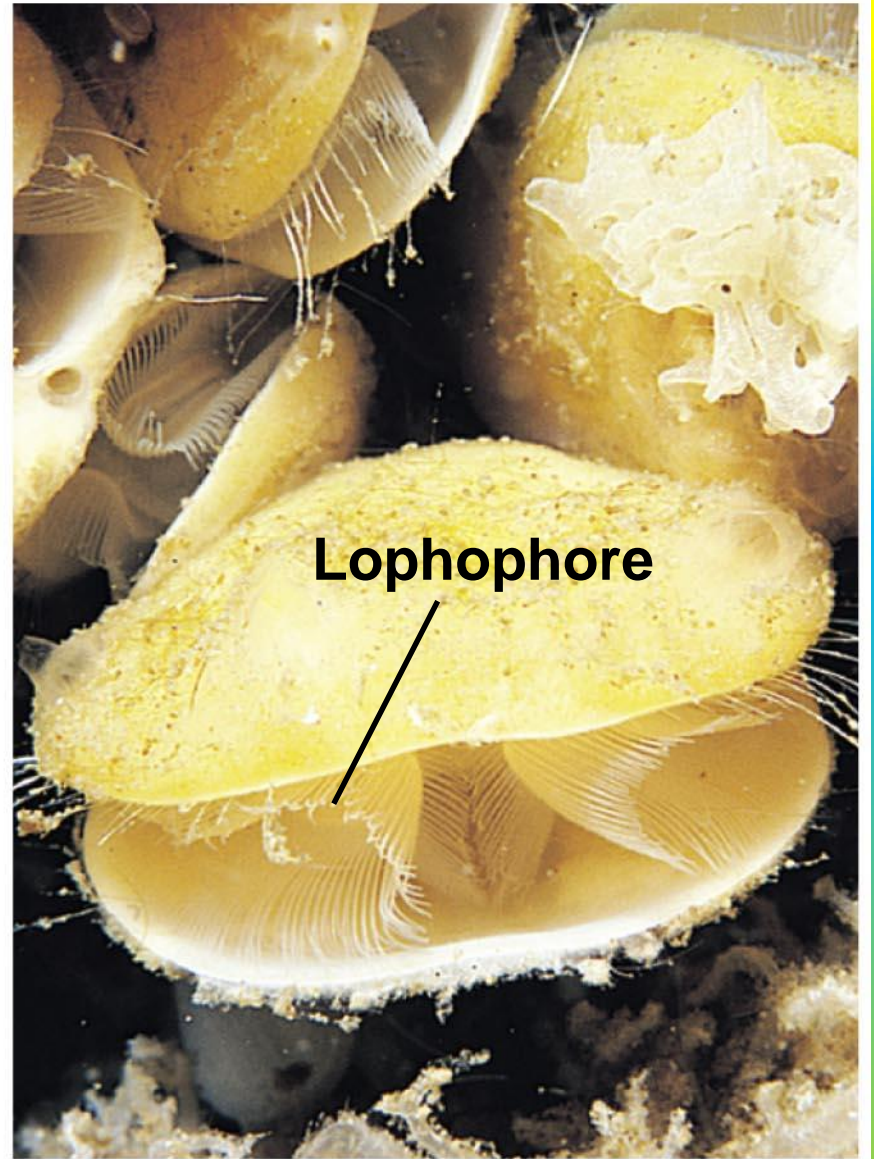
# Lophophorates: Ectoprocts and Brachiopods

---

- Lophophorates have a ***lophophore***, a horseshoe-shaped, suspension-feeding organ with ciliated tentacles
- Lophophorates include two phyla: Ectoprocta and Brachiopoda
- **Ectoprocts** (also called bryozoans) are colonial animals that superficially resemble plants
- A hard **exoskeleton** encases the colony, and some species are reef builders



**(a) Ectoproct (sea mat)**



**(b) Brachiopods**

# Phylum Mollusca

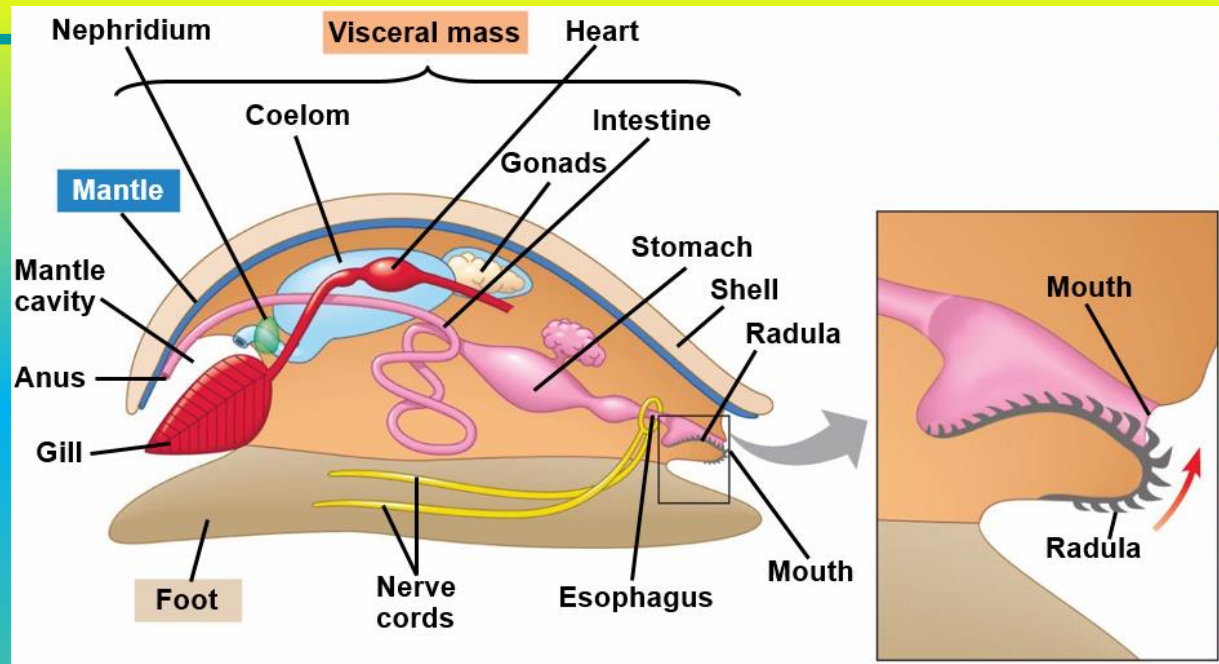
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- **Phylum Mollusca** includes snails and slugs, oysters and clams, and octopuses and squids.
- Most molluscs are marine, though some inhabit fresh water and some are terrestrial.
- Molluscs are soft-bodied animals, but most are protected by a hard shell.

# Basic Body plan of a Mollusc

- All molluscs have a similar body plan with three main parts:

- Muscular **foot**
- **Visceral mass**
- **Mantle**



- Many molluscs also have a water-filled **mantle cavity**, and feed using a rasp-like **radula**.

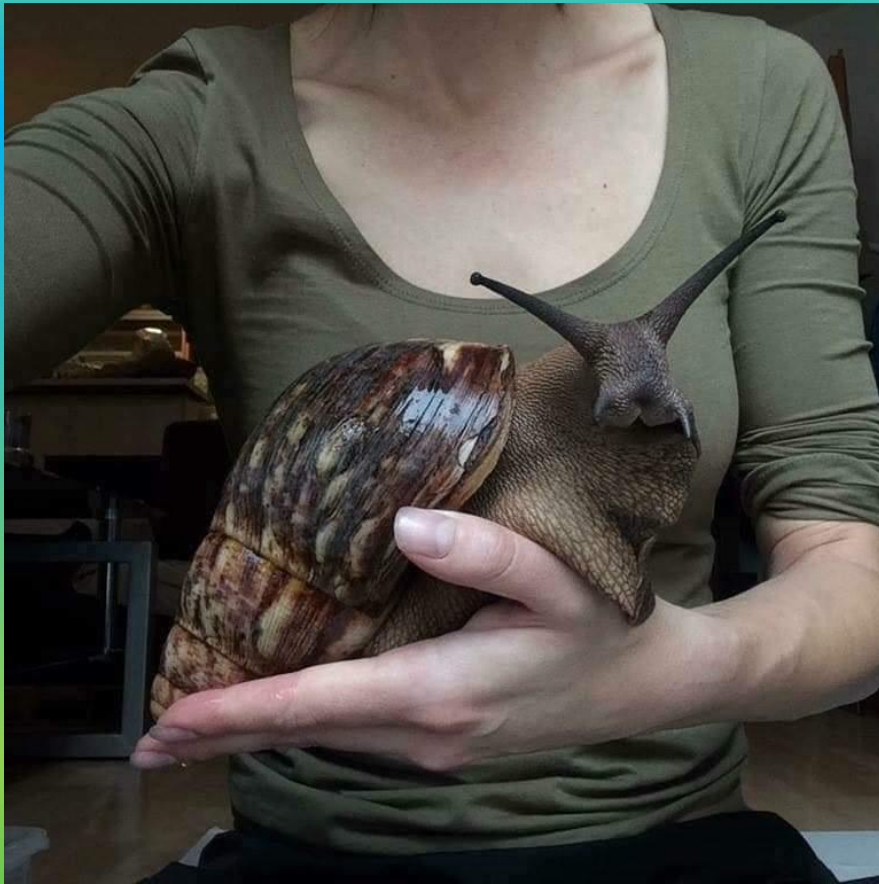
- There are four major classes of molluscs:
  - **Polyplacophora** (chitons)
  - **Gastropoda** (snails and slugs)
  - **Bivalvia** (clams, oysters, and other bivalves)
  - **Cephalopoda** (squids, octopuses, cuttlefish, and chambered nautilus)





# *Gastropods*

- About three-quarters of all living species of molluscs are gastropods



# Gastropods



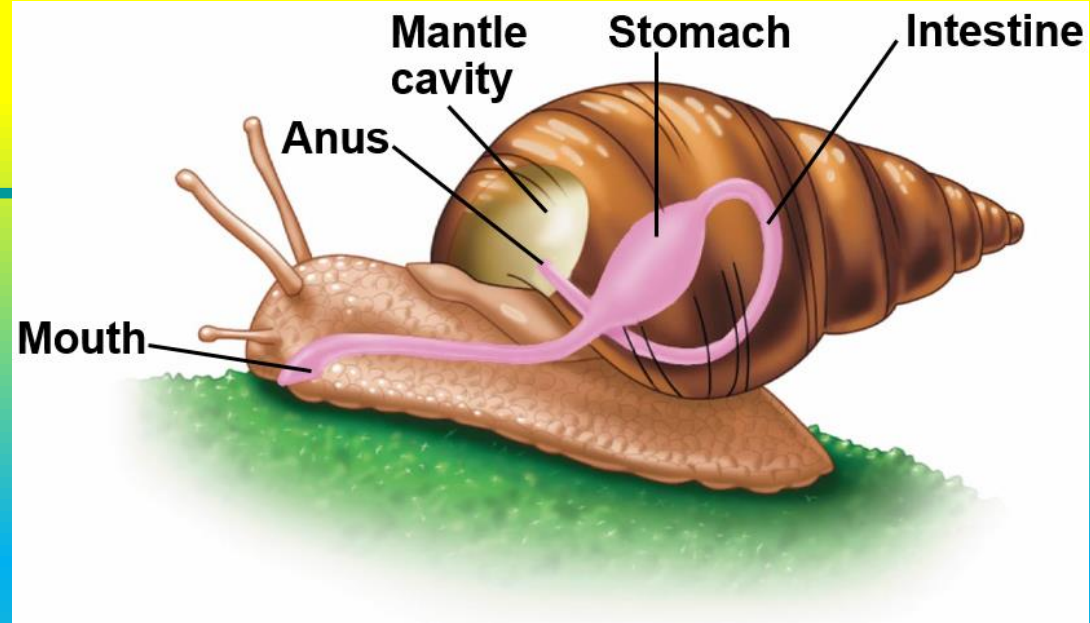
**(a) A land snail**



**(b) A sea slug**

# Gastropods

- Most gastropods are marine, but many are freshwater and terrestrial species.
- Most have a single, spiraled shell.
- Slugs lack a shell or have a reduced shell.
- The most distinctive characteristic of gastropods is **torsion**, which *causes the animal's anus and mantle to end up above its head*.



**Torsion - causes the animal's anus and mantle to end up above its head.**

# *Bivalves*

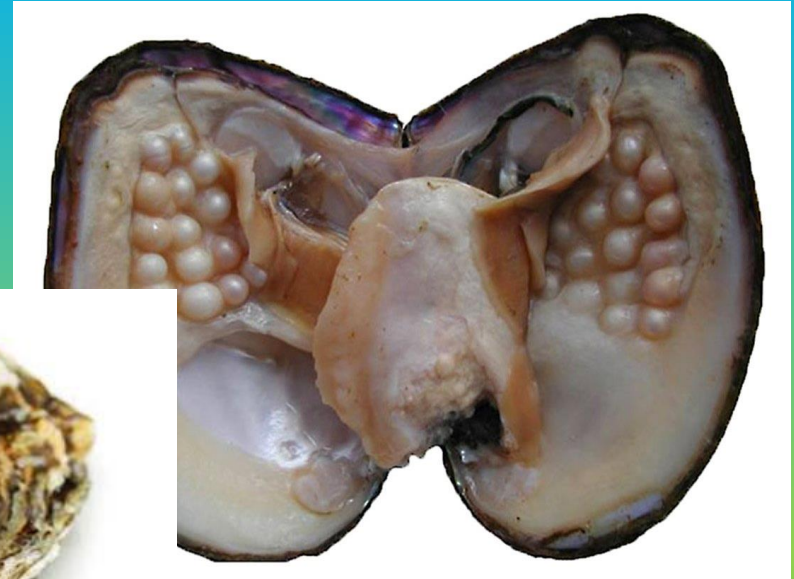
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- Molluscs of class Bivalvia include many species of clams, oysters, mussels, and scallops.
- They have a shell divided into two halves.
- The mantle cavity of a bivalve contains gills that are used for feeding as well as gas exchange.

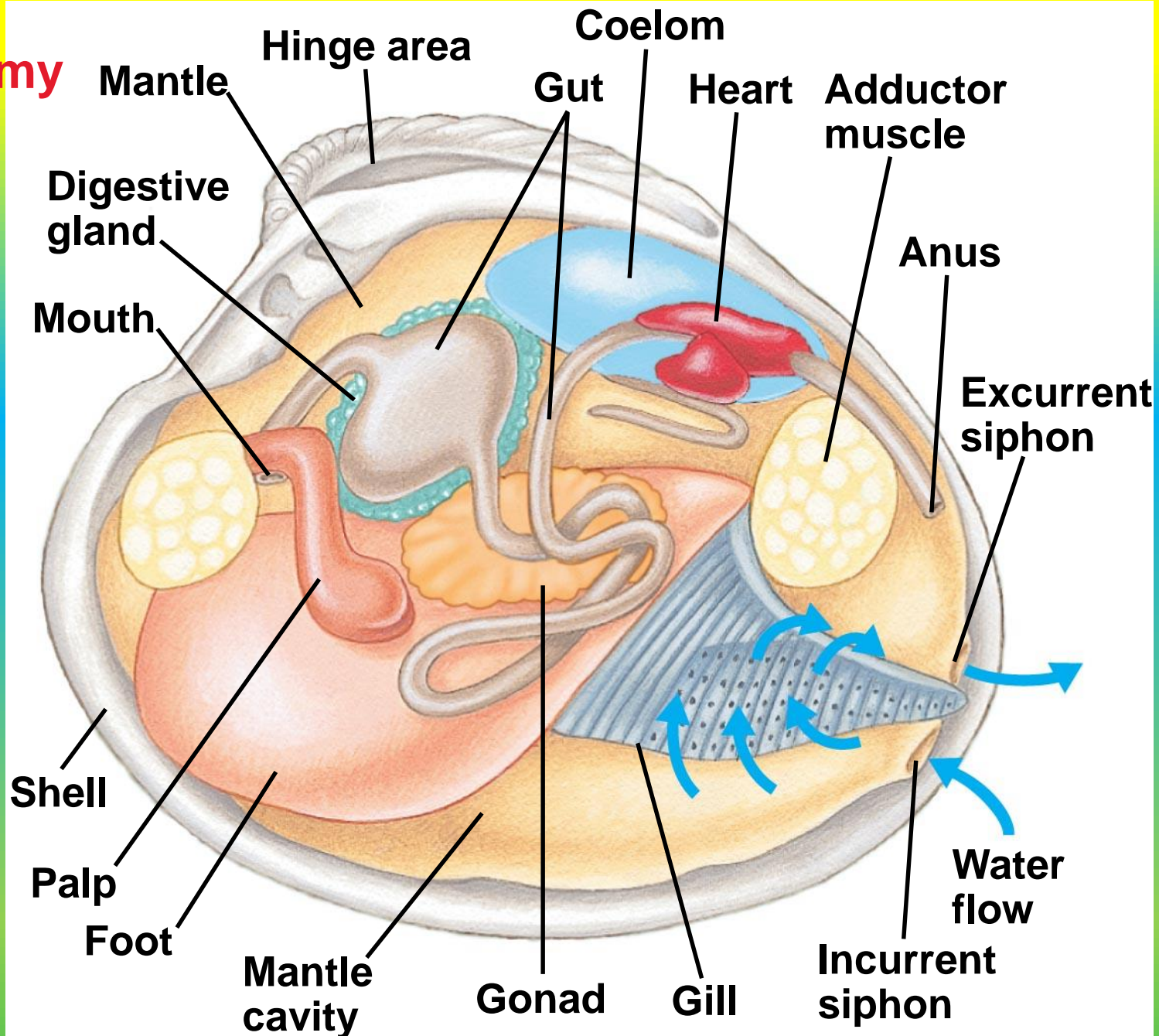
# Bivalve



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# Clam Anatomy



# *Cephalopods*

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- **Class Cephalopoda** includes squids and octopuses, carnivores with beak-like jaws surrounded by tentacles of their modified foot.
- Most octopuses creep along the sea floor in search of prey.

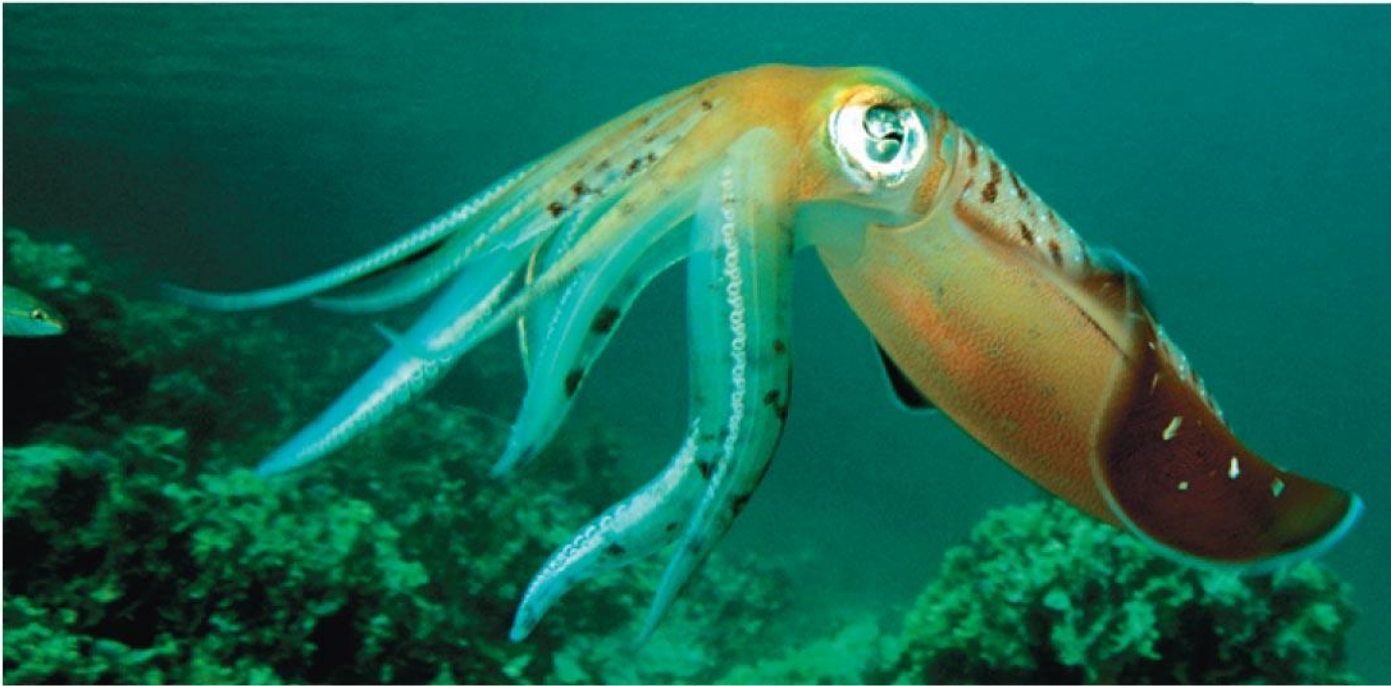
# Cephalopods





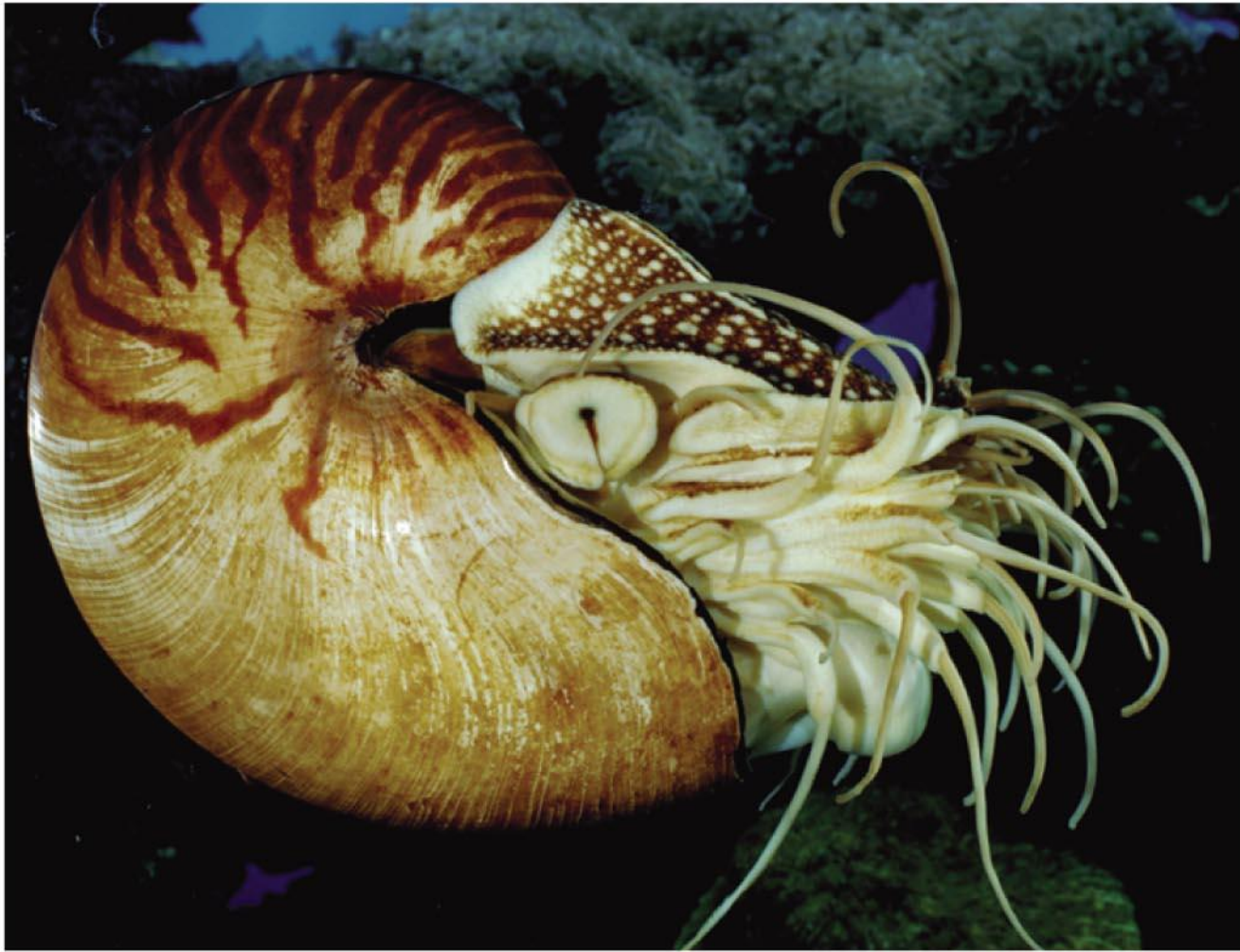
**Squids use their siphon to fire a jet of water, which allows them to swim very quickly.**

▼ **Squid**



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**One small group of shelled cephalopods, the nautiluses, survives today.**



◀ **Chambered  
nautilus**

- 
- Cephalopods have a closed circulatory system, well-developed sense organs, and a complex brain.
  - Shelled cephalopods called **ammonites** were common but went extinct at the end of the Cretaceous.

# Annelids

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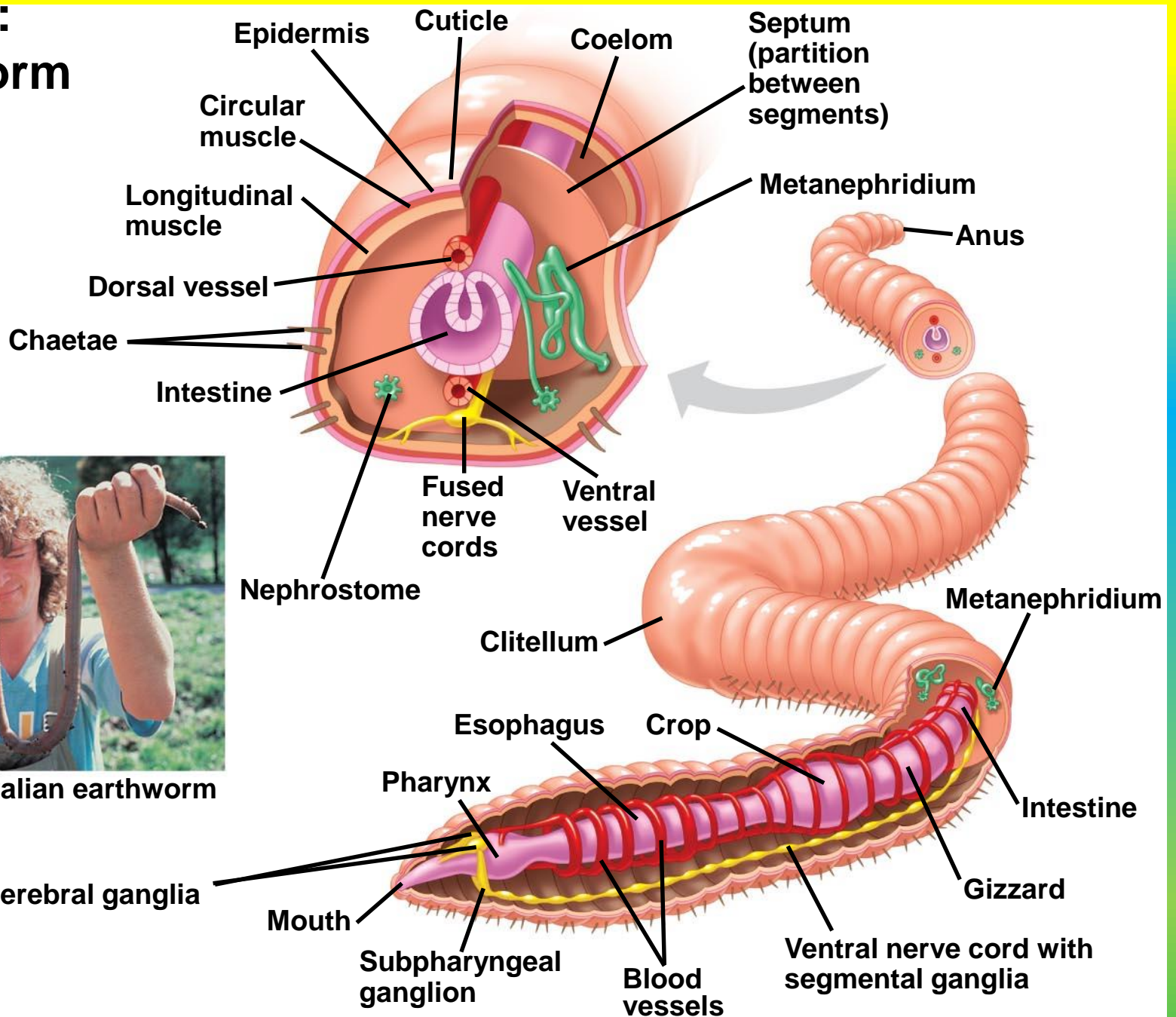
- Annelids have bodies composed of a series of fused rings.
- The phylum Annelida is divided into three classes:
  - Oligochaeta (earthworms and their relatives)
  - Polychaeta (polychaetes)
  - Hirudinea (leeches)

# *Oligochaetes*

---

- Oligochaetes (class Oligochaeta) are named for relatively sparse chaetae, bristles made of chitin.
- They include the earthworms and a variety of aquatic species.
- Earthworms eat through soil, extracting nutrients as the soil moves through the alimentary canal.
- Earthworms are hermaphrodites but cross-fertilize.

# Annelid: Earthworm



Giant Australian earthworm

# *Leeches*

---

- Members of class Hirudinea are blood-sucking parasites, such as leeches.
- Leeches secrete a chemical called hirudin to prevent blood from coagulating.

# Leech



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## Concept 33.4: Ecdysozoans are the most species-rich animal group

---

- Ecdysozoans are covered by a tough coat called a **cuticle**.
- The cuticle is shed or **molted** through a process called **ecdysis**.
- The two largest phyla are nematodes and arthropods.

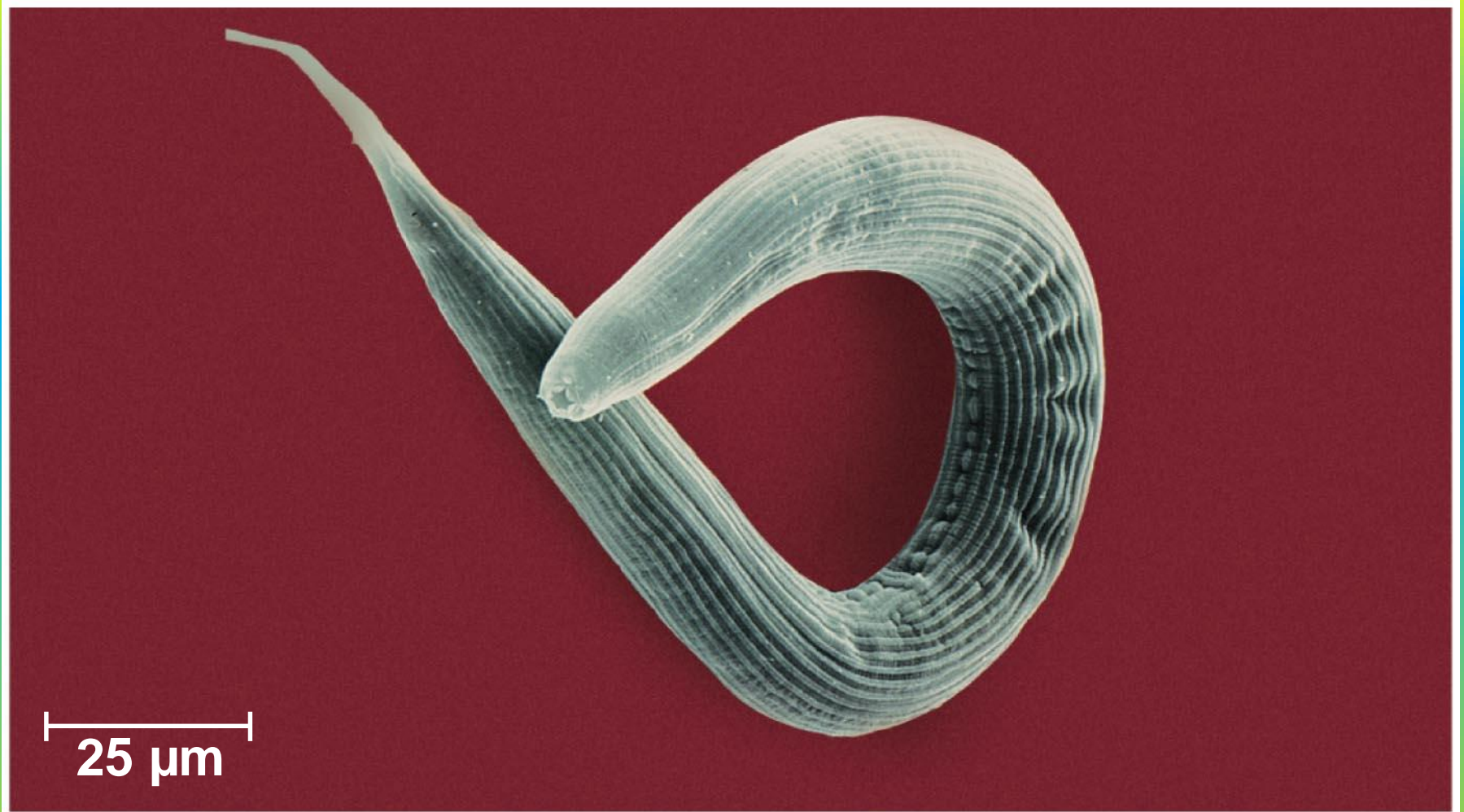


# Nematodes

---

- Nematodes, or roundworms, are found in most aquatic habitats, in the soil, in moist tissues of plants, and in body fluids and tissues of animals.
- They have an alimentary canal, but lack a circulatory system.
- Reproduction in nematodes is usually sexual, by internal fertilization.

# A free-living nematode - round worm



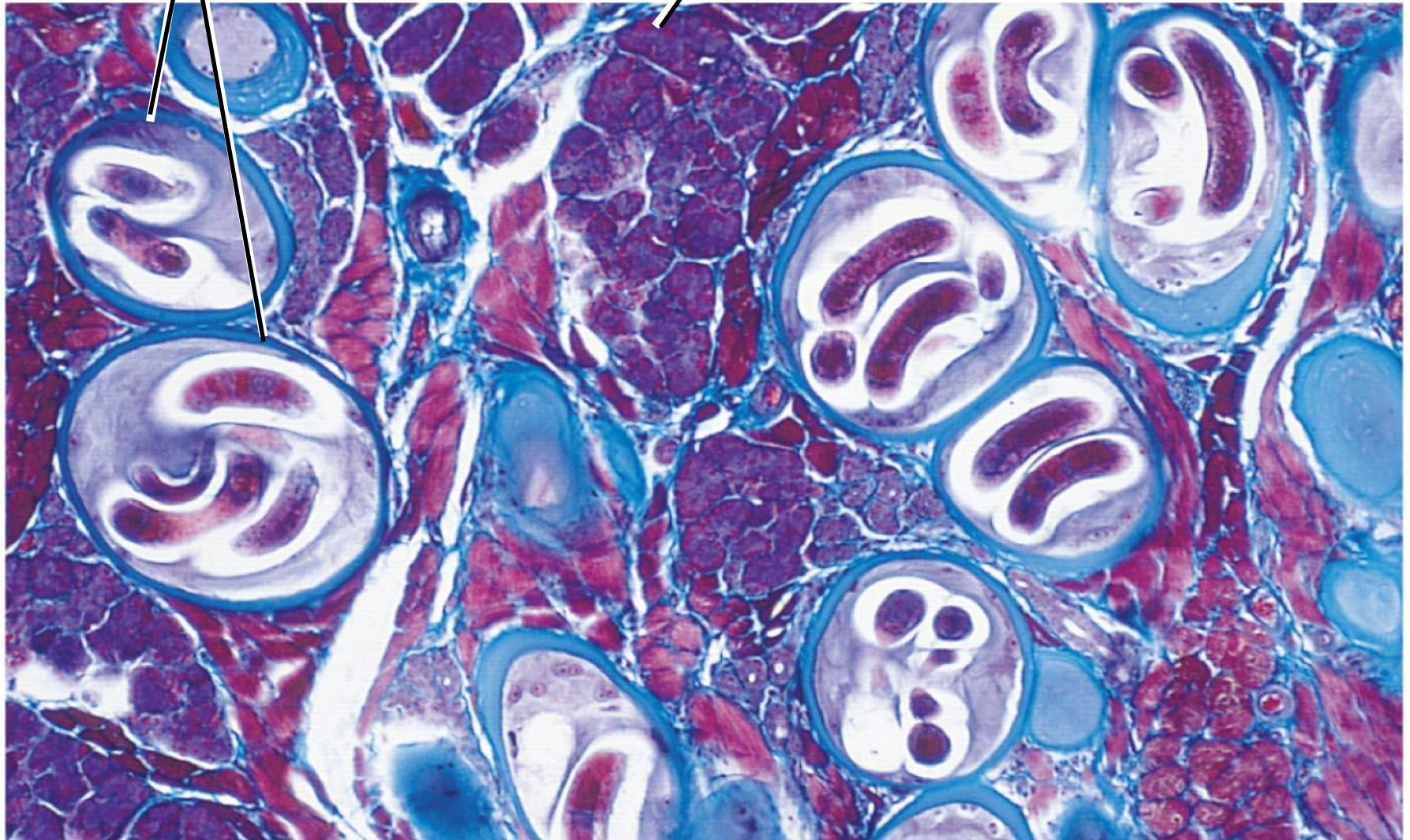
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# Juveniles of the parasitic nematode *Trichinella spiralis* encysted in human muscle tissue

50  $\mu\text{m}$

Encysted juveniles

Muscle tissue

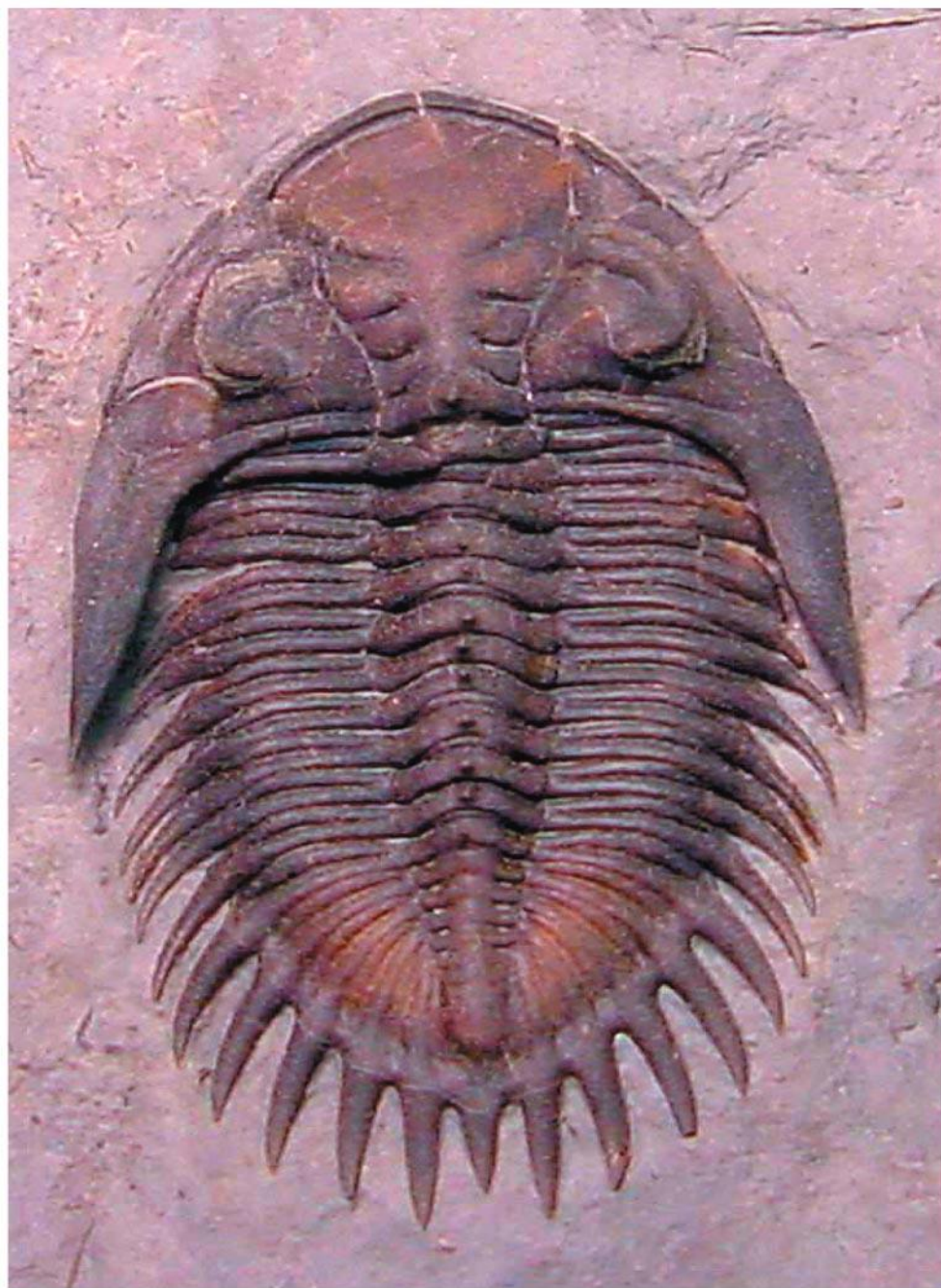


# Arthropods

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- Two out of every three known species of animals are arthropods.
- Members of the phylum Arthropoda are found in nearly all habitats of the biosphere.
- The **arthropod** body plan consists of a segmented body, hard exoskeleton, and jointed appendages, and dates to the Cambrian explosion (535–525 million years ago).
- Early arthropods show little variation from segment to segment.

# trilobite fossil

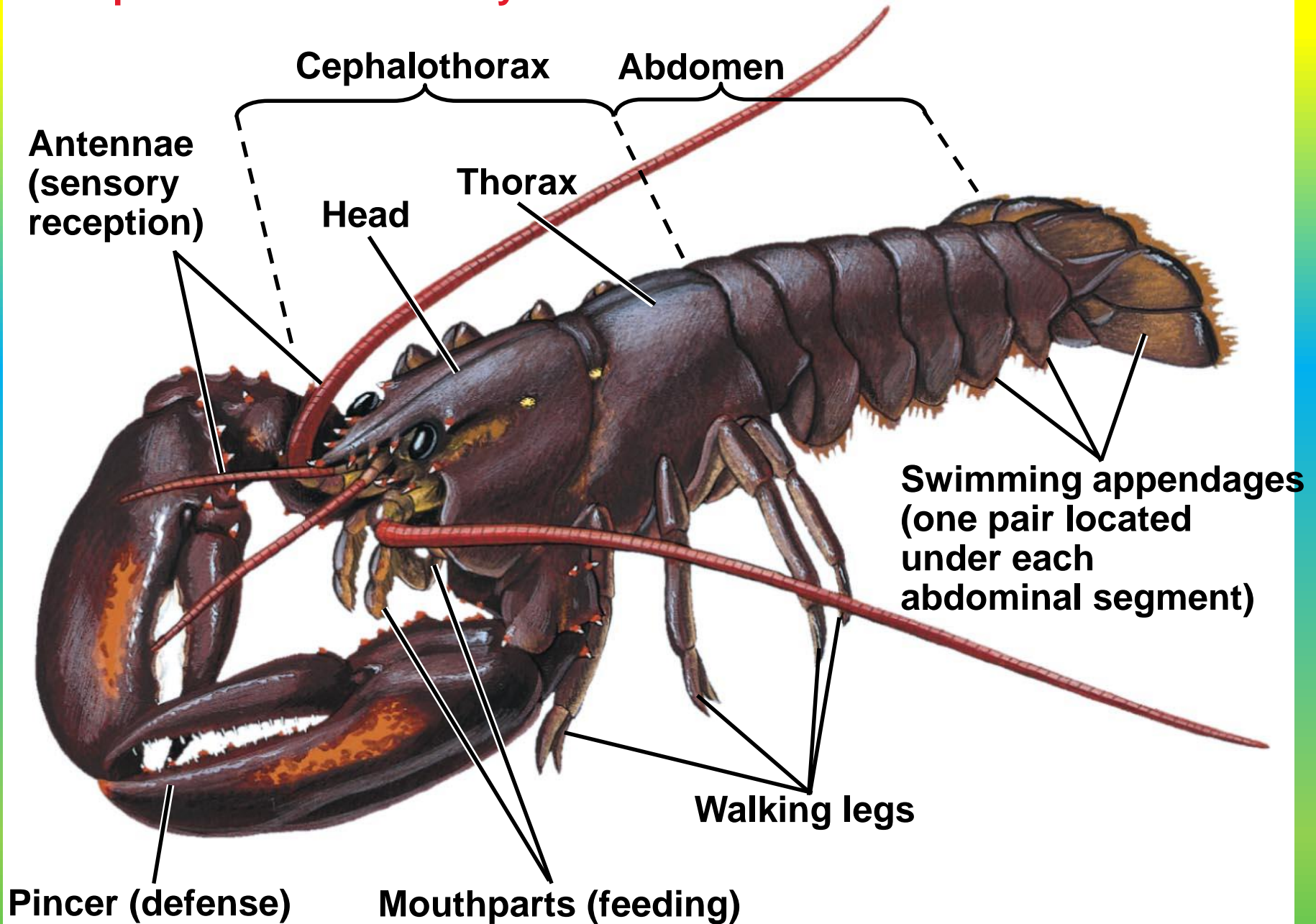


# *General Characteristics of Arthropods*

---

- The appendages of some living arthropods are modified for many different functions.
- The body of an arthropod is completely covered by the cuticle, an exoskeleton made of layers of protein and the polysaccharide chitin.
- When an arthropod grows, it molts its exoskeleton.

# Arthropod External Anatomy





- 
- Arthropods have an **open circulatory system** in which fluid called *hemolymph* is circulated into the spaces surrounding the tissues and organs.
  - A variety of organs specialized for gas exchange have evolved in arthropods.

- 
- Molecular evidence suggests that living arthropods consist of four major lineages that diverged early in the phylum's evolution:
    - **Cheliceriforms** (sea spiders, horseshoe crabs, scorpions, ticks, mites, and spiders)
    - **Myriapods** (centipedes and millipedes)
    - **Hexapods** (insects and relatives)
    - **Crustaceans** (crabs, lobsters, shrimps, barnacles, and many others).

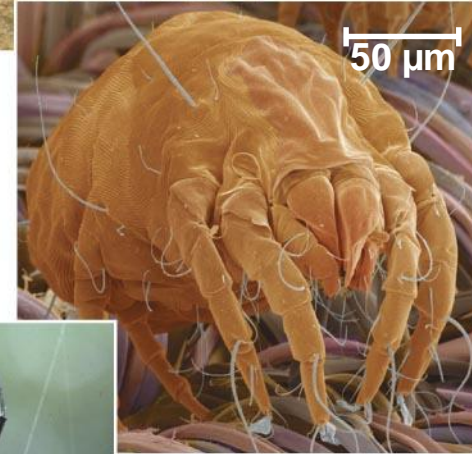
# Horseshoe crabs



- Most modern cheliceriforms are **arachnids**, which include spiders, scorpions, ticks, and mites.



▲ Scorpion

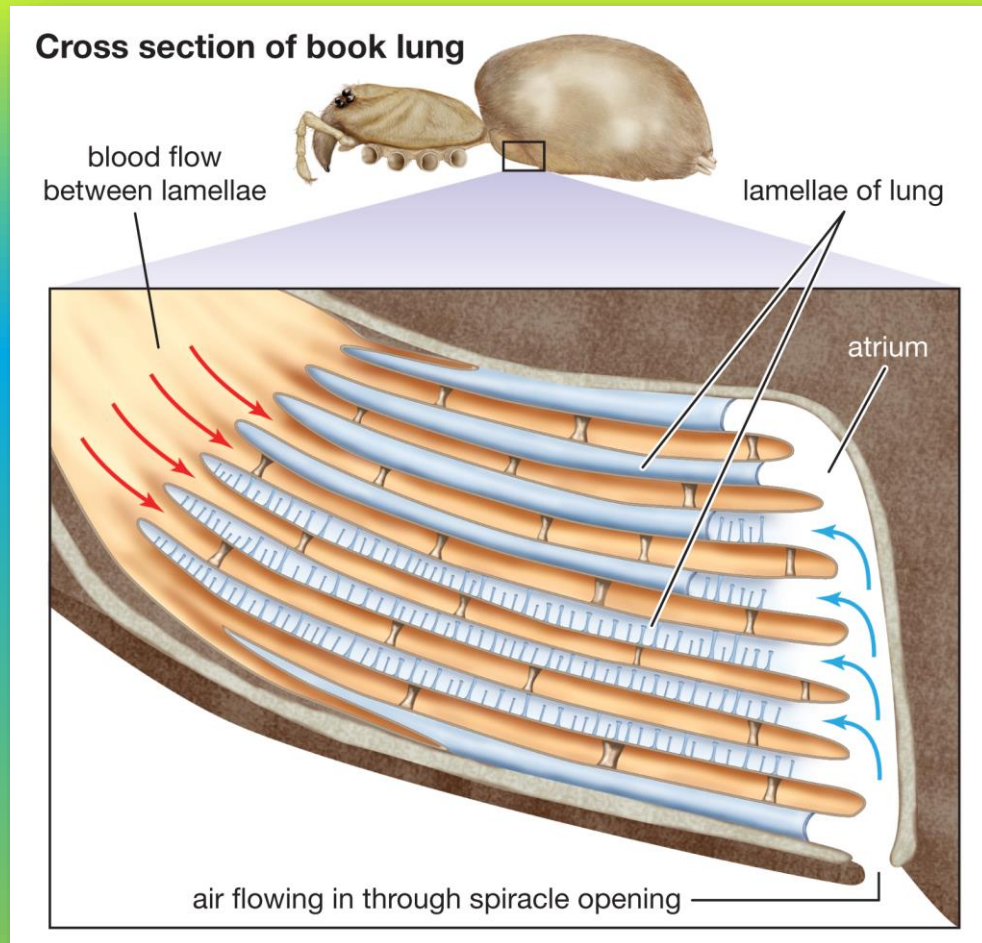


▲ Dust mite

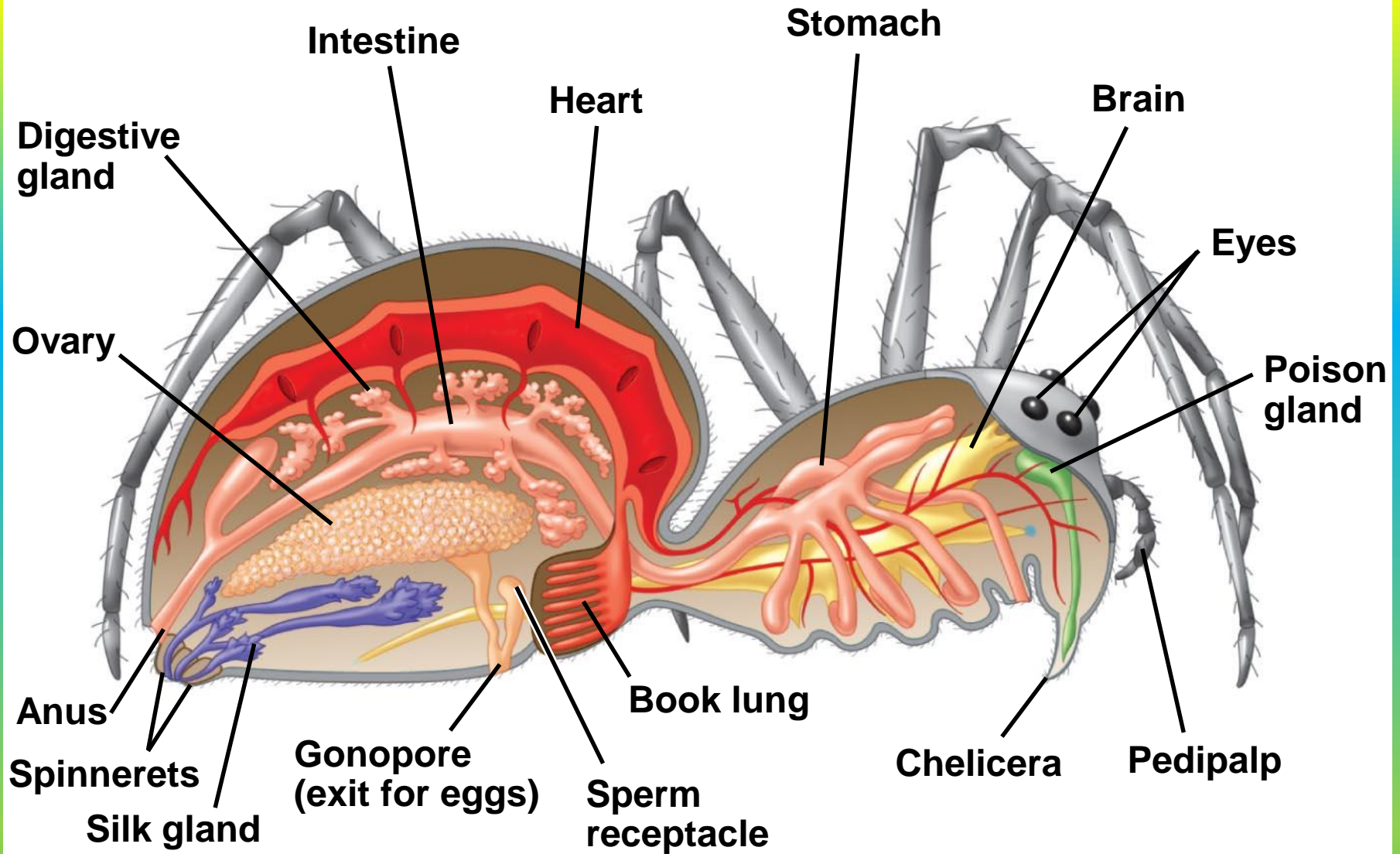


◀ Web-building spider

- Arachnids have an abdomen and a cephalothorax, which has six pairs of appendages, the most anterior of which are the chelicerae.
- Gas exchange in spiders occurs in respiratory organs called **book lungs**.
- Many spiders produce silk, a liquid protein, from specialized abdominal glands.



# Anatomy of a spider



# *Myriapods*

- **Subphylum Myriapoda** includes millipedes and centipedes
  - Myriapods are terrestrial, and have jaw-like **mandibles**
- Millipedes, class Diplopoda, have many legs
  - Each trunk segment has two pairs of legs



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- Centipedes, class Chilopoda, are carnivores
  - They have one pair of legs per trunk segment



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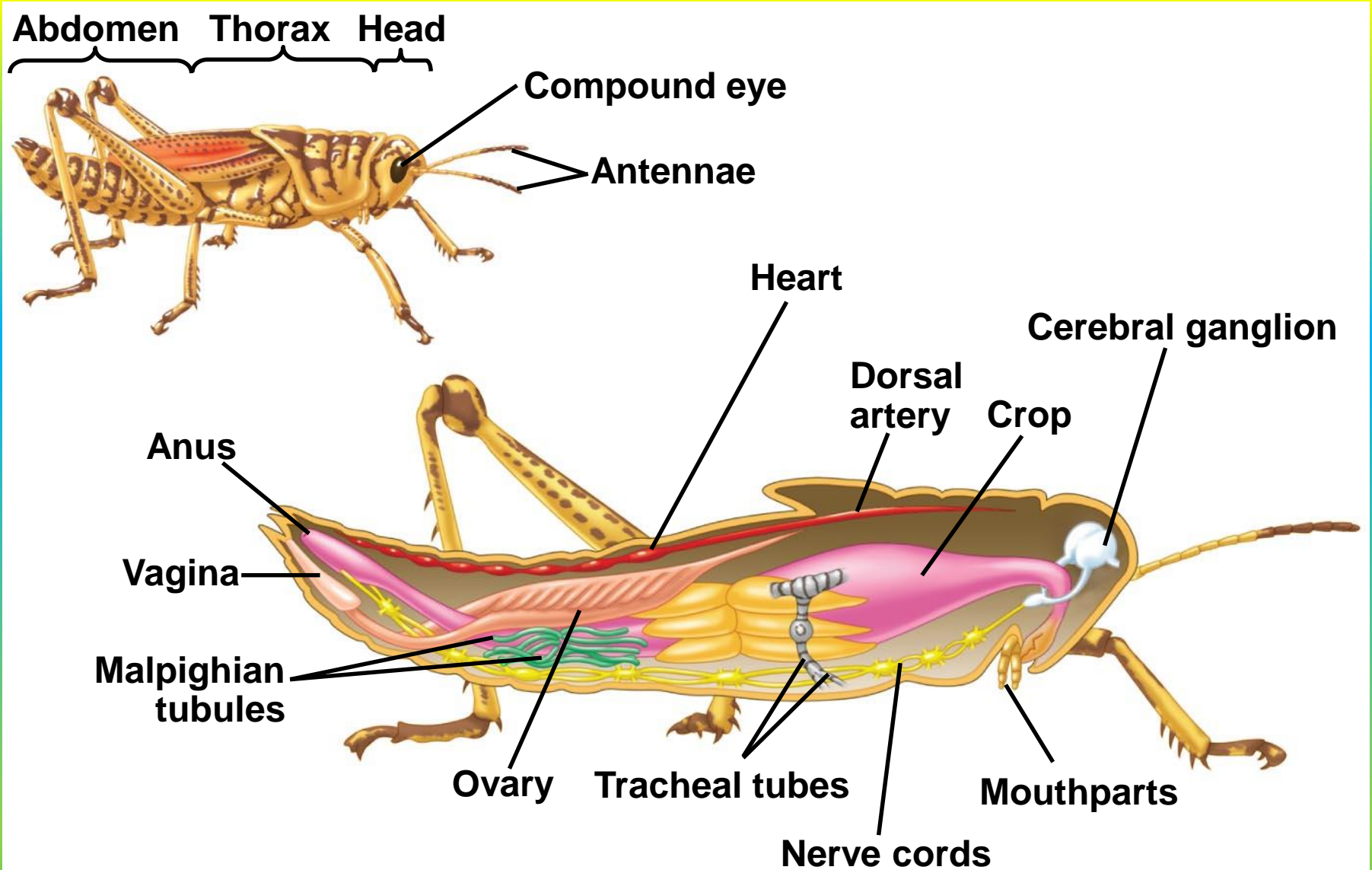


# *Insects*

---

- **Subphylum Hexapoda**, insects and relatives, has more species than all other forms of life combined.
- They live in almost every terrestrial habitat and in fresh water.
- The internal anatomy of an insect includes several complex organ systems.
- Insects diversified several times following the evolution of flight, adaptation to feeding on gymnosperms, and the expansion of angiosperms.

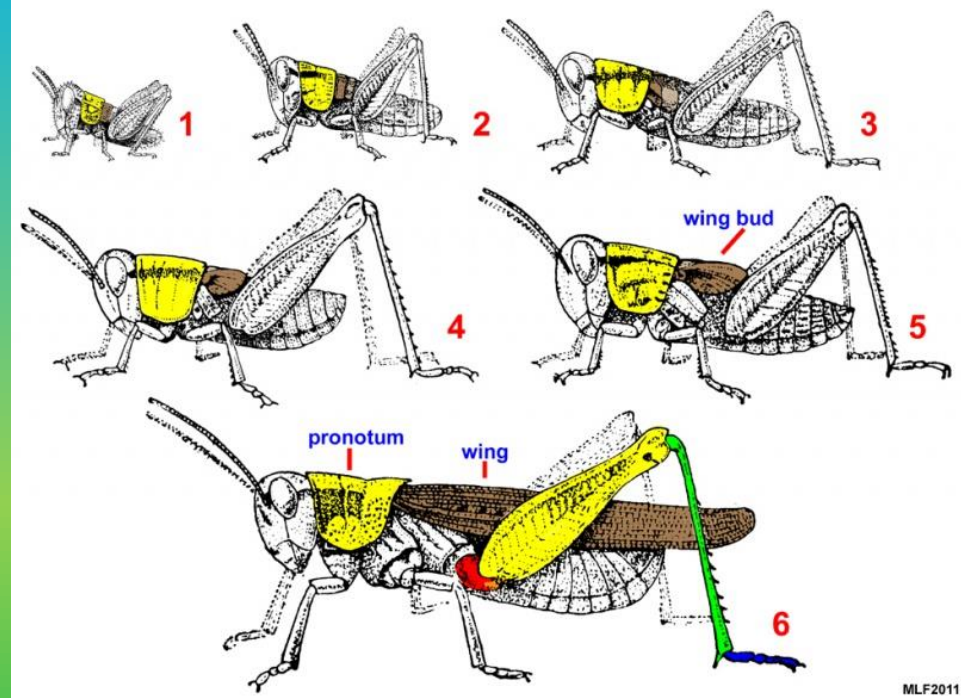
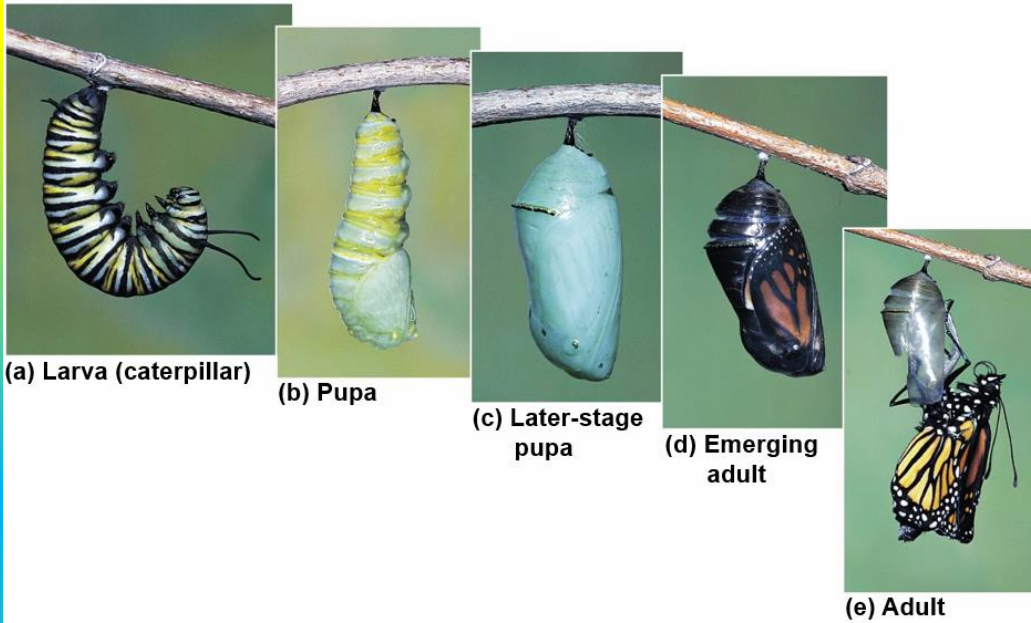
# Anatomy of a grasshopper, an insect



- 
- Flight is one key to the great success of insects.
  - An animal that can fly can escape predators, find food, and disperse to new habitats much faster than organisms that can only crawl.








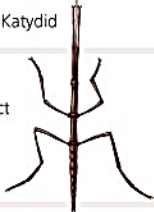







- 
- Many insects undergo metamorphosis during their development.
  - In **incomplete metamorphosis**, the young, called nymphs, resemble adults but are smaller and go through a series of molts until they reach full size.
  - Insects with **complete metamorphosis** have larval stages known by such names as maggot, grub, or caterpillar.
  - The larval stage looks entirely different from the adult stage.

# Metamorphosis of a butterfly



- 
- Most insects have separate males and females and reproduce sexually.
  - Individuals find and recognize members of their own species by bright colors, sound, or odors.
  - Some insects are beneficial as pollinators, while others are harmful as carriers of diseases, or pests of crops.

# Insect diversity

Order	Approximate Number of Species	Examples	Order	Approximate Number of Species	Examples
Blattodea	4,000	German cockroach 	Lepidoptera	120,000	Swallowtail butterfly 
Coleoptera	350,000	Japanese beetle 	Odonata	5,000	Dragonfly 
Dermaptera	1,200	Earwig 	Orthoptera	13,000	Katydid 
Diptera	151,000	Horsefly 	Phasmatodea	2,600	Stick insect 
Hemiptera	85,000	Leaf-footed bug 	Phthiraptera	2,400	Human body louse 
Hymenoptera	125,000	Cicada-killer wasp 	Siphonaptera	2,400	Flea 
Isoptera	2,000	Termite 	Thysanura	450	Silverfish 
			Trichoptera	7,100	Caddisfly 

# *Crustaceans*

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- While arachnids and insects thrive on land, crustaceans, for the most part, have remained in marine and freshwater environments.
- Crustaceans, subphylum Crustacea, typically have branched appendages that are extensively specialized for feeding and locomotion.
- Most crustaceans have separate males and females.



- **Isopods** include terrestrial, freshwater, and marine species
  - Pill bugs are a well known group of terrestrial isopods
- **Decapods** are all relatively large crustaceans and include lobsters, crabs, crayfish, and shrimp.



(a) Ghost crab



(b) Krill



(c) Barnacles

**Planktonic crustaceans include many species of copepods.**

**These are among the most numerous of all animals**



**Krill**

**Barnacles  
are a group  
of mostly  
sessile  
crustaceans.**

**They have a  
cuticle that  
is hardened  
into a shell.**

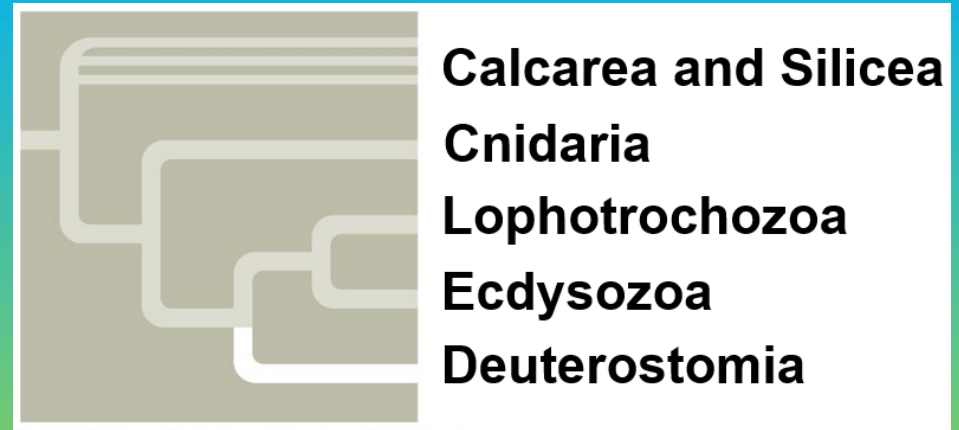


**Barnacles**

# Concept 33.5: Echinoderms and chordates are deuterostomes

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- Sea stars and other echinoderms, phylum Echinodermata, may seem to have little in common with phylum Chordata, which includes the vertebrates
- Shared characteristics define deuterostomes (Chordates and Echinoderms)
  - Radial cleavage
  - Formation of the mouth at the end of the embryo opposite the blastopore.

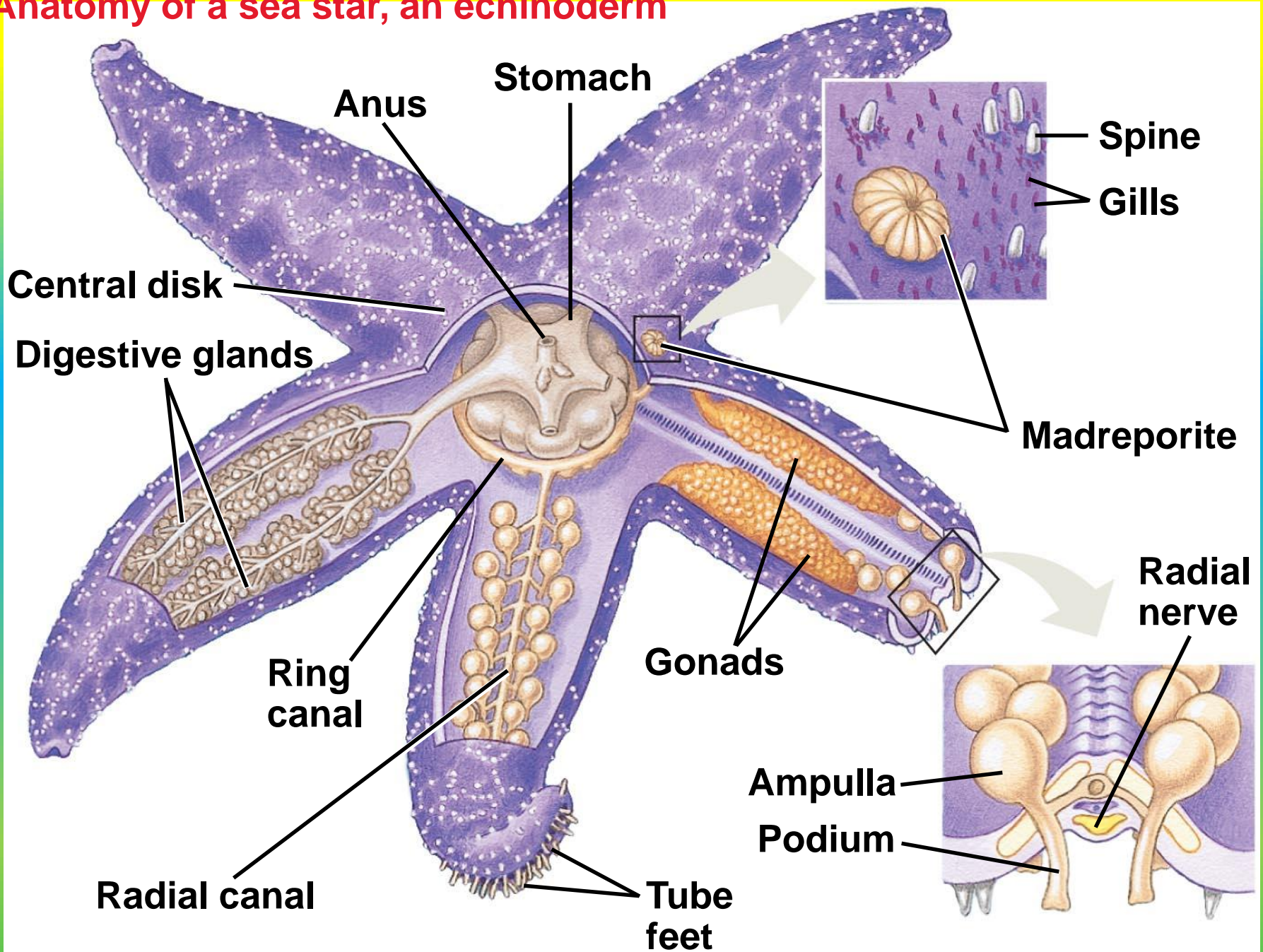


# Echinoderms

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- Sea stars and most other **echinoderms** are slow-moving or sessile marine animals.
- A thin epidermis covers an endoskeleton of hard calcareous plates.
- Echinoderms have a unique **water vascular system**, a network of hydraulic canals branching into **tube feet** that function in locomotion, feeding, and gas exchange.
- Males and females are usually separate, and sexual reproduction is external.

# Anatomy of a sea star, an echinoderm

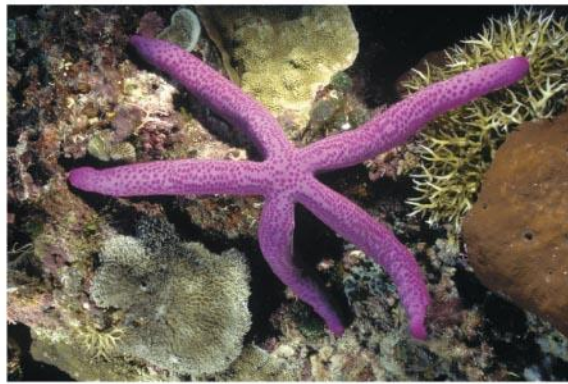


# *Sea Stars*

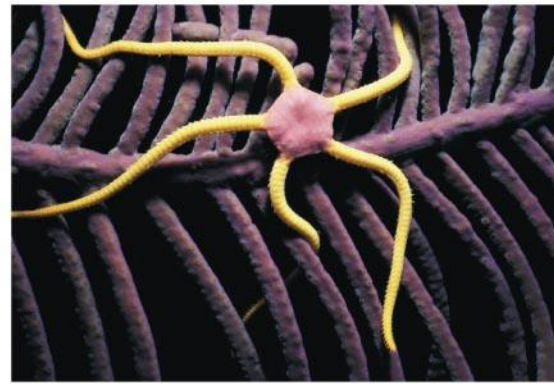
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- Sea stars, class Asteroidea, have multiple arms radiating from a central disk.
- The undersurfaces of the arms bear tube feet, each of which can act like a suction disk.
- Sea stars can regrow lost arms - regeneration.

# Echinoderms



(a) A sea star (class Asterozoidea)



(b) A brittle star (class Ophiurozoidea)



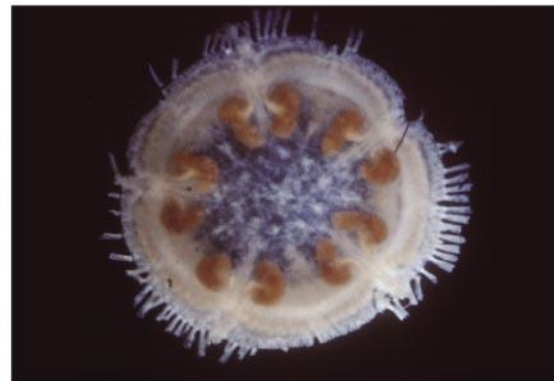
(c) A sea urchin (class Echinozoidea)



(d) A feather star (class Crinozoidea)

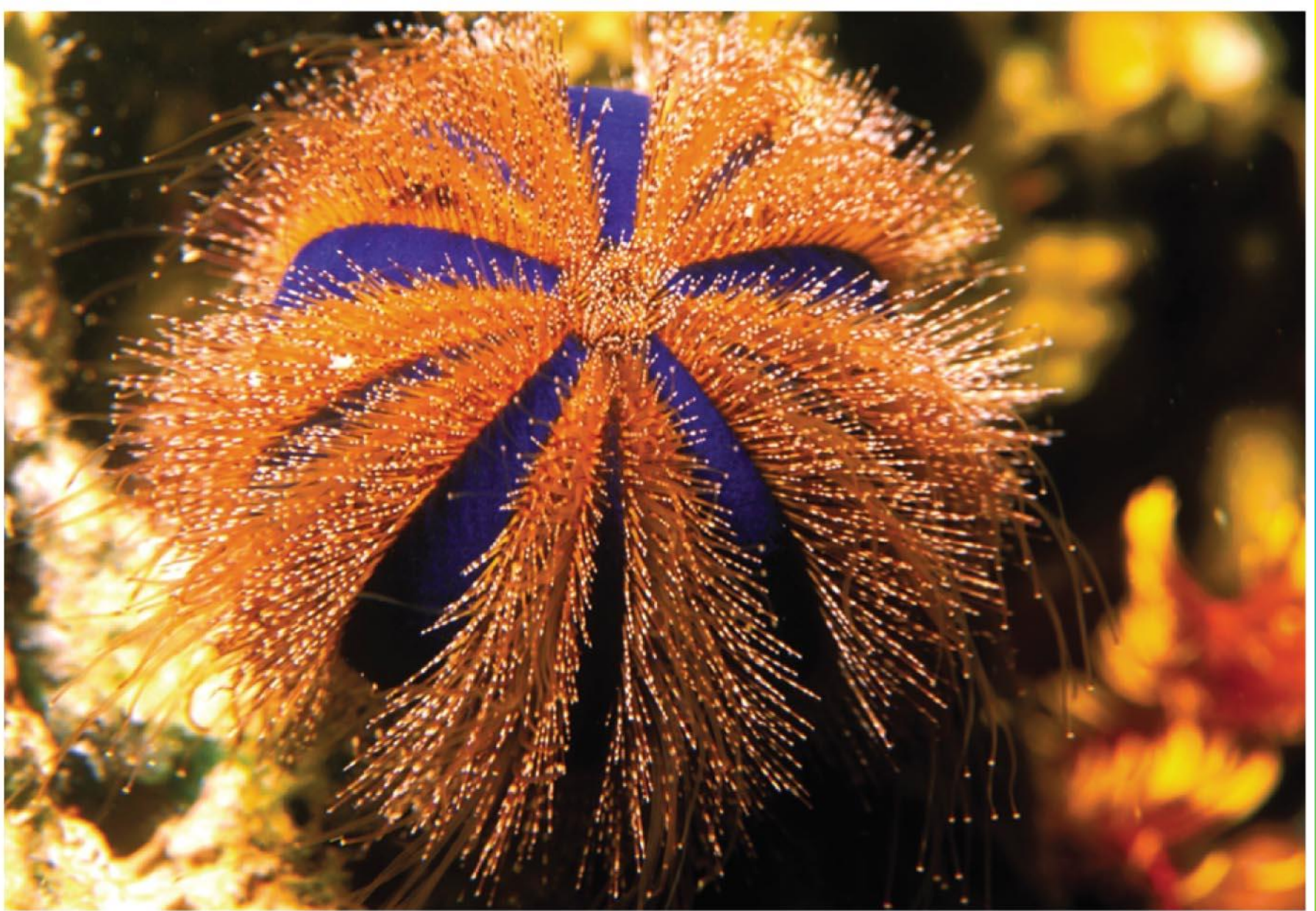


(e) A sea cucumber (class Holothurozoidea)



(f) A sea daisy (class Concentricyclozoidea)





**Sea urchins and sand dollars have no arms  
but have five rows of tube feet**

# *Sea Cucumbers*

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- Sea cucumbers lack spines, have a very reduced endoskeleton, and do not look much like other echinoderms.
- Sea cucumbers have five rows of tube feet; some of these are developed as feeding tentacles.














**Echinoderm - A sea cucumber**

# Chordates

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- Phylum Chordata consists of two subphyla of invertebrates as well as hagfishes and vertebrates.
- Chordates share many features of embryonic development with echinoderms, but have evolved separately for at least 500 million years.

# Animal Phyla

Key Concept	Phylum	Description			
<b>Concept 33.1</b> Sponges are basal animals that lack true tissues	Calcarea, Silicea (sponges)	 Lack true tissues; have choanocytes (collar cells—flagellated cells that ingest bacteria and tiny food particles)			
	<b>Concept 33.2</b> Cnidarians are an ancient phylum of eumetazoans	Cnidaria (hydras, jellies, sea anemones, corals)	 Unique stinging structures (cnidae), each housed in a specialized cell (cnidocyte); diploblastic; radially symmetrical; gastrovascular cavity (digestive compartment with a single opening)		
<b>Concept 33.3</b> Lophotrochozoans, a clade identified by molecular data, have the widest range of animal body forms	Metazoa Eumetazoa Bilateria Lophotrochozoa	Platyhelminthes (flatworms)	 Dorsoventrally flattened, unsegmented acoelomates; gastrovascular cavity or no digestive tract		
		Rotifera (rotifers)	 Pseudocoelomates with alimentary canal (digestive tube with mouth and anus); jaws (trophi) in pharynx; head with ciliated crown		
		Lophophorates: Ectoprocta, Brachiopoda	 Coelomates with lophophores (feeding structures bearing ciliated tentacles)		
		Mollusca (clams, snails, squids)	 Coelomates with three main body parts (muscular foot, visceral mass, mantle); coelom reduced; most have hard shell made of calcium carbonate		
		Annelida (segmented worms)	 Coelomates with segmented body wall and internal organs (except digestive tract, which is unsegmented)		
		<b>Concept 33.4</b> Ecdysozoans are the most species-rich animal group	Ecdysozoa	Nematoda (roundworms)	 Cylindrical, unsegmented pseudocoelomates with tapered ends; no circulatory system; undergoes ecdysis
				Arthropoda (crustaceans, insects, spiders)	 Coelomates with segmented body, jointed appendages, and exoskeleton made of protein and chitin
		<b>Concept 33.5</b> Echinoderms and chordates are deuterostomes	Deuterostomia	Echinodermata (sea stars, sea urchins)	 Coelomates with bilaterally symmetrical larvae and five-part body organization as adults; unique water vascular system; endoskeleton
				Chordata (lancelets, tunicates, vertebrates)	 Coelomates with notochord; dorsal, hollow nerve cord; pharyngeal slits; post-anal tail (see Chapter 34)

# You should now be able to:

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1. Describe how a sponge feeds and digests its food.
2. List the characteristics of the phylum Cnidaria that distinguish it from other animal phyla.
3. List the four classes of Cnidaria and distinguish among them based on life cycle morphology.
4. List the characteristics of Platyhelminthes and distinguish among the four classes.
5. Describe the features of molluscs and distinguish among the four classes.

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6. Describe the features of annelids and distinguish among the three classes.
  7. List the characteristics of nematodes that distinguish them from other wormlike animals.
  8. List three features that account for the success of arthropods.
    - Define and distinguish among the four major arthropod lineages.
    - Describe the developmental similarities between echinoderms and chordates.