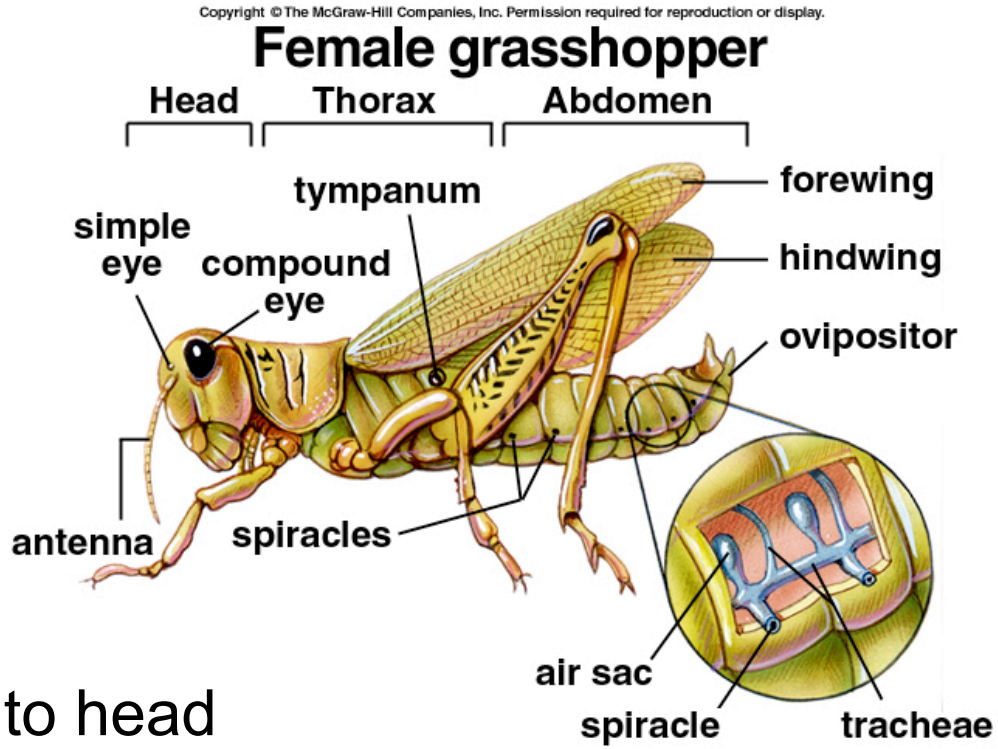
Subphylum Hexapoda

Capitulo 21

Diversity and Characteristics

- Members named for the presence of *six legs*
  - All legs are *uniramous*



- Have *3 tagmata*
  - Head
  - Thorax
  - Abdomen
    - *Appendages* attach to head and thorax

Diversity and Characteristics

Two classes within Hexapoda

Entognatha

Insecta

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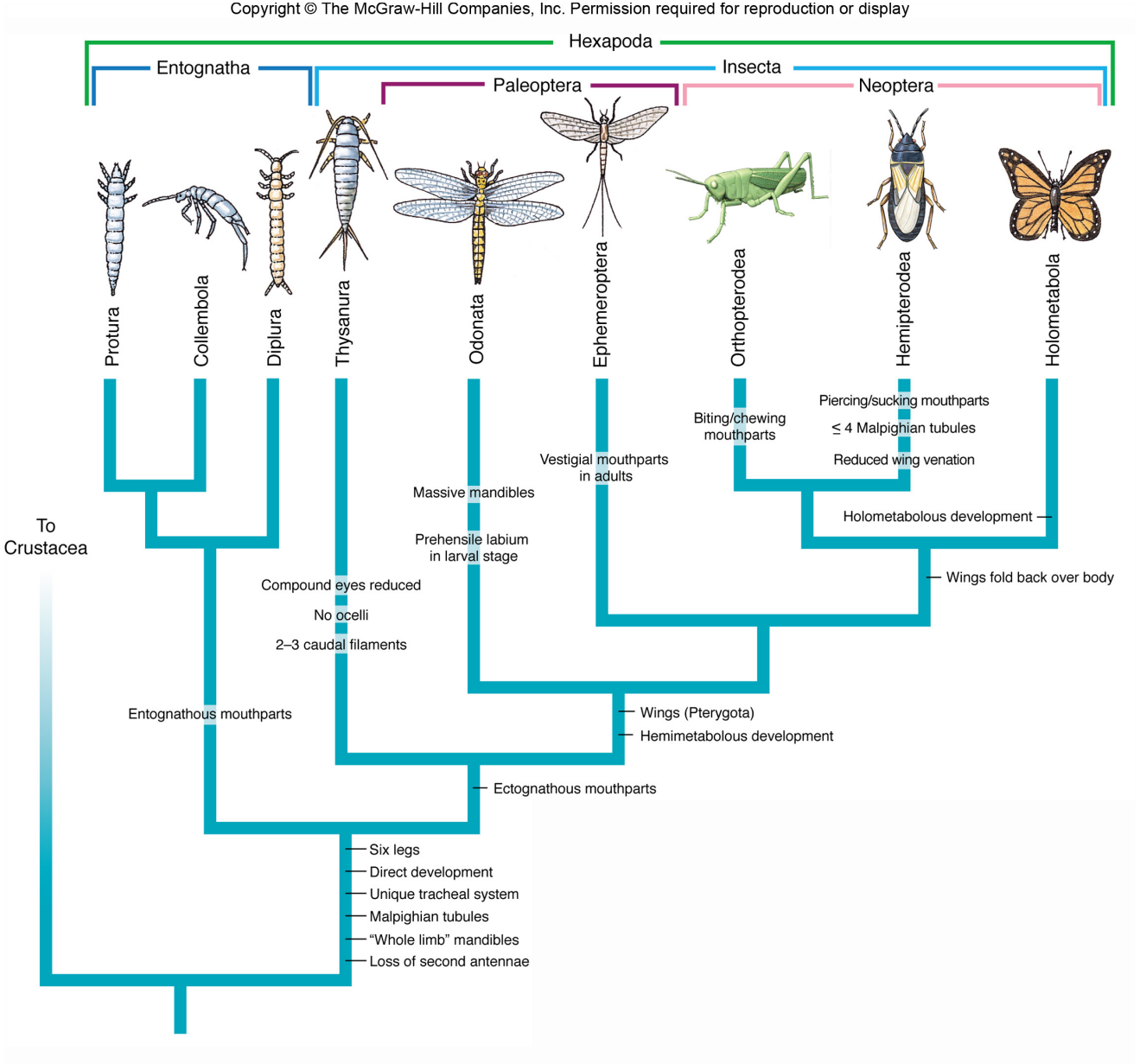
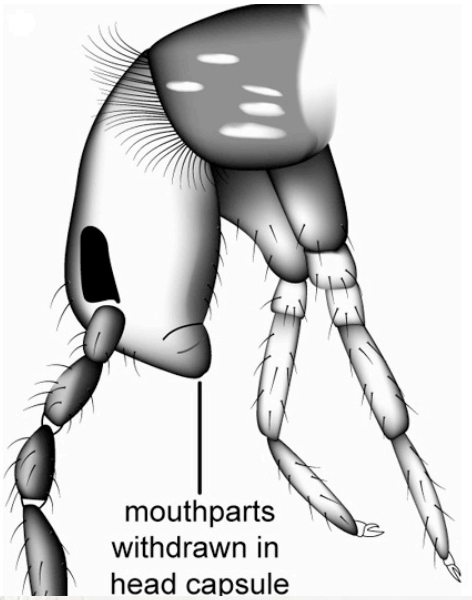


Class Entognatha

- Small group characterized by *bases of mouthparts enclosed within the head capsule*
  - 3 orders: Protura, Diplura, and Collembola
    - *Protura and Diplura*
      - Tiny, eyeless, and inhabit soils or dark, damp places
    - *Collembola*
      - Commonly called *springtails* because of ability to leap
      - Animal 4 mm long may leap *20 times its body length*
      - Members live in soil, decaying plant matter, on freshwater pond surfaces, and along seashore
      - Can be very abundant, reaching *millions per hectare*

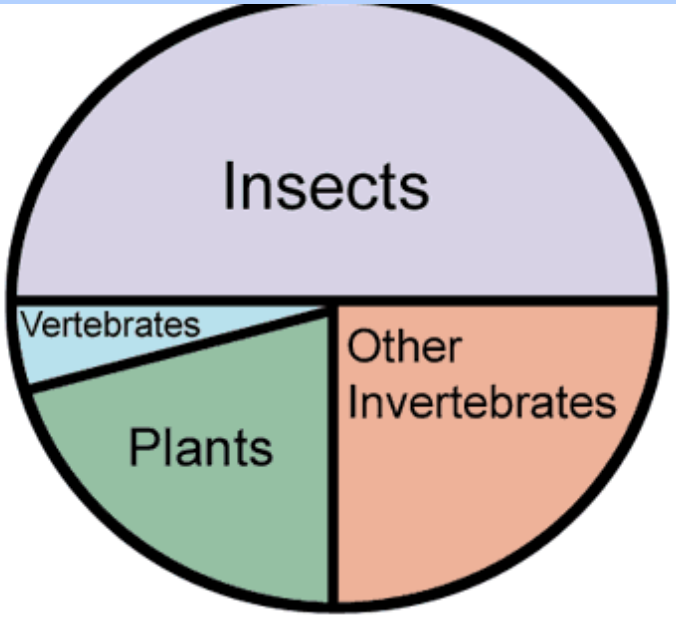


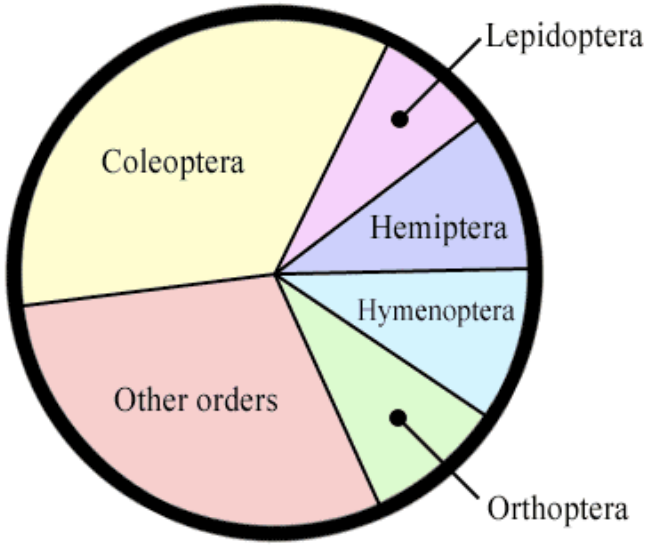
Class Insecta

- Enormous class whose members have ectognathous mouthparts, however, bases of mouthparts lie *outside the head capsule*
  - **Pterogotes**: winged insects
    - pair of wings on the thoracic region of the body
  - **Apterogotes**: wingless insects
  - Range from less than 1 mm to 20 cm in length
    - **Larger insects are tropical**

Class Insecta

- *Diversity*
  - *Most diverse and abundant* of al arthropods
  - Number of known species estimated at 1.1 million, but estimated that there *may be as many as 30 million species worldwide*
  - Play major medical and economic roles with humans, and also play critical ecological roles



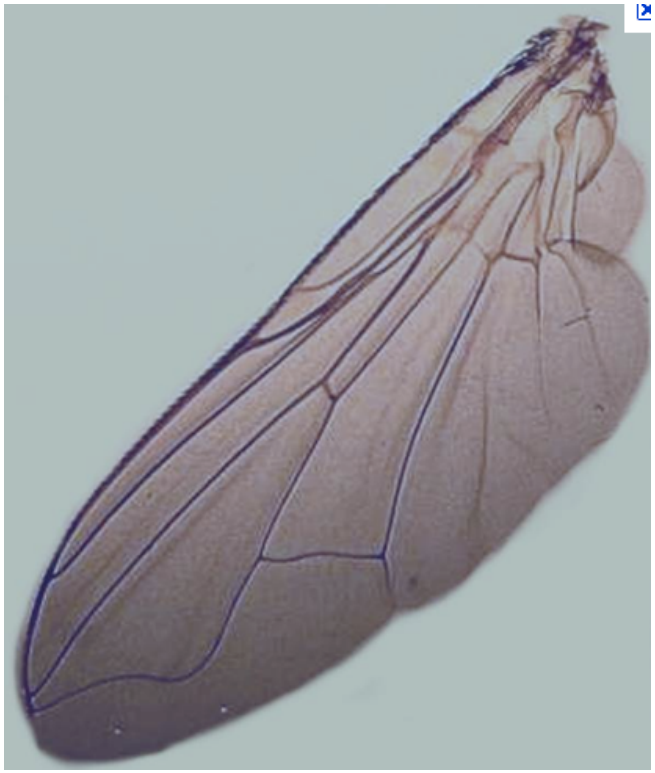


Class Insecta

- *Distribution*
  - Found in nearly all habitats except the sea
  - Common in freshwater, brackish water, and salt marshes
  - Abundant in soils, forest canopies, and can be found in deserts and wastelands
  - Most animals and plants have insects as parasites externally and internally

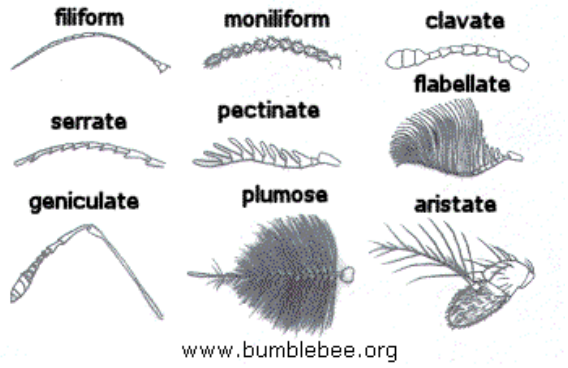
Class Insecta

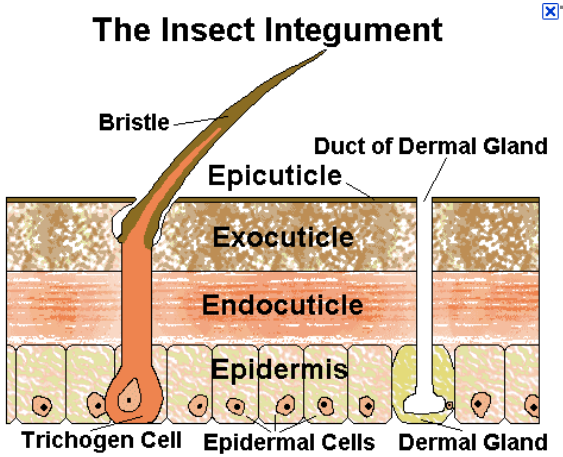
- *Adaptive Traits*
  - Flight and small size makes insects widely distributed
  - Well-protected eggs withstand rigorous conditions and are readily dispersed
  - Wide variety of structural and behavioral adaptations gains them access to every possible niche

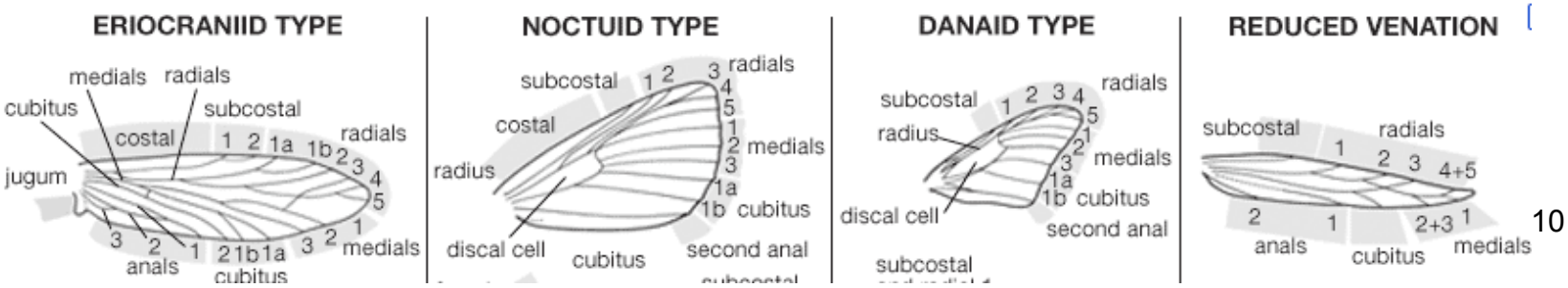


Class Insecta

- *Adaptability*
  - Most structural modifications are in wings, legs, antennae, mouthparts, and alimentary canal
  - Hard, protective exoskeleton well-adapted to life in desert regions
  - Exoskeleton holds in water, a factor that allows desert survival







Class Insecta

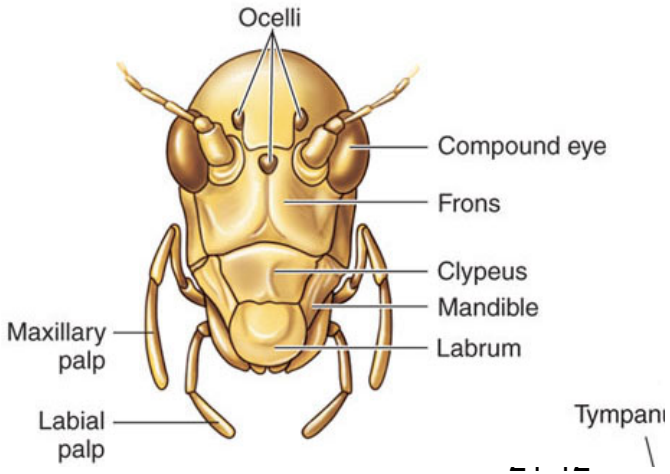
External Form and Function

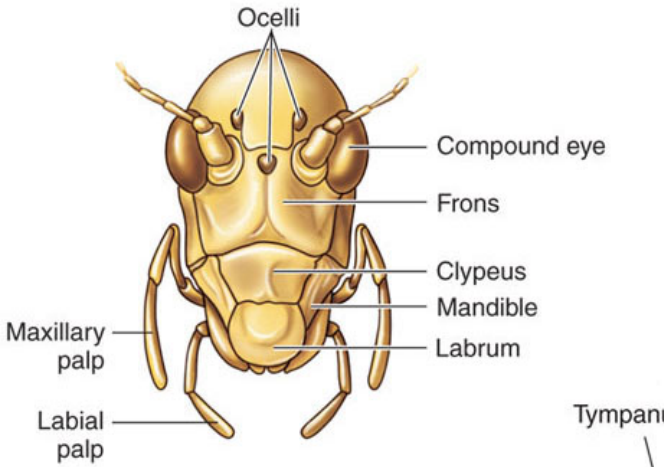
- Exoskeleton composed of complex plates, or *sclerites,* connected by hinge joints
  - **Muscles attaching sclerites allow *precise movement***

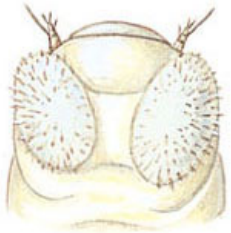
- *More homogenous in tagmatization than the variable crustaceans*

Class Insecta

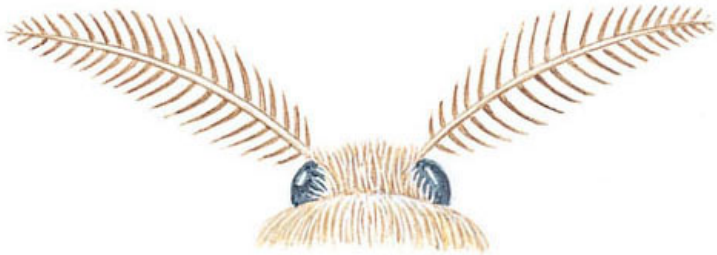
- *Head*
  - Usually equipped with pair of large compound eyes
  - One pair of antennae varies greatly in
    - Function in touch, taste, hearing
  - Mouthparts consist
    - Labrum
    - Pair of mandibles and maxillae,
    - Labium
    - Hypopharynx





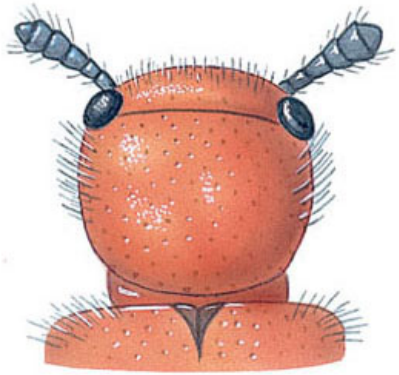


Silkworm larva

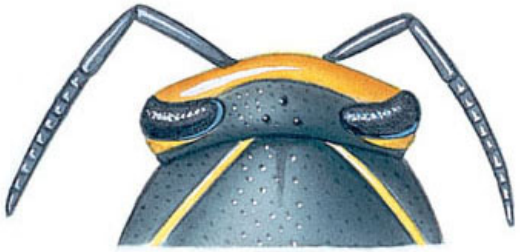


Silkworm moth

Japanese beetle



Checkered beetle

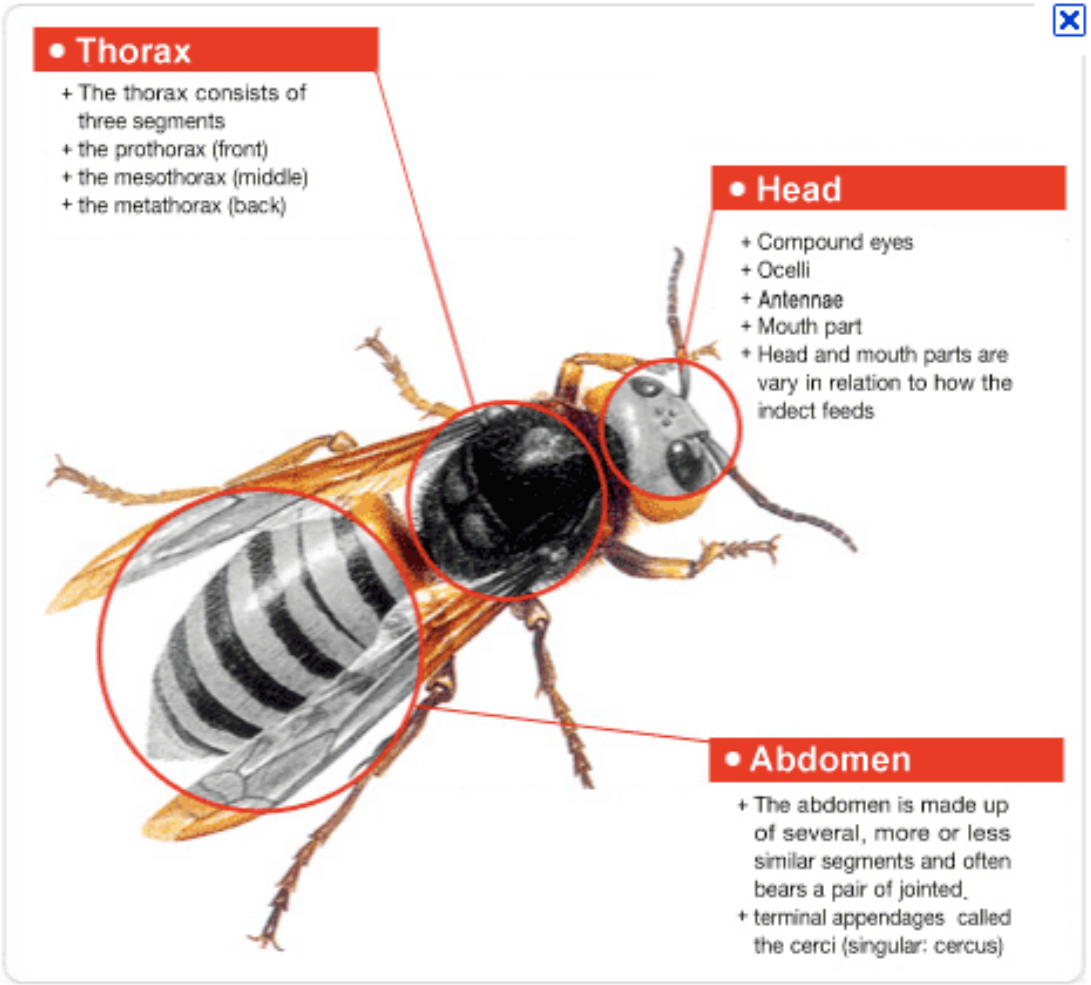


Yellow jacket

Syrphid fly

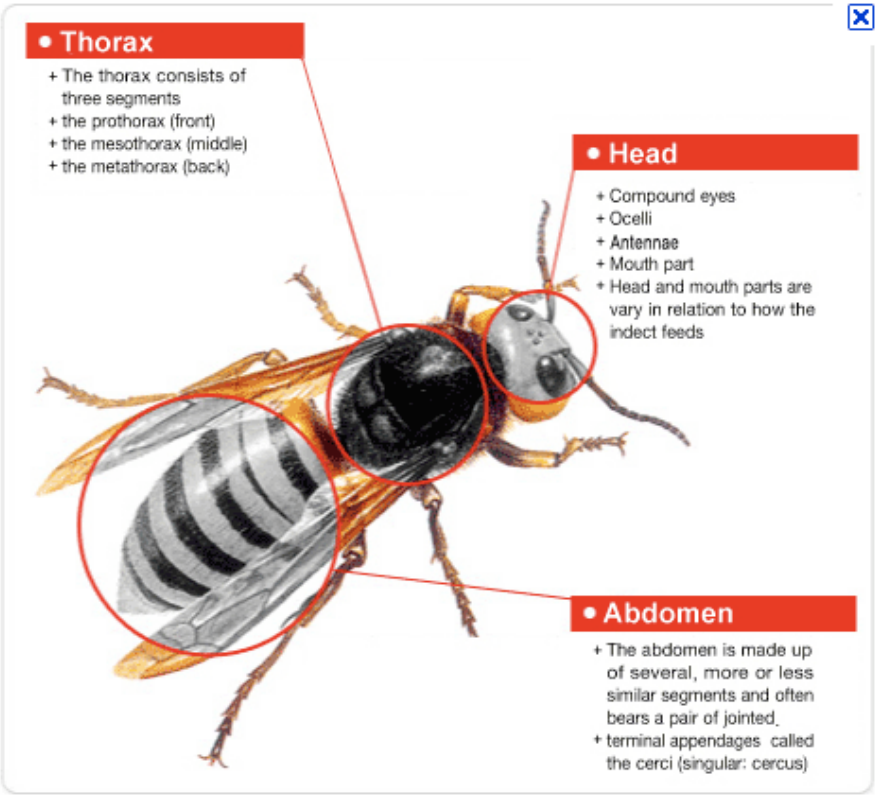
Class Insecta

- *Thorax*
  - Consists of the *prothorax, mesothorax and metathorax*
  - Each section has a pair of legs



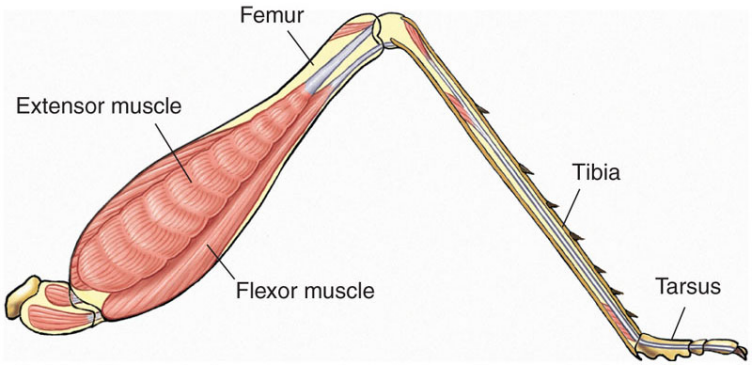
Class Insecta

- *Wings*
  - *If two pairs present:* located on the mesothorax and metathorax
  - Consist of a *double membrane*
  - Veins serve to strengthen the wing
    - *Vein pattern* used to identify insect taxa



Class Insecta

- *Legs*
  - Walking legs end in terminal pads and claws
  - Hindlegs of grasshoppers and crickets are enlarged for jumping
  - Mole crickets have front legs adapted for burrowing in ground



Class Insecta

- *Legs*
  - Forelegs of praying mantis allow it to grasp prey

  - Honeybees have leg adaptations for collecting pollen

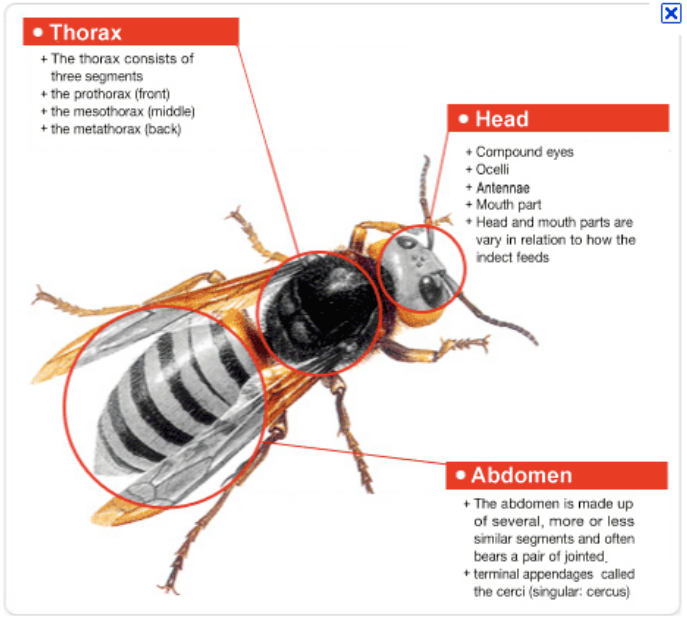
Class Insecta

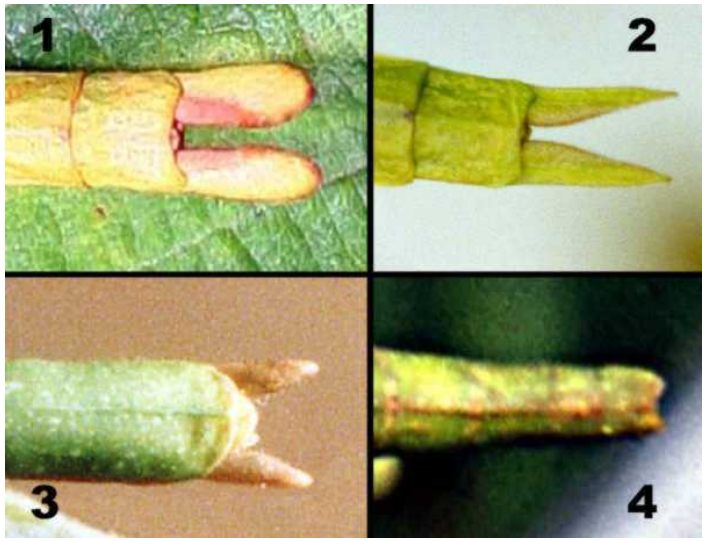
Abdomen

- 9 to 11 segments
- Last is reduced to a pair of cerci

- **Larval and nymphal forms may have abdominal appendages <u>lacking in adults</u>**

- External genitalia usually at end of abdomen





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Class Insecta

- *Variations in Body Form*

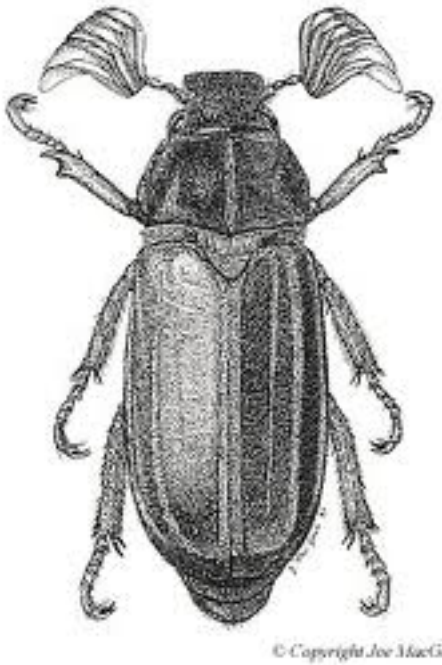
Aquatic beetles are streamlined

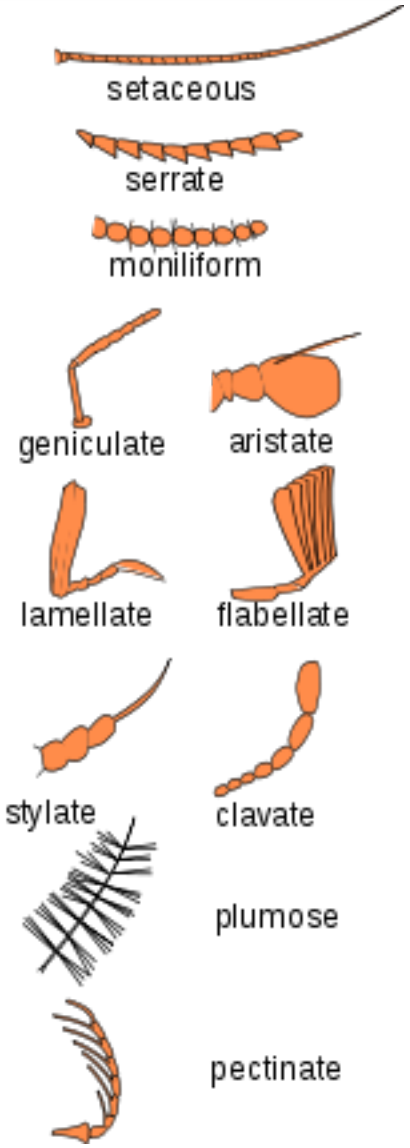
Land beetles are thick and shielded

Cockroaches are flat and live in crevices

Class Insecta

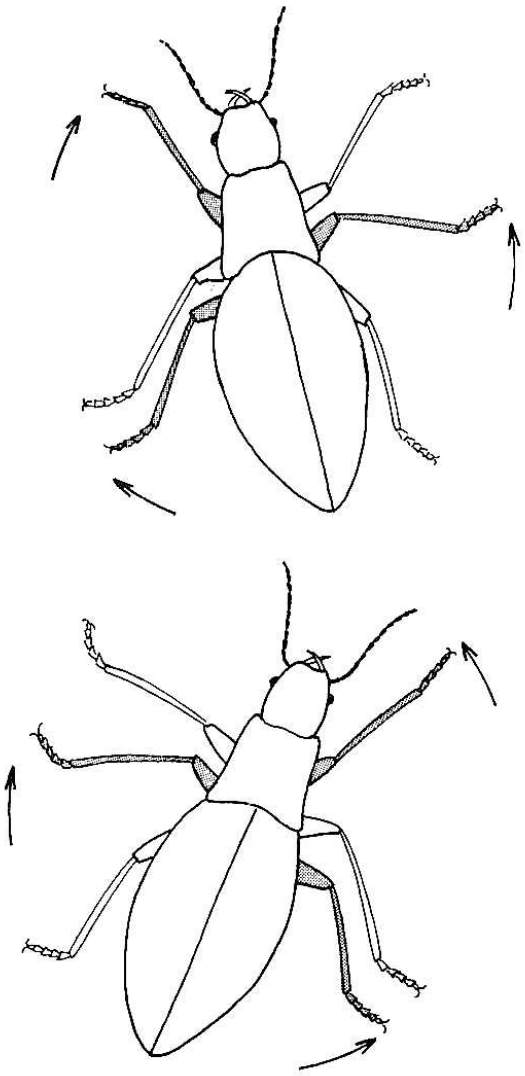
- *Variations in Body Form*
  - Antennae vary widely from long to short, plumed to knobbed





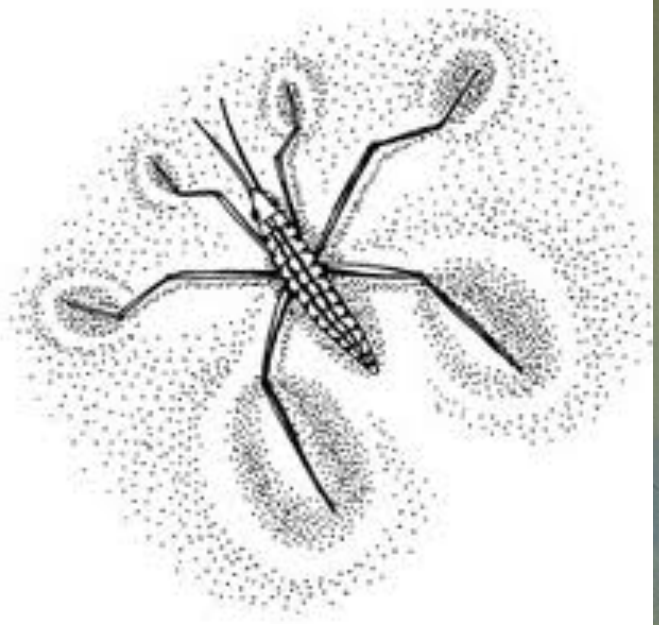
Class Insecta

- *Locomotion: Walking*
  - Insects walk using first and last leg on one side and middle leg on the opposite side in alteration with the reverse
    - Provides stability



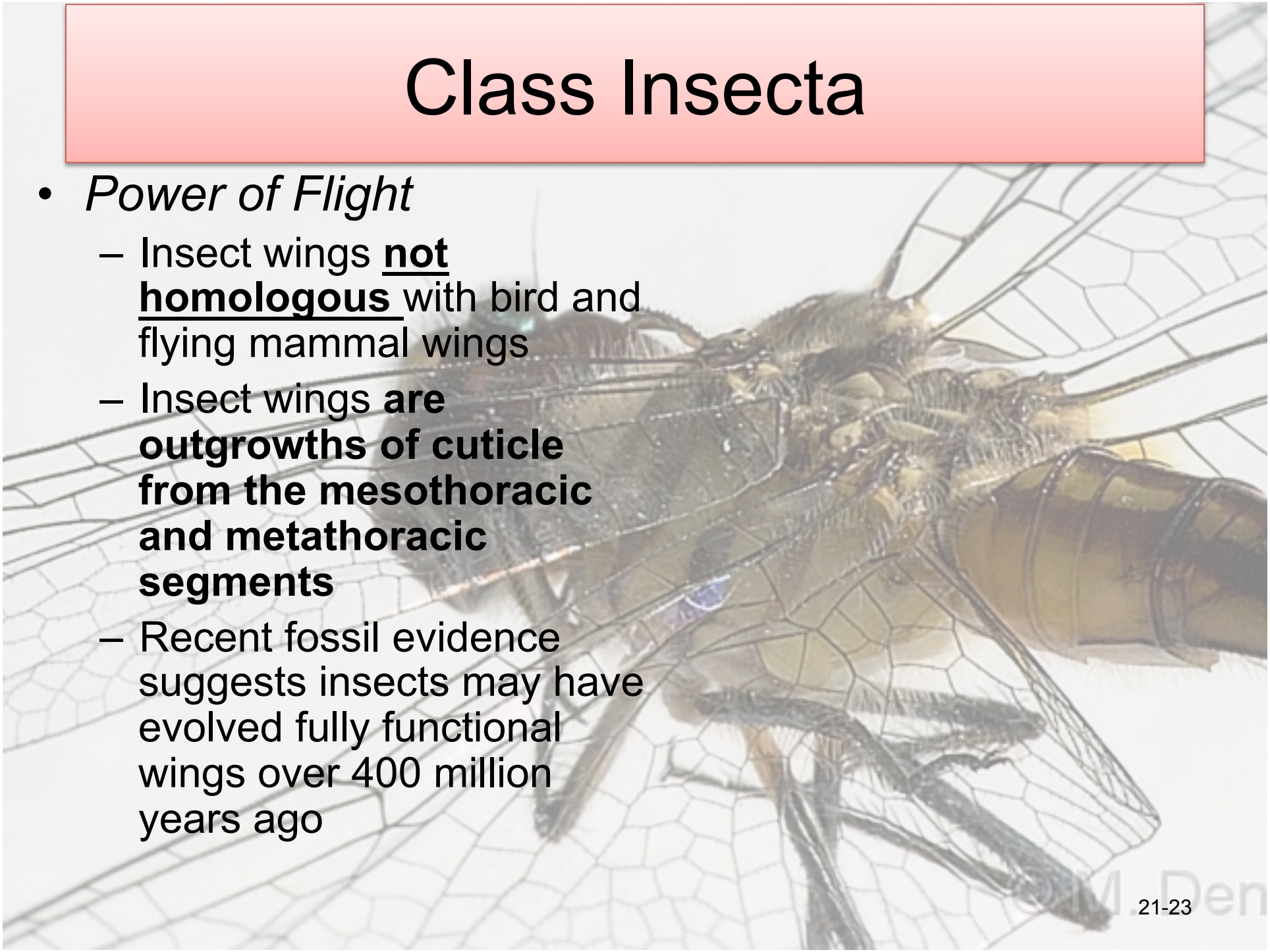
Class Insecta

- *Locomotion: Walking*
  - A water strider has non-wetting footpads that do not break the surface water tension



Class Insecta

- *Power of Flight*
  - Insect wings **not homologous** with bird and flying mammal wings
  - Insect wings **are outgrowths of cuticle from the mesothoracic and metathoracic segments**
  - Recent fossil evidence suggests insects may have evolved fully functional wings over 400 million years ago



Class Insecta

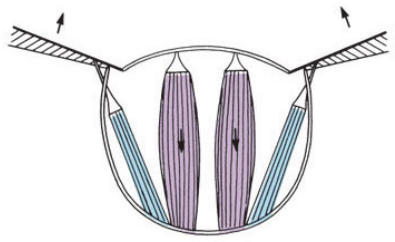
- Most flying insects have 2 pairs of wings
  - Diptera (true flies) have one pair
  - *Halteres* are reduced wings that provide the fly with balance during flight
  - Non-reproductive ants and termites are wingless
  - Lice and fleas have also lost wings

Class Insecta

- *Modifications of Wings*
  - *Wings for flight* are thin and membranous
  - The thick and horny front wings of beetles are protective
  - Butterflies have wings covered with scales
  - Caddisflies have wings covered with hairs

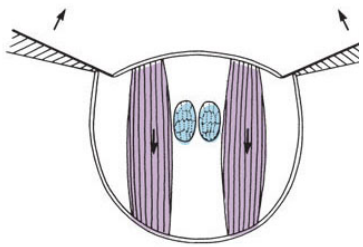
Class Insecta

- *Flight Muscles of Insects*
  - *Direct flight muscles* attach to wing directly
  - *Indirect flight muscles* alter the shape of the thorax to cause wing movement
  - Wing is hinged on a pleural process that forms a fulcrum
  - Insects cause the *upstroke* with indirect muscles that pull the *tergum downward*



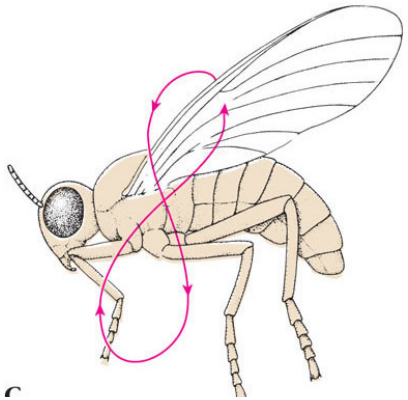
Direct and indirect flight muscles of locusts and dragonflies

A



Indirect flight muscles of flies and midges

B



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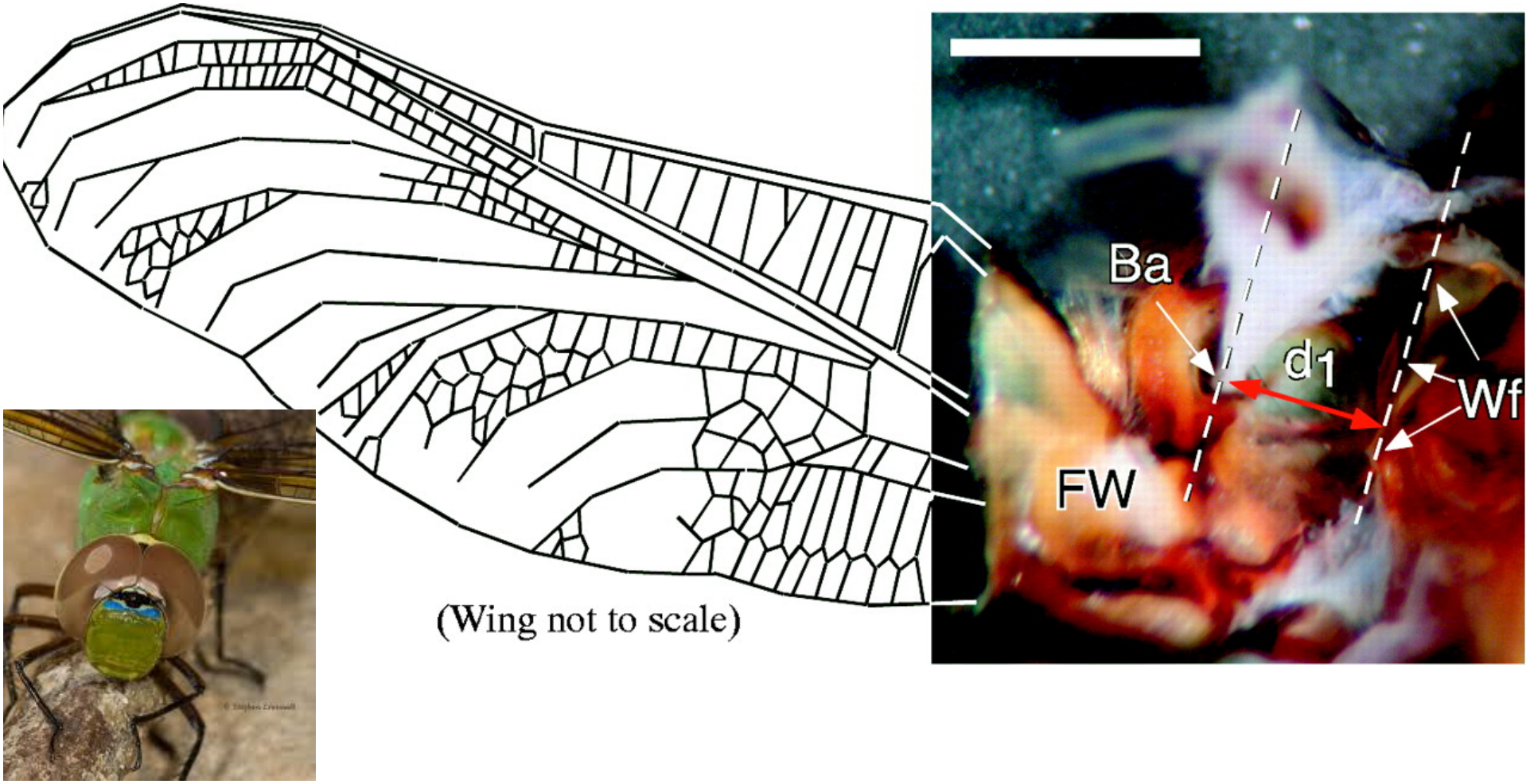
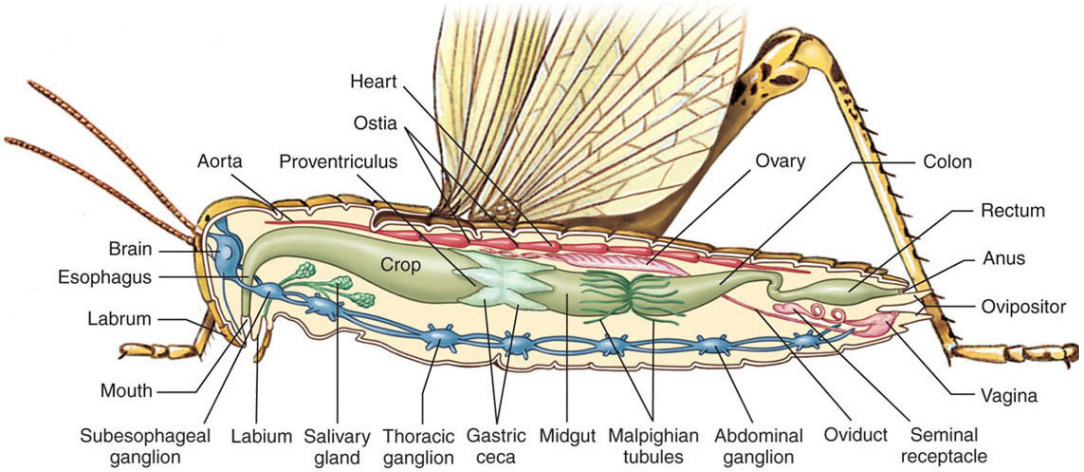


Detailed ventral view of the internal surface of the *Anax junius* dorsal thorax at the base of the forewing, showing the location of the basalar muscle apodeme (Ba) and the wing fulcrum (Wf) of the forewing (FW). The distance between these two structures is the muscle apodeme-to-wing fulcrum lever arm length (d1). All muscle tissue has been removed. Scale bar, 1 mm. A portion of the wing is drawn to orient the reader; this wing is not to scale.

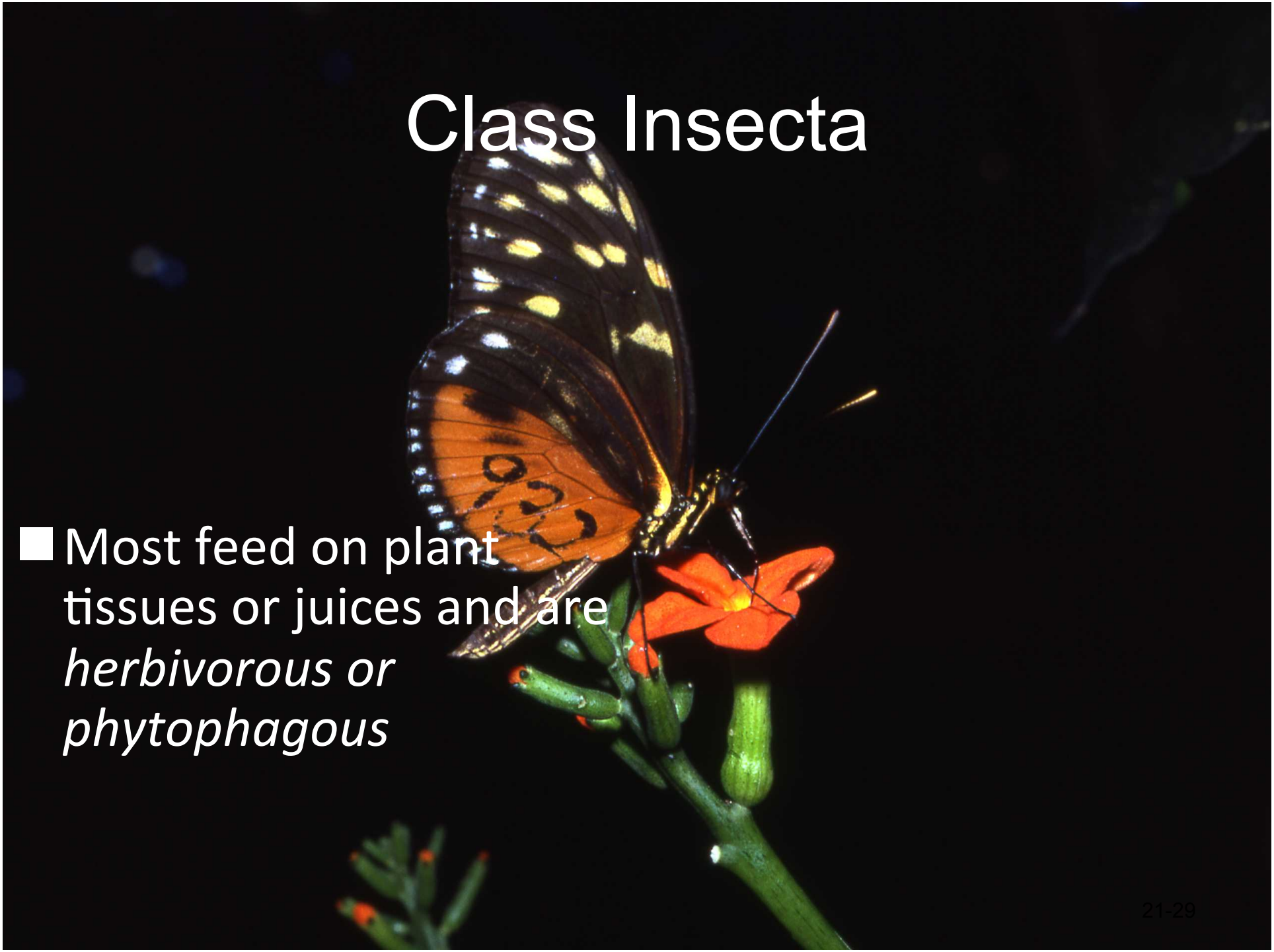
Class Insecta



Digestive System

- Foregut
  - Mouth with salivary glands, esophagus, crop, and gizzard
  - Some digestion, but no absorption, occurs in crop as salivary enzymes mix with food
  - Gizzard grinds food before it enters the midgut
- Midgut
  - Primary site of digestion and absorption
  - Ceca may increase digestive and absorptive area
- Hindgut
  - Primarily a site for water absorption

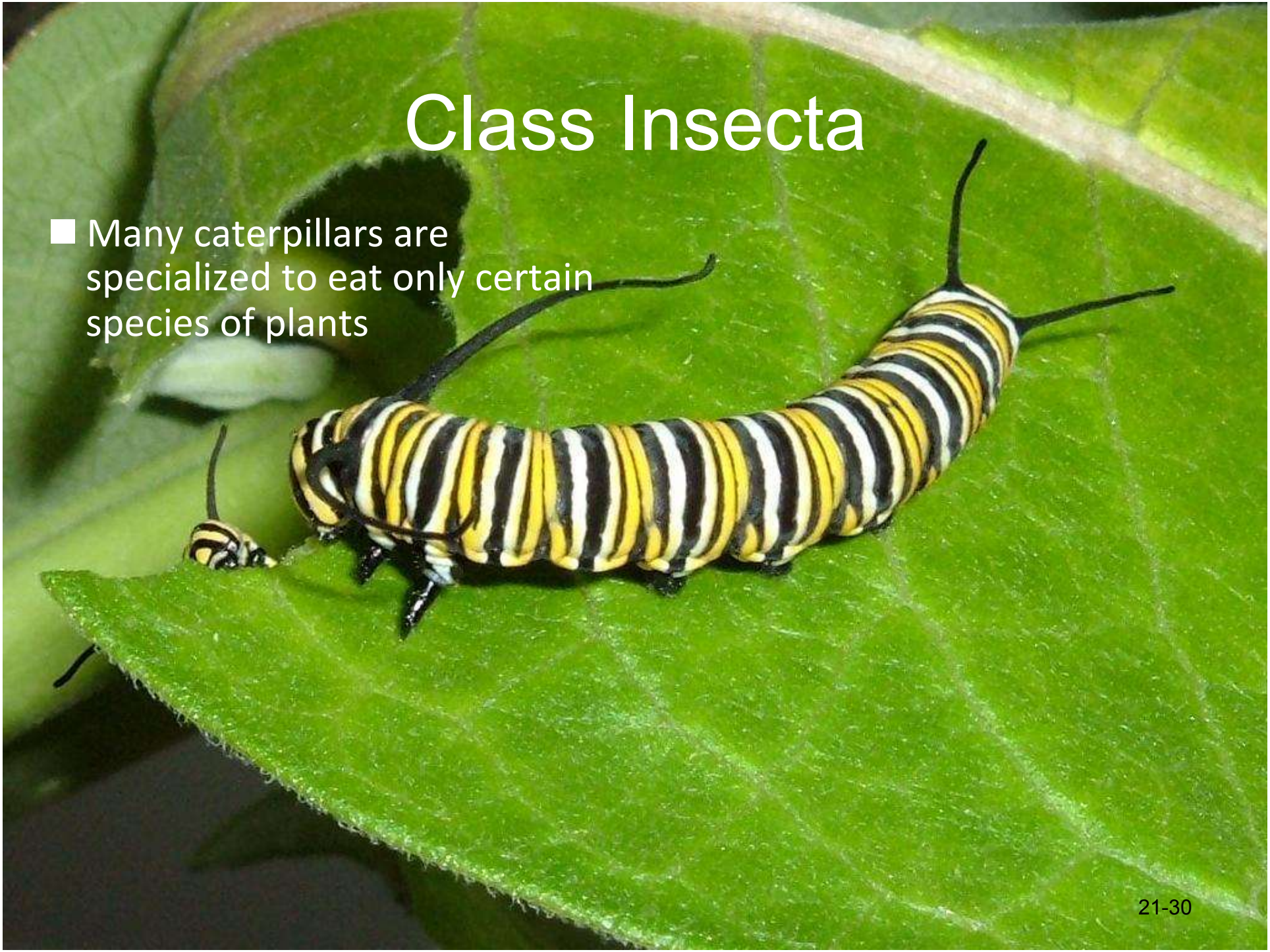
Class Insecta



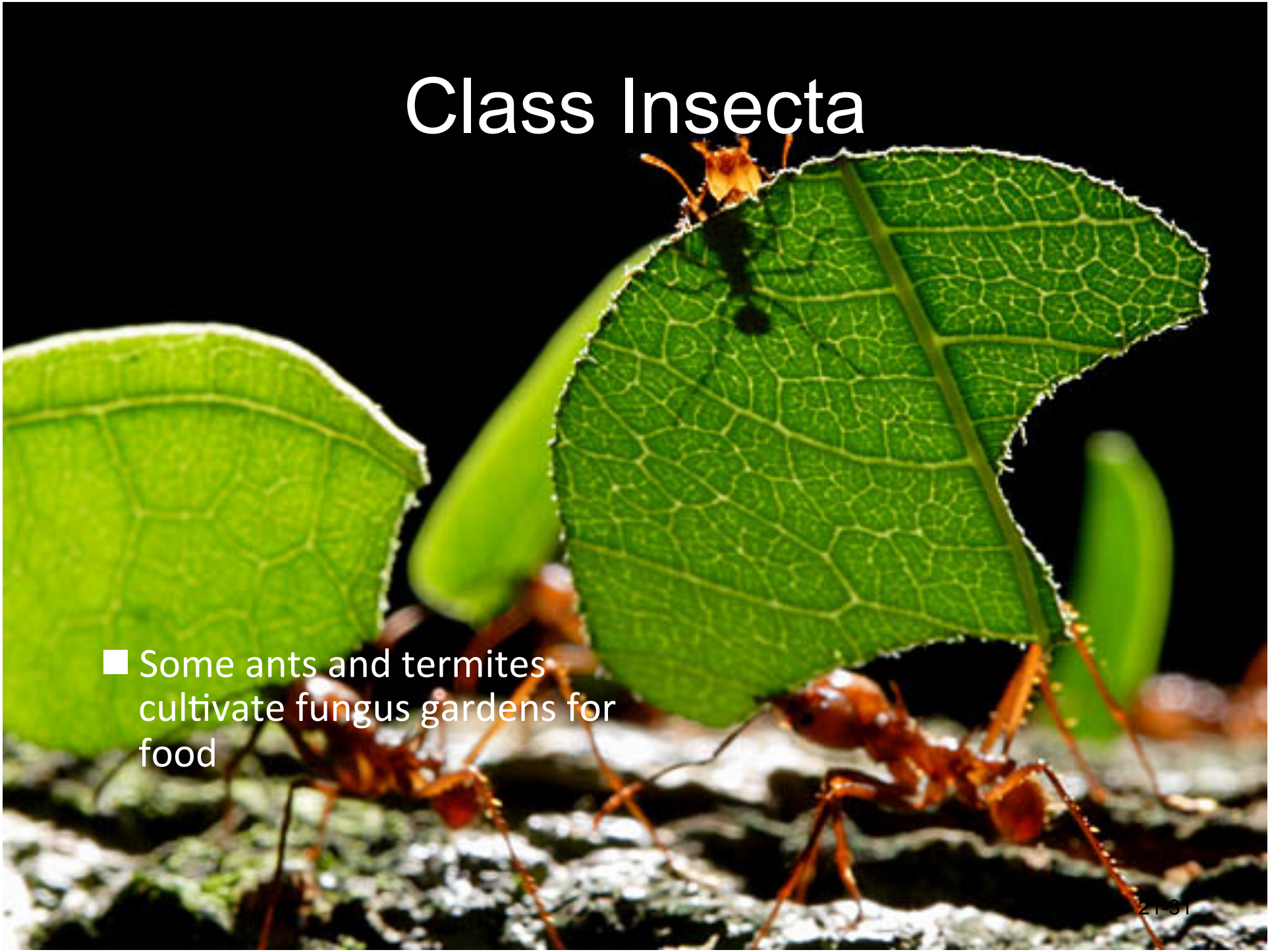
- Most feed on plant tissues or juices and are *herbivorous or phytophagous*

Class Insecta

- Many caterpillars are specialized to eat only certain species of plants



Class Insecta



- Some ants and termites cultivate fungus gardens for food

Class Insecta

- Many beetles and other insect larvae eat dead animals and are *saprophagous*

Class Insecta

- Some species are predaceous on other insects or other animals

Class Insecta

- Many species are parasitic as adults and/or larvae

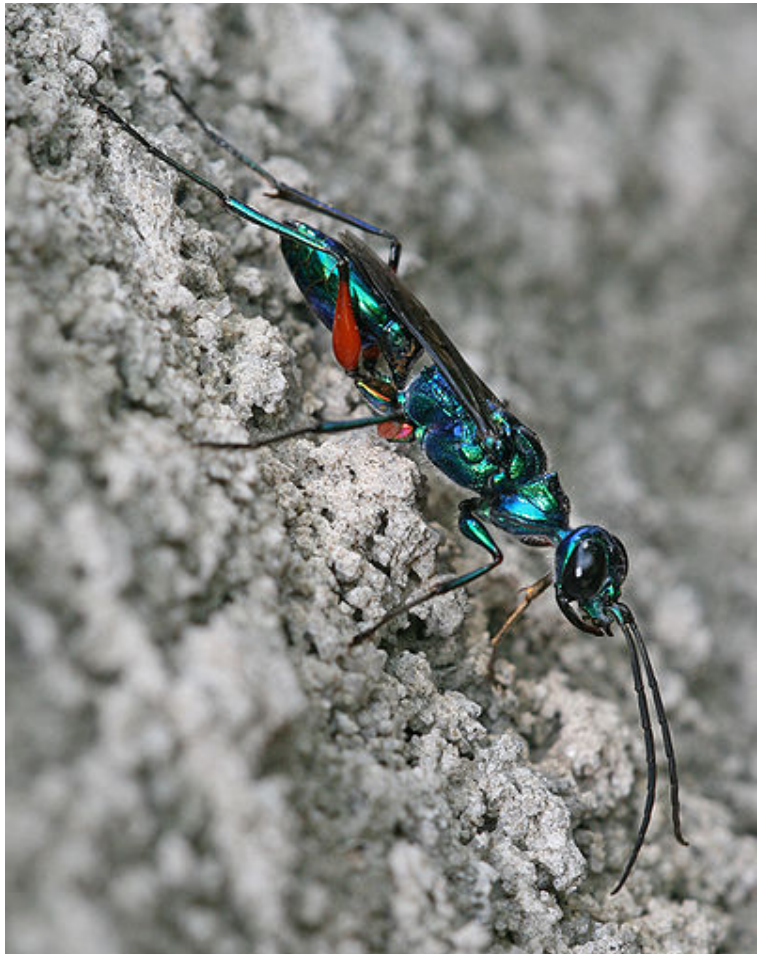
Class Insecta

Many parasitic insects, in turn, have parasites, a condition called *hyperparasitism*

- Parasitoids live inside a host and eventually kill the host
  - Important in *pest control*

- Entomophagous parasites are insects that are parasitic on other insects.
- Nearly all insects are attacked by one or more insect parasites.
- This parasitic mode of life is most often confined to the larvae with the adults usually leading free lives.
- The vast majority of Hymenopterous insect parasites are usually restricted to specific hosts, such as Embidobia (parasitic on Embioptera), Platygaster and Polygnotus (on Cecidomyiidae), Scelio (on locust eggs) and Aphidiuc (on Aphids).
- Often, species that are hyperparasites are less host-specific.

Parasitoids



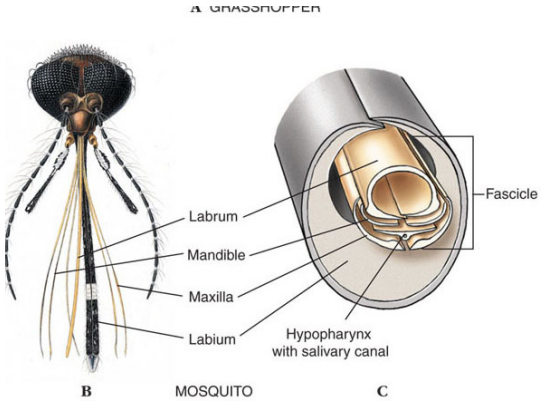
Larvae of the *Ampulex compressa* feed on cockroaches paralyzed by the adult.

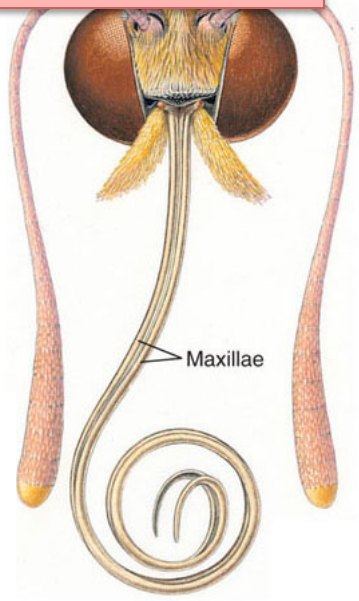
Parasitoids

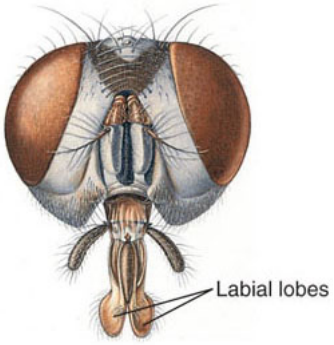
Cotesia female wasp and *Manduca* caterpillar host

Class Insecta

- *Mouthparts*
  - Sucking mouthparts form a tube to pierce tissues of animals or plants
  - Houseflies and blowflies have sponging mouthparts
    - Soft lobes at the tip absorb food
  - Biting mouthparts can seize and crush food

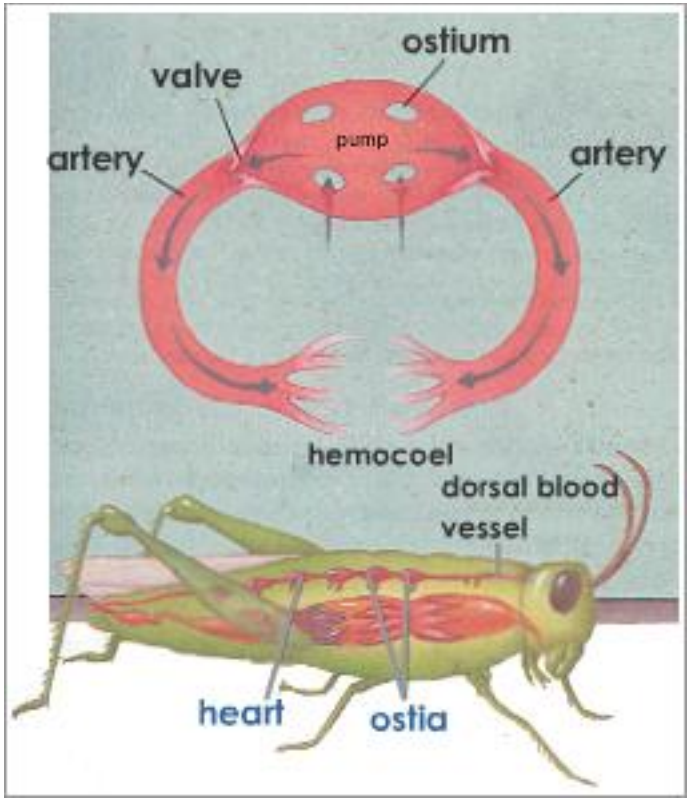






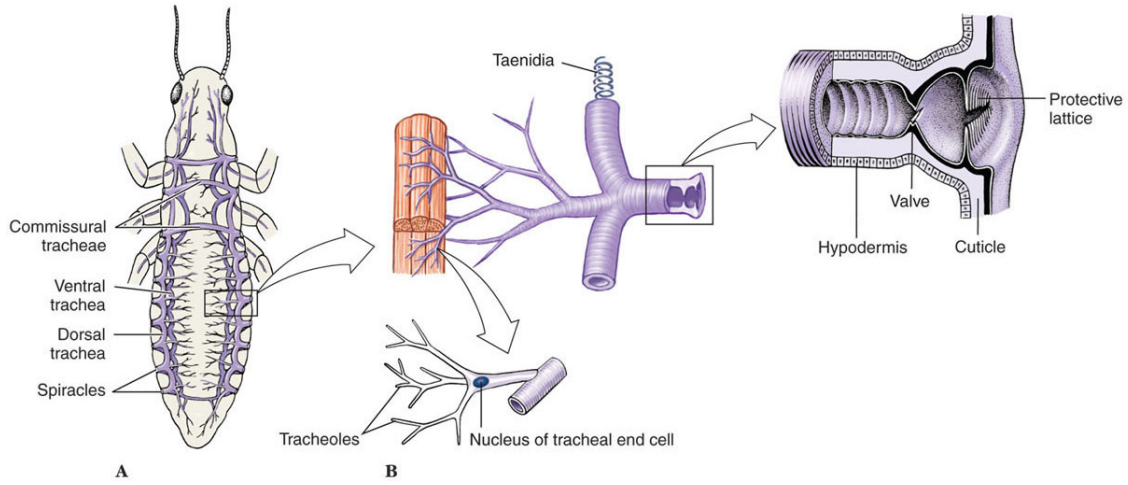
Class Insecta

- *Circulation*
  - Tubular heart in the pericardial cavity moves hemolymph forward through dorsal aorta
  - Accessory pulsatile organs help move hemolymph into wings and legs
  - Hemolymph composed of plasma and amebocytes but ***does not function in oxygen transport in most insects***
  - In some insects, ***particularly aquatic immature in low oxygen environments***
    - Hemoglobin is present and functions in oxygen transport



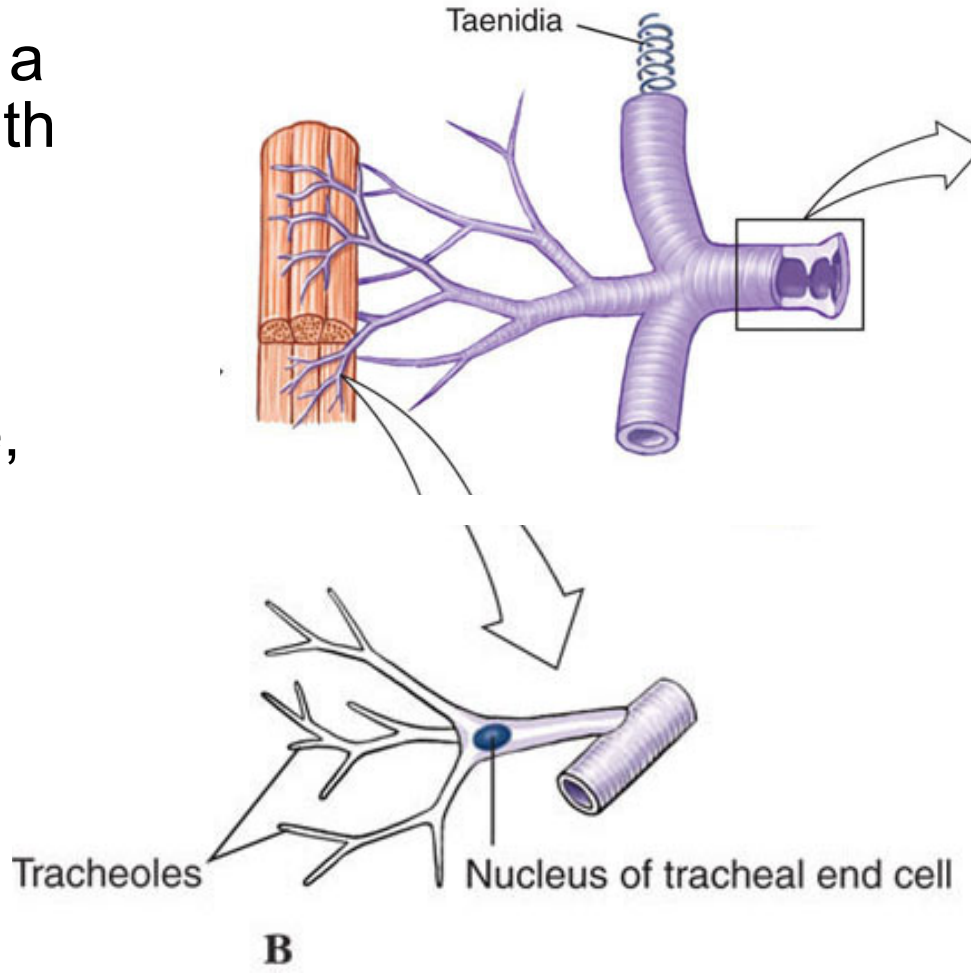
Class Insecta

- *Gas Exchange*
  - Terrestrial animals are faced with the dilemma of exchanging gases while preventing water loss
  - *Tracheal system*
    - Network of thin-walled tubes that branch throughout the insect body
    - *Evolved independently* of that of other arthropod groups
  - *Spiracles* open to the tracheal trunks
    - 2 spiracles on thorax and 7–8 on abdomen
  - *Valve* on the spiracle
    - Reduces on water loss and may serve as a dust filter



Class Insecta

- *Tracheae* are composed of a single layer of cells lined with cuticle that is shed at each molt
- Spiral thickenings of cuticle, called *taenidia,* prevent the tracheae from collapsing
- Tracheae branch out into fluid-filled tubules called *tracheoles* that reach individual body cells

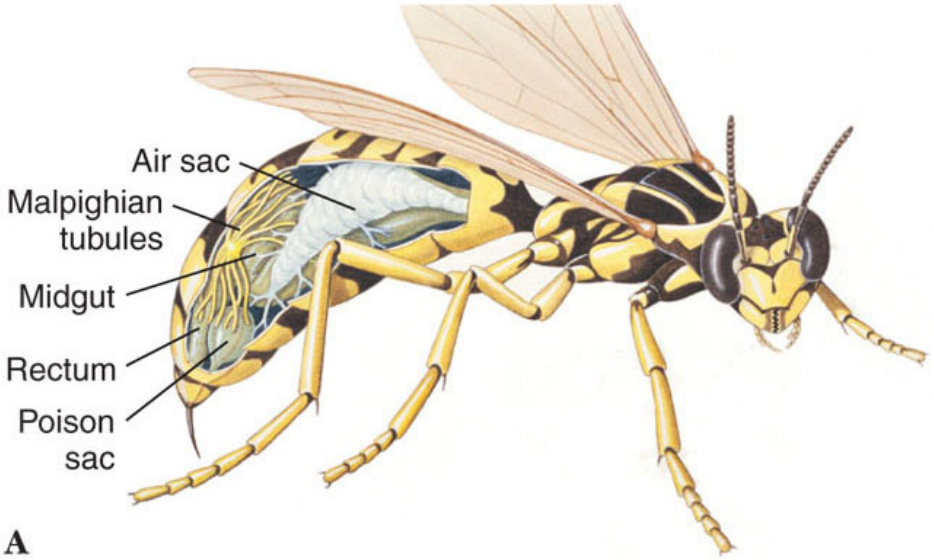


Class Insecta

- System provides gas transport *without use of oxygen-carrying pigments*
- Diving beetles use abdominal hairs to maintain a bubble under wings, an *"artificial gill"*
- *Mosquito larvae* use short breathing tubes to snorkel surface air

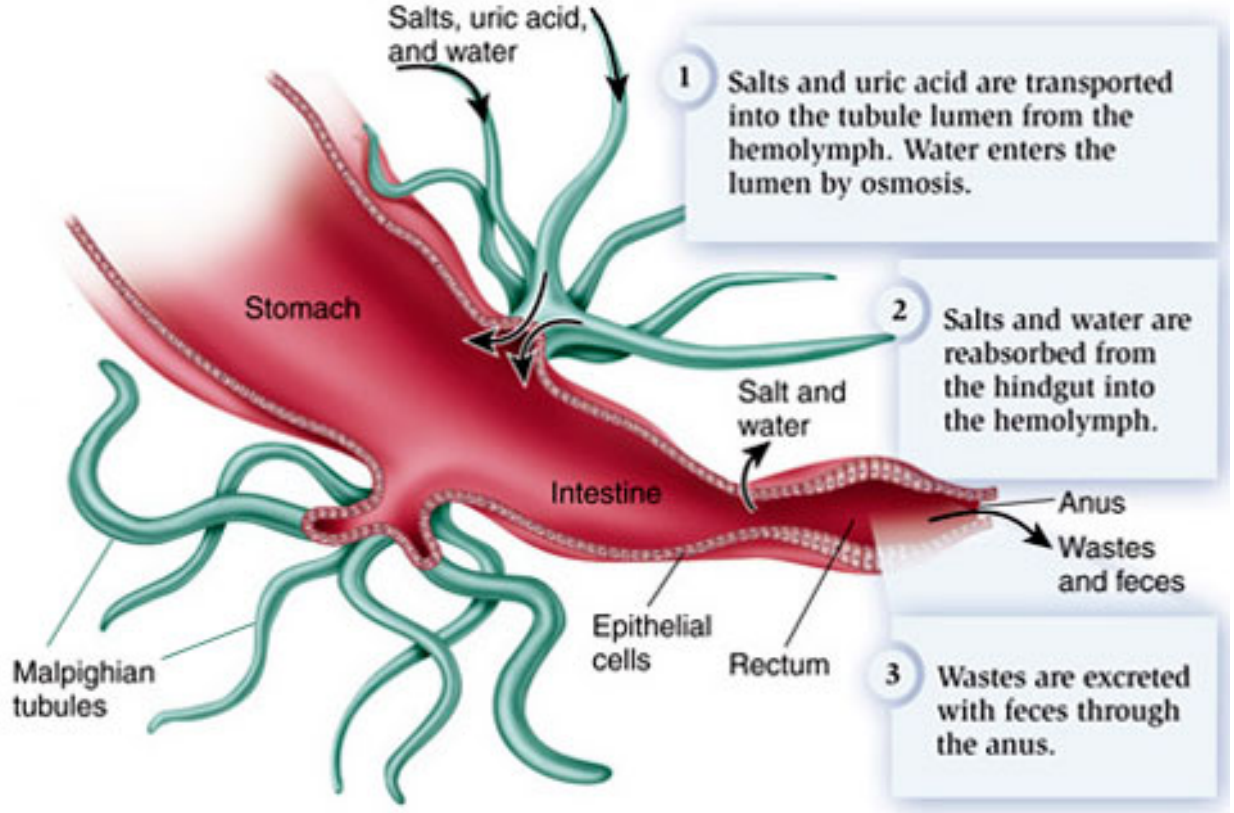
Class Insecta

- Excretion and Water Balance
  - Insects and spiders utilize **Malpighian tubules** in conjunction with rectal glands
  - Malpighian tubules vary in number but join between the midgut and hindgut
  - Blind ends of tubules float freely in hemocoel bathed in hemolymph



Class Insecta

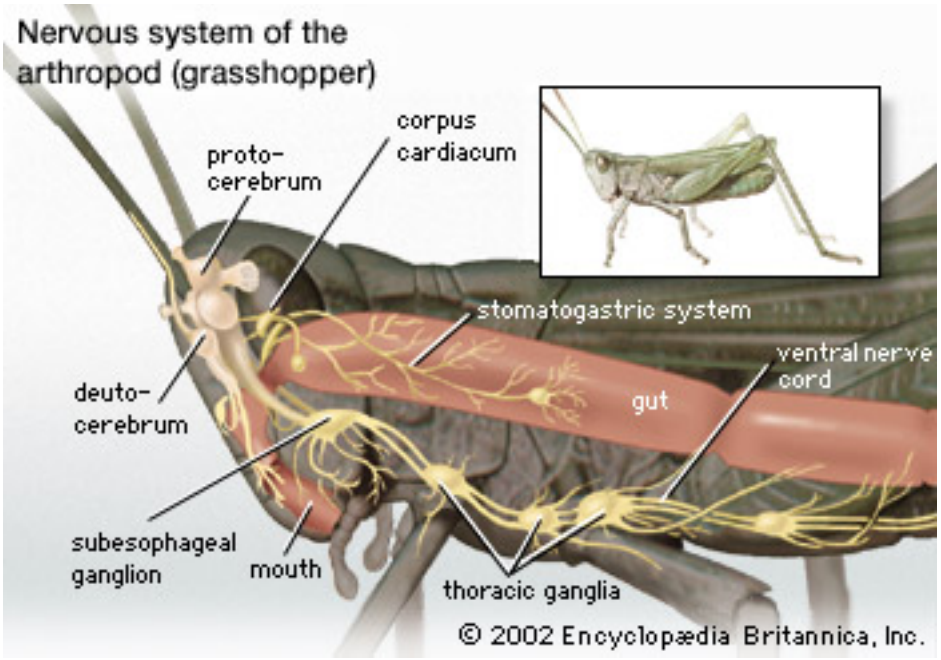
- Excretion and Water Balance
  - **Main waste product is uric acid**
  - In the lower end of the tubule
    - Potassium combines with CO_2 and is reabsorbed
  - **Rectal glands reabsorb chloride, sodium and water**
    - Wastes pass out of body

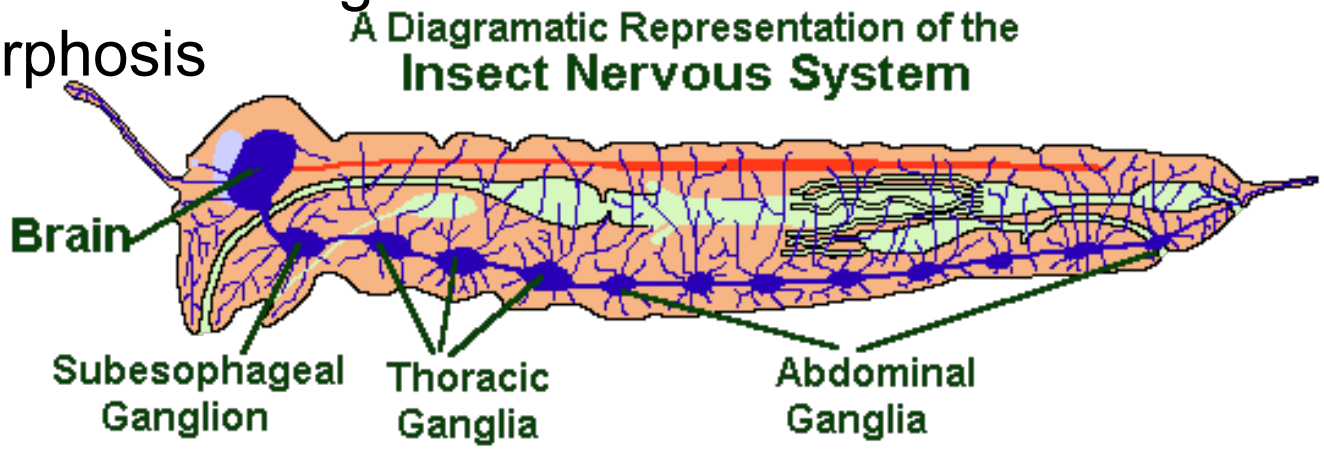


Class Insecta

Nervous System

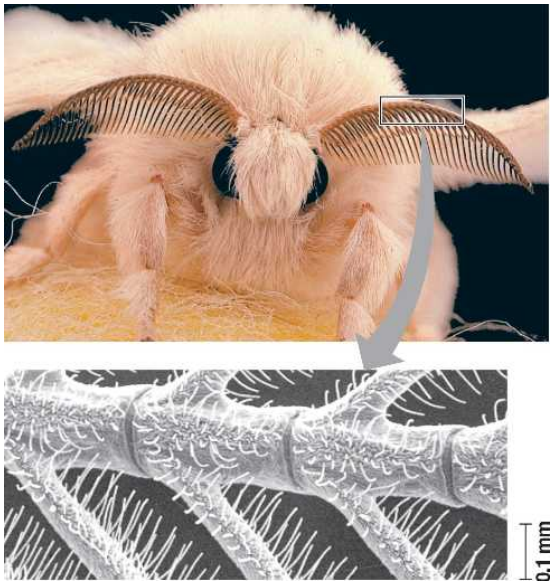
- Resemble that of larger crustaceans, with fusion of ganglia
- Some have a giant fiber system
- *Neurosecretory cells* in brain function to control molting and metamorphosis





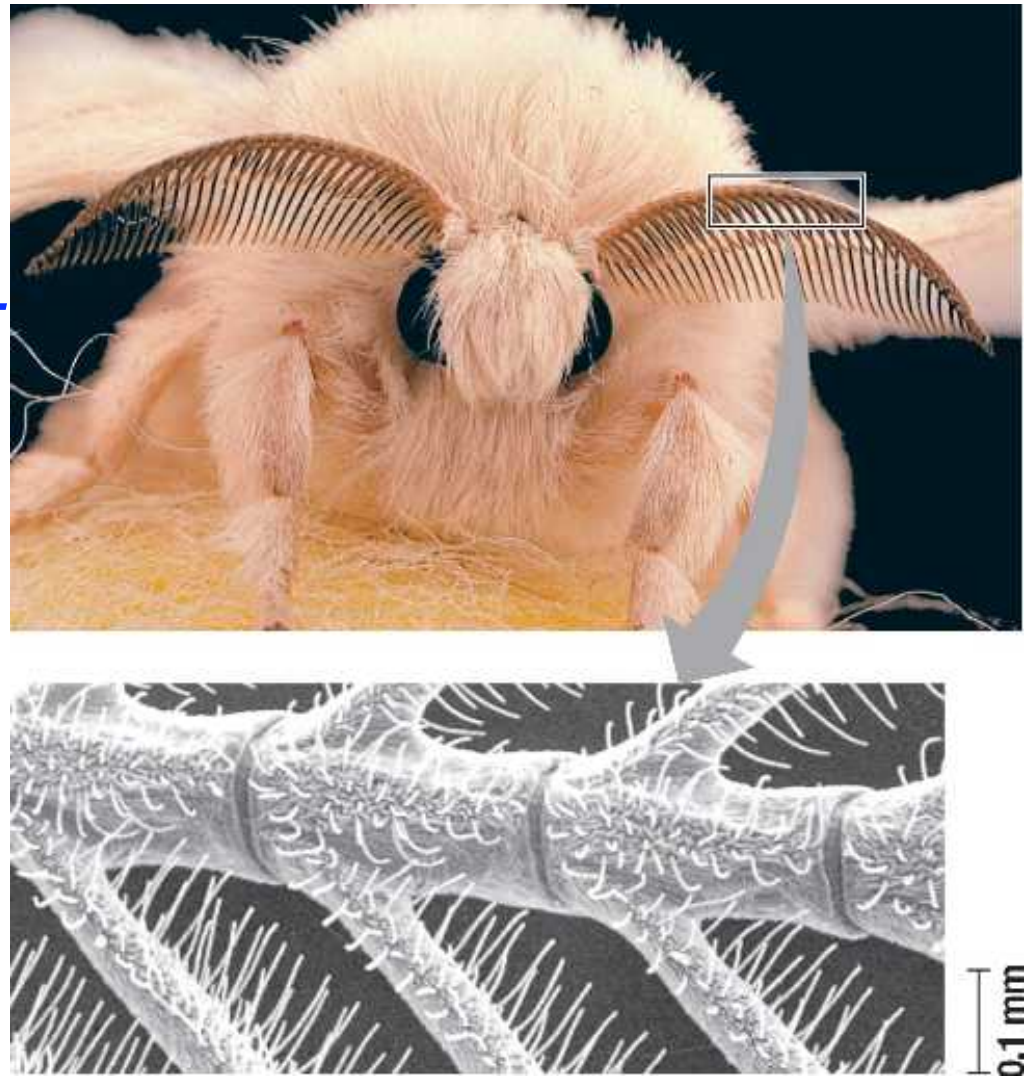
Class Insecta

- *Sense Organs*
  - Many insects have keen sensory perception
  - Most sense organs are microscopic and located in body wall
  - Different organs respond to mechanical, auditory, chemical, visual, and other stimuli



Class Insecta

- *Mechanoreception*
  - Touch, pressure, vibration, etc. are detected by *sensilla*
    - –May be a *single hair-like seta or a complex organ*
    - –Distributed widely over antennae, legs, and body



Class Insecta

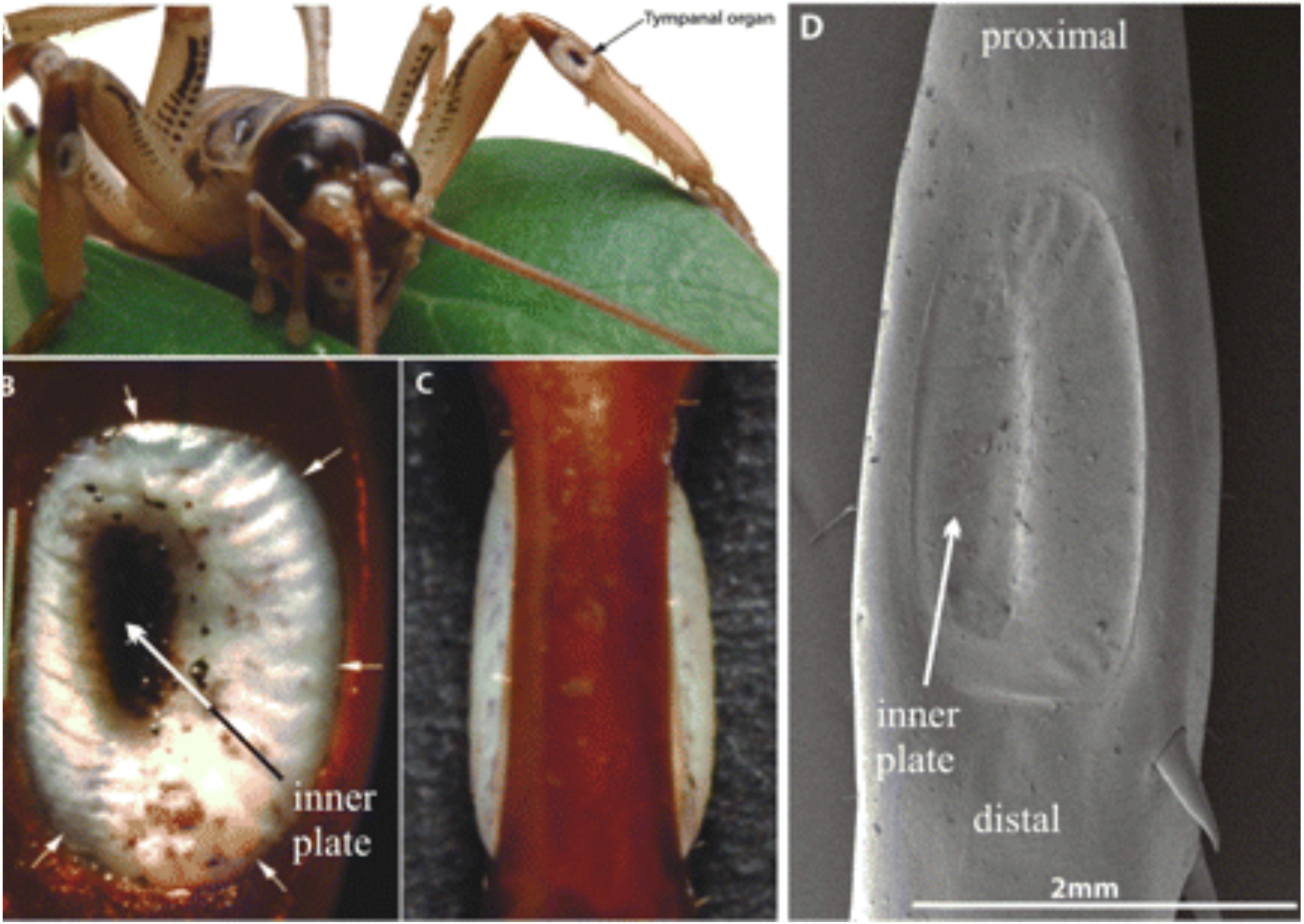
– *Tactile and Visual Communication*

- Involves tapping, stroking, grasping, and antennae touching
- Some beetles, flies and springtails use bioluminescence
- Some female fireflies mimic another species' flash pattern to attract males and then eat them

Class Insecta

– *Auditory Reception*

- Sensitive setae (hair sensilla) or tympanal organs *detect airborne sounds*
- Tympanal organs occur in Orthoptera, Hemiptera and Lepidoptera
- Organs in legs can detect vibrations of substrate


Tympanal organ
B
inner
plate
C
D
proximal
inner
plate
distal
2mm

Class Insecta

Sound Production and Reception

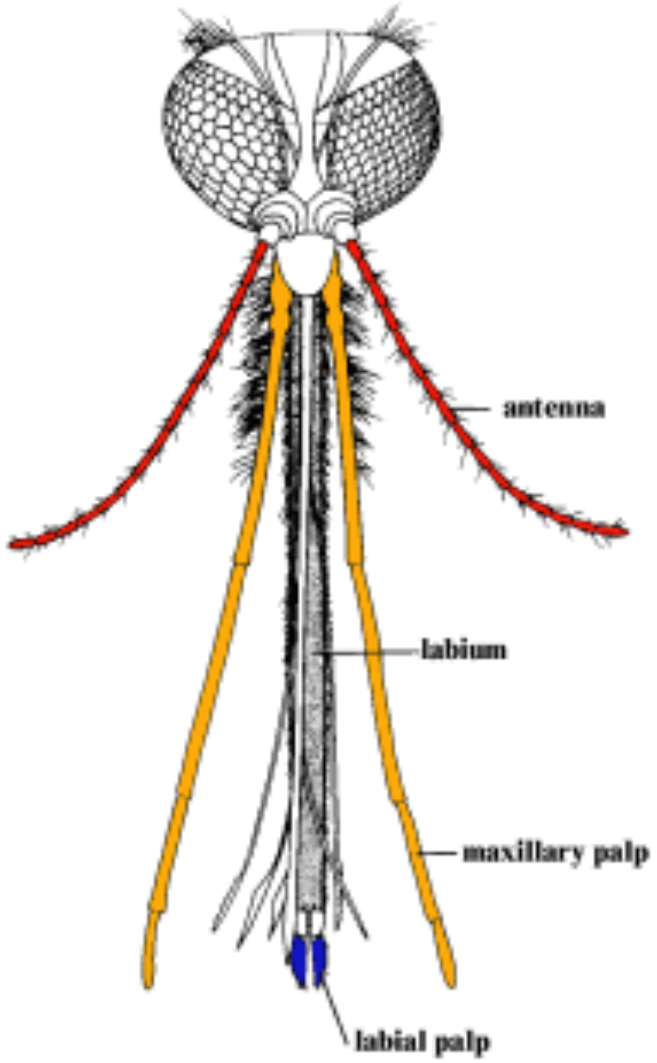
- Sounds are used as warning devices, advertisement of territory, and courtship songs.
- Crickets chirp for courtship and aggression
- Male cicada vibrates paired membranes on abdomen to attract females

signalling males are often attacked and killed by acoustically orienting parasitoid flies. Female flies lay their larvae on and around the signalling cricket.

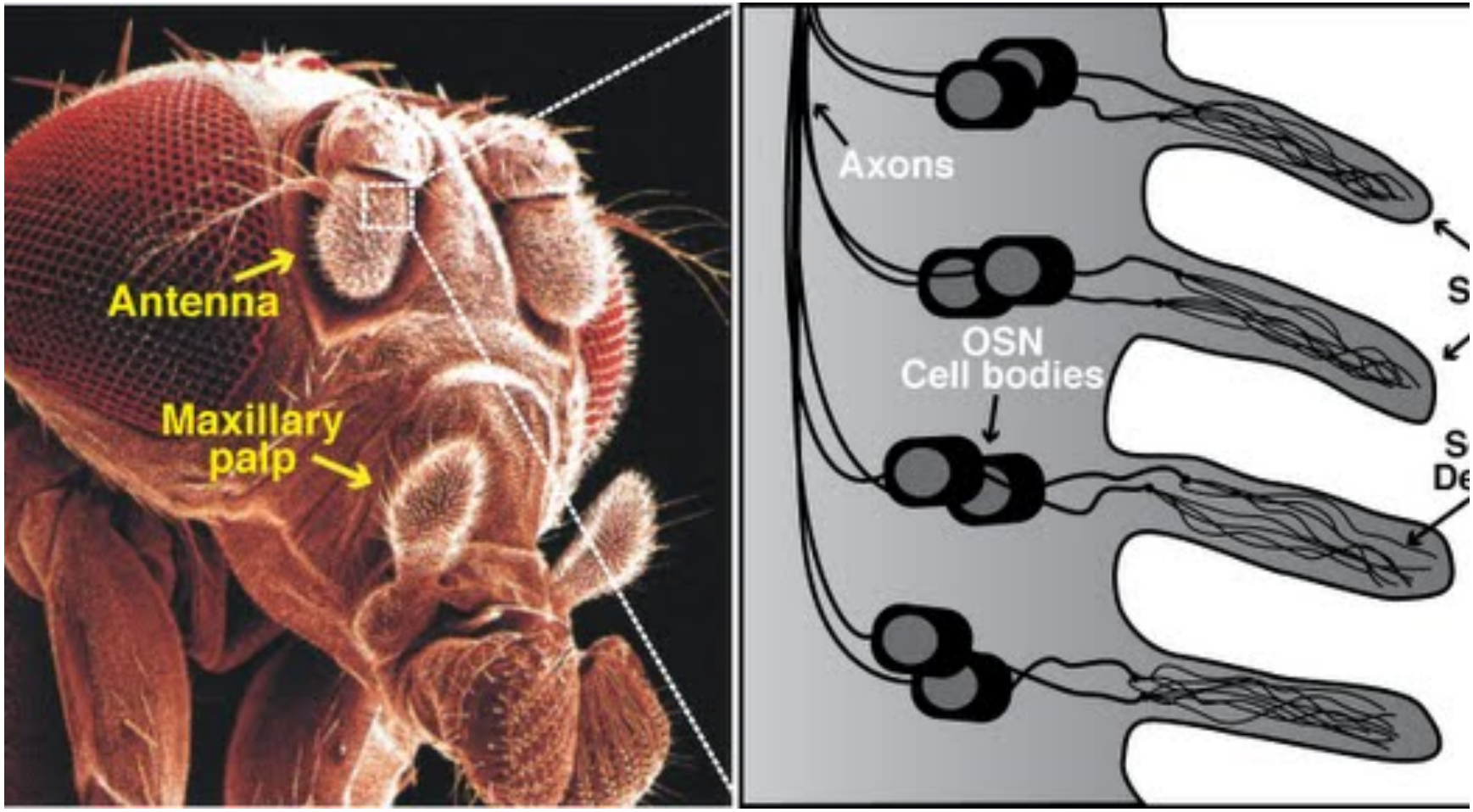
Class Insecta

– *Chemoreception*

- Usually bundles of sensory cell processes located in sensory pits
- May occur on mouthparts, antennae, and legs
- Some insects can detect odors several kilometers away
- Feeding, mating, habitat selection, and host-parasite relationships are mediated through chemical senses



Chemoreception



Class Insecta

- *Pheromones*
  - *Chemicals secreted by one individual to affect the behavior of another individual*
  - Attract the opposite sex, trigger aggregation, fend off aggression, and mark trails
  - Bees, wasps, and ants can recognize nestmates and signal an alarm if strangers enter the nest
  - Can be used to trap insects to monitor populations

Attacking an ant from a neighbor nest

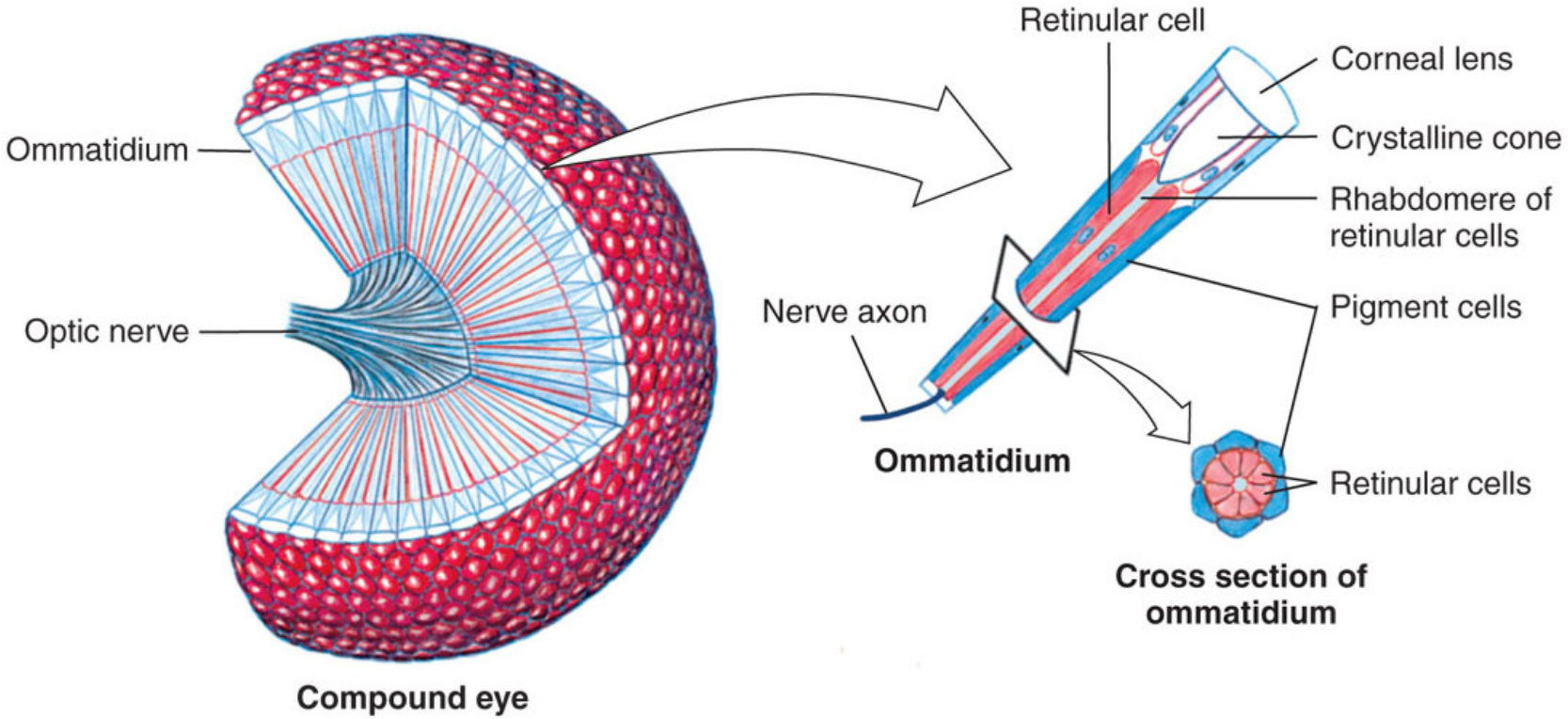
Class Insecta

- *Visual Reception*
  - 2 types of eyes: *simple (ocelli) and compound*
  - Honeybee studies indicate that ocelli monitor light intensity *but do not form images*

Simple eyes

http://www.youtube.com/watch?v=D2gIf1RXOh8

A bee can distinguish ultraviolet light but cannot detect shades of red



- Compound eyes may contain thousands of *ommatidia*
  - Ommatidia structure similar to that of crustaceans
- Insects can see *simultaneously in almost all directions*
  - Image is *myopic and fuzzy*

Class Insecta

– *Other Senses*

- Insects are very sensitive to temperature, especially cells in antennae and legs

- Insects also detect humidity, proprioception, gravity, and other physical properties

Class Insecta

- *Reproduction*
  - *Parthenogenesis* occurs predominantly in some **Hemiptera and Hymenoptera**

Parthenogenesis is a form of asexual reproduction found in females, where growth and development of embryos occur without fertilization by a male.

Class Insecta

- *Reproduction*
  - *Sexual reproduction* is the norm
  - Sexes are *separate*
  - *Sexual Attraction*
    - Female moths secrete a pheromone to attract males from a great distance
    - Fireflies use flashes of light to detect mates
    - Some insects use sounds, color signals, and other courtship behaviors

http://www.youtube.com/watch?v=lopc1CrGCX4

Class Insecta

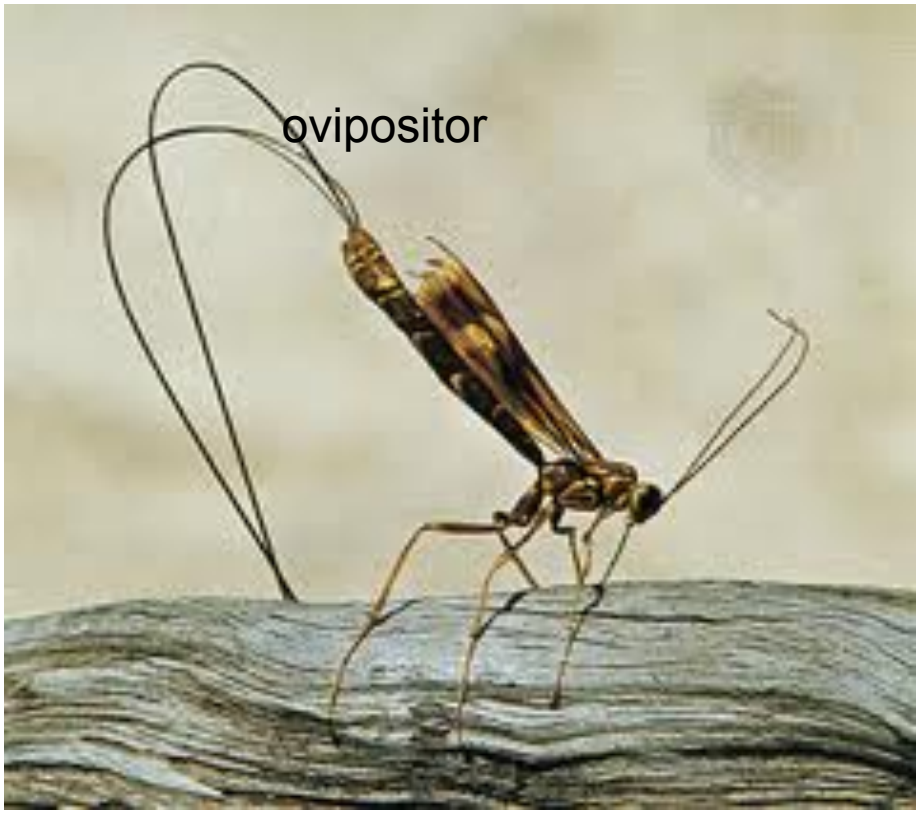
- Fertilization usually *internal*
- Sperm may be released directly or packaged into *spermatophores*
  - Spermatophores are result of an evolutionary transition from marine to terrestrial existence
  - May be transferred both without copulation and during copulation.
- Female may only mate once and *store sperm to fertilize eggs throughout her life*
- Females may lay a few eggs and provide care of young, or lay huge numbers

Class Insecta

– *Butterflies and moths* must lay eggs on the host plant if the caterpillars are to survive

Class Insecta

– *Wasps* may have to locate a specific species that is the only host to their young



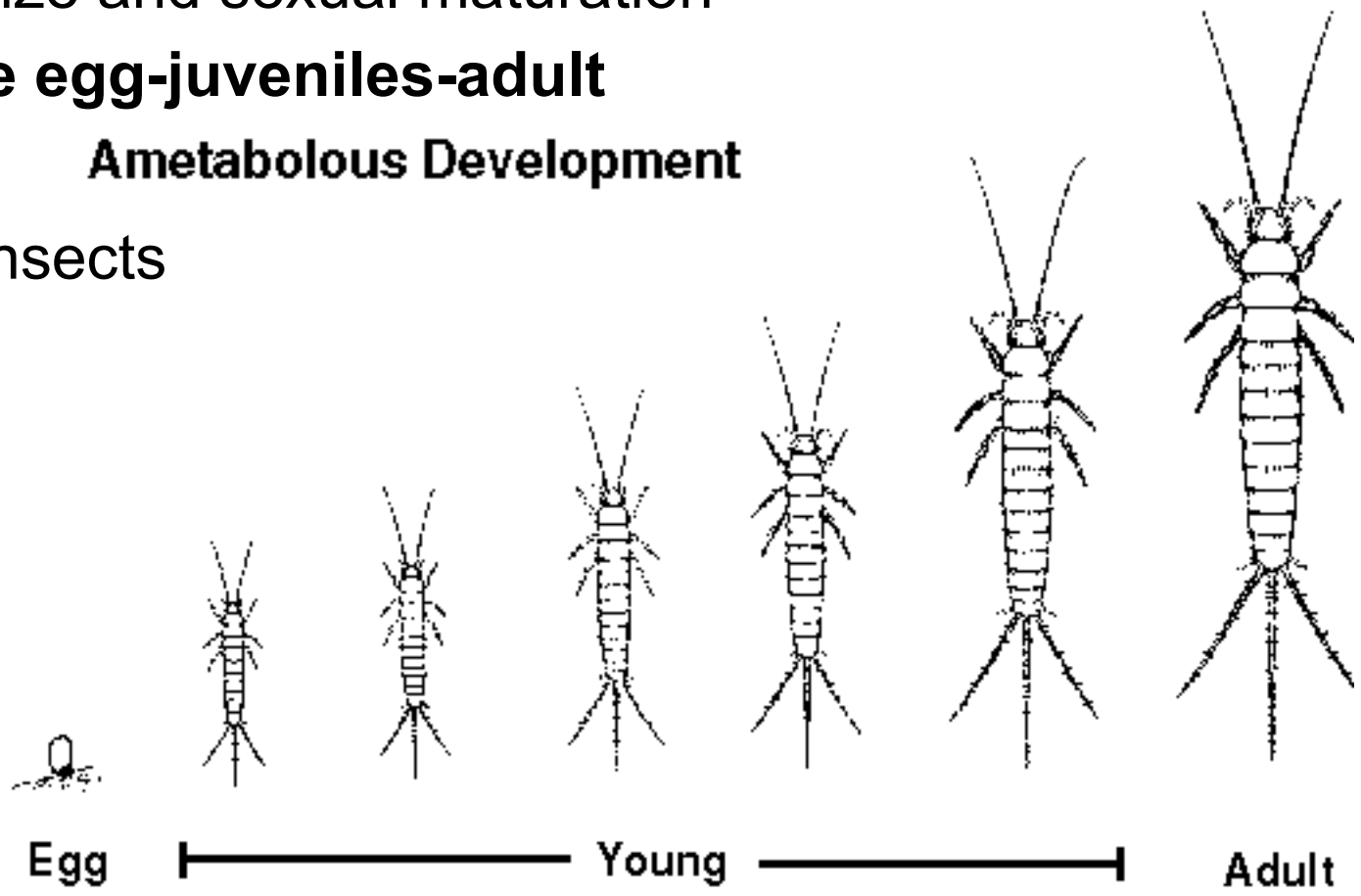
Class Insecta

- *Metamorphosis and Growth*
  - Various forms of metamorphosis produce degrees of change among different insect groups
  - Most insects change form after hatching from egg
  - Each stage between molts is called an *instar*
  - Insects develop wings during the last stage

Class Insecta

Ametabolous (Direct) Development

- Silverfish and springtails have young similar to adults except in size and sexual maturation
- **Stages are egg-juveniles-adult**

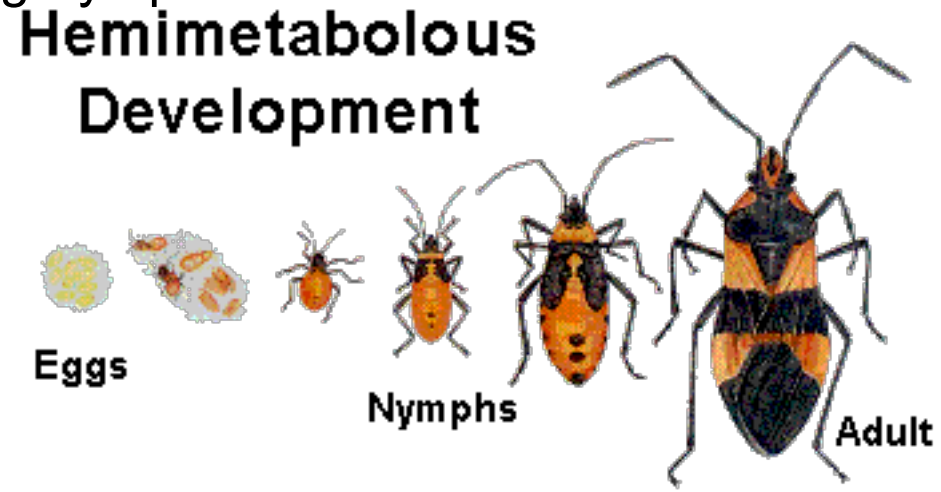


- Wingless insects

Class Insecta

Hemimetabolous Metamorphosis

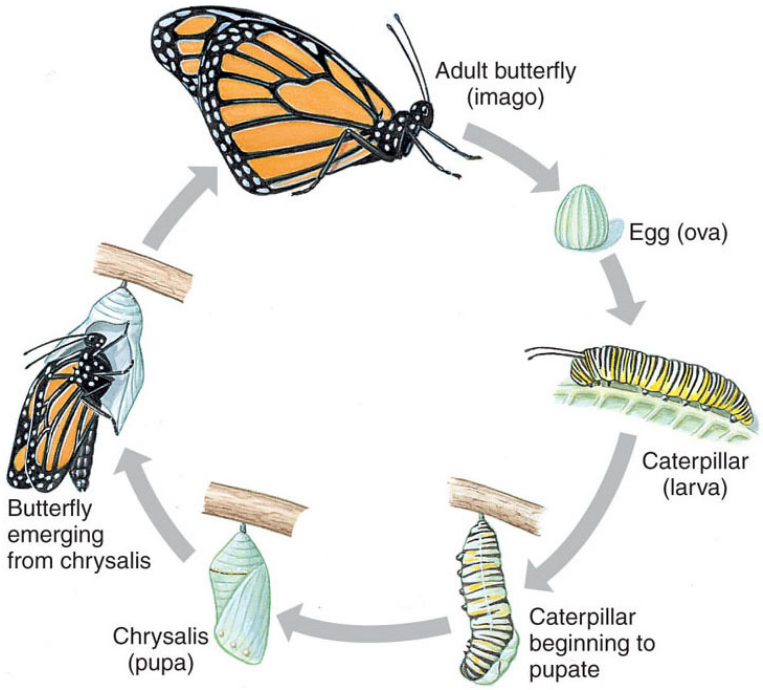
- Some insects undergo a gradual metamorphosis: 3 stages: egg, nymphs, adultos
- Grasshoppers, cicadas, mantids, true bugs, mayflies and dragonflies exhibit this metamorphosis
- Young are called nymphs
- Bud-like growths in early instars show where the adult wings will eventually develop
- Stages are egg-nymph-adult



Class Insecta

Holometabolous Metamorphosis

- *About 88% of insects undergo complete metamorphosis*
- Separates the physiology of larval growth, pupal differentiation, and adult reproduction
- Larvae and adults often live in completely different environments
  - No competition
- After several larval instars
  - Larval moth or butterfly becomes a pupa inside a cocoon or chrysalis
  - Pupae often pass the winter in this stage
  - Final molt occurs and the adult emerges in spring
- *Stages are egg-larva-pupa-adult*



Class Insecta

Physiology of Metamorphosis

- Hormones regulate insect metamorphosis
- Brain and nerve cord ganglia produce *brain hormone or ecdysiotropin*
- Brain hormone circulates in the hemolymph to the prothoracic gland in the head or prothorax
- Prothoracic gland produces *molting hormone or ecdysone in response*
- *Ecdysone* starts the molting process

Class Insecta

Diapause

- Period of dormancy in the annual life cycle that is independent of conditions
  - Winter dormancy: hibernation
  - Summer dormancy: estivation
- Any stage (eggs, larvae, pupae, or adults) may remain dormant to *survive adverse conditions*
- Internally controlled but may be triggered by environmental cues such as day length
- Always occurs at *end of an active growth stage*
  - Insect is then ready for another molt
- Many larvae do not develop beyond this point until spring in spite of mild temperatures

Class Insecta

– *Defense*
  - Protective coloration, warning coloration, and mimicry are protective adaptations
  - Stink bugs and others have *repulsive odors and tastes*
  - Some insects are *aggressive* (e.g., bees and ants)
  - The monarch caterpillar *incorporates a poisonous substance* from its food plant, milkweed
  - The bombardier beetle can spray an attacking enemy with *irritating chemicals*

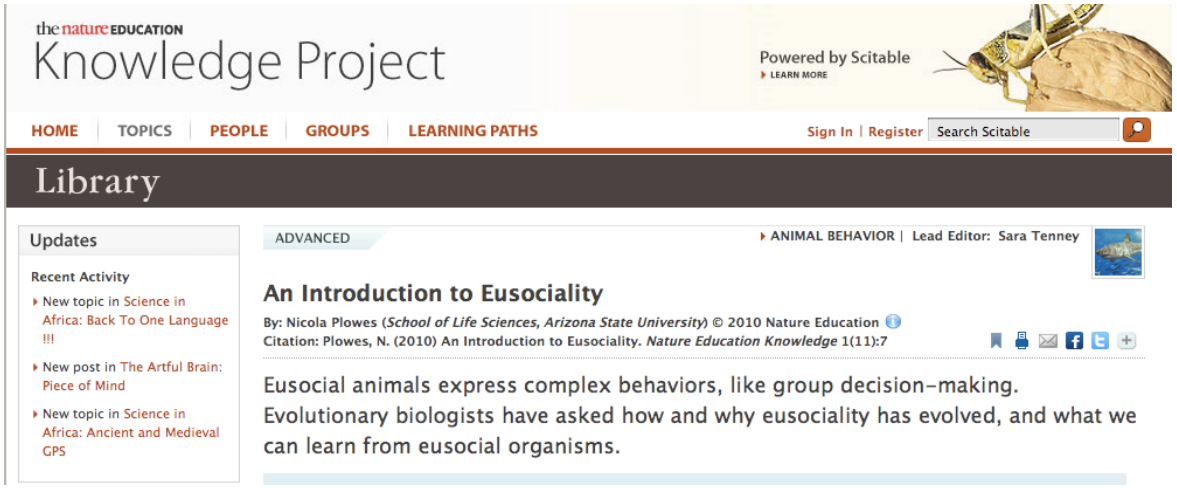
Bombardier Beetle

Class Insecta

– *Social Behavior*

- Some social communities are temporary and uncoordinated
- Others are highly organized and depend on chemical and tactile communication
- Caste differentiation is common in most organized social groups

http://www.nature.com/scitable/knowledge/library/an-introduction-to-eusociality-15788128



Class Insecta

Honeybees

- Have a few *male drones,* a *fertile female queen* and many *female workers*
- Drones develop by parthenogenesis
- Development of a fertile queen requires ingestion of *"royal jelly"*
- Queen secretes *"queen substance"* to prevent workers from maturing or feeding larvae royal jelly
- A honeybee hive may contain 60,000–70,000 individuals
- Scouts inform workers on location of food

Drone

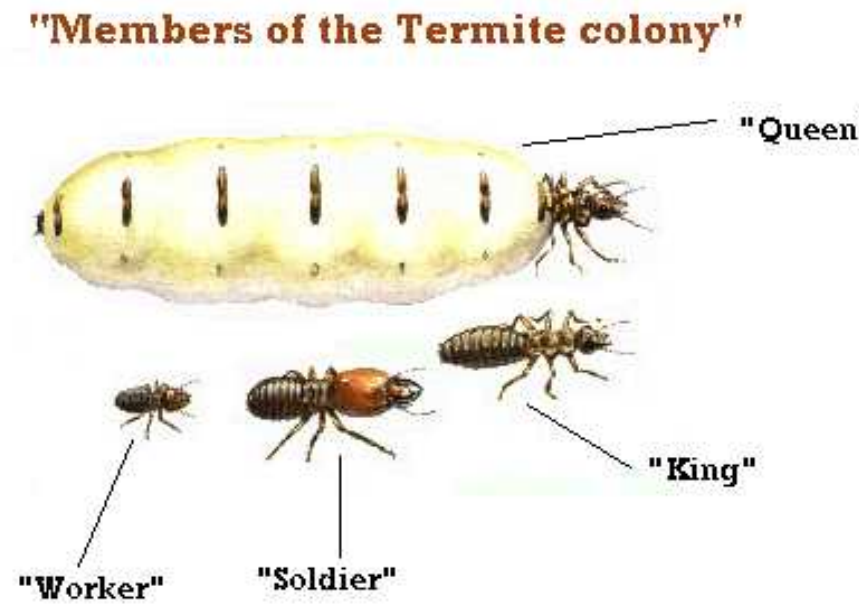
Worker

Queen

Class Insecta

Termites

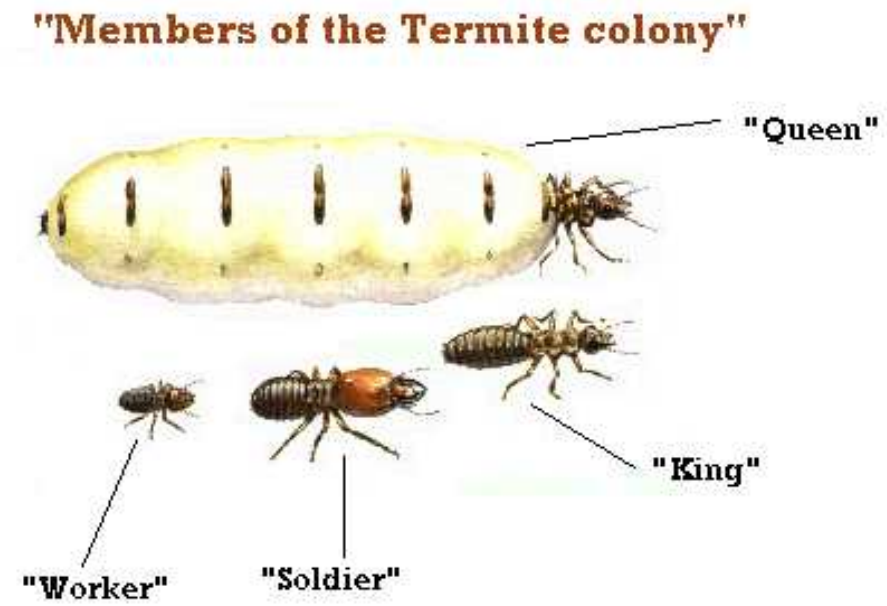
- *Fertile king and queen* fly away to start a new colony
  - Mate and lose wings
- Immature members are wingless and become workers and soldiers
- Soldiers have large heads and defend colony
- Reproductive individuals *secrete inhibiting pheromones* that produce sterile workers
- Nymphs feed from each other in *trophallaxis,* thus spreading the pheromone about



Trophallaxis is the transfer of food or other fluids among members of a community through mouth-to-mouth (stomodeal) or anus-to-mouth (proctodeal) feeding. It is most highly developed in social insects such as ants, termites, wasps and bees.

Class Insecta

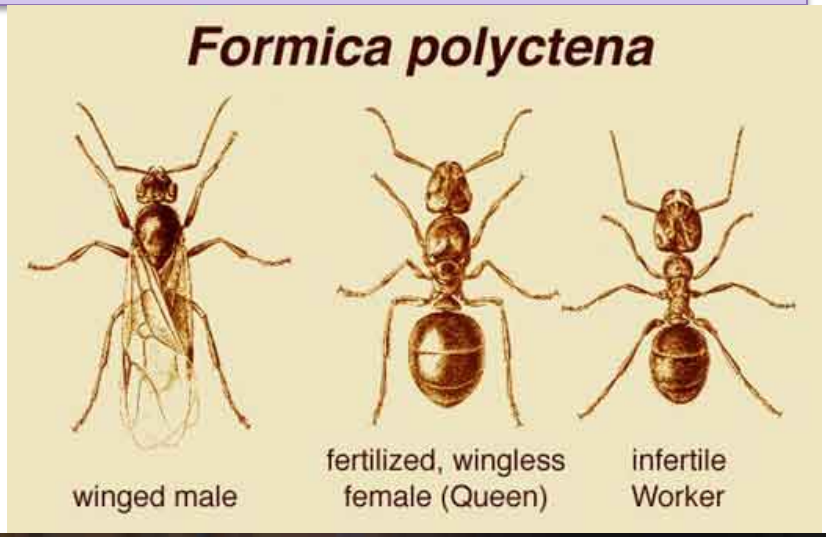
- Worker castes also produce *worker and soldier substances*
- Drops in these *pheromone levels* result in more of the needed caste developing in the next generation



Class Insecta

Ants

- Differ from termites
  - Ants are darker, hard-bodied, and have thread-like waist
- In ant colonies, the male ant dies after mating
- Ants have wingless soldiers and workers, and often have variations of these castes
- Ants have also evolved striking patterns of "economic" behavior: *making slaves, fungus farming, sewing nests together, tool use, and herding*



Insects and Human Welfare

- *Beneficial Insects*
  - Insects produce honey, beeswax, silk and shellac
  - Of more economic importance, bees *pollinate $10 billion worth of food crops in the U.S. annually*
  - Pollinating insects and flowering plants are tightly co-evolved
  - Predaceous and parasitoid insects are vital in *controlling many pest insect populations*

Insects and Human Welfare

- *Harmful Insects*
  - Harmful insects eat and destroy plants and fruits
  - Nearly every cultivated crop has several insect pests
    - *Requires substantial money for insect control*
  - Bark beetles, spruce budworms, the gypsy moth and others are serious forest pests.
  - Insects also destroy food, clothing, and property

Insects and Human Welfare

- Medically important insects include vectors for disease agents
- 10% of all arthropod species are parasites or *"micropredators"*
- *Warble and bot flies* attack humans and domestic livestock
- *Malaria* is carried by *Anopheles* mosquitos
  - Most common major world disease
- *Yellow fever and lymphatic filariasis* are also mosquito-borne

Insects and Human Welfare

- Fleas carry *plague,* a disease that changed human history in the Middle Ages
- Lice carry *typhus fever*
- The tsetse fly carries *African* sleeping sickness
- The newest viral plague to hit North America, the *West Nile virus,* is carried by mosquitos

Insects and Human Welfare

- *Control of Insects*
  - *Broad-spectrum insecticides* damage beneficial insect populations along with targeted pest
  - Some *chemical pesticides* persist in the environment and accumulate as they move up the food chain
  - Some strains of insects have evolved a *resistance to common insecticides*
  - *Biological control*
    - Use of natural agents, including diseases, to suppress an insect population

Insects and Human Welfare

- *Bacillus thuringiensis*
  - Bacterium that controls *lepidopteran pests*
  - Gene coding for the "B.t." toxin has been introduced to other bacteria and transferred to crop plants
- Some viruses and fungi may be economical pesticides
- Natural predators or parasites of insect pests can be raised and released to control pest
- Release of sterile males can eradicate the few insect species that only mate once

Insects and Human Welfare

- *Pheromones* can monitor pests and *hormones* may play a role in disrupting the life cycle
- *Integrated pest management*
  - Combined use of all possible, practical techniques listed above, to reduce reliance on chemical insecticides