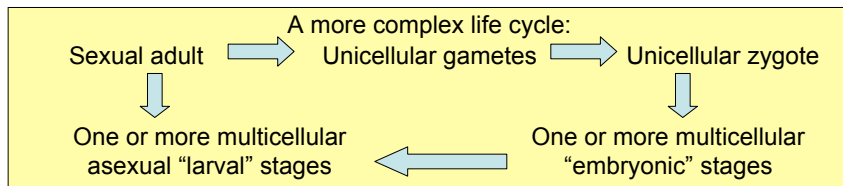


Animal body plans and developmental patterns

Multicellular organisms have a new problem: **development**. This is because they have a **life cycle** that includes a *unicellular* stage (or stages). Typically:



Animal body plans and developmental patterns

Four basic developmental processes lead from a unicellular zygote to the adult organism:

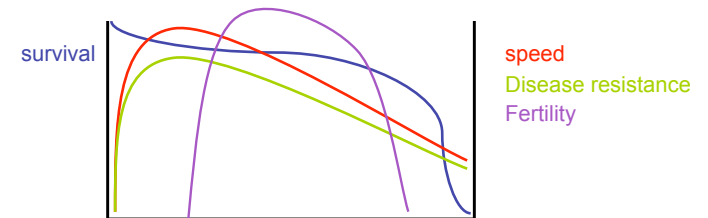
- **cell proliferation**: more cells produced by cell divisions
- **cell differentiation**: cells change into various types (differing structurally, biochemically, etc.) for specialized functions--*but remember that all have the same genetic information*
- **cell death** (apoptosis): a programmed process that contributes to formation of body structures
- **cell migration**: embryonic cells move with respect to each other

Animal body plans and developmental patterns

Another characteristic of multicellular organisms:

Senescence (aging)

- Unicellular forms divide without limit
- Multicellular forms have limited life span (~115 years in humans)



Animal body plans and developmental patterns

These four processes create an enormous increase in complexity-- *but with no change in genetic information*:

- Start development as an *undifferentiated* single cell; finish as a *very complex* structure containing many types of cells arranged in precise ways.

➡ About 10^{14} cells of 80-100 types in human, for example

Developmental biology is a key to understanding animal diversity and the overall body 'plan' of an organism.

The body plan is specified by four fundamental properties established during development; these are also crucial traits that differentiate the major animal groups.

Animal body plans and developmental patterns

1. The degree of differentiation and specialization of cells and tissues.

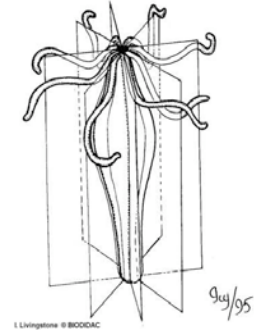
- One group, the sponges or **Parazoa**, is at a **cellular grade of organization**: few cell types that are very **loosely organized** into functional units.
- Other animal phyla have a more complex organization. Cells are more specialized, there are more cell types, and cells are organized into distinct **tissues** (tissues are groups of specialized cells with integrated function, isolated from other tissues by membranous layers).

These are **Eumetazoans**, or 'true' multicellular animals.

Animal body plans and developmental patterns

2. Fundamental symmetry: the directionality of the body plan--whether it has more than one plane of division that yields equal 'mirror images' of the body.

- One group, the Radiata (including the Cnidarians) has radial primary symmetry: the body can be 'cut' into identical halves (mirror images) along any plane around a major axis, as shown in this diagram:



- The major axis runs through the center of the organism. The 'cutting plane' can be rotated to any position around the major axis, and will still produce identical halves.

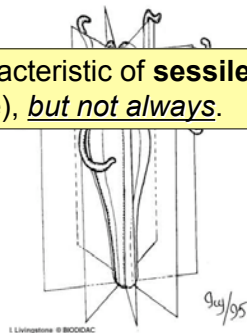
Animal body plans and developmental patterns

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- One group, the Radiata (including the Cnidarians) has radial primary symmetry: the body can be 'cut' into identical halves (mirror images) along any plane around a major axis, as shown in this diagram:

- The center of symmetry is the major axis. The 'cutting plane' can be rotated to any position around the major axis, and will still produce identical halves.

Radial symmetry is often characteristic of **sessile animals** (fixed to the substrate), *but not always*.

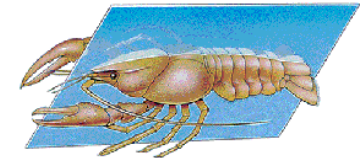


Animal body plans and developmental patterns

2. Fundamental symmetry: the directionality of the body plan--whether it has more than one plane of division that yields equal 'mirror images' of the body.

- Most animals groups (including all other eumetazoans) are **Bilaterians**. They have a primary symmetry that is **bilateral**: there is a major axis but the body can be 'cleaved' in **only one plane** and still produce identical mirror-image halves, as shown here:

Bilateral symmetry is the rule in animals that **move**; one end (the "head") encounters new environment; the other end often contains propulsion. So there are front and back ends = bilateral symmetry.

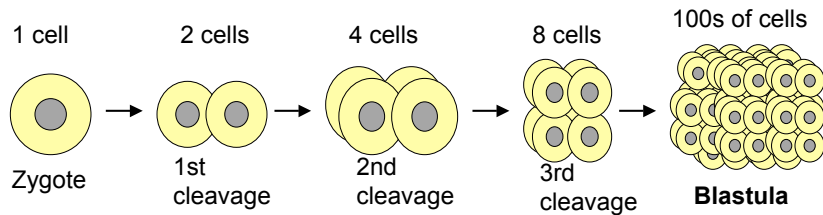


Bilaterally symmetrical animals are usually **cephalized**--sensors and brains are in the **head**

Animal body plans and developmental patterns

3. **Number, development, and arrangement of germ layers:**
embryonic cell layers that lead to the three basic cell types:
ectoderm, endoderm, and (in most animals) **mesoderm.**

Germ layer formation begins with the first cell division in the newly fertilized **zygote** -- on its way to becoming a multicellular **embryo**.



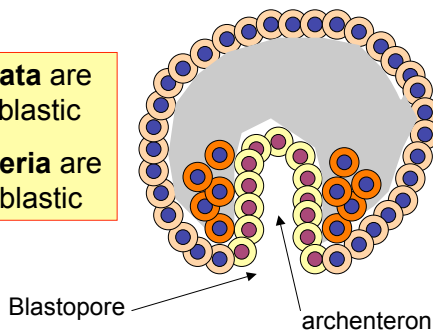
Through *cell movements*, **blastula** becomes a hollow sphere

Animal body plans and developmental patterns

3. **Number, development, and arrangement of germ layers:**
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In most (but not all) animals, the diploblastic embryo adds a third primary germ layer called **mesoderm**, becoming **triploblastic**

Radiata are diploblastic
Bilateria are triploblastic



Mesoderm forms between ectoderm and endoderm, but arises in two different ways:

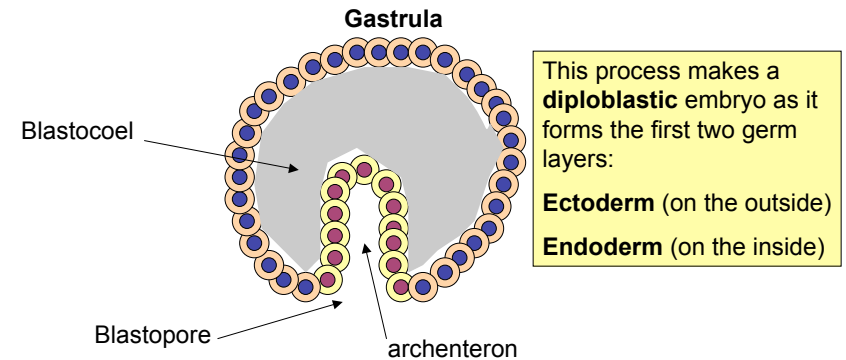
Schizocoely (mesoderm arises from **ectoderm**) -- **Protostomes**

Enterocoely (mesoderm arises from **endoderm**) -- **Deuterostomes**

Animal body plans and developmental patterns

3. **Number, development, and arrangement of germ layers:**
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Next stage is an **invagination** of the hollow blastula, called **gastrulation**



Animal body plans and developmental patterns

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The three primary germ layers go on to form all the other cell types and tissues in the animal. This is what happens in **triploblastic** animals:

Ectoderm: → Skin and nervous system

Endoderm: → Gut and associated organs and structures

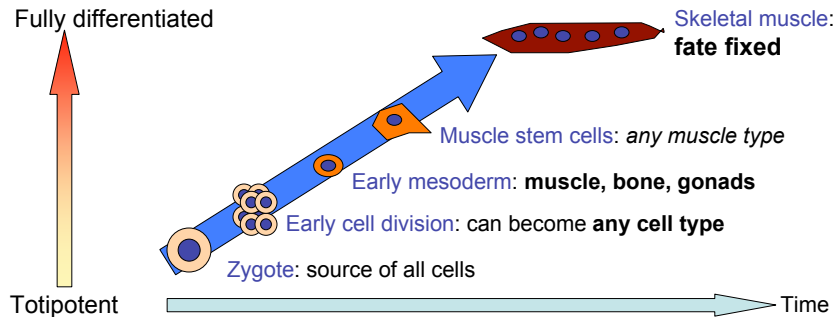
Mesoderm: → Muscles, gonads, internal skeletons

Animal body plans and developmental patterns

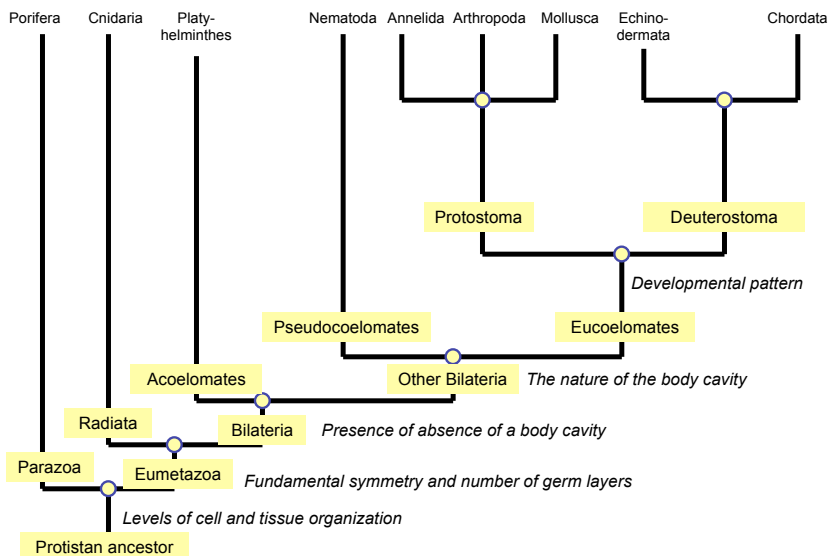
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Development requires increasing **differentiation**, from *totipotent* stem cells (can become any cell type) to full specialized cells with fixed **fates**.

Example: differentiation of muscle



Major animal phyla, showing morphological and developmental phylogenetic tree and divergences at ancestral branch points

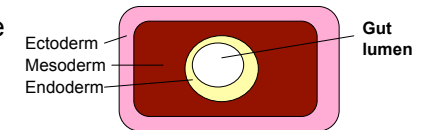


Animal body plans and developmental patterns

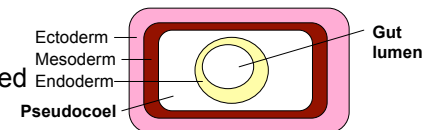
4. In **Bilateria**, the presence and arrangement of body cavities.

Schematic cross-sections:

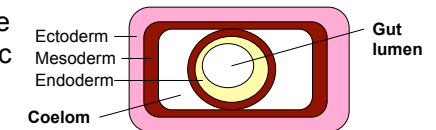
- **Acoelomates:** no body cavity; the space between ectoderm and endoderm is filled with mesoderm (*mesenchyme*)



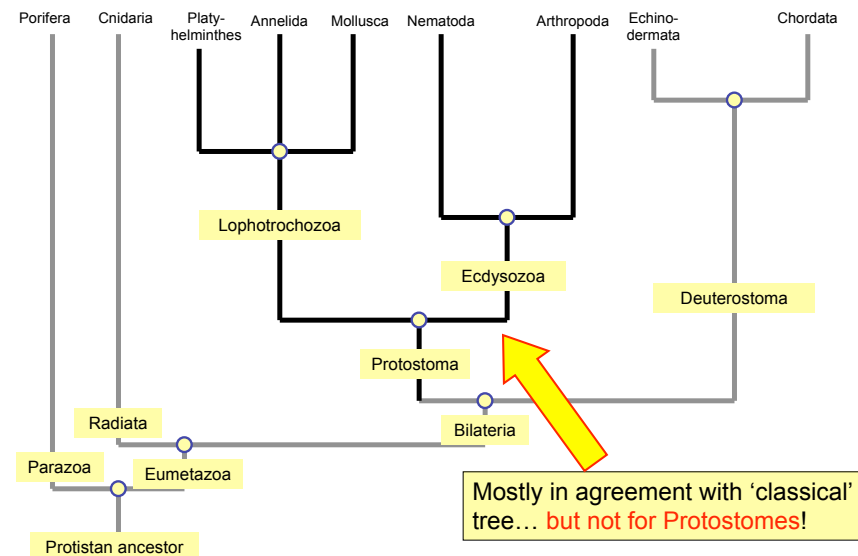
- **Pseudocoelomates:** body cavity (**pseudocoel**) derived from the embryonic blastocoel; *partially* lined with mesoderm (the gut has no mesoderm)



- **Eucoelomates:** body cavity -- the **coelom** -- derived from embryonic *mesoderm* (completely lined with mesoderm)



Major animal phyla, showing molecular sequence-based phylogenetic tree and divergences at ancestral branch points



Major animal phyla, showing **molecular sequence-based** phylogenetic tree and divergences at ancestral branch points ○

Porifera Cnidaria Platyhelminthes Annelida Mollusca Nematoda Arthropoda Echinodermata Chordata

Both schemes have evolutionary puzzles and peculiarities:

- in the '**classical**' tree, molting of the cuticle is assumed to have independently evolved twice (in nematodes and arthropods)
- in the '**molecular**' tree, segmentation is assumed to have independently evolved twice (in annelids and arthropods)

More data should help resolve these issues.

In Zoology, I'll mainly use the classical tree.

