Animal Origins and Evolution
Common Features of Animals

- **multicellular**
- **heterotrophic**
- **motile**
- **Sexual reproduction, embryo**
Evolution of Animals

• All animals are multicellular and heterotrophic, which means they must acquire nutrients from an external source.
  – Fungi digest their food externally and absorb nutrients.
  – Animals ingest (eat) whole food and digest internally.

• Animals have a variety of life cycles.
  – Many reproduce sexually and some asexually and some combine both life cycles.
  – Many animals have a diploid life cycle.

• Animals are descended from a single common ancestor.
  – Within the animal lineage are two main branches: **invertebrates** and **vertebrates**.
    • Vertebrates are animals that at some stage have a spinal cord (backbone), whereas invertebrates do not.
Animal Origins and Evolution

Phylogenetic Tree

- Phylum Chordata
- Phylum Echinodermata
- Phylum Platyhelminthes
- Phylum Porifera
- Phylum Annelida
- Phylum Arthropoda
- Phylum Mollusca
- Phylum Nematoda
- Phylum Cnidaria

Ancestral Flagellates
Some major episodes in the history of life.

Note that molecular evidence puts origin of animals at 1 BYA.

YouTube Video
The Story Of Earth And Life
https://www.youtube.com/watch?v=Y1DPzY6o6hQ
Archean Eon: 4-2 BYA
Great Age of Bacteria
Cyanobacteria – Photosynthesis – Oxygen – 2.5 BYA
The origin and early evolution of the eukaryotes, about 2 BYA
Multicellular Animals

Protista Ancestor

• Plants, animals, and fungi trace their ancestry to protists

• Common ancestor of animals and fungi was aquatic, flagellated, single-celled protist.
Metazoan animals probably evolved from colonial, flagellated protists, like this Choanoflagellate.

Found as individuals or colonies.
One hypothesis for the origin of animals with tissues from a flagellated protist.

Gastrea Hypothesis – proposed by Haeckel in 1870s

Infolding created two layers of cells
Individual sponge cells resemble Choanoflagellates
Ediacaran Fossils – 600-542 MYA

• Just before the Cambrian explosion, worldwide proliferation of multicellular organisms
• Flat, segmented, soft-bodied.
• Ancestral to jellyfish or soft-bodied arthropods? Or an extinct kingdom of life?
• Few or none survived into the Paleozoic era.
Ediacaran Life - 600-542 MYA

All of these were soft-bodied, and are known only from impressions. Became extinct in early Cambrian.
The Cambrian Explosion

• Most animal phyla originated in a relatively brief span of geologic time, 40 MY.

• During the Cambrian Explosion (543 to 524 million years ago), nearly all major body plans appeared
Between about 542 and 510 million years ago, skeletonized organisms appeared in a huge explosion of diversity (in geological time).

This event is called *The Cambrian Explosion*.

Seascapes changed...

From peaceful oasis...

...to war zone with weapons and armor
Cambrian Explosion

Cambrian YouTube Video
https://www.youtube.com/watch?v=Y1DPzY6o6hQ
Cambrian Seas
Some Cambrian creatures very strange - *Opabinia*
Pikaia
One of earliest known Chordates

A notochord (an internal band of elastic tissue that could be flexed by muscle packs down its length) allowed early chordates to swim without the burden of heavy external armor.

We ultimately evolved from an animal that looked like this!
Figure 23.10

Notochord

Segmented muscle

Pikaia

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Characteristics of Animals

- Multicellular
- Heterotrophs – digest internally
- Require oxygen
- Reproduce sexually (mostly, a few asexual)
- Go through blastula stage
- Motile at some point
- Tissues – muscles and nerves
- Eggs much larger than sperm
- Diverse
Animal Phylogeny

– Biologists categorize animals by:
  • General features of body structure
  • More recently, using genetic data
– One major branch point distinguishes sponges from all other animals because, unlike more complex animals, sponges lack true tissues.
– A second major evolutionary split is based on body symmetry.
  • **Radial symmetry** refers to animals that are identical all around a central axis.
  • **Bilateral symmetry** exists where there is only one way to split the animal into equal halves.
Evolution of Body Plans

Figure 17.5

Ancestral protist

- No true tissues
- Radial symmetry

- Tissues
- Bilateral symmetry

Sponges
Cnidarians
Molluscs
Flatworms
Annelids
Roundworms
Arthropods
Echinoderms
Chordates
A basic feature of a multicellular body is the presence or absence of a plane of symmetry

- **asymmetry** – irregular shape
- **radial symmetry** - at least two planes of symmetry.
- **bilateral symmetry** - a single plane of symmetry; face their environment in one direction.
Animal Symmetry

- **Asymmetrical** occurs mainly among sponges.
- **Radial symmetry** occurs among the Cnidarians (jellyfish) and Echinoderms (starfish, sea urchins).
- **Bilateral symmetry** commonest form of symmetry. Strongly associated with cephalization or development of a head with associated sensory and feeding apparatus.
Cephalization

Bilateral symmetry allowed:

Evolution of a head, or anterior region, where structures for feeding, sensing the environment, and processing information are concentrated

Concentration of neural tissue (eyes, brain, senses)
Ancestral protist

No true tissues

Radial symmetry

Tissues

Bilateral symmetry

Sponges

Cnidarians

Molluscs

Flatworms

Annelids

Roundworms

Arthropods

Echinoderms

Chordates

Figure 17.5
Development of body plans

• An animal’s body results from division of cells during embryonic development.

• Differences in developmental patterns have been used to classify more complex animals so an understanding of basic embryology is necessary to follow this.
Differences in Early Development

Three events in early development differ in protostomes and deuterostomes

• Cleavage
• Gastrulation
• Coelom formation
Embryonic development

• Once an egg is fertilized it becomes a **zygote**. This cell divides into a large number of cells called **blastomeres**.

• Cleavage of cells proceeds until a fluid-filled hollow ball of cells is formed. This is a **blastula**.

• In multicellular animals other than sponges the blastula invaginates to begin forming the future gut. At this stage the embryo is a **gastrula**.
Embryonic Development - Cleavage in a frog embryo
Spiral and Radial Cleavage

(a) Spiral cleavage

(b) Radial cleavage

Saunders College Publishing
Cleavage
(zygote undergoes rapid divisions, eventually forming a ball of cells)

** PROTOSTOMES **

2-cell stage

4-cell stage

8-cell stage  Spiral cleavage

** DEUTEROSTOMES **

Radial cleavage

Figure 31-8a Biological Science, 2/e © 2005 Pearson Prentice Hall, Inc.
Embryonic development

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Early embryonic development

1. **Zygote**
   - Cleavage
   - Eight-cell stage
   - Cleavage
   - Blastula (hollow ball)
   - Cross section of blastula

- **Blastocoel**
- **Endoderm**
- **Ectoderm**
- **Gastrula**
- **Blastopore**

Gastrulation
The first tissue layers that appear are called germ layers.

– These give rise to organs and organ systems.

• *Diploblastic* – Two tissue layers
• *Triploblastic* – Three tissue layers
Germ layers

- **Endoderm** - innermost germ layer of an embryo. Forms the gut, liver, pancreas.

- **Ectoderm** - Outer layer of cells in early embryo. Surrounds the blastocoel. Forms outer epithelium of body and nervous system.

- **Mesoderm** - Third germ layer formed in gastrula between ectoderm and endoderm. Gives rise to connective tissue, muscle, urogenital and vascular systems and peritoneum.
Gastrulation
(ball of cells formed by cleavage invaginates to form gut and embryonic tissue layers)

Protostome

Deuterostome
Coeloms

• The coelom is a cavity entirely surrounded by mesoderm.

• A coelom provides a tube-within-a-tube arrangement which has many advantages:
  – Allows flexibility in arranging visceral organs
  – permits greater size and complexity by exposing more cells to surface exchange
  – fluid-filled ceolom can act as a hydrostatic skeleton
Coeloms
The tube-within-a-tube body plan

- Muscles and organs derived from mesoderm
- Body wall derived from ectoderm
- Gut derived from endoderm
Coelom forms in different ways......

Coelom formation (body cavity lined with mesoderm develops)

**PROTOSTOMES**
- Gut
- Mesoderm
- Block of solid mesoderm splits to form coelom

**DEUTEROSTOMES**
- Gut
- Mesoderm
- Mesoderm pockets pinch off of gut to form coelom

Cross section

Figure 31-8c Biological Science, 2/e © 2005 Pearson Prentice Hall, Inc.
Eight-cell stage

Gastrulation

Archenteron

Coelum

Mesoderm

Blastopore → Mouth

Protostomes

Anus

Deuterostomes

Mouth

Mesoderm

Coelum

Digestive tube

Blastopore → Anus

radial cleavage

spiral cleavage
Protostomes and Deuterostomes

• Within the eucolomates there are two major evolutionary lineages that split early in the history of animals and follow quite different developmental pathways.

These are the protostomes “mouth first” and deuterostomes “mouth second”.
Important differences in development between protostomes and deuterostomes

• The differences in development that distinguish the protostomes and deuterostomes include:
  – Whether cleavage of cells in the early zygote is spiral or radial.
  – Whether or not, if the early blastomere is separated, each cell can develop into a normal larva or not.
  – Whether the blastopore ultimately forms the mouth or anus of the organism.
  – Whether or not the organism possesses a coelom and how that coelom is formed.
One hypothesis of animal phylogeny is based mainly on morphological and developmental comparisons.
Protostomes and Deuterostomes

• Protostomes include the annelids, mollusks, and arthropods.

• Deuterostomes include the echinoderms and vertebrates.
The Cambrian radiation of animals
Macroevolutionary patterns

- **Adaptive Radiation** - evolutionary divergence of members of a single phyletic line into a series of rather different niches or adaptive zones.
- **Punctuated equilibrium** – abrupt changes in fossil record followed by long periods of stasis
What caused the Cambrian explosion?

1. Oxygen levels reached present levels that allow for rapid metabolism, larger size, exhibited by animals.

2. Development of predators and escaping predators. Increased need for speed and better sensory equipment. Evolution of eyes.

3. Genetic Factors - Homeotic Genes
   • Hox Genes – encode transcription factors that control other genes
   • $Hox$ genes evolved at that time and allowed for differential development.
   • Small genetic changes $\Rightarrow$ big morphological differences
Hox genes, responsible for the growth of the different body segments from head to tail, in humans, and in fruit flies. Control development, size, sequence.
• Hox gene clusters in several phyla. Each Hox gene is a colored box, and each organism has about 8 to over 40 Hox genes.
• The multiple copies of Hox genes in more derived vertebrates is due to the fact that this single cluster was duplicated as a result of successive rounds of whole genome duplication in the vertebrate lineage, with subsequent loss of some copies in various lineages.
Ancestral protist

- No true tissues
  - Sponges
  - Cnidarians

Radial symmetry

- Tissues
  - Molluscs
  - Flatworms

Bilateral symmetry

- Annelids
  - Roundworms
  - Arthropods
  - Echinoderms
  - Chordates

Figure 17.5
<table>
<thead>
<tr>
<th>Group and Phylum</th>
<th>Common Name or Example Taxa</th>
<th>Estimated Number of Species</th>
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</thead>
<tbody>
<tr>
<td>Protostomes: Lophotrochozoa</td>
<td></td>
<td></td>
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<tr>
<td>Porifera</td>
<td>Sponges</td>
<td>5500</td>
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<tr>
<td>Cnidaria</td>
<td>Jellyfish, corals, anemones, hydroids, sea fans</td>
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<tr>
<td>Ctenophora</td>
<td>Comb jellies</td>
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</tr>
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<td>Acoelomorpha</td>
<td>Acoelomate worms</td>
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<td>Rotifera</td>
<td>Rotifers</td>
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<td>Platyhelminthes</td>
<td>Flatworms</td>
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<td>Nemertea</td>
<td>Ribbon worms</td>
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<td>Gastrotricha</td>
<td>Gastrotrichs</td>
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<td>Sipuncula</td>
<td>Peanut worms</td>
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<td>Echiura</td>
<td>Spoon worms</td>
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<td>Annelida</td>
<td>Segmented worms</td>
<td>16,500</td>
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<tr>
<td>Mollusca</td>
<td>Mollusks (clams, snails, octopuses)</td>
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<td>Phoronida</td>
<td>Phoronids</td>
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<td>Ectoprocta</td>
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<td>Brachiopoda</td>
<td>Brachiopods; lamp shells</td>
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<tr>
<td>Group and Phylum</td>
<td>Common Name or Example Taxa</td>
<td>Estimated Number of Species</td>
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<tr>
<td><strong>Protostomes: Ecdysozoa</strong></td>
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<td>Nematoda</td>
<td>Roundworms</td>
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<td>Kinorhyncha</td>
<td>Kinorhynchs</td>
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<tr>
<td>Nematomorpha</td>
<td>Hair worms</td>
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<tr>
<td>Priapula</td>
<td>Priapulans</td>
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<td>Onychophora</td>
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<td>Tardigrada</td>
<td>Water bears</td>
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<tr>
<td>Arthropoda</td>
<td>Arthropods (spiders, insects, crustaceans)</td>
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<tr>
<td><strong>Deuterostomes</strong></td>
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<tr>
<td>Echinodermata</td>
<td>Echinoderms (sea stars, sea urchins, sea cucumbers)</td>
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<td>Chaetognatha</td>
<td>Arrow worms</td>
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<td>Hemichordata</td>
<td>Acorn worms</td>
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</tr>
<tr>
<td>Chordata</td>
<td>Chordates (tunicates, lancelets, sharks, bony fish, frogs, reptiles, mammals)</td>
<td>50,000</td>
</tr>
</tbody>
</table>
The relative number of species contributed to the total by each phylum of animals. 97% invertebrates. Lots of Arthropods!
End