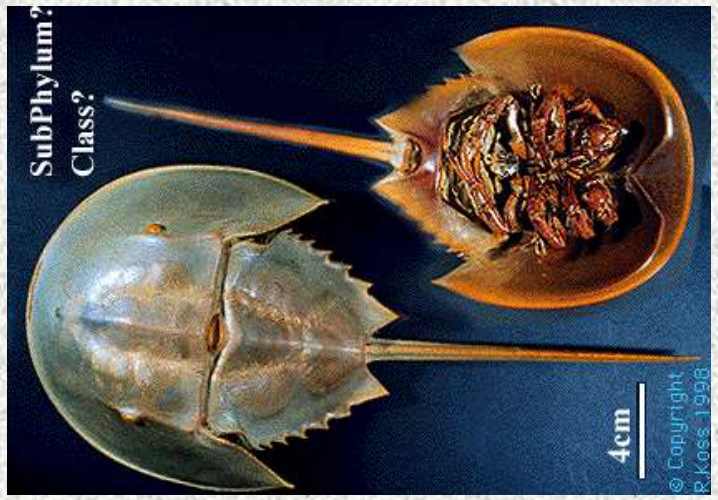
Phylum Arthropoda

Phylum Arthropoda

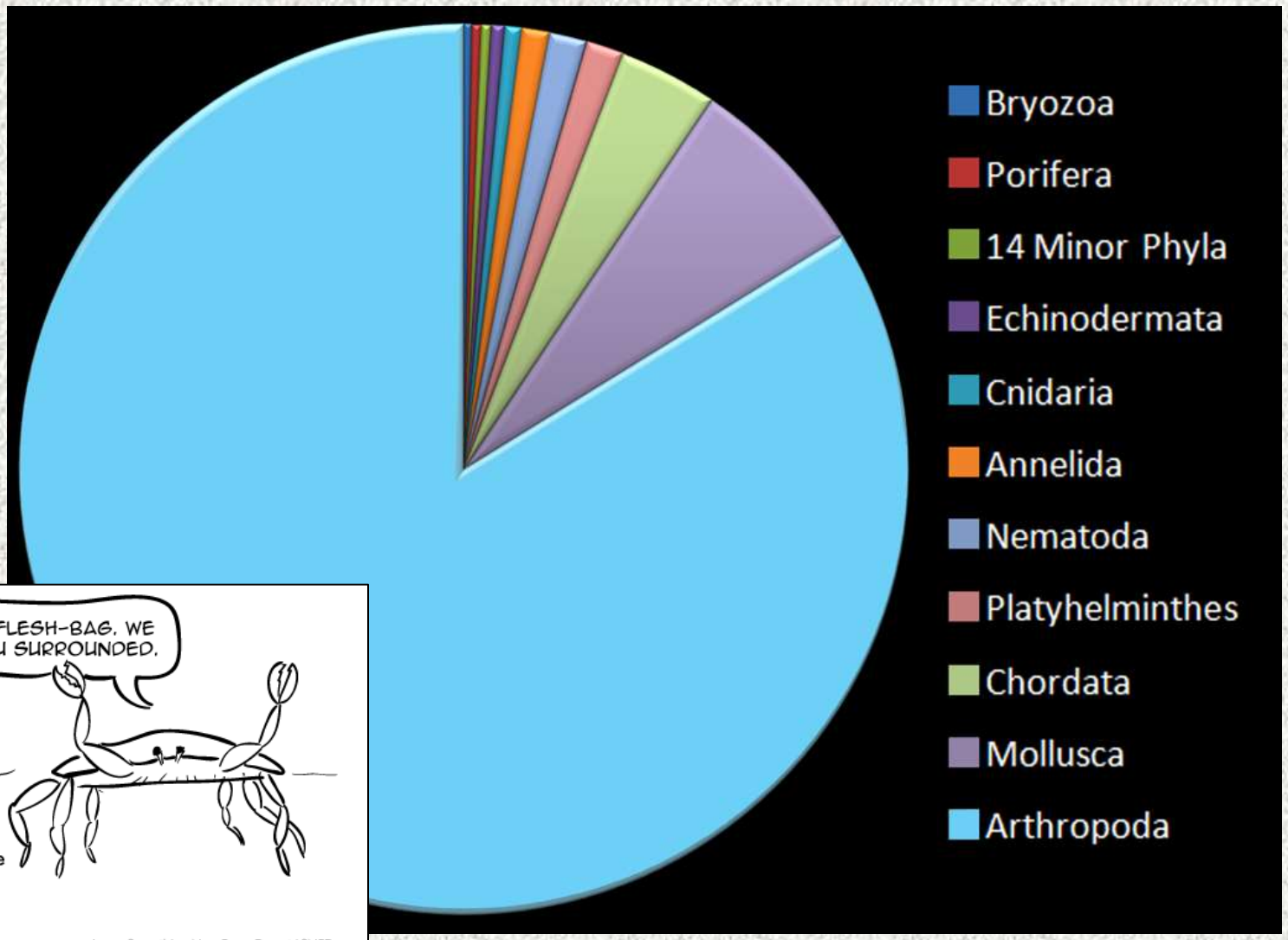
- "jointed foot"
- Largest phylum
- 900,000 species
  - 75% of all known species
- Insects, spiders, crustaceans, millipedes, scorpions, ticks, etc.

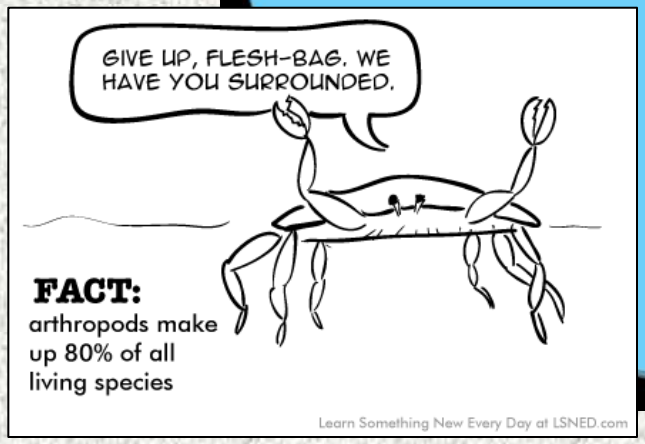
Phylum Arthropoda

- Most successful phylum
  - Ecologically diverse
  - Present in all regions of the earth
    - Adapted to air, land, freshwater, marine, other organisms



The relative number of species contributed to the total by each phylum of animals.
97% invertebrates. Lots of Arthropods! (Molluscs second)





Reasons for success

1. Versatile exoskeleton
2. Efficient locomotion
3. Air piped directly to cells (terrestrial)
4. Highly developed sensory organs
5. Complex behavior
6. Metamorphosis

Molecular evidence places insects WITHIN the Crustacea

Insects

Many Others

Myriapoda

Crustacea

Chelicerata

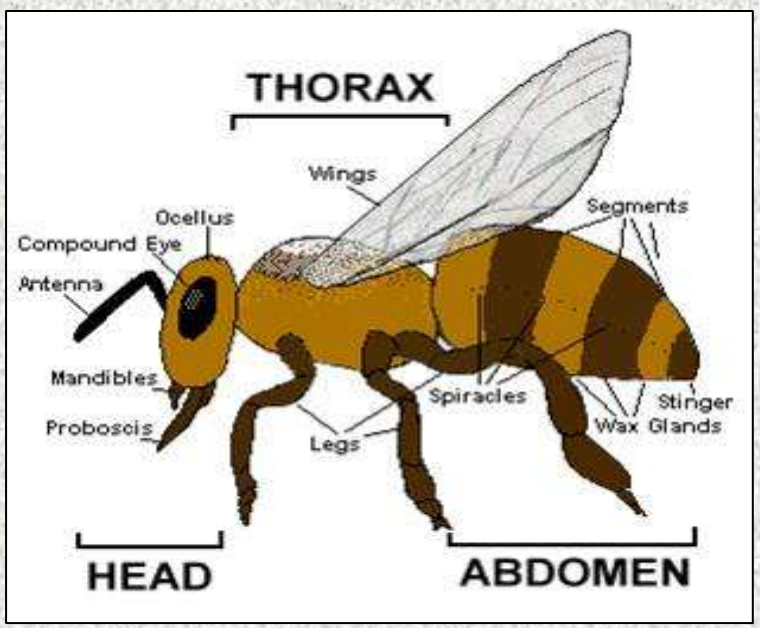
Trilobites

Mandibulata

ARTHROPODA

Characteristics of the Arthropoda

- Bilaterally symmetrical
- Protostome, coelomate (reduced)
- Segmented (metameric)
- Body divided into head, thorax and abdomen; cephalothorax and abdomen; or fused head and trunk.



Rove beetle

Goliath bird-eating spider

Exoskeleton

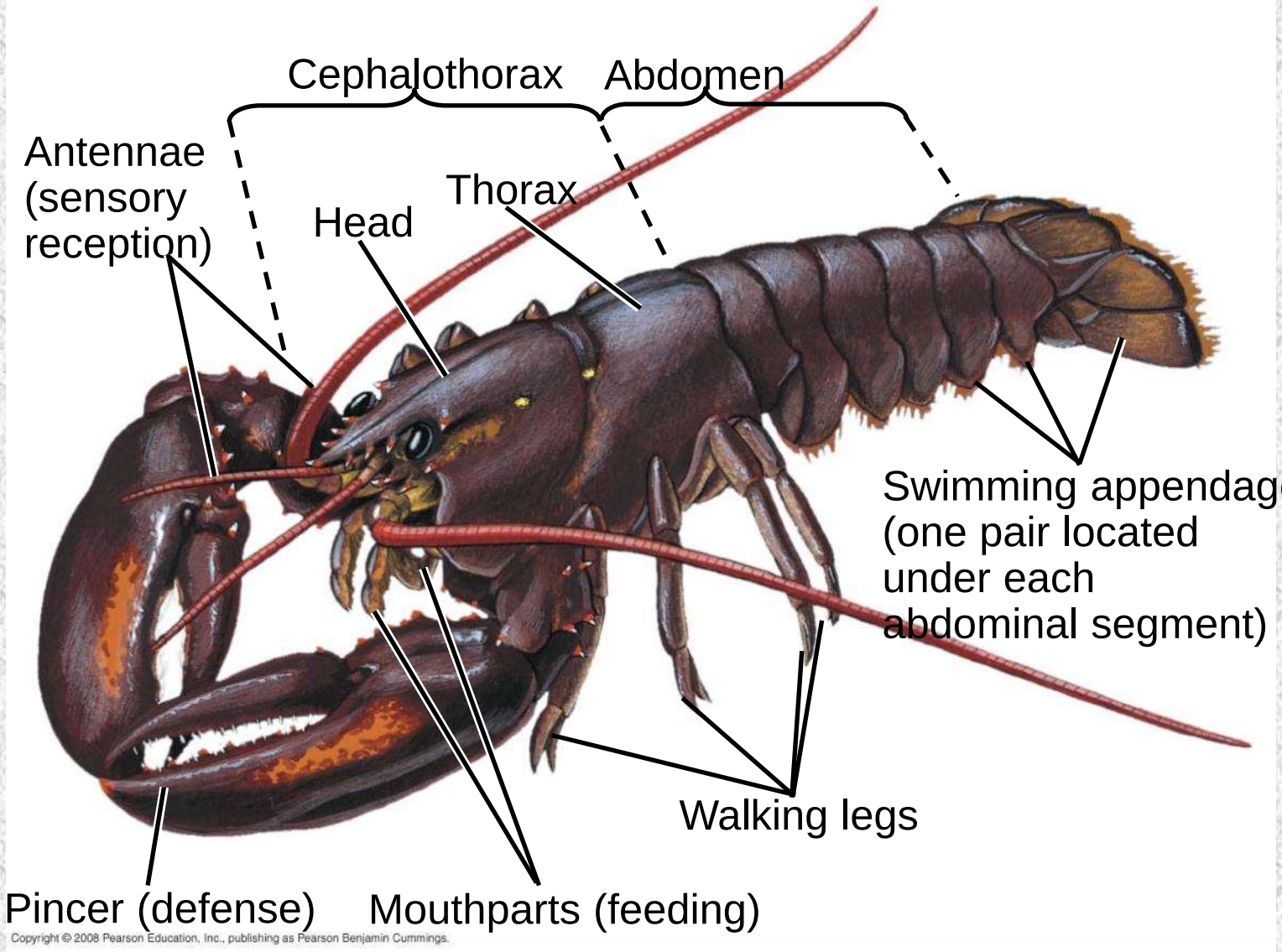
- Exoskeleton of cuticle.
- Exoskeleton secreted by underlying epidermis. Made of chitin, protein, waxes, and often calcium carbonate.
- Exoskeleton is shed periodically (ecdysis) as the organism grows.
- Provides strength and protection

Jointed Legs

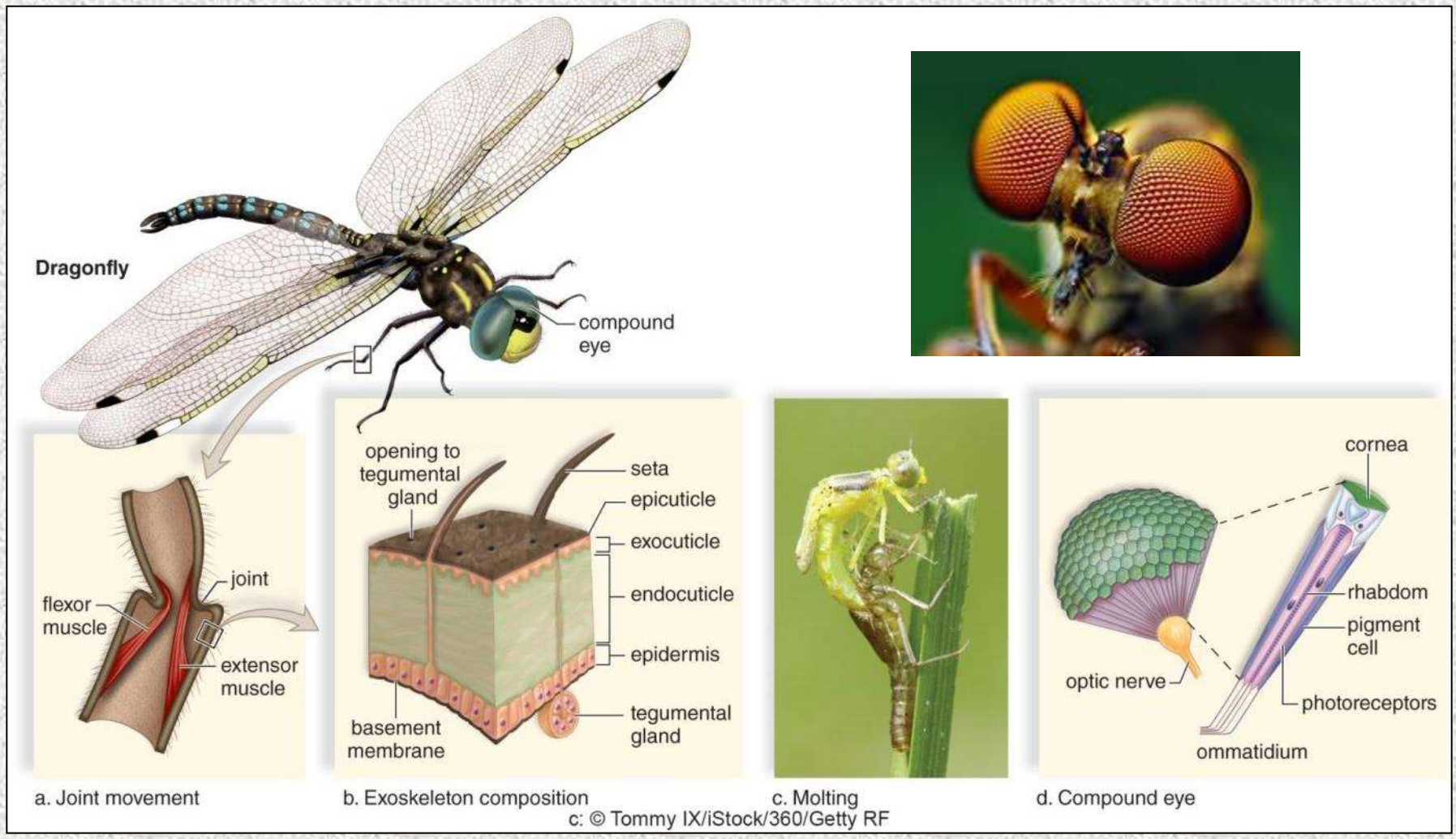
- Jointed appendages. Primitively one pair per segment, but number often reduced.
- Appendages often greatly modified for specialized tasks.

Segmented, jointed appendages

Appendages adapted for special tasks

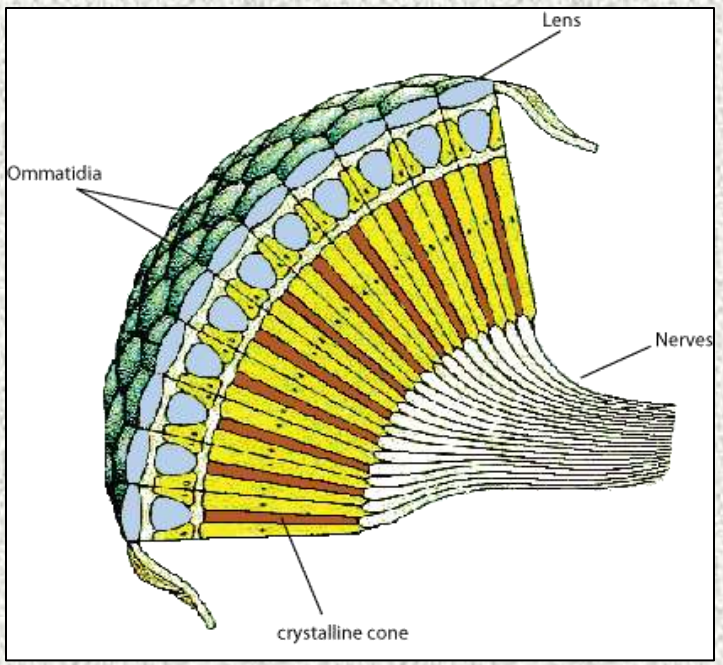


Arthropod Skeleton and Compound Eye



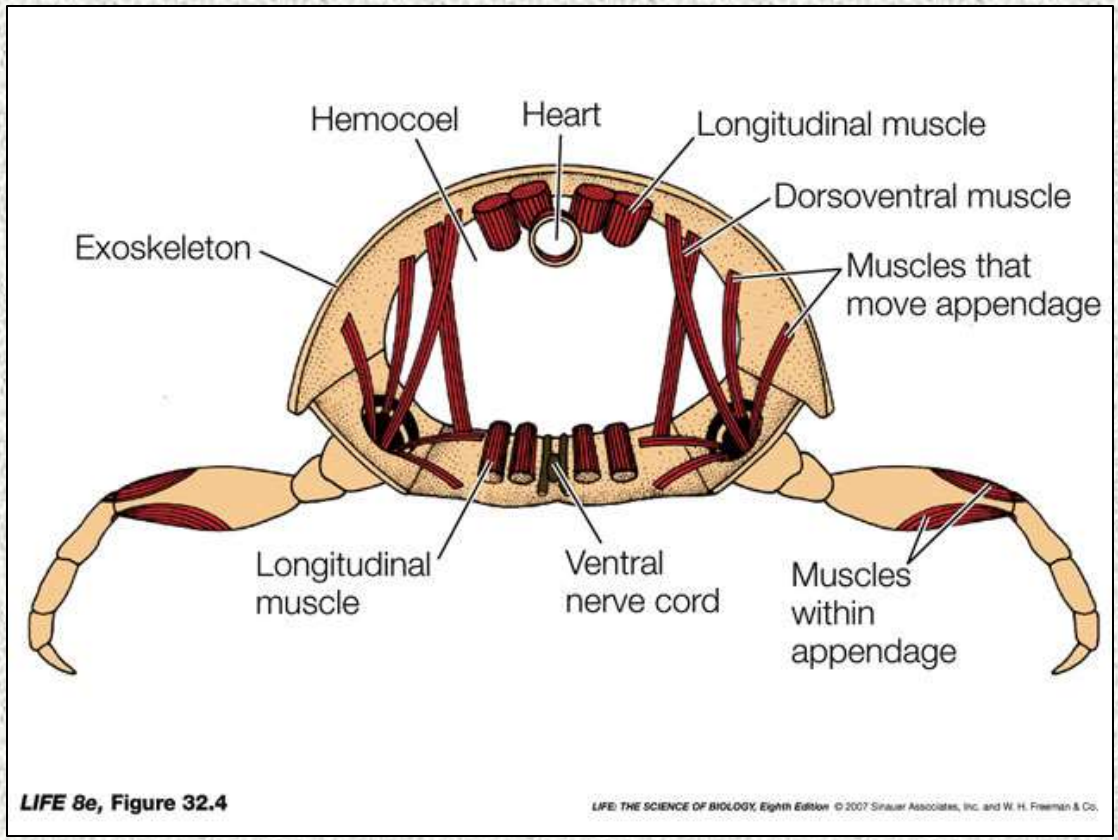
Compound Eye

- Composed of many similar, closely-packed facets (called **ommatidia**) which are the structural and functional units of vision.
- Very sensitive to movement.
- Wide light spectrum - UV



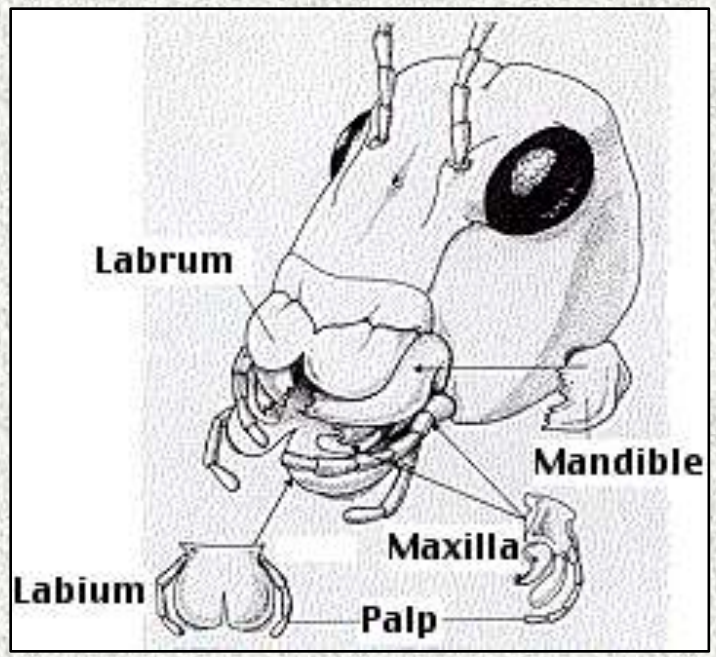
Muscular System

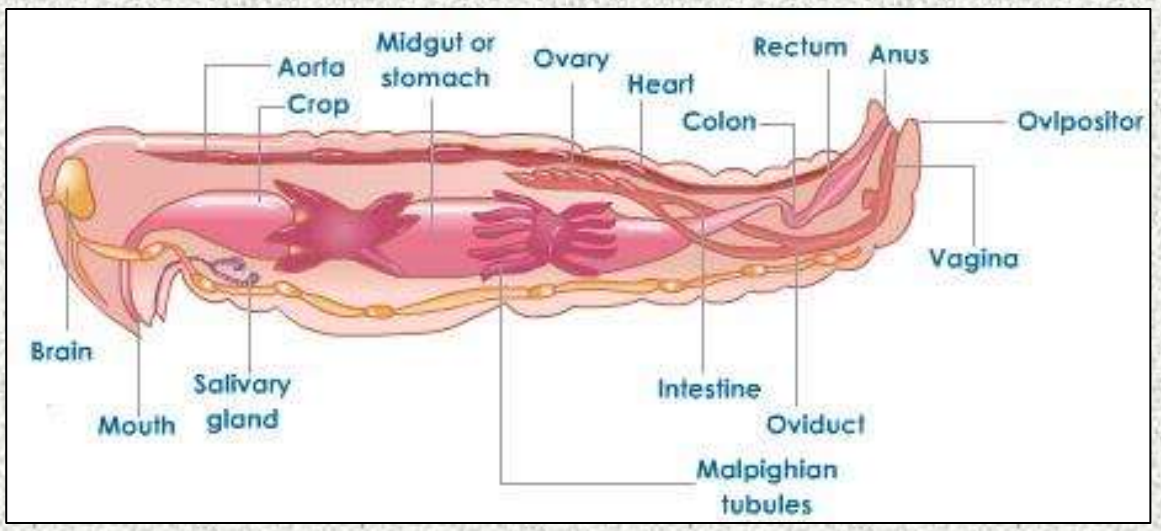
- Muscular system is complex and muscles attach to the exoskeleton.
- Striated muscles for voluntary movement and smooth muscles for the viscera.

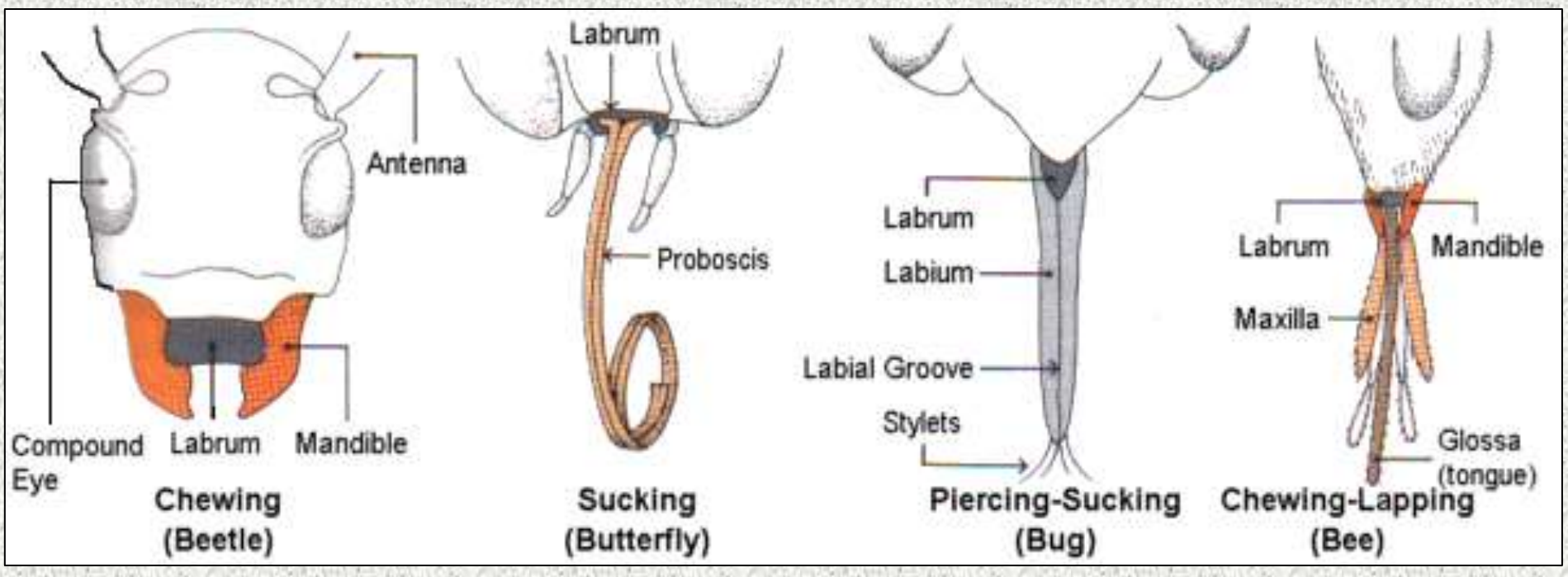


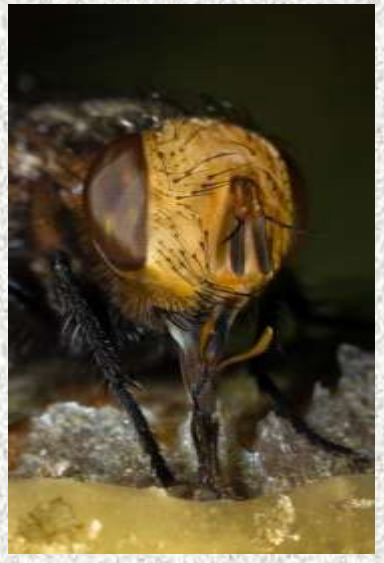
Digestive System

- Complete digestive system.
- Mouthparts are specialized for dealing with various types of food



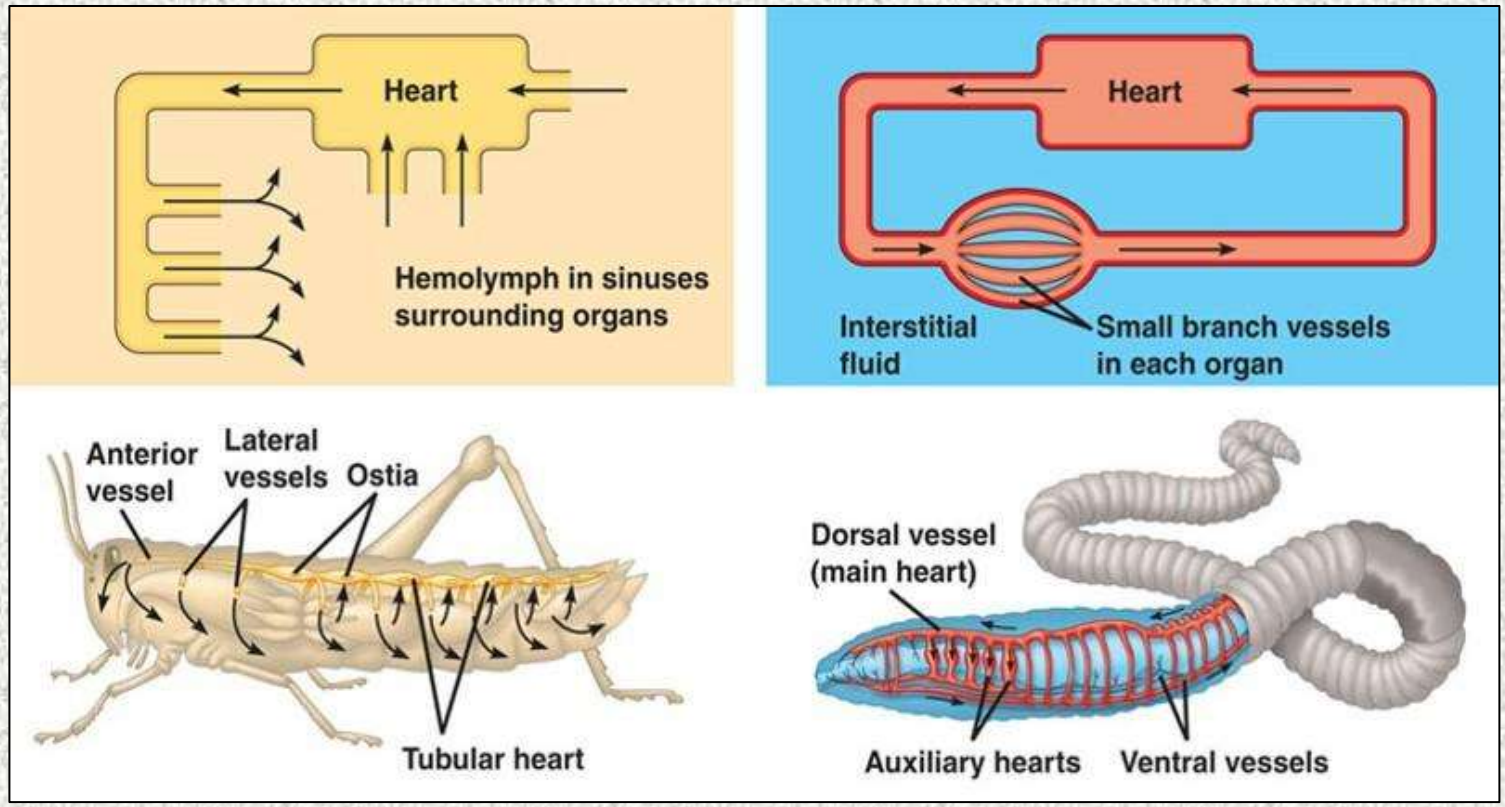



Antenna
Compound Eye
Labrum
Mandible
Chewing (Beetle)
Labrum
Proboscis
Sucking (Butterfly)
Labrum
Labium
Labial Groove
Stylets
Piercing-Sucking (Bug)
Labrum
Mandible
Maxilla
Glossa (tongue)
Chewing-Lapping (Bee)



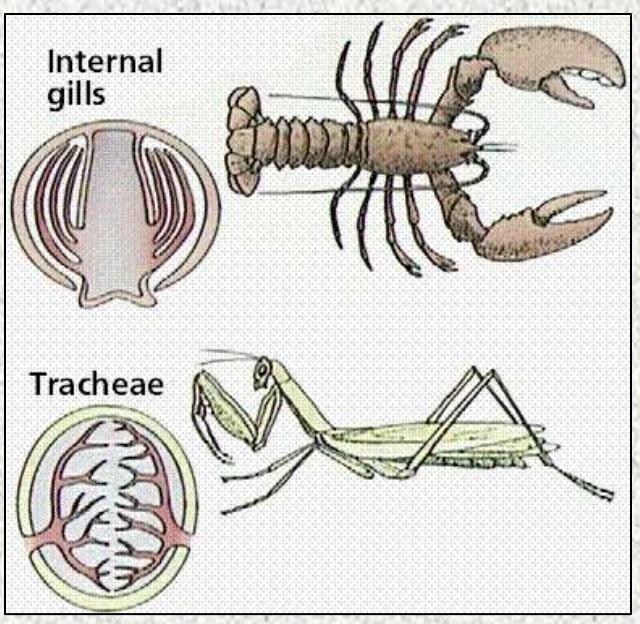
Circulatory System

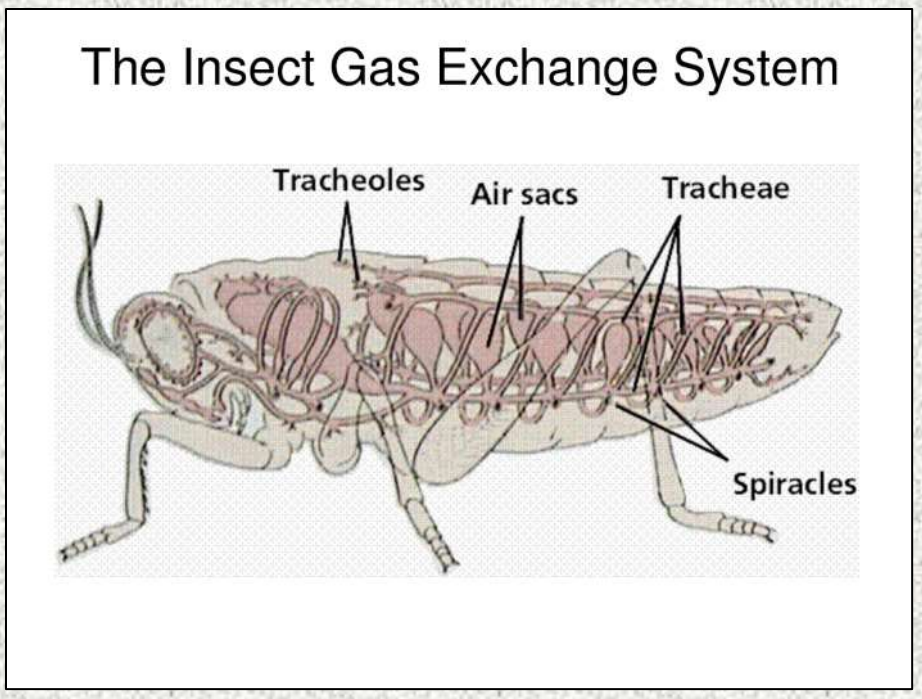
- Most of body cavity is a hemocoel (sinuses or spaces) filled with blood
- Open circulatory system with a dorsal contractile heart arteries and hemocoel



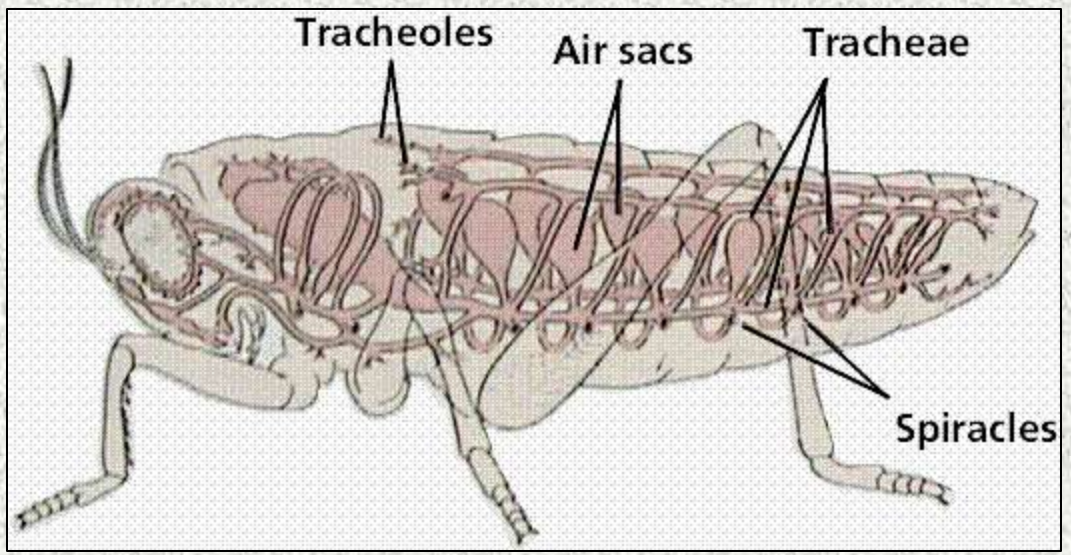
Respiratory System

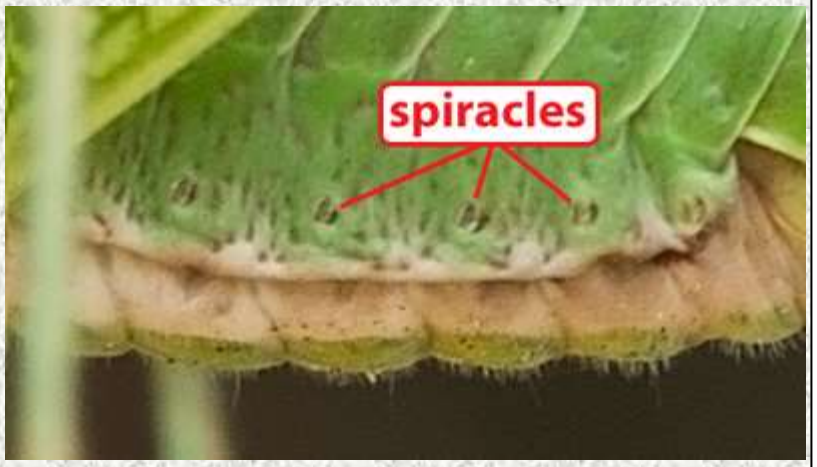
- Respiration occurs in multiple possible ways
  - across the body surface
  - via a system of tracheal tubes (e.g. beetle)
  - Gills (e.g. crabs)
  - book lungs (spiders)

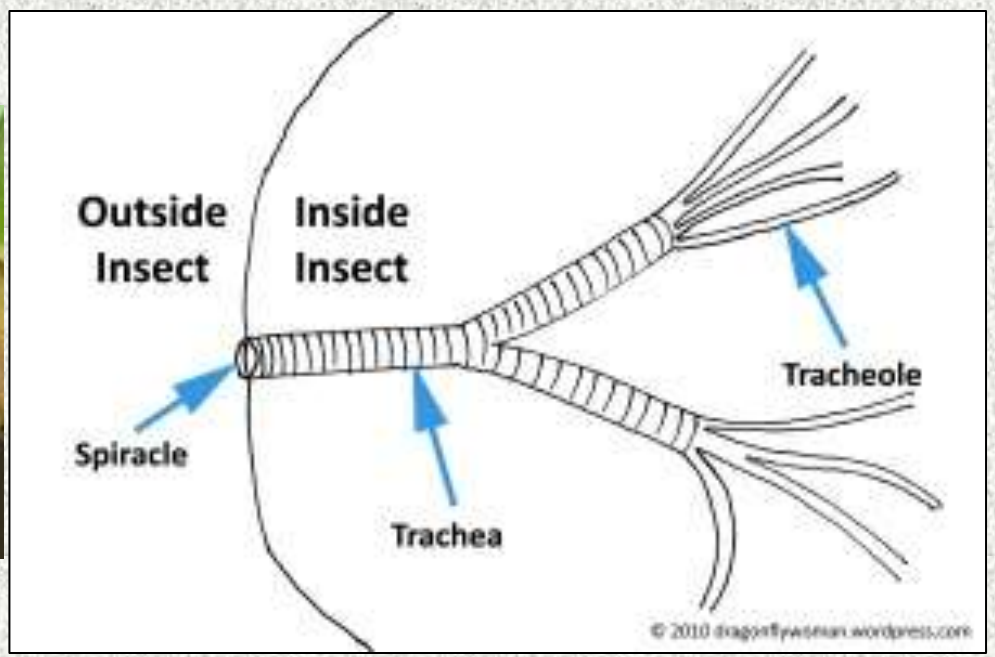




Respiratory System

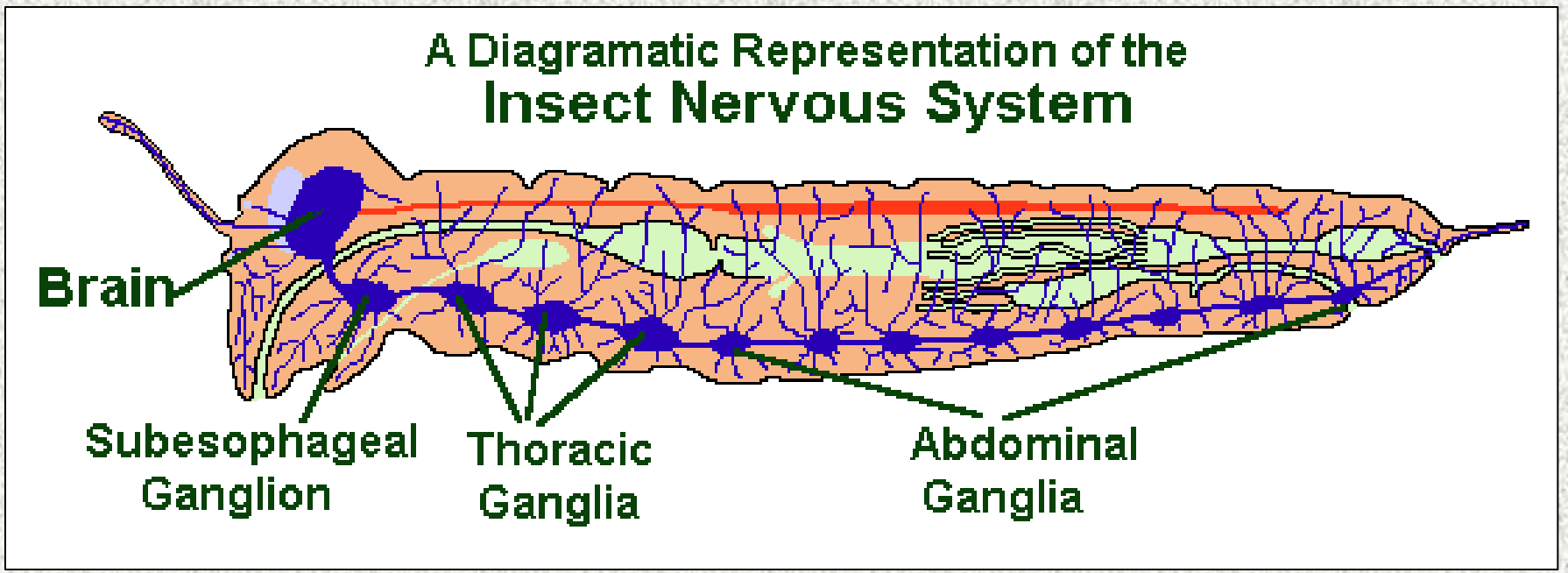






Nervous System

- Nervous system is similar to that of annelids. A dorsal brain connected via a ring around the pharynx to a double ventral nerve cord.

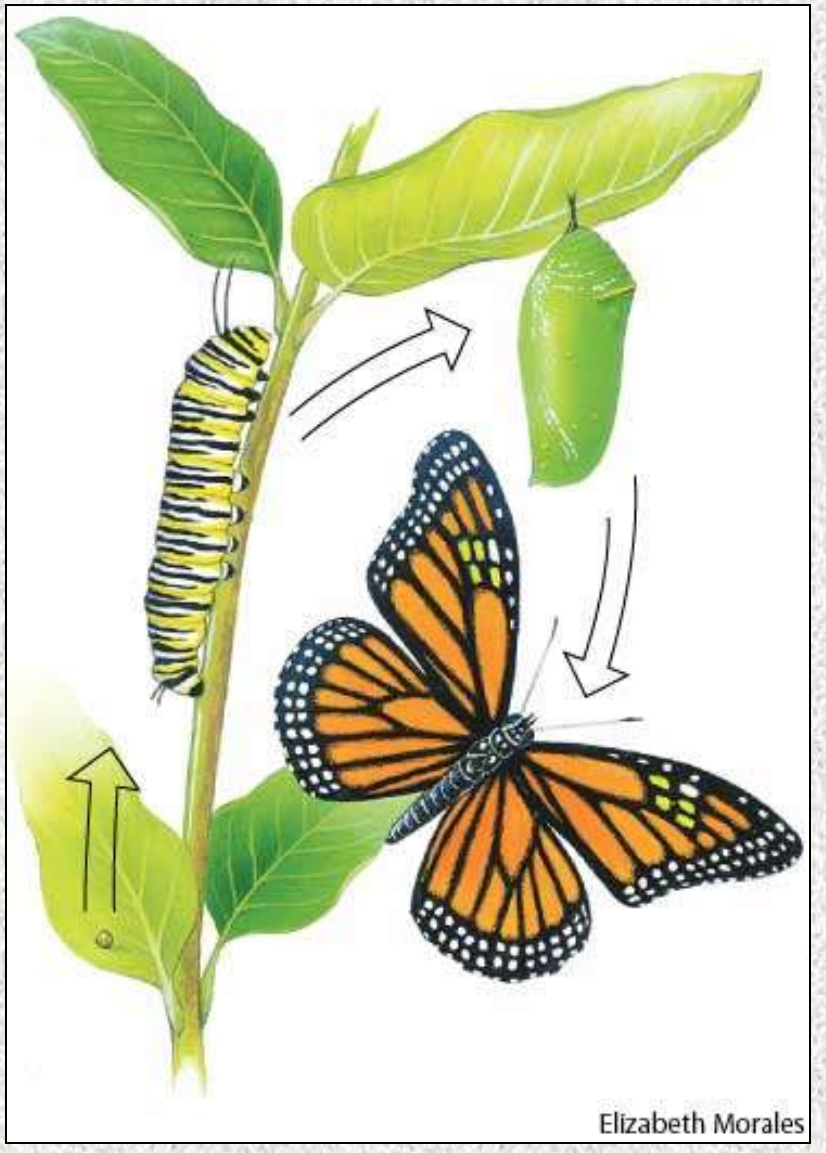


Development

- Sexes are usually separate with internal fertilization.
- Offspring often go through process of metamorphosis.
- Parthenogenesis (reproduction without fertilization) occurs in a some species (e.g. aphids).

Aphid giving birth, parthenogenesis

Metamorphosis



Arthropod Groups

1. Subphylum Trilobita
   - extinct trilobites
2. Subphylum Chelicerata
   - horseshoe crabs, spiders, ticks, mites, and some extinct groups
3. Subphylum Myriapoda
   - centipedes, millipedes
4. Subphylum Crustacea
   - crabs, lobsters, shrimps, barnacles
5. Subphylum Hexapoda
   - Insects

Molecular evidence places insects WITHIN the Crustacea

Insects

Many Others

Myriapoda

Crustacea

Chelicerata

Trilobites

Mandibulata

ARTHROPODA

Trilobites

- The **arthropod** body plan dates to the Cambrian explosion (535–525 million years ago)
- Early arthropods show little variation from segment to segment

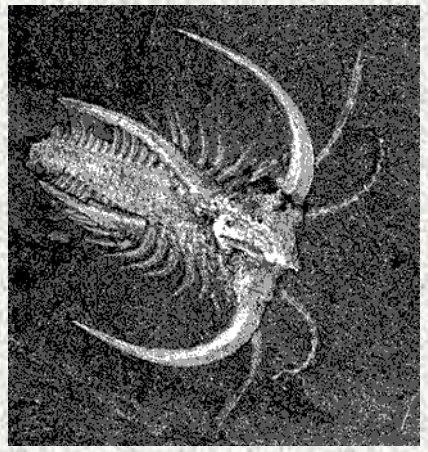
***Trilobite* fossil**

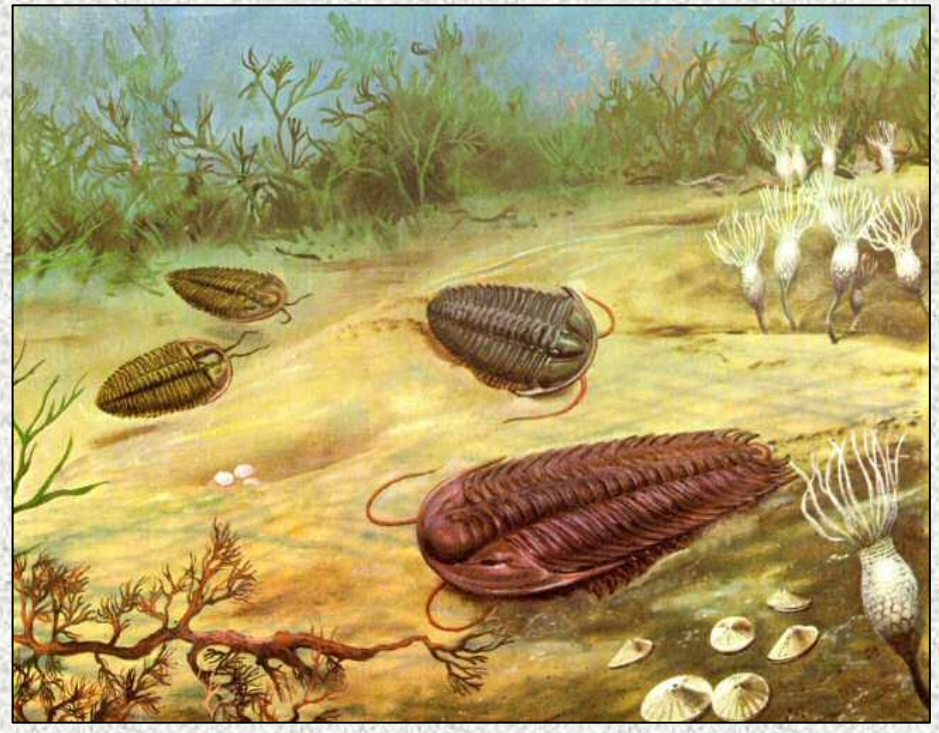
Arthropod evolution is characterized by a
- decrease in the number of segments
- increase in appendage specialization

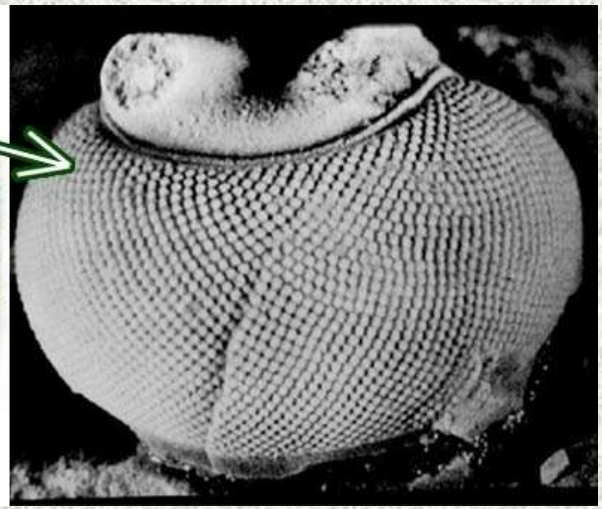
These changes may have been caused by changes in *Hox* gene sequence or regulation

Trilobites

- Abundant in Paleozoic
- 500 – 280 MYA





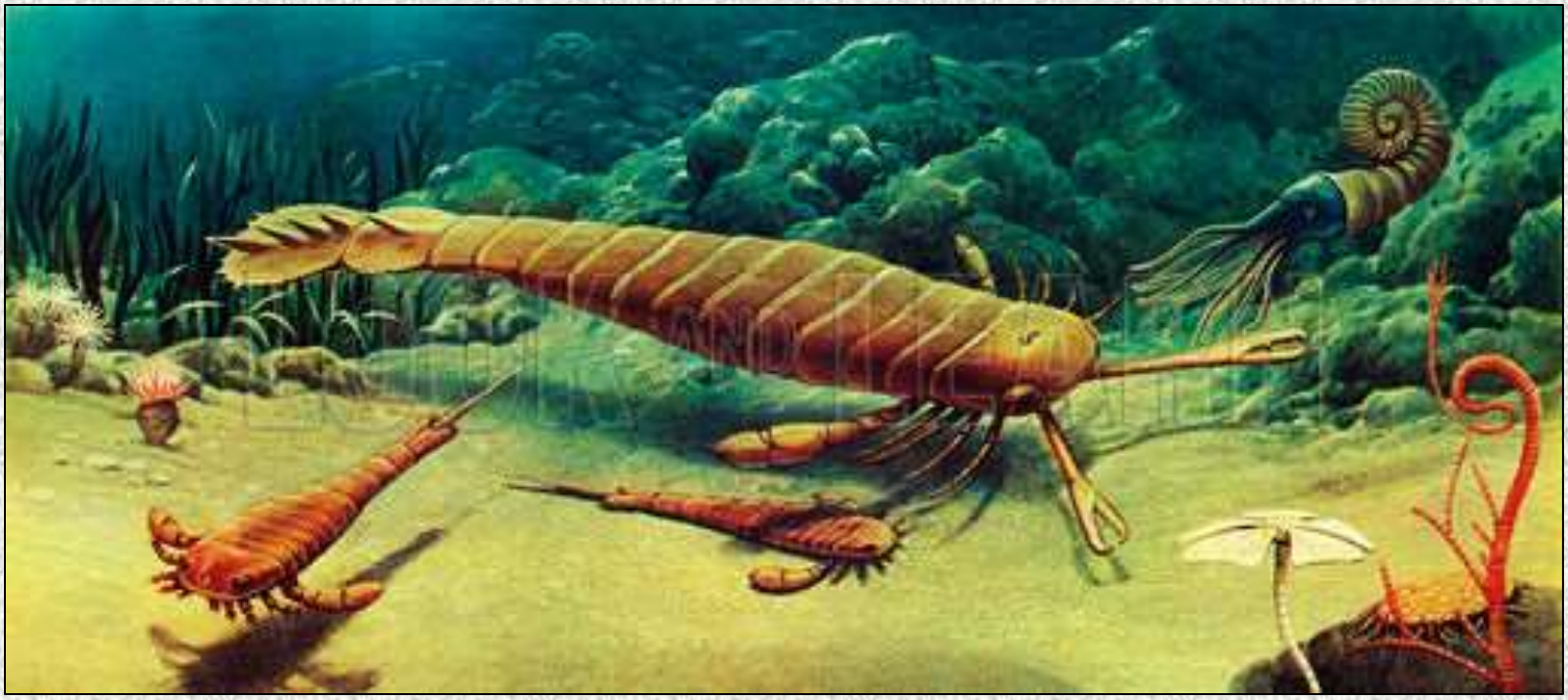


Subphylum Chelicerata

- Named for claw-like feeding appendages called **chelicerae**
- Body is divided into two tagmata (fused segments)
  - Cephalothorax (fused head & thorax)
  - Abdomen
- Six pairs of appendages:
  - a pair of chelicerae, first pair of appendages used for feeding (often fangs)
  - a pair of pedipalps (not in horseshoe crabs)
  - 4 pairs of walking legs (5 in horseshoe crabs).
- No mandibles or antennae.

Subphylum Chelicerata

- Very ancient group that includes the extinct Eurypterids (giant water scorpions (200-500 mya), which were the largest known arthropods reaching up to 3m long.



- *Eurypterus* (left) from the Silurian of New York State. *Eurypterus remipes* was voted the New York state fossil in 1983.
- *Mixopterus* (right) from the Devonian reached about one meter in length

Horseshoe Crabs

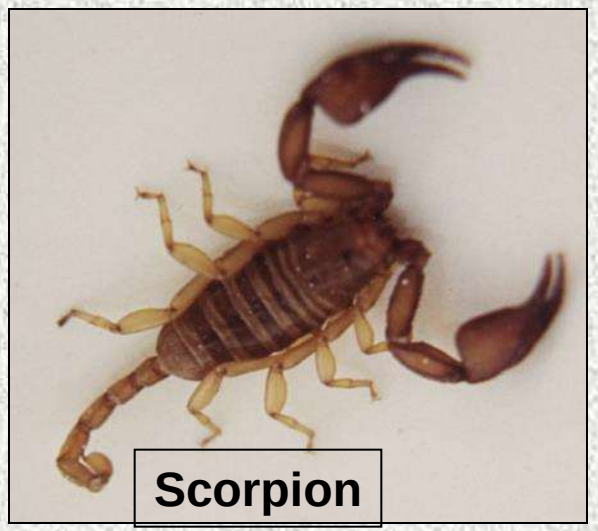
- Most marine cheliceriforms (including eurypterids) are extinct, but some species survive today, including Horseshoe crabs

Class Merostomata – Horshoe Crabs

- Ancient group of species
- Changed little over 350 million years
- Aquatic, mostly found on Atlantic & gulf coasts of United States
- Unsegmented carapace
- Synchronized breeding

Class Arachnida

- Spiders, ticks, scorpions
- Most are predaceous



Two feeding appendages

Leg (four pairs)

Scorpion

Dust mite

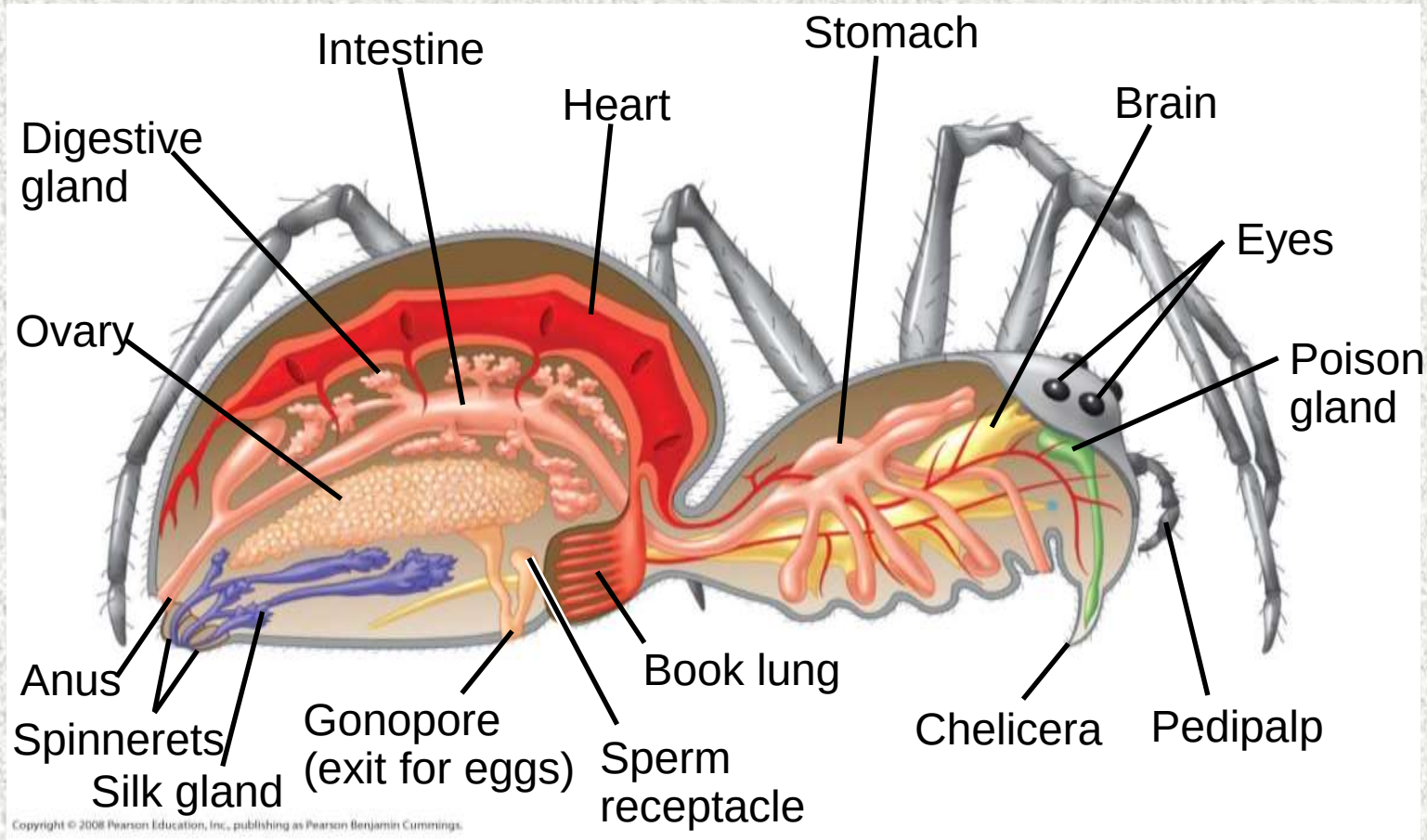
Black widow spider

Wood tick

Class Arachnida

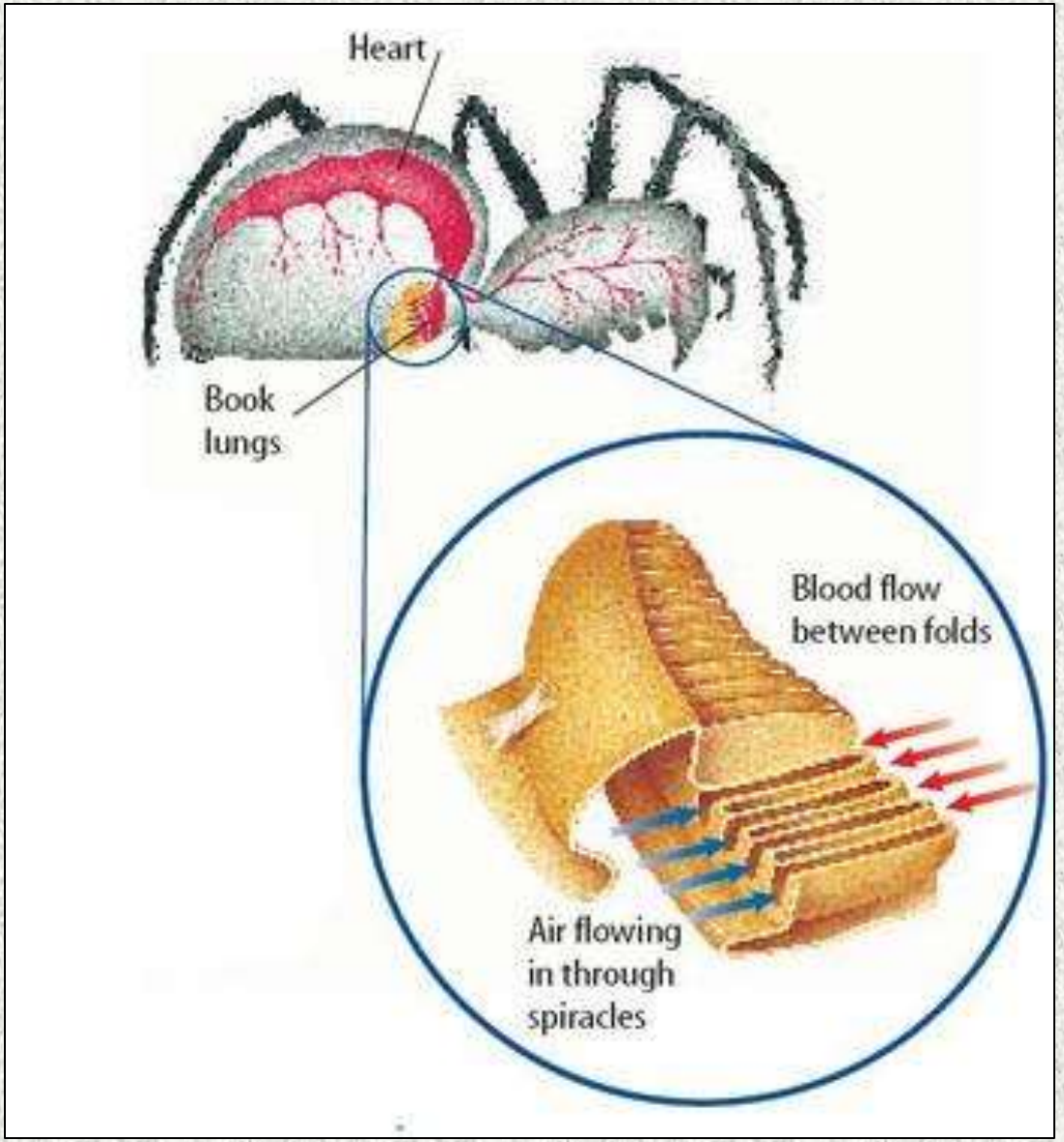
- Live on land
- 4 pairs walking legs
- Abdomen
- Book lungs for gas exchange
- Fangs – chelicera
- Spider webs, polymer, silk

Arachnids - Spiders



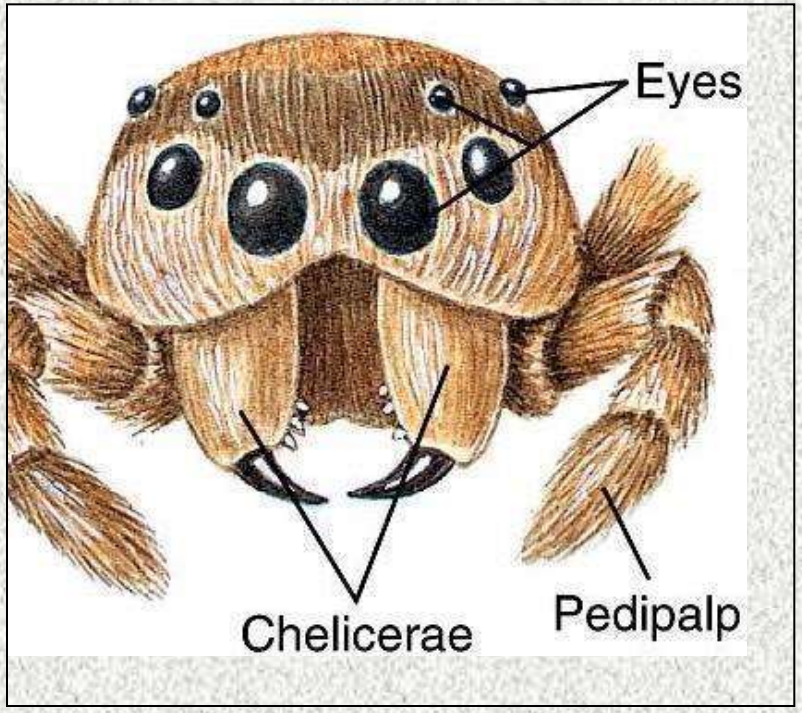
Book Lungs

- Book lungs are unique to spiders
- Consist of a large number of air pockets extending into a blood-filled chamber
- Not related to vertebrate lungs



Spiders

- All predaceous
  - Mostly insects
- Chelicerae have fangs



- Spider venom is used to subdue prey
- Venom liquifies tissues with a digestive fluid
- Spider sucks up soupy prey (ewwww!)


Wolf spider

Prey capture among the spiders

- Some species are cursorial predators
  - stalk and ambush their prey
  - they usually have well-developed eyes

Jumping spider

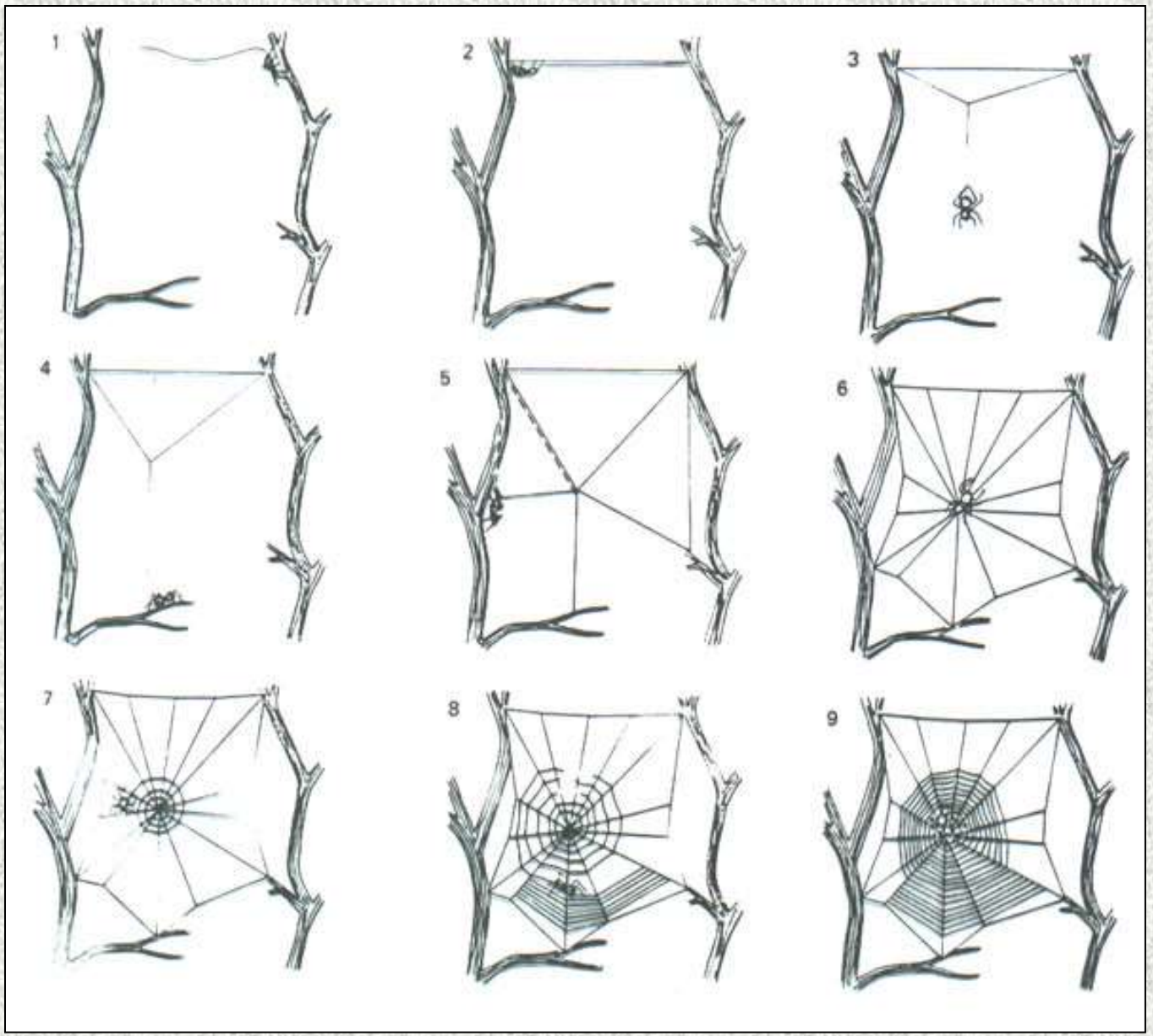
Prey capture among the spiders

- Some are web-building spiders
  - Eyes not as well developed
  - sensory hairs for detecting vibrations

Grass spider

- Many spiders (and mites) producing silk
  - Used for trapping prey, building nests, forming egg cases

Orb web construction



Toxic Spiders

- Most spiders are harmless to humans, or beneficial
- Some spiders (ie. black widow, brown recluse spider) give painful, dangerous bites

The brown recluse and its bite wounds

Day 3

Day 9

The Camel Spider in Iraq

Order Acari - ticks and mites

- Cephalothorax and abdomen are fused with
- No evidence of a division between the segments.
- The mouthparts are mounted on a small projection called a capitulum.

Dust mite

Figure 18.11a

Wood tick

A

Disease carrying ticks

- A wide variety of diseases are tick borne, with ticks being second only to mosquitoes in the variety and seriousness of the conditions they spread.

- Diseases spread include Rocky Mountain spotted fever, tularemia, red-water fever and best known of course Lyme Disease.

Lyme Disease

- Symptoms of Lyme disease, which is spread by the bite of a deer tick, include fever, headache, fatigue, and a diagnostic skin rash with bull's eye appearance
- Lyme disease can be treated with antibiotics if caught early enough.

Chiggers

- Tiny mites (< 0.05 mm long)
- Cause skin irritations
- Larvae climb on to vegetation and wait
- Pierces the skin and injects a salivary secretion of powerful, digestive enzymes
- Break down skin cells into a liquid, which the chigger ingests.

Commensal mites

- A variety of mites live commensally with us including tiny species that live in hair follicles especially around the nose and eyes.

- These mites (<0.4mm long) are vaguely wormlike having quite long bodies and live head down in follicles feeding on dead skin cells and secretions.

Eyelash mites. Above left: three embedded head down in a follicle; above right an individual *Demodex folliculorum* and right close up of the anterior end.

Order Scorpionida: Scorpions

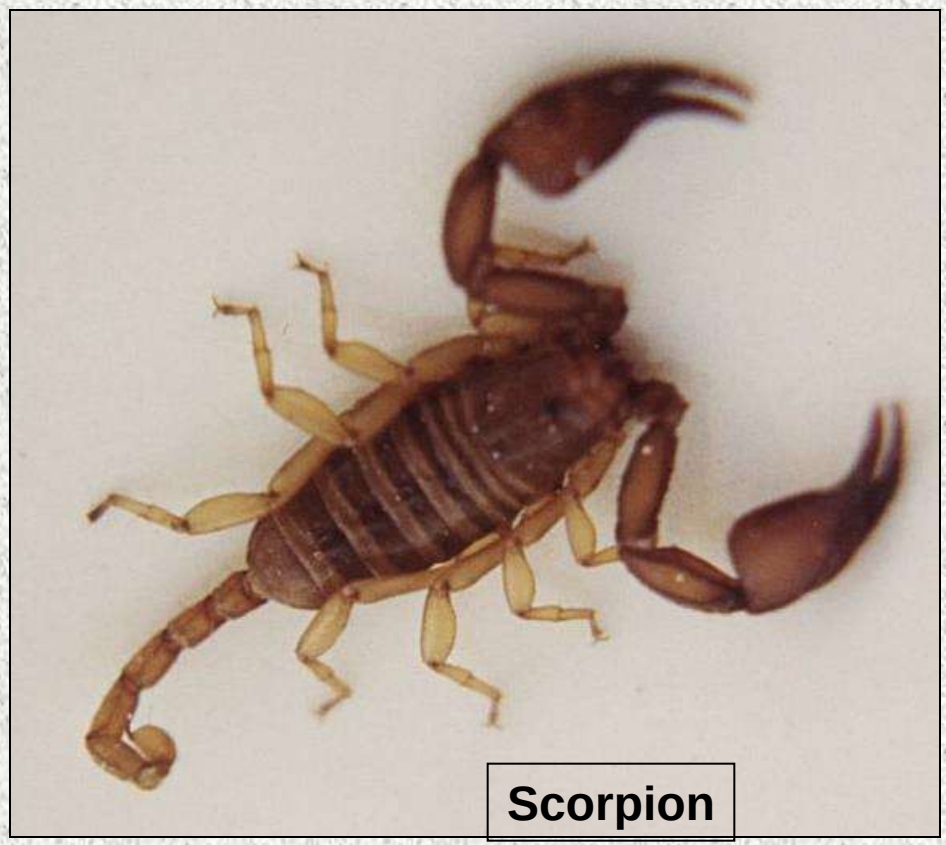
Prey is gripped with the pincers (pedipalps) and either crushed or stung to death

Order Scorpionida - Scorpions

- About 1,500 species of scorpions
- Common tropics and deserts
- Prominent front claws
- 4 pairs of walking legs and a long, segmented abdomen
- Stinging tail, with which they inject venom.

Class Arachnida - Scorpions

- Mostly tropical and deserts
- Nocturnal
- Venom in stinger
- Scorpion sting can be painful, dangerous



- Active at night
- Scorpions glow when a black light (UV light) is shone on them, makes nocturnal surveys of scorpions quite easy

Order Opiliones: harvestmen

Order Opiliones: harvestmen

- Harvestmen or “daddy longlegs” are common and easily separated from spiders by a number of features:
  - Abdomen and cephalothorax are not separated by a narrow “waist” or pedicel as they are in spiders.
  - Extremely long thin legs.
  - Cannot spin silk.
  - Have only two eyes rather than then the eight of spiders.

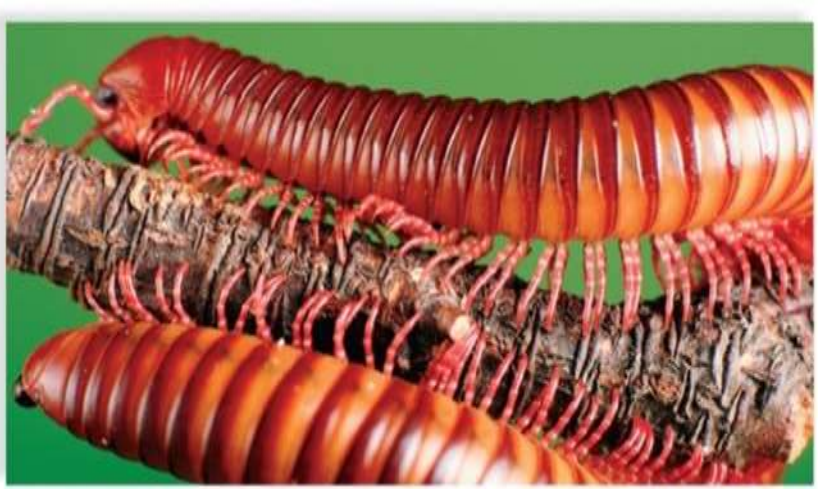
Order Opiliones: harvestmen

Harvestmen

- The chelicerae of harvestmen are pincerlike and they use them to catch small insects and also commonly scavenge dead items.
- Unlike spiders they can eat solid food
- There are about 6400 described species.

Subphylum Myriapoda
Centipedes and Millipedes

a.



b.

Myriapods have a head with simple eyes and a segmented trunk which carries paired appendages, one per segment in centipedes and in most segments two in millipedes.

Centipedes and Millipedes

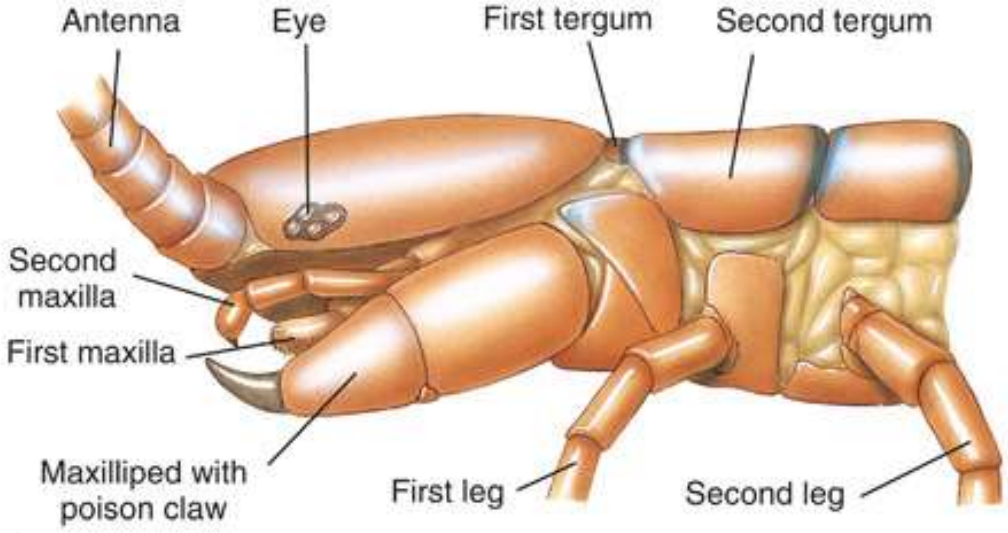
Millipedes and centipedes have similar segments over most of the body.

– **Centipedes**:
  - Are terrestrial carnivores with poison claws
  - Have one pair of short legs per body segment

– **Millipedes**:
  - Eat decaying plant matter
  - Have two pairs of short legs per body segment

Figure 20.01

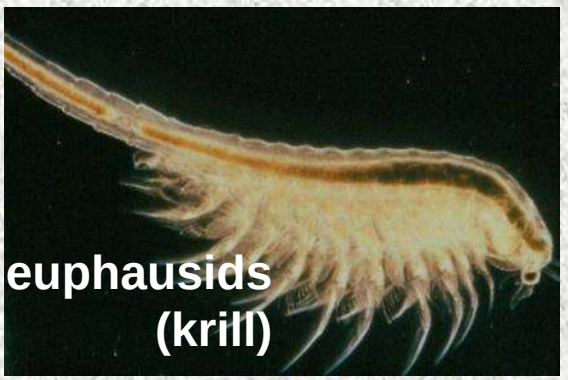
A



B

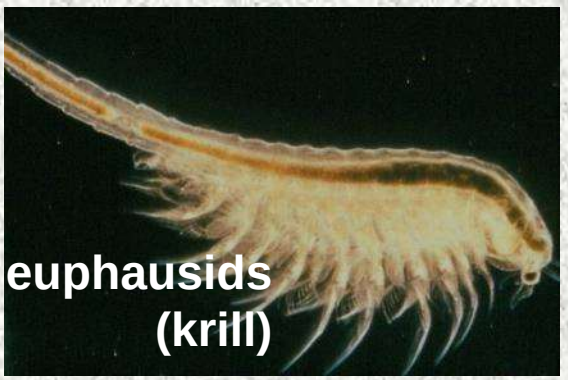
The Crustaceans

- Phylum Arthropoda
  - Subphylum Crustacea
    - crusta= shell
- Lobster, crayfish, shrimp, crab, water flea, barnacles



Subphylum Crustacea

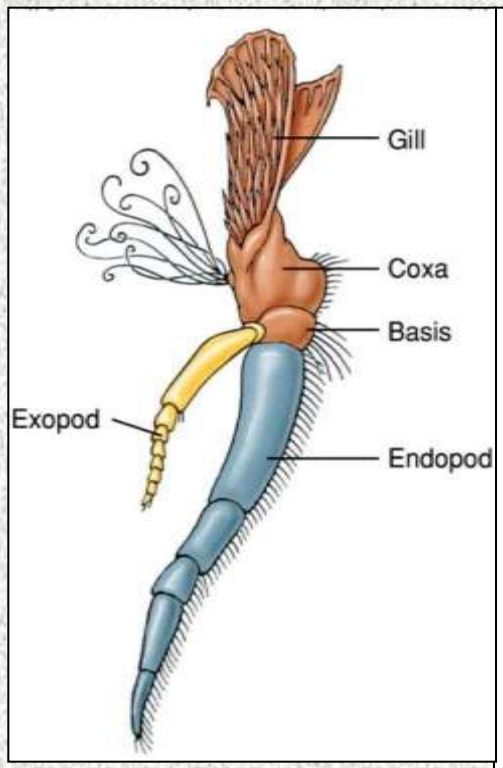
- Aquatic (mostly marine)
  - a few terrestrial forms
- Major ecological and economical importance.

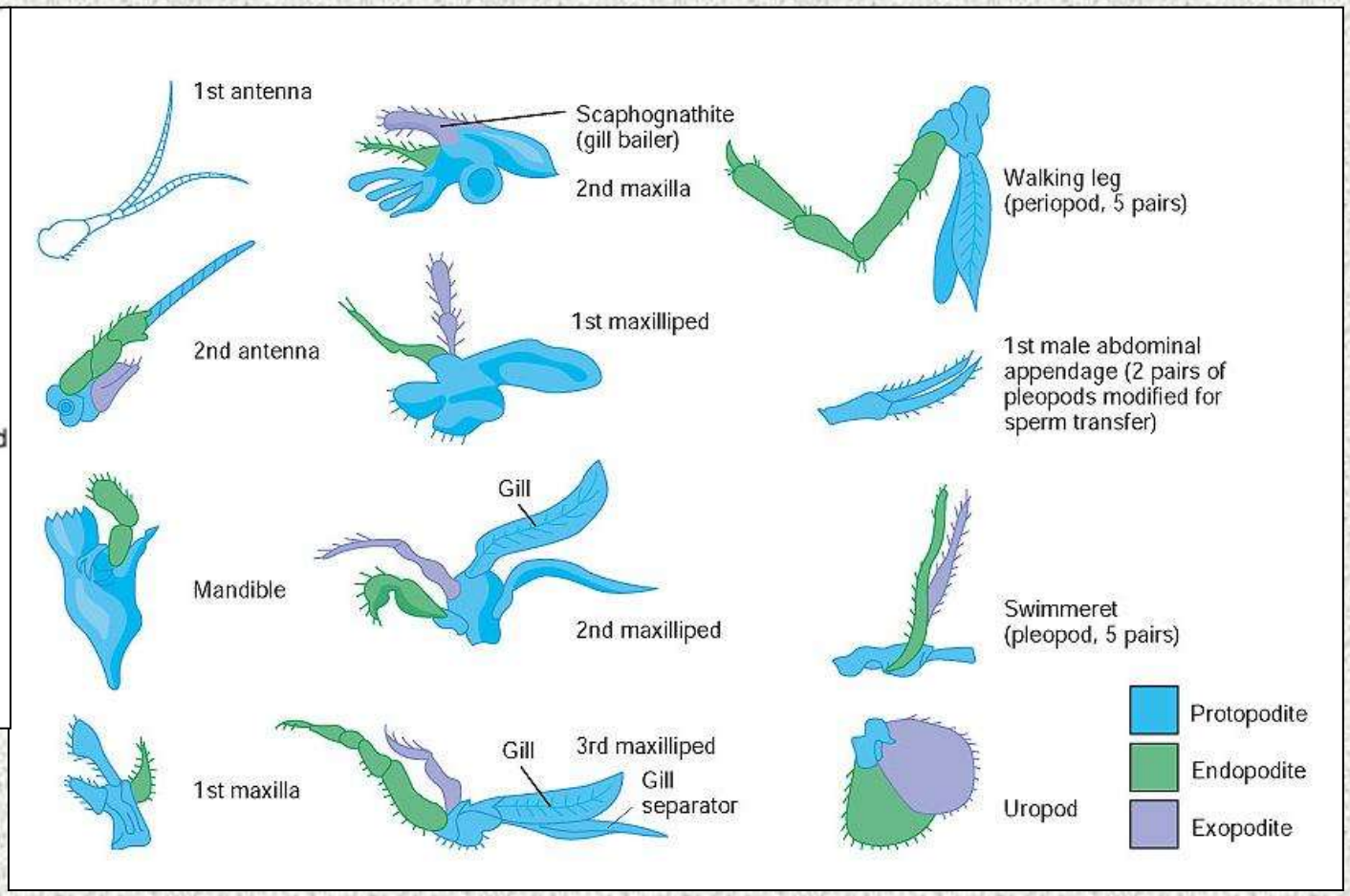


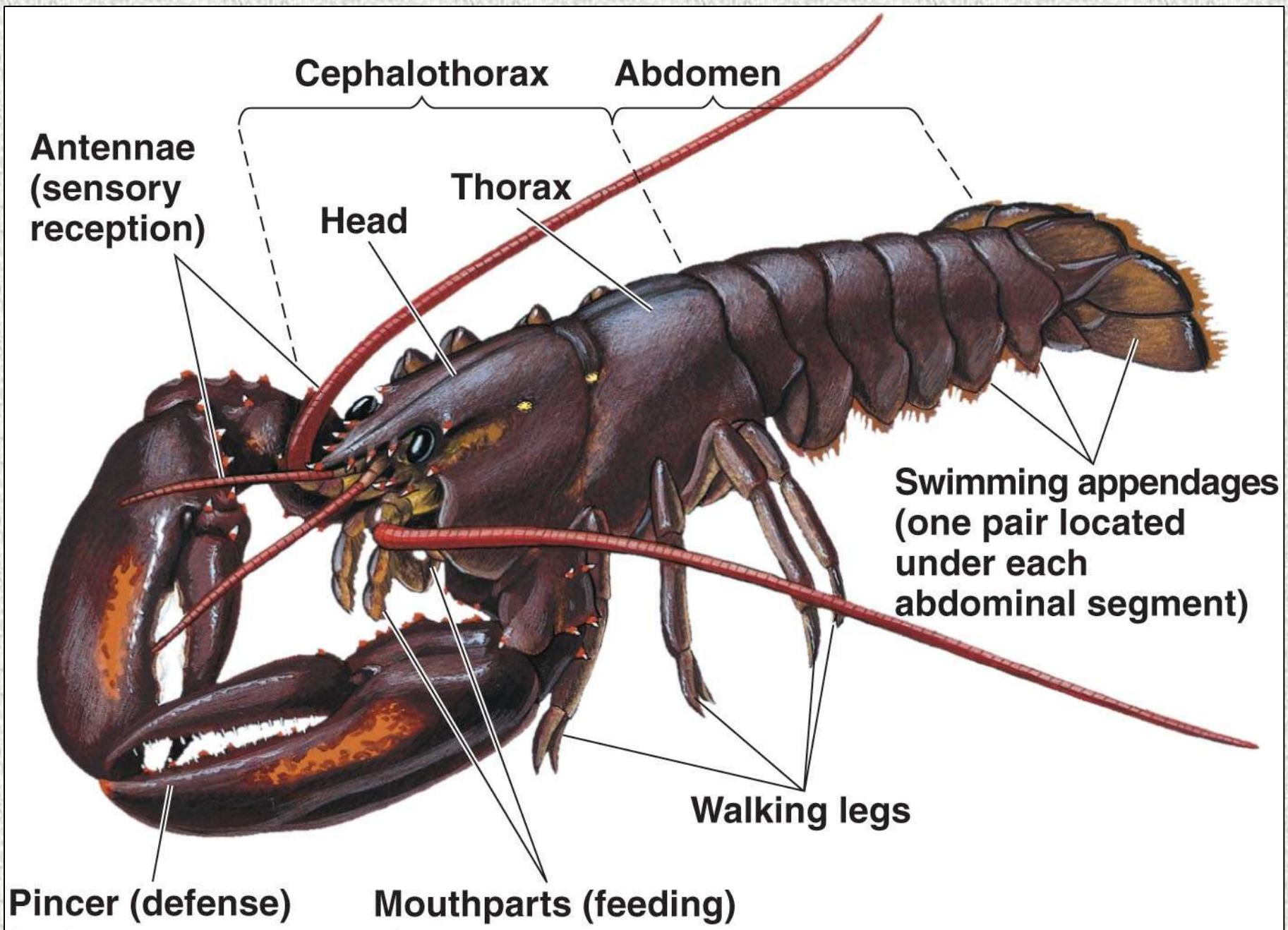
The Crustaceans

- Over 40,000 species
- Hard, crusty exoskeleton containing calcium carbonate and chitin.
  - *crusta* meaning "crust, shell, or hard surface."
- Compound eyes and five pairs of appendages
- Appendages are often highly specialized
- Gas exchange is usually through gills

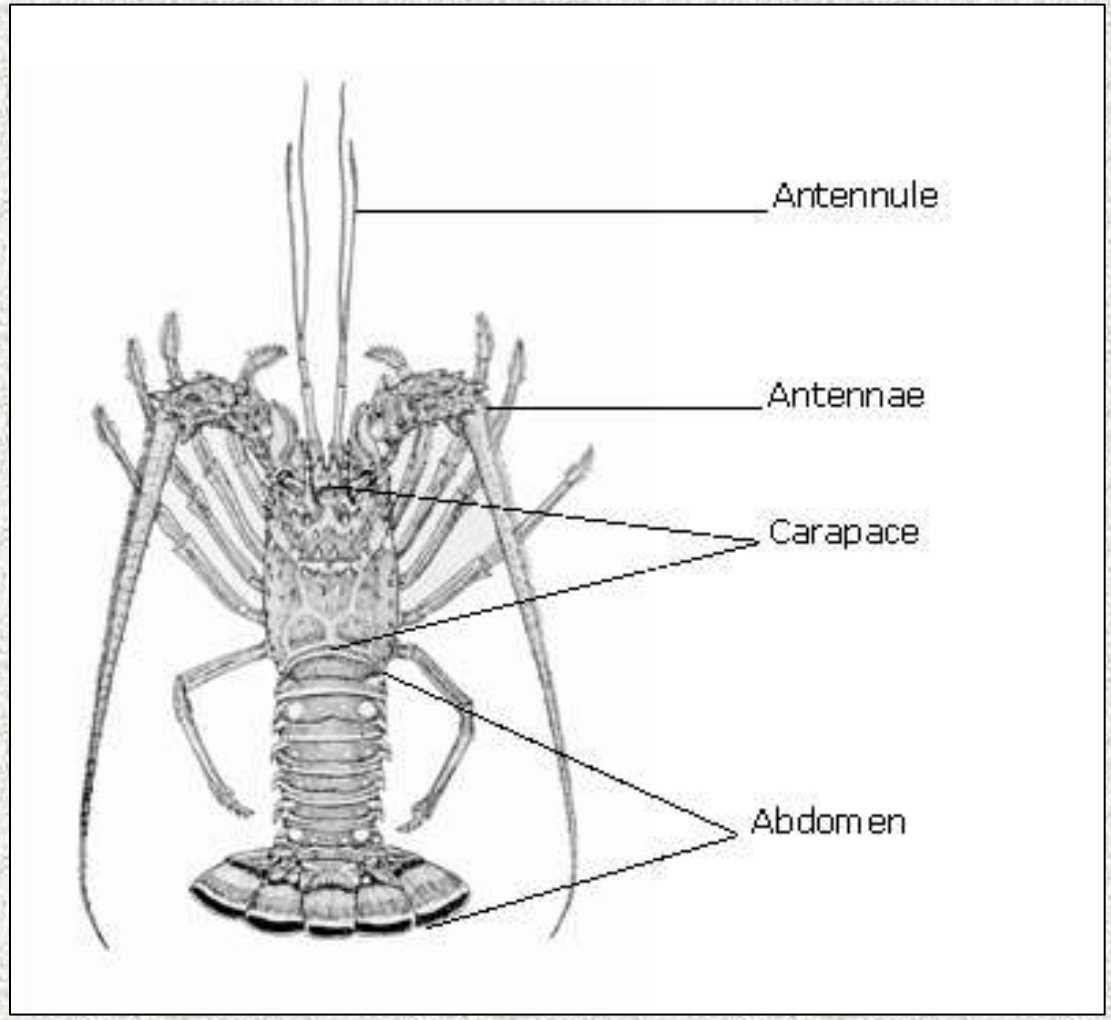
- Appendages typically biramous
- Greatly specialized
  - Mouthparts chewing, grinding, handling



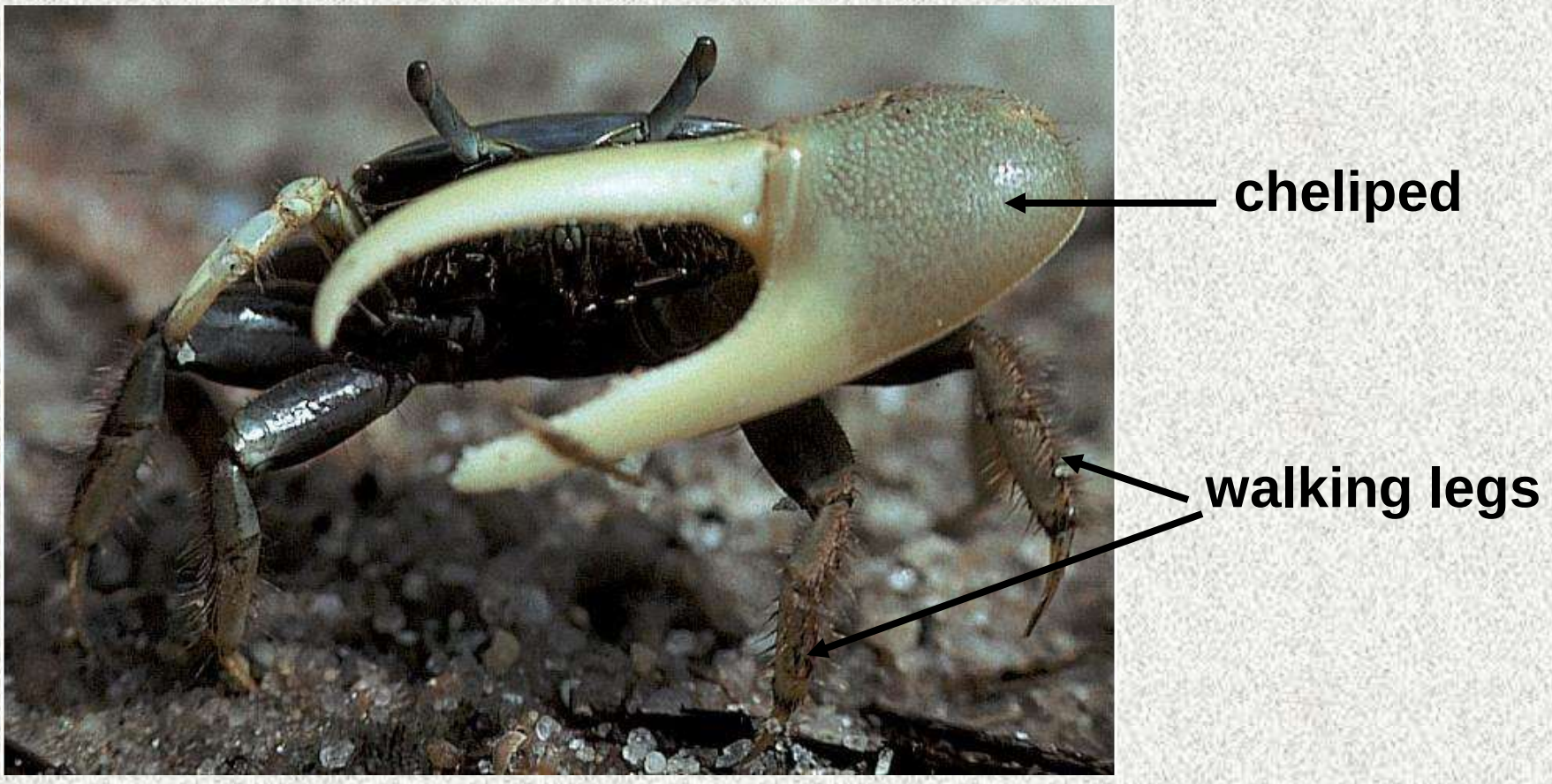




- Only arthropods with 2 pairs of antennae

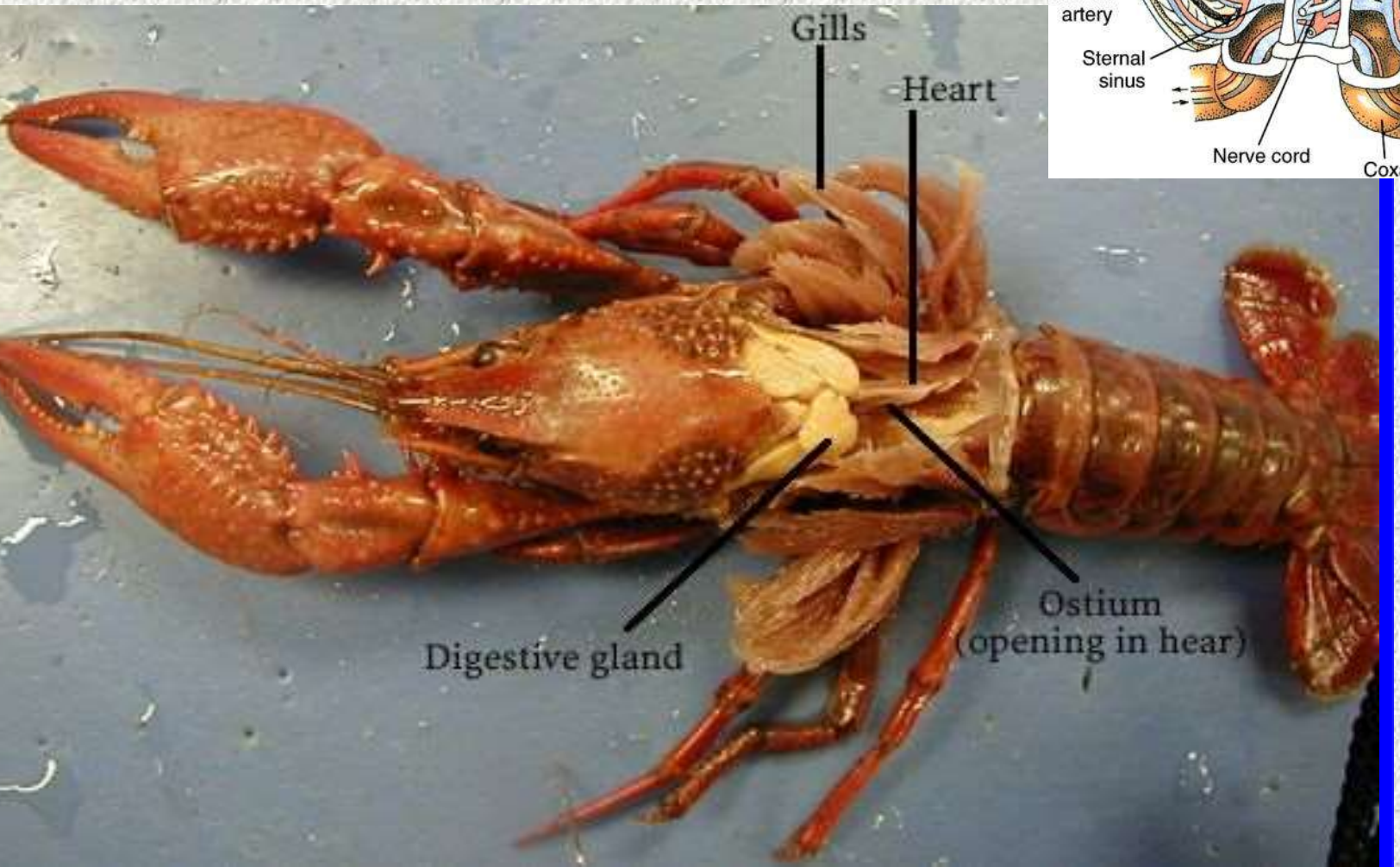


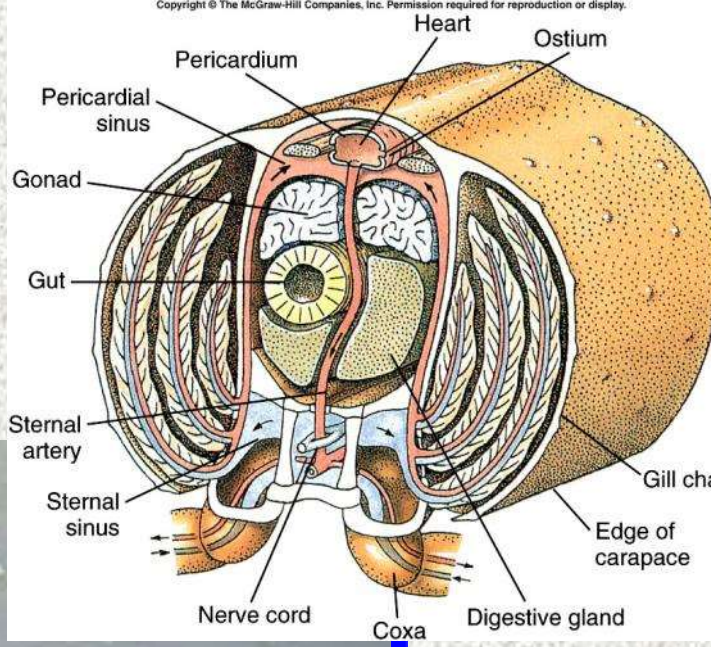
- Appendages strengthened for walking or protection (chelipeds, pincer-like claws)



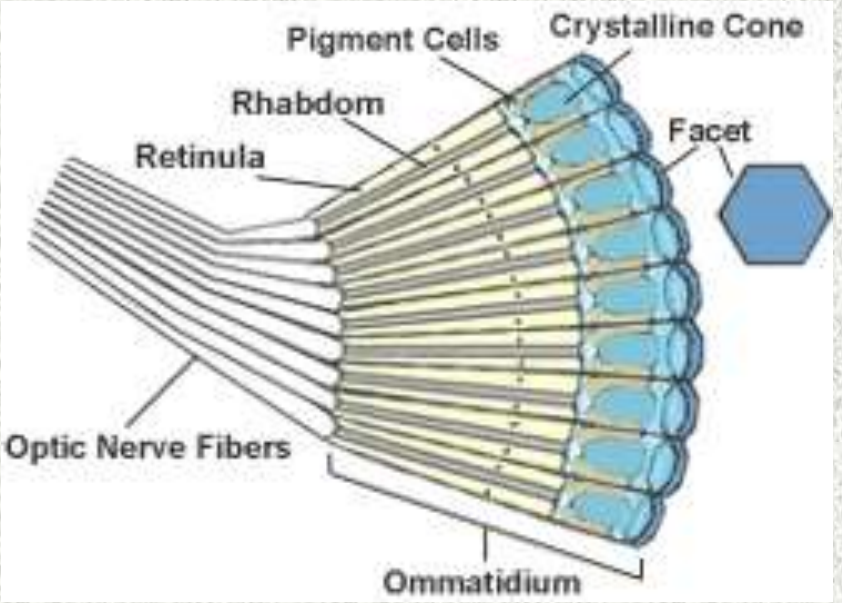
Respiration

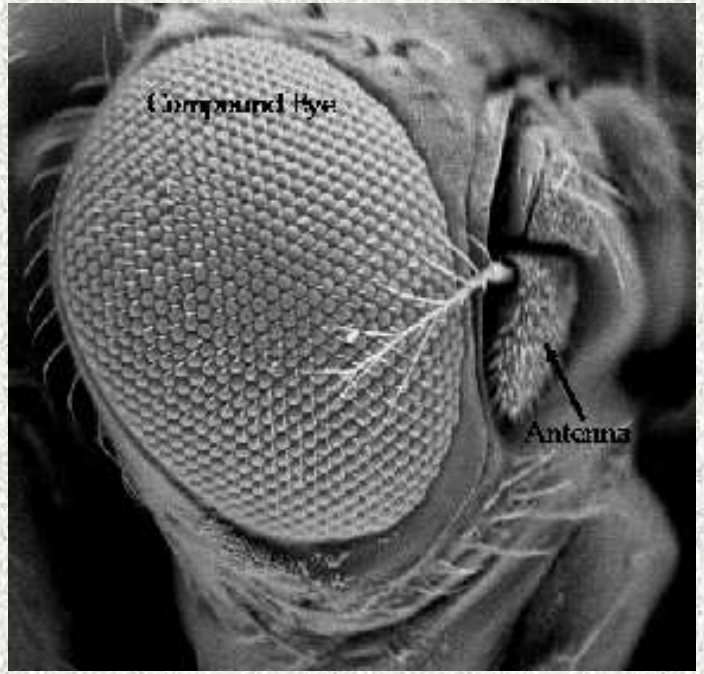
- gills (usually)



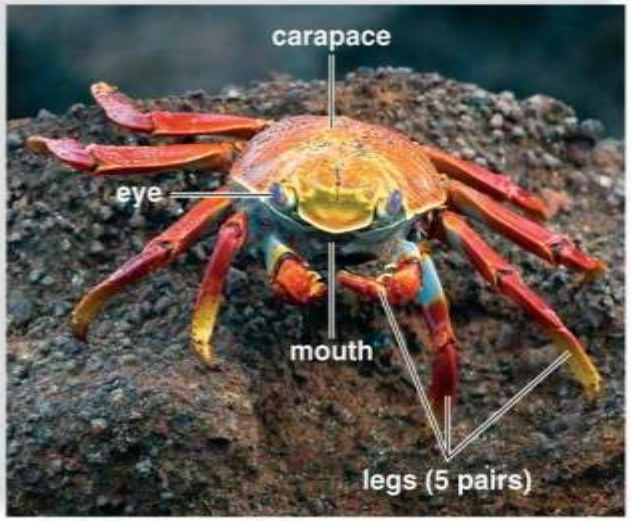


- Compound eye is typical of phylum

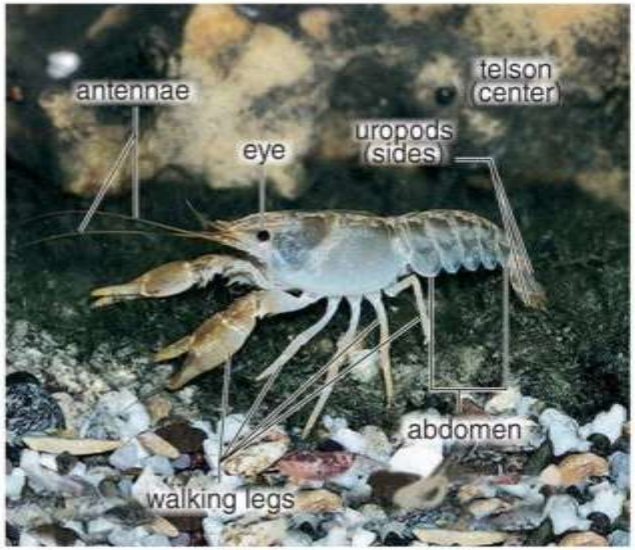




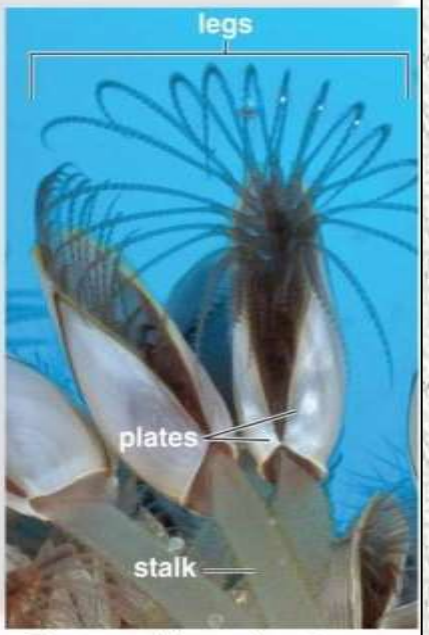
Crustacean Diversity



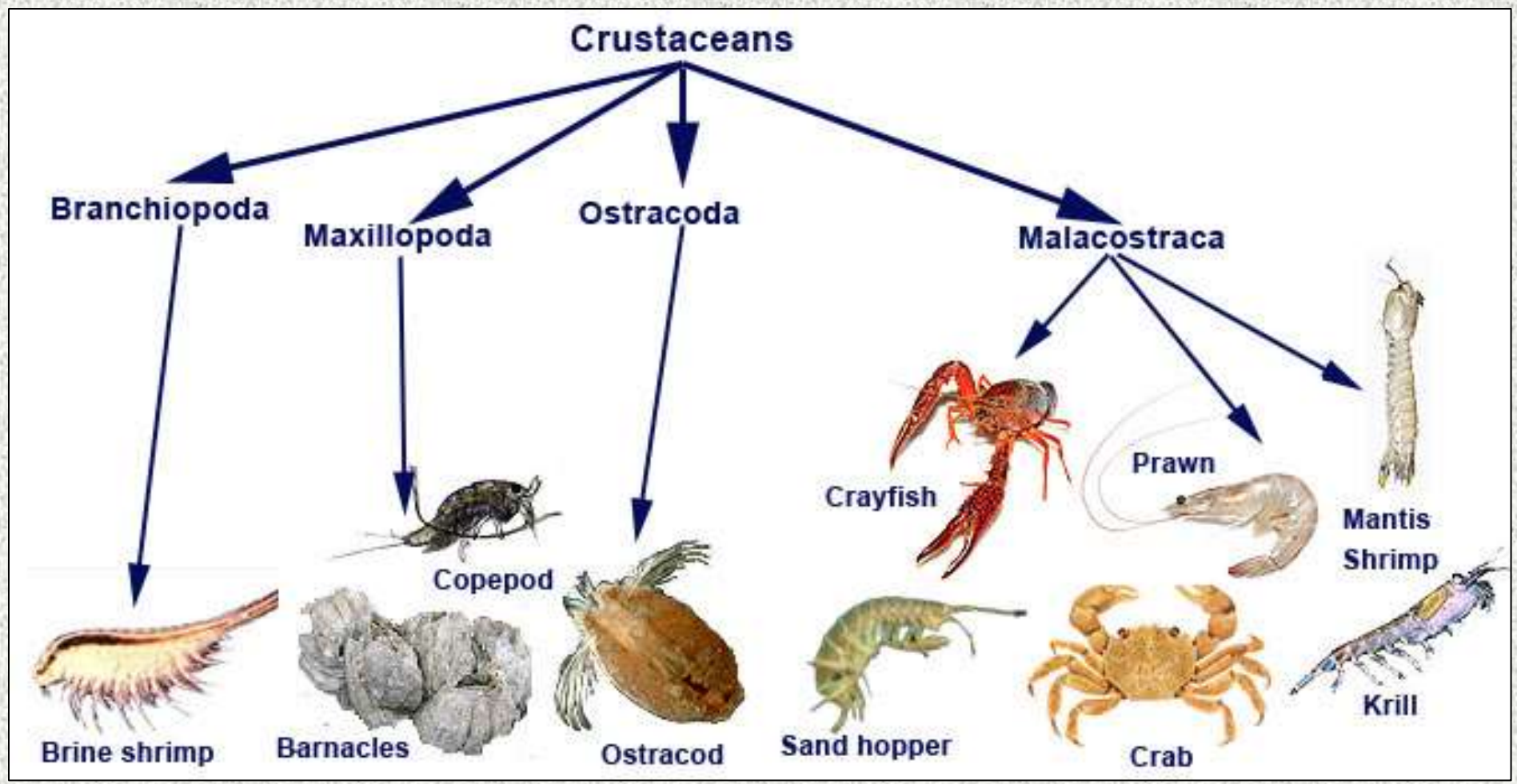
a. Sally lightfoot crab, *Grapsus grapsus*

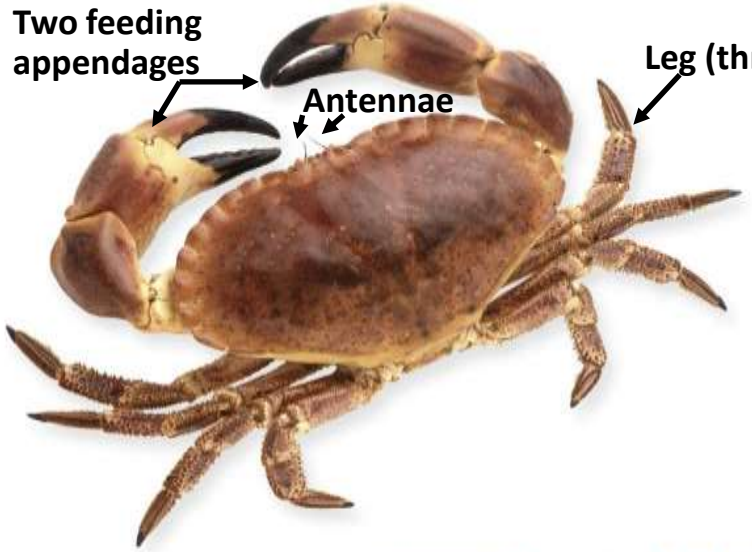


b. European crayfish, *Actacus fluviatilis*



c. Gooseneck barnacles, *Lepas anatifera*


Crustaceans
Branchiopoda
Maxillopoda
Ostracoda
Malacostraca
Brine shrimp
Barnacles
Copepod
Ostracod
Sand hopper
Crayfish
Prawn
Crab
Mantis Shrimp
Krill



Crab

Shrimp

Pill bug

Crayfish

Barnacles

Crustacean Diversity

- Majority marine and aquatic environments.
- Decapods are the most familiar and numerous of crustaceans 5 pairs walking legs).
  - Shrimp, lobsters, crayfish, and crabs
- Copepods and krill are small, free-living crustaceans that live in water and feed on algae.
- Barnacles live on wharf pilings.

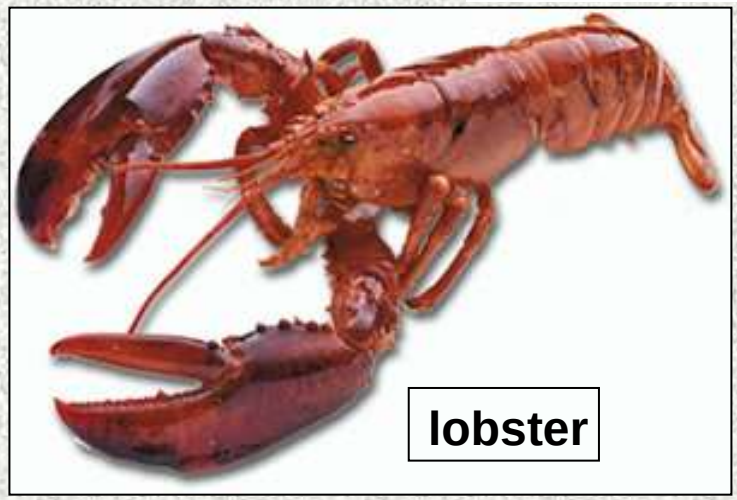
Lobster and Crayfish

Marine Maine Lobster

Crayfish

What's the difference between a crayfish and a lobster?

- Same Order, but different families
- Lobsters are bigger
- Lobsters are marine; crayfish live in freshwater creeks, ditches, or lakes



Crabs

Barnacles

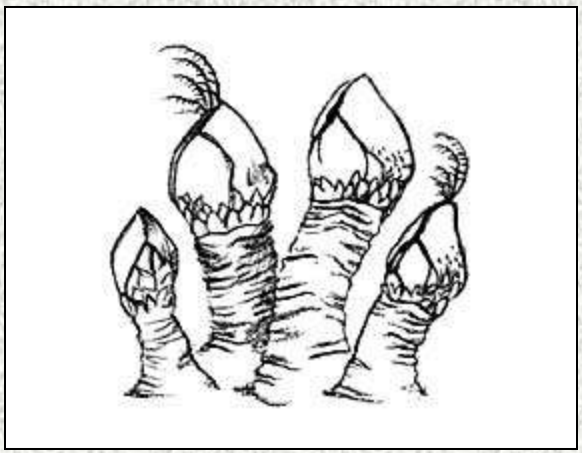
- Calcareous plates attached to solid substrate.
- Head reduced, rudimentary abdomen
- Larva resemble other crustaceans

"nothing more than a little shrimplike animal standing on its head in a limestone house and kicking food into its mouth"

-Louis Agassiz

Barnacles

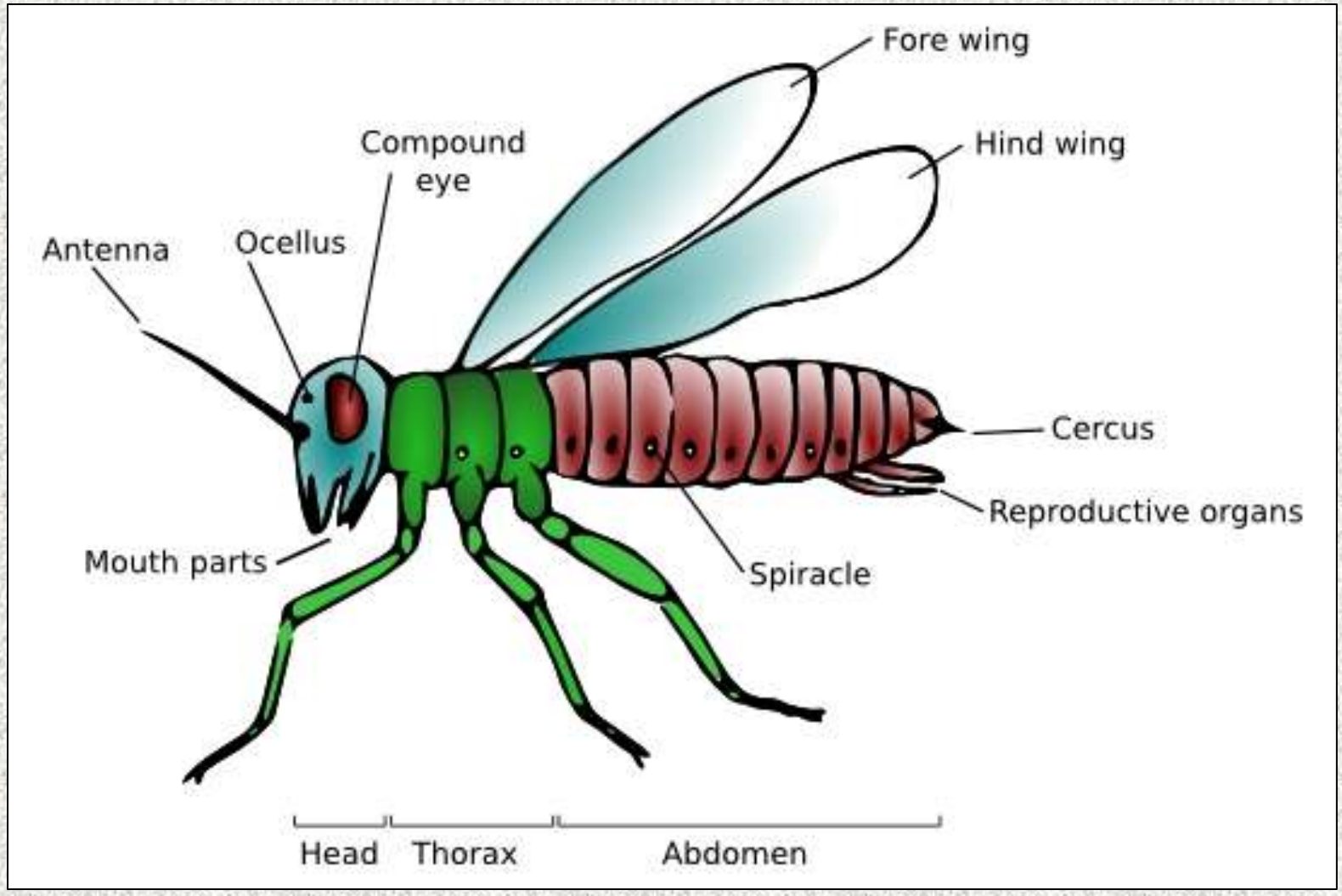
Legs form "cirri" which draw food into the mouth



Krill

- Small shrimp-like species.
- Lack maxillipeds and chelae.
- All the thoracic legs are used for filter feeding
- Component of plankton
- Major food for whales

Insects


Fore wing
Hind wing
Compound eye
Ocellus
Antenna
Cercus
Reproductive organs
Mouth parts
Spiracle
Head
Thorax
Abdomen

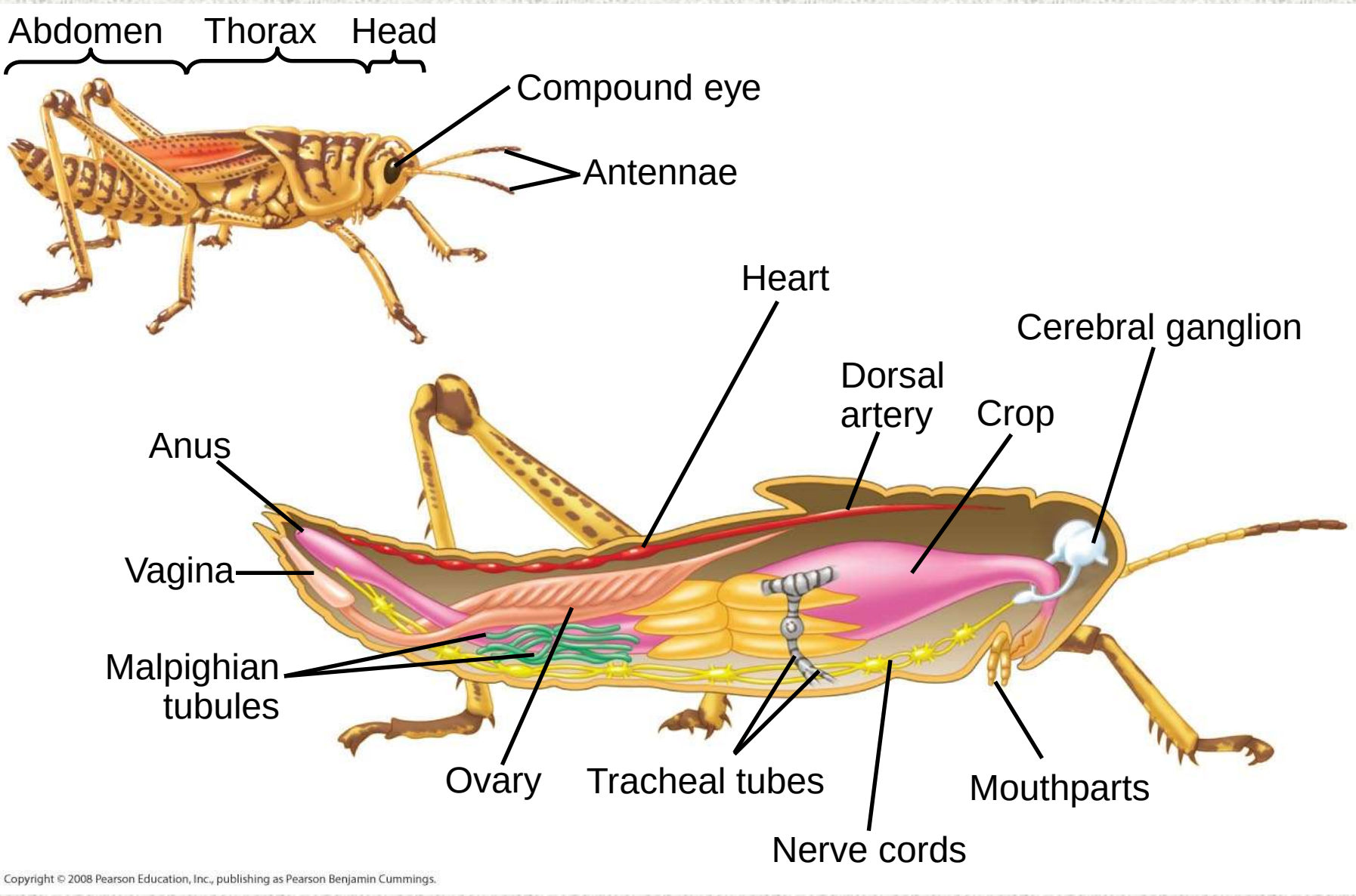
Subphylum Hexapoda - Insects

- More species than all other forms of life combined
- Almost every terrestrial habitat and in fresh water
- Complex organ systems
- Most insects live on land
- Early colonizer of land
- Diversified several times:
  - evolution of flight,
  - adaptation to feeding on gymnosperms, and the
  - expansion of angiosperms

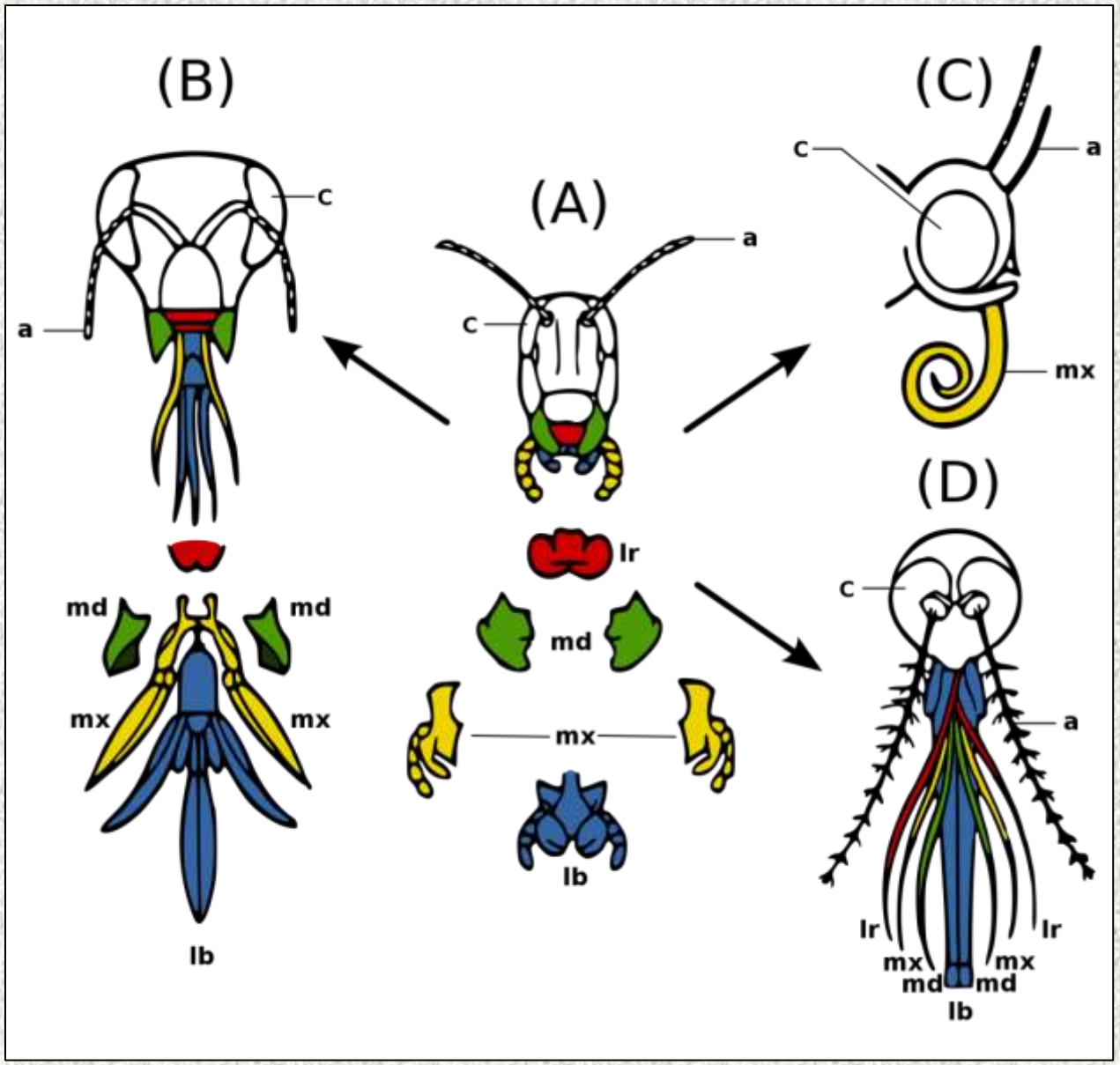
Insect Morphology

- Body segments
  - Head bears sense organs and mouthparts.
  - Thorax bears three pairs of legs and sometimes one or two pairs of wings.
  - Abdomen contains most internal organs.
- The insect head usually bears:
  - A pair of sensory antennae
  - A pair of eyes
- Mouthparts are adapted for particular kinds of eating.
- Flight is one key to the great success of insects.

Insect Morphology

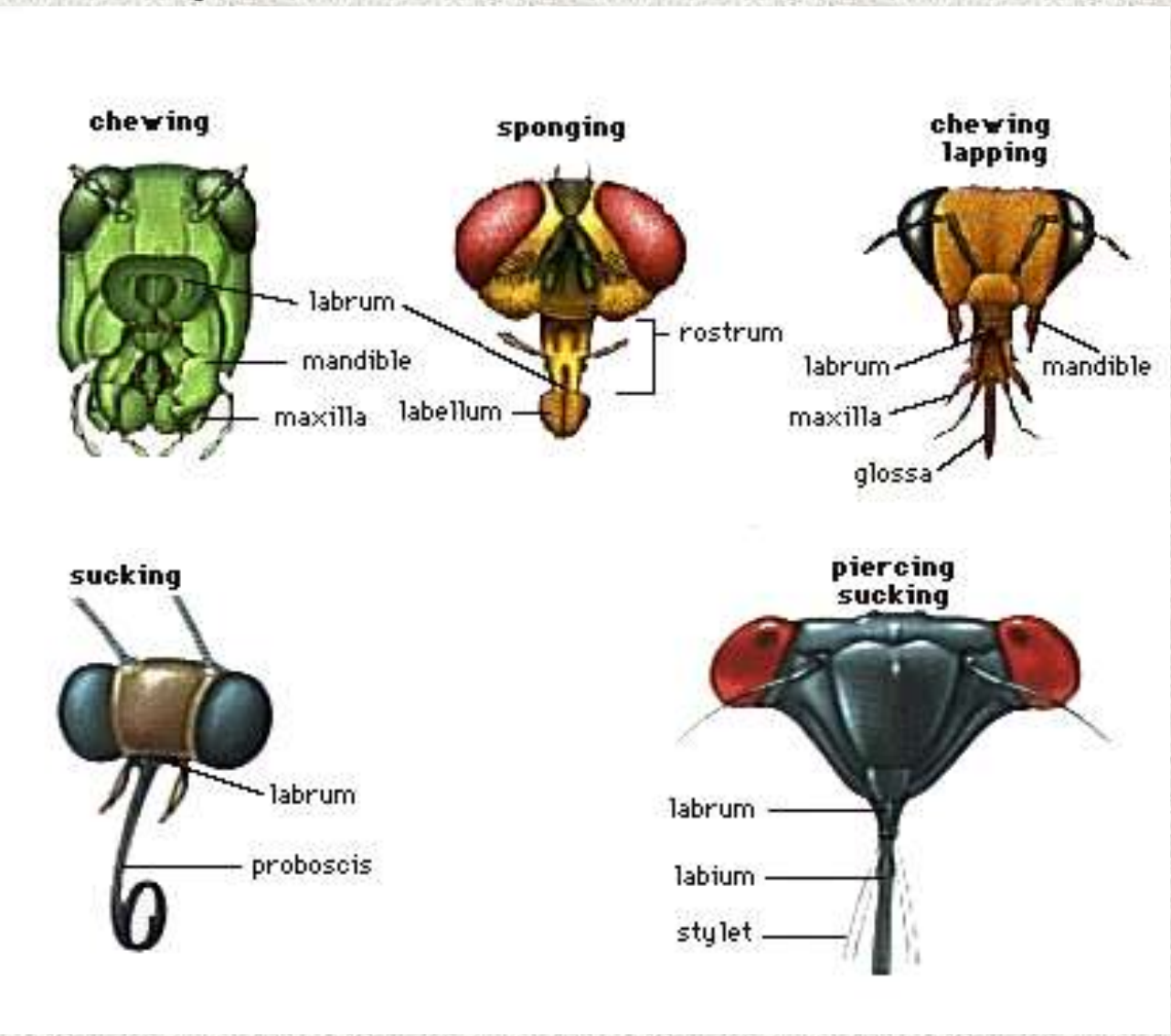


Feeding / Mouthparts



Feeding / Mouthparts

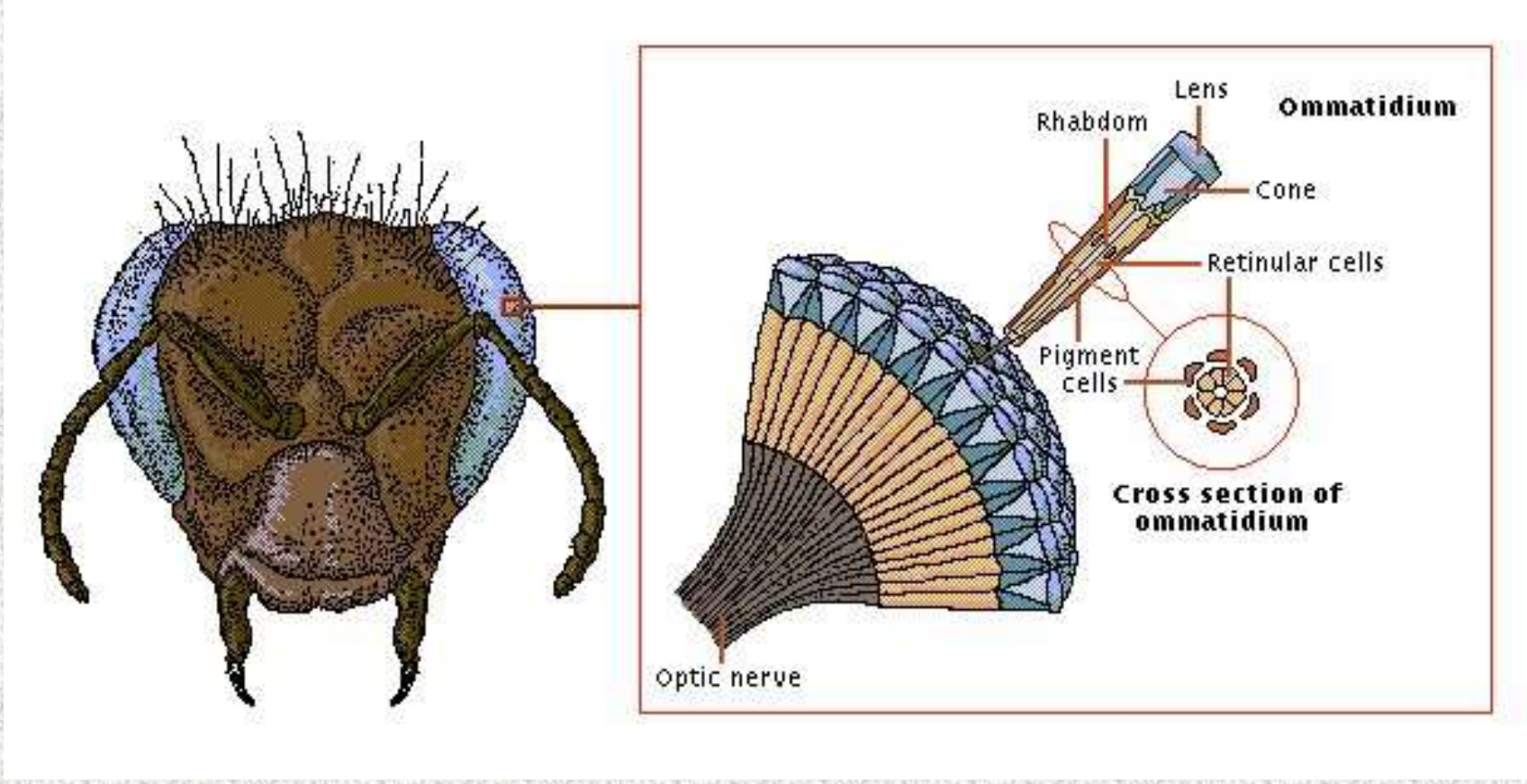
- Insects usually have specialized jaws/mouthparts suited to their ecological niche



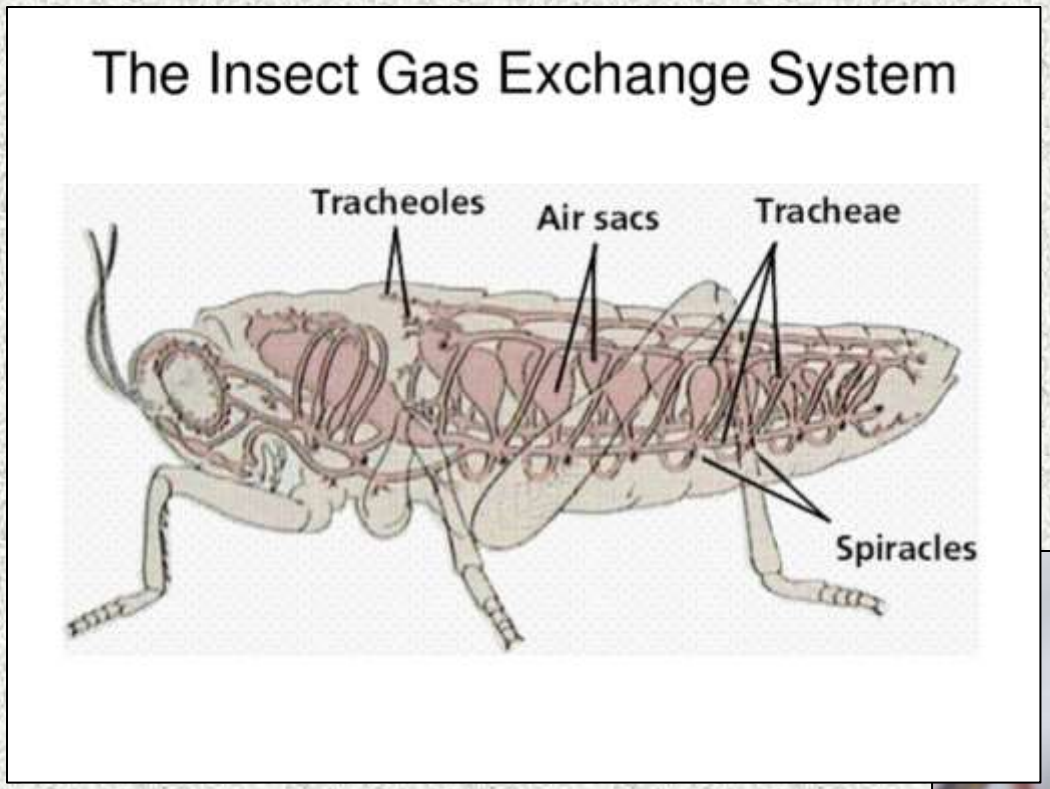
Feeding / Mouthparts

Vision

- Have complex <u>compound eye</u> which is usually extremely sensitive to motion and allows 360^0 vision
- Most insects see well into the UV spectrum



- Insects live on land and breathe by **tracheae.**



Insect Diversity

- Insects outnumber all other forms of life combined.
- Insects live in:
  - Almost every terrestrial habitat
  - Freshwater
  - The air
- Many insects undergo **metamorphosis** in their development.
- Young insects may:
  - Appear to be smaller forms of the adult or
  - Change from a larval form to something much different as an adult

Complete Metamorphosis

egg

larva

pupa

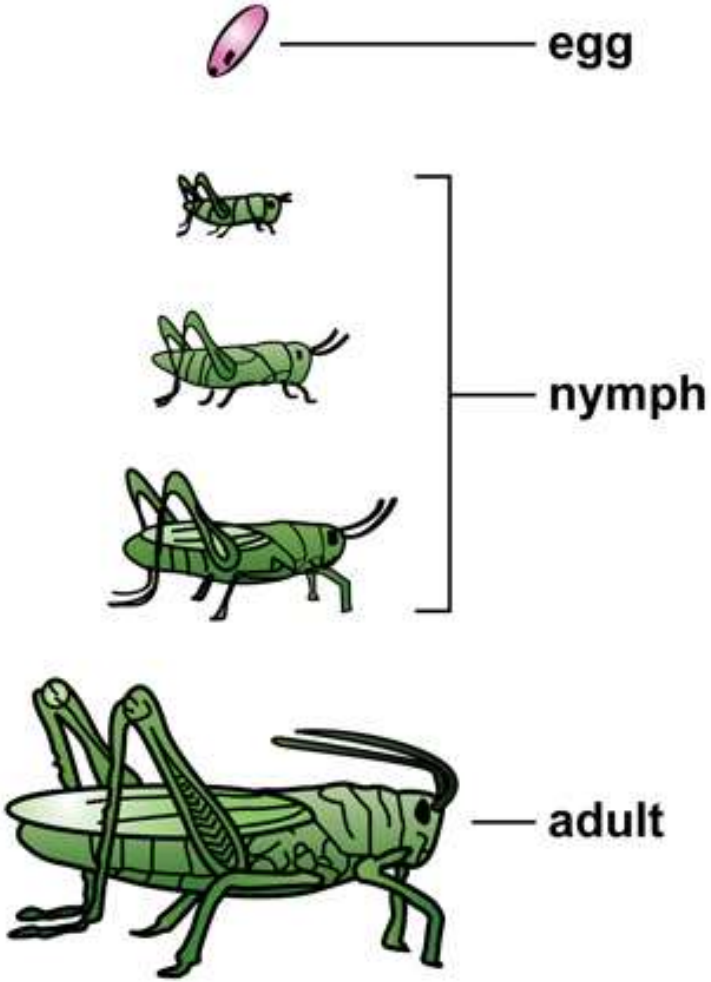
adult

Incomplete Metamorphosis

egg

nymph

adult



Many insects undergo *complete metamorphosis.*

Body parts are completely reorganized.

The larva (caterpillar) spends its time eating and growing, molting as it grows.

After several molts, the larva becomes a pupa encased in a cocoon.

Within the pupa, the larval organs break down and adult organs develop from cells that were dormant in the larva.

Finally, the adult emerges from the cocoon.

The butterfly flies off and reproduces, nourished mainly by calories stored when it was a caterpillar.

Banded Orange Heliconian

Giraffe weevil

Peacock katydid

Leaf roller

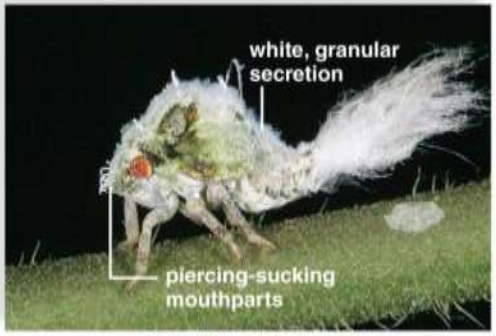
Praying mantis

Yellow jacket wasp

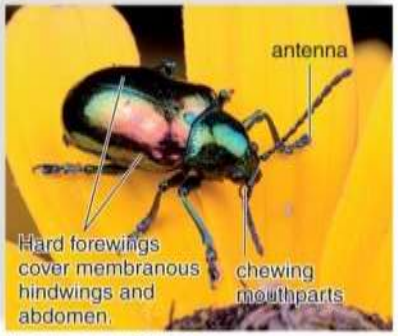
Leaf beetle

Longhorn beetle

Insect Diversity

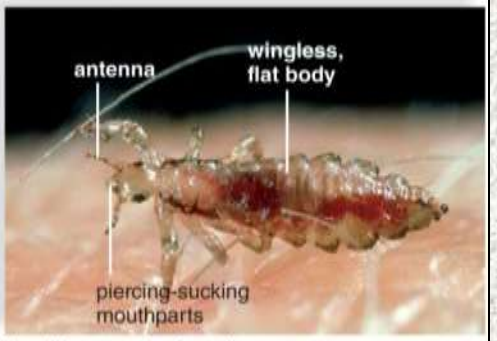


Mealybug, order Homoptera

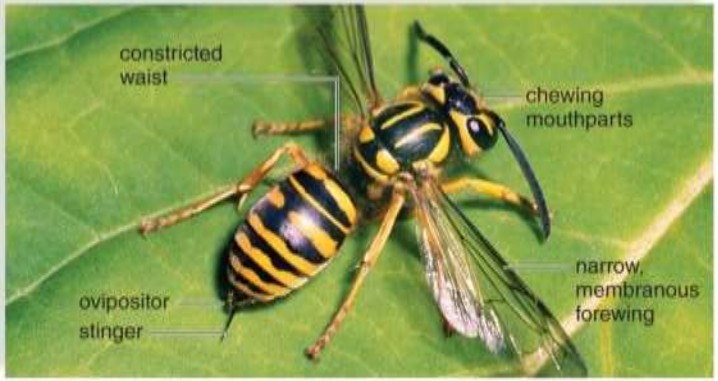


Beetle, order Coleoptera

Leafhopper, order Homoptera



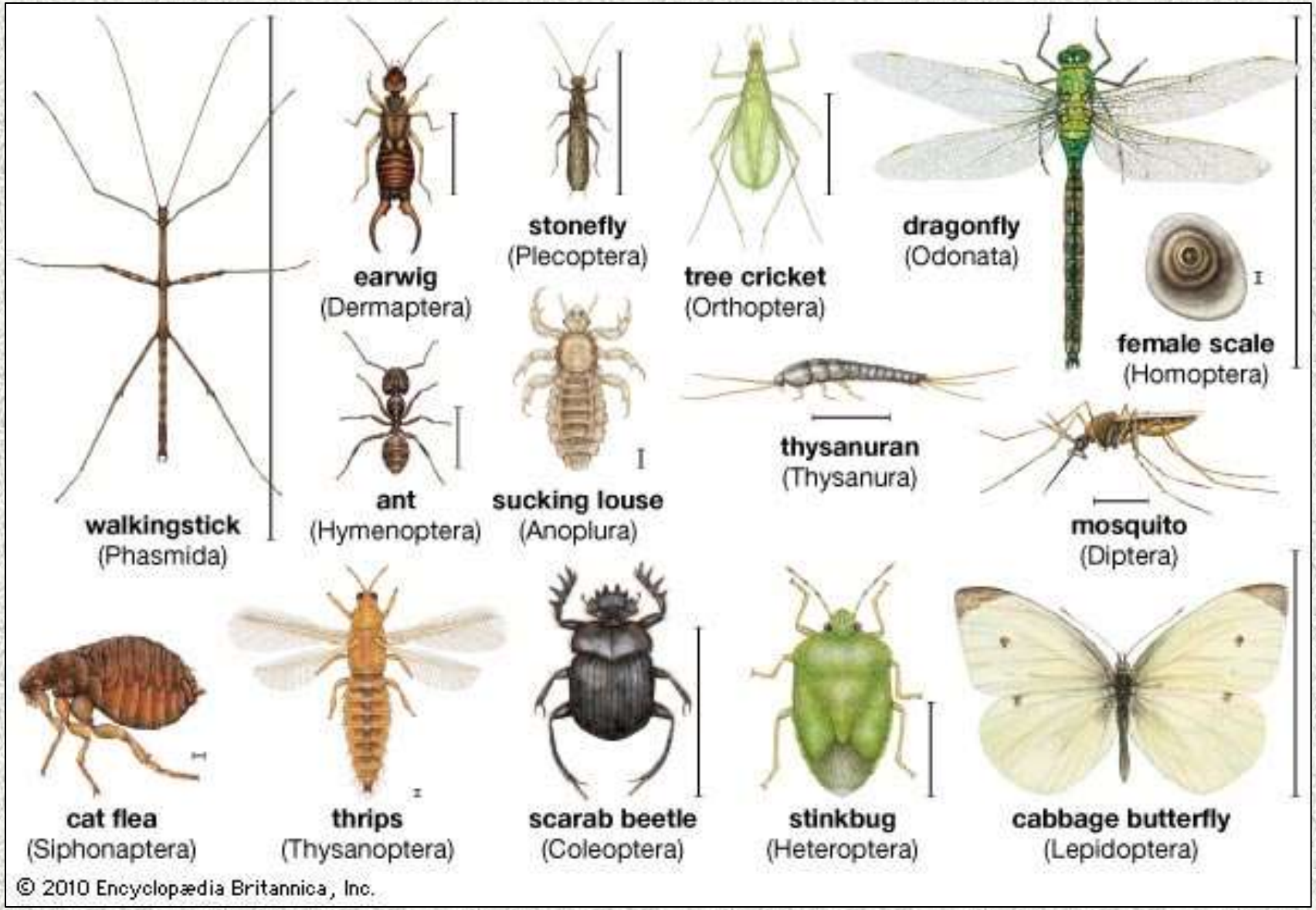
Head louse, order Anoplura



Wasp, order Hymenoptera

Dragonfly, order Odonata

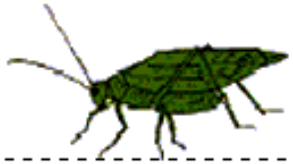
Insect Diversity



Dragonflies and Damselflies
Order Odonata

Beetles
Order Coleoptera

Grasshoppers and Crickets
Order Orthoptera



True Flies
Order Diptera

True Bugs
Order Hemiptera

Butterflies and Moths
Order Lepidoptera

Cicadas and Leafhoppers
Order Homoptera

Wasps, Bees, and Ants
Order Hymertoptera

Insect Origins

Class Collembola
Springtails

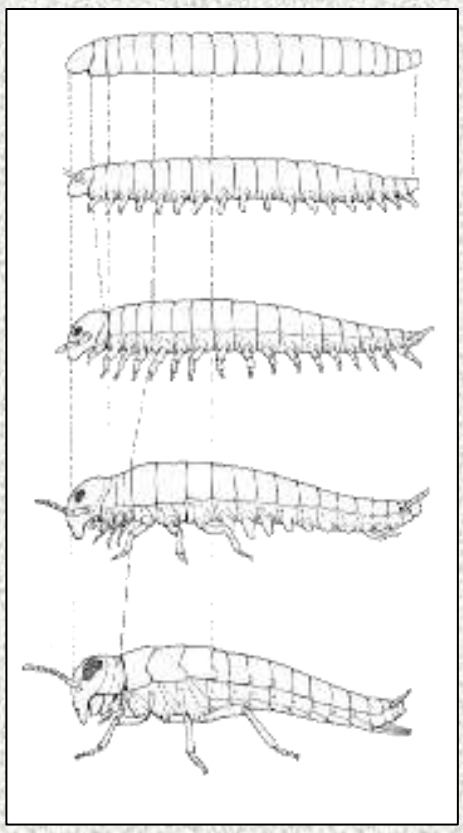
- Old group, 400 MY
- Among first Arthropods on land
- Small, live in leaf litter
- Jump by flicking tail

Springtails - Collembola, isotomurus species
https://www.youtube.com/watch?v=aX_s2edYauo

The Springtail – Part I and 2
https://www.youtube.com/watch?v=OwOL-MHcQ1w
https://www.youtube.com/watch?v=0Sq2gjsysG0

Insect Origins

- Oldest terrestrial Arthropods – 400 MYA, scorpions, centipedes, and millipedes
- Many Paleozoic Insect groups became extinct
- Oldest modern flying Insects - Carboniferous



Order Thysanura – Silverfish

- Never develop wings
- Feed on starch and glue

Order Plecoptera
Stoneflies

- Primitive group
- Carboniferous
- Generalized anatomy
- Chewing mouthparts
- Wings, but not strong fliers
- Most of life spent as a nymph in the water
- Adults short-lived
- Intolerant of pollution

Imitation Stonefly for Fly Fishing

Order Ephemeroptera - Mayflies

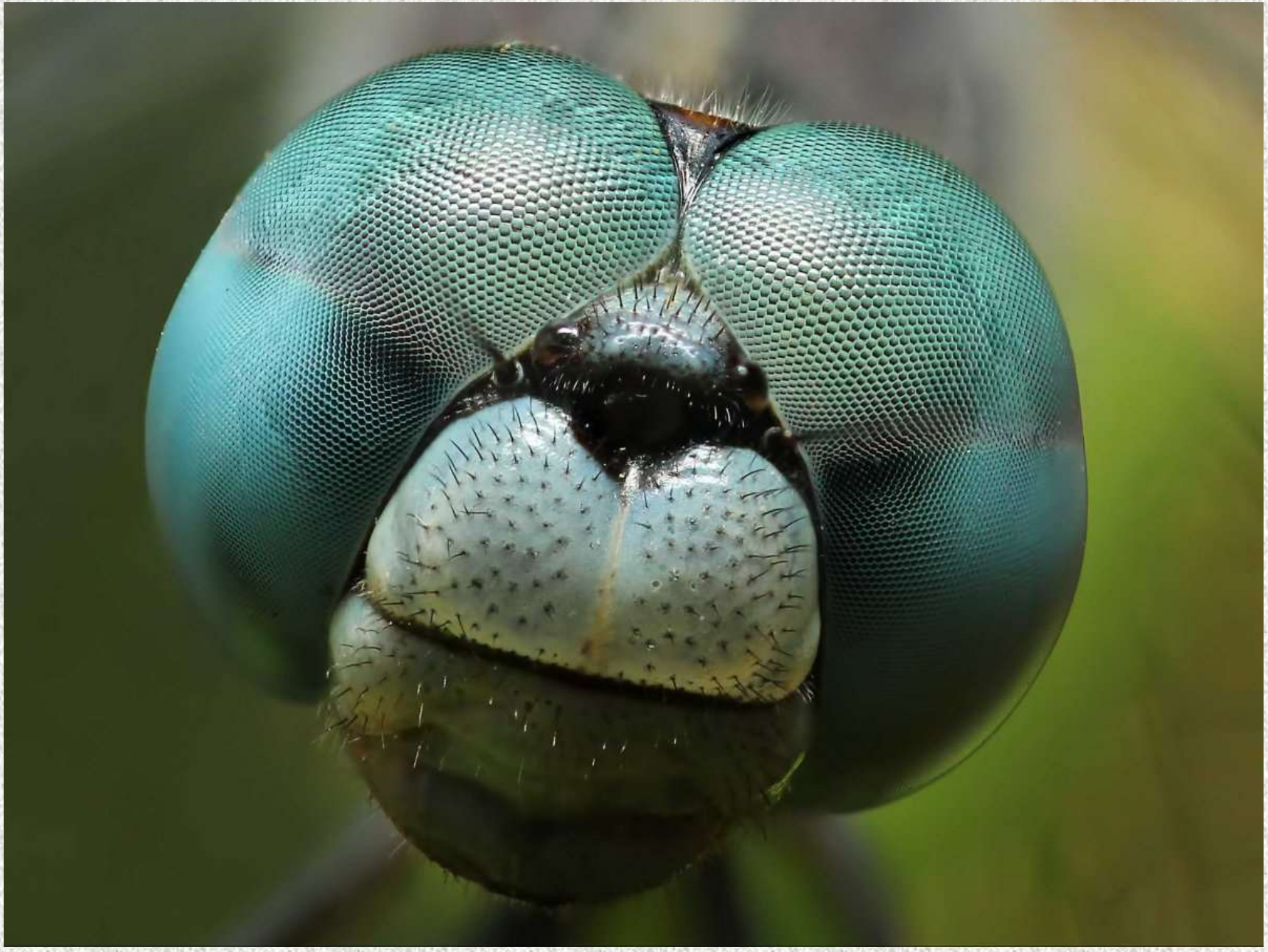
- Live for months as wingless aquatic larvae
- Adults emerge in great swarms, short-lived,
- Adults do not eat, mate only and lay eggs

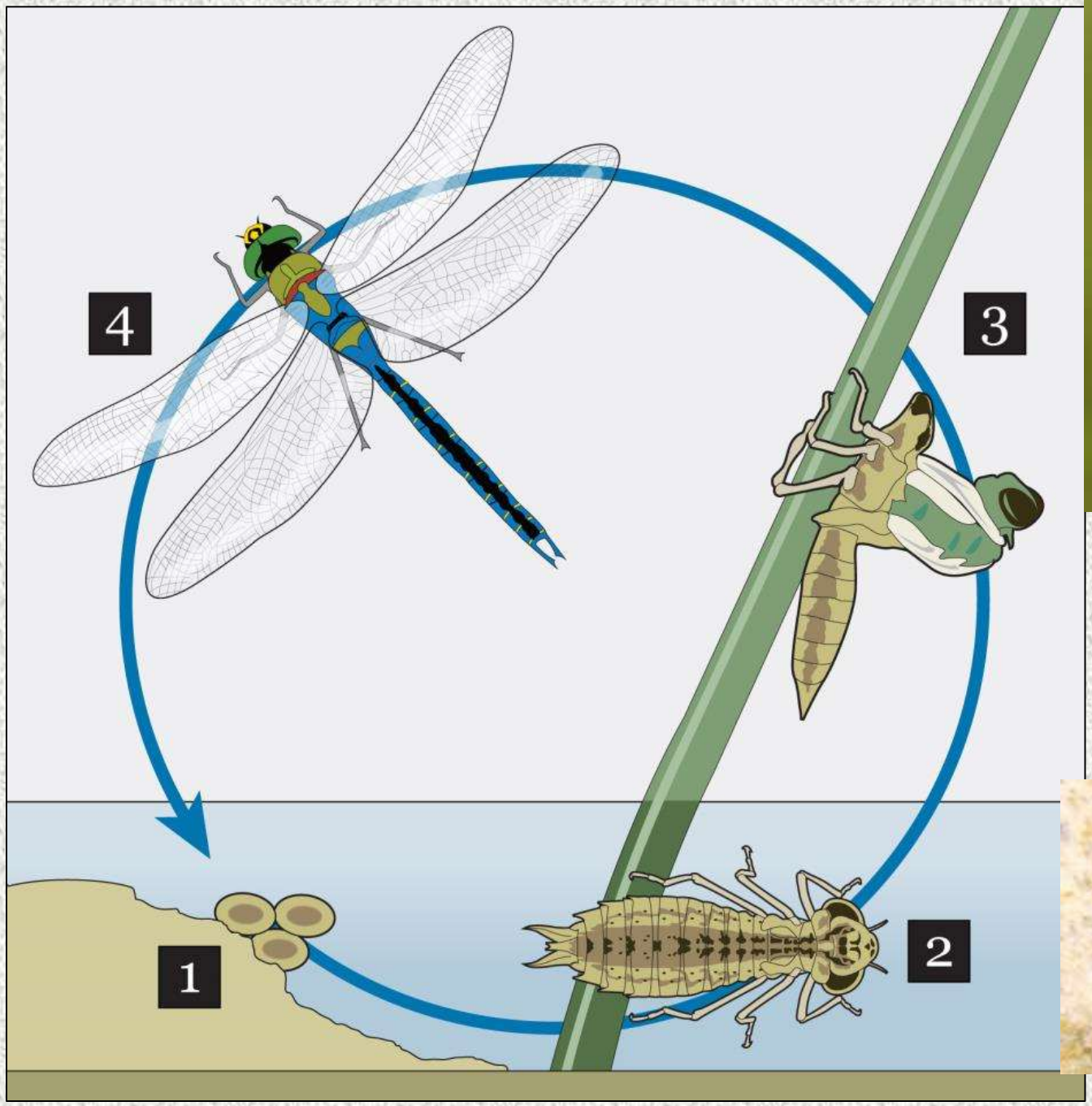
Swarming Mayflies in Wisconsin
https://www.youtube.com/watch?v=Nz_gAjp3zYc

Order Odonata
Dragonflies and Damselflies

- Ancient flying insects
- Cannot fold wings
- Larvae develop underwater, voracious predators
- Adults fast fliers, seize prey on the wing
- Damselflies more delicate

The Secret World of Dragonflies
https://www.youtube.com/watch?v=edW30jsCy6M
Dragonflies Hunting
https://www.youtube.com/watch?v=XWROwMxepoM
Sky Hunters, The World of the Dragonfly
https://www.youtube.com/watch?v=knlXTU1R_rE




4
3
1
2

Order Orthoptera
Crickets and Grasshoppers

- Long hind legs used for hopping
- Chewing mouthparts
- Most can fly
- Sometimes swarm and destroy crops
- Young develop directly into adults, no metamorphosis
- Grasshoppers have shorter antennae than crickets, tend to be diurnal
- Crickets nocturnal

Edible Grasshoppers

Entomophagy, the consumption of insects as food

Edible insects
https://www.youtube.com/watch?v=r9M2JPscbmQ
Why eating insects makes sense
https://www.youtube.com/watch?v=euTBQOrpOmM
Edible Insects--Cambodian-style!
https://www.youtube.com/watch?v=0yULy-ikeEU

Order Coleoptera
Beetles

- “Sheathed wing”
- First pair wings hardened, often shiny, as long as body, protect membranous flying wings
- Almost ¼ to ½ of all known animals are beetles
- Eat wide range of foods
- Many have chemical defenses
- Larvae often destructive


(c) A. Bockoven

Order Hemiptera
True Bugs

- “Half wing” part of first wing toughened or hard
- Posterior half of the front wings somewhat translucent or thinner and with veins
- Piercing and sucking mouthparts

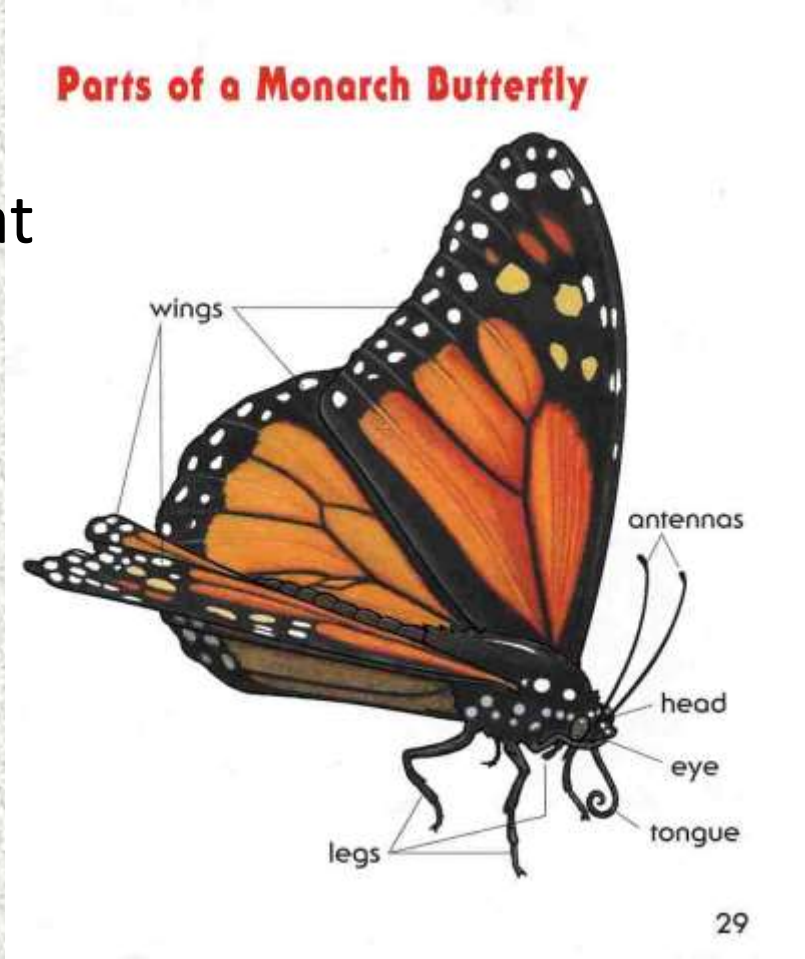
Order Diptera
Flies: mosquitos, gnats, midges

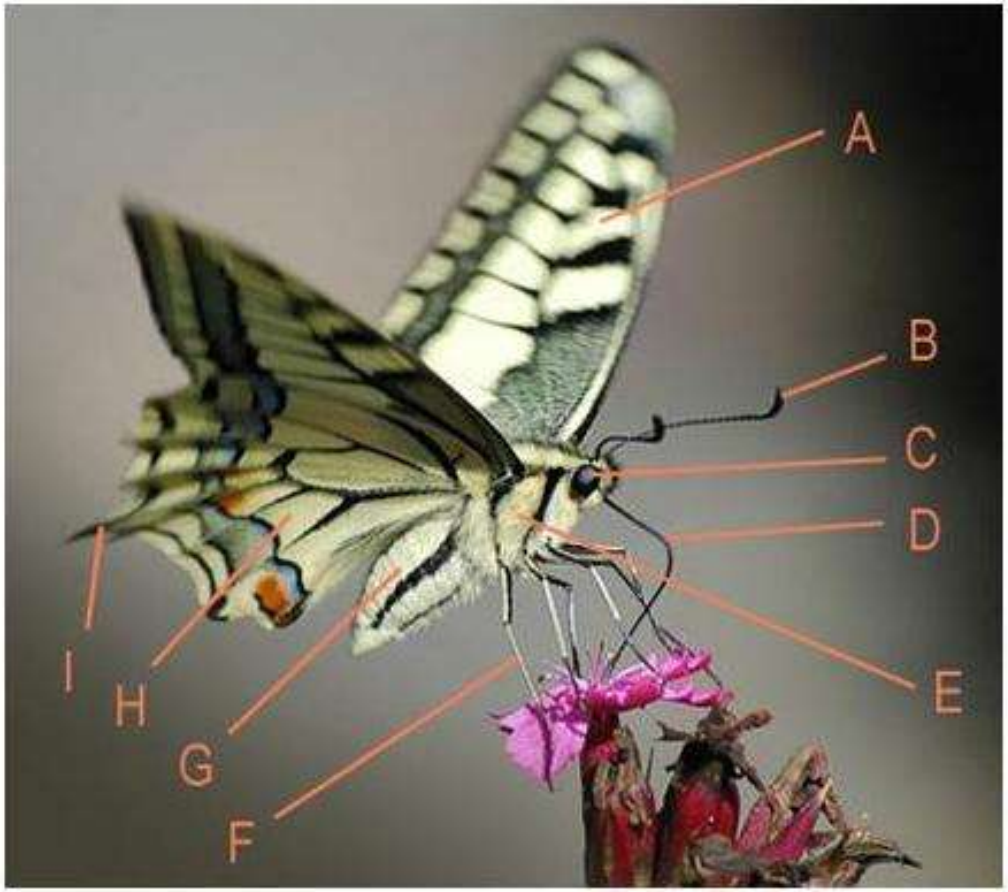
- “Two wings”
- Single pair of wings
- Hindwings reduced to halteres, stabilizers
- Sucking mouthparts
- Some pollinators, fly syndrome
- Some carry disease, mosquitos - malaria

Flies lifecycle (#115)
https://www.youtube.com/watch?v=lcjAedlIPoU
World's Weirdest: Flies and Maggots
http://video.nationalgeographic.com/video/weirdest-housefly-maggots

Order Lepidoptera
Butterflies and Moths

- 4 large wings, covered with small overlapping scales
- Thin antennae, small clubs at end
- Long **proboscis** for drinking nectar from flowers
- Caterpillars browse vegetation
- Pupae encased in cocoon
- Adults sip nectar

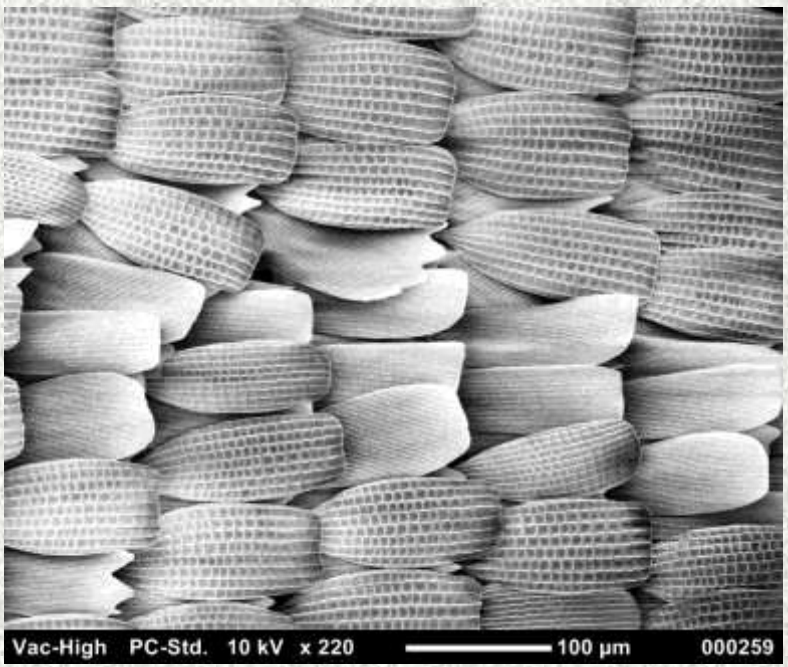


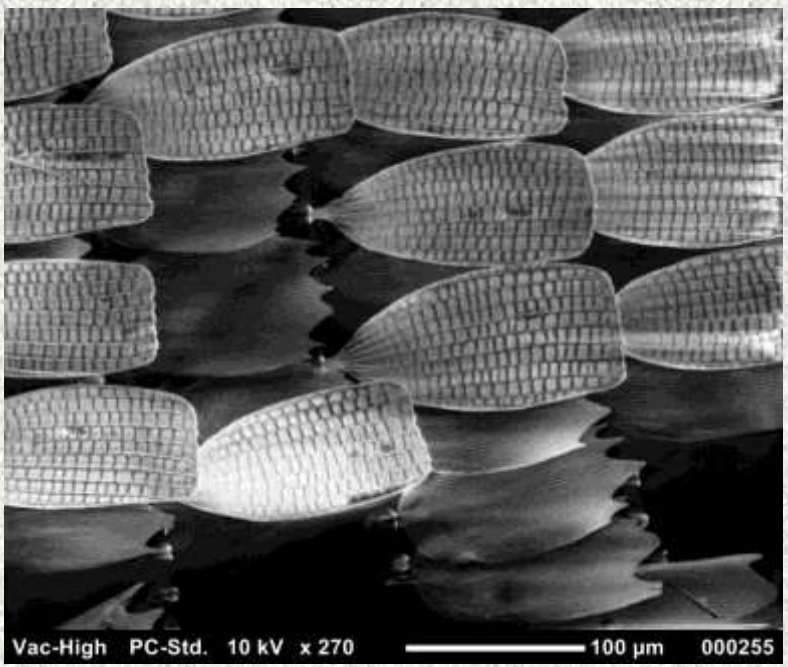


A. 2 Forewings
B. 2 Antennae
C. Head and 2 Eyes
D. Proboscis
E. Thorax
F. 6 Legs
G. Abdomen
H. 2 Hindwings
I. Scale on the wing

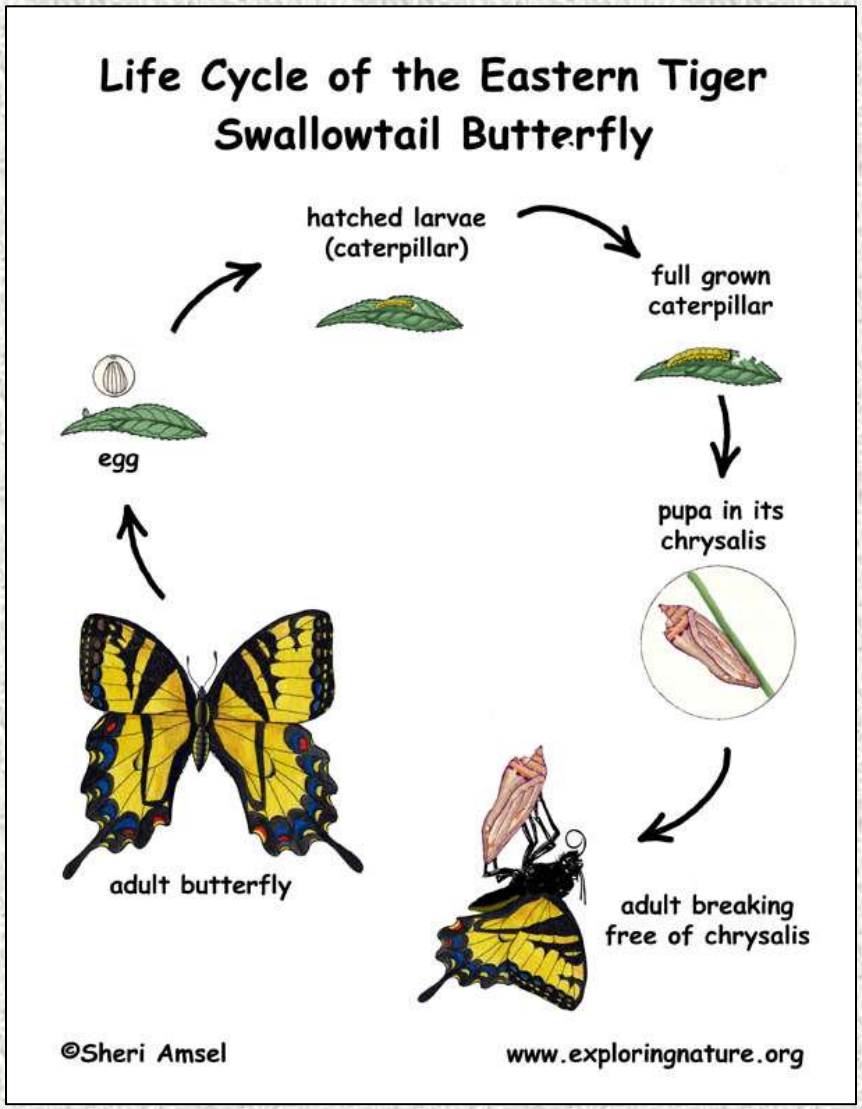
The wings are made up of many tiny scales and veins.

Emerald Swallowtail
Papilio palinurus
Wing Scales
MBG Butterfly House



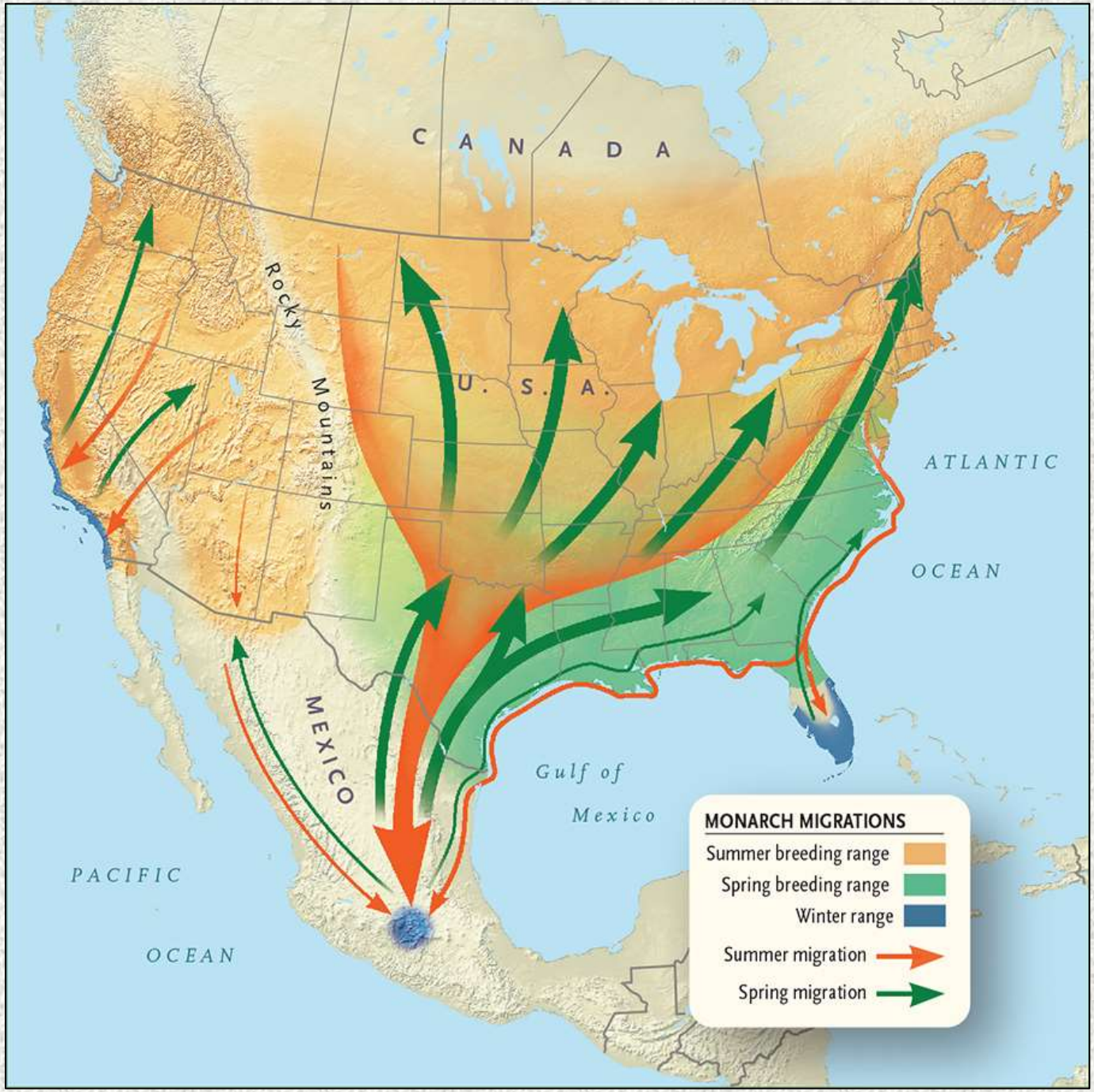


Butterfly Metamorphosis



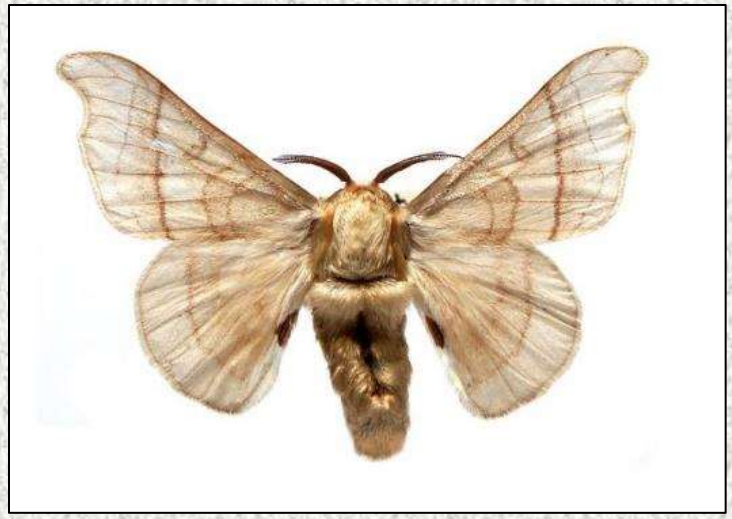
Monarch Butterfly Metamorphosis time-lapse
https://www.youtube.com/watch?v=ocWgSgMGxOc

Monarch Butterfly Migration



Lepidoptera - Moths

- Related to butterflies
- Most lepidopterans are moths, 160,000 spp.
- Mostly nocturnal, some diurnal
- Attracted to lights
- Dull colors
- Antennae lack clubs
- Silk Moths make silk
- Some pests in forest, damage clothes



Luna Moth life cycle
https://www.youtube.com/watch?v=atOSro3_W7c

Silkworm Moth, *Bombyx mori*

- Feeds on the leaves of the mulberry tree
- Cocoon thick , composed of a single thread commonly 900 meters (2,950 ft) long.
- Unraveled to provide commercial silk
- Domesticated 5,000 years ago in China

How silkworms make silk

https://www.youtube.com/watch?v=77ktNSPFbwQ

Order Hymenoptera
Bees, Wasps, Ants

- Very numerous and diverse
- Social ants and bees, worker and soldier castes, live in colonies controlled by a queen

- Bees important pollinators
- Flowers pollinated by bees are typically yellow or blue, provide nectar and pollen

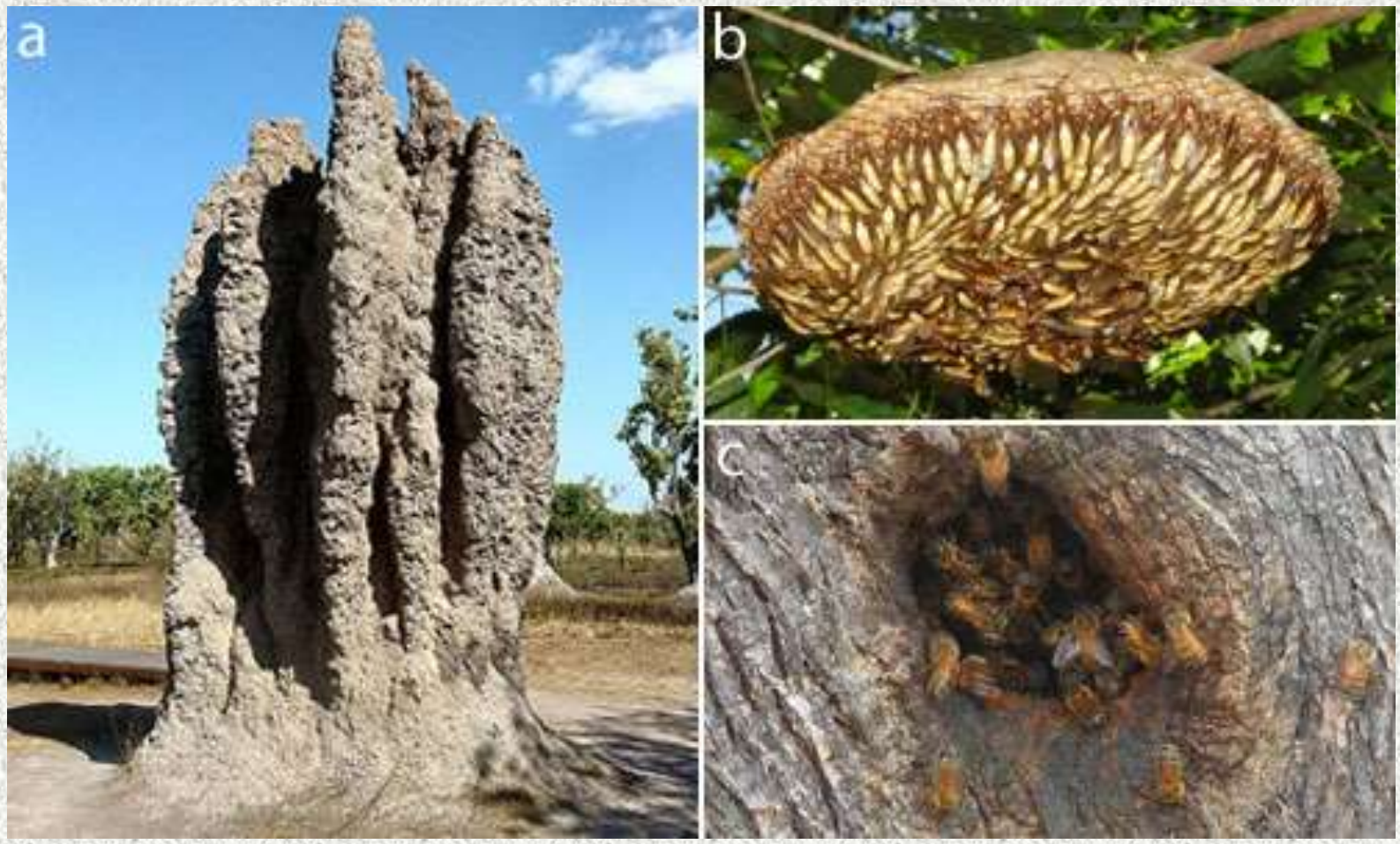
Honey bees are important pollinators in agriculture

Colony Collapse Disorder
Honeybees

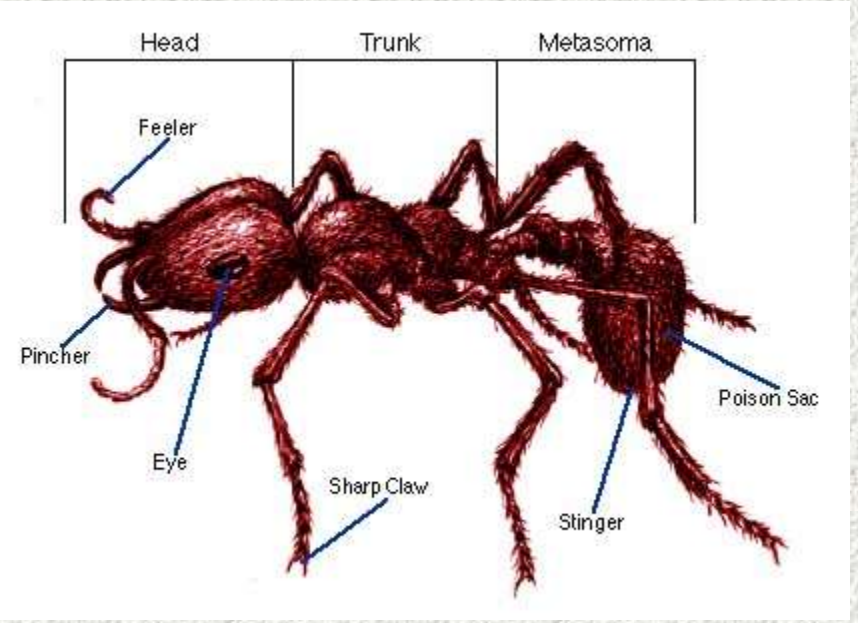
- Occurs when the majority of worker bees in a colony disappear and leave behind a queen, plenty of food and a few nurse bees to care for the remaining immature bees and the queen.
- 1972 to 2006, dramatic reductions in feral bees and commercial hives
- Possible causes – neonicotinoid pesticides, parasitic mites, disease, loss of habitat, stress

Great diversity of Native Bees

Social insects have well protected or defended nests, including termites (a), wasps (b), and bees (c).



Hymenoptera - Ants



Ant Sociality

Major and minor workers of leafcutter ants

Ant colony raids a rival nest
https://www.youtube.com/watch?v=X5YaihAtnC4

Army Ants Eat Everything
https://www.youtube.com/watch?v=UozWJTuhbMQ

Imported Fire Ant Biology
https://www.youtube.com/watch?v=NYKEprUQWZ4

ANTS - Nature's Secret Power (Full)
https://www.youtube.com/watch?v=Z-gIx7LXcQM

Ant Documentary
https://www.youtube.com/watch?v=AWLdJOHXH0U

Leaf Cutter Ants Documentary
https://www.youtube.com/watch?v=LJXVa8gxrOo

Order Isoptera - Termites

- Feed on decaying wood
- Social castes – workers, soldiers, queen
- Live in large colonies with single queen
- Build giant nests in tropics

Termites - The Inner Sanctum - The Secrets of Nature
https://www.youtube.com/watch?v=DXbo5ubYS9I
Lifestyle of the Termite Queen
http://video.nationalgeographic.com/video/termite_queen

End