Animal Development & Differentiation

Tissues and Morphogenesis

Animal Cells

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

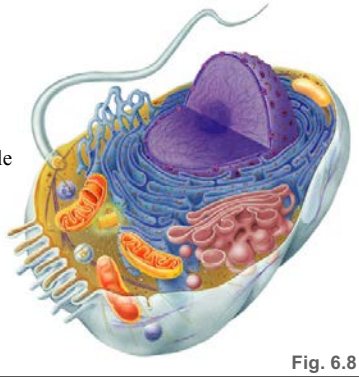


Fig. 6.8

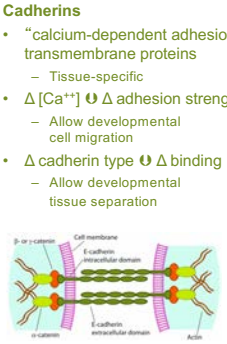
Animals

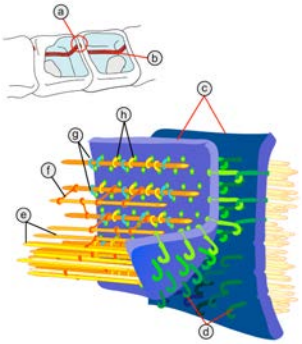
- Motile
- Highly differentiated tissues
- Intercellular junctions
  - tissue-specific **cadherins**
- Extracellular protein fibers
  - **collagen**
- Diploid life cycle
- **Blastula/gastrula** embryo

Cadherins & Cell junctions

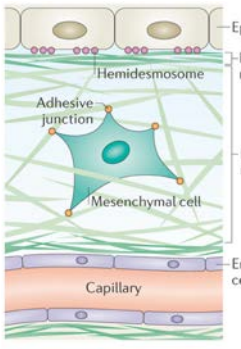
Cadherins

- "calcium-dependent adhesion" transmembrane proteins
  - Tissue-specific
- Δ [Ca^{++}] ↭ Δ adhesion strength
  - Allow developmental cell migration
- Δ cadherin type ↭ Δ binding
  - Allow developmental tissue separation

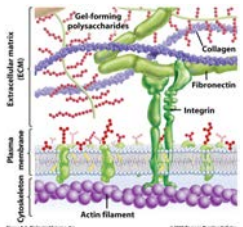




Extracellular Matrix (ECM)



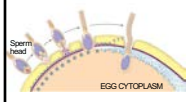
- **Collagen fibers**
- **Elastin fibers**
- **Fibronectin**
  - Attachment / movement along ECM



Nature Reviews | Molecular Cell Biology

post-fertilization events

- sea urchin (echinoderm), a model organism



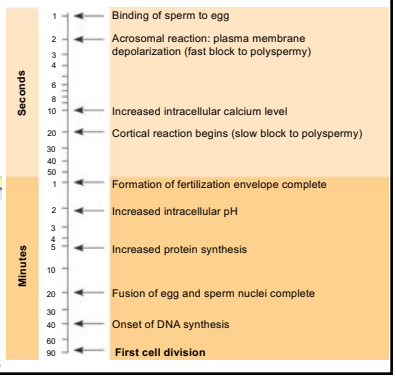
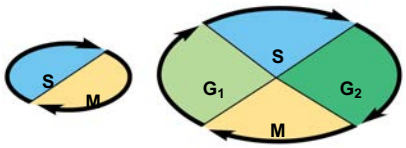


Figure 47.5

Cleavage: DNA replication / mitosis / cytokinesis with no growth phases
products of cytokinesis smaller & smaller **blastomeres**

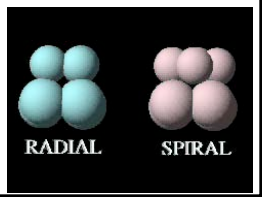


Cell cycle during cleavage stage | **Cell cycle after cleavage stage**

- 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)

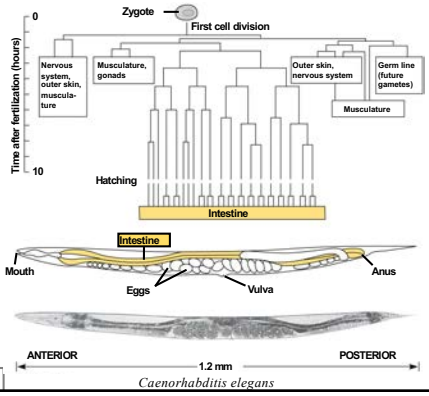


Figure 47.19 *Caenorhabditis elegans*

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

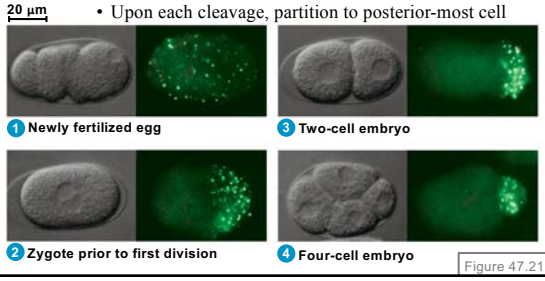


Figure 47.21

Indeterminate cleavage in a deuterostome (frog)

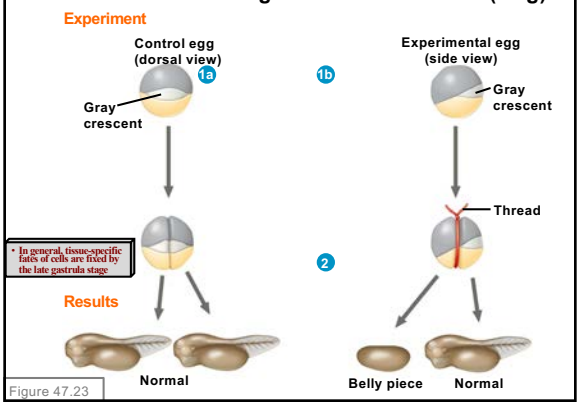
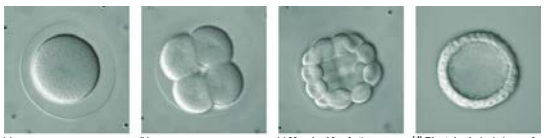


Figure 47.23

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**



(a) **Fertilized egg.** Shown here is the zygote shortly before the first cleavage division, surrounded by the fertilization envelope. The nucleus is visible in the center.

(b) **Four-cell stage.** Remnants of the mitotic spindle can be seen between the two cells that have just completed the second cleavage division.

(c) **Morula.** After further cleavage divisions, the embryo is a multicellular ball that is still surrounded by the fertilization envelope. The blastocoel cavity has begun to form.

(d) **Blastula.** A single layer of cells surrounds a large blastocoel cavity. Although not visible here, the fertilization envelope is still present; the embryo will soon hatch from it and begin swimming.

Figure 47.6

Morphogenesis

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

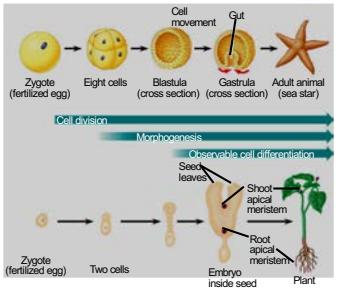
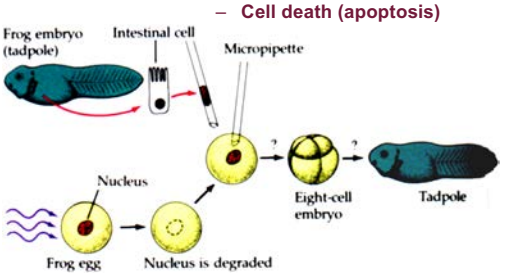


Figure 21.4

Animal Morphogenesis

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



Blastulation & Gastrulation

- Early embryonic development in animals

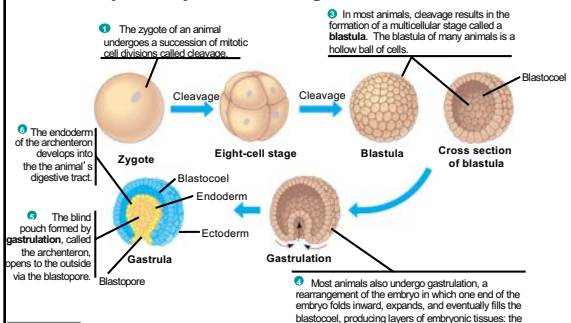
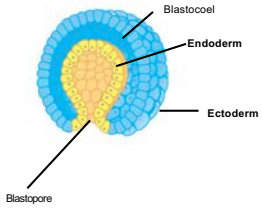


Figure 32.2

Primary embryonic germ layers

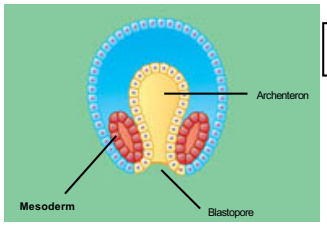
- **Diploblastic**: two germ layers
  - **Ectoderm**: develops into epidermal & neural tissues
  - **Endoderm**: develops into feeding tissues
  - Blastocoel: becomes filled with acellular **mesoglia**



Examples: Porifera & Cnidaria

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, connective tissues, & vasculature



Examples: everything else

Figure 32.10b

Triploblastic gastrulation forms three germ layers

ECTODERM	MESODERM	ENDODERM
• Epidermis of skin and its derivatives (including sweat glands, hair follicles) • Epithelial lining of mouth and rectum • Sense receptors in epidermis • Cornea and lens of eye • Nervous system • Adrenal medulla • Tooth enamel • Epithelium or pineal and pituitary glands	• Notochord • Endoskeletal system • Muscular system • Muscular layer of stomach, intestine, etc. • Excretory system • Circulatory and lymphatic systems • Reproductive system (except germ cells) • Dermis of skin • Lining of body cavity • Adrenal cortex	• Epithelial lining of digestive tract • Epithelial lining of respiratory system • Lining of urethra, urinary bladder, and reproductive system • Liver • Pancreas • Thymus • Thyroid and parathyroid glands

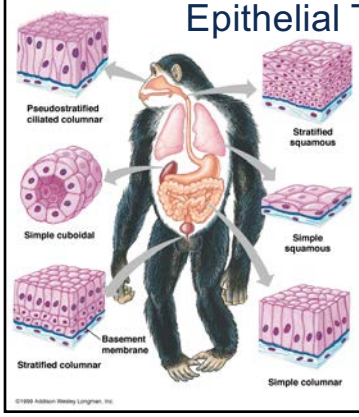
Figure 47.16

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

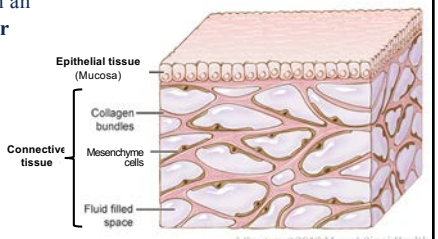
c.f., Figure 40.5



- 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

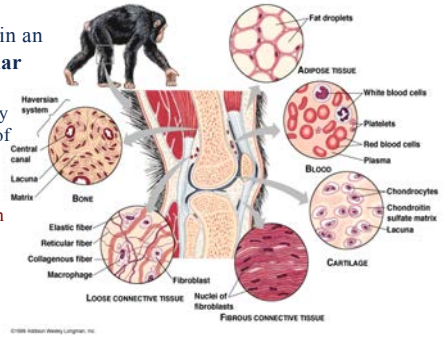
- Cells are suspended in an **extracellular matrix**.
  - often largely composed of collagen fibers.
- Derived from **mesoderm**.



Connective Tissue

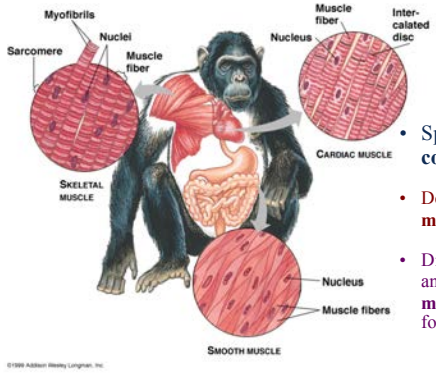
c.f., Figure 40.5

- Cells are suspended in an **extracellular matrix**.
  - often largely composed of collagen fibers.
- Derived from **mesoderm**.



Muscle Tissue

c.f., Figure 40.5

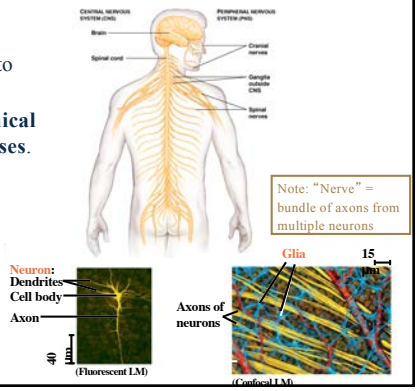


- Specialized for **contraction**.
- Derived from **mesoderm**.
- Diploblastic animals have **myo-epithelia** for contraction.

Nervous Tissue

c.f., Figure 40.5

- Specialized to conduct **electrochemical** nerve **impulses**.
- Derived from **ectoderm**.



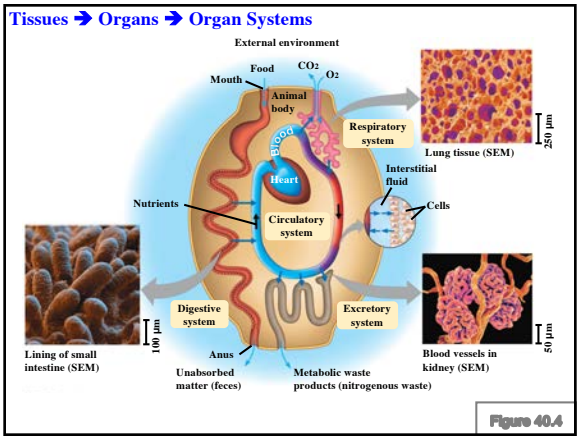


Table 40.1 Organ Systems in Mammals

Organ System	Main Functions
Digestive	Food processing (ingestion, digestion, absorption, elimination)
Circulatory	Internal distribution of materials
Respiratory	Gas exchange (uptake of oxygen; disposal of carbon dioxide)
Immune and lymphatic	Body defense (fighting infections and cancer)
Excretory	Disposal of metabolic wastes; regulation of osmotic balance of blood
Endocrine	Coordination of body activities (such as digestion and metabolism)
Reproductive	Reproduction
Nervous	Coordination of body activities; detection of stimuli and formulation of responses to them
Integumentary	Protection against mechanical injury, infection, dehydration; thermoregulation
Skeletal	Body support, protection of internal organs, movement
Muscular	Locomotion and other movement

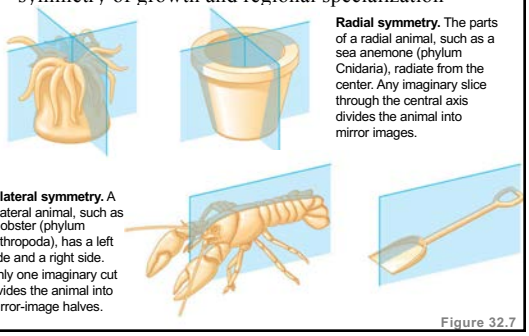
Bauplan:

Ger. "Life Plan" (*pl*: baupläne)

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

Body Symmetry

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



Radial symmetry. The parts of a radial animal, such as a sea anemone (phylum Cnidaria), radiate from the center. Any imaginary slice through the central axis divides the animal into mirror images.

Bilateral symmetry. A bilateral animal, such as a lobster (phylum Arthropoda), has a left side and a right side. Only one imaginary cut divides the animal into mirror-image halves.

Figure 32.7

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

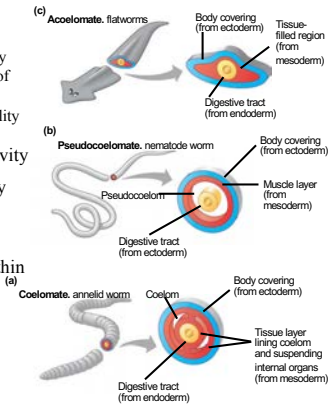
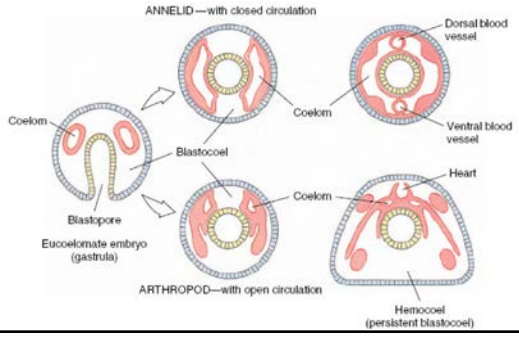
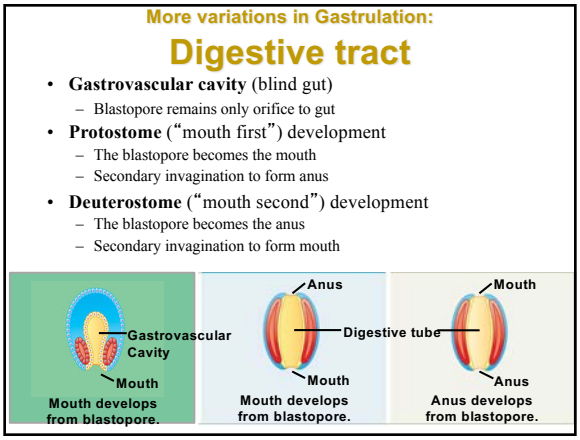


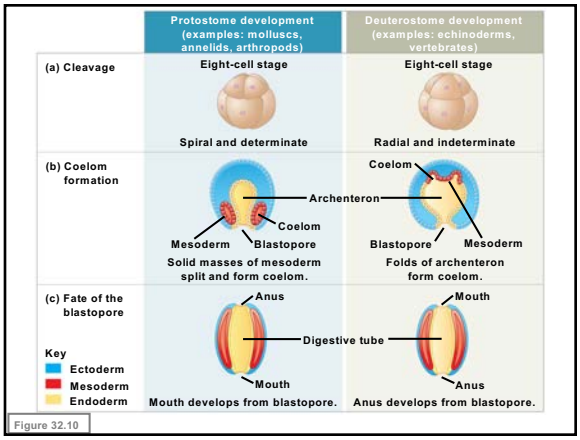
Figure 32.9

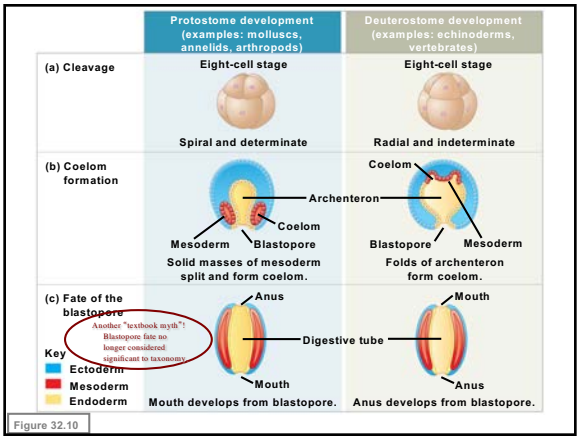
Variations in Eucoelomate Gastrulation

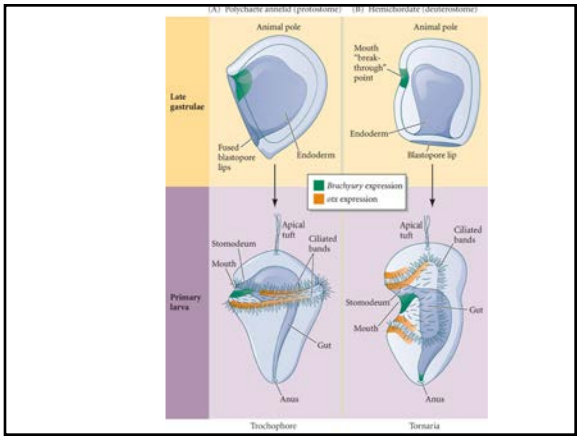
- Coelom development in open vs. closed circulation

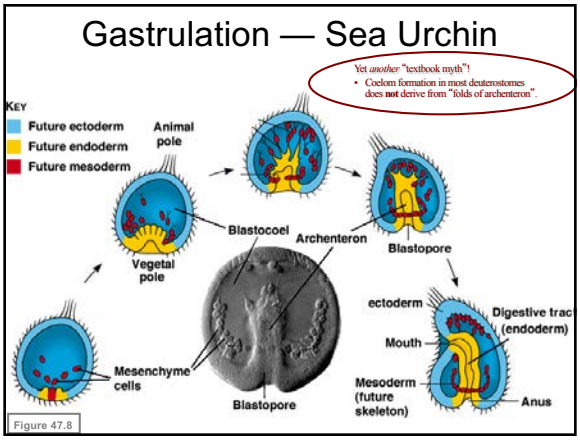


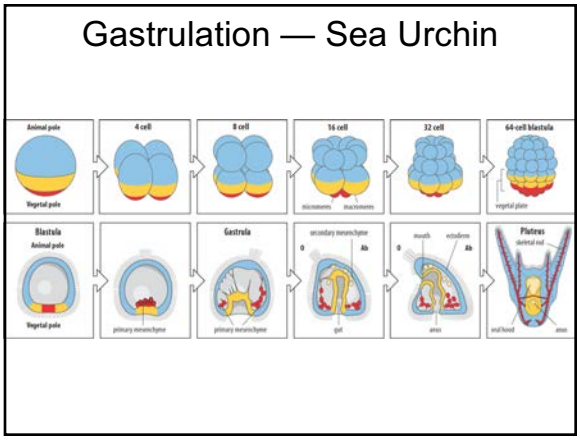

More variations in Gastrulation:
Digestive tract
• Gastrovascular cavity (blind gut)
– Blastopore remains only orifice to gut
• Protostome ("mouth first") development
– The blastopore becomes the mouth
– Secondary invagination to form anus
• Deuterostome ("mouth second") development
– The blastopore becomes the anus
– Secondary invagination to form mouth
Gastrovascular Cavity
Mouth
Mouth develops from blastopore.
Anus
Digestive tube
Mouth
Mouth develops from blastopore.
Mouth
Anus
Anus develops from blastopore.


Protostome development (examples: molluscs, annelids, arthropods)
Deuterostome development (examples: echinoderms, vertebrates)
(a) Cleavage
Eight-cell stage
Spiral and determinate
Eight-cell stage
Radial and indeterminate
(b) Coelom formation
Archenteron
Coelom
Mesoderm
Blastopore
Solid masses of mesoderm split and form coelom.
Coelom
Blastopore
Mesoderm
Folds of archenteron form coelom.
(c) Fate of the blastopore
Anus
Digestive tube
Mouth
Mouth develops from blastopore.
Mouth
Anus
Anus develops from blastopore.
Key
Ectoderm
Mesoderm
Endoderm
Figure 32.10


Protostome development (examples: molluscs, annelids, arthropods)
Deuterostome development (examples: echinoderms, vertebrates)
(a) Cleavage
Eight-cell stage
Spiral and determinate
Eight-cell stage
Radial and indeterminate
(b) Coelom formation
Archenteron
Coelom
Mesoderm
Blastopore
Solid masses of mesoderm split and form coelom.
Coelom
Blastopore
Mesoderm
Folds of archenteron form coelom.
(c) Fate of the blastopore
Another "textbook myth"! Blastopore fate no longer considered significant to taxonomy
Anus
Digestive tube
Mouth
Mouth develops from blastopore.
Mouth
Anus
Anus develops from blastopore.
Key
Ectoderm
Mesoderm
Endoderm
Figure 32.10


Late gastrulae
Animal pole
Mouth "break-through" point
Fused blastopore lips
Endoderm
Blastopore lip
Brachyury expression
otx expression
Primary larva
Apical tuft
Ciliated bands
Stomodeum
Mouth
Gut
Anus
Trochophore
Tornaria


Gastrulation — Sea Urchin
Yet another "textbook myth"!
• Coelom formation in most deuterostomes does not derive from "folds of archenteron".
KEY
Future ectoderm
Future endoderm
Future mesoderm
Animal pole
Vegetal pole
Blastocoel
Archenteron
Blastopore
ectoderm
Digestive tract (endoderm)
Mouth
Mesoderm (future skeleton)
Anus
Mesenchyme cells
Blastopore
Figure 47.8


Gastrulation — Sea Urchin

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)

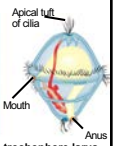
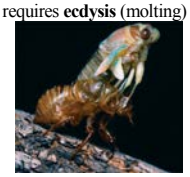
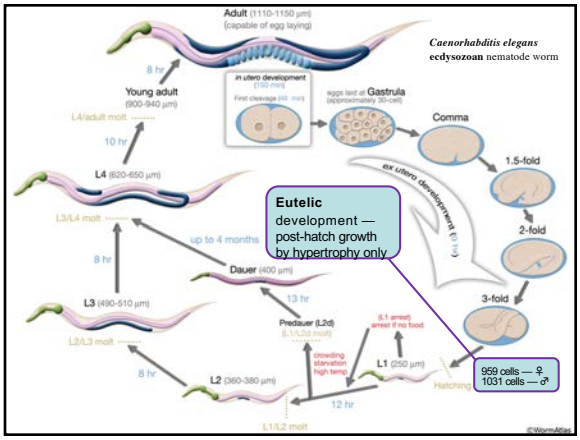


Figure 32.12



ecdysis



More Variations in Deuterostome Gastrulation

Vertebrate Development

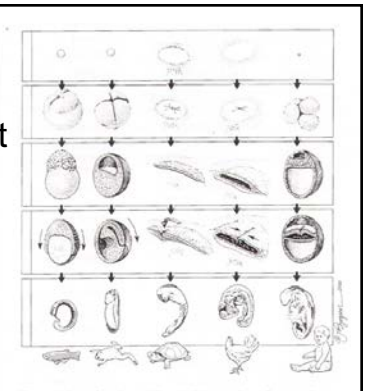
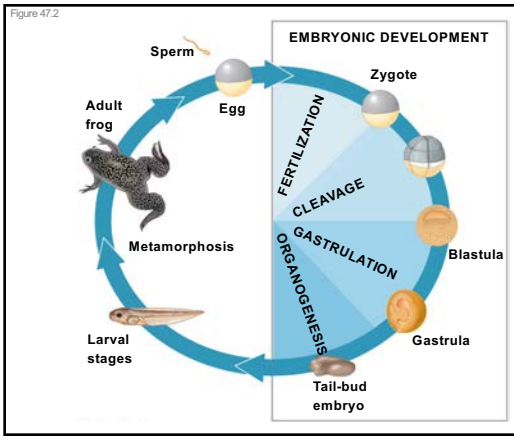


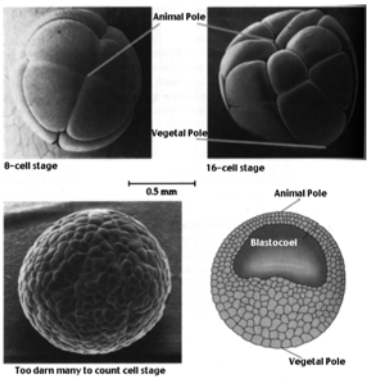
Figure 1-3: A drawing of the early stages of vertebrate embryos.

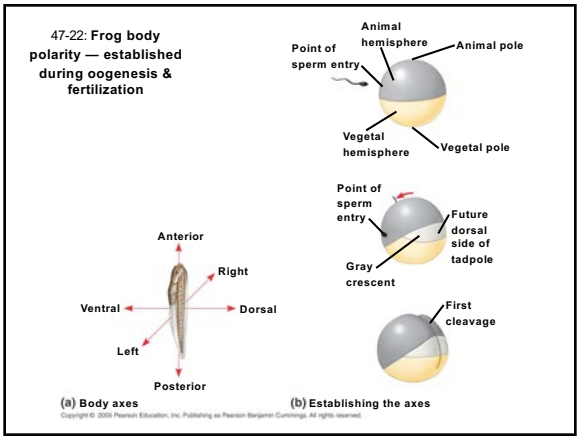
From M.K. Richardson (1997) *Anatomy & Embryology*

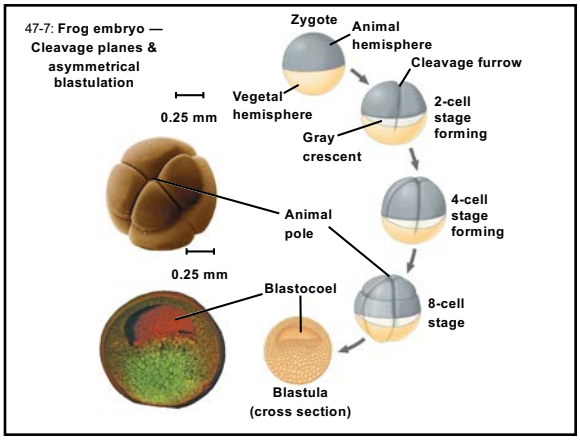


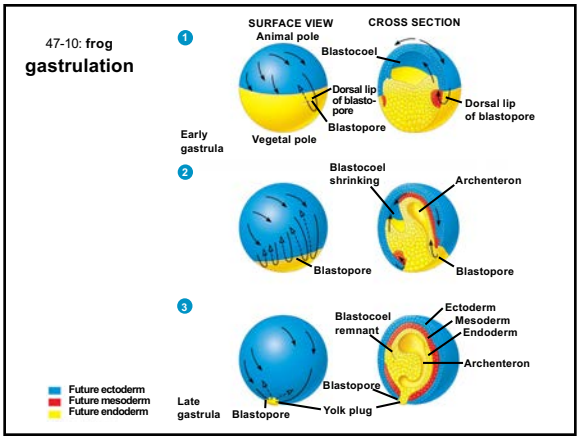
Radial Cleavage & Blastulation — Frog

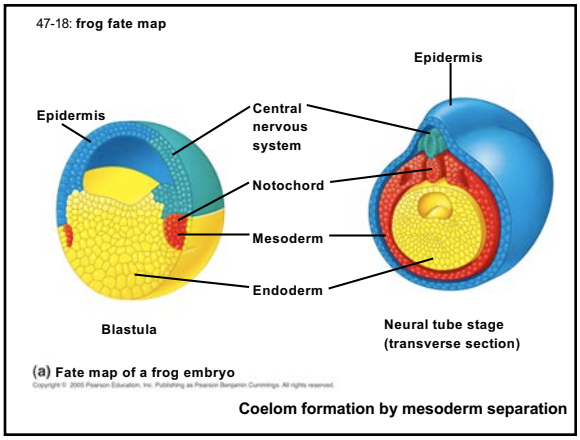
- Large yolk content necessitates **asymmetrical blastulation**







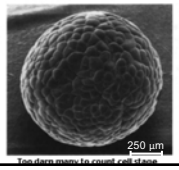


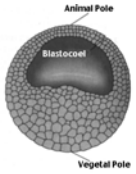


Holoblastic cleavage

- 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



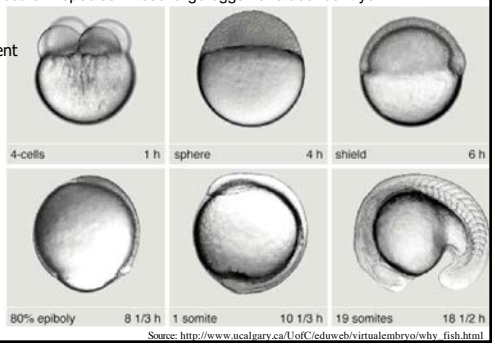


Frog:
- larger egg; moderate yolk
- Asymmetrical holoblastic cleavage

Meroblastic cleavage

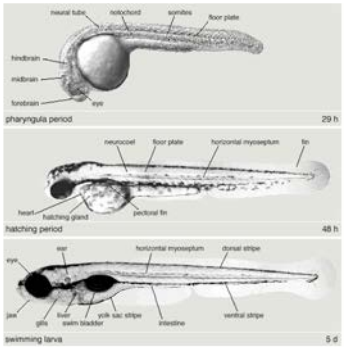
- Only non-yolk cytoplasm of the egg cleaved
  - Occurs in species whose large eggs have abundant yolk

Fish Development



Source: http://www.ucalgary.ca/UofC/eduweb/virtualembryo/why_fish.html

Fish Development



Source: http://www.ucalgary.ca/UofC/eduweb/virtualembryo/why_fish.html

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.

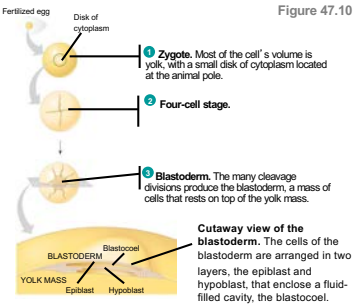


Figure 47.10

Cutaway view of the blastoderm. The cells of the blastoderm are arranged in two layers, the epiblast and hypoblast, that enclose a fluid-filled cavity, the blastocoel.

Gastrulation — Chick

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

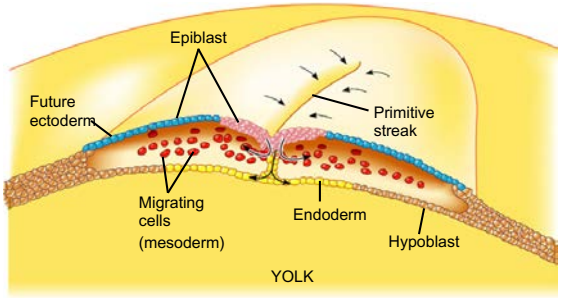
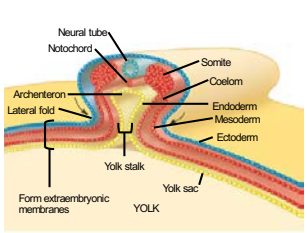


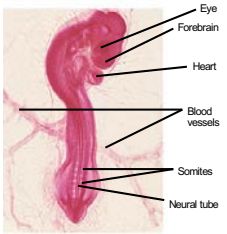
Figure 47.11

Gastrulation — Chick

- Organogenesis from germ layers.



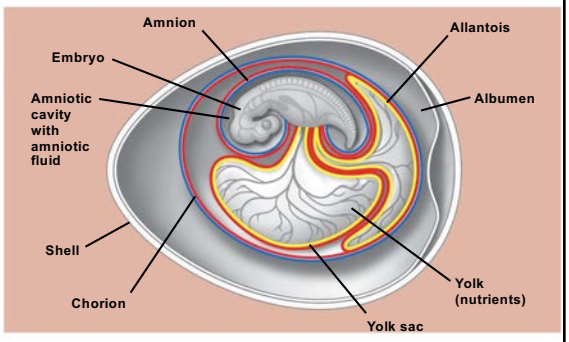
(a) Early organogenesis. The archenteron forms when lateral folds pinch the embryo away from the yolk.



(b) Late organogenesis. 56 hours old chick embryo, about 2–3 mm long (LM).

Figure 47.15

Amniotes: extra-embryonic membranes



47-13: **chick extra-embryonic membranes**

Amniote embryo & extraembryonic membranes