

## Chapter Outline

### 30.1 A Coelom

#### A. Protostome Organization

1. Protostomes are bilaterally symmetrical, have three germ layers, the organ level of organization, the tube-within-a-tube body plan, and a true coelom.
2. The **coelom** is a body cavity between the digestive tract and body wall; it is lined by mesoderm.
3. The coelom allows the digestive system to move independent of the body wall; internal organs can be complex.
4. Coelomic fluid assists respiration and circulation by diffusing nutrients, and assists excretion by accumulating wastes.
5. This cavity may serve as a storage area for eggs and sperm.
6. The coelomic fluid protects internal organs against damage and temperature changes and also serves as a **hydrostatic skeleton**.

#### B. Coelomates Are Protostomes and Deuterostomes.

1. **Protostomes** include molluscs, annelids, and arthropods; they have three embryological traits.
  - a. In **spiral cleavage**, the cells divide without an increase in the size of cells; the fate of cells is also fixed.
  - b. The blastopore is associated with the mouth.
  - c. A coelom (**schizocoelom**) forms by splitting mesoderm on either side of the primitive gut.
2. **Deuterostomes** include echinoderms and chordates.
  - a. They undergo **radial cleavage** where the new daughter cells sit on top of previous cells; the fate of these cells varies.
  - b. The blastopore is associated with the anus.
  - c. A coelom (**enterocoelom**) forms by the fusion of mesodermal pouches from the primitive gut.

### 30.2 Molluscs

#### A. Over 110,000 living species of molluscs belong to the phylum **Mollusca**.

1. Most are marine, but some are freshwater and terrestrial.
2. Molluscs have a three-part body plan: a visceral mass, a mantle, and a foot.
3. The **visceral mass** contains internal organs: digestive tract, paired kidneys, and reproductive organs.
4. A **mantle** covering partly surrounds the visceral mass; it may secrete a shell and help develop the gills or lungs.
5. The **foot** is muscular and adapted for locomotion, attachment, food capture, or a combination of functions.
6. The **radula** in the mouth bears many rows of teeth and is used for grazing on food.
7. The nervous system consists of several ganglia connected by nerve cords.
8. In molluscs, the coelom is reduced and limited to the region around heart.
9. Most molluscs have an **open circulatory system**: a heart pumps hemolymph through vessels into a hemocoel.
10. Blue **hemocyanin**, not red hemoglobin, is the respiratory pigment found in molluscs.
11. Some are slow moving with no head; others are active predators with a head and sense organs.
12. **Chitons** are in the class **Polyplacophora**.
  - a. Chiton shells consists of a row of eight overlapping plates.
  - b. The flat chiton foot is muscular and creeps along or clings to rocks.
  - c. They scrape algae and other plant food from rocks with a well-developed **radula**.

## B. Bivalves

1. Class **Bivalvia** contains the bivalves (clams, oysters, mussels, scallops).
2. “Bivalves” are two-part shells that are hinged and close by powerful muscles.
3. They have no head, no radula, and little cephalization.
4. Clams burrow with a **hatchet-shaped foot**; mussels use it to produce threads to attach to objects.
5. Scallops both burrow and swim; rapid clapping of their valves releases water in spurts.
6. The shell is secreted by the mantle.
  - a. Shell is composed of protein and calcium carbonate with an inner layer of pearl.
  - b. Shell deposits around a foreign particle inserted between mantle and shell to form a pearl.
7. A compressed muscular foot projects down from shell; by expanding the tip, it pulls in the body.
8. The beating cilia of the gills causes water to enter the mantle cavity by way of an **incurrent siphon** and exit by way of an **excurrent siphon**.
9. The cilia of gills move water through mantle cavity.
10. Gills capture particles and move them toward the mouth; the mouth leads to the stomach, which leads to the intestine, which passes through a heart and ends at the anus.
11. The circulatory system is open; the heart pumps hemolymph into vessels that open into the hemocoel.
12. The nervous system consists of three pairs of ganglia that connect the front, back, and foot.
13. Two excretory kidneys below the heart remove ammonia waste from the pericardial cavity.
14. The sexes are separate; the gonad is located around coils of intestine.
15. Some clams and annelids have the same type of larva, indicating an evolutionary relationship between molluscs and annelids.

## C. Cephalopods

1. Class **Cephalopoda** (“head-footed”) includes squids, cuttlefish, octopuses, and nautilus.
2. Squids and octopuses squeeze water out of the mantle cavity; the water forced out through a funnel propels them by **jet propulsion**.
3. Around the head are tentacles with suckers or adhesive secretions adapted for grasping prey.
4. A head equipped with a powerful beak can tear prey apart.
5. Well-developed sense organs include focusing **camera-type eyes**.
6. Cephalopods, particularly octopuses, have well-developed brains with a capacity for learning.
7. Nautilus are enclosed in shells; squids have a reduced internal shell and octopuses lack shells.
8. Squids and octopuses possess **ink sacs**; they squirt a cloud of ink to escape predators.
9. Squids possess a vestigial shell under the mantle (the pen) which surrounds the visceral mass.
10. Squids direct the funnel to squeeze water out to move forward or backward.
11. Squids have a closed circulatory system where blood is always within blood vessels or the heart.
12. A squid has three hearts, one pumps blood to internal organs; two pump blood to the gills.
13. Gonads make up a large portion of the visceral mass; the sexes are separate.
  - a. **Spermatophores** are packets that contain sperm which a male tentacle passes to the female mantle cavity.
  - b. After the eggs are fertilized, they are attached to substratum in strings of up to 100 eggs.

## D. Gastropods

1. Class **Gastropoda** includes snails, land slugs, whelks, conchs, periwinkles, sea hares, and sea slugs.
2. Most are marine but some are freshwater or terrestrial.
3. Herbivores use a radula to scrape food from surfaces; carnivorous gastropods use the radula to bore through a surface, such as a bivalve shell, to obtain food.
4. A developed head with eyes and tentacles projects from a coiled shell that protects visceral mass.
5. Nudibranchs (sea slugs) and terrestrial slugs lack shells.
6. In development, gastropods undergo a **torsion**—the body is twisted to bring the anus and mantle cavity downward, forward and around to a position above head—to position the visceral mass above the foot.
7. In aquatic gastropod, the gills are in the mantle cavity.
8. In land gastropods, a mantle has blood vessels and functions as a lung when air is moved in and out through respiratory pores.
9. Terrestrial gastropod embryonic development does not go through a swimming larval stage found in aquatic species.
10. For terrestrial snails, the shell not only offers protection but it also prevents desiccation.

11. The foot contracts in peristaltic waves from anterior to posterior; this movement is aided by a lubricating mucus that is secreted.
12. Land snails are hermaphroditic.
  - a. In pre-mating behavior, they meet and shoot calcareous darts into each other's body wall.
  - b. Each inserts a penis into the other's vagina; this provides sperm for future fertilization of eggs.
  - c. Eggs are deposited in soil and development proceeds without the formation of a larva.
13. Hermaphroditism assures that any two animals can mate—very useful in slow-moving animals.

### 30.3 Annelids

#### A. Segmented Worms

1. About 12,000 species of segmented worms are in phylum **Annelida**.
2. Segmentation is evidenced by the rings that encircle the body; **septa** are internal walls that partition the coelom.
3. A well-developed, fluid-filled coelom and tough integument act as a hydrostatic skeleton.
4. **Segmentation** may have evolved in conjunction with a hydrostatic skeleton.
5. Using a hydrostatic skeleton, partitioning the coelom allows for independent movement of the segments so it can not only burrow but crawl on the surface.
6. Once segmentation and the tube-within-a-tube plan appeared, each segment could specialize to perform a particular function.
7. The digestive system is specialized to include a pharynx, stomach, and accessory glands.
8. The extensive **closed circulatory system** has blood vessels running the length of the body and to every segment.
9. The nervous system has a **brain** connected to a **ventral solid nerve cord** with a **ganglion** in each segment.
10. Paired **nephridia** in each segment collect waste material from coelom and excrete it through openings in the body wall.

#### B. Polychaete Worms

1. Most polychaetes (class **Polychaeta**) are marine.
2. Polychaetes possess *parapodia* and *setae*.
  - a. **Parapodia** are paddle-like appendages used in swimming and for respiration.
  - b. **Setae** are bristles, attached to parapodia, that help anchor polychaetes or help them move.
3. Clam worms such as *Nereis* are active predators.
4. Many have well-developed cephalization; the head has well-developed jaws, eyes, and other sense organs.
5. Other sedentary filter feeders possess tentacles with cilia to create water currents and sort out food particles.
6. Only during breeding do polychaetes have reproductive organs.
7. In *Nereis*, many worms coordinate the shedding of a portion of their bodies that contain either eggs or sperm; these segments float to the surface where fertilization takes place.
8. Marine worm zygotes develop larva similar to those of marine clams; again this shows a relatedness between annelids and molluscs.

#### C. Earthworms

1. Class **Oligochaeta** includes earthworms with only a few setae, protruding in pairs directly from the body.
2. Earthworms lack both a well-developed head and any parapodia.
3. Locomotion requires coordinated movement of body muscles and the help of setae.
  - a. As longitudinal muscles contract, segments bulge and setae protrude to anchor into soil.
  - b. When circular muscles contract, a worm lengthens, setae are withdrawn and the segment can be pulled forward.
4. Earthworms live in moist soil; a moist body wall allows for gas exchange.
5. Earthworms are scavengers that extract organic remains from soil they eat.
6. A muscular pharynx draws food into the mouth.
7. Food is stored in a crop and ground up in a thick, muscular gizzard.
8. The dorsal surface of the intestine is expanded into a **typhlosole** for more surface area for digestion.
9. Each external segment corresponds to an internal septum; a wall that separates each body segment.
10. A long ventral nerve cord leads from the brain to ganglionic swellings and lateral nerves in each segment.

11. The excretory system involves nephridia.
  - a. The coiled nephridia tubules in each segment have two openings: one is a ciliated funnel that collects coelomic fluid, and the other is an exit through the body wall.
  - b. Between the two openings, a coiled nephridia tubule removes waste from blood vessels.
12. The dorsal blood vessel moves red blood anteriorly; five pairs of hearts pump blood to a ventral vessel.
13. Reproduction
  - a. Earthworms are **hermaphroditic**.
  - b. The male organs are the testes, sperm ducts, and seminal vesicles.
  - c. The female organs are the ovaries, oviducts, and seminal receptacles.
  - d. Mating involves aligning parallel to each other facing opposite directions to exchange sperm.
  - e. Each possesses a **clitellum** that secretes mucus that slides off, forming a slime tube that protects the sperm and eggs from drying out.
  - f. The slime tube forms a cocoon around the fertilized eggs as they develop.
  - g. Embryonic development lacks a larval stage.
14. Comparison of the clam worm and earthworm show adaptations to marine and terrestrial life through presence or absence of cephalization, parapodia, a slime tube cocoon, and trochophore larvae.

#### D. Leeches

1. Leeches belong to the class **Hirudinea**.
2. Most are freshwater species but a few are marine or terrestrial.
3. They lack setae and each body ring has several transverse grooves.
4. Leeches possess a small anterior sucker around the mouth and a larger posterior sucker.
5. Although some are free-living predators, most feed on body fluids.
6. Leeches keep blood from coagulating by **hirudin**, an anticoagulant in their saliva.

### 30.4 Arthropods

#### A. Arthropods Have Jointed Appendages

1. Over 1,000,000 species are in phylum **Arthropoda**; they are considered highly successful because they have adapted to so many different habitats.
2. Arthropods have a rigid **exoskeleton** with freely movable jointed appendages.
  - a. The exoskeleton is a strong but flexible outer covering composed mainly of **chitin**.
  - b. Chitin is a strong, flexible, nitrogenous polysaccharide.
  - c. The exoskeleton serves for protection, attachment for muscles, locomotion, and prevention of desiccation.
  - d. Because the exoskeleton is hard and nonexpandable, arthropods must **molt** (shed) the exoskeleton to grow larger.
    - 1) Before molting, the body secretes a larger soft and wrinkled exoskeleton underneath.
    - 2) Enzymes partially dissolve and weaken old exoskeleton.
    - 3) The arthropod breaks the old exoskeleton open and wriggles out.
    - 4) The new exoskeleton then quickly expands and hardens.
3. Some segments of arthropods have fused into regions (e.g., a head, a thorax, and an abdomen).
  - a. Trilobites (Cambrian period) had a pair of appendages on each body segment.
  - b. Modern arthropod appendages specialize for walking, swimming, reproduction, etc.
  - c. These modifications account for the diversity and success of arthropods.
4. Arthropods have a well-developed nervous system.
  - a. A brain is connected to a ventral solid nerve cord.
  - b. The head bears various sensory organs.
  - c. Compound eyes have many complete visual units; each collects light independently.
  - d. The lens of each visual unit focuses the image on the light-sensitive membranes of a few photoreceptors.
  - e. In simple eyes, a single lens brings the image to focus into many receptors, each of which receives only a portion of the image.
5. Arthropods use a variety of respiratory organs.
  - a. Marine forms use gills with vascularized, thin-walled tissue specialized for gas exchange.
  - b. Terrestrial forms have **book lungs** (e.g., spiders) or **tracheae air tubes** (e.g., insects).
6. **Metamorphosis** is a drastic change in form and physiology that occurs as a larva becomes an adult.
  - a. Metamorphosis contributes to the success of arthropods.
  - b. A larva eats foods and lives in environments different from the adult.

- c. Competition between the immatures and adults of a species is reduced.
- d. This reduction in competition allows more members of the species to exist at one time.

#### B. Crustaceans

1. About 40,000 species of crustacea belong to subphylum **Crustacea**.
2. Crustaceans are successful and mostly marine arthropods.
3. The head usually bears compound eyes and five pairs of appendages.
  - a. The first two appendages are antennae and antennules; in front of the mouth, they have sensory functions.
  - b. The next three pairs (mandibles, first and second maxillae) lie behind the mouth and are used in feeding.
4. **Biramous appendages** have two branches; one branch is a gill and the other is the leg branch.
5. Copepods and krill feed on algae; numerous, they are an important link in marine food chains.
6. **Barnacles** have a thick, heavy shell and are sessile.
  - a. Stalked barnacles attach by their stalk; stalkless barnacles attach directly to the shell.
  - b. Barnacles begin as free-swimming larvae and become sessile on wharf pilings, rocks, etc.
  - c. They extend feathery structures (cirri) to filter feed.
7. **Decapods** include shrimps, lobsters, crabs, etc.
  - a. Their thorax bears five pairs of walking legs; the first pair may be modified as claws.
  - b. Usually respiratory gills are above the walking legs.
  - c. The nonsegmented **carapace** covers the fused head and thorax (**cephalothorax**).
  - d. Abdominal segments have a pair of **swimmerets**, small paddlelike structures.
  - e. The first pair of swimmerets in a male are stronger to pass sperm to the female.
  - f. The last tail segments are the **uropod** and the **telson**, which together make a fan-shaped tail.
  - g. A crayfish awaits prey and uses its claws to carry it to the mouth.
  - h. The crayfish stomach has two main regions.
    - 1) The anterior **gastric mill** with chitinous teeth grinds food.
    - 2) A posterior region filters coarse particles before absorption in the digestive glands.
  - i. **Green glands** in the head area excrete metabolic wastes through a duct at the base of the antennae.
  - j. The coelom is reduced in arthropods and forms the space about the reproductive system.
  - k. Heart pumps hemolymph containing bluish hemocyanin into a **hemocoel** where it washes around the organs.
  - l. A brain is connected to a **ventral nerve cord**; periodic ganglia give off lateral nerves.
  - m. The sexes are separate in crayfish.
    - 1) The male has a coiled sperm duct that opens to the outside at the base of fifth walking leg.
    - 2) The female's ovaries open at the base of the third walking legs.
    - 3) The fold between the bases of the fourth and fifth pair of legs serves as a seminal receptacle.
    - 4) Following fertilization, the eggs are attached to the swimmerets of the female.

#### C. Uniramians

1. The subphylum **Uniramia** includes the millipedes, centipedes, and insects.
2. The **uniramous appendages** attached to the thorax and abdomen have only one branch—the leg branch.
3. The head appendages include one pair of antennae, one pair of mandibles, and one or two pairs of maxillae.
4. Uniramia live on land and breathe by air tubes called **tracheae**.

#### D. Insects

1. Over 900,000 species of **insects** are in the superclass **Insecta**; this exceeds all other animal species combined.
2. Most insects live on land; some are secondarily aquatic.
3. Insect body is divided into a **head, thorax, and abdomen**.
  - a. The head bears sense organs and mouthparts.
  - b. The thorax bears three pairs of legs and one or two pairs of wings; the wings provide advantages in escaping enemies, finding food, and mating.
  - c. The abdomen contains most of the internal organs.
4. The exoskeleton of an insect is lighter and contains less chitin than that of many other arthropods.

5. Grasshoppers have adaptations as herbivorous insects.
    - a. The third pair of legs is suited to jumping.
    - b. The front wings are protective and leathery; the thin hind pair of wings fold up.
    - c. Each side of the first abdominal segment has a **tympanum** for sound wave reception.
    - d. Two paired projections form an ovipositor in females used to dig a hole for laying eggs.
    - e. The grasshopper digestive system is complex.
      - 1) The mouth mechanically breaks apart food, and salivary secretions begin digestion.
      - 2) The crop temporarily stores food.
      - 3) A gizzard finely grinds the food.
      - 4) Digestion is completed in stomach; gastric ceca cavities assist absorption of nutrients.
    - f. The excretory system consists of **Malpighian tubules**.
      - 1) Tubules extend into hemocoel.
      - 2) Nitrogenous wastes are collected and excreted into the digestive system.
      - 3) Formation of solid nitrogenous wastes (uric acid) conserves water.
    - g. The respiratory system begins with openings in the exoskeleton called spiracles.
      - 1) Air enters into small tubules called tracheae.
      - 2) Tracheae branch many times until they reach moist areas of gas absorption.
      - 3) Air movement through this tracheal system is assisted by air sacs.
      - 4) Air enters anterior four spiracles and exits by the posterior six.
      - 5) Using tracheae is a factor that limits the size of insects.
    - h. The circulatory system contains a slender, tubular heart.
      - 1) This heart lies against the dorsal wall of the abdominal exoskeleton.
      - 2) The heart pumps hemolymph into a hemocoel where it circulates before returning to the heart.
      - 3) Insect hemolymph is colorless—it lacks any respiratory pigment since the tracheal system transports gases.
    - i. Reproduction is adapted to life on land.
      - 1) A male grasshopper has a penis to transfer sperm to the female.
      - 2) Internal fertilization protects the gametes from drying out.
      - 3) Female grasshoppers deposit eggs in the ground with her ovipositor.
    - j. Grasshoppers undergo incomplete metamorphosis; the immature nymph resembles adult.
    - k. Other insects undergo complete metamorphosis; the wormlike larvae reorganize into different adults.
    - l. Some species (e.g., bees and ants) exhibit colonial social behavior.
    - m. Entomology, the study of insects, is a major field of biology..
  6. Crustacea are primarily marine or freshwater organisms, use gills and an oxygen carrying pigment, and excrete liquid ammonia wastes; insects are primarily terrestrial or freshwater organisms, use tracheae and lack respiratory pigments, and excrete solid wastes.
- E. Centipedes and Millipedes (Superclass **Myriapoda**)
1. The class **Chilopoda** includes about 2,500 species of **centipedes**.
    - a. The body is composed of a head and trunk with many segments; each segment has one pair of legs.
    - b. Centipedes are carnivorous; the head bears antennae and mouthparts with poison fangs.
  2. The class **Diplopoda** includes about 10,000 species of **millipedes**.
    - a. Millipedes have a cylindrical segmented body.
    - b. Some body segments are fused with two pair of legs on each resulting segment.
    - c. They possess more legs than centipedes, although not one thousand as the name states.
    - d. Millipedes dwell in the soil, feeding on dead organic matter.
- F. Chelicerates
1. Chelicerates in the subphylum **Chelicerata** include spiders, scorpions, ticks, mites, marine horseshoe crabs, and sea spiders.
  2. The first pair of appendages are **chelicerae**, the second pair are **pedipalps**, and the next four pairs are walking legs.
    - a. **Chelicerae** are appendages that function as feeding organs.
    - b. **Pedipalps** are feeding or sensory structures.
  3. All of the appendages attach to a **cephalothorax**, a fusion of head and thoracic regions.
  4. The head lacks antennae, mandibles, or maxillae appendages.

5. The marine horseshoe crab (genus *Limulus*) is common along the east coast of North America.
  - a. They scavenge sandy and muddy substrates for annelids, molluscs and other invertebrates.
  - b. The anterior shield is a horseshoe-shaped carapace with two compound eyes.
  - c. A long, unsegmented telson tail projects to the rear.
  - d. They possess book gills that resemble the pages in a book.
6. Scorpions
  - a. Scorpions are arachnids and are the oldest terrestrial arthropods known from fossils.
  - b. They are nocturnal and spend the day hidden under a log or rock.
  - c. Pedipalps are large pincerlike appendages; the abdomen ends in a stinger containing venom.
7. Ticks and mites number over 25,000 species and outnumber all other arachnids.
  - a. Ticks are parasites that suck blood and sometimes transmit diseases.
  - b. Chiggers are larvae of certain mites and feed on the skin of vertebrates.
8. Spiders have a narrow waist separating cephalothorax from abdomen.
  - a. Spiders have numerous simple eyes rather than compound eyes.
  - b. Spider chelicera are modified as fangs with ducts leading from poison glands.
  - c. The abdomen has silk glands; they may spin a web to trap prey.
  - d. Invaginations of the body wall form lamellae (pages) of book lungs.