Chapter 18

The Evolution of Invertebrate Diversity

PowerPoint Lectures for

Biology: Concepts & Connections, Sixth Edition
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Lecture by Joan Sharp
Animals are **eukaryotic, multicellular heterotrophs** that **ingest their food**.

Animal cells **lack cell walls**.
18.1 What is an animal?

- Most adult animals are diploid, producing short-lived gametes by meiosis
  - Two gametes fuse to produce a diploid zygote, which grows to maturity by mitosis

- The life cycle of most animals includes a blastula, gastrula, and larval stage

- Hox genes control transformation of the zygote into an adult animal
Egg
Meiosis
Zygote (fertilized egg)
Eight-cell stage
Blastula (cross section)
Early gastrula (cross section)
Later gastrula (cross section)
Future mesoderm
Ectoderm
Endoderm
Internal sac
Digestive tract
Larva
Adult
Metamorphosis

Key
- Haploid (n)
- Diploid (2n)
A hypothesis for the evolution of animals from a colonial flagellated protist

1. Colonial protist, an aggregate of identical cells
2. Hollow sphere of unspecialized cells
3. Beginning of cell specialization
4. Infolding
5. Gastrula-like “proto-animal”
18.3 Animals can be characterized by basic features of their “body plan”

- Animal body plans vary in symmetry, body cavity, and number of germ layers

- With radial symmetry, any slice through the central axis divides the animal into mirror image halves
  - A radially symmetrical animal has a top and bottom but lacks back and front or right and left sides
  - Animals with bilateral symmetry have mirror-image right and left sides, a distinct head and tail, and a back (dorsal) and belly (ventral) surface
Radial (left) and bilateral (right) symmetry
Animal body plans vary in organization of tissues

- Sponges lack true tissues
- In other animals, cell layers formed during gastrulation give rise to tissues and organs

- Some animals have only ectoderm and endoderm, but most animals also have mesoderm

The body cavities of animals vary too

- Flatworms have a solid body and lack a coelom
- A pseudocoelom is partially lined by tissue derived from mesoderm
- A true coelom is completely lined by tissue derived from mesoderm
No body cavity (a flatworm)

- Digestive sac (from endoderm)
- Body covering (from ectoderm)
- Tissue-filled region (from mesoderm)
Pseudocoelom (a roundworm)

- Body covering (from ectoderm)
- Muscle layer (from mesoderm)
- Digestive tract (from endoderm)
- Pseudocoelom
True coelom (a segmented worm)
18.4 The body plans of animals can be used to build phylogenetic trees.
INVERTEBRATE DIVERSITY
18.5 Sponges have a relatively simple, porous body

- **Sponges** (phylum Porifera) are simple, sedentary (sessile) animals **without true tissues**
  - Water is drawn in through pores in the body wall into a **central cavity**, and then flows out through a larger opening

- The body of a sponge consists of **two layers of cells** separated by a gelatinous region
  - The inner layer of flagellated **choanocytes** filters food and engulfs it by phagocytosis
  - **Amoebocytes** wander through the middle body region and produce skeletal fibers
Scypha

A purple tube sponge

An azure vase sponge
Structure of a simple sponge

Pores

Amoebocyte

Skeletal fiber

Central cavity

Choanocyte

Choanocyte in contact with an amoebocyte

Flagella

Water flow
18.5 Sponges have a relatively simple, porous body

- Sponges are **suspension feeders**, filtering **food particles** from water passed through food-trapping equipment
  - To grow by 100 g, a sponge must filter 1,000 kg of water

- Adult sponges are **sessile** and cannot escape from predators
  - They produce defensive toxins and antibiotics that deter pathogens, parasites, and predators
18.6 Cnidarians are radial animals with tentacles and stinging cells

- Cnidarians (phylum Cnidaria) have two tissue layers: an outer epidermis and an inner cell layer lining the digestive cavity
  - A jelly-filled middle region may have scattered amoeboid cells

- Cnidarians use tentacles to capture prey and push them into their mouths
  - The mouth leads to the gastrovascular cavity, which functions in digestion and circulation and as a hydrostatic skeleton
  - Cnidocytes on tentacles sting prey and function in defense
Cnidocyte action

Tentacle

“Trigger”

Discharge of thread

Prey

Cnidocyte

Capsule (nematocyst)

Coiled thread
Cnidarians have two kinds of radially symmetrical body forms—polyp and medusa

- Some cnidarians have alternating polyp and medusa forms in their life cycle, while others exist only as polyp or medusa forms.
Polyp body form: a hydra (about 2–25 mm high)

Medusa body form: a marine jelly called a sea nettle (about 5 cm in diameter)

Sea anemones, such as this *Anthopleura* (about 6 cm in diameter), exist only as polyps

Medusa body form: a marine jelly called a sea nettle (about 5 cm in diameter)
18.7 Flatworms are the simplest bilateral animals

- **Flatworms** (phylum Platyhelminthes) are the **simplest bilateral animals**

- There are **three** major groups of flatworms
  - **Free-living flatworms** (planarians) have heads with light-sensitive eyespots and flaps to detect chemicals
  - Dense clusters of nerve cells form a **simple brain**, and a pair of nerve cords runs the length of the body
  - Planarians have a branched **gastrovascular cavity** with a single opening (mouth/anus)
Gastrovascular cavity

Mouth/anus

Nerve cords

Eyespots

Nervous tissue clusters

Bilateral symmetry
Flukes and tapeworms are parasitic flatworms with complex life cycles.

Flukes live as parasites, with suckers to attach to their hosts.

Tapeworms inhabit the digestive tracts of vertebrates.
- They consist of a ribbon-like body with repeated units.
- The anterior scolex is armed with hooks and suckers for attachment, while posterior units are full of eggs and sperm.
- Tapeworms lack a digestive tract and absorb nutrients from the intestines of their hosts.
Units with reproductive structures

Hooks

Scolex (anterior end)

Sucker
Roundworms (phylum Nematoda) have bilateral symmetry and three tissue layers.

- They are abundant and diverse, with an estimated 500,000 species.
- The body cavity is a pseudocoelom, which functions to distribute nutrients and as a hydroskeleton.
- The complete digestive tract has a mouth and anus.

Humans host at least 50 species of nematodes.
A free-living nematode
Dog heart infected by heartworm, a parasitic nematode
Mollusks (phylum Mollusca) have a true coelom and a circulatory system.

Many molluscs feed with a rasping radula, used to scrape up food.

All molluscs have:
- A muscular foot that functions in locomotion
- A visceral mass containing most of the internal organs
- A mantle, which may secrete a shell that encloses the visceral mass
Visceral mass

Coelom

Kidney

Heart

Reproductive organs

Digestive tract

Shell

Mantle

Mantle cavity

Anus

Gill

Foot

Nerve cords

Digestive tract

Radula

Mouth
18.9 Diverse molluscs are variations on a common body plan

- **Gastropods** are the largest group of molluscs and include the **snails** and **slugs**
  - Most snails are protected by a single, spiral shell
  - In land snails, **the lining** of the mantle cavity functions as a **lung**
  - Slugs have lost their mantle and shell and have long colorful projections that function as gills

Video: Nudibranchs

A terrestrial gastropod: a land snail

A marine gastropod: a sea slug
18.9 Diverse molluscs are variations on a common body plan

- **Bivalves** have **shells divided into two halves** that are hinged together
  
  - Bivalves include **clams, oysters, mussels, and scallops**
  
  - Most bivalves are **sedentary suspension feeders**, attached to the substrate by strong threads
A bivalve: a scallop
Cephalopods are fast, agile predators and include squids and octopuses.

Cephalopods have large brains and sophisticated sense organs, including complex image-focusing eyes.

In most cephalopods, the shell is small and internal (squid) or missing (octopuses).

- Squid are fast, streamlined predators that use a muscular siphon for jet propulsion.
- Octopuses live on the seafloor, where they creep about in search of food.
A cephalopod with an internal shell: a squid
Annelids (phylum Annelida) have a closed circulatory system in which blood is enclosed in vessels.

- Their nervous system includes a simple brain and ventral nerve cord with cluster of nerve cells in each segment.
- The true coelom functions as hydrostatic skeleton.

Earthworms ingest soil and extract nutrients, aerating soil and improving its texture.
Segmentation and internal anatomy of an earthworm

- **Segment wall**
- **Mucus-secreting organ**
- **Bristles**
- **Dorsal blood vessel**
- **Coelom**
- **Digestive tract**
- **Excretory organ**
- **Segment wall**
- **Ventral blood vessel**
- **Endothelialization**
- **Brain**
- **Mouth**
- **Pumping segmental vessels**
- **Nerve cord**
- **Epidermis**
- **Circular muscle**
- **Longitudinal muscle**
- **Dorsal blood vessel**
- **Intestine**
- **Nerve cord**
- **Ventral blood vessel**
- **Bristles**

Giant Australian earthworm
Epidermis
Circular muscle
Segment wall (partition between segments)
Longitudinal muscle
Dorsal blood vessel
Intestine
Nerve cord
Excretory organ
Bristles
Ventral blood vessel

Video: Earthworm Locomotion
Giant Australian earthworm
18.10 Annelids are segmented worms

- Polychaetes are the largest group of annelids
  - Each polychaete segment has a pair of fleshy appendages with stiff bristles or chaetae.
  - Polychaetes search for prey on the seafloor or live in tubes and filter food particles.

- Most leeches are free-living carnivores, but some suck blood.
  - Blood-sucking leeches use razor-like jaws, secrete an anesthetic and an anticoagulant, and suck up to 10 times their own weight in blood.
A free-swimming marine polychaete

A tube-building polychaete

A medicinal leech
18.11 Arthropods are segmented animals with jointed appendages and an exoskeleton

- There are over a million species of arthropods (phylum Arthropoda), including crayfish, lobsters, crabs, barnacles, spiders, ticks, and insects.
- The diversity and success of arthropods are due to segmentation, a hard exoskeleton, and jointed appendages.
- Arthropods have an open circulatory system.
- The body of most arthropods includes a head, thorax, and abdomen.
18.11 Arthropods are segmented animals with jointed appendages and an exoskeleton

- Living arthropods represent **four** major lineages
- **Chelicerates** include **horseshoe crabs** and arachnids, such as **spiders**, **scorpions**, **mites**, and **ticks**
- Most are terrestrial
- Scorpions are nocturnal hunters, while spiders hunt or trap prey during the day
Millipedes and centipedes are identified by the number of jointed legs per body segment

- 2 in herbivorous millipedes, 1 in carnivorous centipedes
18.11 Arthropods are segmented animals with jointed appendages and an exoskeleton

- **Crustaceans** are nearly all aquatic
  - They include **crabs, shrimps, and barnacles**, which feed with jointed appendages

Crustaceans: goose barnacles (about 2 cm high)

Other barnacle species
70% of all animal species are **insects**

- There may be as many as 30 million insect species

The body of an insect includes a head, thorax, and abdomen; **three sets** of legs; and (in most insects) wings
Insect anatomy, as seen in a grasshopper

- Head
- Thorax
- Abdomen

- Antenna
- Forewing
- Eye
- Mouthparts
- Hindwing
The success of insects is due to

- Body segmentation
- An exoskeleton
- Jointed appendages
- Flight
- A waterproof cuticle
- A complex life cycle with short generations and large numbers of offspring
18.12 EVOLUTION CONNECTION: Insects are the most successful group of animals

- Insect life cycles
  - Many insects undergo incomplete or complete **metamorphosis**, with different body forms specialized for different roles
    - Larval stage is **specialized for eating and growing**
    - Adult stage is **specialized for reproduction and dispersal**

Video: Butterfly Emerging

Video: Bee Pollinating
Complete metamorphosis of regal moth. Caterpillar (hickory horned devil, above left) is about 13 cm long; pupa, about 7 cm long (above right); adult moth, up to 15 cm in wingspan (right).
18.12 EVOLUTION CONNECTION: Insects are the most successful group of animals

- Modular body plan of insects
  - Insect mouthparts are adapted for various types of feeding, such as **chewing** (grasshoppers), **biting and tearing prey** (mantids), **lapping up fluids** (houseflies), **piercing and sucking** fluids of plants (aphids) and animals (mosquitoes)
  - Insects have **three pairs of legs**, which are adapted for walking, jumping, grasping prey, digging in soil, or paddling on water
  - Most adult insects have **one or two pairs of wings**, allowing dispersal and escape from predators
Protective color patterns

- Many insects have protective color patterns and disguises, including modifications to antennae, wings, and bodies
Remarkable resemblances. A stick insect
Remarkable resemblances. A leaf mimic
Remarkable resemblances. A caterpillar resembling bird dropping
Hawk moth caterpillar
Owl butterfly (above) and long-eared owl (right)
Echinoderms (phylum Echinodermata) include slow-moving or sessile radially symmetrical organisms such as sea stars and sea urchins.

- The water vascular system has water-filled canals branching into tube feet, which are used for respiration, feeding, and locomotion.

- Echinoderms have an endoskeleton of hard calcareous plates under a thin skin.

- Echinoderms and chordates belong to a clade of bilateral animals called deuterostomes.
18.13 Echinoderms have spiny skin, an endoskeleton, and a water vascular system for movement.
A sea star feeding on a clam
A sea urchin (about 12 cm in diameter)
18.14 Our own phylum, Chordata, is distinguished by four features

- **Chordates** *(phylum Chordata)* have
  - A dorsal hollow nerve cord
  - A flexible, supportive notochord
  - Pharyngeal slits
  - A muscular post-anal tail
18.14 Our own phylum, Chordata, is distinguished by four features

- The simplest chordates are **tunicates** and **lancelets**, which use their pharyngeal slits for suspension feeding
  - Adult tunicates are sessile and attached, while the **tunicate larva** is a **tadpole-like organism**
  - Tunicates represent the deepest branch of the chordate lineage

- Lancelets are small, bladelike chordates that live in marine sands
  - Lancelets are **the closest living relatives of vertebrates**
A tunicate

- Excurrent siphon
- Adult (about 3 cm high)
- Post-anal tail
- Dorsal, hollow nerve cord
- Pharyngeal slits
- Mouth
- Muscle segments
- Notochord
- Larva
A lancelet (5–15 cm long)

- Head
- Mouth
- Pharynx
  - Pharyngeal slits
- Digestive tract
- Notochord
- Dorsal, hollow nerve cord
- Water exit
- Segmental muscles
- Anus
- Post-anal tail

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18.15 An animal phylogenetic tree is a work in progress

- This phylogenetic tree is based on molecular data
A molecular-based phylogenetic tree

- No true tissues
- Eumetazoans
  - Radial symmetry
    - Eumetazoans
      - Lophotrochozoans
        - Deuterostomes
          - Bilaterians
            - Bilateral symmetry
              - Bilaterians
              - Echinoderms
                - Chordates
                  - Flatworms
                    - Molluscs
                      - Annelids
                        - Edgyzoans
                          - Arthropods
                          - Nematodes
                          - Sponges
                            - Cnidarians
18.4 The body plans of animals can be used to build phylogenetic trees
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Thank you for your attention and participation!
You should now be able to

1. Describe the defining characteristics of animals

2. Describe the general animal life cycle and the basic body plan

3. Explain how a hydrostatic skeleton helps an animal move and keep its shape

4. Compare the nine animal phyla discussed in this chapter with respect to the following traits: (a) presence of true tissues; (b) no symmetry, radial symmetry, or bilateral symmetry; (c) no coelom, a pseudocoelom, or a true coelom; and (d) protostome or deuterostome
You should now be able to

5. Define segmentation, explain its functions, and note the animal phyla where it occurs

6. Compare the characteristics of the four major arthropod lineages; note examples of each

7. Describe the common characteristics of insects

8. Describe the process and significance of complete metamorphosis

9. Compare the phylogenetic relationships shown in Figures 18.4 and 18.15, noting similarities and differences