Chapter 33

Invertebrates

Key Concepts

Framework

This chapter surveys the amazing diversity of invertebrate animals. Characteristics and representatives of the major animal phyla are presented. The groups covered are the sponges, cnidarians, flatworms, rotifers, three lophophorate phyla, nemerteans, molluscs, annelids, nematodes, arthropods, echinoderms, and chordates.

Chapter Summary

More than 95% of known animal species, and all except one of the 35 described phyla of animals, are **invertebrates,** animals that lack backbones.

33.1 Sponges are sessile and have a porous body and choanocytes

Sponges (phylum Porifea) are sessile animals found in fresh and marine waters. Water is drawn through pores in the body wall of this saclike animal into a central cavity, the **spongocoel,** and flows out through the **osculum.** Sponges are **suspension feeders,** collecting food particles by the action of collared, flagellated **choanocytes** lining the spongocoel or internal water chambers. Choanocytes resemble the cells of choanoflagellates. Molecular evidence indicates that animals originated from a choanoflagellate-like ancestor.

Sponges lack true tissues. In the **mesohyl,** or gelatinous matrix between the two body-wall layers, are **amoebocytes.** These cells take up food from the water and from choanocytes, digest it, and carry nutrients to other cells. Amoebocytes also form skeletal fibers, which may be sharp spicules or flexible fibers.

Most sponges are **hermaphrodites,** producing both eggs and sperm, although usually sequentially functioning as one sex or the other. Sperm, carried out through the osculum, fertilize eggs retained in the mesohyl of neighboring sponges. Flagellated larvae disperse to a suitable substratum and develop into sessile adults. Sponges produce defensive compounds that may have pharmaceutical uses.

■ INTERACTIVE QUESTION 33.1

Give the locations and functions of the following:

a. choanocytes

b. amoebocytes

33.2 Cnidarians have radial symmetry, a gastrovascular cavity, and cnidocytes

One of the oldest groups of the clade Eumetazoa, animals with true tissues, is the phylum Cnidaria. The

cnidarians include hydras, jellies, and corals. Their simple anatomy consists of a sac with a central **gastrovascular cavity** and a single opening serving as both mouth and anus. This body plan has two forms: **polyps,** which are sessile, cylindrical forms with mouth and tentacles extending upward, and **medusas,** which are flattened, mouth-down polyps that move by passive drifting and weak body contractions. Both these body forms occur in the life histories of some cnidarians.

Cnidarians use their ring of tentacles, armed with **cnidocytes,** to capture prey. Cnidocytes contain cnidae, which are capsules that can evert and discharge long threads; stinging capsules are called **nematocysts.** A gelatinous mesoglea is sandwiched between the epidermis and gastrodermis. Cells of these layers have bundles of microfilaments arranged into contractile fibers acting as simple muscles. A nerve net is associated with simple sensory receptors and coordinates the contraction of cells against the hydrostatic skeleton of the gastrovascular cavity, producing movement.

Hydrozoans Most hydrozoans alternate between an asexually reproducing polyp and a sexually reproducing medusa form. The common, freshwater hydras exist only in polyp form.

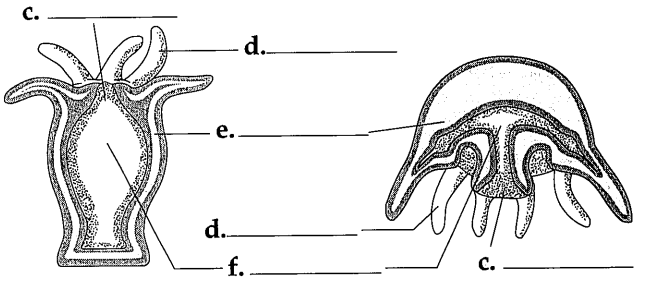
Scyphozoans The medusa stage is more prevalent in the scyphozoans. The sessile polyp stage often does not occur in the jellies of the open ocean.

Cubozoans Cubozoans have a box-shaped medusa stage and complex eyes in the fringe of their medusae. Many species, such as the sea wasp, have highly toxic cnidocytes.

Anthozoans Sea anemones and corals occur only as polyps. Corals secrete calcified external skeletons, and the accumulation of such skeletons produces coral.

■ INTERACTIVE QUESTION 33.2

Name these two cnidarian body plans and identify the indicated structures.



33.3 Most animals have bilateral symmetry

Clade Bilateria consists of bilaterally symmetrical animals with triploblastic development. Most are coelomates.

Flatworms Free-living flatworms live in marine, freshwater, and damp terrestrial habitats, and many are parasitic. They are triplobastic acoelomates. Most flatworms have a branching gastrovascular cavity, which functions in both digestion and distribution of food. Gas exchange and diffusion of nitrogenous wastes occur across the body wall. Ciliated flame bulbs associated with branched ducts function in osmoregulation. Phylum Platyhelminthes is divided into four classes.

Turbellarians include freshwater **planarians** and other, mostly marine, free-living flatworms. Planarians move using cilia to glide on secreted mucus or may use body undulations to swim. Eyespots on the head detect light, and lateral head flaps detect chemicals. Their nervous system consists of pairs of anterior ganglia and ventral nerve cords. Planarians reproduce asexually by regeneration or sexually by copulation between hermaphroditic worms.

Adapted to live as parasites in or on other animals, flukes (trematodes) have a tough outer covering, suckers, and extensive reproductive organs. The life cycles of trematodes are complex, usually including asexual and sexual stages and intermediate hosts in which larvae develop. Most monogeneans are external parasites of fishes and have a simple life cycle with ciliated larvae dispersing to new hosts.

As parasites, mostly of vertebrates, tapeworms (class Cestoidea) consist of a scolex, with suckers and hooks for attaching to the host's intestinal lining, and a ribbon of proglottids packed with reproductive organs. Predigested food is absorbed from the host. The life cycles of tapeworms may include intermediate hosts.

■ INTERACTIVE QUESTION 33.3

a. Describe the digestive system of a planarian.

b. Why do tapeworms, which are also flatworms, lack a digestive system?

Rotifers Rotifers are smaller than many protists but have an **alimentary canal,** with separate mouth and anus, and other organ systems. A pseudocoelom, a body cavity not completely lined by mesoderm, functions as

a hydrostatic skeleton and a circulatory system. A crown of cilia draws microscopic food into the mouth. The pharynx bears jaws that grind the ingested microorganisms. Some species reproduce by **parthenogenesis,** in which female offspring develop from unfertilized eggs. In other species, two types of eggs develop parthenogenically: one type forming females and the other developing into simplified males that produce sperm. The resulting resistant zygotes survive harsh conditions in a dormant state.

Lophophorates: Ectoprocts, Phoronids, and Brachiopods The three phyla of lophophorates all have a lophophore, a horseshoe-shaped or circular fold bearing ciliated tentacles, which surrounds the mouth and functions in feeding. This complex structure suggests that all three phyla are related. They have a true coelom.

Ectoprocts, commonly called bryozoans, are tiny, mostly marine animals living in colonies that are often encased in a hard exoskeleton, with pores through which their lophophores extend. Some species are important reef builders. **Phoronids** are marine, tube-dwelling worms that often live buried in sand, extending and withdrawing their lophophore from the tube opening. **Brachiopods,** or lamp shells, attach to the sea floor by a stalk and open their hinged shell to allow water to flow through the lophophore.

Nemerteans Most ribbon or proboscis worms are marine. Although their body is structurally acoelomate, a fluid-filled sac allows these worms to hydraulically operate an extensible proboscis to capture prey. Their excretory, sensory, and nervous systems are similar to those of flatworms, but they differ in having an alimentary canal and a **closed circulatory system.**

33.4 Molluscs have a muscular foot, a visceral mass, and a mantle

Molluscs are soft-bodied, mostly marine animals, most of which are protected by a shell. The molluscan body plan has three main parts: a muscular **foot** used for movement, a **visceral mass** containing the internal organs, and a **mantle** that covers the visceral mass and may secrete a shell. In many molluscs, a **mantle cavity,** a water-filled chamber formed by the extension of the mantle, encloses the gills, anus, and excretory pores. A rasping **radula** is used for feeding by many molluscs.

Most molluscs have separate sexes. Many marine molluscs have a life cycle that includes a ciliated larva called the **trochophore,** also found in marine annelids. Four of the eight molluscan classes are discussed in the text.

Chitons Chitons are oval marine animals with shells that are divided into eight dorsal plates. Chitons cling to and creep slowly over rocks, where they feed on algae.

Gastropods Most members of this largest molluscan class are marine, although there are many freshwater species, and some snails and slugs are terrestrial. A distinctive feature of this class is **torsion,** the embryonic rotation of the visceral mass that results in the anus and mantle cavity being above the head. Most gastropods have single coiled shells. Many gastropods have distinct heads with eyes at the tips of tentacles. Moving by the rippling of the foot, most gastropods graze on plant material with their radula. Land snails lack gills; the lining of the mantle cavity functions as a lung.

Bivalves Clams, oysters, mussels, and scallops have the two halves of their shell hinged at the mid-dorsal line. Most bivalves are suspension feeders; water flows into and out of the mantle cavity through siphons, and food particles are trapped in the mucus that coats the gills and then are swept to the mouth by cilia.

Cephalopods Squids and octopuses are rapid-moving carnivores. The mouth has beaklike jaws to bite prey and is surrounded by tentacles. The shell is reduced and internal in squids, absent in octopuses, and external only in the chambered nautilus. In squid, the foot has been modified to form parts of the tentacles and head and the muscular siphon used to jet-propel the squid when water from the mantle cavity is expelled.

Cephalopods are the only molluscs with a closed circulatory system. They have a well-developed nervous system, sense organs, and a complex brain—important features for active predators. The ancestors of octopuses and squids were probably shelled, predaceous molluscs. Shelled **ammonites** were the dominant invertebrate predators until their extinction at the end of the Cretaceous period.

■ INTERACTIVE QUESTION 33.4

a. Describe the three parts of the molluscan body plan.

1.

2.

3.

b. Compare the feeding behaviors and activity levels of snails, clams, and squid.

1. Snails:

2. Clams:

3. Squid:

33.5 Annelids are segmented worms

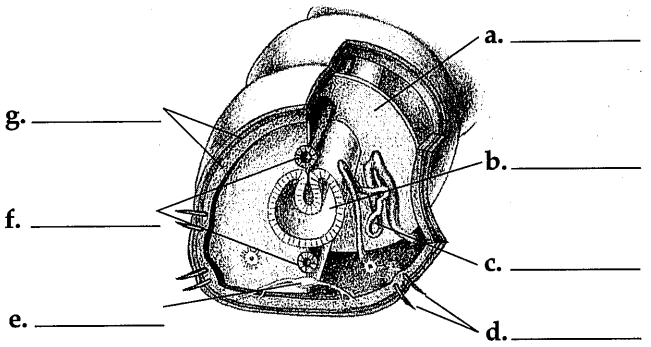
Annelids are segmented worms found in marine, freshwater, and damp soil habitats.

Oligochaetes This class includes the earthworms and several aquatic species. Earthworm castings improve soil texture. The earthworm has a closed circulatory system. Respiration occurs across the moist, highly vascularized skin. Septa partition the coelom into segments, in each of which is found a pair of excretory metanephridia, which filter metabolic wastes from the blood and coelomic fluid. The nervous system consists of a pair of cerebral ganglia, a subpharyngeal ganglion, and fused segmental ganglia along the ventral nerve cord. Earthworms are hermaphrodites; sperm are exchanged between worms during mating. A mucous cocoon, secreted by the clitellum, slides off the worm after picking up its eggs and stored sperm.

Noncompressible coelomic fluid within the body segments serves as a hydrostatic skeleton; circular and longitudinal muscles contract alternately to move. Pairs of chaetae provide traction for burrowing.

■ INTERACTIVE QUESTION 33.5

Identify the structures shown in this body segment of an earthworm.



Polychaetes These mostly marine worms have parapodia on each segment that may function in gas exchange and locomotion. Polychaetes may be planktonic, bottom burrowers, or tube dwellers.

Leeches Most leeches inhabit fresh water. Many feed on small invertebrates, whereas others are parasites that temporarily attach to animals, slit or digest a hole through the skin, and suck the blood of their host.

33.6 Nematodes are nonsegmented pseudocoelomates covered by a tough cuticle

Roundworms are among the most widespread of all animals, found inhabiting water, soil, and the bodies of plants and animals. These cylindrical worms have a tough covering called a **cuticle,** which is periodically shed as they grow. They have a complete digestive tract. Their thrashing movement is produced by contraction of longitudinal muscles. Fluid in the pseudocoelom circulates nutrients. Reproduction is usually sexual, fertilization is internal, and most zygotes form resistant cells.

Numerous nematode species are ecologically important decomposers. Other nematodes are serious agricultural pests and animal parasites. Parasitic nematodes can enlist the cells of their host to supply nutrients or to expand to house them.

■ INTERACTIVE QUESTION 33.6

Compare the locomotion of an earthworm and a nematode.

33.7 Arthropods are segmented coelomates that have an exoskeleton and jointed appendages

In terms of species diversity, distribution, and vast numbers, arthropods are the most successful group of animals.

General Characteristics of Arthropods Characteristics of **arthropods** include segmentation, which allows for regional specialization; a hard exoskeleton; and jointed appendages. **Trilobites** were early arthropods with uniform appendages. Appendages have become modified for walking, feeding, sensing, mating, and defense. A cuticle of chitin and protein completely covers the body as an **exoskeleton,** providing protection and points of attachment for the muscles that move the appendages. To grow, an arthropod must **molt,** shedding its exoskeleton and secreting a larger one. The exoskeleton probably first evolved in the seas as protection and anchorage for muscles, but as arthropods diversified on land, its functions came to include protection from desiccation and support.

Arthropods have extensive cephalization and well-developed sensory organs. A heart pumps hemolymph through an **open circulatory system** consisting of short arteries and a network of sinuses known as the hemocoel. The embryonic coelom becomes reduced during development, and the hemocoel becomes the main body cavity. Gas exchange in most aquatic species occurs through gills, whereas terrestrial arthropods have tracheal systems of branching internal ducts.

Molecular systematics suggests that arthropods diverged into four evolutionary lineages: **cheliceriforms, myriapods, hexapods,** and **crustaceans.**

Cheliceriforms Cheliceriforms (horseshoe crabs, scorpions, spiders, mites, and ticks) have clawlike **chelicerae** that serve as pincers or fangs used for feeding. They have an anterior cephalothorax and an abdomen. The earliest cheliceriforms were large, predatory **eurypterids.** The horseshoe crab and sea spiders are the few marine cheliceriforms that survive today.

Most modern cheliceriforms are arachnids. Most ticks are blood-sucking parasites on reptiles or mammals. Many mites are also parasites. In arachnids, the cephalothorax has six pairs of appendages: four pairs of walking legs, the chelicerae, and sensing or feeding appendages called pedipalps. In most spiders, **book lungs,** consisting of stacked internal plates, function in gas exchange. Many spiders spin characteristic webs of silk from special abdominal glands.

INTERACTIVE QUESTION 33.7

a. What are chelicerae?

b. How do spiders trap, kill, and eat their prey?

Myriapods Millipedes and centipedes are in the subphylum Myriapoda. The millipedes of class Diplopoda are wormlike, segmented vegetarians with two pairs of walking legs per segment. Millipedes may have been one of the first land animals. The centipedes of class Chilopoda are terrestrial carnivores with appendages modified as jaw-like **mandibles** and poison claws. Each segment of the trunk has one pair of legs.

Insects Insects and their relatives in the subphylum Hexapoda have more known species than all other forms of life combined. In a typical insect, the head has fused segments and has one pair of antennae, a pair of compound eyes, and several pairs of mouthparts modified for various types of ingestion. The thorax and abdomen have obvious segments. The nervous system consists of a cerebral ganglion and paired ventral nerve cords with segmental ganglia. Malpighian tubules, outpocketings of the digestive tract, function in excretion. Trachael tubes form the respiratory system.

The oldest insect fossils are from the Devonian period (about 416 mya), but a major diversification occurred in the Carboniferous and Permian periods with the evolution of flight and modification of mouthparts for specialized feeding on plants. The major diversification of insects appears to have preceded and probably influenced the radiation of flowering plants.

Flight is a major key to the success of insects. Many insects have one or two pairs of wings that are extensions of the cuticle of the dorsal thorax. Dragonflies were among the first flying insects.

In **incomplete metamorphosis,** the young are smaller versions of the adult and pass through several molts before developing wings and becoming sexually mature. In **complete metamorphosis,** the larvae look entirely different from the adult. The larvae eat and grow; adults primarily reproduce and disperse. Metamorphosis occurs in a pupal stage. Reproduction is usually sexual; fertilization is usually internal.

Insects are classified into about 26 orders. Insects affect humans as pollinators of crops, vectors of disease, and competitors for food.

Crustaceans The mostly aquatic crustaceans have two pairs of antennae; three or more pairs of mouthpart appendages, including mandibles; walking legs on the thorax; and appendages on the abdomen. Larger crustaceans have gills. Nitrogenous wastes pass by diffusion through thin areas of the cuticle, and a pair of glands regulates the salt balance of the hemolymph. Sexes usually are separate. One or more swimming larval stages occur in most aquatic crustaceans.

Isopods are mostly small aquatic crustaceans but include terrestrial pill bugs. Lobsters, crayfish, crabs, and shrimp are large crustaceans called **decapods.** Their cuticle is hardened by calcium carbonate, and a carapace covers the dorsal side of their cephalothorax. The small, very numerous **copepods** are important members of marine and freshwater plankton communities. Barnacles are sessile crustaceans that strain food from the water with their appendages.

■ INTERACTIVE QUESTION 33.8

Compare and contrast the following features for insects and crustaceans.

Feature	Insects	Crustaceans
Habitat	**a.**	**b.**
Locomotion	**c.**	**d.**
Respiration	**e.**	**f.**
Excretion	**g.**	**h.**
Antennae Number	**i.**	**j.**
Appendages	**k.**	**l.**

33.8 Echinoderms and chordates are deuterostomes

The echinoderms and chordates are grouped together based on their common embryological traits of radial cleavage, coelom formation from the archenteron, and origin of the mouth opposite the blastopore. Molecular systematics also supports Deuterostomia as a clade.

Echinoderms Most **echinoderms** are sessile or slow-moving marine animals. They have a thin skin covering an endoskeleton of calcareous plates. A **water vascular system** with a network of hydraulic canals controls extensions called **tube feet** that function in locomotion, feeding, and gas exchange. Sexual reproduction usually involves separate sexes and external fertilization. Bilateral larvae metamorphose into radial adults.

Sea stars (class Asteroidea) have multiple arms radiating from a central disk and use tube feet lining the undersurfaces of these arms to creep slowly and to grasp and open prey. They evert their stomach through their mouth and slip it into a slightly opened bivalve shell. Sea stars can regenerate lost arms.

Brittle stars (class Ophiuroidea) have distinct central disks and move by lashing their long, flexible arms. They may be predators, scavengers, or suspension feeders.

Sea urchins and sand dollars, members of class Echinoidea, have no arms but are able to move slowly using their five rows of tube feet. Long spines also aid a sea urchin's movement. A sea urchin's mouth is ringed by complex jaw-like structures used to eat seaweeds and other foods.

Sea lilies live attached to the substrate by stalks; feather stars crawl about. Their long, flexible arms extend upward from around the mouth and are used in suspension feeding. Members of class Crinoidea have changed little in 500 million years of evolution.

Sea cucumbers (Class Holothuroidea) are elongated animals that bear little resemblance to other echinoderms other than having five rows of tube feet.

Discovered in 1986, sea daisies (class Concentricycloidea) have an armless, disk-shaped body with a five-fold symmetry.

■ INTERACTIVE QUESTION 33.9

List the key characteristics that distinguish the phylum Echinodermata.

a.

b.

c.

Chordates Echinoderms and chordates have existed as separate phyla for at least 500 million years. Phylum Chordata contains two subphyla of invertebrates in addition to the hagfishes and vertebrates.

Word Roots

arthro- = jointed; **-pod** = foot (*Arthropoda:* segmented coelomates with exoskeletons and jointed appendages)

arachn- = spider (*Arachnida:* the arthropod group that includes scorpions, spiders, ticks, and mites)

brachio- = the arm (*brachiopod:* also called lamp shells, these animals superficially resemble clams and other bivalve molluscs, but the two halves of the brachiopod shell are dorsal and ventral to the animal rather than lateral, as in clams)

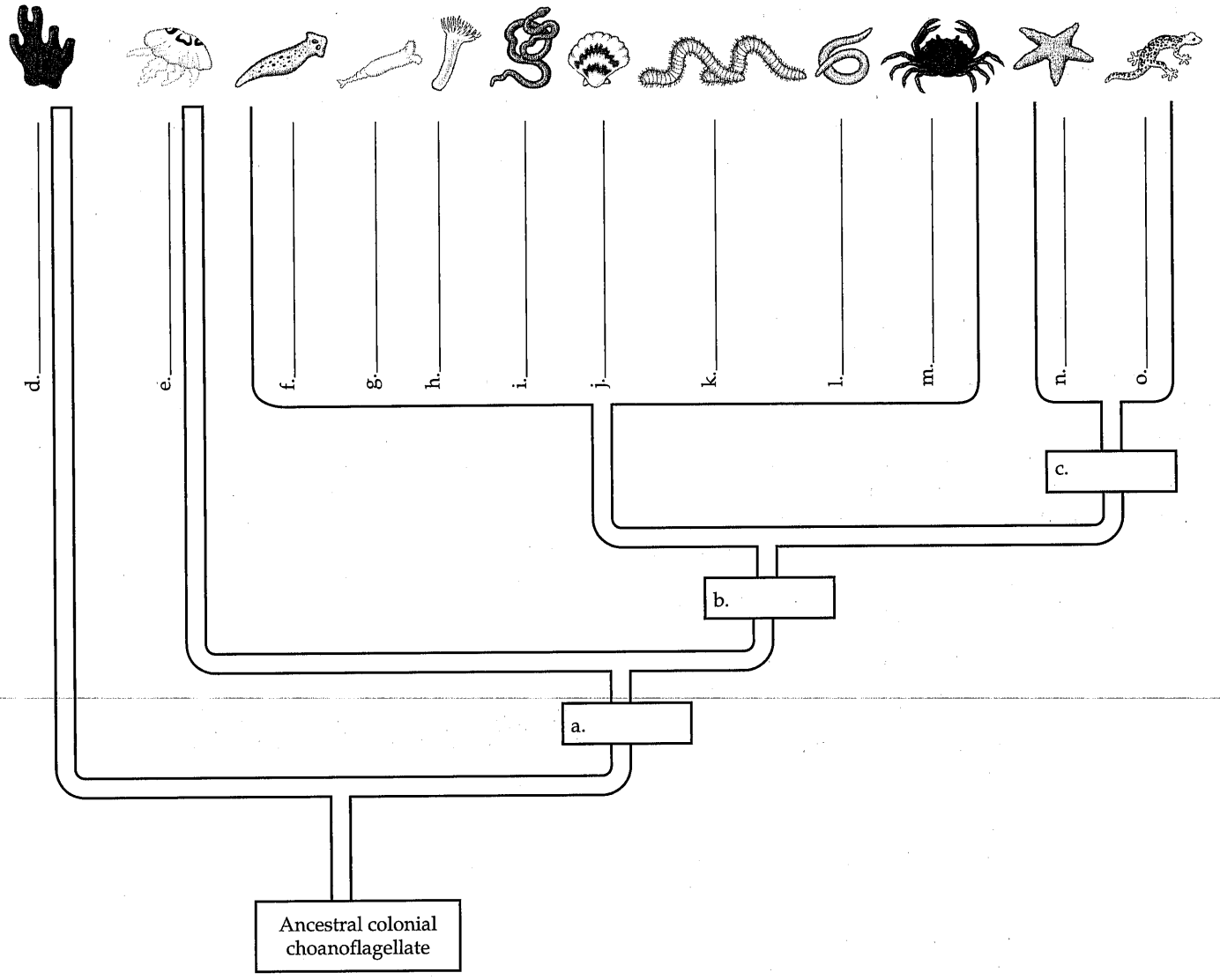
bryo- = moss; **-zoa** = animal (*bryozoan:* colonial animals (phylum Ectoprocta) that superficially resemble mosses)
cheli- = a claw (*chelicerae:* clawlike feeding appendages characteristic of the cheliceriform group)
choano- = a funnel; **-cyte** = cell (*choanocyte:* flagellated collar cells of a sponge)
cnido- = a nettle (*cnidocytes:* unique cells that function in defense and prey capture in cnidarians)
-coel = hollow (*spongocoel:* the central cavity of a sponge)
cope- = an oar (*copepods:* a group of small crustaceans that are important members of marine and freshwater plankton communities)
cuti- = the skin (*cuticle:* the exoskeleton of an arthropod)
deca- = ten (*decapod:* a large group of crustaceans that includes lobsters, crayfish, crabs, and shrimp)
diplo- = double (*Diplopoda:* the millipede class)
echino- = spiny; **-derm** = skin (*echinoderm:* sessile or slow-moving animals with a thin skin that covers an exoskeleton; the group includes sea stars, sea urchins, brittle stars, crinoids, sea cucumbers, and sea daisies)
eury- = broad, wide; **-pter** = a wing, a feather, a fin (*eurypterid:* mainly marine and freshwater, extinct cheliceriforms; these predators, also called water scorpions, ranged up to 3 meters long)
exo- = outside (*exoskeleton:* a hard encasement on the surface of an animal)
gastro- = stomach; **-vascula** = a little vessel (*gastrovascular cavity:* the central digestive compartment, usually with a single opening that functions as both mouth and anus)
hermaphrod- = with both male and female organs (*hermaphrodite:* an individual that functions as both male and female in sexual reproduction by producing both sperm and eggs)
in- = without (*invertebrates:* animals without a backbone)
iso- = equal (*isopods:* one of the largest groups of crustaceans, primarily marine, but including pill bugs common under logs and moist vegetation next to the ground)
lopho- = a crest, tuft; **-phora** = to carry (*lophophore:* a horseshoe-shaped or circular fold of the body wall bearing ciliated tentacles that surround the mouth)
meso- = the middle; **-hyl** = matter (*mesohyl:* a gelatinous region between the two layers of cells of a sponge.)
meta- = change; **-morph** = shape (*metamorphosis:* the resurgence of development in an animal larva that transforms it into a sexually mature adult)
nemato- = a thread; **-cyst** = a bag (*nematocysts:* the stinging capsules in cnidocytes, unique cells that function in defense and capture of prey)
nephri- = the kidney (*metanephridium:* in annelids, a type of excretory tubule with internal openings called nephrostomes that collect body fluids)
oscul- = a little mouth (*osculum:* a large opening in a sponge that connects the spongocoel to the environment)
partheno- = without fertilization; **-genesis** = producing (*parthenogenesis:* a type of reproduction in which females produce offspring from unfertilized eggs)
plan- = flat or wandering (*planarians*: flatworms that prey on smaller animals or feed on dead animals)
tri- = three; **-lobi** = a lobe (*trilobite:* an extinct group of arthropods with pronounced segmentation)
trocho- = a wheel (*trochophore:* a ciliated larva common to the life cycle of many molluscs; it is also characteristic of marine annelids and some other groups)

Structure Your Knowledge

1. Recall from Chapter 32 that there are several hypotheses of animal phylogeny, and the relationships among the groups may become more evident with further molecular comparisons. To help you review the incredible diversity of animal phyla, let's use this simplified tree that shows the groupings agreed upon by both the body plan grade and molecular hypotheses. The small sketches at the top represent the phyla surveyed in this chapter. (The three lophophorate phyla, Ectoprocta, Brachiopoda, and Phoronida, are represented by a figure of a phoronid.) Identify and give common name examples for each of these phyla. The following list of phyla should help:

Annelida	Nematoda
Arthropoda	Nemertea
Chordata	Platyhelminthes
Cnidaria	Porifera
Echinodermata	Rotifera
Mollusca	

Lophophorates: Ectoprocta, Brachiopoda, Phoronida



Test Your Knowledge

MATCHING: *Match the following organisms with their phylum and class. Answers may be used more than once or not at all.*

Organism	Phylum	Class
1. jelly (jellyfish)	_____	_____
2. crayfish	_____	_____
3. snail	_____	_____
4. leech	_____	_____
5. tapeworm	_____	_____
6. cricket	_____	_____
7. scallop	_____	_____
8. tick	_____	_____
9. sea urchin	_____	_____
10. hydra	_____	_____
11. planaria	_____	_____
12. chambered nautilus	_____	_____

Phyla	Classes
A. Annelida	**a.** Arachnida
B. Arthropoda	**b.** Bivalvia
C. Cnidaria	**c.** Cephalopoda
D. Echinodermata	**d.** Cestoidea
E. Mollusca	**e.** Crustacea
F. Nematoda	**f.** Echinoidea
G. Nemertea	**g.** Gastropoda
H. Platyhelminthes	**h.** Hirudinea
I. Porifera	**i.** Hydrozoa
J. Rotifera	**j.** Insects (Hexopoda)
	k. Oligochaeta
	l. Scyphozoa
	m. Turbellaria

MULTIPLE CHOICE: *Choose the one best answer.*

1. Invertebrates include
   a. all animals except for the phylum Vertebrata.
   b. all animals without backbones.
   c. only animals that use hydrostatic skeletons.
   d. members of the parazoa, radiata, and protostomes, but not of the deuterostomes.
   e. all animals without an endoskeleton.

2. Which of the following is the best description of the phylum Porifera?
   a. no real symmetry, diploblastic, cnidocytes for capturing prey
   b. radial symmetry, triploblastic, nematocysts
   c. no real symmetry, without true tissues, choanocytes for trapping food particles
   d. bilateral symmetry, pseudocoel, flame bulbs for excretion
   e. bilateral symmetry, osculum and spongocoel for filtering water

3. Which of the following does *not* have a gastrovascular cavity for digestion?
   a. flatworm
   b. hydra
   c. polychaete worm
   d. sea anemone
   e. fluke

4. The oldest and least-derived group in clade Eumetazoa is
   a. Porifera.
   b. Lophophorates.
   c. Platyhelminthes.
   d. Parazoa.
   e. Cnidaria.

5. Hermaphrodites
   a. contain male and female sex organs but usually cross-fertilize.
   b. include sponges, earthworms, and most insects.
   c. are characteristically parthenogenic rotifers.
   d. are both a and b.
   e. are a, b, and c.

6. Which of the following is *not* true of cnidarians?
   a. An alternation of medusa and polyp stage is common in class Hydrozoa.
   b. They use a ring of tentacles armed with stinging cells to capture prey.
   c. They include hydras, jellies, sponges, and sea anemones.
   d. They have a nerve net that coordinates contraction of microfilaments for movement.
   e. They have a gastrovascular cavity.

7. Which of the following combinations of phylum and characteristics is *incorrect?*
   a. Nemertea—proboscis worm, complete digestive tract
   b. Rotifera—parthenogenesis, crown of cilia, microscopic animals
   c. Nematoda—gastrovascular cavity, tough cuticle, ubiquitous
   d. Annelida—segmentation, closed circulatory system, hydrostatic skeleton
   e. Echinodermata—radial anatomy, endoskeleton, water vascular system

8. Which of the following is an excretory or osmoregulatory structure that is *incorrectly* matched with its class?
   a. metanephridia—Oligochaeta
   b. Malpighian tubules—Echinoidea
   c. flame cells—Turbellaria
   d. thin region of cuticle—Crustacea
   e. diffusion across cell membranes—Hydrozoa

9. Torsion
   a. is embryonic rotation of the visceral mass that results in a U-shaped digestive tract in gastropods.
   b. is characteristic of molluscs.
   c. is responsible for the spiral growth of bivalve shells.
   d. describes the thrashing movement of nematodes.
   e. is responsible for the metamorphosis of insects.

10. Bivalves differ from other molluscs in that they
    a. are predaceous.
    b. have no heads and are suspension feeders.
    c. have shells.
    d. have open circulatory systems.
    e. use a radula to feed as they burrow through sand.

11. The exoskeleton of arthropods
    a. functions in protection and anchorage for muscles.
    b. is composed of chitin and cellulose.
    c. is absent in millipedes and centipedes.
    d. expands at the joints when the arthropod grows.
    e. functions in respiration and movement.
12. Which of the following does *not* function in suspension feeding?
    a. lophophore of brachiopods
    b. radula of snails
    c. choanocytes of sponges
    d. mucus-coated gills of clams
    e. crown of cilia of rotifers
13. What do nematodes and arthropods have in common?
    a. They are both segmented.
    b. They are both pseudocoelomates.
    c. They include important members of plankton communities.
    d. They both have exoskeletons and undergo ecdysis (molting).
    e. Both a and d are correct.
14. Which of the following structures is *not* associated with prey capture?
    a. chaetae of earthworm
    b. mandibles of centipedes
    c. cnidocytes of hydra
    d. proboscis of ribbon or proboscis worm
    e. tube feet of sea star
15. Many animals are parasitic. Which of the following is an *incorrect* description of one of these parasites?
    a. Ticks are blood-sucking parasites belonging to class Arachnida.
    b. Some roundworms (Nematoda) are internal parasites of humans.
    c. Lice are wingless ectoparasites in class Insecta.
    d. Flukes are flatworms and may have complex life cycles.
    e. Tapeworms are annelids that reproduce by shedding proglottids.