

An Introduction to the Invertebrates, Arthropods, Part One

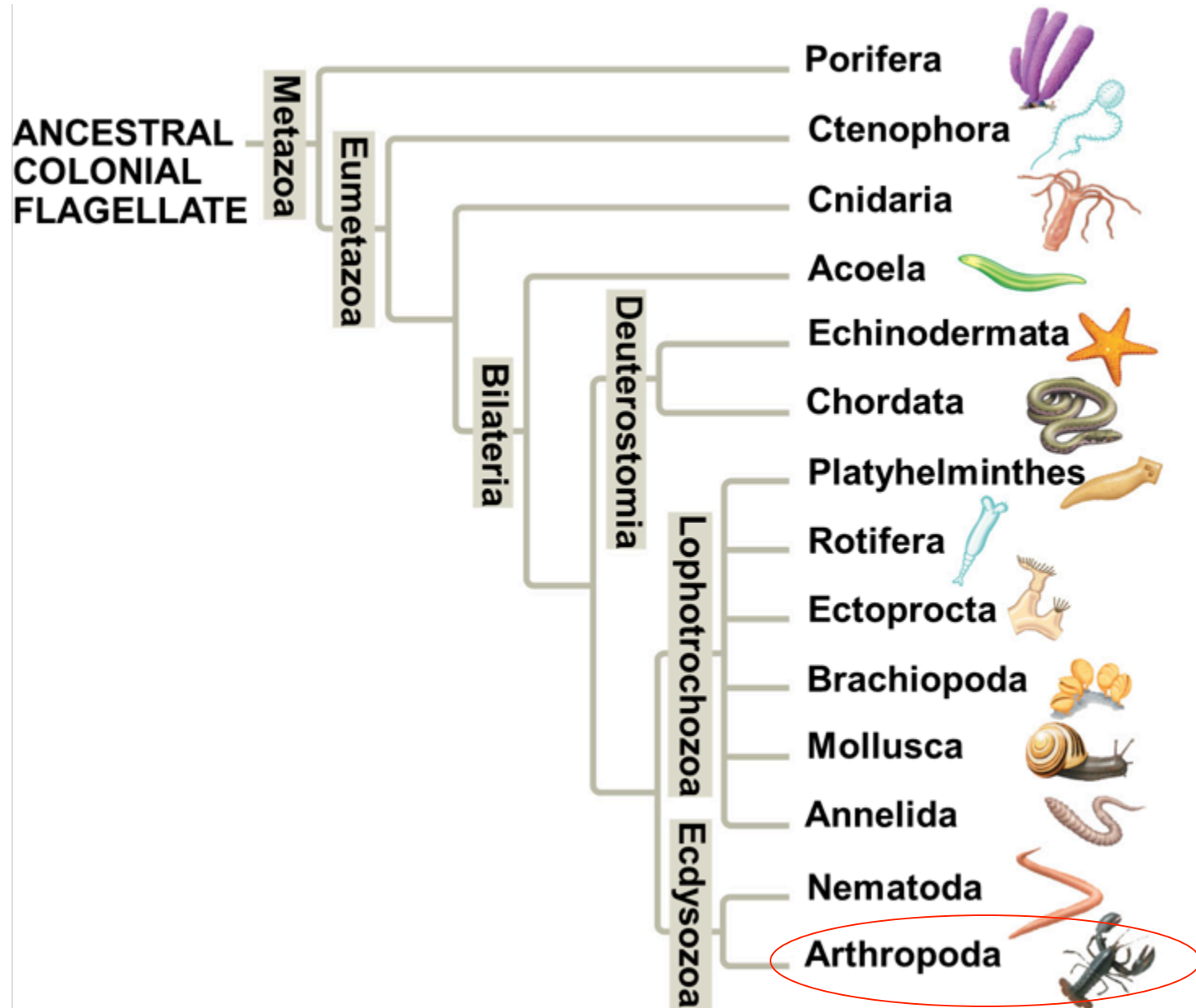
Reference: Chapter 33

"Don't accept the chauvinistic tradition that labels our era the age of mammals. This is the age of arthropods. They outnumber us by any criterion – by species, by individuals, by prospects for evolutionary continuation."

[Stephen Jay Gould](#), 1988



More Relationships...



Arthropod = “jointed leg”

- ❖ Eumetazoan protostome, bilateral symmetry, triploblastic, coelomate (mostly)
- ❖ Defining characteristics
 - **Segmented body**
 - Some segments are fused by **tagmosis** into **tagmata**
 - **Exoskeleton made of chitin**
 - Secreted by epidermis
 - **Molting (Ecdysis → Ecdysozoa)**
 - Exoskeleton shed regularly during life or only during larval development
 - **No cilia in larvae or adults**
- ❖ Most successful in terms of diversity and sheer numbers
 - >1,000,000 species!

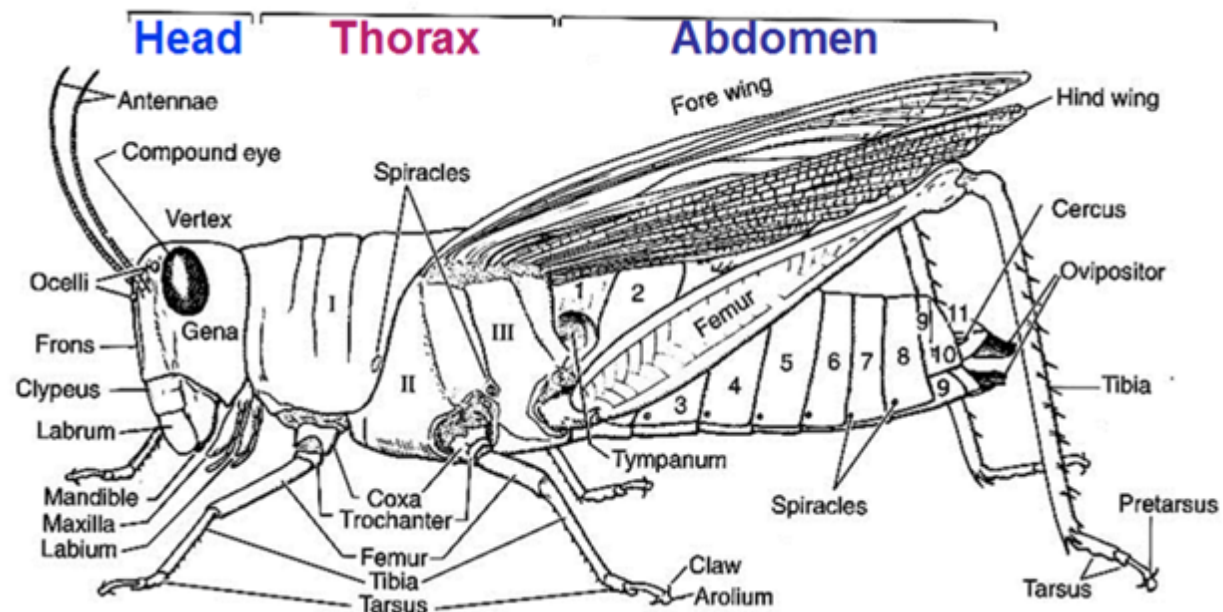
Arthropod Origins

- ❖ The arthropod body plan consists of a segmented body, hard exoskeleton, and jointed appendages
- ❖ This body plan dates to the Cambrian explosion (535-525 million years ago)
- ❖ Early arthropods show little variation from segment to segment



Phylum Arthropoda - general body plan

- ❖ Body divided into segments (**somites**)
 - Regionally fused into specialized groups by **tagmosis** (i.e., 5 segments form head)
 - Internal cavity → hemocoel (not coelom!)
 - No internal segmentation (no septa - contrast w/annelids)
- ❖ Each body segment has a pair of **jointed appendages**



Tagmosis allows for specialization & diversity

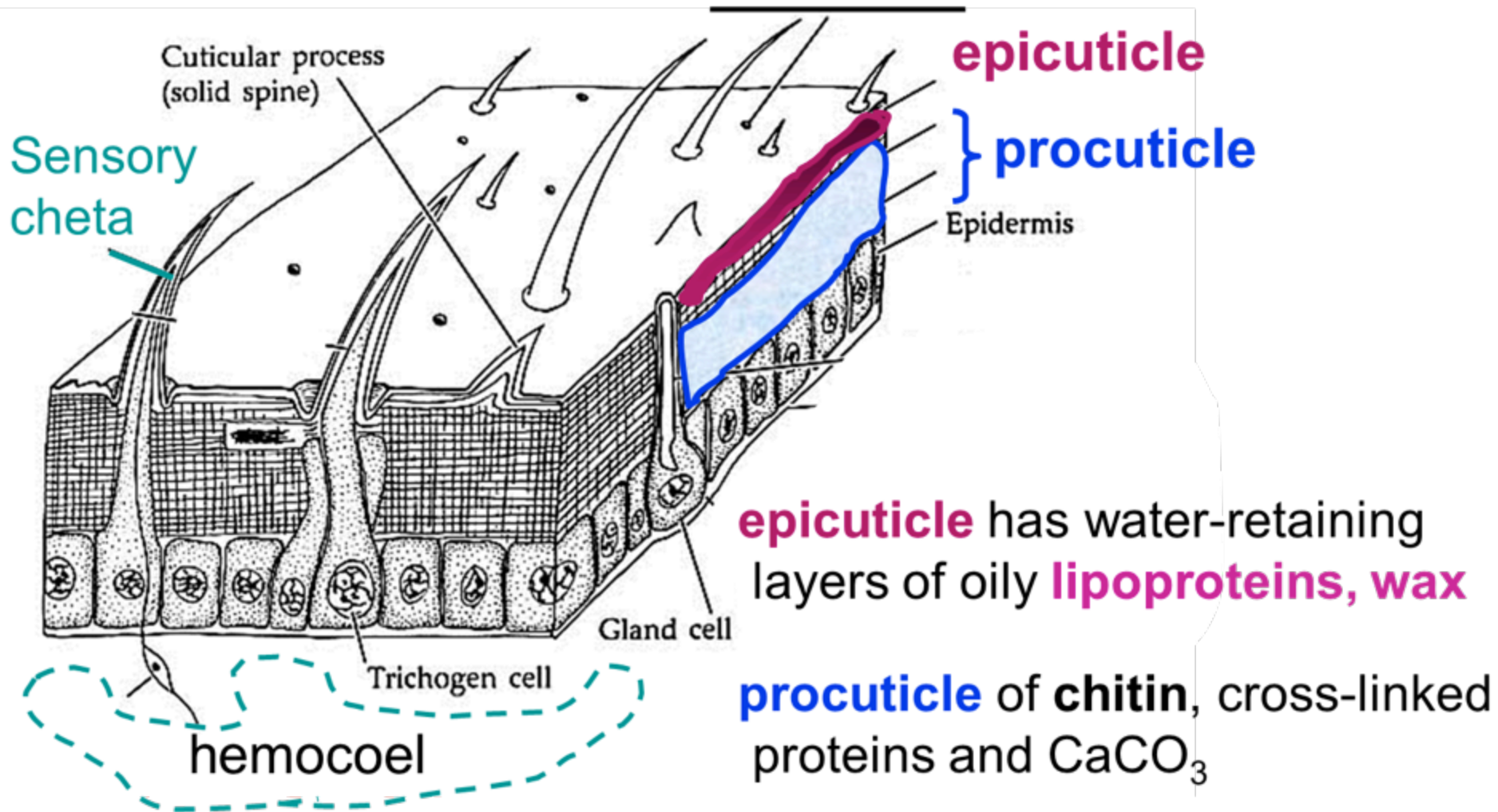
- ❖ Diversity of body form possible because of **specialization** of segments, regions and appendages
- ❖ **Tagmosis** = segments grouped together
 - Specialized for particular functions for greater efficiency
- ❖ **Head, thorax and abdomen** are tagmata
 - Regions specialized for performing different tasks



Exoskeleton Structure

- ❖ Cuticle forms well-developed exoskeleton made up of plates (**sclerites**)
 - Growth by **ecdysis** (hormone-induced molting)
- ❖ Epidermis is a single layer of epithelial cells that secrete the cuticle in layers
 - Outer layer = **epicuticle**, with water-repellant **hydrophobic** layers
 - Inner layer = **procuticle**, protein & **chitin**
 - Procuticle is hardened by
 1. **Sclerotization** = cross-linking of proteins into 3D matrix
 2. **Mineralization** (in crustaceans) = depositing calcium carbonate in procuticle (i.e., crab shell)

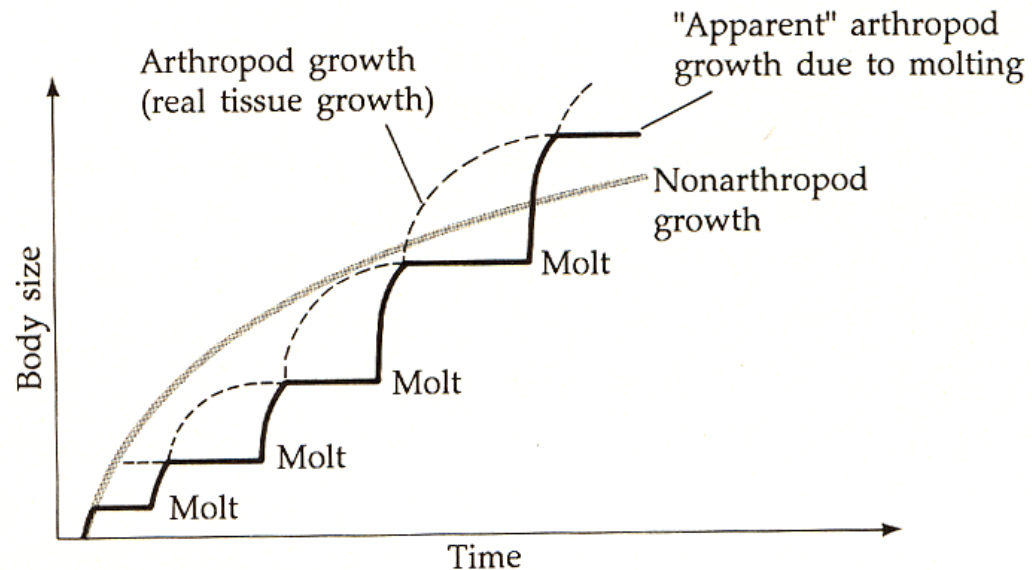
The Arthropod Cuticle



Chitin = high mol. weight nitrogenous polysaccharide

Molting

- ❖ Stages between molts are termed **instars**
 - This is when actual tissue growth occurs, although there's no size increase until after the molt
 - Usually applies to immature stages
- ❖ Frequency of molting is under hormonal control (ecdysone)
- ❖ Cuticle is weakened enzymatically, then animal crawls out
- ❖ After molting, animal sucks in air/water to inflate new cuticle which then hardens



The pros and cons of the arthropod exoskeleton

❖ Pros

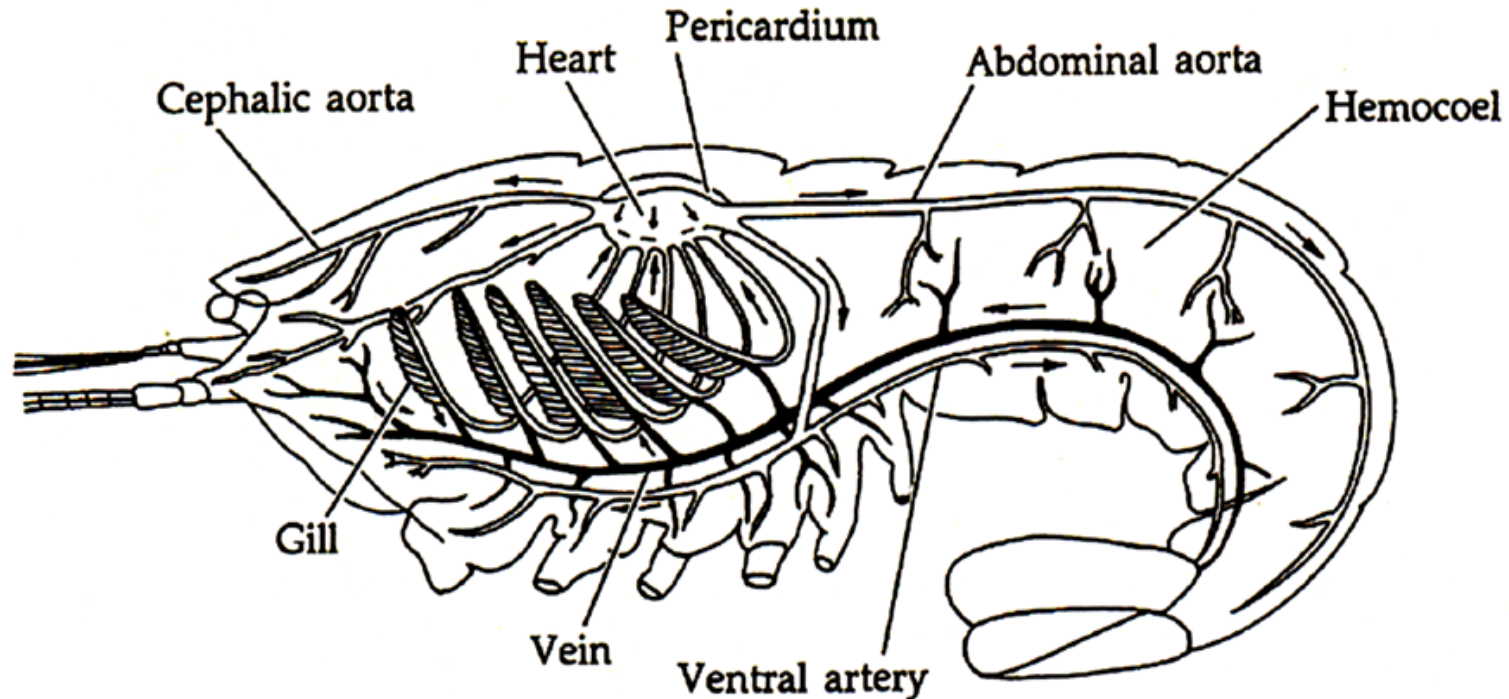
1. Provides protection; hard covering over muscles & viscera
2. Facilitates osmoregulation in terrestrial environment (less water loss through epidermis)
3. No need for hydrostatic skeleton, so body plan could diversify
4. Better leverage than endoskeleton (or no skeleton) for moving muscles attached to limbs

❖ Cons

1. Growth must proceed through a series of molts
2. Chitin exoskeleton is heavy – constraint on size

Arthropod circulation

- ❖ Open circulatory system
 - Hemolymph moves through hemocoel, and has amebocytes, pigments, and sometimes clotting factors
 - Muscular heart required since rigid exoskeleton prevents body movements from moving hemolymph

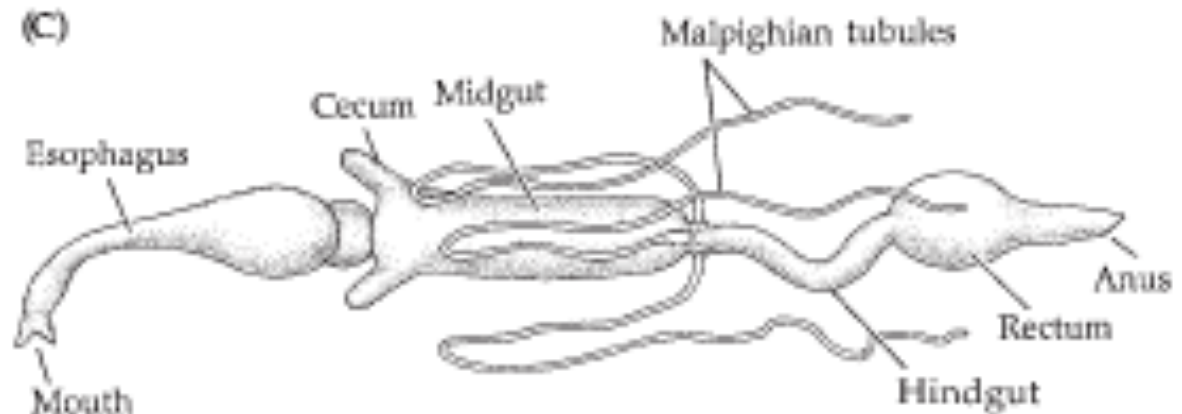


Arthropod Respiration

- ❖ Varies between groups but usually by **gills** in aquatic habitats and a **tracheal system** in terrestrial arthropods
 - The tracheal system is composed of tubes that distribute air throughout the body
 - Some arthropods have a specialized lung-like structure called a **book lung** or **book gill**
 - Special chamber with platelike structures
 - Enhanced surface area facilitates rapid exchange of CO_2 and O_2
 - Diffusion of gases across thin areas of the cuticle also contributes to respiration

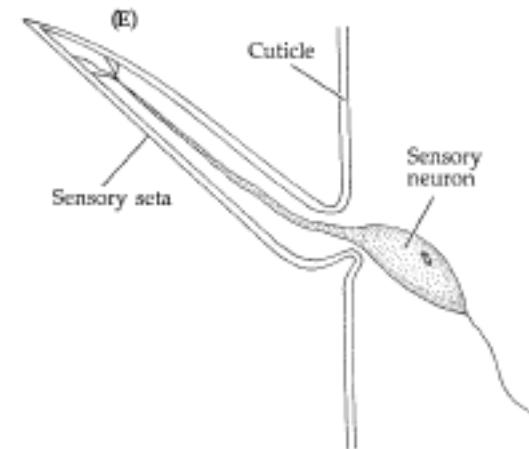
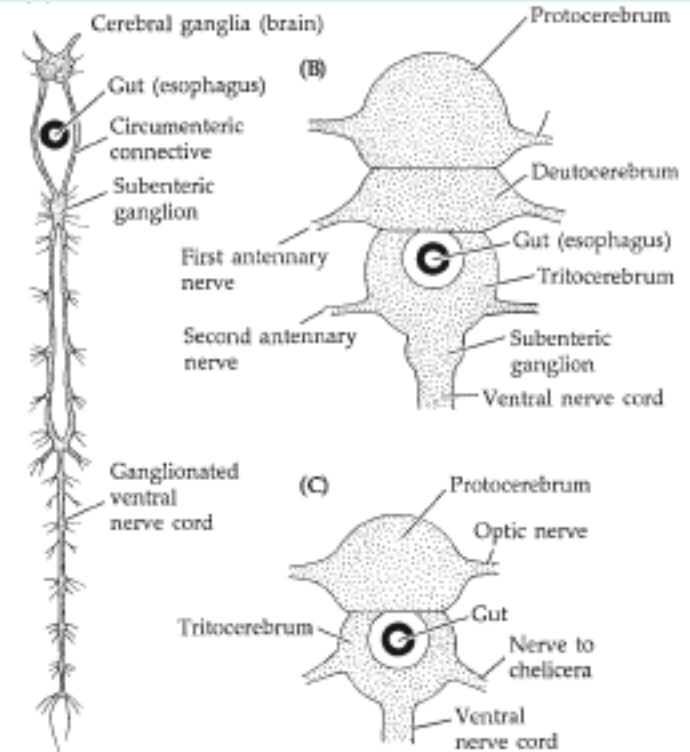
Arthropod Osmoregulation and Waste Excretion

- ❖ Reuptake of salts and nutrients
- ❖ **Antennal and maxillary glands** in crustaceans
 - Produce **urine**; **ammonia** also excreted from gills
- ❖ **Malpighian tubules** in arachnids and insects
 - Blind tubes extend into hemocoel and empty into gut
 - Produce uric acid which is passed through the anus
 - Solid matter may also be passed through the anus



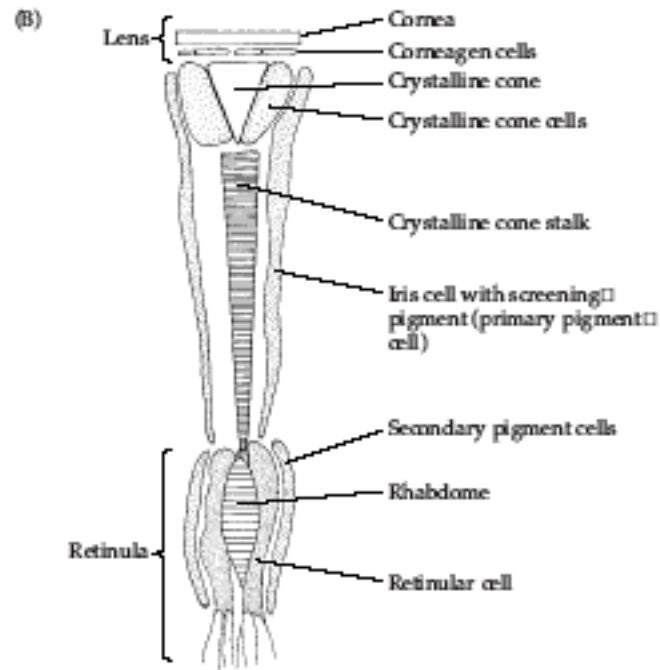
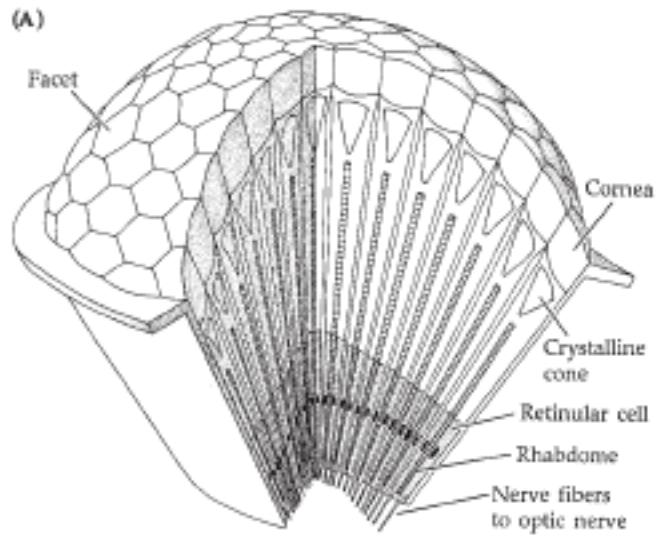
Arthropod Nervous System

- ❖ “Brain” is 2-3 ganglia with specific functions
- ❖ Ganglionated ventral nerve cord
- ❖ Sense organs (**sensilla**) protrude out of cuticle
- ❖ Membranous drums (“ears”)
- ❖ Chemoreceptors with thin cuticle



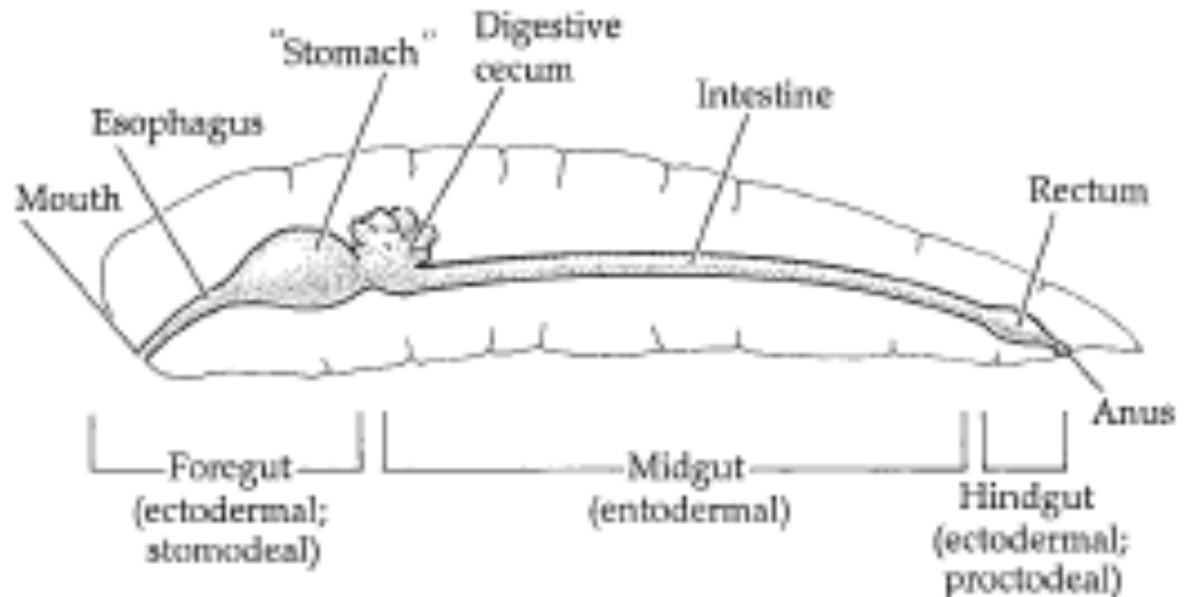
Arthropod Vision

- Simple ocelli
- Complex lensed ocelli
- Compound eyes made of **ommatidia**



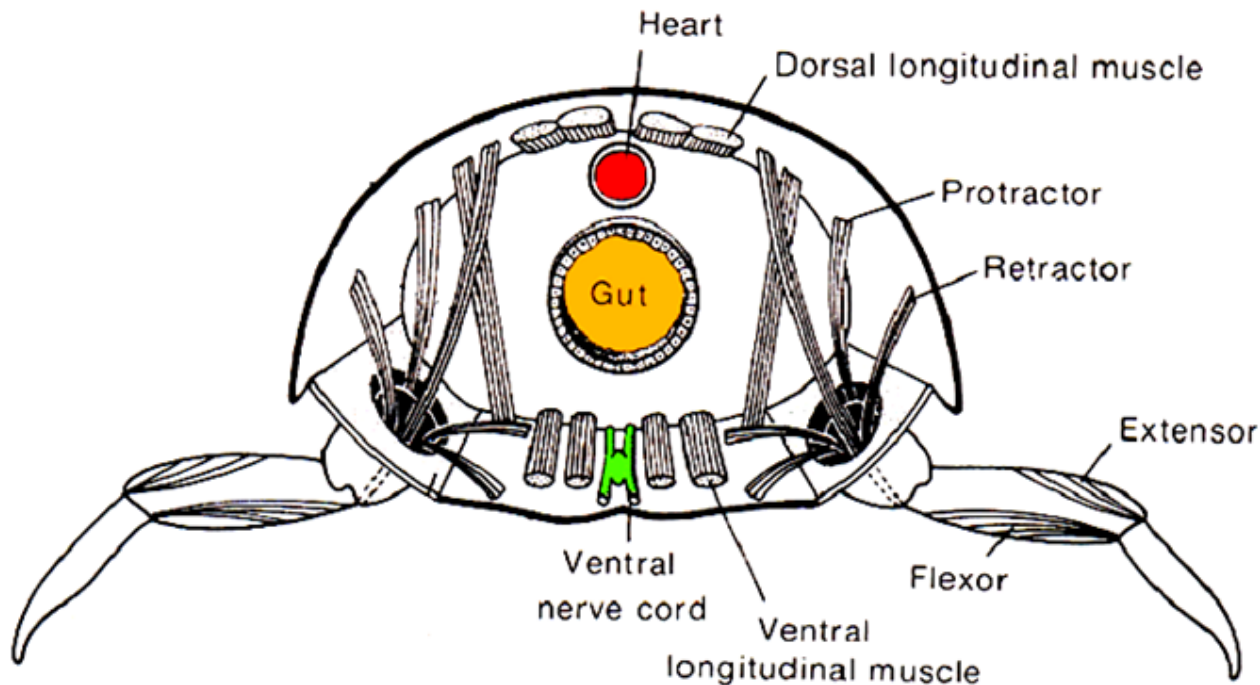
Arthropod Digestive System

- ❖ Complete, with regional specialization
 - **Foregut** - food intake, transport, storage, mechanical digestion (**jaws, pharynx, gizzard**)
 - **Midgut** - extracellular digestion, nutrient uptake (**cecae, digestive gland, hepatopancreas**)
 - **Hindgut** - excretion of undigested material, water reabsorption



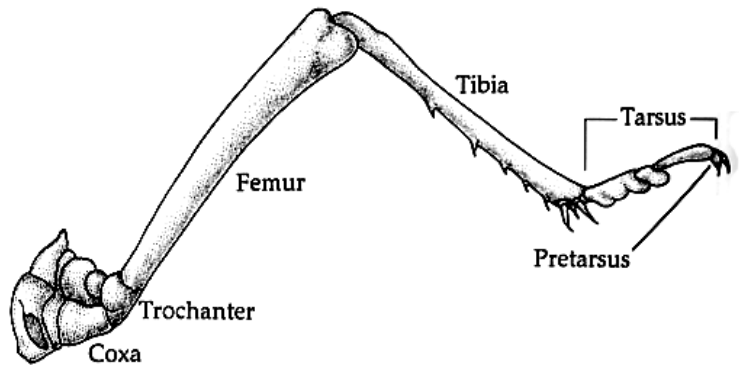
Arthropod Locomotion

- ❖ Striated muscle
 - Exoskeleton used as attachment point for muscles
- ❖ Muscles anchor on inside of cuticle
 - Connect into the jointed appendages on each segment

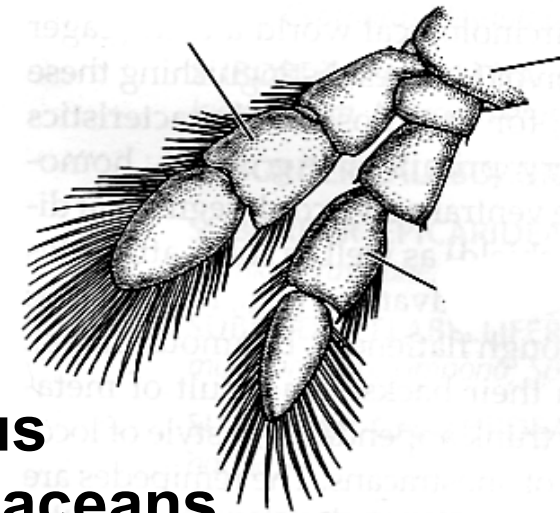


Arthropod locomotion

- ❖ Jointed appendages (limbs) + specialized muscles to move the limb pieces (**podites**)
 - Extrinsic muscles connect to body wall
 - Intrinsic muscles are contained entirely inside the limb
- ❖ Ancestral condition, found in crustaceans, is to have **biramous limbs** (each limb has 2 branches)

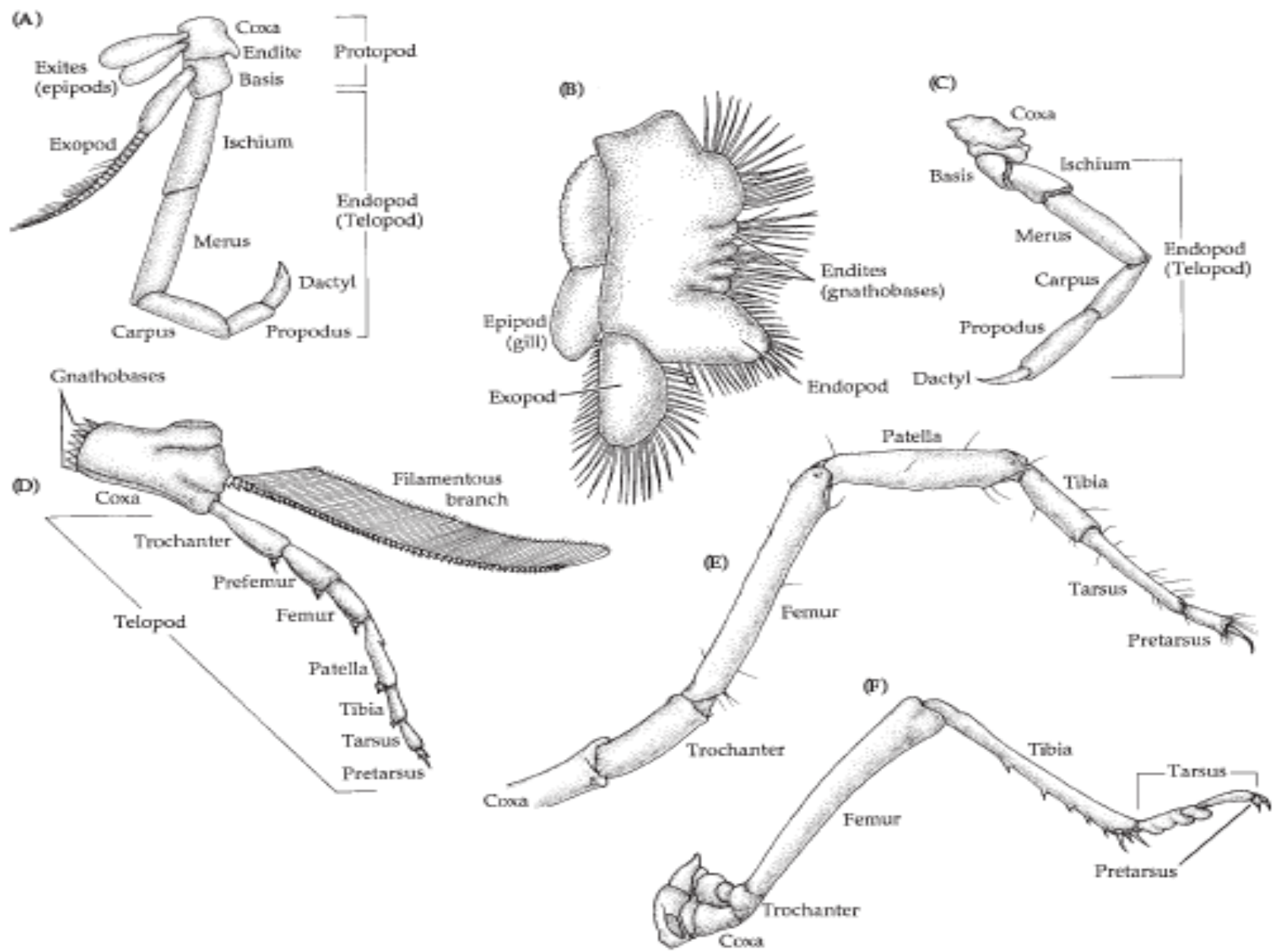


Uniramous (1 branch)
- insects



Biramous
- crustaceans

Diversity of Arthropod legs

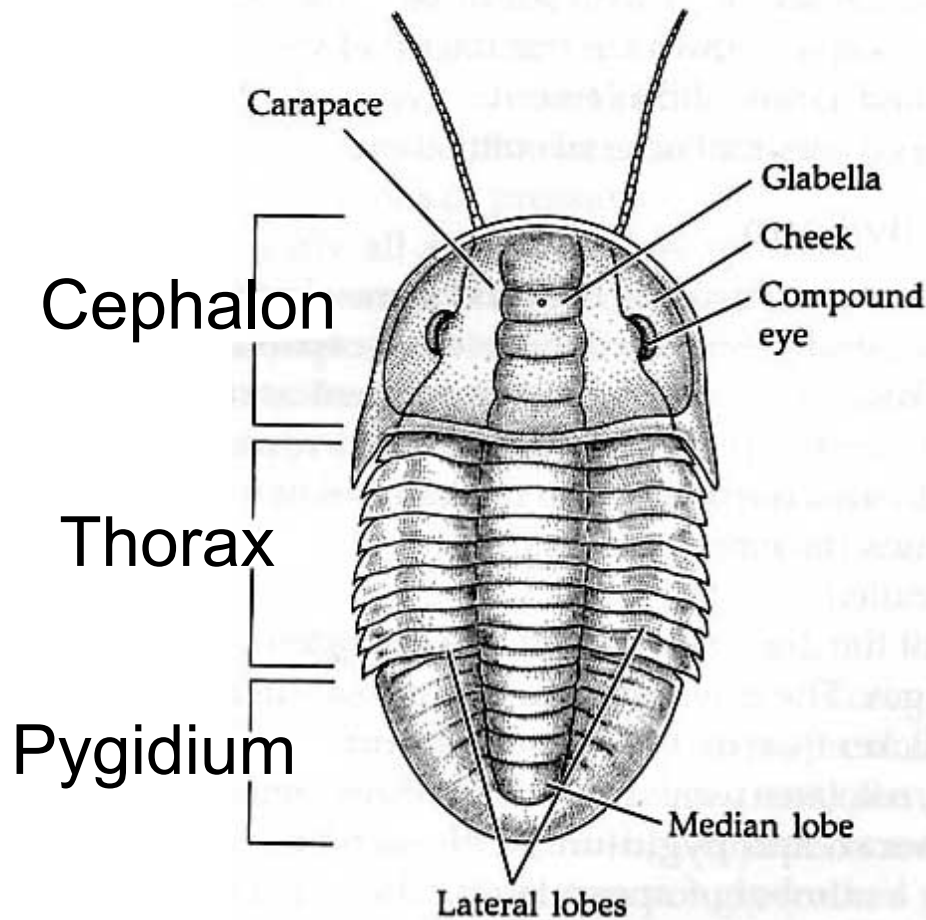


Arthropod Taxonomy

Seven Subphyla:

1. **Trilobites** (extinct since Paleozoic)
2. **Onychophora** (velvet worms)
3. **Tartigrada** (water bears)
4. **Crustacea** (crabs, lobsters, shrimp)
5. **Chelicerata** (spiders, horseshoe crabs, pycnogonids)
6. **Myriapoda** (centipedes, millipedes)
7. **Hexapoda** (Insects)

Subphylum Trilobitomorpha (Extinct)



Most common group of fossil arthropods

- Once abundant in oceans
- Disappeared by Paleozoic (345 million yr ago)

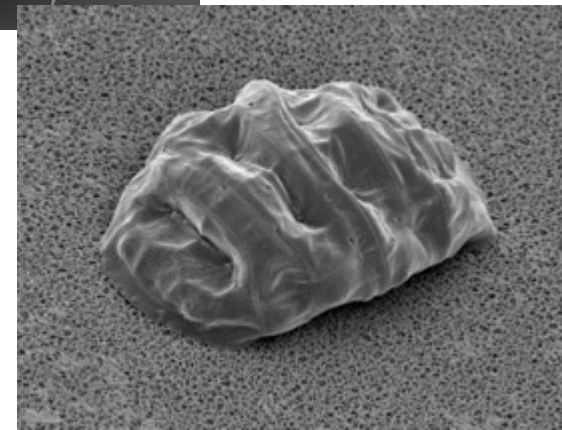
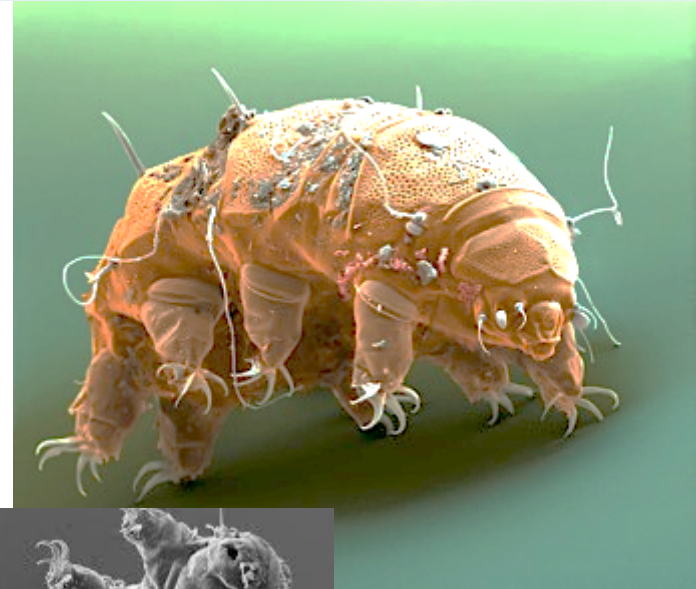
Subphylum Onychophora

- ❖ Onychophora - “nail bearers” or “velvet worms”
 - 1-3 cm
- ❖ Transitional group within the Ecdysozoa - possess some features not characteristic of arthropods
 - Pseudocoelomate
 - Soft cuticle - no exoskeleton!
 - No jointed appendages
 - Legs are hollow - “stub legs”
- ❖ Found in litter layer & decaying logs
 - Prey on small worms, arthropods



Subphylum Tardigrada

- ❖ “Water bears” or “moss piglets”
 - About 0.5 mm
 - Terrestrial and aquatic habitats
- ❖ true **extremophiles**: can survive
 - Wide temperature extremes (-80C to >100C)
 - Ionizing radiation
 - Outer space! (for a while)
- ❖ Capable of **anhydrobiosis**
 - Able to desiccate to <3% water and stay that way for >10 years



Subphylum Crustacea

- ❖ Most occur in marine and freshwater environments
- ❖ External Features:
 - Distinguishing feature: only arthropods with 2 pairs of antennae
 - Body of 3 tagmata: **head, thorax, abdomen**
 - Cephalic shield or **carapace** present to protect dorsum
 - Mandibles, modified limbs, act as jaws; 2 pairs of antennae
 - Limbs are **biramous (2 forks)**
 - “Gills” are actually legs modified for gas exchange

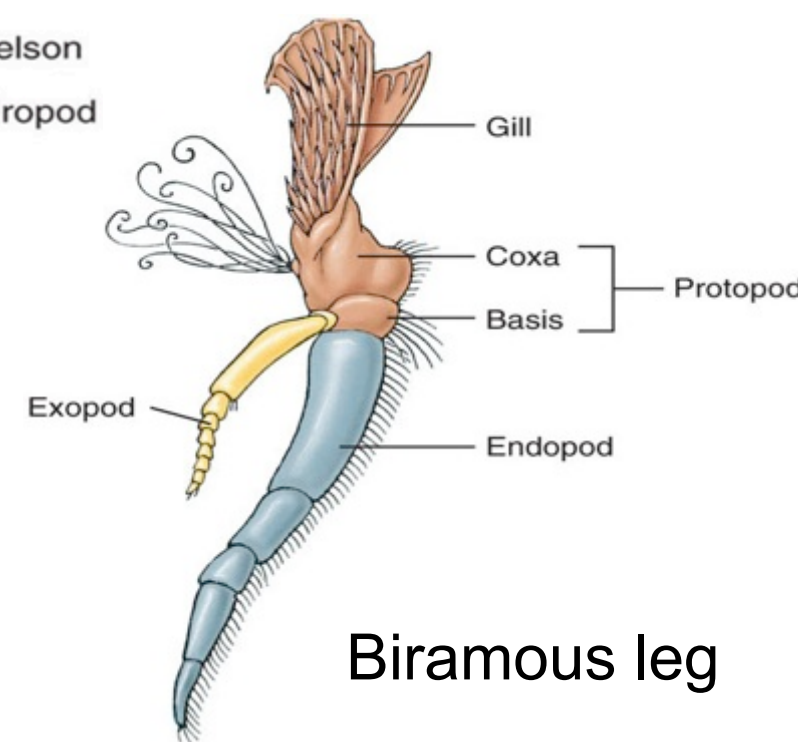
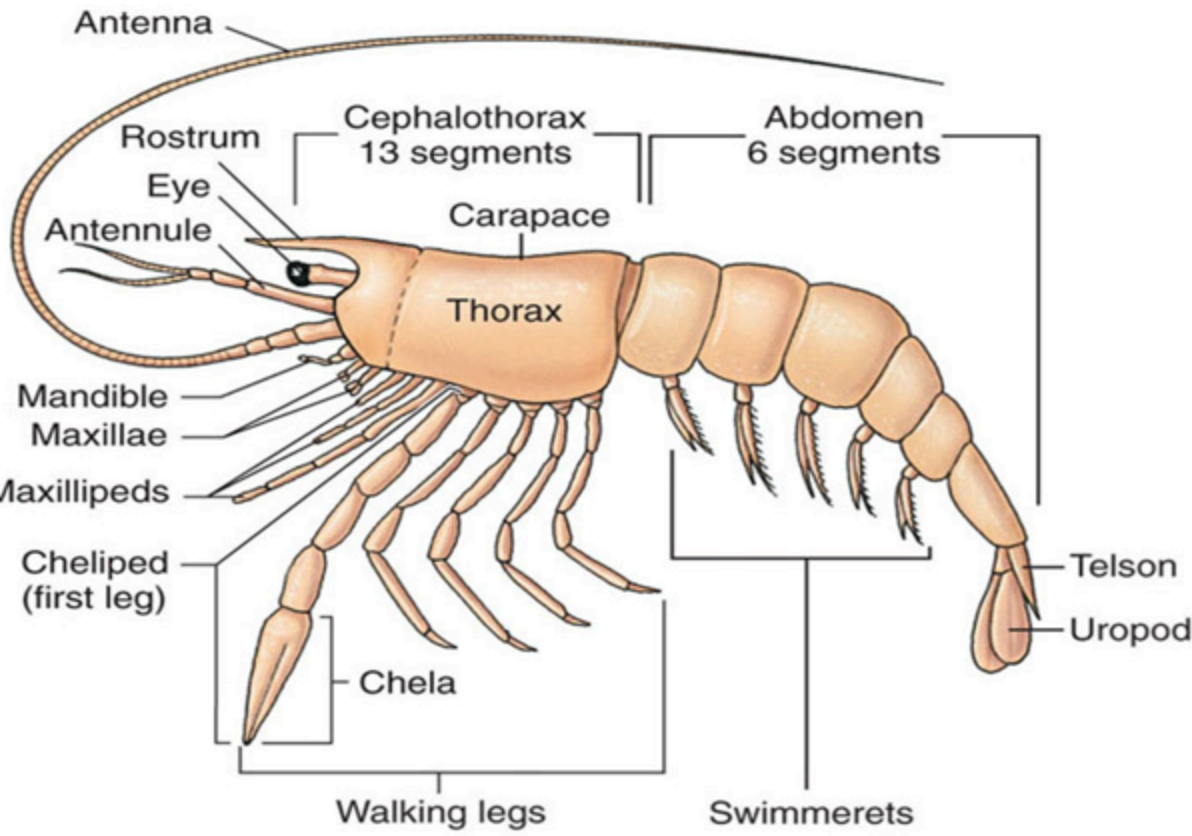
Subphylum Crustacea



Marine arthropods video (~10 min):

<http://shapeoflife.org/video/phyla/marine-arthropods-successful-design>

Generalized Crustacean Body Plan



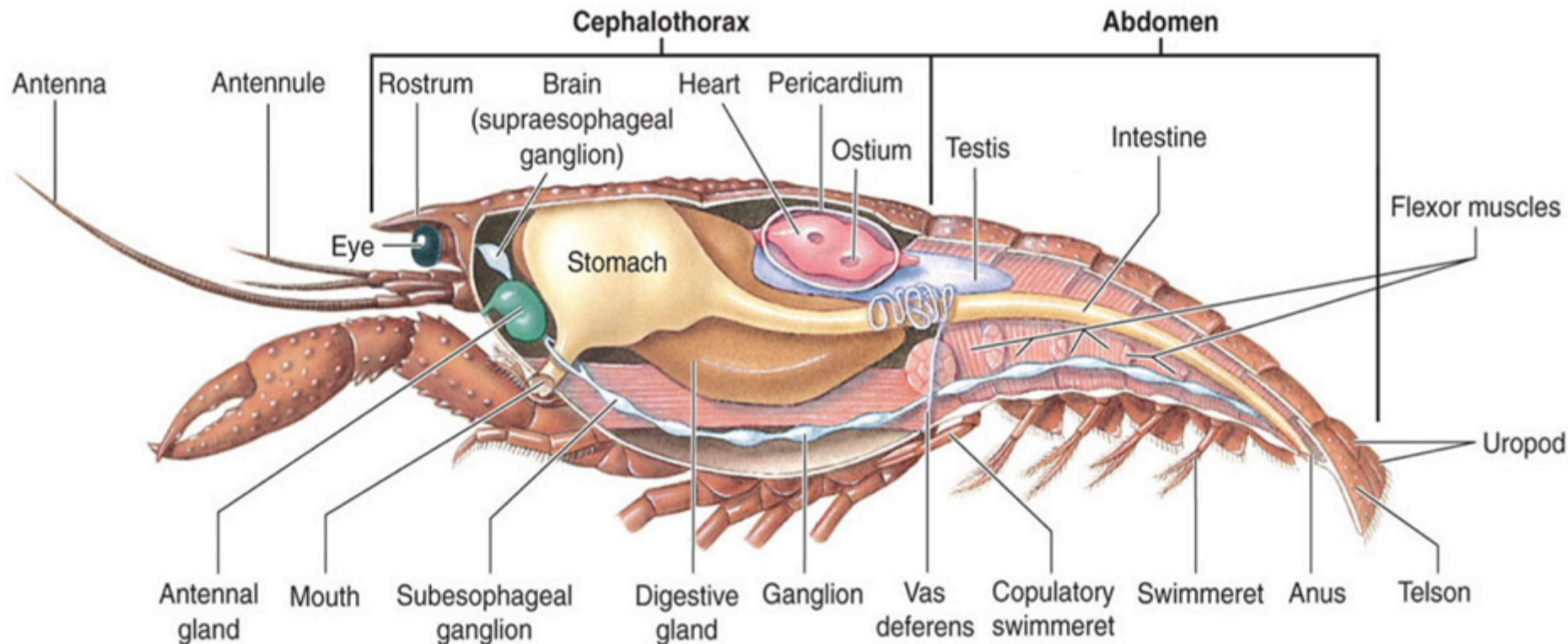
Subphylum Crustacea- Internal Features

❖ Hemocoel

- Major body cavity; filled with hemolymph
- Coelom restricted to compartment around gonads

❖ Muscular System

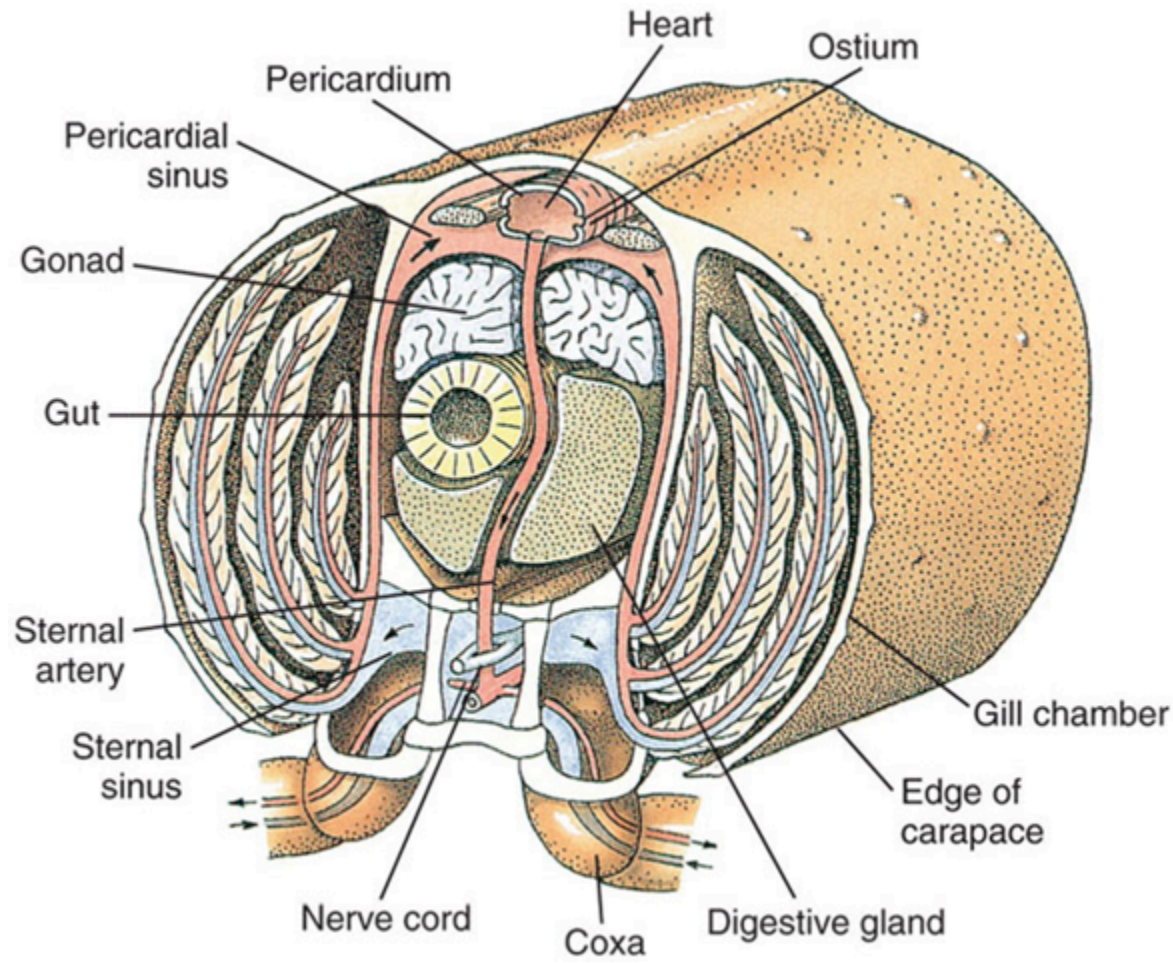
- Striated muscles form a large part of the body
- Capable of fast, strong movement



Subphylum Crustacea - Internal Features

❖ Respiratory System

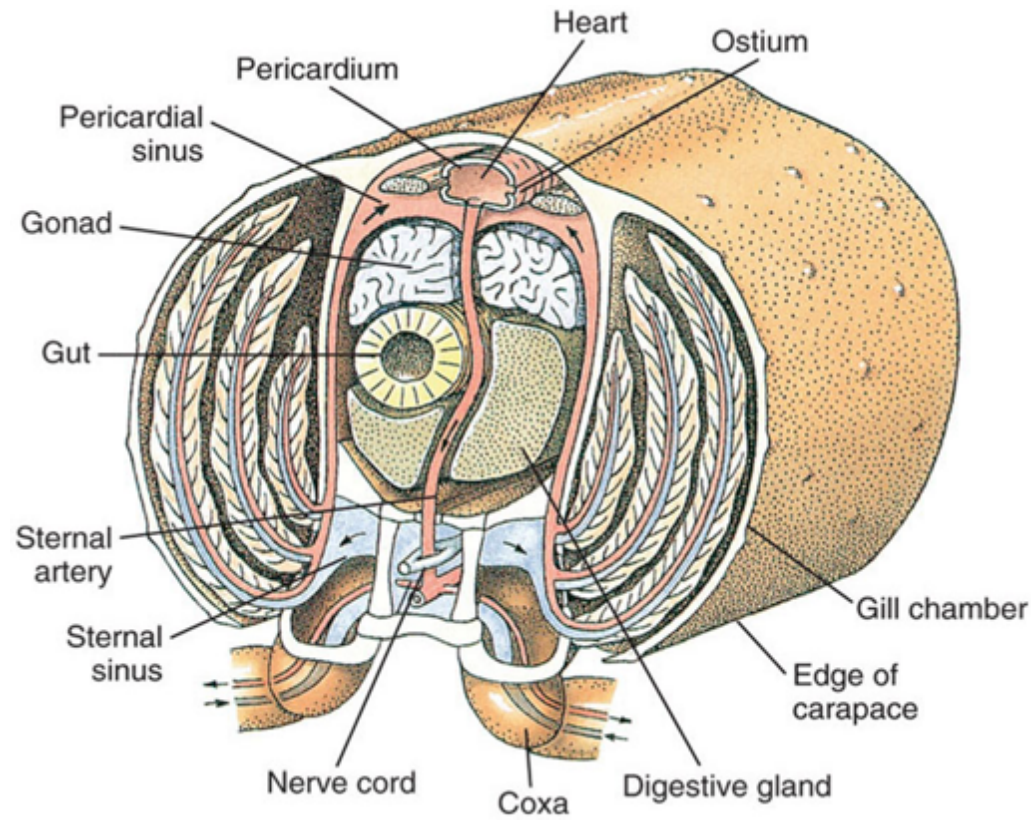
- Very small crustaceans conduct gas exchange across thin areas of the cuticle
- Larger crustaceans have gills



Subphylum Crustacea - Internal Features

❖ Circulatory system

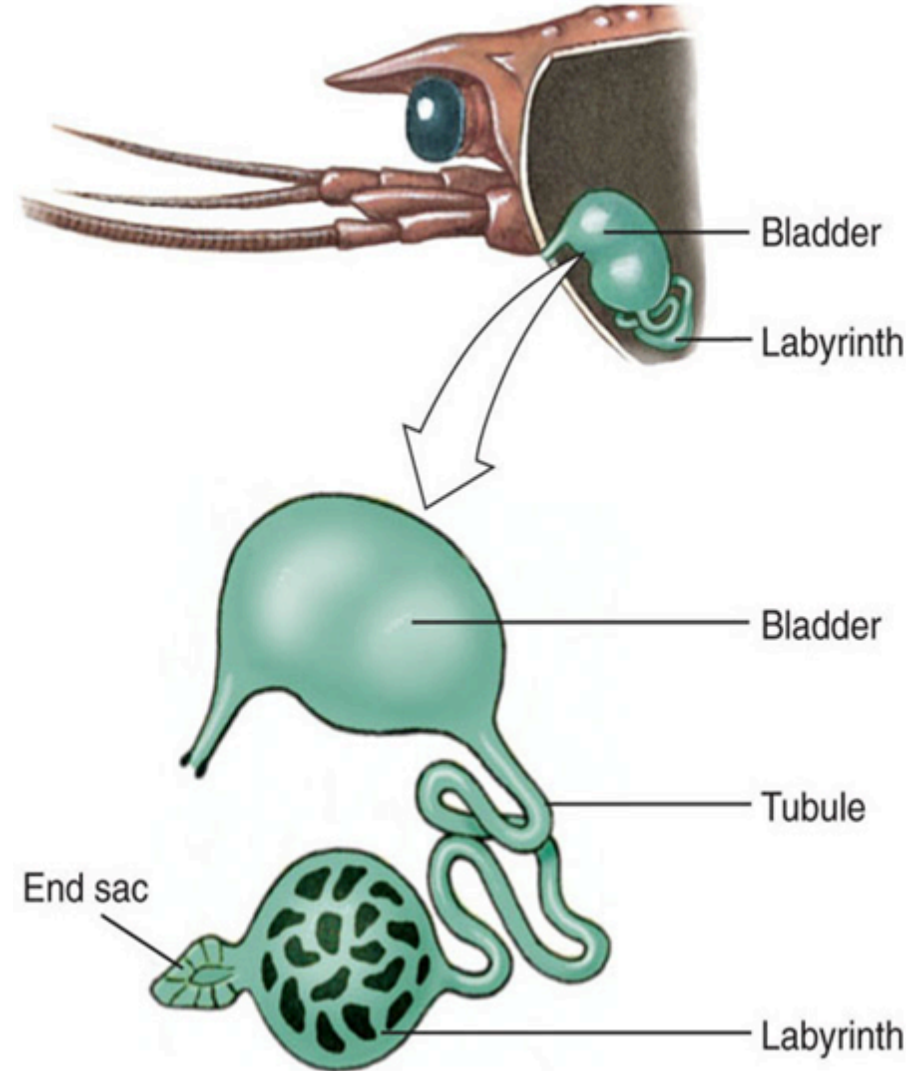
- **Open** - no system of veins to separate blood from interstitial fluid
- Hemolymph exits heart through arteries and passes through hemocoel and gills to return to the heart via sinuses
- Hemolymph may be colorless, reddish, or bluish
 - Contains ameboid cells that may help prevent clotting
- Hemocyanin and/or hemoglobin are respiratory pigments



Subphylum Crustacea - Internal Features

Excretory System

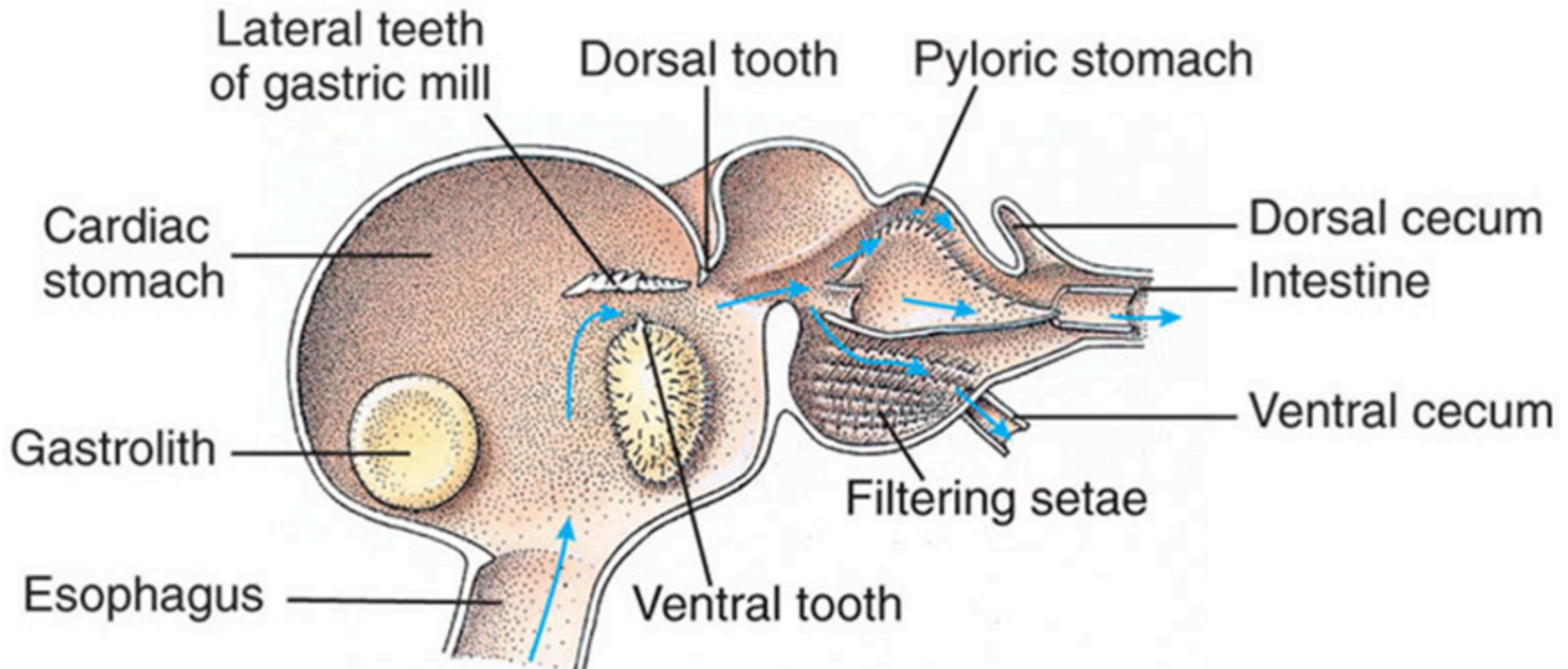
- ❖ Nitrogenous wastes (mostly ammonia) excreted across thin areas of cuticle in the gills
- ❖ Antennal or Maxillary Gland (“green glands”)
 - ❖ Excrete urine
 - ❖ Function is to regulate ionic and osmotic composition of body fluids



Subphylum Crustacea - Internal Features

Digestive System

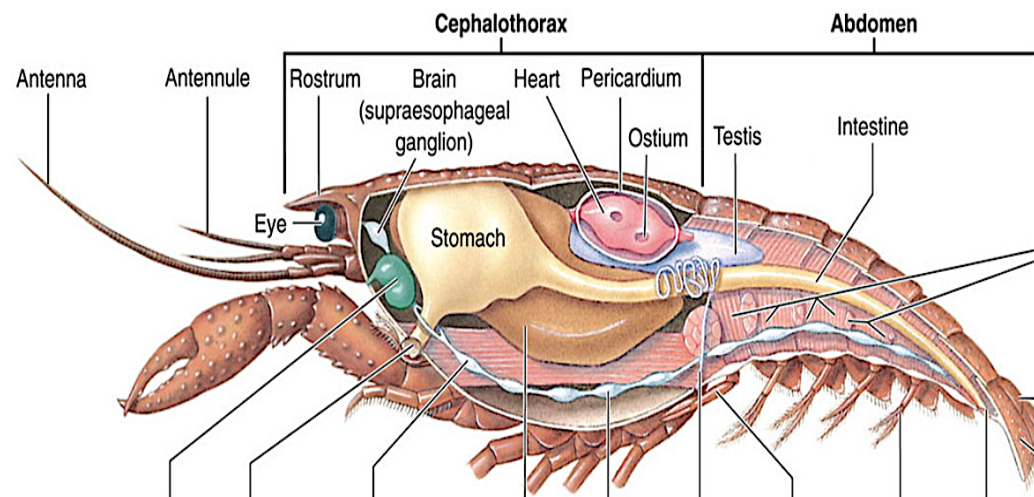
- ❖ Complete gut
- ❖ Stomach often consists of more than one chamber
 - ❖ Gastric stomach - includes “gastric mill” for grinding
 - ❖ Pyloric stomach



Subphylum Crustacea - Internal Features

Nervous and Sensory Systems

- Fused ganglia form **brain**
- Double ventral **nerve cord** has a pair of ganglia for each somite (segment)
- **Tactile hairs** on the body
- **Chemical sensing** of taste and smell occurs in hairs on antennae and mouth
- **Statocysts** controls balance
- **Compound eyes**; often on stalks



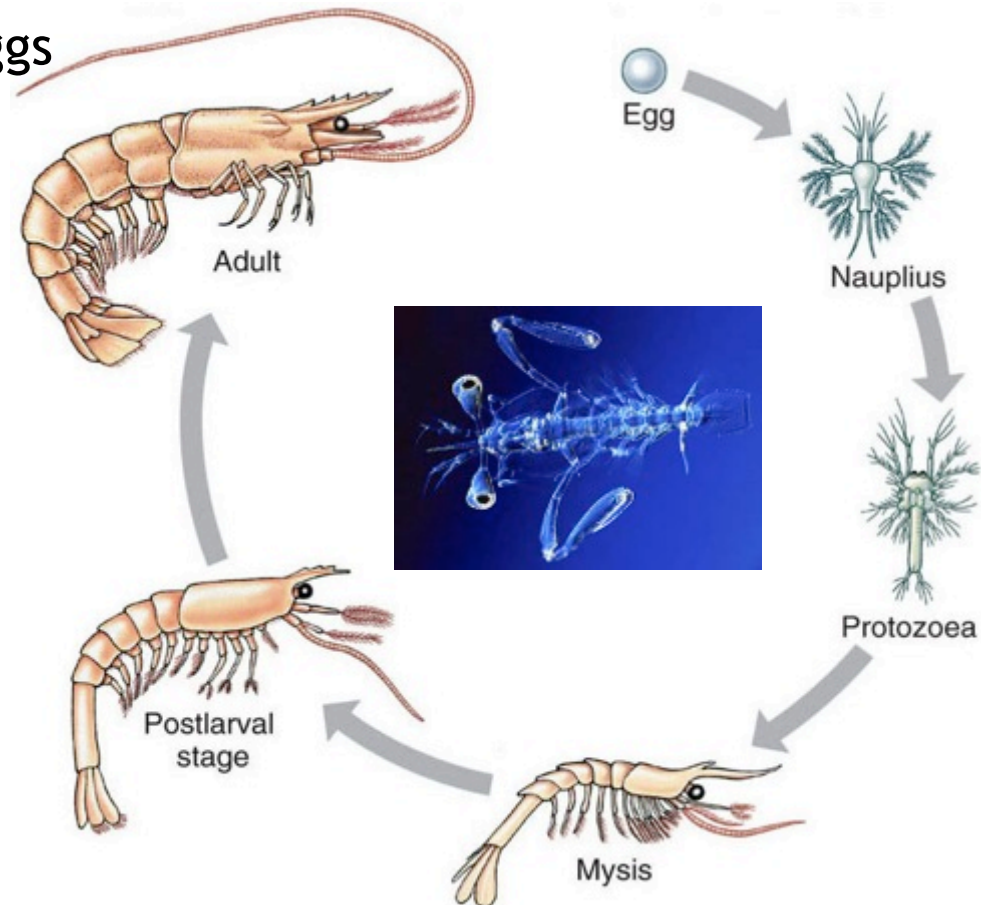
Subphylum Crustacea - Reproduction & Life Cycles

❖ Diverse reproductive modes

- Barnacles are hermaphrodites, but cross-fertilize
- Some ostracods reproduce parthenogenetically (eggs don't require fertilization)
- Most crustaceans brood their eggs

❖ Most common life cycle involves **metamorphosis**

- Egg hatches into **nauplius larva**, which molt and goes through several instars
- Segments and appendages are added in successive molts

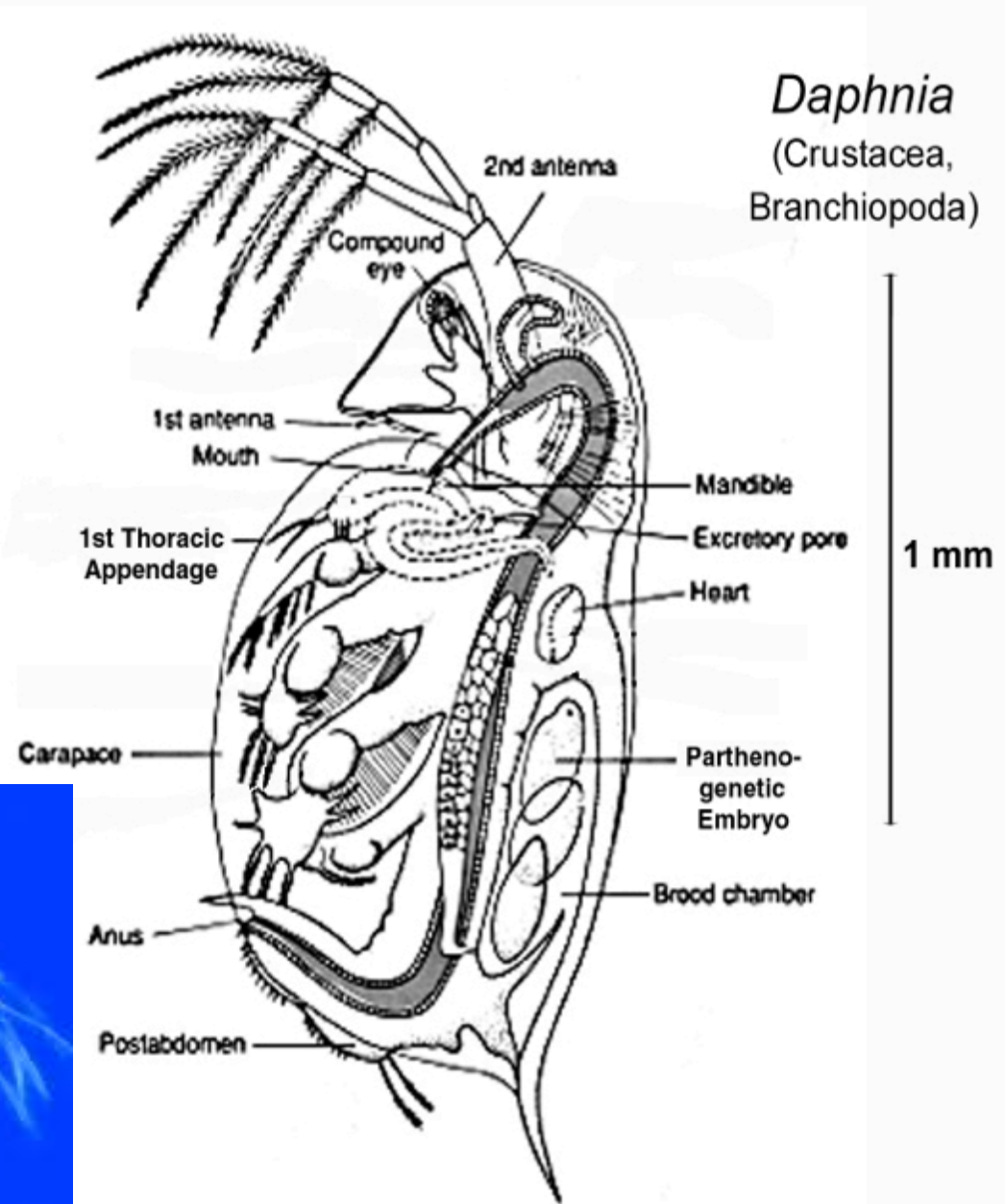


Classes of Subphylum Crustacea

- ❖ **Branchiopoda & Ostracoda**
- ❖ **Maxillopoda (Copepods, Barnacles)**
- ❖ **Malacostraca (Isopods, Decapods [Crab, shrimp, lobsters])**

Classes of Subphylum Crustacea - Branchiopoda & Ostracoda

- ❖ Small, aquatic or marine crustaceans
 - Important in food webs
 - Many have a bivalve carapace that encloses the body
 - Example - *Daphnia* (Class Branchiopoda)



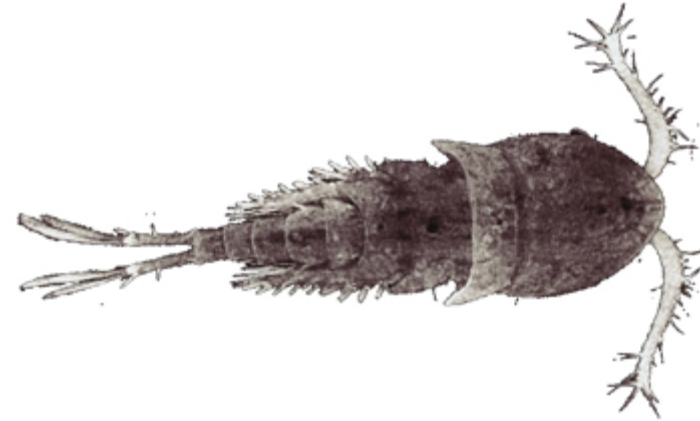
Class Maxillopoda

❖ Subclass Copepoda

- **Copepods** form important links in aquatic food webs

❖ Subclass Cirripedia

- **Barnacles** are a group of mostly sessile crustaceans
 - But start life as a motile, nauplius larva
- They have a cuticle that is hardened into a shell
- Hermaphroditic - one of the few arthropods that are



Class Malacostraca (shrimp, lobsters, crabs, isopods)

- ❖ Largest class of crustacean - and most diverse
 - Over 20,000 species worldwide
 - Ecologically and commercially important



Class Malacostraca - Order Isopoda (“same feet”)

- ❖ Terrestrial, marine and freshwater species
 - Terrestrial species are the only crustacean to have become fully terrestrial (“pill bugs”)
 - Restricted to moist environments
 - Marine species include a few bizarre parasites of fish- and very large species!



Class Malacostraca - Order Decapoda (“10 feet”)

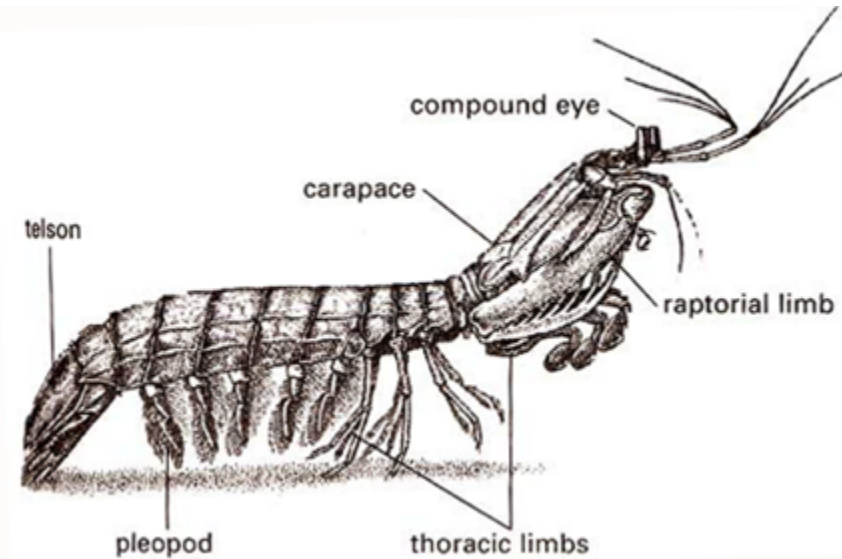
- ❖ Crabs, shrimp, lobsters
- ❖ One or more pairs of walking legs modified to form pincers (chelae)
- ❖ Many species have bright coloration and/or camouflage



Class Malacostraca - Order Stomatopoda

❖ Mantis Shrimp

- Voracious predators
- Some species are ambush hunters and snag prey with raptorial limbs
- Others have forelimbs modified into clubs that carry a powerful concussive force

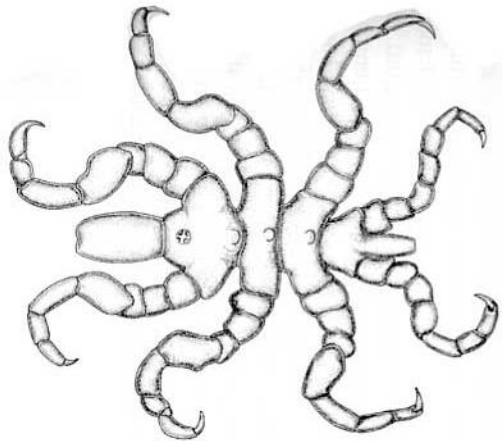


Subphylum Chelicerata

- ❖ Body of 2 tagmata: **cephalothorax + abdomen**
- ❖ 1st pair of appendages = **chelicerae** (look like fangs)
- ❖ **No antennae**
- ❖ Gas exchange by **book gills, book lungs or tracheae**
- ❖ Separate sexes
- ❖ Classes:
 - **Pycnogonida (sea spiders)**
 - **Merostomata (horseshoe crabs)**
 - **Arachnida (spiders)**

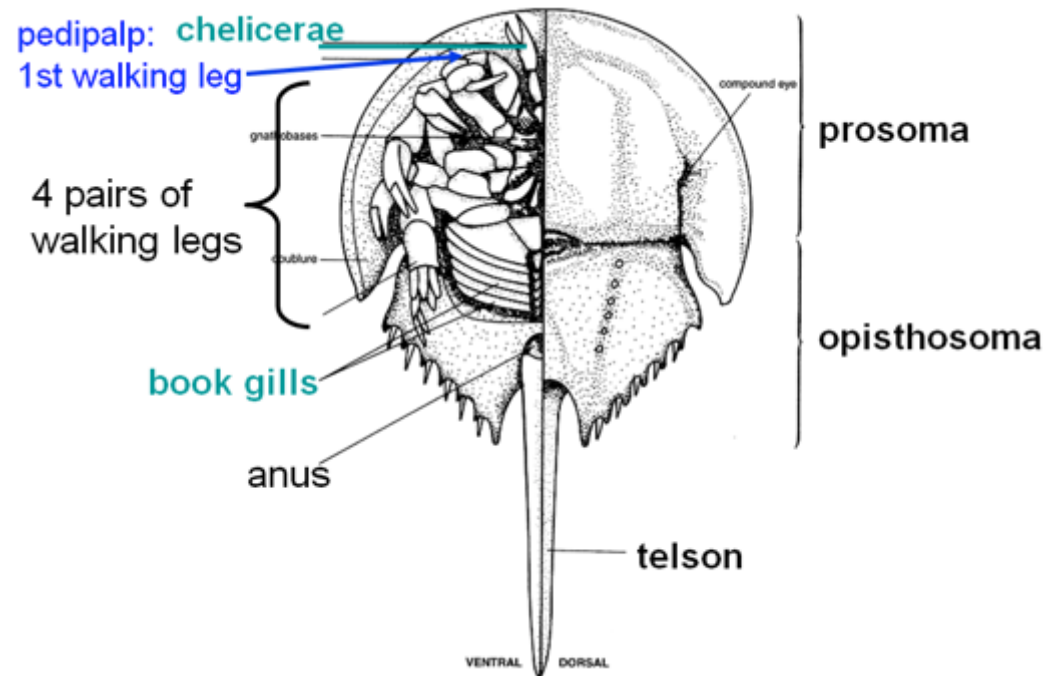
Class Pycnogonida: Sea spiders

- ❖ Marine, intertidal to abyssal depths; worldwide distribution
 - About 1,000 species
- ❖ Benthic, live on seaweeds or other invertebrates
- ❖ Sucking **proboscis** on 1st head segment used to feed on soft-bodied invertebrates
- ❖ Males: brood eggs on **ovigers**, special leg appendages
- ❖ Females: hollow legs filled with eggs



Class Merostomata: Horseshoe crabs

- ❖ Inhabit shallow marine waters
- ❖ Burrow just under sand surface, prey on buried animals like bivalves
- ❖ Small chelicerae
- ❖ Limited distribution: *Limulus polyphemus* restricted to east coast of North America
- ❖ Distinctive **telson**, or tail spine

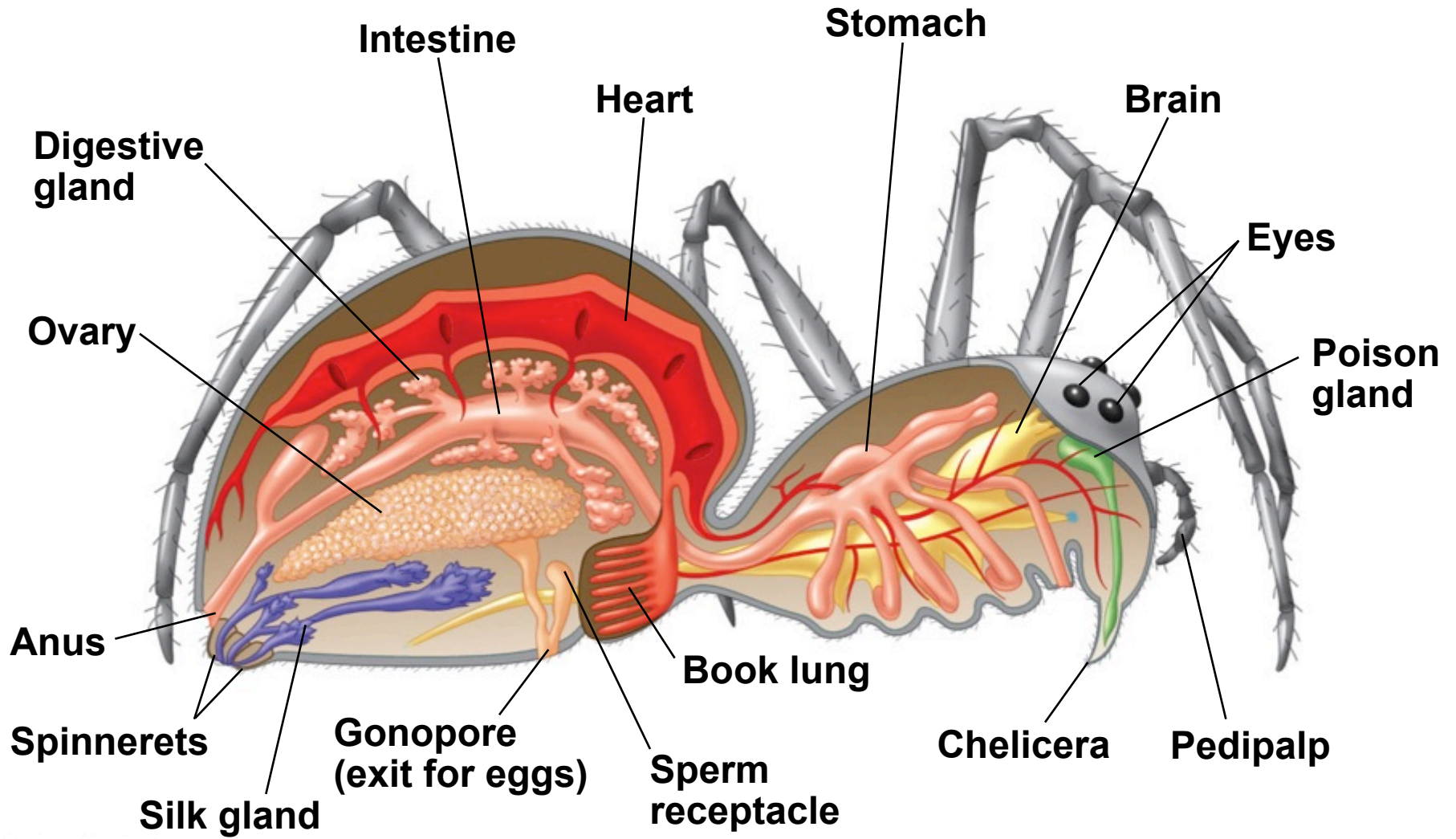


Class Arachnida: Scorpions, spiders, mites, ticks

- ❖ Arachnids have an abdomen and a cephalothorax, which has six pairs of appendages: the **chelicerae**, the **pedipalps**, and four pairs of **walking legs**
- ❖ Gas exchange by tracheae or book lungs
- ❖ No compound eyes but have **ocelli** (often multiple)
- ❖ Many spiders produce silk, a liquid protein, from specialized abdominal glands

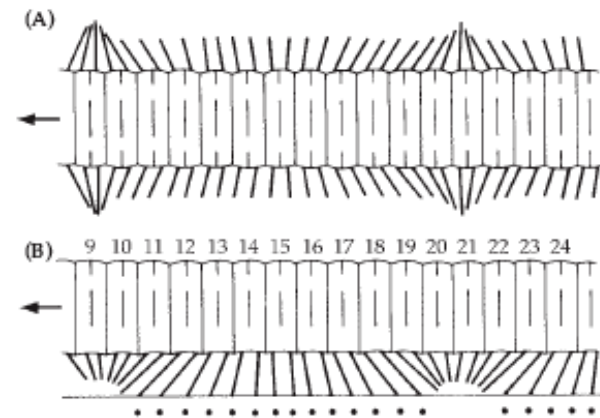


Figure 33.33

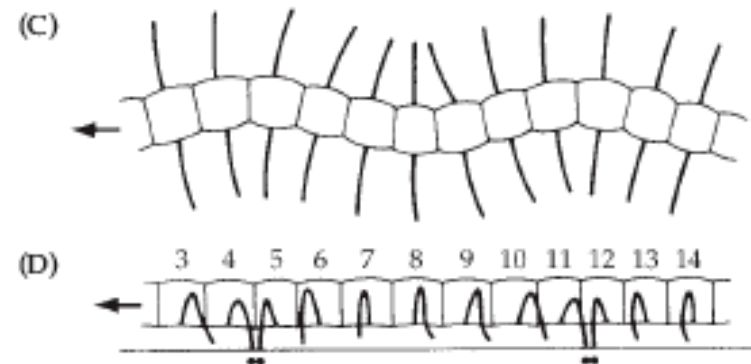


Subphylum Myriapoda = “lots of legs”

- ❖ Myriapods are terrestrial, and have jaw-like **mandibles**
- ❖ Classes:
 - **Diplopoda (millipedes)**- have two legs per segment on each side; slow but powerful



- **Chilopoda (centipedes)**- have one leg per segment on each side; fast but not as powerful



Class Diplopoda - Millipedes

- ❖ Eat decaying leaves and plant matter
- ❖ Have many legs, with two pairs per trunk segment
- ❖ Non-venomous, but some can secrete noxious chemicals



Class Chilopoda - Centipedes

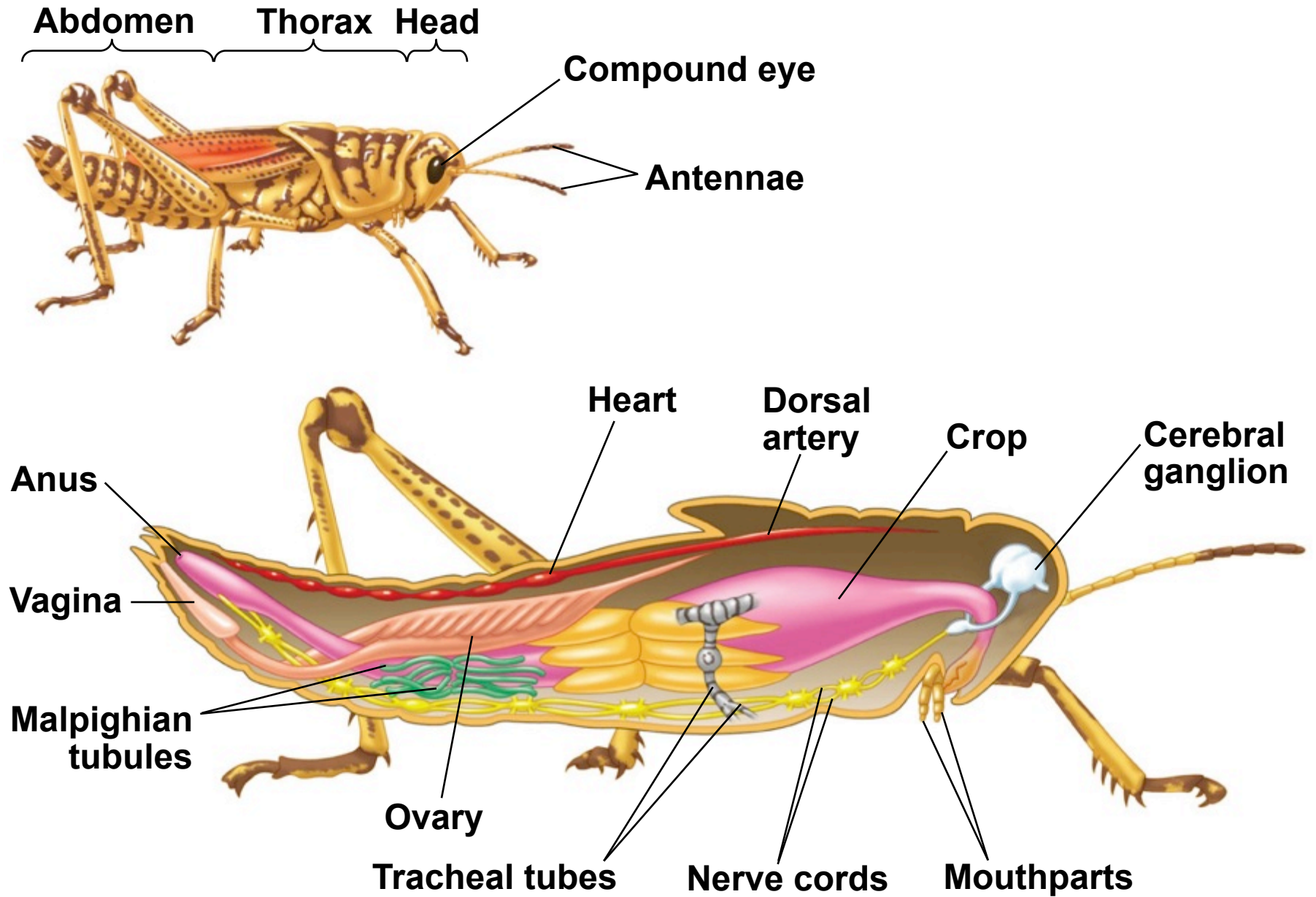
- ❖ Carnivores
- ❖ One pair of legs per trunk segment
- ❖ Most are venomous



Subphylum Hexapoda = 6 legs- Insects and relatives

- ❖ More species than all other forms of life combined
 - Live in almost every terrestrial habitat and in fresh water
 - Internal anatomy includes several complex organ systems
- ❖ Insects diversified several times
 - Following the evolution of flight
 - Adaptation to feeding on gymnosperms
 - Expansion of angiosperms
- ❖ Insect and plant diversity declined during the Cretaceous extinction, but has been increasing in the 65 million years since

Figure 33.35



Insect Success: the power of flight

- ❖ 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

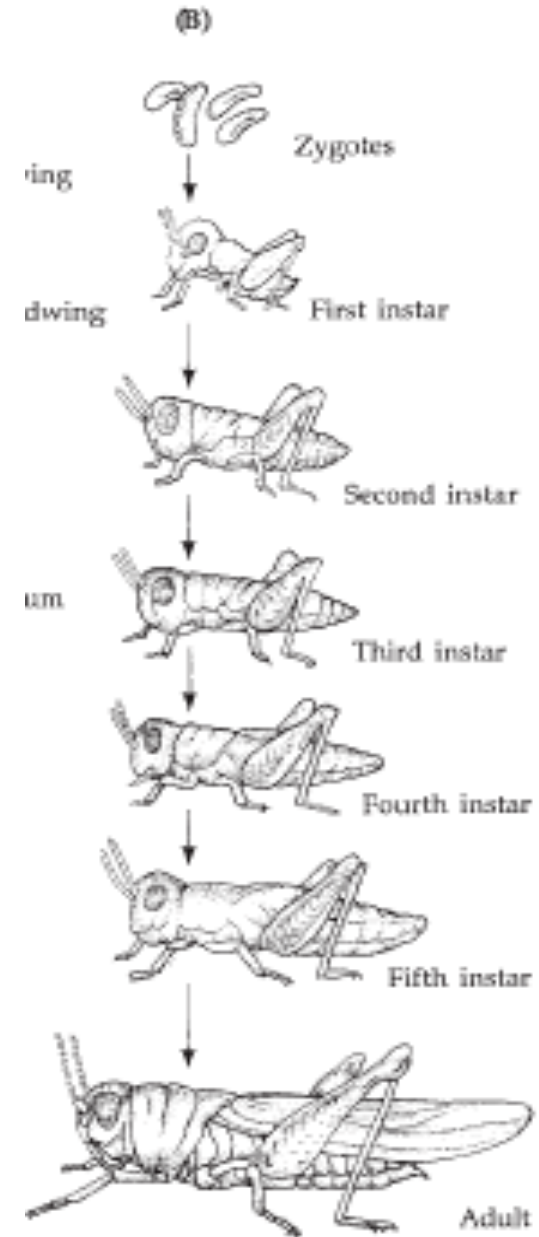


Insect Development

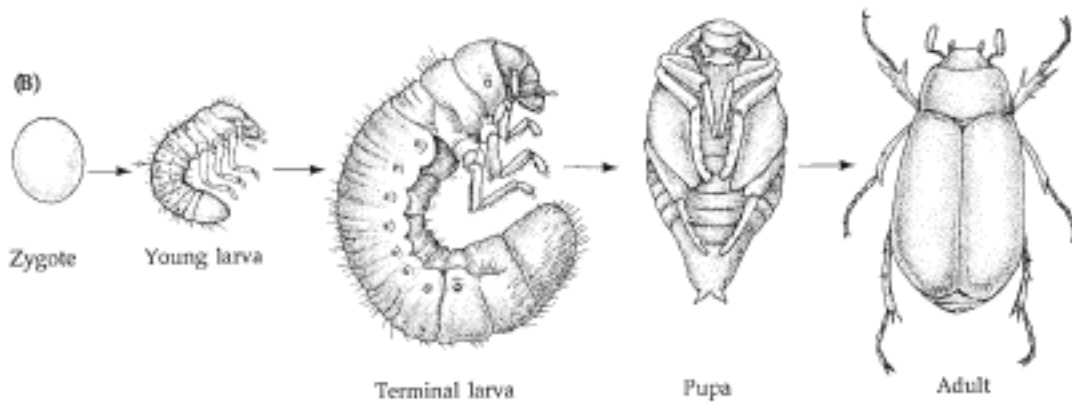
- ❖ Many insects undergo **metamorphosis** during their development
- ❖ **Incomplete (hemimetabolous) metamorphosis**
 - Young are called **nymphs**
 - Resemble adults but smaller and go through a series of molts until they reach full size
- ❖ **Complete (holometabolous) metamorphosis**
 - Larval stages known by such names as maggot, grub, or caterpillar
 - Larval stage looks entirely different from adult stage
 - Usually involves some sort of **pupation**

Insect Development

Hemimetabolous - insects hatch looking much like adults. **Nymphs** gradually attain adult form.



Holometabolous - young very different from adults
Pupal stage metamorphosis into adult





(a) Larva (caterpillar)



(b) Pupa



(c) Later-stage pupa



(d) Emerging adult



(e) Adult

Insect Life Habit



- ❖ Most insects have separate sexes and reproduce sexually
 - Individuals find and recognize members of their own species by bright colors, sound, or odors
- ❖ Insects may be predators, herbivores, microbivores, parasites
 - Insect parasites that prey on other insects are referred to **parasitoids**, because they kill their host
- ❖ Some insects are beneficial as pollinators, while others are harmful as carriers of diseases, or pests of crops
- ❖ Ants, bees and termites have evolved **eusociality**
 - Decentralised, self-organized colony with division of labor and physical differences between castes
- ❖ Insects are classified into more than 30 orders

Summary of Terrestrial Arthropods



Terrestrial arthropods video (~14 min):

<http://shapeoflife.org/video/phyla/terrestrial-arthropods-conquerors>