Overview: Life Without a Backbone

- **Invertebrates** are animals that lack a backbone
- They account for 95% of known animal species
Fig. 33-2

ANCESTRAL PROTIST
Common ancestor of all animals

Eumetazoa

Calcarea and Silicea

Cnidaria

Lophotrochozoa

Ecdysozoa

Deuterostomia
<table>
<thead>
<tr>
<th>Taxon</th>
<th>Species</th>
<th>Image Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calcarea and Silicea</strong></td>
<td>5,500 species</td>
<td>A sponge</td>
</tr>
<tr>
<td><strong>Cnidaria</strong></td>
<td>10,000 species</td>
<td>A jelly</td>
</tr>
<tr>
<td><strong>Acoela</strong></td>
<td>400 species</td>
<td>Acoel flatworms (LM)</td>
</tr>
<tr>
<td><strong>Placozoa</strong></td>
<td>1 species</td>
<td>A placozoan (LM)</td>
</tr>
<tr>
<td><strong>Ctenophora</strong></td>
<td>100 species</td>
<td>A ctenophore, or comb jelly</td>
</tr>
<tr>
<td><strong>Platyhelminthes</strong></td>
<td>20,000 species</td>
<td>A marine flatworm</td>
</tr>
<tr>
<td><strong>Rotifera</strong></td>
<td>1,800 species</td>
<td>A rotifer (LM)</td>
</tr>
<tr>
<td><strong>Ectoprocta</strong></td>
<td>4,500 species</td>
<td>Ectoprocts</td>
</tr>
<tr>
<td><strong>Brachiopoda</strong></td>
<td>335 species</td>
<td>A brachiopod</td>
</tr>
<tr>
<td><strong>ECDYSOZOA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
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<td></td>
</tr>
<tr>
<td><strong>Loricifera (10 species)</strong></td>
<td><strong>Priapula (16 species)</strong></td>
<td></td>
</tr>
<tr>
<td>A loriciferan (LM)</td>
<td>A priapulan</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>ACANTHOCEPHALA (1,100 species)</strong></th>
<th><strong>Cycliophora (1 species)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>An acanthocephalan (LM)</td>
<td>A cyclophoran (colorized SEM)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Nemertea (900 species)</strong></th>
<th><strong>Mollusca (93,000 species)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>A ribbon worm</td>
<td>An octopus</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Annelida (16,500 species)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A marine annelid</td>
<td></td>
</tr>
<tr>
<td>Animal Group</td>
<td>Number of Species</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Tardigrada</td>
<td>800 species</td>
</tr>
<tr>
<td>Onychophora</td>
<td>110 species</td>
</tr>
<tr>
<td>Nematoda</td>
<td>25,000 species</td>
</tr>
<tr>
<td>Arthropoda</td>
<td>1,000,000 species</td>
</tr>
<tr>
<td>Hemichordata</td>
<td>85 species</td>
</tr>
<tr>
<td>Echinodermata</td>
<td>7,000 species</td>
</tr>
<tr>
<td>Chordata</td>
<td>52,000 species</td>
</tr>
</tbody>
</table>

- Tardigrades (colorized SEM)
- An onychophoran
- A roundworm
- A scorpion (an arachnid)
- An acorn worm
- A sea urchin
- A tunicate
A sponge
A jelly
A placozoan (LM)

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A ctenophore, or comb jelly
Acoel flatworms (LM)

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Fig. 33-3f

A marine flatworm

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A rotifer (LM)

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Ectoprocts
A brachiopod
An acanthocephalan (LM)

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.
A cyclophorphan (colorized SEM)
A ribbon worm
An octopus
A marine annelid

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A loriciferan (LM)

Fig. 33-3o
A priapulan

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Tardigrades (colorized SEM)

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.
An onychophoran
A roundworm
A scorpion (an arachnid)
An acorn worm
A sea urchin
A tunicate

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Concept 33.1: Sponges are basal animals that lack true tissues

• Sponges are sedentary animals from the phyla Calcarea and Silicea

• They live in both fresh and marine waters

• Sponges lack true tissues and organs
Calcarea and Silicea
Cnidaria
Lophotrochozoa
Ecdysozoa
Deuterostomia
• Sponges are **suspension feeders**, capturing food particles suspended in the water that pass through their body

• **Choanocytes**, flagellated collar cells, generate a water current through the sponge and ingest suspended food

• Water is drawn through pores into a cavity called the **spongocoel**, and out through an opening called the **osculum**
Azure vase sponge (*Callyspongia plicifera*)

- **Osculum**
- **Spongocoel**
- **Pore**
- **Epidermis**
- **Mesohyl**
- **Water flow**
- **Spicules**
- **Choanocyte**
- **Flagellum**
- **Collar**
- **Food particles in mucus**
- Phagocytosis of food particles
- **Amoebocyte**
- **Amoebocytes**

Fig. 33-4

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.
• Sponges consist of a noncellular **mesohyl** layer between two cell layers

• **Amoebocytes** are found in the mesohyl and play roles in digestion and structure

• Most sponges are **hermaphrodites**: Each individual functions as both male and female
Concept 33.2: Cnidarians are an ancient phylum of eumetazoans

- All animals except sponges and a few other groups belong to the clade Eumetazoa, animals with true tissues

- Phylum Cnidaria is one of the oldest groups in this clade
Calcarea and Silicea
Cnidaria
Lophotrochozoa
Ecdysozoa
Deuterostomia
• Cnidarians have diversified into a wide range of both sessile and motile forms including jellies, corals, and hydras

• They exhibit a relatively simple diploblastic, radial body plan
• The basic body plan of a cnidarian is a sac with a central digestive compartment, the gastrovascular cavity
• A single opening functions as mouth and anus
• There are two variations on the body plan: the sessile polyp and motile medusa
• Cnidarians are carnivores that use tentacles to capture prey
• The tentacles are armed with **cnidocytes**, unique cells that function in defense and capture of prey
• **Nematocysts** are specialized organelles within cnidocytes that eject a stinging thread
Fig. 33-6

Nematocyst

“Trigger”

Thread (coiled)

Cnidocyte

Thread discharges

Cuticle of prey

Thread
Phylum Cnidaria is divided into four major classes:

- Hydrozoa
- Scyphozoa
- Cubozoa
- Anthozoa
<table>
<thead>
<tr>
<th>Class and Examples</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrozoa (Portuguese man-of-wars, hydras, <em>Obelia</em>, some corals)</td>
<td>Most marine, a few freshwater; both polyp and medusa stages in most species; polyp stage often colonial</td>
</tr>
<tr>
<td>Scyphozoa (jellies, sea nettles)</td>
<td>All marine; polyp stage absent or reduced; free-swimming; medusae up to 2 m in diameter</td>
</tr>
<tr>
<td>Cubozoa (box jellies, sea wasps)</td>
<td>All marine; box-shaped medusae; complex eyes; potent venom</td>
</tr>
<tr>
<td>Anthozoa (sea anemones, most corals, sea fans)</td>
<td>All marine; medusa stage completely absent; most sessile; many colonial</td>
</tr>
</tbody>
</table>
(a) Colonial polyps (class Hydrozoa)
(b) Jellies (class Scyphozoa)
(c) Sea wasp (class Cubozoa)
(d) Sea anemone (class Anthozoa)
(a) Colonial polyps (class Hydrozoa)
(b) Jellies (class Scyphozoa)
(c) Sea wasp (class Cubozoa)
(d) Sea anemone (class Anthozoa)
Hydrozoans

• Most hydrozoans alternate between polyp and medusa forms
ASEXUAL REPRODUCTION (BUDDING)

Feeding polyp
Reproductive polyp
Medusa bud
Medusa

Portion of a colony of polyps

Key
Haploid (n)
Diploid (2n)
ASEXUAL REPRODUCTION (BUDDING)

Portion of a colony of polyps

Reproductive polyp

Medusa bud

Feeding polyp

Key

- Haploid ($n$)
- Diploid (2$n$)

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ASEXUAL REPRODUCTION (BUDDING)

**Key**

- Blue: Haploid (n)
- Orange: Diploid (2n)

**Portion of a colony of polyps**

- Feeding polyp
- Reproductive polyp
- Medusa bud
- Medusa

**SEXUAL REPRODUCTION**

- MEIOSIS
- FERTILIZATION
- Egg
- Sperm
- Zygote
- Planula (larva)
- Developing polyp
- Mature polyp

**Gonad**

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Scyphozoans

• In the class Scyphozoa, jellies (medusae) are the prevalent form of the life cycle
Cubozoans

- In the class Cubozoa, which includes box jellies and sea wasps, the medusa is box-shaped and has complex eyes.
- Cubozoans often have highly toxic cnidocytes.
Anthozoans

• Class Anthozoa includes the corals and sea anemones, which occur only as polyps
Concept 33.3: Lophotrochozoans, a clade identified by molecular data, have the widest range of animal body forms

- Bilaterian animals have bilateral symmetry and triploblastic development
- The clade Bilateria contains Lophotrochozoa, Ecdysozoa, and Deuterostomia
Calcarea and Silicea
Cnidaria
Lophotrochozoa
Ecdysozoa
Deuterostomia
• The clade Lophotrochozoa was identified by molecular data

• Some develop a lophophore for feeding, others pass through a trochophore larval stage, and a few have neither feature

• Lophotrochozoa includes the flatworms, rotifers, ectoprocts, brachiopods, molluscs, and annelids
Flatworms

- Members of phylum Platyhelminthes live in marine, freshwater, and damp terrestrial habitats
- Although flatworms undergo triploblastic development, they are acoelomates
- They are flattened dorsoventrally and have a gastrovascular cavity
- Gas exchange takes place across the surface, and protonephridia regulate the osmotic balance
Flatworms are divided into four classes:

- Turbellaria (mostly free-living flatworms)
- Monogenea (monogeneans)
- Trematoda (trematodes, or flukes)
- Cestoda (tapeworms)
<table>
<thead>
<tr>
<th>Class and Examples</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbellaria (mostly free-living flatworms, such as <em>Dugesia</em>)</td>
<td>Most marine, some freshwater, a few terrestrial; predators and scavengers; body surface ciliated</td>
</tr>
<tr>
<td>Monogenea (monogeneans)</td>
<td>Marine and freshwater parasites; most infect external surfaces of fishes; life history simple; ciliated larva starts infection on host</td>
</tr>
<tr>
<td>Trematoda (trematodes, also called flukes)</td>
<td>Parasites, mostly of vertebrates; two suckers attach to host; most life cycles include intermediate and final hosts</td>
</tr>
<tr>
<td>Cestoda (tapeworms)</td>
<td>Parasites of vertebrates; scolex attaches to host; proglottids produce eggs and break off after fertilization; no head or digestive system; life cycle with one or more intermediate hosts</td>
</tr>
</tbody>
</table>
Turbellarians

- Turbellarians are nearly all free-living and mostly marine
- The best-known turbellarians are commonly called planarians
• Planarians have light-sensitive eyespots and centralized nerve nets

• The planarian nervous system is more complex and centralized than the nerve nets of cnidarians

• Planarians are hermaphrodites and can reproduce sexually, or asexually through fission
Fig. 33-10

- Pharynx
- Gastrovascular cavity
- Mouth
- Eyespots
- Ganglia
- Ventral nerve cords
Monogeneans and Trematodes

- Monogeneans and trematodes live as parasites in or on other animals
- They parasitize a wide range of hosts, and most have complex life cycles with alternating sexual and asexual stages
- Trematodes that parasitize humans spend part of their lives in snail hosts
- Most monogeneans are parasites of fish
Tapeworms

• Tapeworms are parasites of vertebrates and lack a digestive system

• Tapeworms absorb nutrients from the host’s intestine

• Fertilized eggs, produced by sexual reproduction, leave the host’s body in feces
Fig. 33-12

Proglottids with reproductive structures

Hooks

Sucker

Scolex

200 µm
Rotifers

- Rotifers, phylum Rotifera, are tiny animals that inhabit fresh water, the ocean, and damp soil.
- Rotifers are smaller than many protists but are truly multicellular and have specialized organ systems.
• Rotifers have an **alimentary canal**, a digestive tube with a separate mouth and anus that lies within a fluid-filled pseudocoelom

• Rotifers reproduce by **parthenogenesis**, in which females produce offspring from unfertilized eggs

• Some species are unusual in that they lack males entirely
Lophophorates: Ectoprocts and Brachiopods

• Lophophorates have a *lophophore*, a horseshoe-shaped, suspension-feeding organ with ciliated tentacles.

• Lophophorates include two phyla: Ectoprocta and Brachiopoda.

• **Ectoprocts** (also called bryozoans) are colonial animals that superficially resemble plants.

• A hard *exoskeleton* encases the colony, and some species are reef builders.
(a) Ectoproct (sea mat)

(b) Brachiopods
Fig. 33-14a

(a) Ectoproct (sea mat)
Brachiopods superficially resemble clams and other hinge-shelled molluscs, but the two halves of the shell are dorsal and ventral rather than lateral as in clams.
(b) Brachiopods
Molluscs

- Phylum Mollusca includes snails and slugs, oysters and clams, and octopuses and squids
- Most molluscs are marine, though some inhabit fresh water and some are terrestrial
- Molluscs are soft-bodied animals, but most are protected by a hard shell
• All molluscs have a similar body plan with three main parts:
  – Muscular **foot**
  – Visceral mass
  – Mantle

• Many molluscs also have a water-filled **mantle cavity**, and feed using a rasplike **radula**
Fig. 33-15

- Nephridium
- Visceral mass
- Heart
- Coelom
- Intestine
- Gonads
- Stomach
- Shell
- Foot
- Gill
- Mouth
- Radula
- Nerve cords
- Esophagus
- Mantle
- Mantle cavity
- Anus
• Most molluscs have separate sexes with gonads located in the visceral mass

• The life cycle of many molluscs includes a ciliated larval stage called a trochophore
There are four major classes of molluscs:

- Polyplacophora (chitons)
- Gastropoda (snails and slugs)
- Bivalvia (clams, oysters, and other bivalves)
- Cephalopoda (squids, octopuses, cuttlefish, and chambered nautiluses)
<table>
<thead>
<tr>
<th>Class and Examples</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyplacophora (chitons)</td>
<td>Marine; shell with eight plates; foot used for locomotion; radula; no head</td>
</tr>
<tr>
<td>Gastropoda (snails, slugs)</td>
<td>Marine, freshwater, or terrestrial; head present; a symmetrical body, usually with a coiled shell; shell reduced or absent; foot for locomotion; radula</td>
</tr>
<tr>
<td>Bivalvia (clams, mussels, scallops, oysters)</td>
<td>Marine and freshwater; flattened shell with two valves; head reduced; paired gills; no radula</td>
</tr>
<tr>
<td>Cephalopoda (squids, octopuses, cuttlefishes, chambered nautiluses)</td>
<td>Marine; head surrounded by grasping tentacles, usually with suckers; shell external, internal, or absent; mouth with or without radula; locomotion by jet propulsion</td>
</tr>
</tbody>
</table>
Chitons

• Class Polyplacophora consists of the chitons, oval-shaped marine animals encased in an armor of eight dorsal plates
Gastropods

• About three-quarters of all living species of molluscs are gastropods
Fig. 33-17

(a) A land snail

(b) A sea slug
(a) A land snail
(b) A sea slug
Most gastropods are marine, but many are freshwater and terrestrial species.

Most have a single, spiraled shell.

Slugs lack a shell or have a reduced shell.

The most distinctive characteristic of gastropods is torsion, which causes the animal’s anus and mantle to end up above its head.
**Bivalves**

- Molluscs of class Bivalvia include many species of clams, oysters, mussels, and scallops
- They have a shell divided into two halves
• The mantle cavity of a bivalve contains gills that are used for feeding as well as gas exchange
Cephalopods

- Class Cephalopoda includes squids and octopuses, carnivores with beak-like jaws surrounded by tentacles of their modified foot
- Most octopuses creep along the sea floor in search of prey
Fig. 33-21

- Octopus
- Squid
- Chambered nautilus
Octopus
• Squids use their siphon to fire a jet of water, which allows them to swim very quickly
Fig. 33-21b

Squid
One small group of shelled cephalopods, the nautiluses, survives today
• Cephalopods have a closed circulatory system, well-developed sense organs, and a complex brain

• Shelled cephalopods called ammonites were common but went extinct at the end of the Cretaceous
Annelids

- Annelids have bodies composed of a series of fused rings

- The phylum Annelida is divided into three classes:
  - Oligochaeta (earthworms and their relatives)
  - Polychaeta (polychaetes)
  - Hirudinea (leeches)
<table>
<thead>
<tr>
<th>Class and Examples</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligochaeta (freshwater, marine, and terrestrial segmented worms)</td>
<td>Reduced head; no parapodia, but chaetae present</td>
</tr>
<tr>
<td>Polychaeta (mostly marine segmented worms)</td>
<td>Many have a well-developed head; each segment usually has parapodia with many chaetae; free-living</td>
</tr>
<tr>
<td>Hirudinea (leeches)</td>
<td>Body usually flattened, with reduced coelom and segmentation; chaetae usually absent; suckers at anterior and posterior ends; parasites, predators, and scavengers</td>
</tr>
</tbody>
</table>
Oligochaetes

• Oligochaetes (class Oligochaeta) are named for relatively sparse chaetae, bristles made of chitin

• They include the earthworms and a variety of aquatic species

• Earthworms eat through soil, extracting nutrients as the soil moves through the alimentary canal

• Earthworms are hermaphrodites but cross-fertilize

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Polychaetes

- Members of class Polychaetes have paddle-like parapodia that work as gills and aid in locomotion
Leeches

- Members of class Hirudinea are blood-sucking parasites, such as leeches
- Leeches secrete a chemical called hirudin to prevent blood from coagulating
Concept 33.4: Ecdysozoans are the most species-rich animal group

• Ecdysozoans are covered by a tough coat called a cuticle

• The cuticle is shed or molted through a process called ecdysis

• The two largest phyla are nematodes and arthropods
Fig. 33-UN4

Calcarea and Silicea
Cnidaria
Lophotrochozoa
Ecdysozoa
Deuterostomia
Nematodes

- Nematodes, or roundworms, are found in most aquatic habitats, in the soil, in moist tissues of plants, and in body fluids and tissues of animals.

- They have an alimentary canal, but lack a circulatory system.

- Reproduction in nematodes is usually sexual, by internal fertilization.

Video: C. elegans Crawling

Video: C. elegans Embryo Development (Time Lapse)
Fig. 33-25

25 µm
• Some species of nematodes are important parasites of plants and animals
Fig. 33-26

Encysted juveniles  Muscle tissue

50 µm
Arthropods

- Two out of every three known species of animals are arthropods
- Members of the phylum Arthropoda are found in nearly all habitats of the biosphere
The arthropod body plan consists of a segmented body, hard exoskeleton, and jointed appendages, and dates to the Cambrian explosion (535–525 million years ago).

Early arthropods show little variation from segment to segment.
• Arthropod evolution is characterized by a decrease in the number of segments and an increase in appendage specialization.

• These changes may have been caused by changes in *Hox* gene sequence or regulation.
Fig. 33-28

EXPERIMENT

Origin of *Ubx* and *abd-A* *Hox* genes? Other ecdysozoans

Other ecdysozoans

Arthropods

Arthropods

Common ancestor of onychophorans and arthropods

Onychophorans

RESULTS

*Ubx* or *abd-A* genes expressed

Ant = antenna

J = jaws

L1–L15 = body segments

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EXPERIMENT

Origin of *Ubx* and *abd-A Hox* genes?

Common ancestor of onychophorans and arthropods

Other ecdysozoans

Arthropods

Onychophorans
RESULTS

Ubx or abd-A genes expressed

Ant = antenna
J = jaws
L1–L15 = body segments
General Characteristics of Arthropods

- The appendages of some living arthropods are modified for many different functions

Video: Lobster Mouth Parts
Fig. 33-29

Cephalothorax

Antennae (sensory reception)

Thorax

Abdomen

Head

Swimming appendages (one pair located under each abdominal segment)

Walking legs

Pincer (defense)

Mouthparts (feeding)
The body of an arthropod is completely covered by the cuticle, an exoskeleton made of layers of protein and the polysaccharide chitin.

When an arthropod grows, it molts its exoskeleton.
• Arthropods have an **open circulatory system** in which fluid called *hemolymph* is circulated into the spaces surrounding the tissues and organs

• A variety of organs specialized for gas exchange have evolved in arthropods
Molecular evidence suggests that living arthropods consist of four major lineages that diverged early in the phylum’s evolution:

- **Cheliceriforms** (sea spiders, horseshoe crabs, scorpions, ticks, mites, and spiders)
- **Myriapods** (centipedes and millipedes)
- **Hexapods** (insects and relatives)
- **Crustaceans** (crabs, lobsters, shrimps, barnacles, and many others)
<table>
<thead>
<tr>
<th>Subphylum and Examples</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheliceriformes (horseshoe crabs, spiders, scorpions, ticks, mites)</td>
<td>Body having one or two main parts; six pairs of appendages mostly terrestrial or marine</td>
</tr>
<tr>
<td>Myriapoda (millipedes and centipedes)</td>
<td>Distinct head bearing antennae and chewing mouthparts; terrestrial</td>
</tr>
<tr>
<td>Hexapoda (insects, springtails)</td>
<td>Body divided into head, thorax, and abdomen; antennae present; three pairs of legs and usually two pairs of wings; mostly terrestrial</td>
</tr>
<tr>
<td>Crustacea (crabs, lobsters, crayfishes, shrimps)</td>
<td>Body of two or three parts; antennae present; chewing mouthparts; three or more pairs of legs; mostly marine and freshwater</td>
</tr>
</tbody>
</table>
Cheliceriforms

- Cheliceriforms, subphylum Cheliceriformes, are named for clawlike feeding appendages called *chelicerae*

- The earliest cheliceriforms were *eurypterids* (water scorpions)

- Most marine cheliceriforms (including eurypterids) are extinct, but some species survive today, including horseshoe crabs
• Most modern cheliceriforms are arachnids, which include spiders, scorpions, ticks, and mites
Fig. 33-31

▲ Scorpion

▲ Dust mite

▲ Web-building spider

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Scorpion

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Fig. 33-31b

Dust mite

50 µm

Dust mite

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Web-building spider
• Arachnids have an abdomen and a cephalothorax, which has six pairs of appendages, the most anterior of which are the chelicerae

• Gas exchange in spiders occurs in respiratory organs called book lungs

• Many spiders produce silk, a liquid protein, from specialized abdominal glands
Myriapods

- Subphylum Myriapoda includes millipedes and centipedes
  - Myriapods are terrestrial, and have jaw-like mandibles
- Millipedes, class Diplopoda, have many legs
  - Each trunk segment has two pairs of legs
Centipede, class Chilopoda, are carnivores

- They have one pair of legs per trunk segment
Insects

• Subphylum Hexapoda, insects and relatives, has more species than all other forms of life combined

• They live in almost every terrestrial habitat and in fresh water

• The internal anatomy of an insect includes several complex organ systems
Insects diversified several times following the evolution of flight, adaptation to feeding on gymnosperms, and the expansion of angiosperms.

Insect and plant diversity declined during the Cretaceous extinction, but have been increasing in the 65 million years since.
• Flight is one key to the great success of insects

• An animal that can fly can escape predators, find food, and disperse to new habitats much faster than organisms that can only crawl
• Many insects undergo metamorphosis during their development

• In *incomplete metamorphosis*, the young, called nymphs, resemble adults but are smaller and go through a series of molts until they reach full size
• Insects with **complete metamorphosis** have larval stages known by such names as maggot, grub, or caterpillar

• The larval stage looks entirely different from the adult stage
Fig. 33-36

(a) Larva (caterpillar)  (b) Pupa  (c) Later-stage pupa
(d) Emerging adult  (e) Adult
(a) Larva (caterpillar)
(b) Pupa
(c) Later-stage pupa
(d) Emerging adult
(e) Adult
• Most insects have separate males and females and reproduce sexually

• Individuals find and recognize members of their own species by bright colors, sound, or odors

• Some insects are beneficial as pollinators, while others are harmful as carriers of diseases, or pests of crops

• Insects are classified into more than 30 orders
<table>
<thead>
<tr>
<th>Order</th>
<th>Approximate Number of Species</th>
<th>Examples</th>
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<td>Blattodea</td>
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</table>
Crustaceans

- While arachnids and insects thrive on land, crustaceans, for the most part, have remained in marine and freshwater environments.

- Crustaceans, subphylum Crustacea, typically have branched appendages that are extensively specialized for feeding and locomotion.

- Most crustaceans have separate males and females.
• **Isopods** include terrestrial, freshwater, and marine species
  – Pill bugs are a well known group of terrestrial isopods

• **Decapods** are all relatively large crustaceans and include lobsters, crabs, crayfish, and shrimp
(a) Ghost crab

(b) Krill

(c) Barnacles
(a) Ghost crab
• Planktonic crustaceans include many species of **copepods**, which are among the most numerous of all animals
(b) Krill
• Barnacles are a group of mostly sessile crustaceans

• They have a cuticle that is hardened into a shell
(c) Barnacles
Concept 33.5: Echinoderms and chordates are deuterostomes

• Sea stars and other echinoderms, phylum Echinodermata, may seem to have little in common with phylum Chordata, which includes the vertebrates

• Shared characteristics define deuterostomes (Chordates and Echinoderms)
  – Radial cleavage
  – Formation of the mouth at the end of the embryo opposite the blastopore
Calcarea and Silicea
Cnidaria
Lophotrochozoa
Ecdysozoa
Deuterostomia
Echinoderms

• Sea stars and most other echinoderms are slow-moving or sessile marine animals

• A thin epidermis covers an endoskeleton of hard calcareous plates

• Echinoderms have a unique water vascular system, a network of hydraulic canals branching into tube feet that function in locomotion, feeding, and gas exchange

• Males and females are usually separate, and sexual reproduction is external
• Living echinoderms are divided into six classes:
  – Asteroidia (sea stars)
  – Ophiuroidea (brittle stars)
  – Echinoidea (sea urchins and sand dollars)
  – Crinoidea (sea lilies and feather stars)
  – Holothuroidea (sea cucumbers)
  – Concentricycloidea (sea daisies)
<table>
<thead>
<tr>
<th>Class and Examples</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asteroidea (sea stars)</td>
<td>Star-shaped body with multiple arms; mouth directed to substrate</td>
</tr>
<tr>
<td>Ophiuroidea (brittle stars)</td>
<td>Distinct central disk; long, flexible arms; incomplete digestive system</td>
</tr>
<tr>
<td>Echinoidea (sea urchins, sand dollars)</td>
<td>Roughly spherical or disk-shaped; no arms; five rows of tube feet; mouth ringed by complex, jaw-like structure</td>
</tr>
<tr>
<td>Crinoidea (sea lilies, feather stars)</td>
<td>Feathered arms surrounding upward-pointing mouth</td>
</tr>
<tr>
<td>Holothuroidea (sea cucumbers)</td>
<td>Cucumber-shaped body; five rows of tube feet; reduced skeleton; no spines</td>
</tr>
<tr>
<td>Concentricycloidea (sea daisies)</td>
<td>Armless, disk-shaped body ringed with small spines; incomplete digestive system</td>
</tr>
</tbody>
</table>
Sea Stars

- Sea stars, class Asteroidea, have multiple arms radiating from a central disk.
- The undersurfaces of the arms bear tube feet, each of which can act like a suction disk.
- Sea stars can regrow lost arms.
(a) A sea star (class Asteroidea)
(b) A brittle star (class Ophiuroidea)
(c) A sea urchin (class Echinoidea)
(d) A feather star (class Crinoidea)
(e) A sea cucumber (class Holothuroidea)
(f) A sea daisy (class Concentricycloidea)
(a) A sea star (class Asteroidea)
Brittle Stars

• Brittle stars have a distinct central disk and long, flexible arms, which they use for movement
(b) A brittle star (class Ophiuroidea)
Sea Urchins and Sand Dollars

- Sea urchins and sand dollars have no arms but have five rows of tube feet
(c) A sea urchin (class Echinoidea)
Sea Lilies and Feather Stars

- Sea lilies live attached to the substrate by a stalk
- Feather stars can crawl using long, flexible arms
(d) A feather star (class Crinoidea)
Sea Cucumbers

- Sea cucumbers lack spines, have a very reduced endoskeleton, and do not look much like other echinoderms.
- Sea cucumbers have five rows of tube feet; some of these are developed as feeding tentacles.
(e) A sea cucumber (class Holothuroidea)
Sea Daisies

- Sea daisies were discovered in 1986, and only three species are known.
(f) A sea daisy (class Concentricycloidea)
Chordates

- Phylum Chordata consists of two subphyla of invertebrates as well as hagfishes and vertebrates
- Chordates share many features of embryonic development with echinoderms, but have evolved separately for at least 500 million years
<table>
<thead>
<tr>
<th>Key Concept</th>
<th>Phylum</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concept 33.1</strong> Sponges are basal animals that lack true tissues</td>
<td>Calcarea, Silicea (sponges)</td>
<td>Lack true tissues; have choanocytes (collar cells—flagellated cells that ingest bacteria and tiny food particles)</td>
</tr>
<tr>
<td><strong>Concept 33.2</strong> Cnidarians are an ancient phylum of eumetazoans</td>
<td>Cnidaria (hydras, jellies, sea anemones, corals)</td>
<td>Unique stinging structures (cnidae), each housed in a specialized cell (nudocyte); diploblastic; radially symmetrical; gastrovascular cavity (digestive compartment with a single opening)</td>
</tr>
<tr>
<td><strong>Concept 33.3</strong> Lophotrochozoans, a clade identified by molecular data, have the widest range of animal body forms</td>
<td>Platyhelminthes (flatworms)</td>
<td>Dorsoventrally flattened, unsegmented acelomates; gastrovascular cavity or no digestive tract</td>
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<tr>
<td></td>
<td>Rotifera (rotifers)</td>
<td>Pseudocoelomates with alimentary canal (digestive tube with mouth and anus); jaws (trophi) in pharynx; head with ciliated crown</td>
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<td>Ectoprocta, Brachiopoda</td>
<td>Coelomates with lophophores (feeding structures bearing ciliated tentacles)</td>
</tr>
<tr>
<td></td>
<td>Mollusca (clams, snails, squids)</td>
<td>Coelomates with three main body parts (muscular foot, visceral mass, mantle); coelom reduced; most have hard shell made of calcium carbonate</td>
</tr>
<tr>
<td></td>
<td>Annelida (segmented worms)</td>
<td>Coelomates with segmented body wall and internal organs (except digestive tract, which is unsegmented)</td>
</tr>
<tr>
<td><strong>Concept 33.4</strong> Ecdysozoans are the most species-rich animal group</td>
<td>Nematoda (roundworms)</td>
<td>Cylindrical, unsegmented pseudocoelomates with tapered ends; no circulatory system; undergoes ecdysis</td>
</tr>
<tr>
<td></td>
<td>Arthropoda (crustaceans, insects, spiders)</td>
<td>Coelomates with segmented body, jointed appendages, and exoskeleton made of protein and chitin</td>
</tr>
<tr>
<td><strong>Concept 33.5</strong> Echinoderms and chordates are deuterostomes</td>
<td>Echinodermata (sea stars, sea urchins)</td>
<td>Coelomates with bilaterally symmetrical larva and five-part body organization as adults; unique water vascular system; endoskeleton</td>
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<td>Chordata (lancelets, tunicates, vertebrates)</td>
<td>Coelomates with notochord; dorsal, hollow nerve cord; pharyngeal slits; post-anal tail (see Chapter 34)</td>
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| **Concept 33.3**  
Lophotrochozoans, a clade identified by molecular data, have the widest range of animal body forms | Platyhelminthes (flatworms)    | Dorsoventrally flattened, unsegmented acoelomates; gastrovascular cavity or no digestive tract |
<p>| Rotifera (rotifers)                                                        |                               | Pseudocoelomates with alimentary canal (digestive tube with mouth and anus); jaws (trophi) in pharynx; head with ciliated crown |
| Lophophorates: Ectoprocta, Brachiopoda                                     |                               | Coelomates with lophophores (feeding structures bearing ciliated tentacles) |
| Mollusca (clams, snails, squids)                                           |                               | Coelomates with three main body parts (muscular foot, visceral mass, mantle); coelom reduced; most have hard shell made of calcium carbonate |
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You should now be able to:

1. Describe how a sponge feeds and digests its food

2. List the characteristics of the phylum Cnidaria that distinguish it from other animal phyla

3. List the four classes of Cnidaria and distinguish among them based on life cycle morphology

4. List the characteristics of Platyhelminthes and distinguish among the four classes
5. Describe a lophophore and name two lophophorate phyla

6. Describe the features of molluscs and distinguish among the four classes

7. Describe the features of annelids and distinguish among the three classes

8. List the characteristics of nematodes that distinguish them from other wormlike animals
9. List three features that account for the success of arthropods

10. Define and distinguish among the four major arthropod lineages

11. Describe the developmental similarities between echinoderms and chordates

12. Distinguish among the six classes of echinoderms