Animal Tissues & Development

**Animal Development & Differentiation**

**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
- Δ [Ca++] Þ Δ adhesion strength
  - Allow developmental cell migration
- Δ cadherin type Þ Δ 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 depolarization (fast block to polyspermy)
- Increased intracellular calcium level
- Cortical reaction begins (slow block to polyspermy)
- Formation of fertilization envelope complete
- Increased intracellular pH
- Increased protein synthesis
- Fusion of egg and sperm nuclei complete
- Onset of DNA synthesis
- First cell division
**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)**

- 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

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

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

Blastulation & Gastrulation
- Early embryonic development in animals
  - In most animals, cleavage results in the formation of a multicellular stage called a blastula. The blastula of many animals is a hollow ball of cells.
  - The endoderm of the archenteron develops into the animal's digestive tract.
  - The blind pouch formed by gastrulation, called the archenteron, opens to the outside via the blastopore.
  - Most animals also undergo gastrulation, a rearrangement of the embryo in which one end of the embryo folds inward, expands, and eventually fills the blastocoel, producing layers of embryonic tissues: the ectoderm (outer layer) and the endoderm (inner layer).

Primary embryonic germ layers
- Diploblastic: two germ layers
  - Ectoderm: develops into epidermal & neural tissues
  - Endoderm: develops into feeding tissues
  - Blastocoel: becomes filled with acellular mesoglea

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

Primary embryonic germ layers examples:
- Porifera & Cnidaria

Triploblastic gastrulation forms three germ layers
- Examples: everything else
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

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

![Gastrulation — Sea Urchin](Image)

**Digestive tube**

- Mouth develops from blastopore.
- Anus develops from blastopore.

**Protostome development** (examples: molluscs, annelids, arthropods)

- **Eight-cell stage**
  - Spiral and determinate
- **Blastopore**
  - Solid masses of mesoderm split and form coelom.
- **Mesoderm**
  - Folds of archenteron form coelom.
- **Anus**
  - From blastopore.

**Deuterostome development** (examples: echinoderms, vertebrates)

- **Eight-cell stage**
  - Radial and indeterminate
- **Blastopore**
  - Mesoderm from coelom.
- **Mesoderm**
  - Folds of archenteron form coelom.
- **Anus**
  - From blastopore.

**Gastrulation — Sea Urchin**

- **Mesenchyme cells**
- **Blastopore**
- **Mesoderm**
- **Future skeleton**

**Figure 32.10**

**Figure 47.8**
Protostome Larval Development

Protostomal development occurs in two distinct animal groups:

- **Lophotrochozoa**: 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)

![Figure 32.12](image)

More Variations in Deuterostome Gastrulation

Vertebrate Development

![Figure 47.2](image)

Radial Cleavage & Blastulation — Frog

- Large yolk content necessitates asymmetrical blastulation

![Figure 32.5](image)
Animal Tissues & Development

**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

**Meroblastic cleavage**

- Only non-yolk cytoplasm of the egg cleaved
  - Occurs in species whose large eggs have abundant yolk

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Sea urchin:
- Small egg; little yolk
- Symmetrical holoblastic cleavage

Frog:
- Larger egg; moderate yolk
- Asymmetrical holoblastic cleavage

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

Anterior

Right

Animal pole

Gray crescent

Dorsal

Ventral

Left

Posterior

Body axes

Establishing the axes

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

**SURFACE VIEW**

- Animal pole
- Vegetal pole
- Blastocoel
- Blastopore
- Dorsal lip of blastopore
- Archenteron
- Ectoderm
- Mesoderm
- Endoderm
- Neural tube stage (transverse section)

**CROSS SECTION**

- Early gastrula
- Late gastrula
- Blastopore
- Blastocoel remnant
- Blastopore Yolk plug

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Heyer 47-10: Frog gastrulation

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Heyer 47-18: Frog fate map

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Heyer 50 μm

Fish Development

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<tr>
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<td>4.0 m</td>
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<tr>
<td>Sashet</td>
<td>6.0 m</td>
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Extreme 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.

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Gastrulation — Chick

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

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Amniotes: extra-embryonic membranes

- Amnion
- Allantois
- Amniotic cavity with amniotic fluid
- Shell
- Chorion
- Yolk sac
- Yolk (nutrients)
- Albumen
- Embryo

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Amniote embryo & extraembryonic membranes

- Reproductive tract
- Extraembryonic Membranes
- Mammal
- Chorion