CHAPTER 46: ARTHROPODS

CHAPTER SYNOPSIS

The arthropods were the first animals to exhibit jointed appendages. With the advent of rigid exoskeletons, jointed appendages were necessary to allow efficient movement in a terrestrial environment. These appendages are modified into various types of antennae, mouthparts, and legs. Although they lack overall intelligence, arthropods are ecologically a highly successful group. This may be a result of their generally small size. It is unlikely that extremely large arthropods could survive because of the large mass of exoskeleton.

The phylum Arthropoda is traditionally divided according to the structure of appendages. The chelicerates possess chelicerae, fangs, or pincers evolved from the most anterior pair of appendages. The most anterior appendages of the mandibulates are antennae, the next set of appendages are the mandibles. The terrestrial mandibulates, have one-branched appendages. The appendages of the crustaceans, aquatic mandibulates, are biramous or two-branched. Some biologists have suggested placing the insects, myrapods (centipedes and millipedes) into their own taxon Tracheata based on their tracheal respiratory system. Recent molecular data suggests that insects and crustaceans are close sister groups, the former likely evolving from the latter, but that insects are quite different from myrapods.

All arthropod bodies are segmented. Some individuals have a large number of separate segments, while others have segments that are fused into functional groups through the process of tagmatization. Arthropods also undergo periodic ecdysis; they shed their exoskeleton in order to grow larger. They are internally characterized by a reduction of the coelom to mere cavities surrounding the reproductive organs and some glands. They possess an open circulatory system with a longitudinal heart and no closed blood vessels. Although arthropods possess well-developed nervous systems with an anterior brain, the majority of body activities are actually controlled by ventral ganglia. Because of this, many insects continue activities for a period of time even when decapitated. In addition, the brain acts through inhibition rather than stimulation as in the vertebrates. The respiratory system of the terrestrial arthropods is a series of hollow, branching tubes called tracheae. Chelicerates have book gills or book lungs alone or in addition to tracheae. The crustaceans possess typical aquatic gills. Several forms of excretory systems exist among the arthropods; the primary component of the terrestrial mandibulates is the Malpighian tubules.

Arthropods are among the most diverse phylum of animals, each subphylum is further divided into numerous classes. Included in the chelicerates are the classes Arachnida (scorpions, spiders, and mites), the class Merostomata (horseshoe crabs), and the class Pycnogonida (sea spiders). It is likely that the horseshoe crabs evolved from the now extinct trilobites. The crustaceans are similarly varied and include a few terrestrial individuals as well as the more populous aquatic ones. The most familiar crustaceans are the decapods (lobsters, crabs, and shrimp) as they are important human food sources. Other members are the sessile barnacles, the terrestrial isopods (pillbugs) and amphipods (sand fleas), and the planktonic copepods.

The Uniramia include the class Chilopoda (centipedes), the class Diplopoda (millipedes), and the class Insecta (insects). This last class is the largest group of organisms on the earth. They characteristically have three body segments with three pairs of legs attached to the thorax. Some insects possess wings, although these structures are not derived from appendages as are the wings of vertebrates. They possess a wide variety of sense receptors that are involved with reproductive activities as well as food collection. Insects undergo hormonally controlled metamorphosis or molting from juvenile to adult stages. Some insects, like grasshoppers, exhibit simple metamorphosis. Others like bees, house flies, and butterflies undergo complete metamorphosis.

CHAPTER OBJECTIVES

- ä Understand the necessity for segmentation and jointed appendages in the arthropods.
- ä Explain the structural and functional size limitations in the arthropods.
- ä Differentiate between appendage / mouthpart structures of chelicerates and mandibulates.
- ä Identify the major external features of arthropods that distinguish them from all previously presented animal phyla.
- ä Describe ecdysis as it applies to arthropods and understand why it is necessary.
- ä Understand the basic internal organization of the arthropods.
- ä Explain the evolutionary relationships among the three subphyla of arthropods.
- ä Describe the diversity of the subphylum Chelicerata.
- ä Understand the general biology of the subphylum Crustacea and indicate how its members differ from the more terrestrial arthropods.
- ä Describe and illustrate the diversity of crustaceans.
- ä Differentiate between centipedes and millipedes.
- ä Describe the external and internal characteristics of the class Insecta.
- ä Understand the complexities of insect metamorphosis and differentiate between simple and complete metamorphosis.

KEY TERMS

ametabolus
apposition eye
book lung
carapace
cephalothorax
chelicerae
chrysalis
complete metamorphosis
compound eye
ecdysis
ecdysone
ectoparasite
exoskeleton
fat body
instar
larva
Malpighian tubules
mandible
molting hormone
nauplius larva
nymph
ocellus (ocelli)
omatidia
ovipositor
pedipalp
pheromone
pupa
rhabdom
sensory hair
simple metamorphosis
simple eye
spiracle
superposition eye
swimmerete
tagma (tagmata)
tagmatization
telson
tracheae
tracheole
tympanum
uropod

CHAPTER OUTLINE

46.0 Introduction

I. NEW COELOMATE INNOVATION: JOINTED APPENDAGES

A. Arthropod Segmented Bodies Show Relationship to Annelids
1. Segments visible during early development
2. Fuse together into functional groups in adults

B. Jointed Appendages Provide Functional Flexibility — fig 46.1

46.1 The evolution of jointed appendages has made the arthropods very successful

I. JOINTED APPENDAGES AND AN EXOSKELETON

A. Yet Another Major Innovation
1. Jointed appendages first accomplished by the arthropods
2. Necessary adaptation with advent of rigid exoskeleton

B. Jointed Appendages
1. Phylum name means "jointed feet"
   a. Number of appendages reduced in more advanced members of phylum
   b. Appendages modified into antennae, mouthparts, and legs
2. Some appendages like wings are not homologous to other appendages
3. Importance of jointed appendages
   a. Necessary for walking, grasping objects
   b. Arthropods also use antennae for sensing environment, mouthparts for feeding

C. Exoskeleton
1. Rigid exoskeleton is a second innovation of arthropod body plan
2. Skeleton functions as attachment for muscles
3. Arthropod muscles attach to interior surface of chitin shell
   a. Shell protects animal from predators
   b. Impedes water loss
4. Chiton similar to cellulose in structure
   a. Also is tough and flexible, can flex in response to attached muscles
   b. Most crustaceans also have deposits of calcium salts in exoskeleton
5. Limitations of an exoskeleton
   a. Must be thicker to bear pull of muscles
   b. Most arthropods cannot attain great size

D. The Arthropods
1. Includes nearly two-thirds of all named species on earth fig 46.2
   a. May include 30 million species of insects alone
   b. Are abundant in all habitats, but dominate terrestrial regions
2. Most arthropods are relatively small, but a few may be as large as 3.6 meters fig 46.3
3. Economically important, especially insects
   a. Compete with humans for food
   b. Pollinate crops, control insects and weeds
   c. Cause extensive damage to food crops, important herbivores
   d. Spread diseases

II. CLASSIFICATION OF ARTHROPODS

A. Very Diverse Phylum
1. Among oldest of animals, appeared 600 million years ago
2. Great size range
3. Share common heritage of segmentation and jointed bodies

B. Origin of the Arthropods
1. Close relationship between arthropods and annelids
2. Phylum Onychophora (velvet worms) shares several features with both groups
3. Supported by some molecular studies, but not by others

C. Traditional Classification
  1. Trilobites
    a. Extinct for 250 million years
    b. First animals with eyes capable of substantial resolution
  2. Chelicerates
    a. Include spiders, horseshoe crabs, sea spiders
    b. Lack jaws, foremost mouthparts are chelicerae fig 46.4a
    c. Are usually pincers or fangs that function in feeding
  3. Mandibulates
    a. Include crustaceans, insects, centipedes, millipedes
    b. Have biting jaws called mandibles fig 46.4b
    c. Most anterior appendages are sensory antennae, one or more pairs
    d. Next appendages are mandibles fig 46.7b
  4. Taxon Tracheata
    a. Insects and myrapods (centipedes and millipedes) separated from crustaceans
    b. Possess tracheal respiratory system
      1) Small branched air ducts transmit oxygen to all cells
      2) Openings in exoskeleton
    c. Use Malpighian tubes for excretion
      1) Slender projections from digestive system
      2) Collect and filter body fluids, empty wastes into hindgut
    d. Possess uniramous (single-branched) legs
      1) Crustacean appendages are biramous (two-branched) fig 46.5
      2) Some have become single-branched by evolutionary reduction

D. Doubts about the Traditional Approach
\ 1. Results from recent research
    a. Branching may not be strong, fundamental character
    b. Not as suitable for making taxonomic distinctions
  2. More valuable data gained through molecular approach
    a. Branching controlled by a single gene
    b. Arthropod appendage pattern orchestrated by homeotic (*Hox*) genes
    c. Single gene, *Distal-less*, initiates development of limbs in insects and crustacea
    d. Same genes found in other animals, including vertebrates

E. A Revolutionary New Phylogeny
  1. Championed by Richard Brusca, Columbia University
  2. Crustaceans are basic group, insects are close sister group fig 46.6
  3. Morphological evidence
    a. Based on 100 conserved anatomical features of central nervous system
    b. Insects more closely related to crustaceans than to any other group
    c. Share pattern of segmental neurons, among other features
  4. Molecular evidence
    a. Based on 18S rRNA sequences, 18S rRNA gene, EF-1a elongation factor, RNA polymerase II gene
    b. Insects sister group to crustaceans not myrapods, arose from crustaceans
    c. Conflicts with 150 years of morphology-based thinking

III. GENERAL CHARACTERISTICS OF ARTHROPODS

A. Body Segmentation
  1. Some members have large numbers of segments
  2. In others the segments are fused into functional units or tagmata
    a. Example head or thorax of an insect fig 46.7

  b. Process called tagmatization
  c. Segmentation may be more obvious during development of larvae
  d. Head and thorax may be fused into a cephalothorax

B. Exoskeleton
1. All arthropods covered by hardened chitinous skeleton or cuticle
  a. Tough outer covering is secreted by and fused with epidermis
  b. Flexible at certain points to allow exoskeleton to bend and appendages to move
2. Functions of exoskeleton
  a. Prevents excessive water loss
  b. Protects from predators, parasites, and injury
3. Molting
  a. Growth requires periodic ecdysis, shedding of outer cuticle
  b. New exoskeleton forms beneath old one
    1) Controlled by hormones
    2) Separated by a fluid that dissolves components of old skeleton
    3) Old skeleton cracks open and is shed as fluid increases in volume
  c. New skeleton is initially quite soft and must be expanded to full size
    1) Blood circulation aids in this expansion
    2) Insects and spiders may take in air to help
  d. Expanded exoskeleton hardens
    1) Animals vulnerable when exoskeleton is soft
    2) Hide under stones, leaves, branches

C. Compound Eye — fig 46.8a
1. Composed of many independent visual units called ommatidia
  a. Each covered with a lens
  b. Linked to eight retinular cells and central light-sensitive rhabdom
2. Apposition eyes
  a. Example: Bee, butterfly, day-active insects
  b. Each ommatidium acts in isolation
  c. Curtain of pigment cells blocks passage of light from one to another
3. Superposition eyes
  a. Example: Moth, night-active insects
  b. Maximize amount of light to each ommatidium
    1) Pigment in pigment cells concentrated at top during night
    2) Low levels of light perceived by many omatidia
    3) Pigment dispersed through cells during daylight
    4) Eye functions like an apposition eye
  c. Insect eye pigments
    1) Pigment in pigment cells give eye color, but is not visual pigment
    2) Visual pigment located in rhabdom, in the center of each ommatidium
  d. Images from ommatidia are combined in brain to form image
4. Ocelli are simple eyes with single lenses — fig 46.9b
  a. Sometimes occur together with compound eyes
  b. Function in distinguishing light and darkness
  c. May also serve as horizon detectors in locusts and dragonflies

D. Evolutionary Reduction of Coelom
1. Consists of cavities housing reproductive organs and some glands
2. Arthropods completely lack cilia
3. Have tubular gut that extends from mouth to anus
4. Posses complex circulatory, nervous, respiratory, and excretory systems — fig 46.9

E. Circulatory System
  1. Open system, blood does not flow through closed vessels
  2. Longitudinal heart along dorsal thorax and abdomen
     a. With contraction, blood flows into head
     b. When heart relaxes, blood returns to it
     c. Series of one-way valves in posterior of heart allows blood to flow inward only
     d. Blood from anterior end flows through spaces to posterior end
     e. Flow is more rapid with greater activity
     f. Blood delivers nutrients, transports wastes

F. Nervous System
  1. Predominant double chain of segmented ganglia runs along ventral surface
  2. Anterior end possess three fused pairs of dorsal ganglia, form the brain
  3. Much control of activities regulated by ventral ganglia
     a. Many activities continued with brain removed
     b. Brain appears to be inhibitor, not stimulator as in vertebrates

G. Respiratory System
  1. In Uniramia, transports oxygen directly to tissues
  2. Vertebrate system more efficient
     a. Blood moves within closed circulatory system to all parts of body
     b. Oxygen moves within blood
  3. In arthropods, all parts of body must be near air passage, limits body size
  4. Possess no single respiratory organ
     a. Terrestrial arthropods have system of branched tracheae fig 46.10
        1) Become smaller tracheoles that are in contact with individual cells
        2) Air passage controlled through external spiracle openings
        3) Closing spiracles conserves water
        4) Air flow assisted by muscular movements in larger organisms
     b. Many chelicerates, like spiders, have book lungs
        1) A series of leaf-like plates within a chamber
        2) Air drawn in and out by muscular contractions
        3) May exist along with or in place of trachaea
     c. Horseshoe crabs have book gills
     d. Onychophora also possess tracheae
     e. Crustaceans have gills

H. Excretory System
  1. Several forms of excretory systems
  2. Principal components of the land uniramians are Malpighian tubules fig 46.3
     a. Slender projections of the digestive tract
     b. Located at the junction of the midgut and hindgut
     c. Fluid of blood passes through walls of tubules
     d. Nitrogenous wastes are precipitated as fluid passes toward hindgut
     e. Waste emptied into hindgut and eliminated
     f. Most water and salts reabsorbed by hindgut and returned to body
     g. Efficient mechanism to conserve water, necessary for adaptation to land

46.2 The chelicerates all have fangs or pincers

I. CLASS ARACHNIDA: THE ARACHNIDS

A. Chelicerates Are a Distinct Evolutionary Line
1. Chelicerae are most anterior appendages and function as fangs or pincers
2. Includes spiders, ticks, mites, scorpions, daddy longlegs
3. Possess a pair of chelicerae, pair of pedipalps, four pair of walking legs
   a. Chelicerae are frontmost appendages, fangs with poison glands
   b. Pedipalps are next set of appendages, like legs but one less segment
      1) Are specialized copulatory organs in spiders
      2) Scorpion pedipalps are large pincers
4. Other general characteristics
   a. Most are carnivorous, mites are herbivorous
   b. Most ingest only preliquified foods, thus digestion is external
   c. Are generally terrestrial, evolved direct transfer of sperm
   d. Breathe by trachea, book lungs or both

B. Order Opiliones: The Daddy Longlegs — fig 46.11
1. Possess compact, oval bodies with extremely long, slender legs
2. Respire by a primary pair of trachea
3. Engage in direct copulation, unusual among arachnids
   a. Males possess penis
   b. Females use ovipositor to deposit eggs in crevices
4. Most are predators, some feed on plant juices or are scavengers

C. Order Scorpiones: The Scorpions — fig 46.12
1. Pedipalps are modified into pincers to handle and tear food apart
2. Have venomous stings on terminal segment
3. Distinctive elongated, jointed abdomens
4. Extremely ancient group of terrestrial arthropods
5. May be as large as 18 centimeters, common in tropical and desert regions
6. Young born alive, 1 to 95 in a single brood

D. Order Araneae: The Spiders
1. Important predators of insects and small animals
2. Hunt prey or catch it in silk webs
   a. Silk formed from fluid protein, forced out spinnerets
   b. Variety of adaptive modifications to webs
3. Many forms are active hunters
   a. Tarantulas do not spin webs, trap-door spiders line burrows with silk
   b. Water spider envelopes body in bubble of air
4. Have poison glands leading through chelicerae
   a. Some are poisonous to man and large mammals
   b. Examples: Black widow and brown recluse — fig 46.13

E. Order Acari: Mites and Ticks
1. Most diverse in terms of numbers and species
2. Generally very small in size
3. Cephalothorax and abdomen fused into an ovoid body
4. Respiration occurs through trachea or directly through exoskeleton
5. Development occurs on many complex successive stages
   a. Inactive 8-legged prelarva gives rise to active 6-legged larva
   b. Produces succession of 3 8-legged stages, finally adult males and females

6. Diverse in structure and habitat
   a. Found in terrestrial, freshwater, and marine habitats
   b. Feed on fungi, plants, and animals
   c. Are predators, internal or external parasites of invertebrates and vertebrates
7. Many mites live on humans, have irritating bites
   a. Some transmit diseases
   b. Follicle mites live in facial hair follicles, no adverse symptoms
8. Ticks are blood-feeding ectoparasites, transmit various diseases — fig 46.14
   a. Include spotted fevers caused by tick borne bacteria
   b. Lyme disease carried by ticks, caused by spirochetes
   c. Red-water fever is protozoan disease of cattle, sheep, and dogs

II. CLASS MEROSTOMATA: HORSESHOE CRABS

A. General Characteristics
1. Example: *Limulus*, common on North Atlantic coasts — fig 46.15
2. Evolution
   a. Ancient group, fossils identical to 220 million years old *Limulus*
   b. May be derived from trilobites due to resemblance of larvae
3. Live in deep water, migrate to shallow coastal waters to mate
4. Feed at night on mollusks and annelids

B. Structural Adaptations
1. Swim on backs by moving abdominal plates
2. Shell protects most body parts
3. Possess four pairs of walking legs
4. Shell also covers chelicerae and pedipalps — fig 46.16

III. CLASS PYCNOGONIDA: THE SEA SPIDERS

A. General Characteristics
1. Common, but rarely observed because of small size
2. Adults are generally external parasites or predators on other animals — fig 46.17

B. Structural Adaptations
1. Have sucking proboscis with terminal mouth
2. Body consists mostly of cephalothorax, no well-defined head
3. Possess four to six pairs of legs
4. Males exhibit parental care of young, carry eggs on legs
5. Lack excretory and respiratory systems, exchange by diffusion
6. Not closely related to other two classes

46.3 Crustaceans have branched appendages

I. CRUSTACEANS

A. General Biology
1. Primarily aquatic, include crabs, shrimp, lobsters, crayfish, barnacles — tbl 46.1
2. Two pairs of antennae, three types of chewing appendages
3. Number of legs varies with the species
4. All appendages are biramous
   a. Excluding first pair of antennae
   b. Single-branched appendages previously biramous, one branch lost in evolution

5. Evolution of crustaceans
   a. All descended from common ancestor as evidenced by nauplius larvae fig 46.18
   b. Some groups pass larval stage in egg, undergo direct development into adult
6. Have legs on abdomen and thorax like millipedes and centipedes (unlike insects)
7. Only arthropods with two pair of antennae
8. Mandibles evolved from limbs that developed a chewing function
9. Many have compound eyes and tactile hairs over whole body
10. Larger forms have feathery gills near base of legs
11. Variety of sex strategies and care of young

B. Decapod Crustaceans
1. Decapods ("ten-footed") include lobsters, shrimp, and crabs fig 46.19
2. Structural adaptations
   a. Exoskeleton reinforced with calcium carbonate
   b. Body segments fused into cephalothorax, covered by carapace
   c. Crushing pincers common, used to obtain food
3. Specializations of lobsters and crayfish
   a. Abdominal swimmeretes used in reproduction and locomotion
   b. Snapping of telson and uropods causes forceful, rapid movements
4. Crabs have larger, broader carapace than lobsters

C. Terrestrial and Freshwater Crustaceans
1. Terrestrial forms include pillbugs, sowbugs, isopods
2. Sand and beach fleas, order Amphipoda are semiterrestrial intertidal species
3. Planktonic crustaceans include copepods fig 46.20

D. Sessile Crustaceans
1. Include barnacles, order Cirripedia fig 46.21
2. Are sessile as adults, but have free-swimming larvae
3. Head attached to submerged object, food swept into mouth by feathery legs
4. Protected by calcareous plates attached to substrate
5. Are hermaphroditic, unusual for crustaceans, but cross-fertilize

46.4 Insects are the most diverse of all animal groups

I. SUBPHYLUM UNIRAMIA

A. Enormous Group of Mandibulates
1. Include millipedes, centipedes, insects
2. Distinct, but related classes

B. General Characteristics
1. Evolved from annelids similar to oligochaetes
2. Respire via trachea
3. Filter waste products through Malpighian tubules

II. CLASSES CHILOPODA AND DIPLOPODA: THE CENTIPEDES AND MILLIPEDES

A. Common Characteristics
1. Both possess head region followed by numerous segments
   a. Segments are nearly identical, possess paired appendages
   b. Centipedes have one pair of legs per segment fig 46.22
   c. Millipedes have two pairs of legs per segment fig 46.23
      1) Millipede segment is a tagma

2) Formed from fusion of two segments, thus two pairs of legs
2. Share similar reproductive strategies
 a. Fertilization is internal, direct transfer of sperm
 b. Sexes separate, all species lay eggs
 c. General appearance of young is similar to adult

B. Distinct Characteristics
1. Centipedes
 a. Are carnivorous, eat mainly insects
 b. Appendages of first trunk segment modified into poison fangs
 c. Poison toxic to humans, bites often painful
2. Millipedes
 a. Most are herbivorous, feed on decaying vegetation
 b. Can roll bodies into a flat coil
 c. May secrete defensive fluids and cyanide gas

III. CLASS INSECTA: THE INSECTS

A. General Ecology of Insects
1. Largest group of organisms on earth, live in all habitats, including the sea
2. Especially numerous in the tropics
3. Enormous diversity fig 46.24, tbl 46.2

B. External Features
1. Primarily terrestrial organisms, aquatic forms had terrestrial ancestors
2. Typical body organization
 a. Have three body segments: Head, thorax, abdomen
 b. Have three pairs of legs, all attached to thorax
 c. Have one pair of antennae
 d. May have one or two pairs of wings
3. Basic structure of mouthparts similar with modifications by feeding habits fig 46.25
4. Most possess compound eyes, many have ocelli
5. Thorax consists of three segments
 a. Each has a pair of legs
 b. Legs may be absent in some larvae, flies for example fig 46.26
6. Structure of insect wings
 a. If two pairs, attach to middle and posterior segments
 b. If one pair, attach to middle segment
 c. Arise as saclike outgrowths, are solid excluding veins
 d. Are not homologous to other appendages
 e. Two pairs are the basic construction for winged insects
 f. One pair lost in the evolution of groups like flies
 g. Most wings folded at rest, except for outstretched dragonfly wings
 h. Forewings may be hard and tough, form covering for hindwings
 i. Most wings composed of sheets of chitin with strengthening veins
 j. May possess detachable scales, like butterflies and moths fig 46.27
 k. Some groups like springtails never evolved wings
 l. Others, like fleas and lice, are derived from winged ancestors

C. Internal Organization
1. Tubular, somewhat coiled digestive tract
 a. Greater coiling associated with sucking mouthparts
 b. Dilute digestive enzymes less effective on liquids than solids
 c. Anterior and posterior digestive regions lined with cuticle

d. Digestion occurs within stomach or midgut
e. Excretion occurs through Malpighian tubules
f. Digestive enzymes secreted from cells in midgut, some from salivary glands

2. Trachea extend throughout body
   a. May form air sacs with muscles that create a bellows system to move air deeper
   b. Spiracles closed via actions of muscles, retards water loss
   c. Spiracles are permanently closed in some aquatic, parasitic forms
      1) Trachea run just below surface
      2) Gas exchange occurs by diffusion
3. Fat body is food-storage organ or is similar to vertebrate liver
   a. More prominent in immature forms
   b. May be completely depleted when metamorphosis is finished
   c. Non-feeding adults rely on fat body for nutrition through short lives

D. Sense Receptors
1. Possess wide variety of sensors in addition to eyes
   a. Sensory hairs located all over bodies
      1) Linked to nerve cells, sensitive to mechanical and chemical stimulation
      2) Abundant on antennae and legs
   b. Sound detected by tympanum, associated with tracheal air sacs
   c. Sensory hairs may also detect sound waves
2. Insect communication
   a. Produce sounds which are mostly inaudible to humans
   b. Produce chemicals called pheromones

IV. INSECT LIFE HISTORIES

A. General Characteristics of Development
1. Most insects hatch from eggs outside of the mother's body
   a. Zygote develops within egg into young insect
   b. Escapes egg by chewing or bursting through it
   c. May have specialized projections to aid in escape
2. Rarely eggs develop within mother's body
3. Young insects undergo regular ecdysis, stages called instars
   a. Exoskeleton is soft immediately after molting
   b. Young is in greater danger from predators

B. Simple Versus Complete Metamorphosis — fig 46.28a
1. Simple metamorphosis
   a. Immature stages generally called nymphs
   b. Appear similar to adults, but smaller size and lack wings
   c. Larvae of mayflies and dragonflies are aquatic
      1) Have gills
      2) Adults are terrestrial, look very different
   d. Nymphs and adult grasshoppers look similar, live in same habitat
2. Complete metamorphosis — fig 46.28b
   a. Wings appear only during resting stage just prior to final molt
   b. Resting stage called a pupa or chrysalis
      1) Does not normally move, except mosquitos
      2) Substantial amount of cellular reorganization occurs
   c. Juveniles and adults live in distinct habitats
   d. Development is indirect, larvae are worm-like
   e. Larva do not have compound eyes
   f. Larvae may or may not have legs

- g. Generally have chewing mouthparts, even if adults have sucking mouthparts
- h. Pupa generally are usually inactive and do not feed
- i. Include moths, butterflies, beetles, bees, wasps, ants, flies, fleas

3. Ametabolus development
   - a. No dramatic change in form from immature to adult stages
   - b. Includes most primitive insects like silverfish and springtails
4. Molting hormone, ecdysone, controls ecdysis and molting
   - a. Released from gland in thorax on stimulus from brain hormone
   - b. Effects of molting hormone determined by juvenile hormone
   - c. Amount of juvenile hormone decreases as insect passes through successive stages
     - 1) When high, produces another larva
     - 2) When lower, produces pupa, then adult

INSTRUCTIONAL STRATEGY

PRESENTATION ASSISTANCE:

Many of the names associated with arthropods involve "poda" or "pedia" indicating the importance of the characteristics of the appendages in determining classification.

Discuss why it is unlikely that the giant insects of science fiction movies could evolve given present conditions on the earth.

Consider why it is likely that arthropods could "inherit the earth" if the ozone layer is destroyed.

Daddy longlegs produce a strong toxin. It does little harm though, because their jaws are too small to grasp animals larger than insects and other spiders.

VISUAL RESOURCES:

Show lots of slides to indicate the enormous diversity of these phyla.

Living examples can be shown in silhouette using the overhead. This is a good way to show the differences between simple and complete metamorphosis. Be careful with winged varieties and certain specimens that cause immediate revulsion in humans. Your specimens may also become more active when warmed by the overhead. Dead specimens from a "bug" collection may work better.