Animal Tissues & Development

**Animal Cells**
- Eukaryotic
- No cell wall
- No plastids
- No central vacuole
- Multicellular:
  - extensive specialization & differentiation
  - unique cell-cell junctions

**Animals**
- Motile
- Highly differentiated tissues
- Intercellular junctions:
  - tissue-specific cadherins
- Extracellular protein fibers:
  - collagen
- Diploid life cycle
- Blastula/gastrula embryo

**Cadherins & Cell junctions**
- "calcium-dependent adhesion" transmembrane proteins
  - Tissue-specific
- $\Delta$ Ca$^{++} \rightarrow \Delta$ adhesion strength
  - Allow developmental cell migration
- $\Delta$ cadherin type $\rightarrow \Delta$ binding
  - Allow developmental tissue separation

**Extracellular Matrix (ECM)**
- Collagen fibers
- Elastin fibers
- Fibronectin
  - Attachment/movement along ECM

**Post-fertilization events**
- Binding of sperm to egg
- Acrosomal reaction: plasma membrane detachment (fast block to polyspermy)
- Increased intracellular calcium level
- Critical reaction begins (slow block to polyspermy)
- Formation of fertilization envelope complete
- Increased intracellular pH
- Increased protein synthesis
- Fusion of egg and sperm nuclei complete
- Start of DNA synthesis
- First cell division

**Figure 47.5**
Binding of sperm to egg
Cleavage: DNA replication / mitosis / cytokinesis with no growth phases; products of cytokinesis smaller & smaller blastomeres

- Little/no synthesis of new RNA or proteins
- All cells dependent upon molecular machines from original ovum

Spiral vs. Radial Cleavage

- **Protostomes**: “mouth first”
  - most invertebrates
  - spiral cleavage
  - determinate

- **Deuterostomes**: “mouth second”
  - echinoderms & vertebrates
  - radial cleavage
  - indeterminate

Determinate cleavage in a protostome (round worm)

- **Cytoplasmic determinates** – RNA-protein complexes
  - Define cell fate and body axis.
  - E.g., “P-granules” in round worm embryo
  - Dispersed in egg cell
  - After fertilization, aggregates at future posterior end
  - Upon each cleavage, partition to posterior-most cell

Indeterminate cleavage in a deuterostome (frog)

- **Experiment**

  - **Control egg (dorsal view)**
  - **Experimental egg (side view)**

  - **Results**

  - **Normal**
  - **Belly piece**
  - **Normal**

Blastulation — Sea Urchin

- Cleavage partitions the cytoplasm of one large cell into many smaller cells called **blastomeres**

- **Continued cleavage** ⇒ hollow structure called a **blastula**
  - The hollow cavity is the **blastocoel**

**Figure 47.19**

**Determinate cleavage in a protostome (round worm)**

**Figure 47.21**

**Figure 47.23**

**Figure 47.24**
**Morphogenesis**

- In plants, by differential growth
- In animals, by both growth & cell migration

![Figure 21.4](image)

**Animal Morphogenesis**

- Creation of form - directed by genes
  - Cell proliferation
  - Cell migration
  - Cell differentiation
  - Cell death (apoptosis)

![Animal Morphogenesis](image)

**Blastulation & Gastrulation**

- Early embryonic development in animals

![Blastulation & Gastrulation](image)

**Primary embryonic germ layers**

- Diploblastic: two germ layers
  - Ectoderm: develops into epidermal & neural tissues
  - Endoderm: develops into gut & accessory organs
  - Blastocoel: becomes filled with acellular mesoglia

Examples: Porifera & Cnidaria

![Primary embryonic germ layers](image)

**Primary embryonic germ layers**

- Triploblastic: three germ layers
  - Ectoderm: develops into epidermal & neural tissues
  - Endoderm: develops into gut & accessory organs
  - Mesoderm — displaces blastocoel: develops into muscle, endoskeleton, & connective tissues

Examples: everything else

![Primary embryonic germ layers](image)
Triploblastic gastrulation forms three germ layers

<table>
<thead>
<tr>
<th>ECTODERM</th>
<th>MESODERM</th>
<th>ENDODERM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidermis of skin and its derivatives (including sweat glands, hair follicles)</td>
<td>Notochord</td>
<td>Epithelial lining of digestive tract</td>
</tr>
<tr>
<td>Sense receptors in epidermis</td>
<td>Endoskeletal system</td>
<td>Epithelial lining of respiratory system</td>
</tr>
<tr>
<td>Nervous system</td>
<td>Muscular systems</td>
<td>Lining of urethra, urinary bladder, and reproductive system</td>
</tr>
<tr>
<td>Tooth enamel</td>
<td>Muscular layer of stomach, intestine, etc.</td>
<td>Liver</td>
</tr>
<tr>
<td>Epitheliun of pineal and pituitary glands</td>
<td>Excretory system</td>
<td>Pancreas</td>
</tr>
<tr>
<td>Notochord</td>
<td>Circulatory and lymphatic systems</td>
<td>Thyroid and parathyroid glands</td>
</tr>
<tr>
<td>Endoskeletal system</td>
<td></td>
<td>Thymus</td>
</tr>
<tr>
<td>Muscular system</td>
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<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>Excretory system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reproductive system (except germ cells)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermis of skin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lining of body cavity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adrenal cortex</td>
<td></td>
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</tr>
</tbody>
</table>

Triploblastic Animal Tissues
- Typical mammalian body is composed of ~50,000,000,000,000 cells
- Typical vertebrate body is composed of >100 specialized types of cells (tissue types)
  - Grouped into four major tissue types:
    - Epithelial
    - Connective
    - Muscle
    - Nervous

Epithelial Tissue
- Continuous sheet or layers of cells with direct cell-cell junctions
- All three germ layers start as epithelia, so epithelial tissues may derive from any germ layer.

Connective Tissue
- Cells are suspended in an extracellular matrix.
  - Often largely composed of collagen fibers.
- Derived from mesoderm.

Muscle Tissue
- Specialized for contraction.
- Derived from mesoderm.
- Diploblastic animals have myo-epithelia for contraction.

Nervous Tissue
- Specialized to conduct electrochemical nerve impulses.
- Derived from ectoderm.
Bauplan: Ger. "Life Plan" (pl: baupläne)

The arrangement, pattern, and development of tissues, organs, and systems unique to a particular type of organism.

Coelom

- Formation of coelom (body cavity) allows movement of organs within the body, esp. gut expansion & motility
  - Acoelomate: no body cavity
  - Pseudocoelomate: cavity between endoderm & mesoderm
  - Eucoelomate: cavity within mesoderm

Body Symmetry

- Developmental pattern formation results in symmetry of growth and regional specialization

Variations in Eucoelomate Gastrulation

- Coelom development in open vs. closed circulation
More variations in Gastrulation:

**Digestive tract**

- Gastrovascular cavity (blind gut)
  - Blastopore remains only orifice to gut
- Protostome (“mouth first”) development
  - The blastopore becomes the mouth
  - Secondary invagination to form anus
- Deuterostome (“mouth second”) development
  - The blastopore becomes the anus
  - Secondary invagination to form mouth

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**Figure 32.10**

Protostome development (examples: molluscs, annelids)

- Eight-cell stage: Spiral and determinate
- Coelom formation: Mesoderm blastopore
  - Solid masses of mesoderm split and form coelom.
  - Folds of archenteron form coelom.

Deuterostome development (examples: echinoderms, chordates)

- Eight-cell stage: Radial and indeterminate
- Coelom formation: Mesoderm blastopore
  - Mesoderm and archenteron form coelom.

**Key**
- Ectoderm
- Mesoderm
- Endoderm

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**Gastrulation — Sea Urchin**

- Animal pole
- Vegetal pole
- Future ectoderm
- Future mesoderm
- Future endoderm
- Mesenchyme
- Ectoderm
- Archenteron
- Blastocele
- Blastopore
- Anus
- Digestive tract (endoderm)

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**Gastrulation — Sea Urchin**

- Early blastula
- Late blastula
- Early gastrula
- Late gastrula
- Early larva
- Late larva

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**Figure 47.8**

Gastrulation — Sea Urchin
Protostome Larval Development

Protostomal development occurs in two distinct animal groups:

- **Lophotrochoza**: have ciliated larval stages
  - Usually with a distinct larval stage called a *trochophore*

- **Ecdysozoa**: have no ciliated tissues
  - All stages have an external cuticle
  - Growth requires *ecdysis* (molting)

_Embryonic Development_ — _Vertebrate Development_

- **Radial Cleavage & Blastulation — Frog**
  - Large yolk content necessitates asymmetrical blastulation
Animal Tissues & Development

47-22: Frog body polarity — established during oogenesis & fertilization

Animal pole
Point of sperm entry
Vegetal hemisphere
Vegetal pole
Point of sperm entry
Future dorsal side of tadpole
Gray crescent
First cleavage

47-7: Frog embryo — Cleavage planes & asymmetrical blastulation

Zygote
Animal hemisphere
Cleavage furrow
Vegetal hemisphere
Gray crescent
2-cell stage forming
0.25 mm
Animal pole
Blastula (cross section)

47-10: Frog gastrulation

1. SURFACE VIEW
   - Animal pole
   - Blastocoele
   - Dorsal lip of blastopore
   - Archenteron
   - Ectoderm
   - Mesoderm
   - Endoderm
2. CROSS SECTION
   - Archenteron
   - Blastocoele
   - Blastopore
   - Endoderm
   - Mesoderm
   - Neural plate formation
3. Early gastrula
4. Late gastrula
5. Blastopore
6. Blastocoele

47-14c: Frog segmentation

Chordate mesoderm segmentation

Mesoderm lateral to the notochord forms blocks called somites
Lateral to the somites, the mesoderm splits to form the coelom
Holoblastic cleavage
- Complete division of the egg into blastomeres
  - Occurs in species whose eggs have little or moderate amounts of yolk
  - Most of yolk partitioned into vegetal pole blastomeres
    - Establishes anterior/posterior axis
  - Sea urchin: small egg; little yolk
    - Symmetrical holoblastic cleavage
  - Frog: larger egg; moderate yolk
    - Asymmetrical holoblastic cleavage
  - Source: http://www.ucalgary.ca/UofC/eduweb/virtualembryo/why_fish.html

Meroblastic cleavage
- Only non-yolk cytoplasm of the egg cleaved
  - Occurs in species whose large eggs have abundant yolk
  - Fish Development
  - Fish Development: Another way — asymmetric blastulation in many vertebrates
    - Large, yolk-rich eggs
    - Extreme meroblastic cleavage forms the blastoderm.
    - Separation of the epiblast from the hypoblast forms the blastocoel.

Gastrulation — Chick
- Instead of blastopore, groove (primitive streak) forms in blastoderm.
- All three germ layers form from infolding epiblast.

Figure 47.10
- Figure 47.10: Cutaway view of the blastoderm. The cells of the blastoderm are arranged in two layers: the epiblast and the hypoblast. The yolk-filled cavity is the blastocoel.

Figure 47.11
- Figure 47.11: Early organogenesis. The archenteron forms when lateral folds pinch the embryo away from the yolk. (a) Early organogenesis, 56-hour-old chick embryo, about 2.5-mm long (LM).

Figure 47.15
- Figure 47.15: Late organogenesis, 56-hour-old chick embryo, about 2.5-mm long (LM).
Amniotes: extra-embryonic membranes

47-12: mammalian blastulation

47-12: mammalian gastrulation

Mammalian Gastrulation

Gastrulation

47-13: chick extra-embryonic membranes

Mammalian embryo & extraembryonic membranes

Amniote embryo & extraembryonic membranes