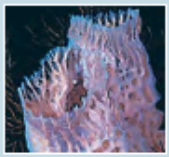
Cheat Sheet

Kingdom Animalia encompasses 1.3 million known species, and estimates of total species range as high as 10–20 million species. Of the 23 phyla surveyed here, 12 are discussed more fully in this chapter, Chapter 32, or Chapter 34; cross-references are given at the end of their descriptions.

Porifera (5,500 species)



A sponge

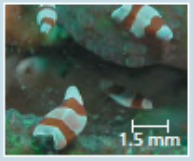
Animals in this phylum are informally called sponges. Sponges are sessile animals that lack true tissues. They live as suspension feeders, trapping particles that pass through the internal channels of their body (see Concept 33.1).

Cnidaria (10,000 species)

Cnidarians include corals, jellies, and hydras. These animals have a diploblastic, radially symmetrical body plan that includes a gastrovascular cavity with a single opening that serves as both mouth and anus (see Concept 33.2).

A jelly

Acoela (400 species)

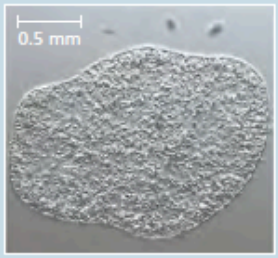


Acoel flatworms (LM)

Acoel flatworms have a simple nervous system and a saclike gut, and thus were once placed in phylum Platyhelminthes. Molecular analyses, however, indicate that Acoela is a separate lineage that diverged before the three main bilaterian clades (see Concept 32.4).

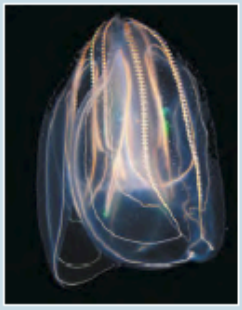
Placozoa (1 species)

The single known species in this phylum, *Trichoplax adhaerens*, doesn't even look like an animal. It consists of a simple bilayer of a few thousand cells. Placozoans are thought to be basal animals, but it is not yet known how they are related to other early-diverging animal groups such as Porifera and Cnidaria. *Trichoplax* can reproduce by dividing into two individuals or by budding off many multicellular individuals.



A placozoan (LM)

Ctenophora (100 species)



A ctenophore, or comb jelly

Ctenophores (comb jellies) are diploblastic and radially symmetrical like cnidarians, suggesting that both phyla diverged from other animals very early (see Figure 32.11). Comb jellies make up much of the ocean's plankton. They have many distinctive traits, including eight "combs" of cilia that propel the animals through the water. When a small animal contacts the tentacles of some comb jellies, specialized cells burst open, covering the prey with sticky threads.

Lophotrochozoa

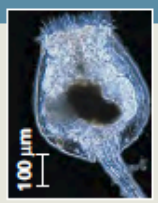
Platyhelminthes (20,000 species)

A marine flatworm

Flatworms (including tapeworms, planarians, and flukes) have bilateral symmetry and a central nervous system that processes information from sensory structures. They have no body cavity or organs for circulation (see Concept 33.3).

Rotifera (1,800 species)

Despite their microscopic size, rotifers have specialized organ systems, including an *alimentary canal* (a digestive tract with both a mouth and an anus). They feed on microorganisms suspended in water (see Concept 33.3).



A rotifer (LM)

Ectoprocta (4,500 species)

Ectoprocts

Ectoprocts (also known as bryozoans) live as sessile colonies and are covered by a tough exoskeleton (see Concept 33.3).

Brachiopoda (335 species)

A brachiopod

Brachiopods, or lamp shells, may be easily mistaken for clams or other molluscs. However, most brachiopods have a unique stalk that anchors them to their substrate, as well as a crown of cilia called a lophophore (see Concept 33.3).

Continued on next page

Lophotrochozoa (continued)

Acanthocephala (1,100 species)

Acanthocephalans are called spiny-headed worms because of the curved hooks on the proboscis at the anterior end of their body. All species are parasites. Some acanthocephalans manipulate the behavior of their intermediate hosts (generally arthropods) in ways that increase their chances of reaching their final hosts (generally vertebrates). For example, acanthocephalans that infect New Zealand mud crabs force their hosts to move to more visible areas on the beach, where the crabs are more likely to be eaten by birds, the worms' final hosts. Some phylogenetic analyses place the acanthocephalans within Rotifera.

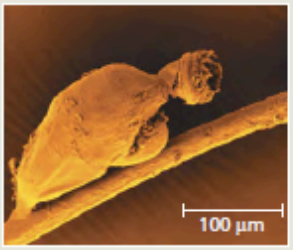
An acanthocephalan (LM)


A ribbon worm

Nemertea (900 species)

Also called proboscis worms or ribbon worms, nemerteans swim through water or burrow in sand, extending a unique proboscis to capture prey. Like flatworms, they lack a true coelom. However, unlike flatworms, nemerteans have an alimentary canal and a closed circulatory system in which the blood is contained in vessels and hence is distinct from fluid in the body cavity.

Cycliophora (1 species)



A cycliophoran (colorized SEM)

The only known cyclophoran species, *Symbion pandora*, was discovered in 1995 on the mouthparts of a lobster. This tiny, vase-shaped creature has a unique body plan and a particularly bizarre life cycle. Males impregnate females that are still developing in their mothers' bodies. The fertilized females then escape, settle elsewhere on the lobster, and release their offspring. The offspring apparently leave that lobster and search for another one to which they attach.

Annelida (16,500 species)

Annelids, or segmented worms, are distinguished from other worms by their body segmentation. Earthworms are the most familiar annelids, but the phylum consists primarily of marine and freshwater species (see Concept 33.3).


A marine annelid

Mollusca (93,000 species)

Molluscs (including snails, clams, squids, and octopuses) have a soft body that in many species is protected by a hard shell (see Concept 33.3).


An octopus

Ecdysozoa

Loricifera (10 species)

Loriciferans (from the Latin *lorica*, corset, and *ferre*, to bear) are tiny animals that inhabit the deep-sea bottom. A loriciferan can telescope its head, neck, and thorax in and out of the lorica, a pocket formed by six plates surrounding the abdomen. Though the natural history of loriciferans is mostly a mystery, at least some species likely eat bacteria.

A loriciferan (LM)

Priapula (16 species)


A priapulan

Priapulans are worms with a large, rounded proboscis at the anterior end. (They are named after Priapos, the Greek god of fertility, who was symbolized by a giant penis.) Ranging from 0.5 mm to 20 cm in length, most species burrow through seafloor sediments. Fossil evidence suggests that priapulans were among the major predators during the Cambrian period.

Ecdysozoa (continued)

Onychophora (110 species)

An onychophoran

Onychophorans, also called velvet worms, originated during the Cambrian explosion (see Chapter 32). Originally, they thrived in the ocean, but at some point they succeeded in colonizing land. Today they live only in humid forests. Onychophorans have fleshy antennae and several dozen pairs of saclike legs.

Tardigrada (800 species)

Tardigrades (from the Latin *tardus*, slow, and *gradus*, step) are sometimes called water bears for their rounded shape, stubby appendages, and lumbering, bearlike gait. Most tardigrades are less than 0.5 mm in length. Some live in oceans or fresh water, while others live on plants or animals. As many as 2 million tardigrades can be found on a square meter of moss. Harsh conditions may cause tardigrades to enter a state of dormancy; while dormant, they can survive temperatures as low as −272°C, close to absolute zero!

Tardigrades (colorized SEM)

Nematoda (25,000 species)

A roundworm (colored SEM)

Also called roundworms, nematodes are enormously abundant and diverse in the soil and in aquatic habitats; many species parasitize plants and animals. Their most distinctive feature is a tough cuticle that coats the body (see Concept 33.4).

Arthropoda (1,000,000 species)

The vast majority of known animal species, including insects, crustaceans, and arachnids, are arthropods. All arthropods have a segmented exoskeleton and jointed appendages (see Concept 33.4).

A scorpion (an arachnid)

Deuterostomia

Hemichordata (85 species)

An acorn worm

Like echinoderms and chordates, hemichordates are members of the deuterostome clade (see Chapter 32). Hemichordates share some traits with chordates, such as gill slits and a dorsal nerve cord. The largest group of hemichordates is the enteropneusts, or acorn worms. Acorn worms are marine and generally live buried in mud or under rocks; they may grow to more than 2 m in length.

Chordata (52,000 species)

More than 90% of all known chordate species have backbones (and thus are vertebrates). However, the phylum Chordata also includes three groups of invertebrates: lancelets, tunicates, and hagfishes. See Chapter 34 for a full discussion of this phylum.

A tunicate

Echinodermata (7,000 species)

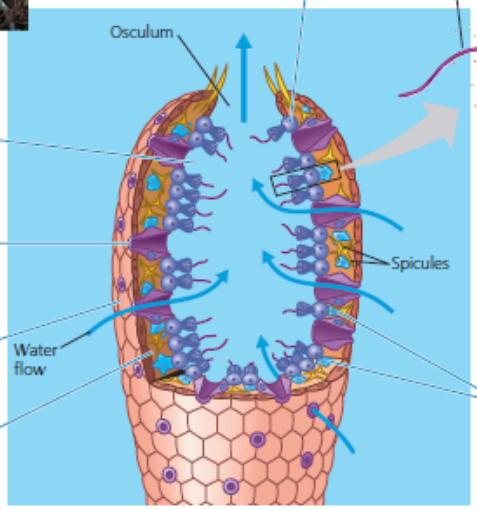
Echinoderms, such as sand dollars, sea stars, and sea urchins, are marine animals in the deuterostome clade that are bilaterally symmetrical as larvae but not as adults. They move and feed by using a network of internal canals to pump water to different parts of their body (see Concept 33.5).

A sea urchin

▼ **Figure 33.4 Anatomy of a sponge.**

Azure vase sponge (*Callyspongia plicifera*)

5 Choanocytes. The spongocoel is lined with flagellated cells called choanocytes. By beating flagella, the choanocytes create a current that draws water in through the pores and out through the osculum.

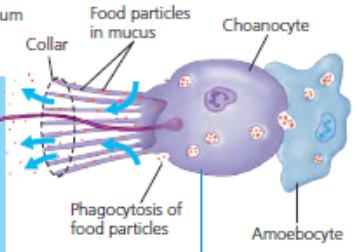


4 Spongocoel. Water passing through pores enters a cavity called the spongocoel.

3 Pores. Water enters the sponge through pores formed by doughnut-shaped cells that span the body wall.

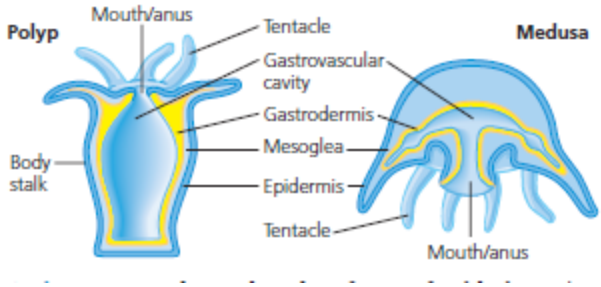
2 Epidermis. The outer layer consists of tightly packed epidermal cells.

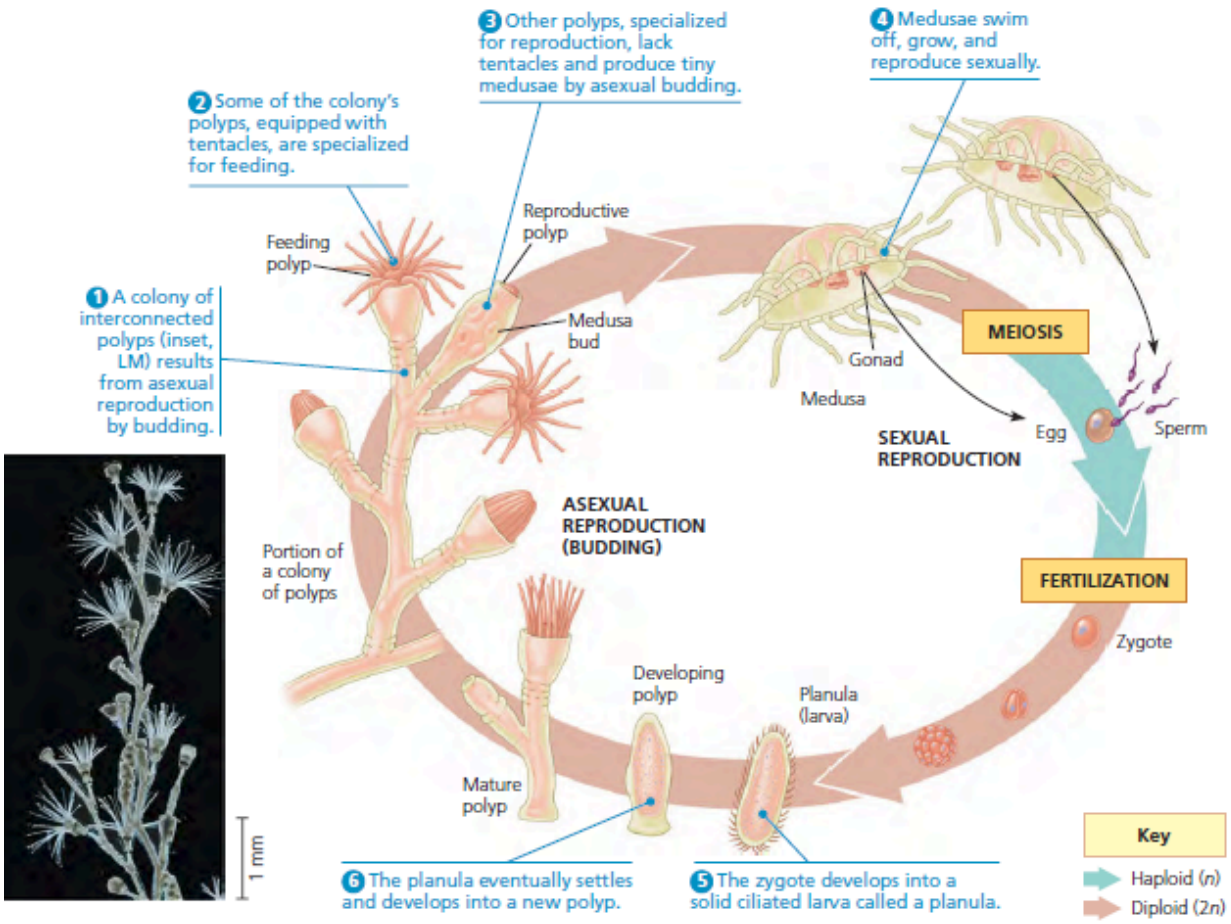
1 Mesohyl. The wall of this sponge consists of two layers of cells separated by a gelatinous matrix, the mesohyl ("middle matter").



6 The movement of a choanocyte's flagellum also draws water through its collar of finger-like projections. Food particles are trapped in the mucus that coats the projections, engulfed by phagocytosis, and either digested or transferred to amoebocytes.

7 Amoebocytes. These cells can transport nutrients to other cells of the sponge body, produce materials for skeletal fibers (spicules), or become any type of sponge cell as needed.



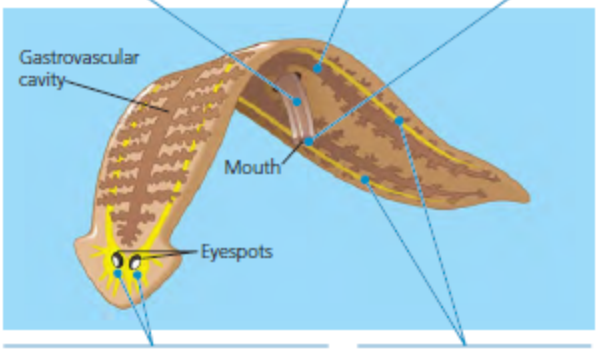


▼ Figure 33.10 Anatomy of a planarian.

Pharynx. The mouth is at the tip of a muscular pharynx. Digestive juices are spilled onto prey, and the pharynx sucks small pieces of food into the gastrovascular cavity, where digestion continues.

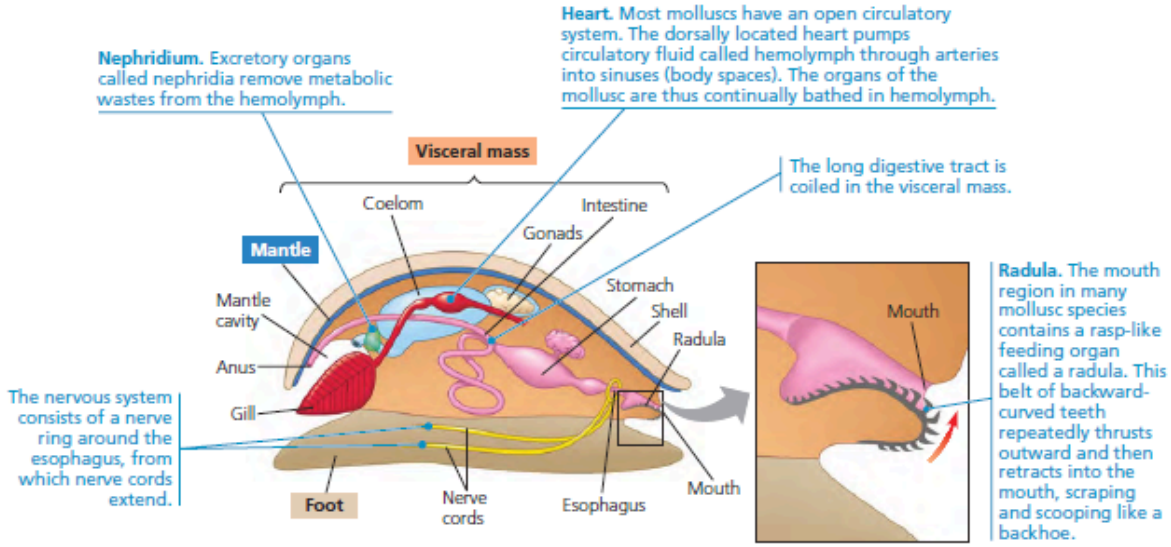
Digestion is completed within the cells lining the gastrovascular cavity, which has many fine subbranches that provide an extensive surface area.

Undigested wastes are egested through the mouth.



Ganglia. At the anterior end of the worm, near the main sources of sensory input, is a pair of ganglia, dense clusters of nerve cells.

Ventral nerve cords. From the ganglia, a pair of ventral nerve cords runs the length of the body.

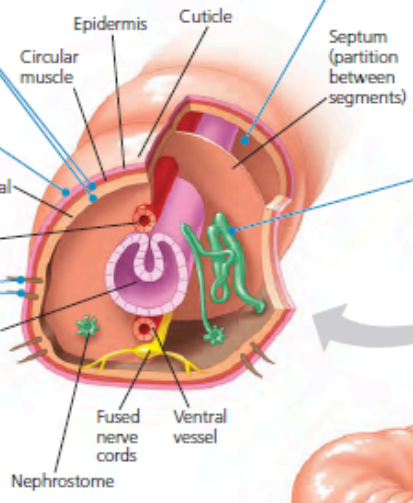

Nephridium. Excretory organs called nephridia remove metabolic wastes from the hemolymph.
Heart. Most molluscs have an open circulatory system. The dorsally located heart pumps circulatory fluid called hemolymph through arteries into sinuses (body spaces). The organs of the mollusc are thus continually bathed in hemolymph.
Visceral mass
The long digestive tract is coiled in the visceral mass.
Coelom
Intestine
Gonads
Mantle
Stomach
Shell
Mantle cavity
Radula
Anus
Gill
The nervous system consists of a nerve ring around the esophagus, from which nerve cords extend.
Foot
Nerve cords
Esophagus
Mouth
Mouth
Radula. The mouth region in many mollusc species contains a rasp-like feeding organ called a radula. This belt of backward-curved teeth repeatedly thrusts outward and then retracts into the mouth, scraping and scooping like a backhoe.

Each segment is surrounded by longitudinal muscle, which in turn is surrounded by circular muscle. Earthworms coordinate the contraction of these two sets of muscles to move (see Figure 50.35). These muscles work against the non-compressible coelomic fluid, which acts as a hydrostatic skeleton.

Coelom. The coelom of the earthworm is partitioned by septa.

Metanephridium. Each segment of the worm contains a pair of excretory tubes, called metanephridia, with ciliated funnel-shaped openings called nephrostomes. The metanephridia remove wastes from the blood and coelomic fluid through exterior pores.

Many of the internal structures are repeated within each segment of the earthworm.



Chaetae. Each segment has four pairs of chaetae, bristles that provide traction for burrowing.

Giant Australian earthworm

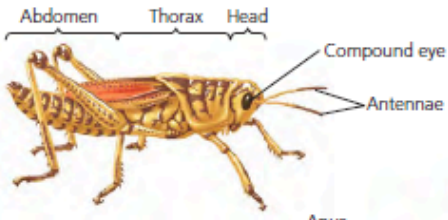
Tiny blood vessels are abundant in the earthworm's skin, which functions as its respiratory organ. The blood contains oxygen-carrying hemoglobin.

Cerebral ganglia. The earthworm nervous system features a brain-like pair of cerebral ganglia above and in front of the pharynx. A ring of nerves around the pharynx connects to a subpharyngeal ganglion, from which a fused pair of nerve cords runs posteriorly.

The circulatory system, a network of vessels, is closed. The dorsal and ventral vessels are linked by segmental pairs of vessels. The dorsal vessel and five pairs of vessels that circle the esophagus are muscular and pump blood through the circulatory system.

Ventral nerve cords with segmental ganglia. The nerve cords penetrate the septa and run the length of the animal, as do the digestive tract and longitudinal blood vessels.

The insect body has three regions: head, thorax, and abdomen. The segmentation of the thorax and abdomen is obvious, but the segments that form the head are fused.



Heart. The insect heart drives hemolymph through an open circulatory system.

Cerebral ganglion. The two nerve cords meet in the head, where the ganglia of several anterior segments are fused into a cerebral ganglion (brain, colored white below). The antennae, eyes, and other sense organs are concentrated on the head.

Dorsal artery

Crop

Anus

Vagina

Malpighian tubules. Metabolic wastes are removed from the hemolymph by excretory organs called Malpighian tubules, which are outpocketings of the digestive tract.

Ovary

Tracheal tubes. Gas exchange in insects is accomplished by a tracheal system of branched, chitin-lined tubes that infiltrate the body and carry oxygen directly to cells. The tracheal system opens to the outside of the body through spiracles, pores that can control air flow and water loss by opening or closing.

Nerve cords. The insect nervous system consists of a pair of ventral nerve cords with several segmental ganglia.

Insect mouthparts are formed from several pairs of modified appendages. The mouthparts include mandibles, which grasshoppers use for chewing. In other insects, mouthparts are specialized for lapping, piercing, or sucking.

▲ **Figure 33.35 Anatomy of a grasshopper, an insect.**

Although there are more than 30 orders of insects, we'll focus on just 8 here. Two early-diverging groups of wingless insects are the bristletails (Archaeognatha) and silverfish (Thysanura). Evolutionary relationships among the other groups discussed here are under debate and so are not depicted on the tree.

Archaeognatha (bristletails; 350 species)

These wingless insects are found under bark and in other moist, dark habitats such as leaf litter, compost piles, and rock crevices. They feed on algae, plant debris, and lichens.

Thysanura (silverfish; 450 species)

These small, wingless insects have a flattened body and reduced eyes. They live in leaf litter or under bark. They can also infest buildings, where they can become pests.

Winged insects (many orders; six are shown below)

Complete metamorphosis

Coleoptera (beetles; 350,000 species)

Beetles, such as this male snout weevil (*Rhiastus lasternus*), constitute the most species-rich order of insects. They have two pairs of wings, one of which is thick and stiff, the other membranous. They have an armored exoskeleton and mouthparts adapted for biting and chewing.

Diptera (151,000 species)

Dipterans have one pair of wings; the second pair has become modified into balancing organs called halteres. Their mouthparts are adapted for sucking, piercing, or lapping. Flies and mosquitoes are among the best-known dipterans, which live as scavengers, predators, and parasites. Like many other insects, flies such as this red tachinid (*Adejeania vexatrix*) have well-developed compound eyes that provide a wide-angle view and excel at detecting fast movements.

Hymenoptera (125,000 species)

Most hymenopterans, which include ants, bees, and wasps, are highly social insects. They have two pairs of membranous wings, a mobile head, and chewing or sucking mouthparts. The females of many species have a posterior stinging organ. Many species, such as this European paper wasp (*Polistes dominulus*), build elaborate nests.

Lepidoptera (120,000 species)

Butterflies and moths have two pairs of wings covered with tiny scales. To feed, they uncoil a long proboscis, visible in this photograph of a hummingbird hawkmoth (*Macroglossum stellatarum*). This moth's name refers to its ability to hover in the air while feeding from a flower. Most lepidopterans feed on nectar, but some species feed on other substances, including animal blood or tears.

Incomplete metamorphosis

Hemiptera (85,000 species)

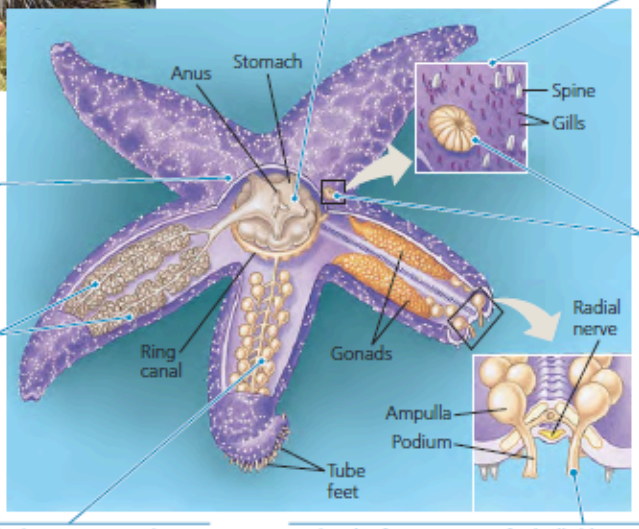
Hemipterans include so-called "true bugs," such as stink bugs, bed bugs, and assassin bugs. (Insects in other orders are sometimes erroneously called bugs.) Hemipterans have two pairs of wings, one pair partly leathery, the other pair membranous. They have piercing or sucking mouthparts and undergo incomplete metamorphosis, as shown in this image of an adult stink bug guarding its offspring (nymphs).

Orthoptera (13,000 species)

Grasshoppers, crickets, and their relatives are mostly herbivorous. They have large hind legs adapted for jumping, two pairs of wings (one leathery, one membranous), and biting or chewing mouthparts. This aptly named spear-bearer katydid (*Cophiphora* sp.) has a face and legs well adapted to making a threatening display. Male orthopterans commonly make courtship sounds by rubbing together body parts, such as ridges on their hind legs.

A short digestive tract runs from the mouth on the bottom of the central disk to the anus on top of the disk.

The surface of a sea star is covered by spines that help defend against predators, as well as by small gills that provide gas exchange.



Central disk. The central disk has a nerve ring and nerve cords radiating from the ring into the arms.

Madreporite. Water can flow in or out of the water vascular system into the surrounding water through the madreporite.

Digestive glands secrete digestive juices and aid in the absorption and storage of nutrients.

Radial canal. The water vascular system consists of a ring canal in the central disk and five radial canals, each running in a groove down the entire length of an arm. Branching from each radial canal are hundreds of hollow, muscular tube feet filled with fluid.

Each tube foot consists of a bulb-like ampulla and a podium (foot portion). When the ampulla squeezes, water is forced into the podium, which expands and contacts the substrate. Adhesive chemicals are then secreted from the base of the podium, attaching it to the substrate. To detach the tube foot, de-adhesive chemicals are secreted and muscles in the podium contract, forcing water back into the ampulla and shortening the podium. As it moves, a sea star leaves an observable "footprint" of adhesive material on the substrate.

Chapter 33 Questions

1. **What is *Glaucus atlanticus*?**
2. **What are invertebrates?**
3. **Describe the phyla of animals (Cnidaria, Placozoa, Porifera, Ctenophora, Platyhelminthes, Syndermata, Ectoprocta, Brachiopoda, Gastrotricha, Cycliophora, Nemertea, Annelida, Mollusca, Loricifera, Priapula, Onychophora, Tardigrada, Nematoda, Arthropoda, Hemichordata, Chordata, Echinodermata, Acanthocephala).**
4. **What are filter feeders?**
5. **What is the spongocoel?**
6. **What is the osculum?**
7. **How do sponges differ from most other animals?**
8. **What are choanocytes (collar cell)?**
9. **What is the mesohyl?**
10. **How do sponges conduct gas exchange and waste removal?**
11. **What are amoebocytes?**
12. **What is the structure of sponge skeletal fibers?**
13. **What are hermaphrodites?**
14. **How does sponge reproduction work?**
15. **What is cribrostatin?**
16. **Describe the body plans of cnidarians.**
17. **How do cnidarians feed?**
18. **Describe the contractile tissues and nerves of cnidarians.**
19. **What are Medusozoans?**
20. **Describe the life cycle of *Obelia*.**
21. **Describe the scyphozoans and cubozoans.**
22. **What is *Chironex fleckeri*?**
23. **What are anthozoans?**
24. **What is the oldest accepted fossil of a bilaterian?**
25. **What are flatworms (phylum Platyhelminthes)?**
26. **What are photonephridia?**
27. **What is Catenulida?**
28. **What is Rhabditophora?**
29. **What are planarians?**
30. **What are trematodes?**
31. **What is *Schistosoma*?**
32. **What are tapeworms?**
33. **What are rotifers (phylum Syndermata (previously Rotifera))?**
34. **What is parthenogenesis?**
35. **When do rotifers reproduce sexually?**
36. **What are acanthocephalans?**

37. What is Syndermata?
38. What are lophophorates?
39. What are ectoprocts?
40. What are brachiopods?
41. What are molluscs (mollusca)?
42. Describe the body plan of molluscs.
43. Describe mollusc reproduction.
44. What are chitons (Polyplacophora)?
45. What are gastropods (Gastropoda)?
46. What are nudibranchs?
47. What are bivalves (Bivalvia)?
48. What are cephalopods (Cephalopoda)?
49. What are the only extant cephalopods with external shells?
50. Describe the circulatory system of cephalopods.
51. Describe the nervous system of cephalopods.
52. What are ammonites?
53. What are *Architeuthis dux* and *Mesonychoteuthis hamiltoni*?
54. What creates pearls?
55. What are annelids (Annelida)?
56. What are chaetae?
57. What is Errantia?
58. What are cirri?
59. What is Sedentaria?
60. What are leeches?
61. What are earthworms?
62. Describe the anatomy of an earthworm.
63. What is Ecdysozoa?
64. What are nematodes (Nematoda)?
65. What is *Trichinella spiralis*?
66. What are arthropods?
67. What are onychophorans?
68. Describe the external structure of an arthropod.
69. Describe the nervous system of arthropods.
70. Describe the circulatory system of arthropods.
71. Describe the gas exchange mechanisms in arthropods.
72. What are chelicerates?
73. What are book lungs?
74. How do spiders use silk?
75. What is Myriapoda?
76. What are pancrustaceans?
77. What are crustaceans?
78. How do crustaceans exchange materials with environment?
79. How does crustacean reproduction work?

80. **What are isopods?**
81. **What are decapods?**
82. **What are copepods?**
83. **What are barnacles?**
84. **What are insects and their six-legged terrestrial relatives called?**
85. **Describe the anatomy of grasshoppers.**
86. **When did an explosion in insect diversity occur?**
87. **What are insect wings made of?**
88. **What is incomplete metamorphosis?**
89. **What is complete metamorphosis?**
90. **How does insect reproduction occur?**
91. **Describe 8 of the over-30 orders of insects (Archaeognatha, Zygentoma/Thysanura, Coleoptera, Diptera, Hymenoptera, Lepidoptera, Hemiptera, Orthoptera).**
92. **What are echinoderms and how are they similar to chordates?**
93. **What is the water vascular system?**
94. **How does reproduction occur in echinoderms?**
95. **Why are echinoderms considered bilateral although they seem radial?**
96. **What is Asteroidea?**
97. **Describe the anatomy of a sea star.**
98. **What is Ophiuroidea?**
99. **What is Echinoidea?**
100. **What is Crinoidea?**
101. **What is Holothuroidea?**

Chapter 33 Answers

1. Blue dragon (sea slug, invertebrate)
2. Animals that lack a backbone, 95% of known animal species
3. See picture. LOok at book for accurate diagram figure 33.3
4. Animals that filter out food particles suspended in the surrounding water as they draw it through their body (in some sponges resembles sac perforated with pores)
5. Central cavity where water is drawn into via pores
6. Larger opening through which water flows out of the sponge
7. Lack tissues, so are basal animals
8. Flagellated cells that line interior of spongocoel, engulf bacteria and other food particles by phagocytosis
9. Gelatinous region that separates the two layers of cells of the sponge's body
10. Both cell layers are in contact with water, so they can occur by diffusion across membranes
11. Cells that use pseudopodia, move through mesohyl (can take up food from surrounding water/choanocytes, digest it, and carry nutrients to other cells, manufacture tough skeletal fibers within mesohyl, are totipotent
12. Sometimes are sharp spicules of calcium carbonate or silica. Sometimes are flexible, made of spongin protein
13. Animals that can function as both male and female in sexual reproduction (produce sperm and egg)
14. Almost all sponges are sequential hermaphrodites (first one sex then become other), fertilization occurs, resulting in zygotes that develop into flagellated larvae that disperse from parent sponge and settle to develop into sessile adult
15. Compound isolated from marine sponges that can kill cancer cells and penicillin-resistant strains of *Streptococcus*
16. Simple, diploblastic, radial. Sac with central digestive compartment (gastrovascular cavity), single opening in cavity functions as mouth and anus. Polyps are cylindrical forms, adhere to substrate by aboral end of body (opposite of mouth) and extend tentacles (e.g. hydras and sea anemones), can move slowly across substrate via muscles at aboral end, can detach and swim by bending body or thrashing tentacles. Medusa is flattened, mouth-down version of polyp, moves freely in water (drifting and contractions of bell-shaped body, tentacles dangle from oral surface, see picture
17. Predators, use tentacles arranged in ring around mouth to capture prey/push food into gastrovascular cavity. Enzymes secreted into cavity, cells lining cavity absorb nutrients. Tentacles covered in cnidocytes (cells unique to cnidarians, help in defense/prey capture, contain cnidae (capsule like organelles that can explode outward, specialized cnidae called nematocysts contain thread that can penetrate body wall of prey))
18. Cells of epidermis (outer) and gastrodermis (inner) have microfilaments arranged into contractile fibers (gastrovascular cavity acts as hydrostatic skeleton against which contractile cells can work)

No brain, movements coordinated by non-centralized nerve net that is associated with sensory structures

19. All cnidarians that produce a medusa, includes scyphozoans (jellies), cubozoans (box jellies), and hydrozoans (most alternate between polyp/medusa forms, includes hydras (among few cnidarians found in freshwater, only in polyp form))
20. see picture
21. Most spend most of cycle as medusa (coastal scyphozoans have brief polyp stage, open ocean ones do not), Cubozoans have box-shaped medusa shape, most live in tropical oceans, equipped with highly toxic cnidocytes
22. Cubozoan of coast of northern Australia,one of deadliest organisms known, sea wasp
23. Sea anemones and corals, occur only as polyps, corals often form symbioses with algae, many secrete hard exoskeleton of calcium carbonate, each polyp generation builds on skeletal remains of earlier generations
24. *Kimberella*, mollusc that lived about 560 mya
25. live in wet habitats, include parasitic species (e.g. flukes/tapeworms), have thin bodies flattened dorsoventrally, undergo triploblastic development, are acoelomates, no organs for gas exchange, gastrovascular cavity with only one opening (branches of cavity distribute food)
26. Networks of tubules with ciliated structures called flame bulbs, pull fluid through branched ducts opening to outside, used to maintain osmotic balance
27. clade of freshwater flatworms (100 species), reproduce asexually by budding from posterior end, offspring produce own buds before detaching, forms chain of clones (called “chain worms” informally)
28. clade of 20,000 water species, 50% are parasites of animals.
29. Free-living rhabditophorans, freshwater species in genus *Dugesia*, are predators/scavengers, move using cilia on ventral surface, glide along film of mucus they secrete, some use muscles to swim by undulation, have pair of light-sensitive eyespots and lateral flaps that detect specific chemicals, see picture, some reproduce by fission (parent constricts in middle), are hermaphrodites, mating cross-fertilize both individuals
30. Parasitic rhabditophorans, have wide range of hosts as group, have alternating sexual/asexual stages, require intermediate host where larvae can develop
31. blood flukes, trematodes, cause schistosomiasis (disease with pain, anemia, diarrhea), mimics surface proteins of hosts, releases molecules that manipulate hosts’ immune systems into tolerating parasite, can survive in humans for more than 40 years
32. Parasitic rhabditophorans, adults live inside vertebrates, anterior end (scolex) armed with suckers and often hooks that are used to attach to intestinal lining of host, lack mouth/gastrovascular cavity, absorb nutrients released by digestion in host intestine (across tapeworm’s body surface). posterior to scolex is ribbon of protoglottids (sacs of sex organs), released after reproduction, leave host in feces, sometimes contaminate food/water of intermediate hosts, form cysts in their muscles, can be killed by oral medications

33. tiny animals, inhabit wet habitats, 50 μm to 2 mm, have specialized organ systems, have alimentary canal (digestive tube with mouth and anus), internal organs lie within pseudocoelom., fluid in pseudocoelom serves as hydrostatic skeleton, helps circulate nutrients, have crown of cilia that draws water into mouth, jaws called trophi grind up food (microorganisms in water)
34. Females produce more females from unfertilized eggs, present in some rotifers, aphids, some bees, some lizards, and some fishes
35. Under conditions such as high levels of crowding, resulting embryos can remain dormant for years, break dormancy to become asexually reproducing females
36. Sexually reproducing parasites of vertebrates, lack complete digestive tract, usually less than 20 cm long, called spiny-headed worms, have curved hooks on proboscis at anterior end of body, may have originated from within Rotifera (have recent common ancestor with rotifer genus *Seison*), all have two or more hosts (intermediate = arthropods, final = vertebrates), modify behavior of intermediates to increase likelihood of getting to final
37. Proposed phylum consisting of Rotifera and Acanthocephala
38. Bilaterians with lophophore (crown of ciliated tentacles around mouth, tentacles trap suspended food particles that cilia draw in), have U-shaped alimentary canal, absence of head, are sessile, are coelomates
39. Lophophorates, Colonial animals that resemble clumps of moss, called bryozoans, colony encased in hard exoskeleton studded with pores through which lophophores extend, most live in sea, most widespread/numerous sessile animals, live in freshwater
40. Lamp shells, resemble clams/other hinge-shelled molluscs, but halves of shell are dorsal and ventral rather than lateral, all are marine, most are attached to floor by stalk, open shell slightly to allow water to flow through lophophore
41. Snails, slugs, oysters, clams, and octopuses (100000 species, second most diverse), all are soft-bodied, most are marine, secrete protective cell of calcium carbonate
42. Coelomates, have muscular foot (used for movement), visceral mass (contains internal organs), mantle (fold of tissue that drapes over visceral mass, secretes exoskeleton, extends past visceral mass to produce mantle cavity (water-filled chamber, houses gills, anus, and excretory pores)), many feed by radula (straplike organ used to scrape up food), see picture
43. Most have separate sexes with gonads in visceral mass, many snails are hermaphrodites, marine molluscs usually have ciliated larval stage (trochophore, characteristic of marine annelids and other lophotrochozoans)
44. Molluscs, oval-shaped body, shell of 8 dorsal plates, body is unsegmented, foot acts as suction cup
45. Molluscs, most are marine, there are freshwater and land species (includes snails and slugs), move by foot or cilia (very slow), most have single spiraled shell (secreted by glands at edge of mantle, use radula to feed, several are predators, in cone snails teeth of radula act as poison darts, have head with eyes at tips of tentacles, lining of mantle cavity functions as a lung in terrestrial gastropods
46. sea slugs

47. Aquatic molluscs, include clams, oysters, mussels, scallops, have shell with two halves, halves are hinged by powerful adductor muscles, no distinct head, radula lost, some have eyes and sensory tentacles, mantle cavity has gills used for feeding and gas exchange, most are suspension feeders (trap food in mucus that coats gills, cilia convey particles to mouth), most are sedentary, secrete strong threads (byssus threades) to tether themselves, scallops can skitter by flapping shell, clam can pull themselves with foot
48. Active marine predators (molluscs), use tentacles to grasp prey, bite with beak-like jaws, immobilize prey with poison in saliva, foot became excurrent siphon and part of tentacles, shell reduces/internal (in most species) or missing (in some cuttlefish and octopuses)
49. Chambered nautiluses
50. Only molluscs with closed circulatory system (blood remains separate from fluid in body cavity)
51. Have well-developed sense organs and complex brain
52. Shelled cephalopods, dominant invertebrate predator of seas until Cretaceous extinction
53. Giant squid (13 m, large suckers and small teeth) and colossal squid (14 m, two rows of sharp hooks)
54. Pearl mussels (freshwater bivalves, secrete layers of a lustrous coating around a grain of sand or other small irritant, very endangered)
55. Segmented worms that live in wet habitats, are coelomates, range from 1 mm to 3m. Divided into Polychaeta, Oligochaeta, and Hirudinea (leeches), but Hirudinea is subgroup of Oligochaeta is subgroup of Polychaeta.
56. Bristles made of chitin, polychaetes have more chaetae than oligochaetes
57. Clade of marine annelids, many are mobile, includes some immobile species, *Platynereis* has become model for studying neurobiology/developent, each body segment often has pair of paddle-like or ridge-like structures called parapodia (function in locomotion, each with chaetae, can function as gill when richly supplied with blood vessels), tend to have well-developed jaws and sensory organs
58. Long sensory organs extending from front of errantian (burrow)
59. Clade of less mobile annelids, some burrow slowly through marine sediments, some live in tubes that protect and support them (often have elaborate gills/tentacles)
60. Sendentarians, some suck blood by attaching to other animals, most are predators that feed on invertebrates are 1-30 cm, most inhabit freshwater, rest live in other wet habitats, some use bladelike jaws to slit skin of host (leech secretes anesthetic that prevents host from noticing, then secretes hirudin (chemical that keeps blood of host from coagulating near incision)
61. sedentarians, extract nutrients as soil passes through alimentary canal, undigested material eliminated from anus, fecal castings improve texture of soil, are hermaphrodites but they do cross-fertilize (align in opposi te directions to exchange sperm), some can fragment to reproduce asexually
62. See picture

63. Includes animals that shed tough external coat (cuticle) as they grow (called ecdysis or molting)
64. Roundworms, found in most aquatic habitats, soil, tissues of plants/animals. cylindrical, 1mm - 1m, taper to fine tip at posterior, blunt tip at anterior end, body covered by taught cuticle, periodically molts and secretes new cuticle, have alimentary canal but no circulatory system, nutrients transported via fluid in pseudocoelom, body wall muscles are longitudinal (contraction produces thrashing motion), includes pinworms and hookworms (human parasites)
65. Nematode that causes trichinosis, acquired by eating raw or undercooked meat that has juvenile worms encysted in muscle tissues, juveniles develop in human intestines, females burrow into intestinal muscles to produce more juveniles that encyst in other organs, regulates expression of specific muscle cell genes encoding proteins that make the cell elastic enough to house the nematode, muscle cell releases signals that promote growth of blood vessels that supply nematode with nutrients
66. 2 of 3 known species, found in nearly all habitat, most successful, have segmented body, hard exoskeleton, and jointed appendages, date from Cambrian explosion, evolved from lobopods (e.g. *Hallucigenia*, had identical-segmented bodies). Trilobites = early arthropods, have two unusual *Hox* genes that influence segmentation
67. Close relatives of arthropods
68. Jointed, paired appendages, body covered in cuticle of protein and chitin, functions in protection, anchorage for muscles, prevention of desiccation, structural support
69. Have well-developed sensory organs (eyes, olfactory receptors, and antennae (touch and smell), most are at anterior end of animal)
70. Open circulatory system (fluid called hemolymph is propelled by heart through short arteries then into spaces called sinuses surrounding tissues/organs, returns to heart through pores equipped with valves). Hemocoel is the hemolymph filled body sinuses, are coelomates but coelom is reduced as development progresses (hemocoel is main body cavity)
71. Specialized gas exchange organs allow diffusion of respiratory gases in spite of exoskeleton, most aquatic species have gills with thin feathery extensions, terrestrial have internal surfaces specialized for gas exchange (most insects have tracheal systems (branched air ducts leading into the interior of the body from pores in cuticle)
72. Arthropods with clawlike feeding appendages (chelicerae, serve as pincers or fangs). Lack antennae, most have eyes with single lens (simple eyes). Earliest were eurypterids (water scorpions, up to 3 m, all extinct). Marine chelicerates that survive today are sea spiders (pycnogonids) and horseshoe crabs. Most are arachnids (scorpions, spiders, ticks, and mites, have six pairs of appendages (chelicerae, pedipalps that function in sensing, feeding, defense, or reproduction, 4 pairs of walking legs)). Spiders use fang-like chelicerae to pierce prey and secrete digestive juices onto torn tissues. Food softens and spider sucks up liquid
73. Stacked platelike structures in most spiders, contained in internal chamber, carry out gas exchange between hemolymph and air

74. Spinnerets spin silk (liquid protein produced by abdominal glands) into fibers that solidify, spider engineers web characteristic of its species on the first try
75. Clade of millipedes and centipedes, all living are terrestrial, head has pair of antennae and 3 pairs of appendages as mouthparts (including jaw-like mandibles). Each trunk segment of a millipede is formed from two fused segments that bear two pairs of legs. Millipedes eat decaying leaves/plant matter, earliest animals on land. Centipedes = carnivores, each segment of trunk has one pair of legs and have poison claws on foremost trunk segment
76. insects and crustaceans (pancrustacea)
77. Crabs, lobsters, shrimps, barnacles, thrive in many habitats, have specialized appendages (lobsters/crayfishes have 19 pairs of appendages, anterior-most form two pairs of antennae, 3 or more are mouthparts, legs present on thorax, unlike terrestrial relatives have appendages on post-genital region)
78. Exchange gases across thin areas of cuticle (small crustaceans) or have gills (larger). Nitrogenous wastes diffuse through thin areas of cuticle, pair of glands regulates salt balance of hemolymph
79. Sexes are separate, in lobster/crayfishes male uses specialized pair of abdominal appendages to transfer sperm to reproductive pore of female during copulation (most aquatic crustaceans go through swimming larval stages)
80. One of largest groups of crustaceans, abundant in habitats on floor of deep ocean, includes pill bugs (woodlice)
81. Relatively large crustaceans such as lobsters, crayfishes, crabs, and shrimps, cuticle hardened by calcium carbonate, most are marine
82. Small crustaceans (members of plankton communities, grazers that feed on algae, predators that eat small animals, etc.)
83. Group of sessile crustaceans whose cuticle is hardened into a cell of calcium carbonate, natural adhesive as strong as synthetic glues (extend appendages from shell to strain food from water), larvae similar to that of other crustaceans
84. Hexapoda, rare in marine habitats
85. See picture
86. When insect flight evolved during Carboniferous and Permian periods
87. Extensions of the cuticle
88. Occurs in grasshoppers, the young (nymphs) resemble adults but are smaller, have different body proportions, and lack wings (undergoes series of molts, progressively becomes more like adult. final molt, insect reaches full size, acquires wing, becomes sexually mature)
89. Larval stages specialized for eating/growing looks entirely different from adult (specialized for dispersal and reproduction). Metamorphosis from larval to adult stage occurs during a pupal stage
90. Usually sexual (separate male and females), fertilization usually internal. May directly copulate or male may leave packet of sperm, female picks it up. Internal structure in female (spermatheca) stores sperm, usually enough to fertilize more that one batch of eggs. Many insects mate only once.

91. See picture
92. Sea stars, sea urchins, etc., have features characteristic of a deuterostome mode of dev (radial cleavage, formation of anus from blastopore) are coelomates, slow-moving or sessile marine animals, thin epidermis covers endoskeleton of hard calcareous plates, most have skeletal bumps and spines
93. Network of hydraulic canals branching into extensions called tube feet that function in locomotion and feeding
94. Sexual reproduction, separate male/female individuals, release gametes into water
95. larvae have bilateral symmetry, adults are actually not radial (madreporite, or opening of water vascular system is shifted to one side)
96. Sea stars and sea daisies; Sea stars have arms coming from central disk, under arms are tube feet, tube feet can attach or detach substrate (have flattened disk as base that uses adhesive chemicals) and grab prey (clams/oysters). Sea stars turn stomach inside out, everting it through mouth, then secretes juices that digest mollusc within shell, brings stomach back to complete digestion, can regrow parts. Sea daisies are armless only 3 species known, disk-shaped, live on submerged wood, has five-sided organization, small, ringed with spines, absorb nutrients through body membrane
97. see picture
98. Brittle stars, have distinct central disk, long, flexible arms, lash arms in serpentine movements to move, base of tube foot lacks flattened disk but secretes adhesive chemicals
99. Sea urchins and sand dollars, no arms, five radially arranged groups of tube feet functioning in slow movement. urchins have muscles that pivot spines, mouth located on underside, ringed by highly complex, jaw-like structures for eating seaweed, roughly spherical. Dollars are flat disks
100. Sea lilies and feather stars. Sea lilies attached to substrate by stalk, feather stars crawl using flexible arms. Both use arms in suspension feeding, arms encircle upward mouth, morphology has changed very little
101. Sea Cucumbers, lack spines, endoskeleton is reduced, elongated in oral-aboral axis, have five radially arranged segments of tube feet, tube feet around mouth developed as feeding tentacles