Chapter 47

Animal Development

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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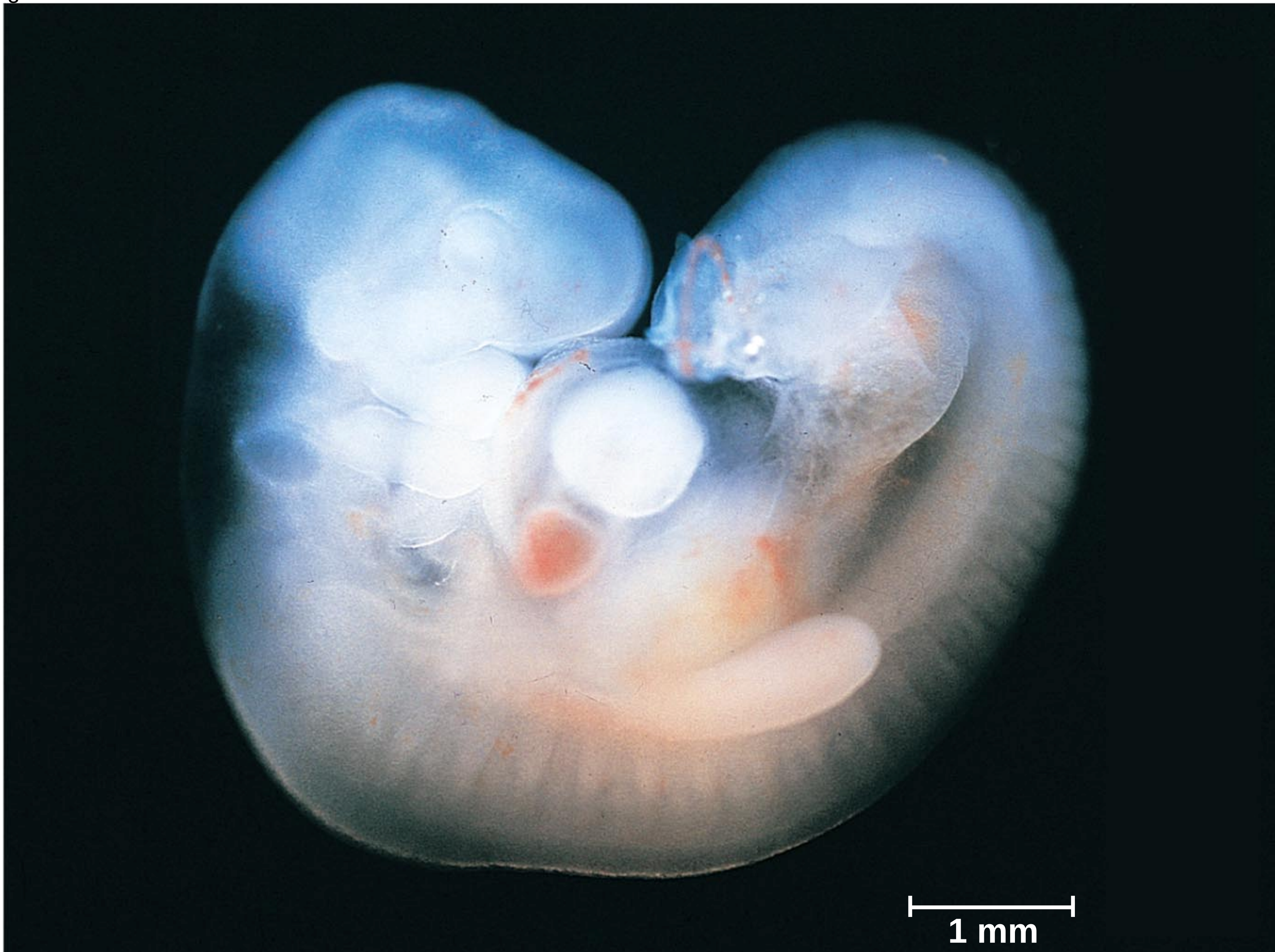
Overview: A Body-Building Plan

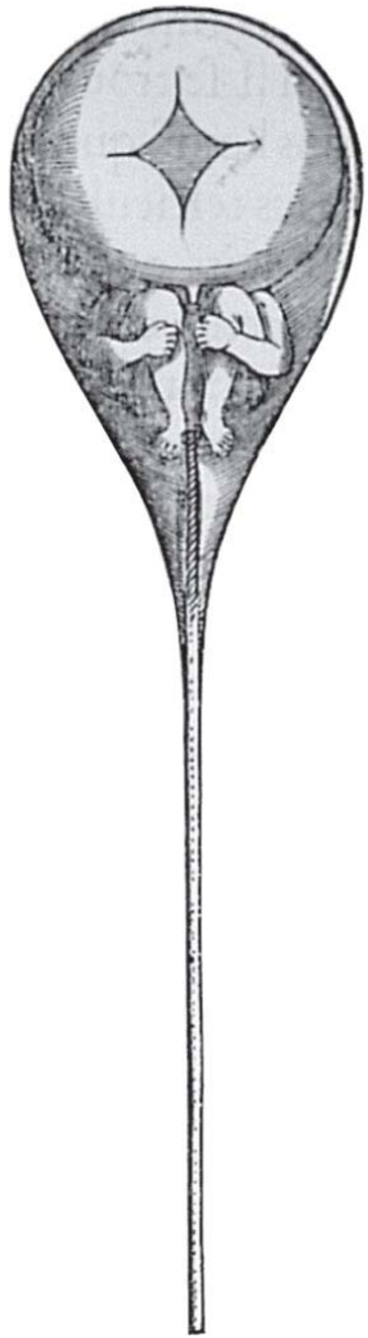
- It is difficult to imagine that each of us began life as a single cell called a zygote
- A human embryo at about 6–8 weeks after conception shows development of distinctive features

Fig. 47-1



- The question of how a zygote becomes an animal has been asked for centuries
- As recently as the 18th century, the prevailing theory was called preformation
- *Preformation* is the idea that the egg or sperm contains a miniature infant, or “homunculus,” which becomes larger during development

Fig. 47-2



- Development is determined by the zygote's genome and molecules in the egg called **cytoplasmic determinants**
- **Cell differentiation** is the specialization of cells in structure and function
- **Morphogenesis** is the process by which an animal takes shape

- **Model organisms** are species that are representative of a larger group and easily studied, for example, *Drosophila* and *Caenorhabditis elegans*

- Classic embryological studies have focused on the sea urchin, frog, chick, and the nematode *C. elegans*

Concept 47.1: After fertilization, embryonic development proceeds through cleavage, gastrulation, and organogenesis

- Important events regulating development occur during fertilization and the three stages that build the animal's body
  - *Cleavage*: cell division creates a hollow ball of cells called a blastula
  - *Gastrulation*: cells are rearranged into a three-layered gastrula
  - *Organogenesis*: the three layers interact and move to give rise to organs

Fertilization

- Fertilization brings the haploid nuclei of sperm and egg together, forming a diploid zygote
- The sperm's contact with the egg's surface initiates metabolic reactions in the egg that trigger the onset of embryonic development

The Acrosomal Reaction

- The **acrosomal reaction** is triggered when the sperm meets the egg
- The **acrosome** at the tip of the sperm releases hydrolytic enzymes that digest material surrounding the egg

Fig. 47-3-1

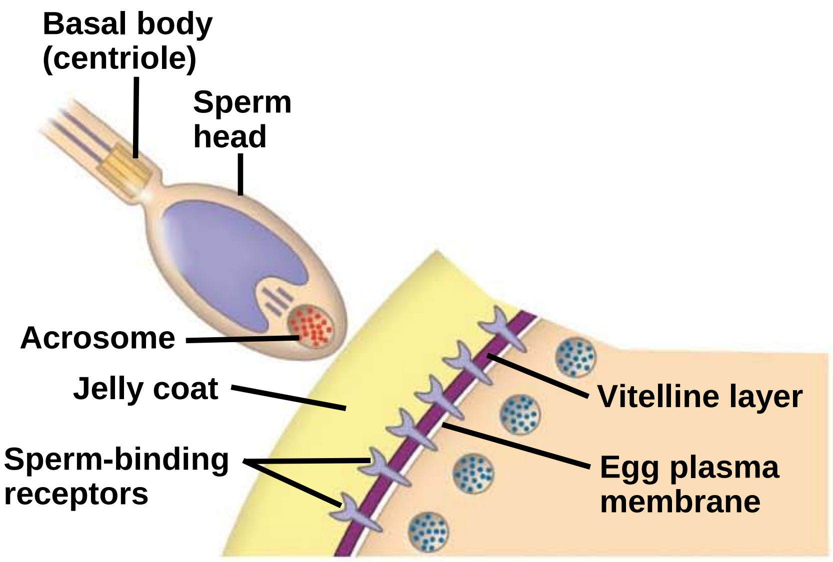
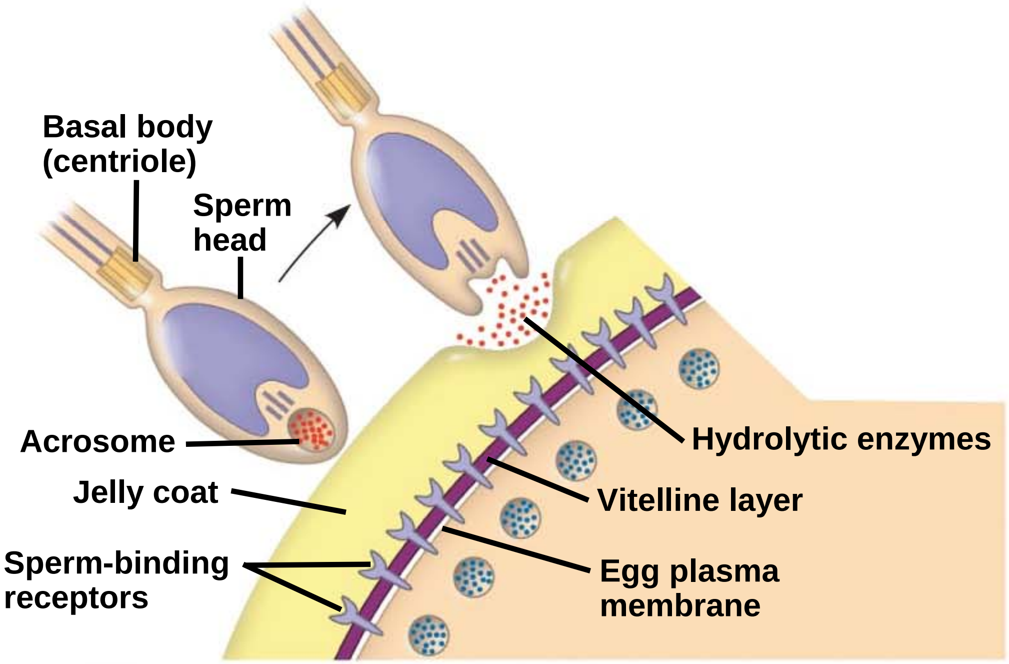
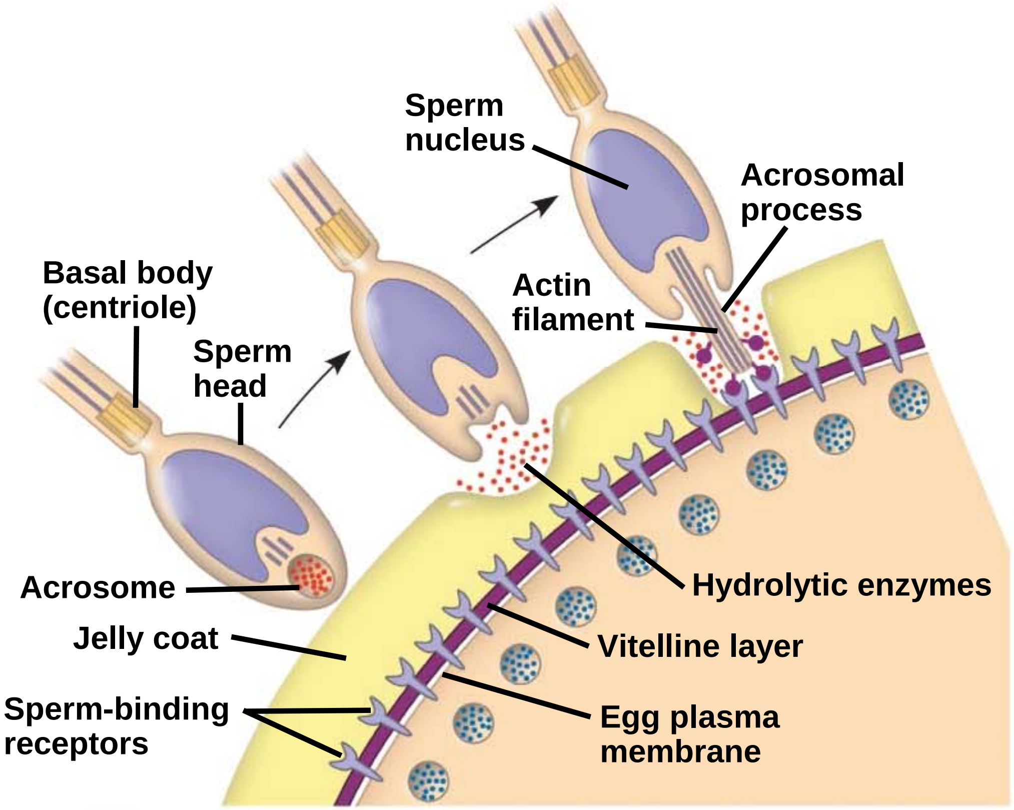

Basal body
(centriole)
Sperm
head
Acrosome
Jelly coat
Sperm-binding
receptors
Vitelline layer
Egg plasma
membrane

Fig. 47-3-2



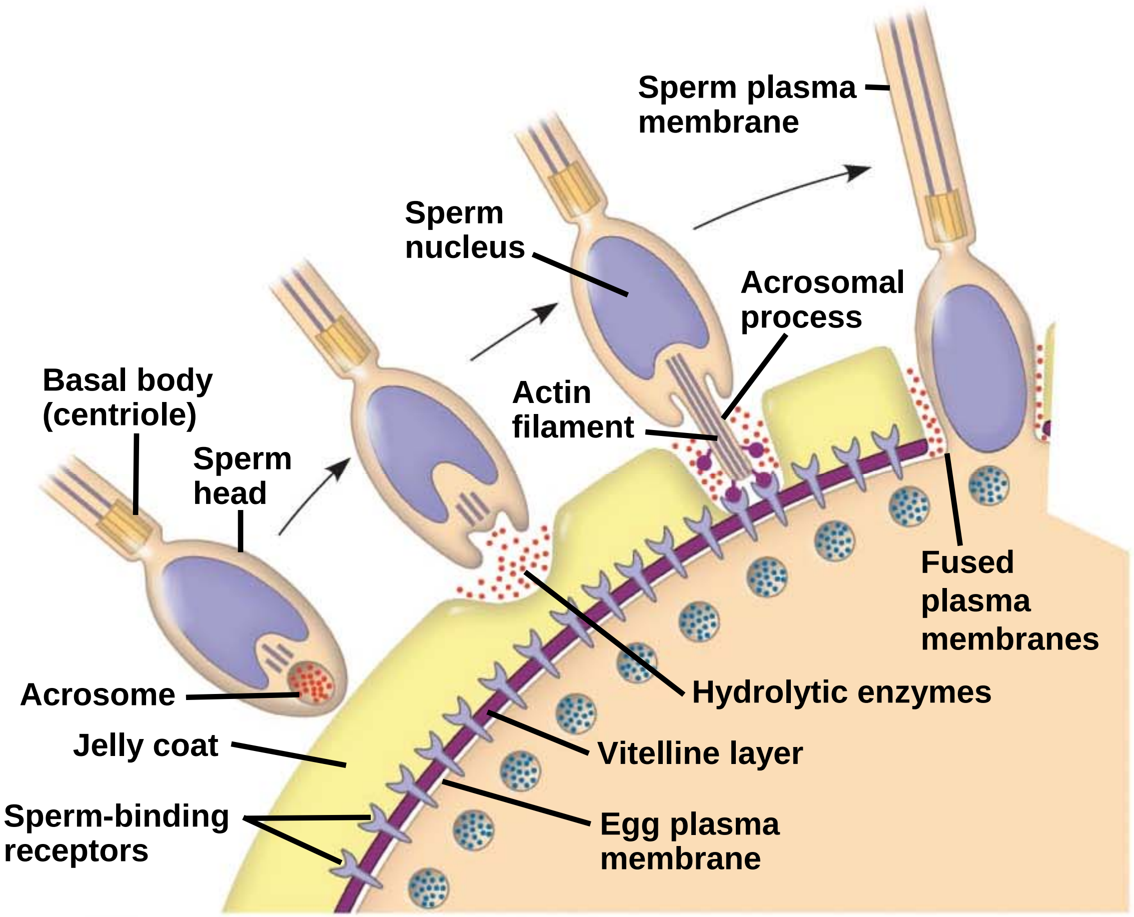
Basal body
(centriole)
Sperm
head
Acrosome
Jelly coat
Sperm-binding
receptors
Hydrolytic enzymes
Vitelline layer
Egg plasma
membrane

Fig. 47-3-3



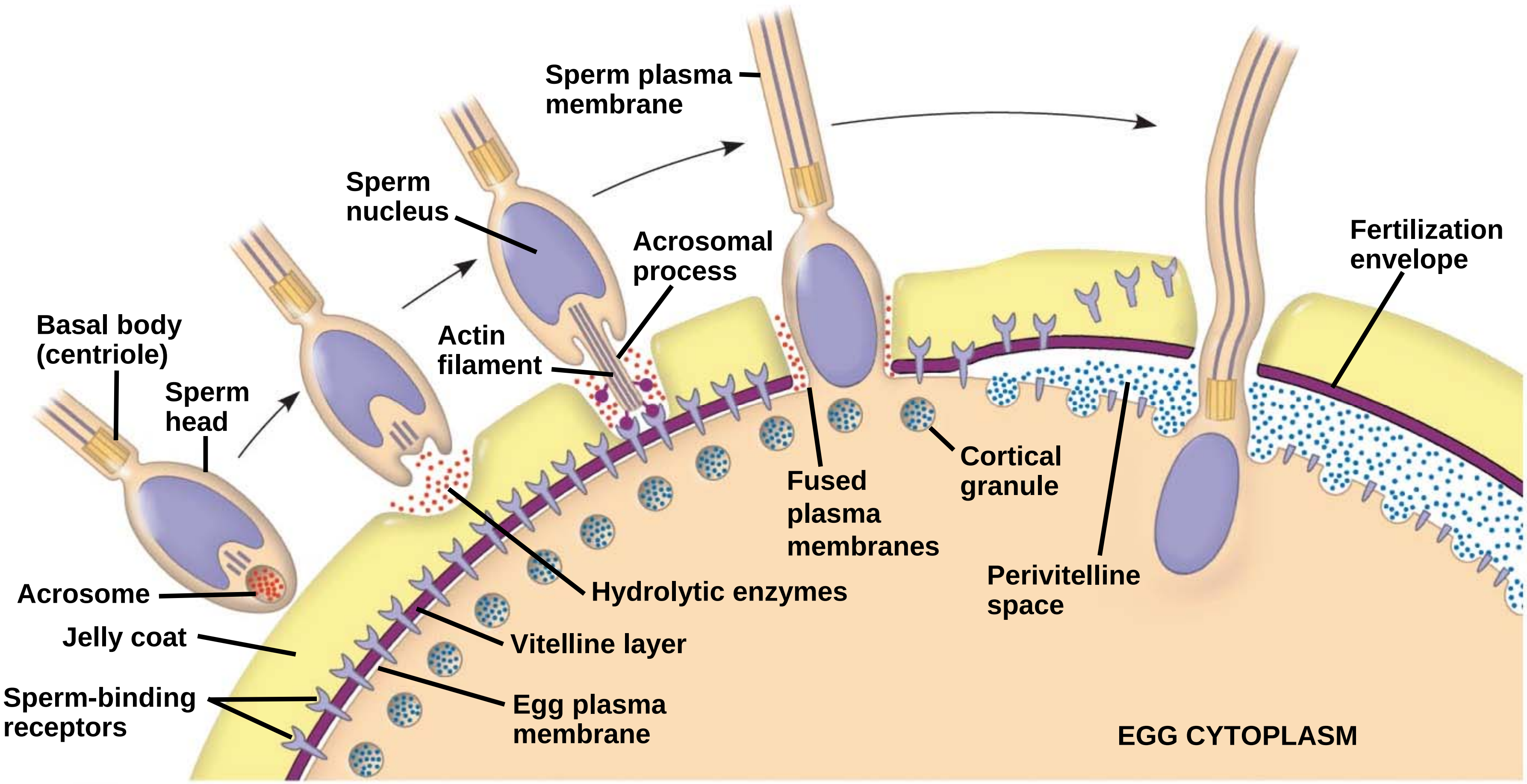
Sperm nucleus
Acrosomal process
Basal body (centriole)
Actin filament
Sperm head
Acrosome
Hydrolytic enzymes
Jelly coat
Vitelline layer
Sperm-binding receptors
Egg plasma membrane

Fig. 47-3-4



Sperm plasma membrane
Sperm nucleus
Acrosomal process
Actin filament
Basal body (centriole)
Sperm head
Fused plasma membranes
Acrosome
Hydrolytic enzymes
Jelly coat
Vitelline layer
Sperm-binding receptors
Egg plasma membrane

Fig. 47-3-5



Sperm plasma membrane
Sperm nucleus
Acrosomal process
Fertilization envelope
Basal body (centriole)
Actin filament
Sperm head
Cortical granule
Fused plasma membranes
Perivitelline space
Acrosome
Hydrolytic enzymes
Jelly coat
Vitelline layer
Sperm-binding receptors
Egg plasma membrane
EGG CYTOPLASM

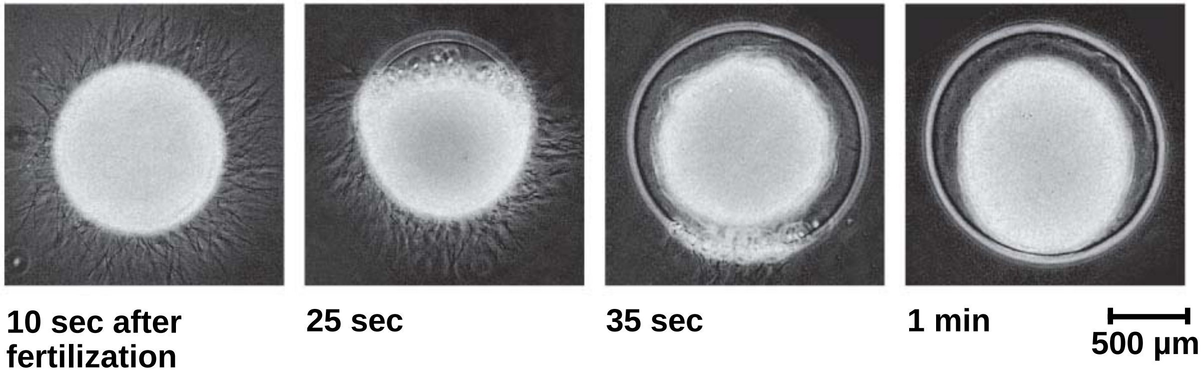
- Gamete contact and/or fusion depolarizes the egg cell membrane and sets up a **fast block to polyspermy**

The Cortical Reaction

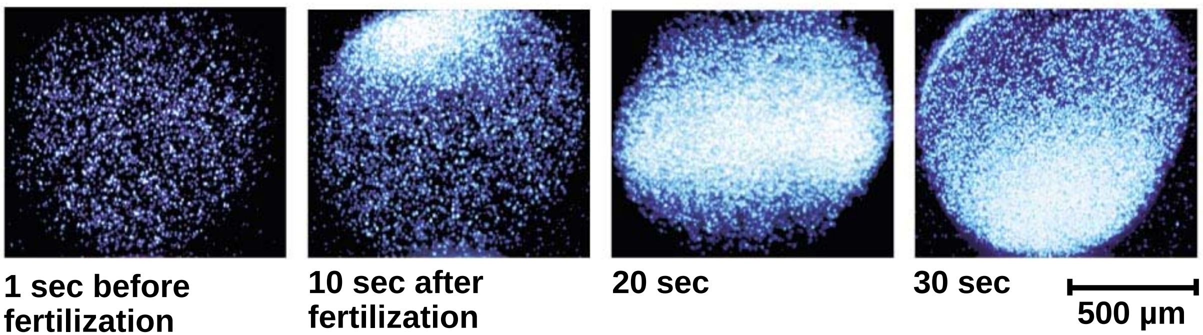
- Fusion of egg and sperm also initiates the **cortical reaction**
- This reaction induces a rise in Ca^{2+} that stimulates **cortical granules** to release their contents outside the egg
- These changes cause formation of a **fertilization envelope** that functions as a **slow block to polyspermy**

Fig. 47-4

EXPERIMENT



RESULTS



CONCLUSION

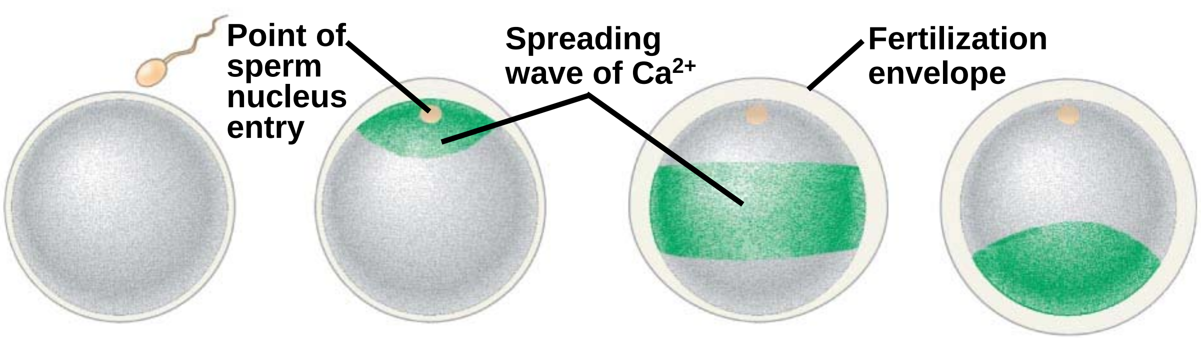
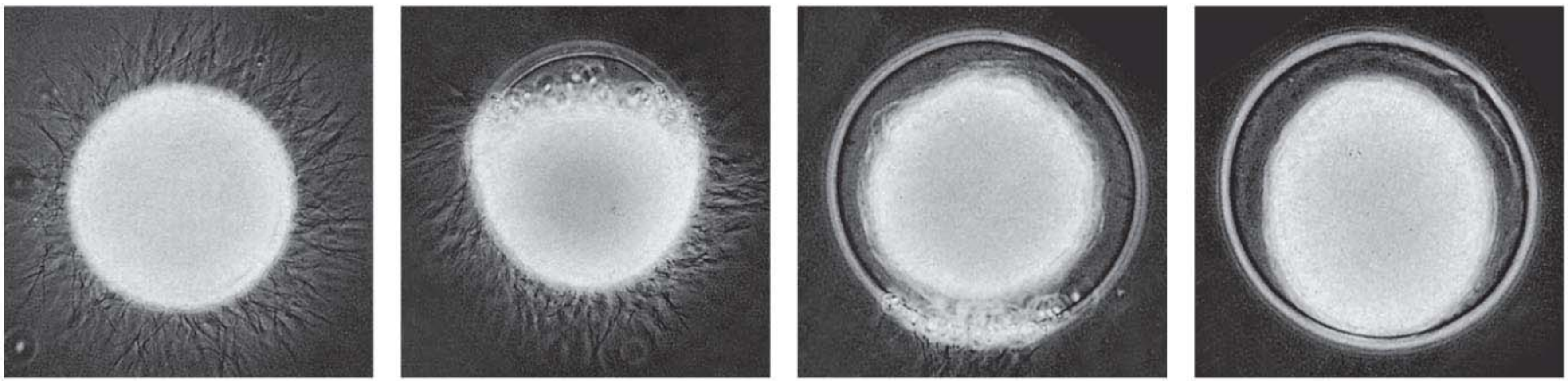


Fig. 47-4a

EXPERIMENT



10 sec after fertilization | 25 sec | 35 sec | 1 min

Fig. 47-4b

RESULTS

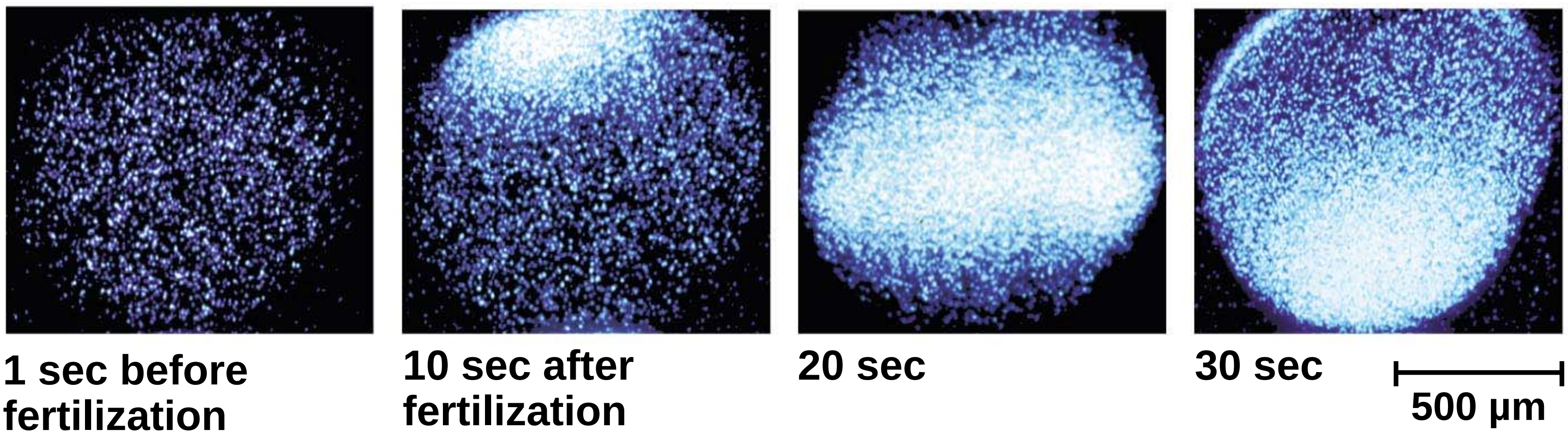
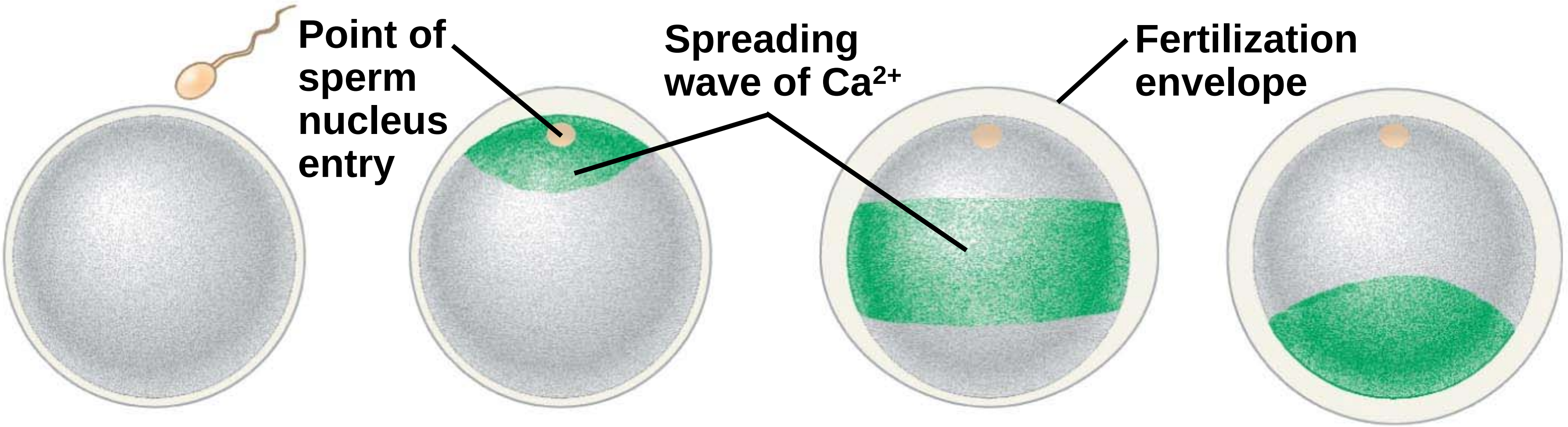


Fig. 47-4c

CONCLUSION



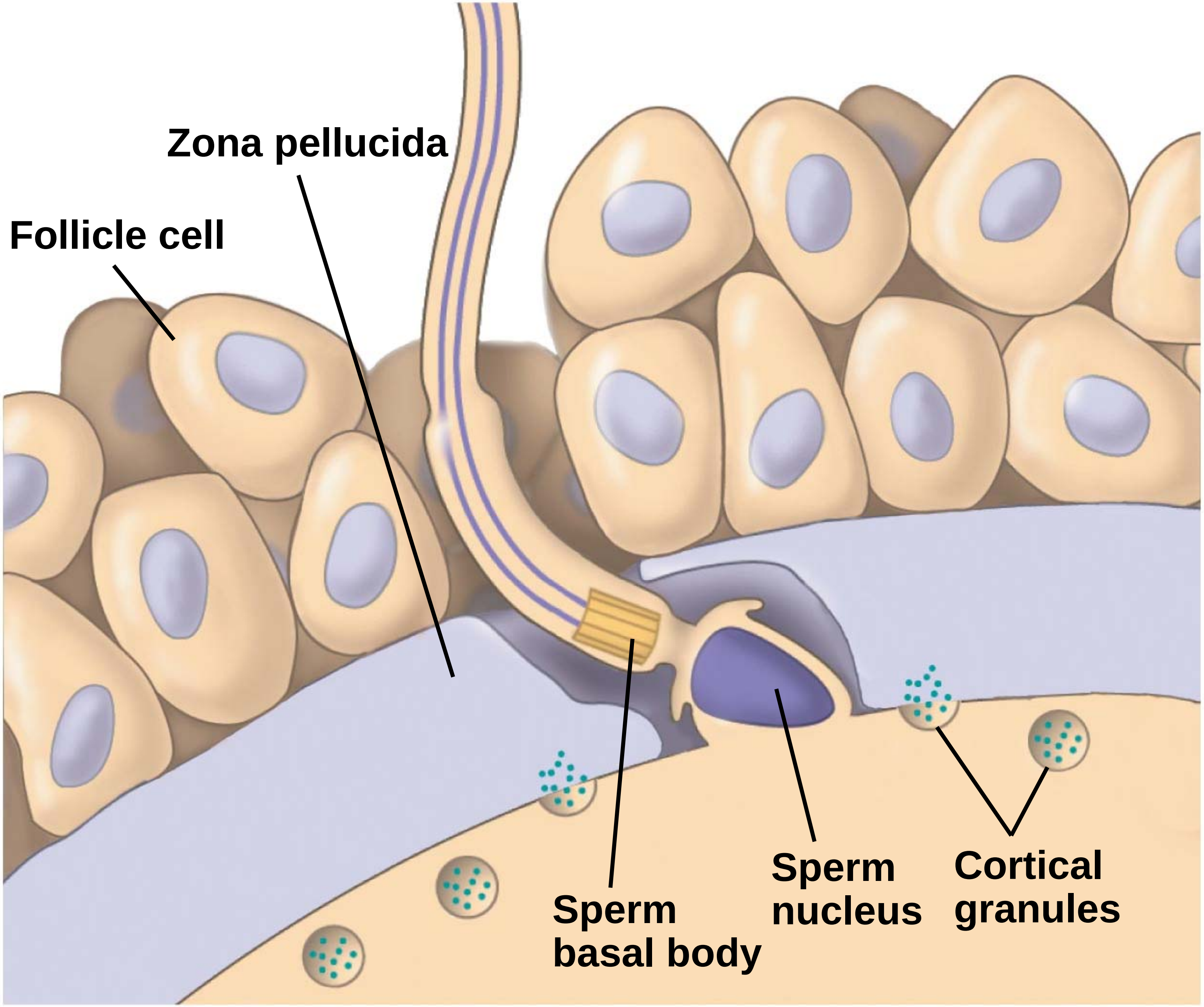
Activation of the Egg

- The sharp rise in Ca^{2+} in the egg's cytosol increases the rates of cellular respiration and protein synthesis by the egg cell
- With these rapid changes in metabolism, the egg is said to be activated
- The sperm nucleus merges with the egg nucleus and cell division begins

Fertilization in Mammals

- Fertilization in mammals and other terrestrial animals is internal
- In mammalian fertilization, the cortical reaction modifies the **zona pellucida**, the extracellular matrix of the egg, as a slow block to polyspermy

Fig. 47-5


Zona pellucida
Follicle cell
Sperm basal body
Sperm nucleus
Cortical granules

- In mammals the first cell division occurs 12–36 hours after sperm binding
- The diploid nucleus forms after this first division of the zygote

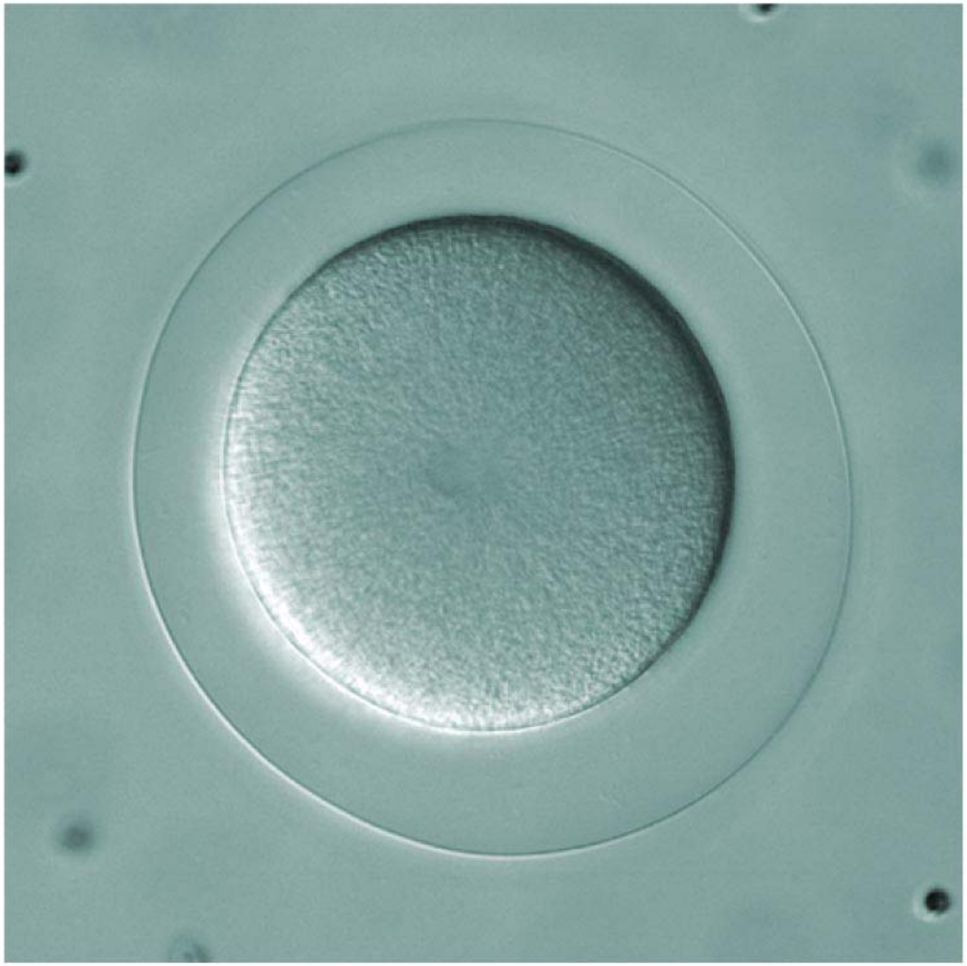
Cleavage

- Fertilization is followed by **cleavage**, a period of rapid cell division without growth
- Cleavage partitions the cytoplasm of one large cell into many smaller cells called **blastomeres**
- The **blastula** is a ball of cells with a fluid-filled cavity called a **blastocoel**

Fig. 47-6

(a) Fertilized egg **(b) Four-cell stage** **(c) Early blastula** **(d) Later blastula**

Fig. 47-6a



(a) Fertilized egg

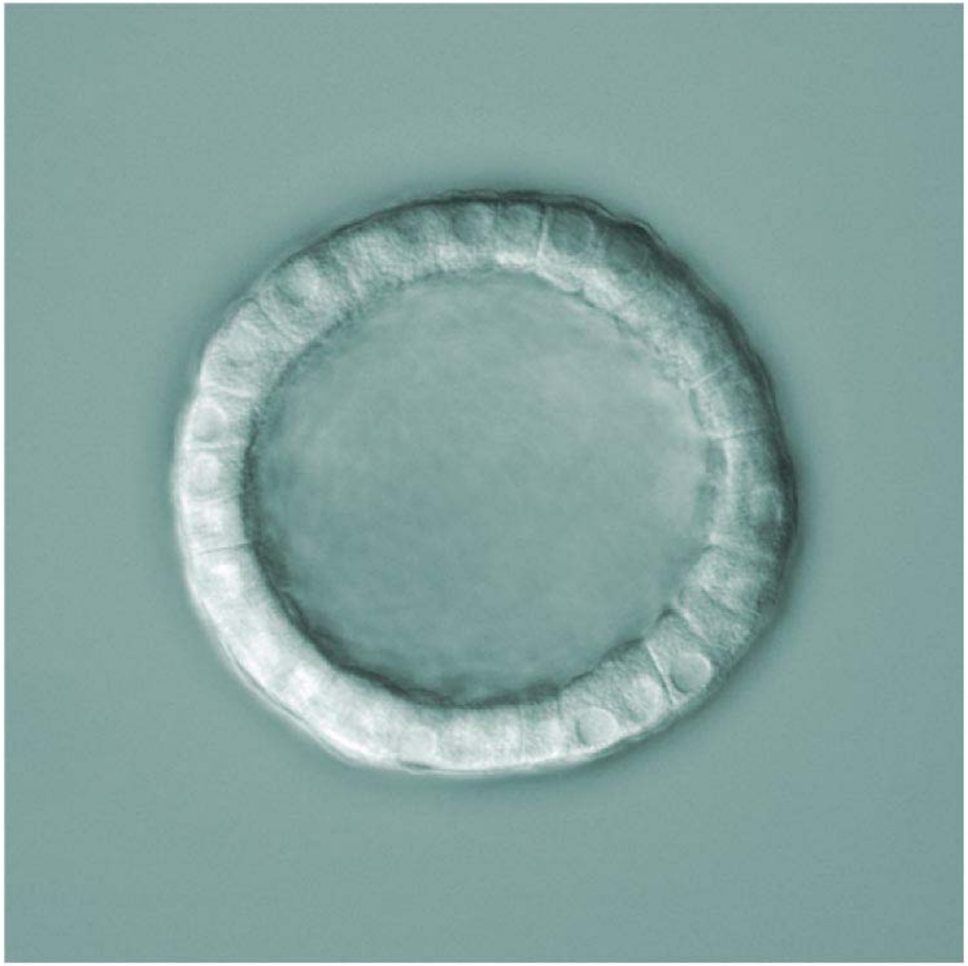
Fig. 47-6b

(b) Four-cell stage

Fig. 47-6c

(c) Early blastula

Fig. 47-6d

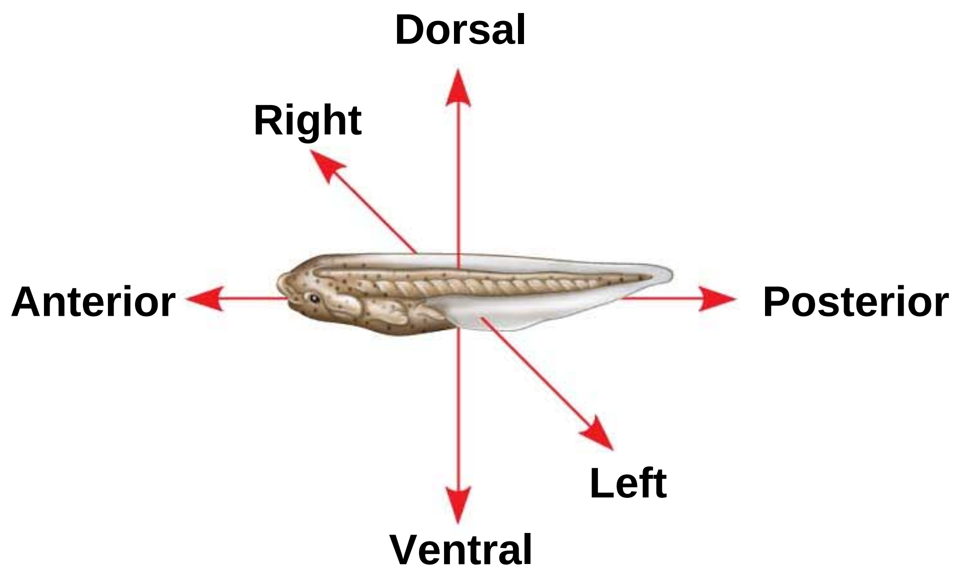


(d) Later blastula

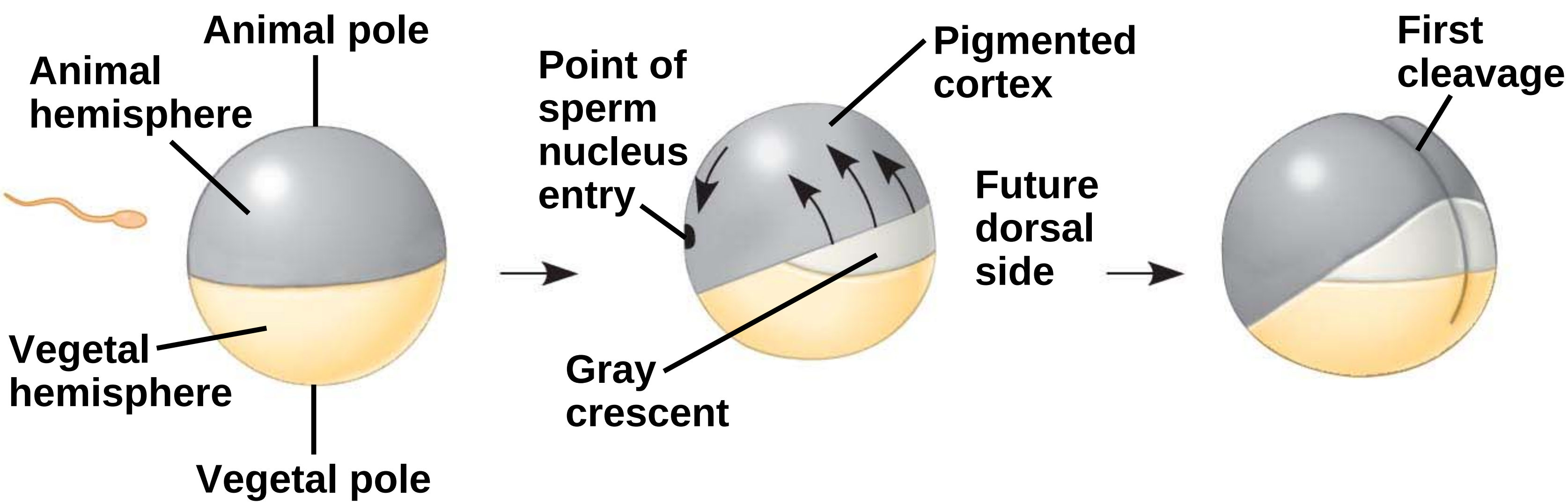
- The eggs and zygotes of many animals, except mammals, have a definite polarity
- The polarity is defined by distribution of **yolk** (stored nutrients)
- The **vegetal pole** has more yolk; the **animal pole** has less yolk

- The three body axes are established by the egg’s polarity and by a cortical rotation following binding of the sperm
- Cortical rotation exposes a **gray crescent** opposite to the point of sperm entry

Fig. 47-7

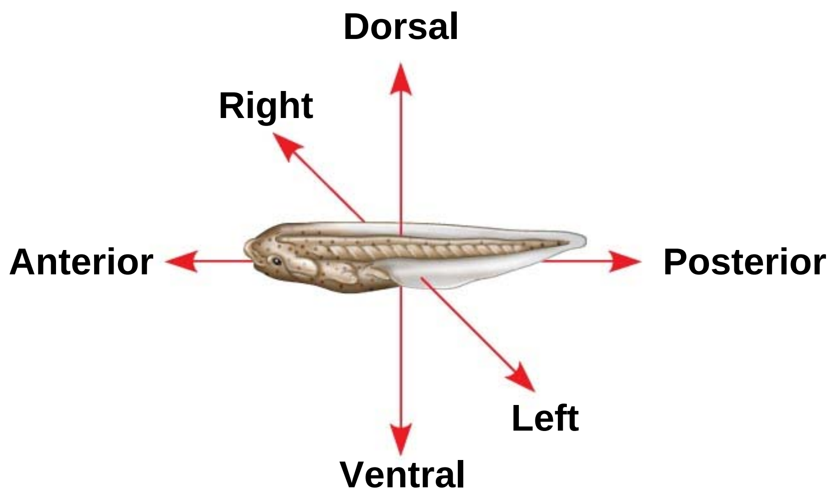


(a) The three axes of the fully developed embryo



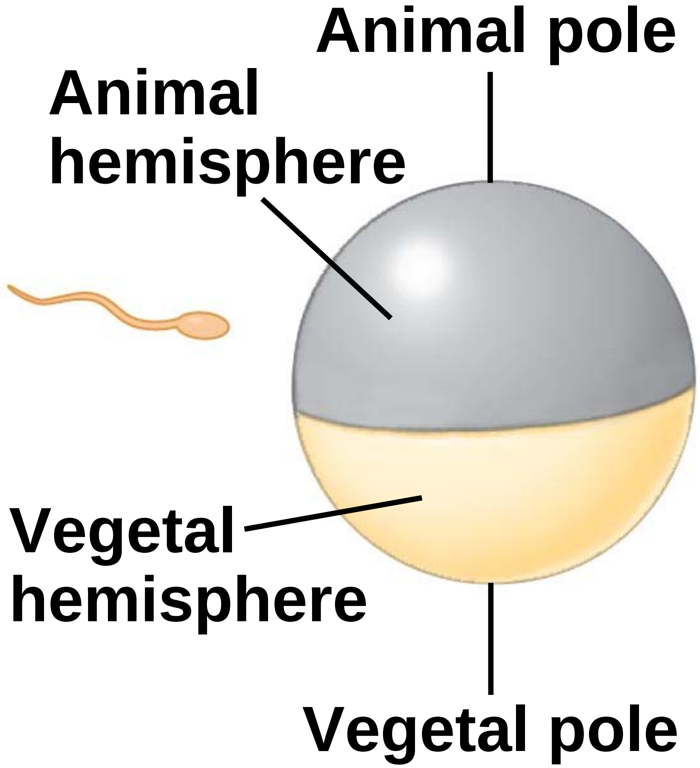
(b) Establishing the axes

Fig. 47-7a



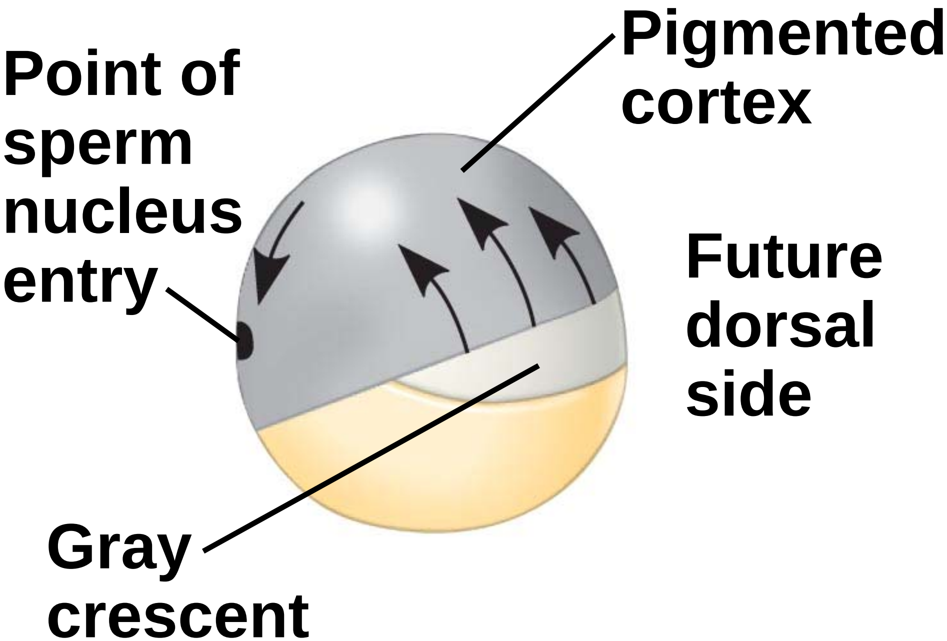
(a) The three axes of the fully developed embryo

Fig. 47-7b-1



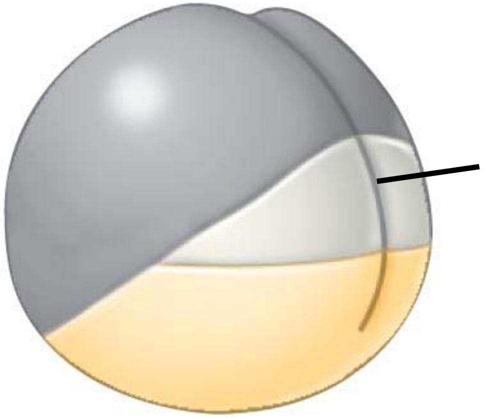
(b) Establishing the axes

Fig. 47-7b-2



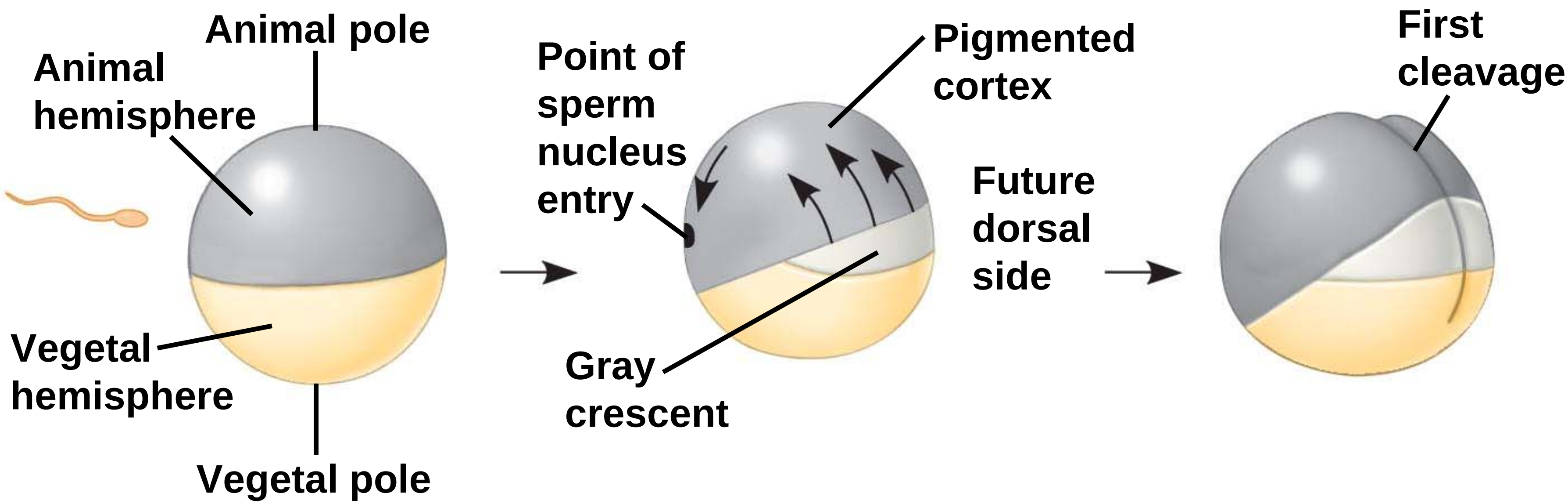
(b) Establishing the axes

Fig. 47-7b-3



(b) Establishing the axes

Fig. 47-7b-4



(b) Establishing the axes

- Cleavage planes usually follow a pattern that is relative to the zygote's animal and vegetal poles

Fig. 47-8-1

Fig. 47-8-2

2-cell
stage
forming

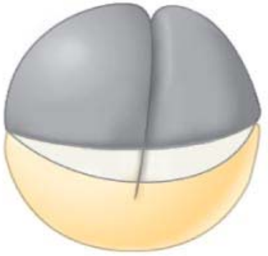


Fig. 47-8-3

4-cell
stage
forming

Fig. 47-8-4

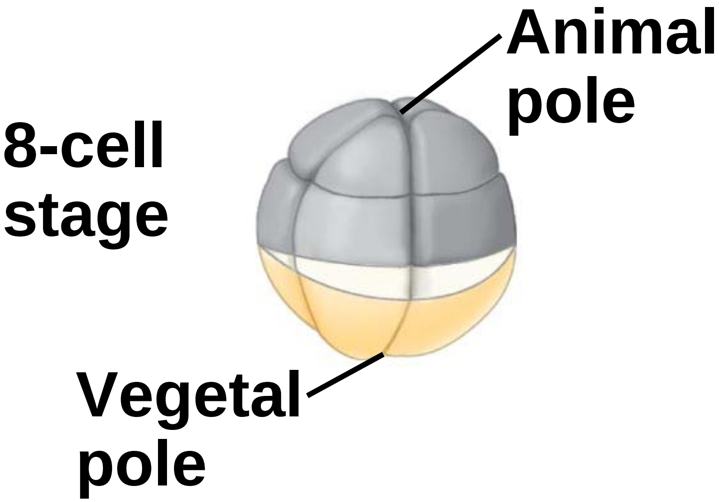


Fig. 47-8-5

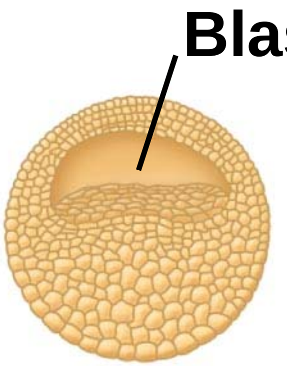
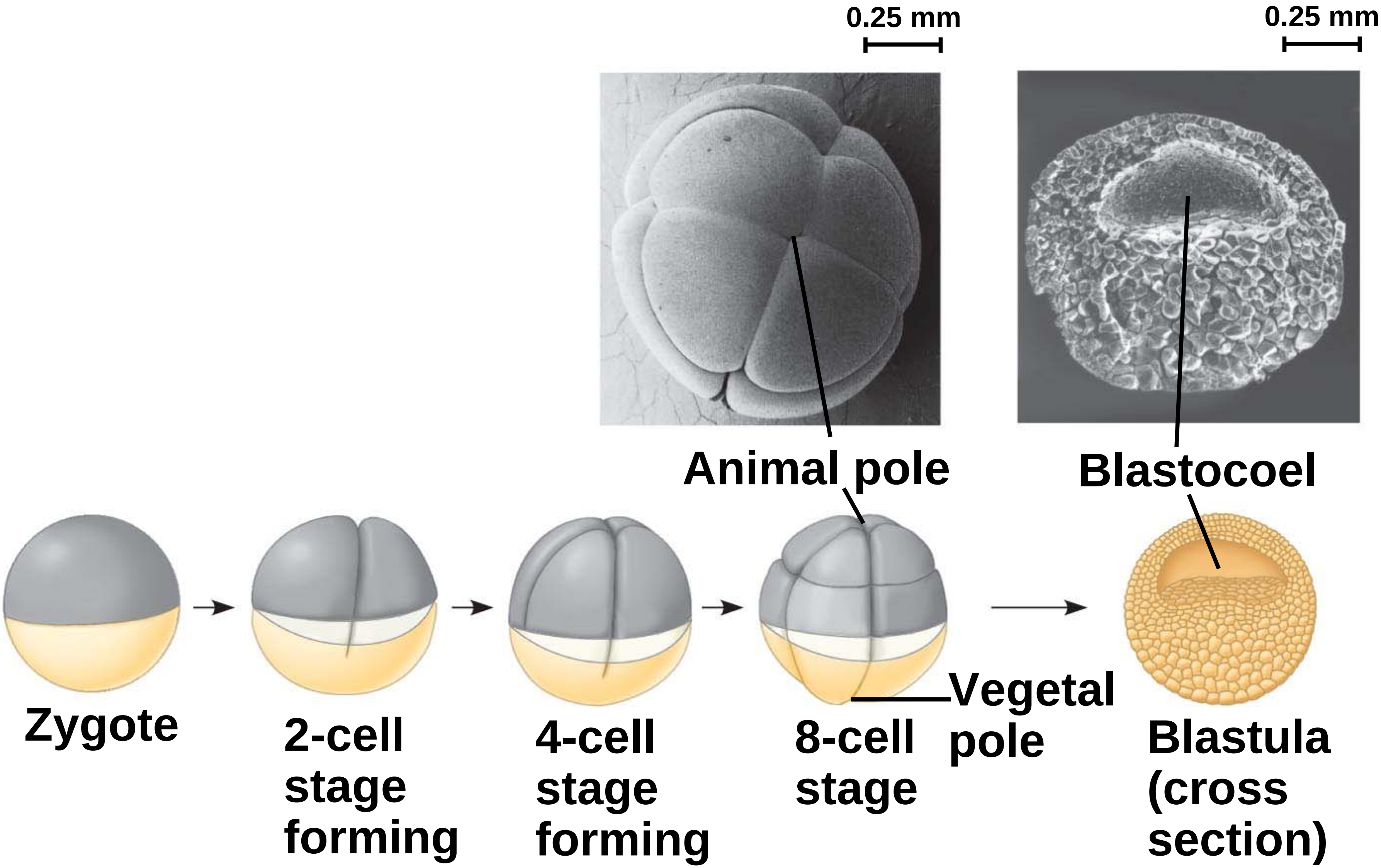


Fig. 47-8-6



0.25 mm
0.25 mm
Animal pole
Blastocoel
Vegetal pole
Zygote
2-cell stage forming
4-cell stage forming
8-cell stage
Blastula (cross section)

- Cell division is slowed by yolk
- **Holoblastic cleavage**, complete division of the egg, occurs in species whose eggs have little or moderate amounts of yolk, such as sea urchins and frogs

- **Meroblastic cleavage**, incomplete division of the egg, occurs in species with yolk-rich eggs, such as reptiles and birds

Gastrulation

- **Gastrulation** rearranges the cells of a blastula into a three-layered embryo, called a **gastrula**, which has a primitive gut

- The three layers produced by gastrulation are called embryonic **germ layers**
  - The **ectoderm** forms the outer layer
  - The **endoderm** lines the digestive tract
  - The **mesoderm** partly fills the space between the endoderm and ectoderm

PLAY Video: Sea Urchin Embryonic Development

- Gastrulation in the sea urchin embryo
  - The blastula consists of a single layer of cells surrounding the blastocoel
  - Mesenchyme cells migrate from the vegetal pole into the blastocoel
  - The vegetal plate forms from the remaining cells of the vegetal pole and buckles inward through **invagination**

- Gastrulation in the sea urchin embryo
  - The newly formed cavity is called the **archenteron**
  - This opens through the **blastopore**, which will become the anus

Fig. 47-9-1

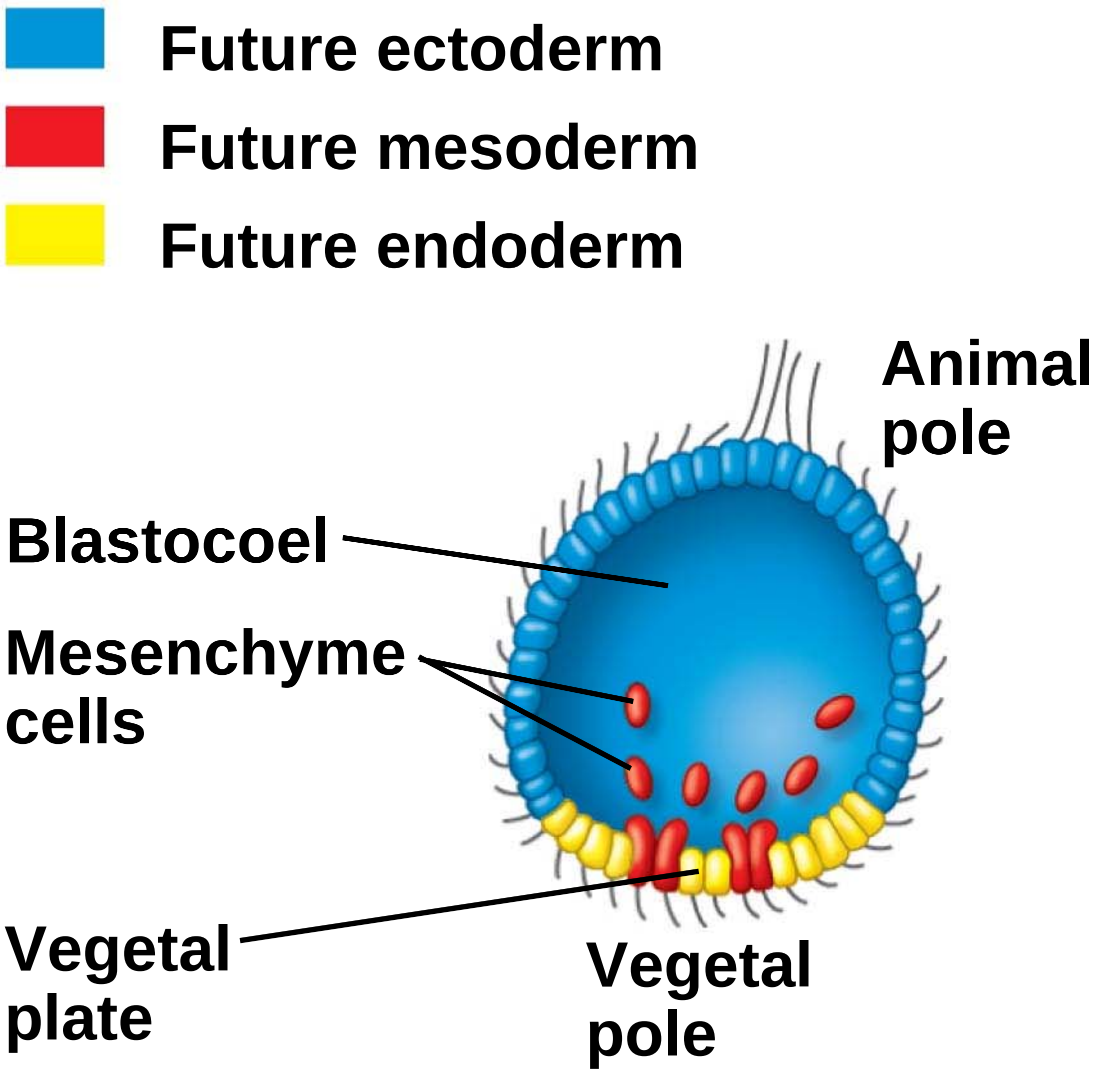

Future ectoderm
Future mesoderm
Future endoderm
Animal pole
Blastocoel
Mesenchyme cells
Vegetal plate
Vegetal pole

Fig. 47-9-2

Future ectoderm

Future mesoderm

Future endoderm

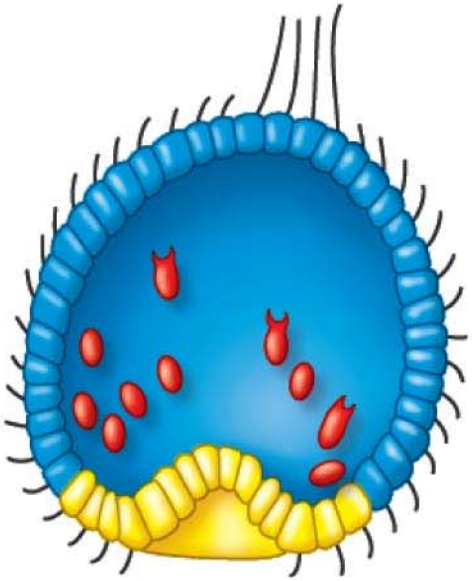


Fig. 47-9-3

Future ectoderm

Future mesoderm

Future endoderm

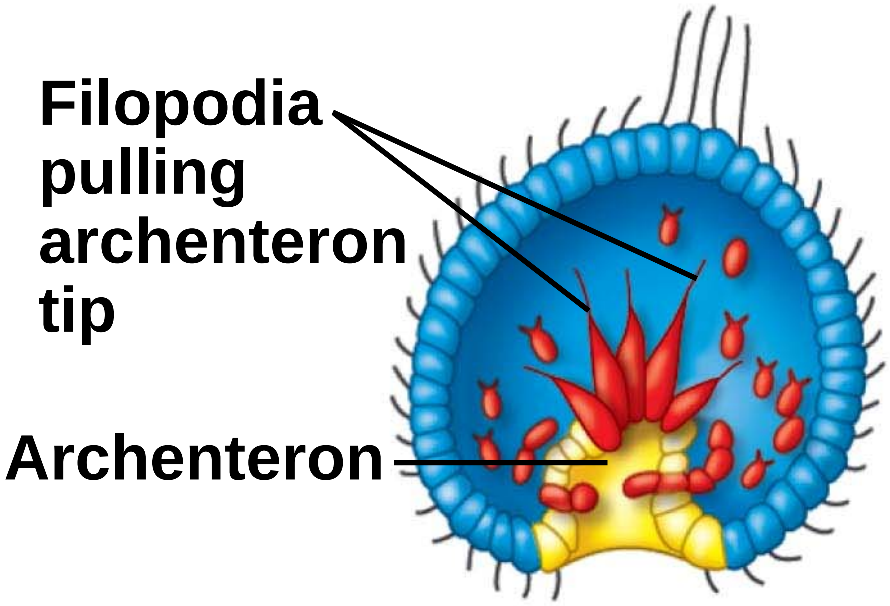


Fig. 47-9-4

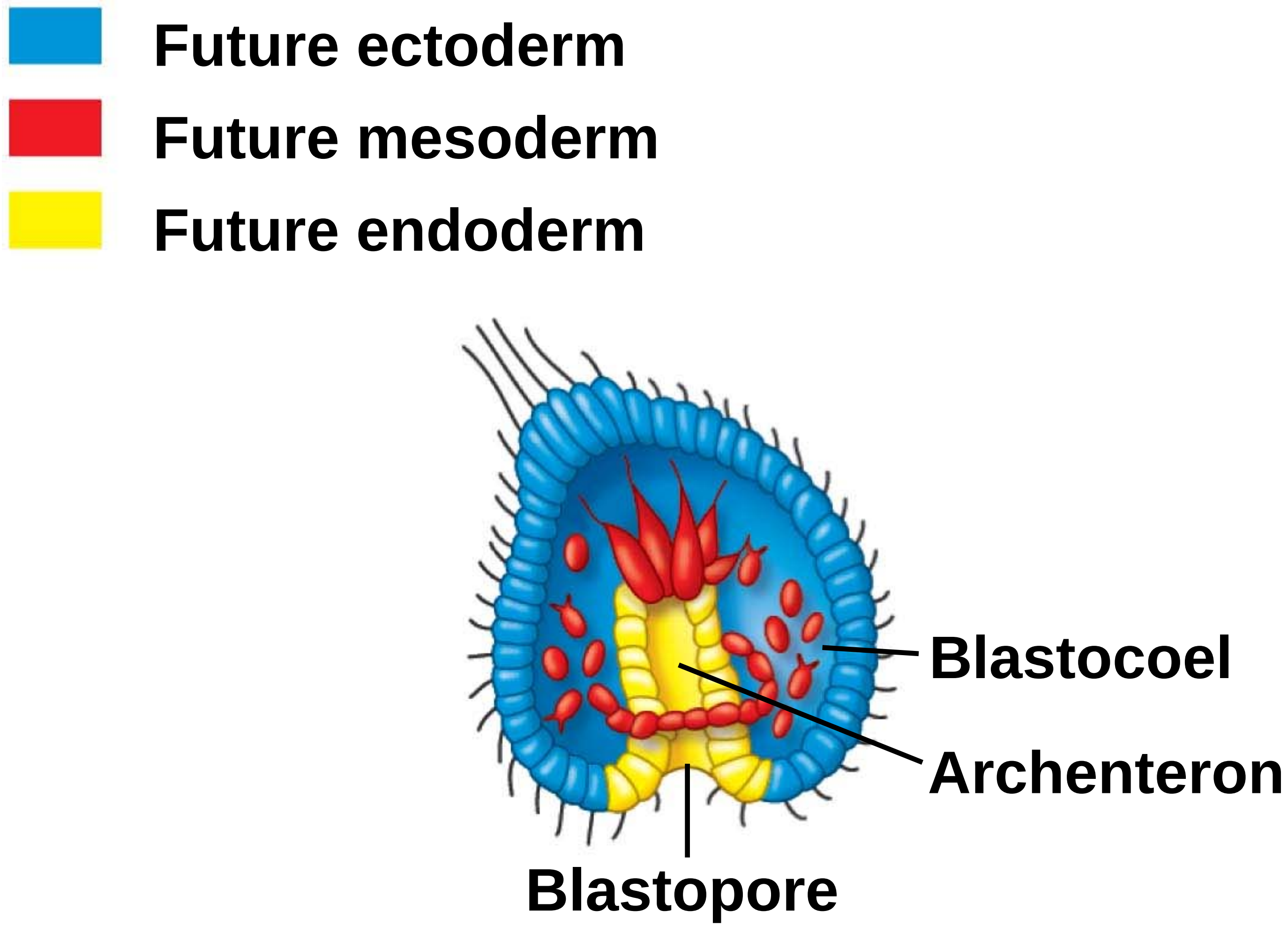

Future ectoderm
Future mesoderm
Future endoderm
Blastocoel
Archenteron
Blastopore

Fig. 47-9-5

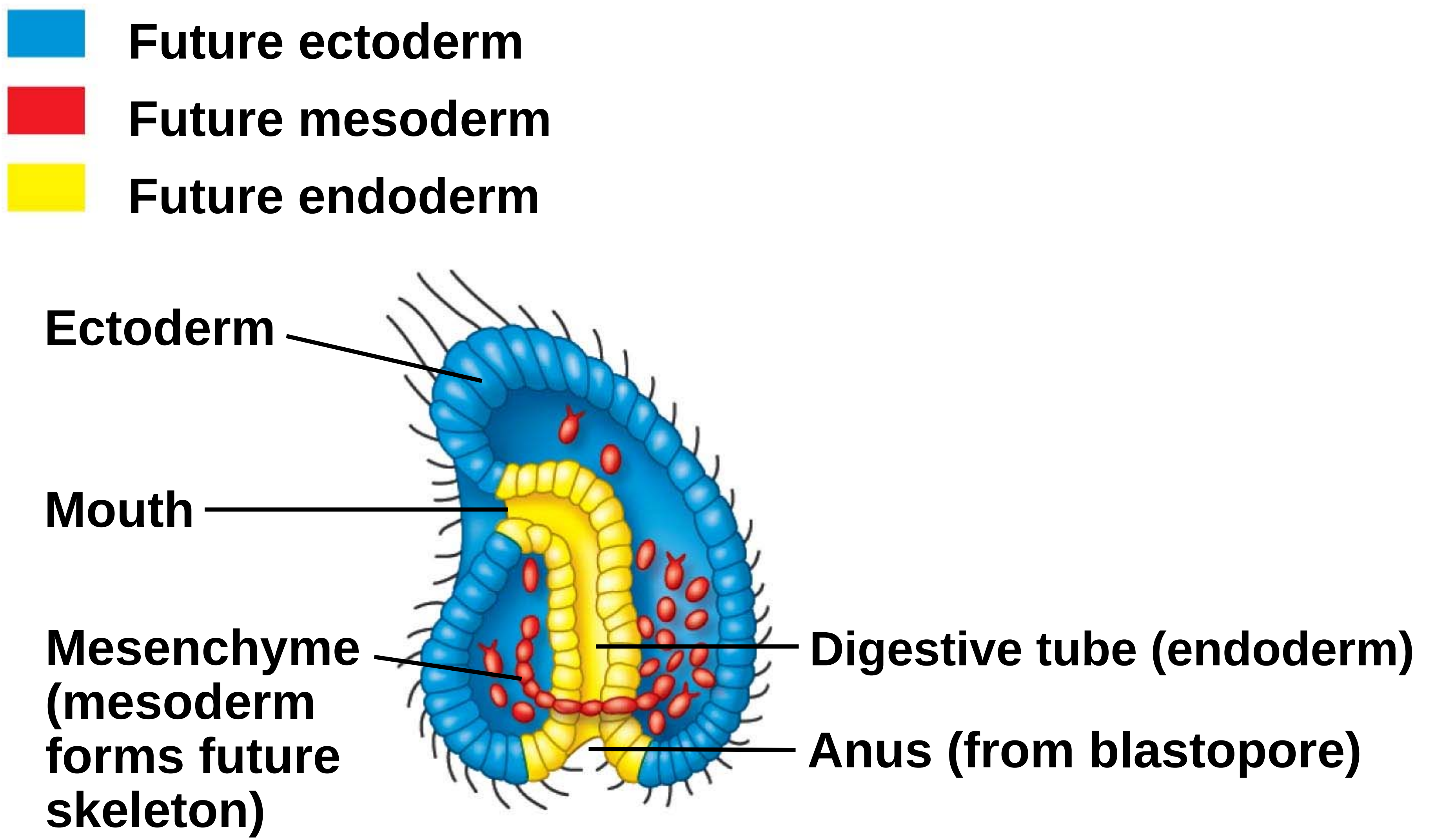
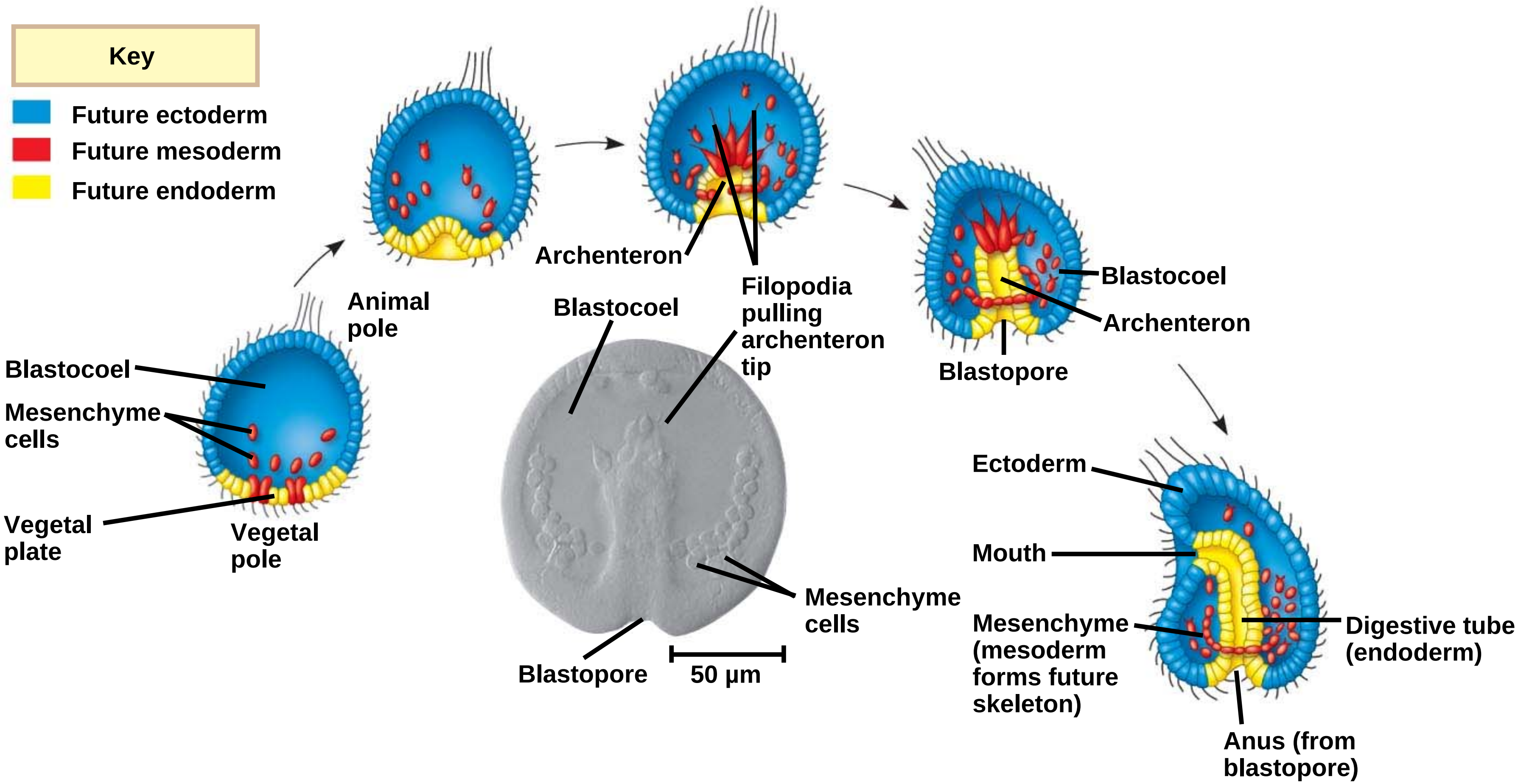

Future ectoderm
Future mesoderm
Future endoderm
Ectoderm
Mouth
Mesenchyme (mesoderm forms future skeleton)
Digestive tube (endoderm)
Anus (from blastopore)

Fig. 47-9-6



Key
Future ectoderm
Future mesoderm
Future endoderm
Blastocoel
Mesenchyme cells
Vegetal plate
Vegetal pole
Animal pole
Archenteron
Blastocoel
Filopodia pulling archenteron tip
Mesenchyme cells
Blastopore
50 µm
Blastocoel
Archenteron
Blastopore
Ectoderm
Mouth
Mesenchyme (mesoderm forms future skeleton)
Digestive tube (endoderm)
Anus (from blastopore)

- Gastrulation in the frog
  - The frog blastula is many cell layers thick
  - Cells of the **dorsal lip** originate in the gray crescent and invaginate to create the archenteron
  - Cells continue to move from the embryo surface into the embryo by **involution**
  - These cells become the endoderm and mesoderm

- Gastrulation in the frog
  - The blastopore encircles a **yolk plug** when gastrulation is completed
  - The surface of the embryo is now ectoderm, the innermost layer is endoderm, and the middle layer is mesoderm

Fig. 47-10-1

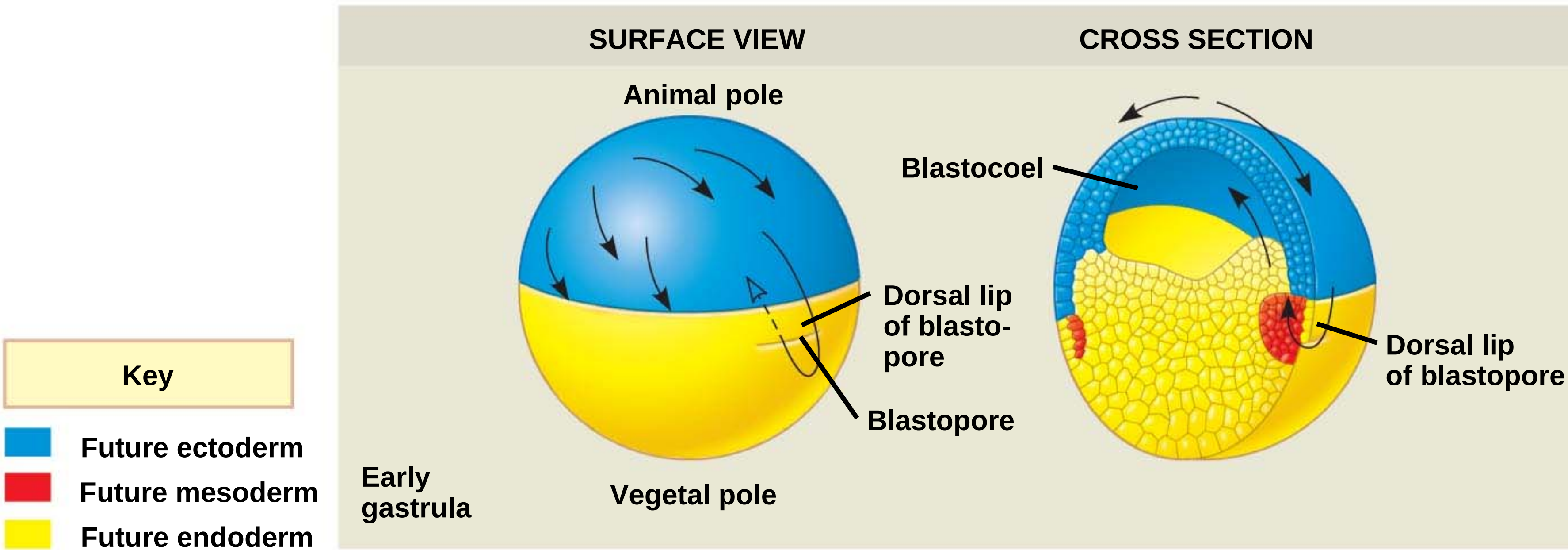

SURFACE VIEW
CROSS SECTION
Animal pole
Blastocoel
Dorsal lip of blasto-pore
Blastopore
Dorsal lip of blastopore
Early gastrula
Vegetal pole
Key
Future ectoderm
Future mesoderm
Future endoderm

Fig. 47-10-2

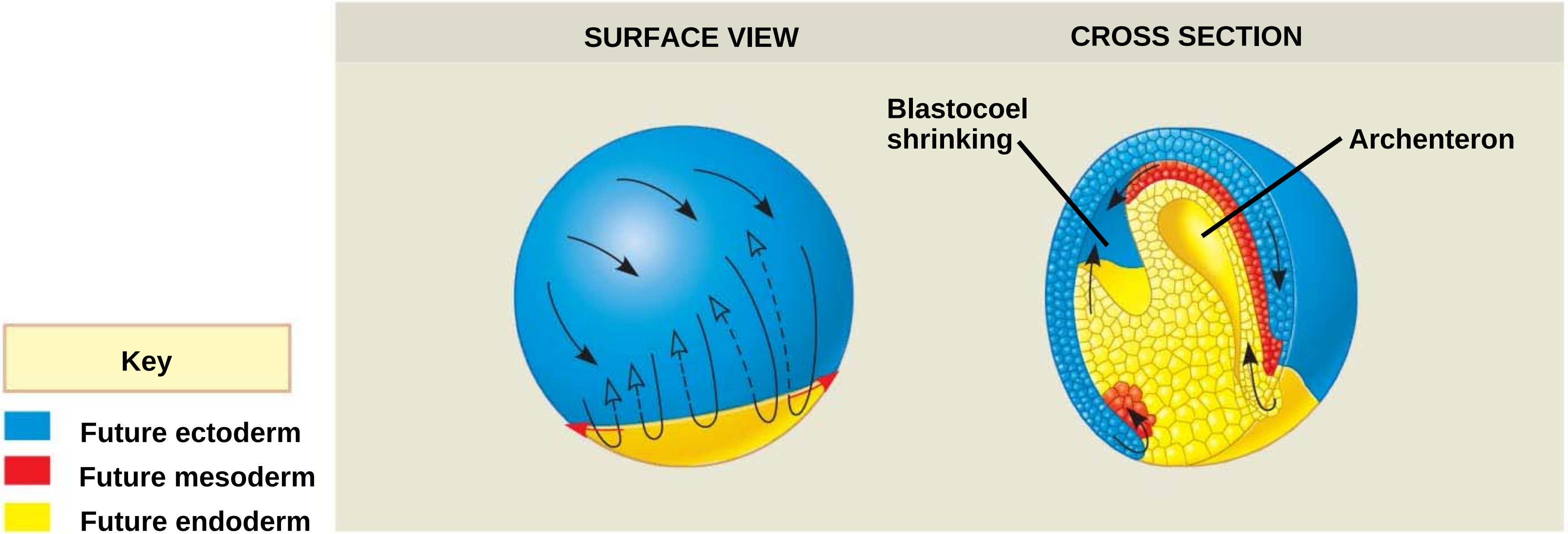

SURFACE VIEW
CROSS SECTION
Blastocoel
shrinking
Archenteron
Key
Future ectoderm
Future mesoderm
Future endoderm

Fig. 47-10-3

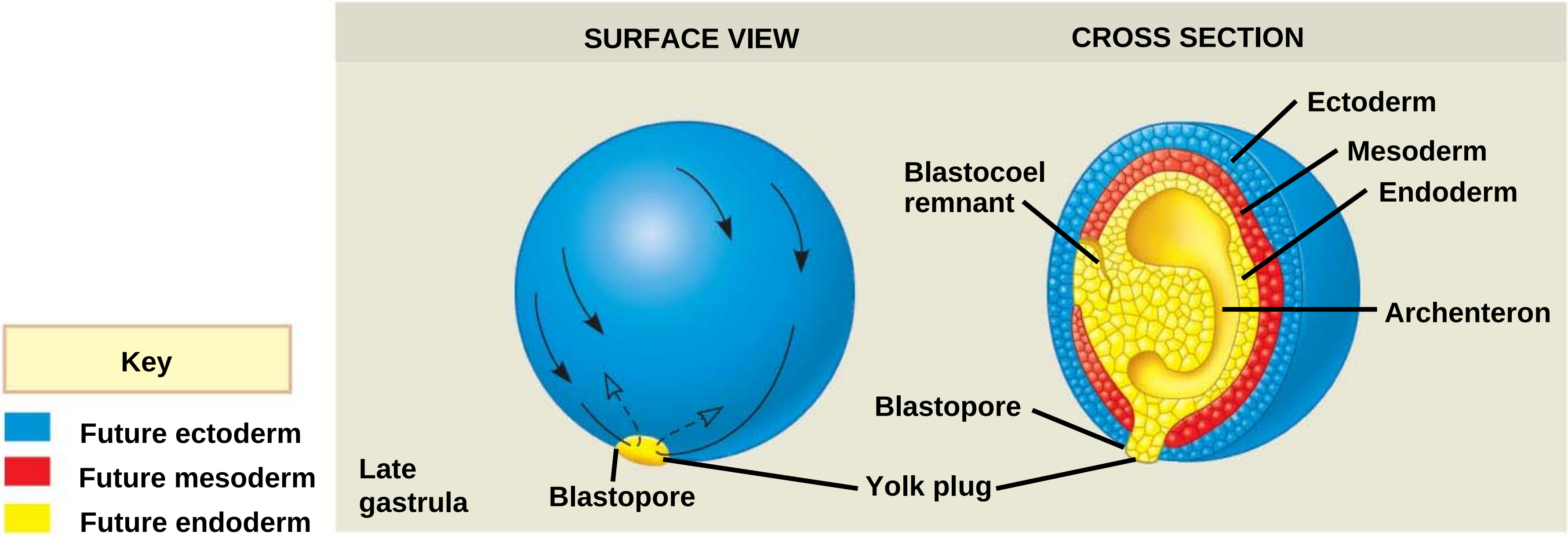
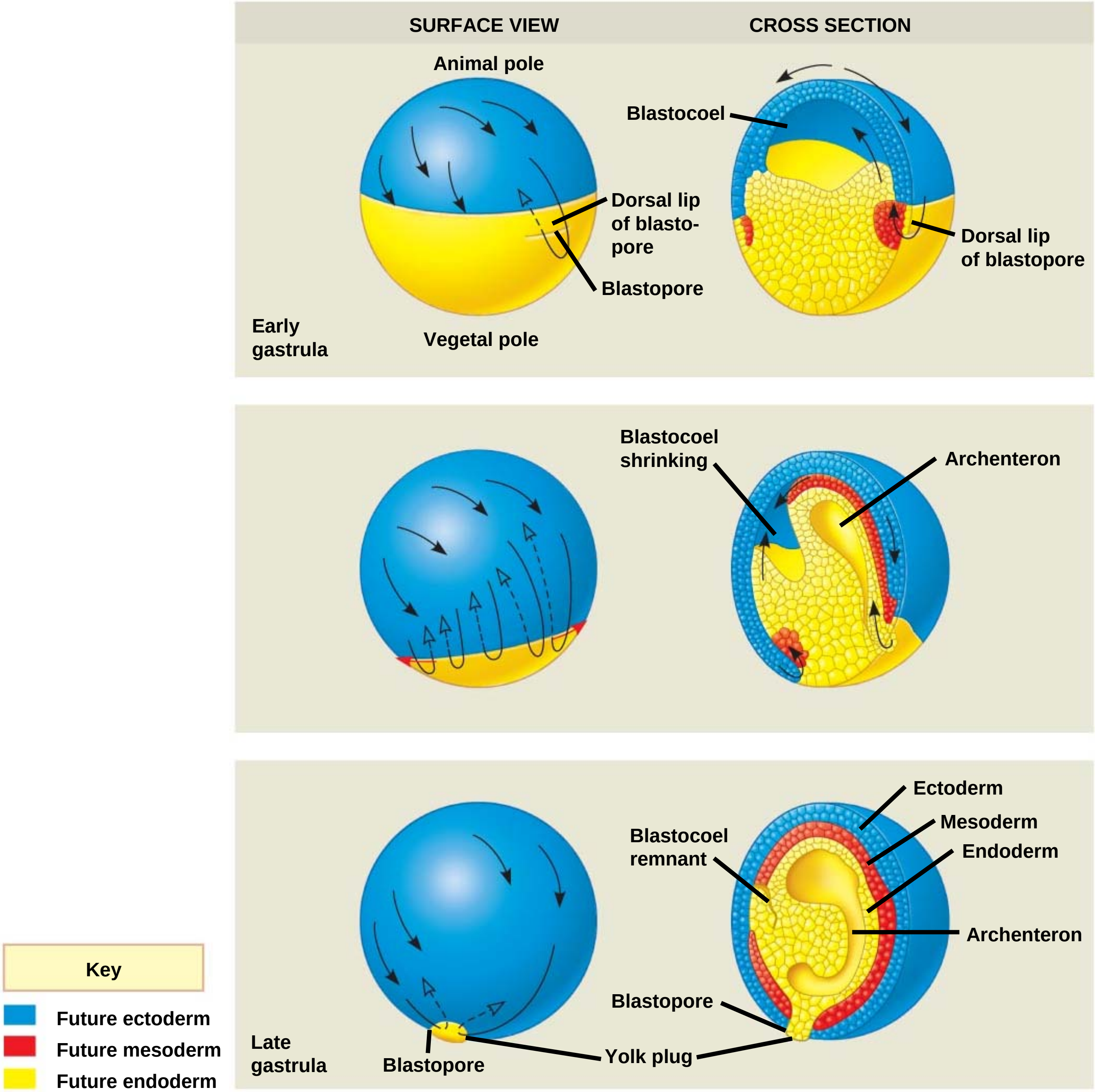

SURFACE VIEW
CROSS SECTION
Ectoderm
Mesoderm
Endoderm
Blastocoel remnant
Archenteron
Blastopore
Yolk plug
Late gastrula
Blastopore
Key
Future ectoderm
Future mesoderm
Future endoderm

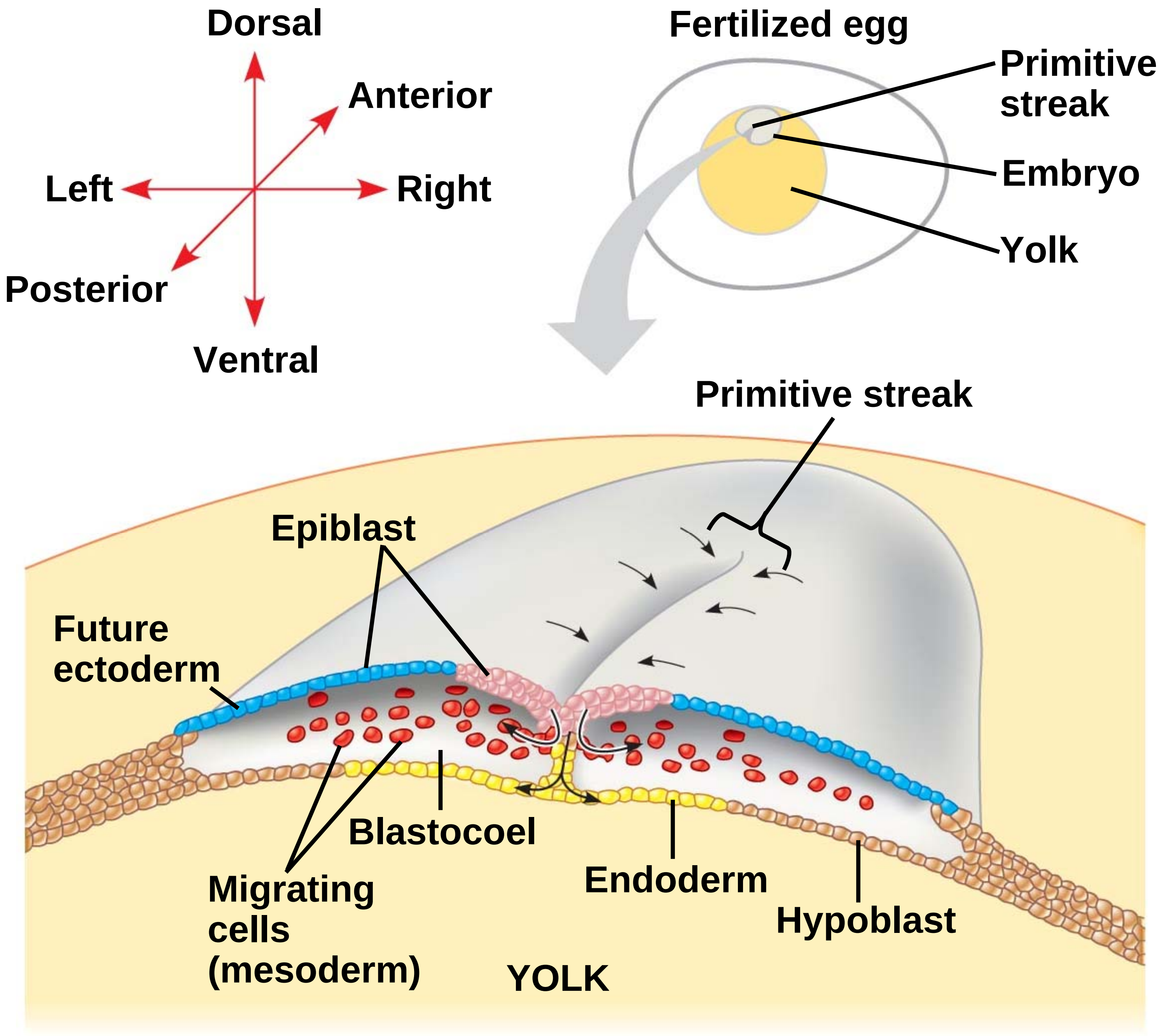
Fig. 47-10-4


SURFACE VIEW
CROSS SECTION
Animal pole
Blastocoel
Dorsal lip of blasto- pore
Blastopore
Dorsal lip of blastopore
Early gastrula
Vegetal pole
Blastocoel shrinking
Archenteron
Ectoderm
Mesoderm
Endoderm
Blastocoel remnant
Archenteron
Blastopore
Yolk plug
Late gastrula
Blastopore
Key
Future ectoderm
Future mesoderm
Future endoderm

- Gastrulation in the chick
  - The embryo forms from a blastoderm and sits on top of a large yolk mass
  - During gastrulation, the upper layer of the blastoderm (epiblast) moves toward the midline of the blastoderm and then into the embryo toward the yolk

- The midline thickens and is called the **primitive streak**
- The movement of different epiblast cells gives rise to the endoderm, mesoderm, and ectoderm

Fig. 47-11



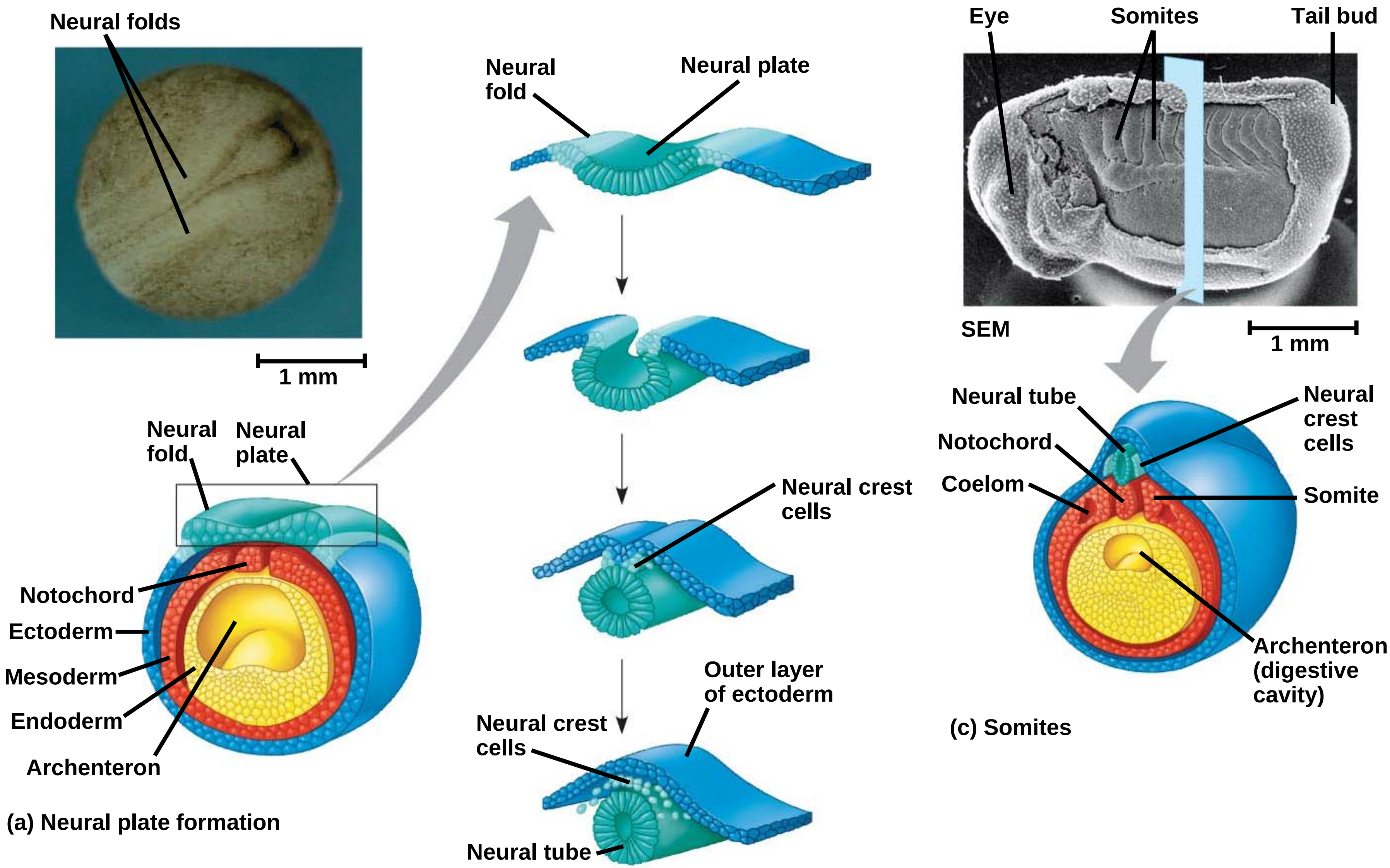
Dorsal
Anterior
Left
Right
Posterior
Ventral
Fertilized egg
Primitive streak
Embryo
Yolk
Primitive streak
Epiblast
Future ectoderm
Blastocoel
Migrating cells (mesoderm)
Endoderm
Hypoblast
YOLK

Organogenesis

- During **organogenesis**, various regions of the germ layers develop into rudimentary organs
- The frog is used as a model for organogenesis

- Early in vertebrate organogenesis, the **notochord** forms from mesoderm, and the neural plate forms from ectoderm

Fig. 47-12

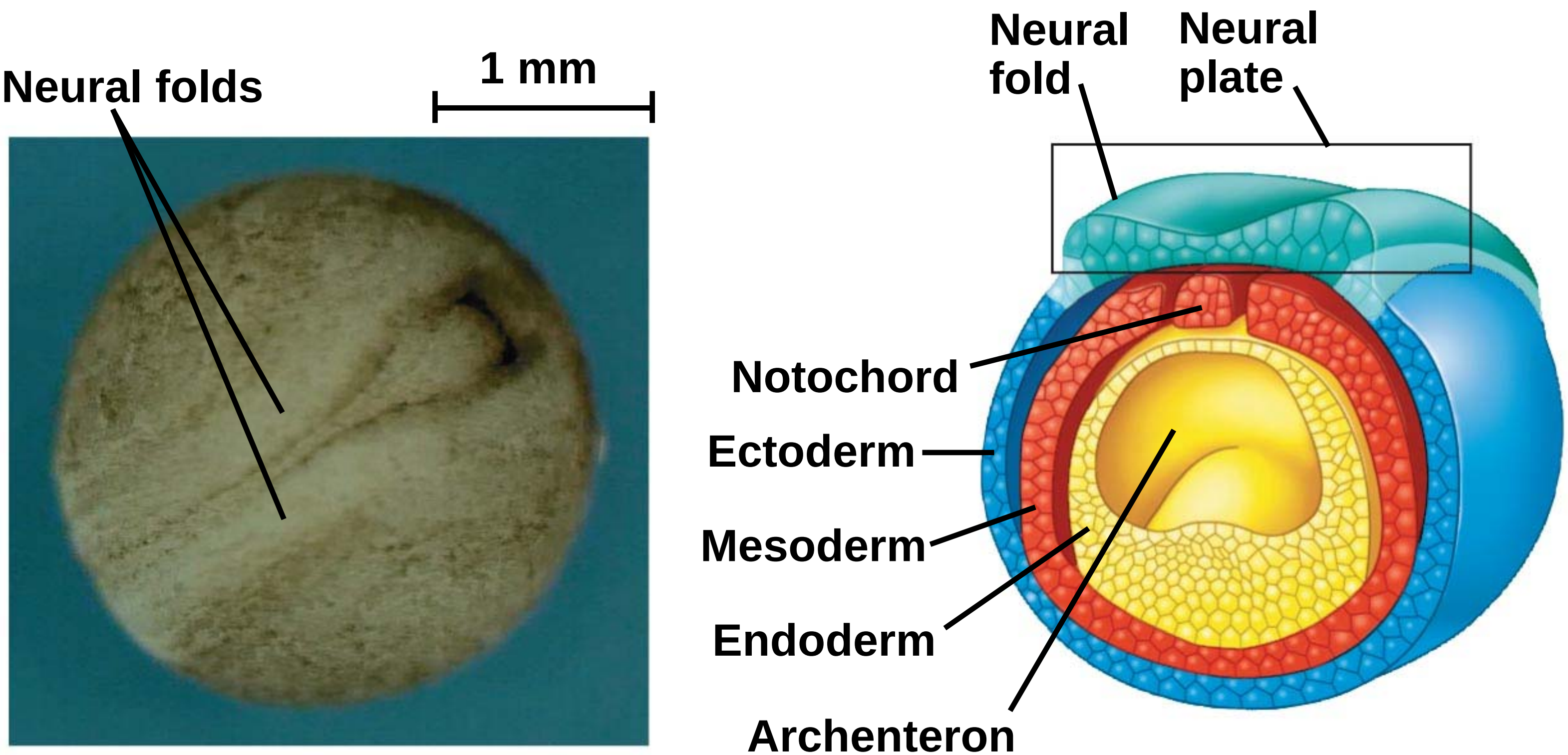


(a) Neural plate formation

(b) Neural tube formation

(c) Somites

Fig. 47-12a



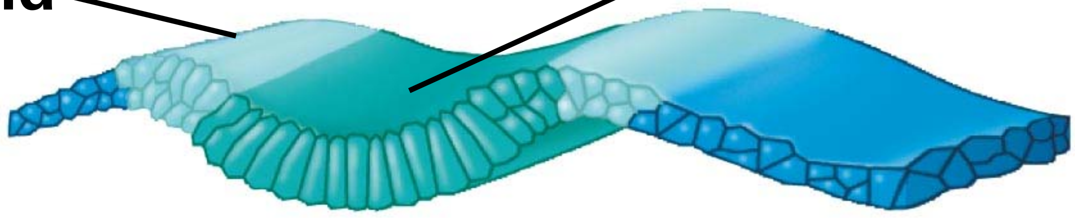
(a) Neural plate formation

- The neural plate soon curves inward, forming the **neural tube**
- The neural tube will become the central nervous system (brain and spinal cord)

PLAY

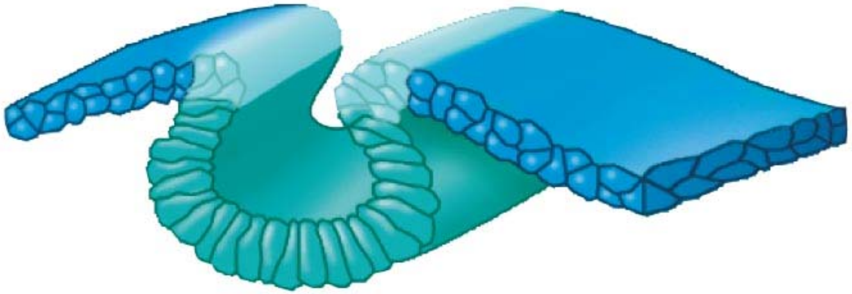
Video: Frog Embryo Development

Fig. 47-12b-1



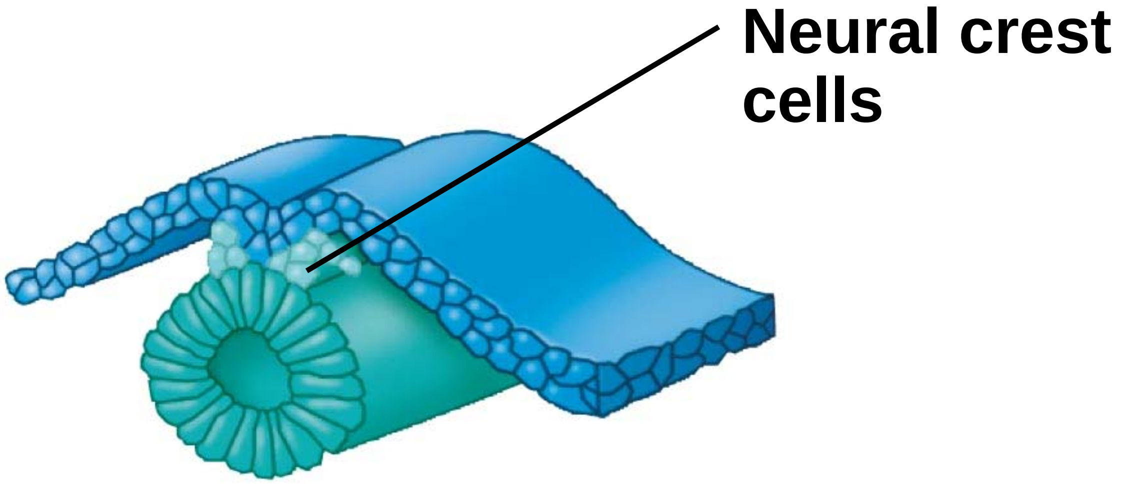
(b) Neural tube formation

Fig. 47-12b-2



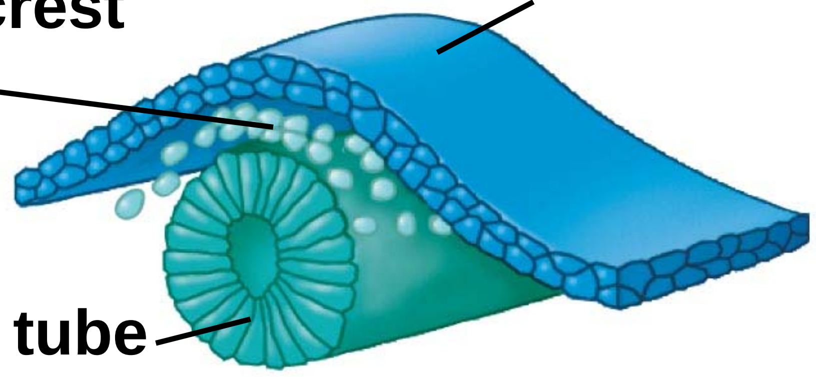
(b) Neural tube formation

Fig. 47-12b-3



(b) Neural tube formation

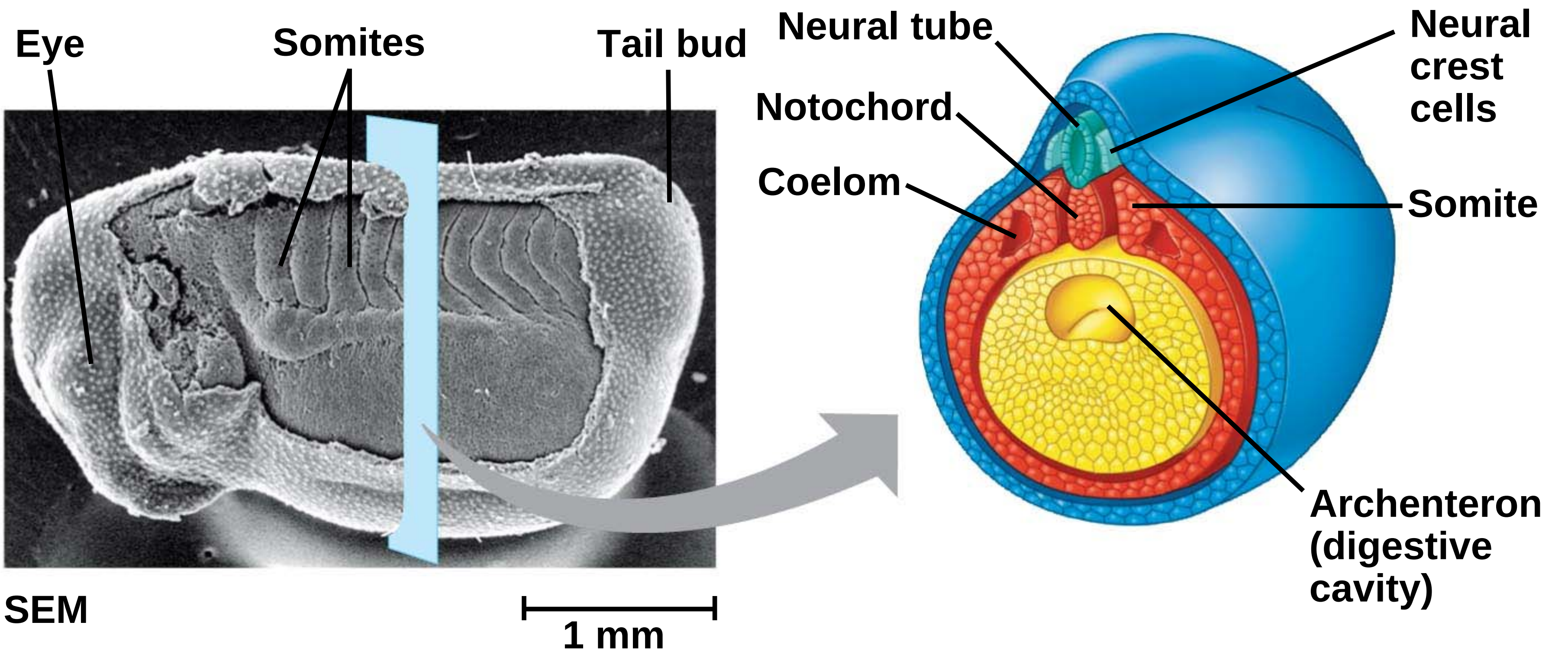
Fig. 47-12b-4



(b) Neural tube formation

- **Neural crest cells** develop along the neural tube of vertebrates and form various parts of the embryo (nerves, parts of teeth, skull bones, and so on)
- Mesoderm lateral to the notochord forms blocks called **somites**
- Lateral to the somites, the mesoderm splits to form the coelom

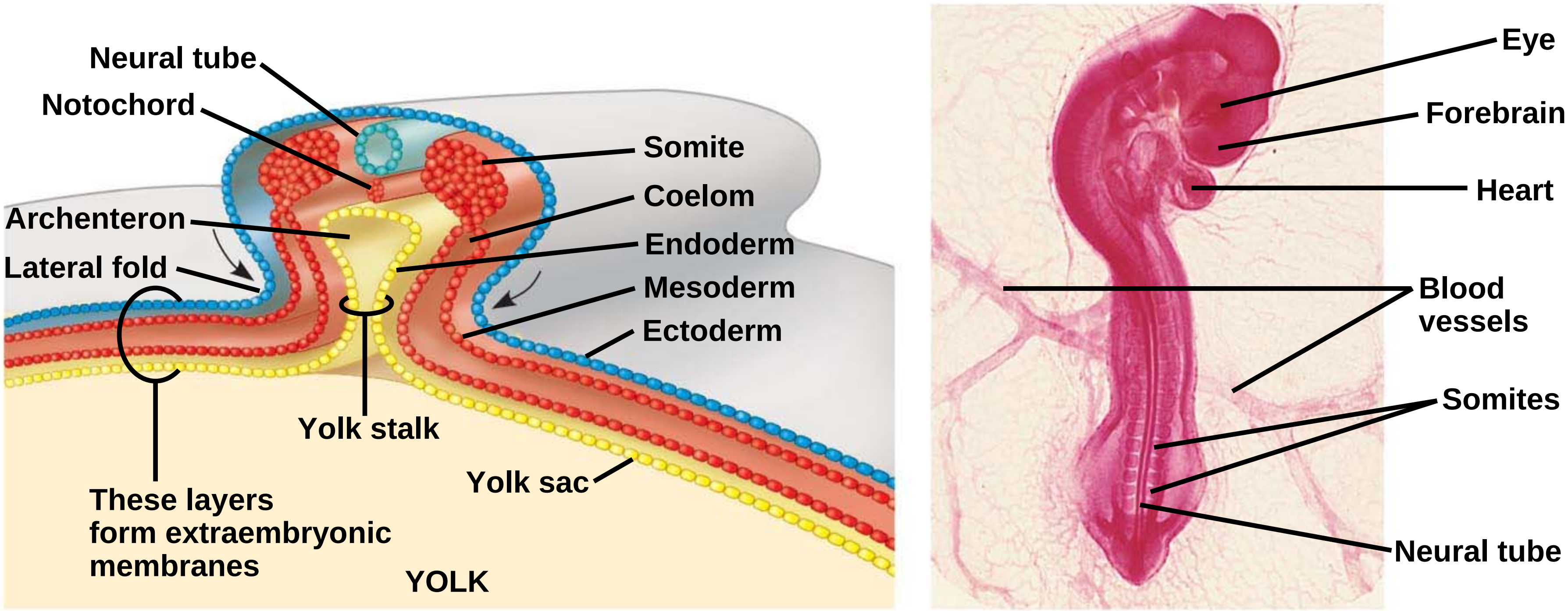
Fig. 47-12c



(c) Somites

- Organogenesis in the chick is quite similar to that in the frog

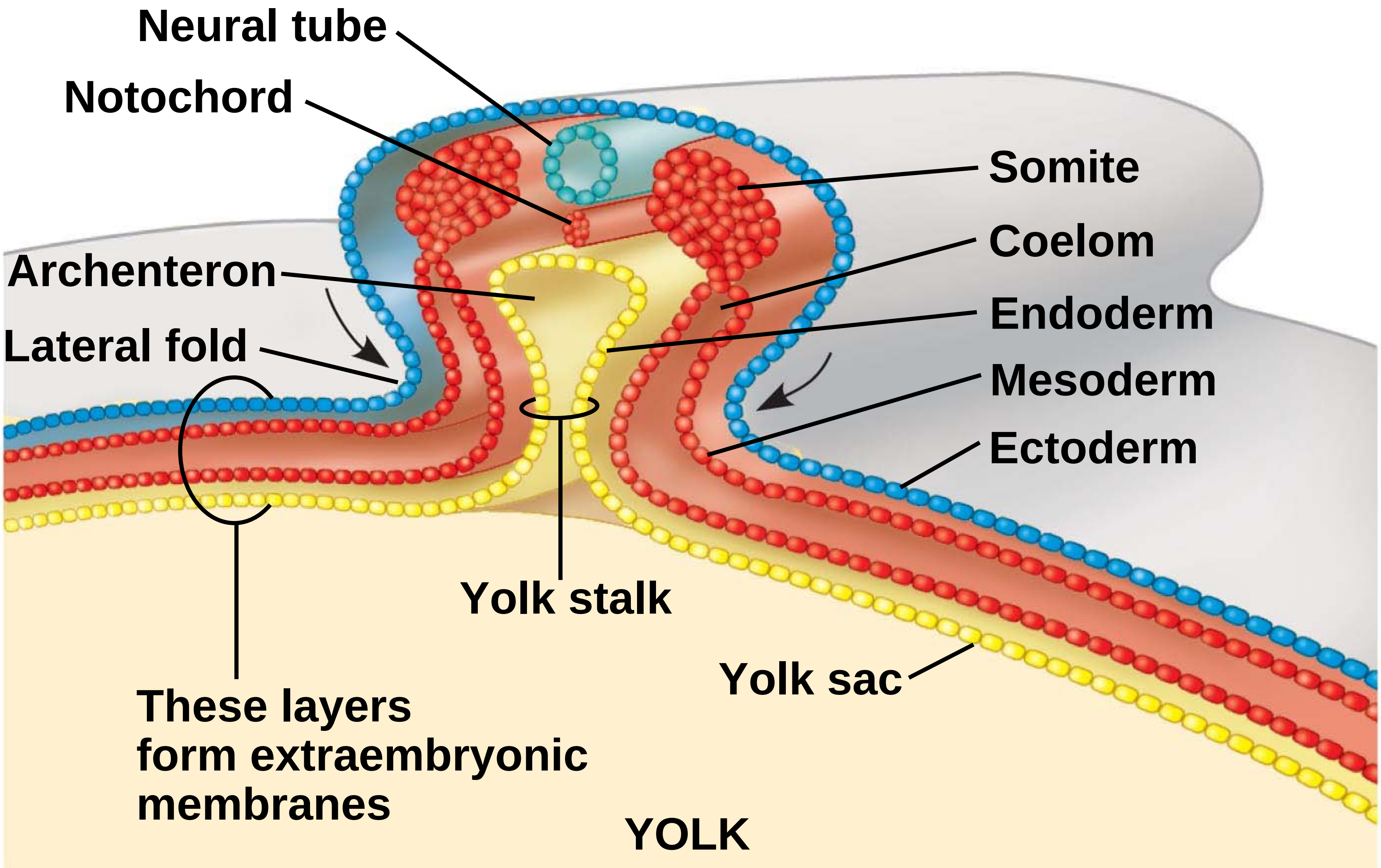
Fig. 47-13



(a) Early organogenesis

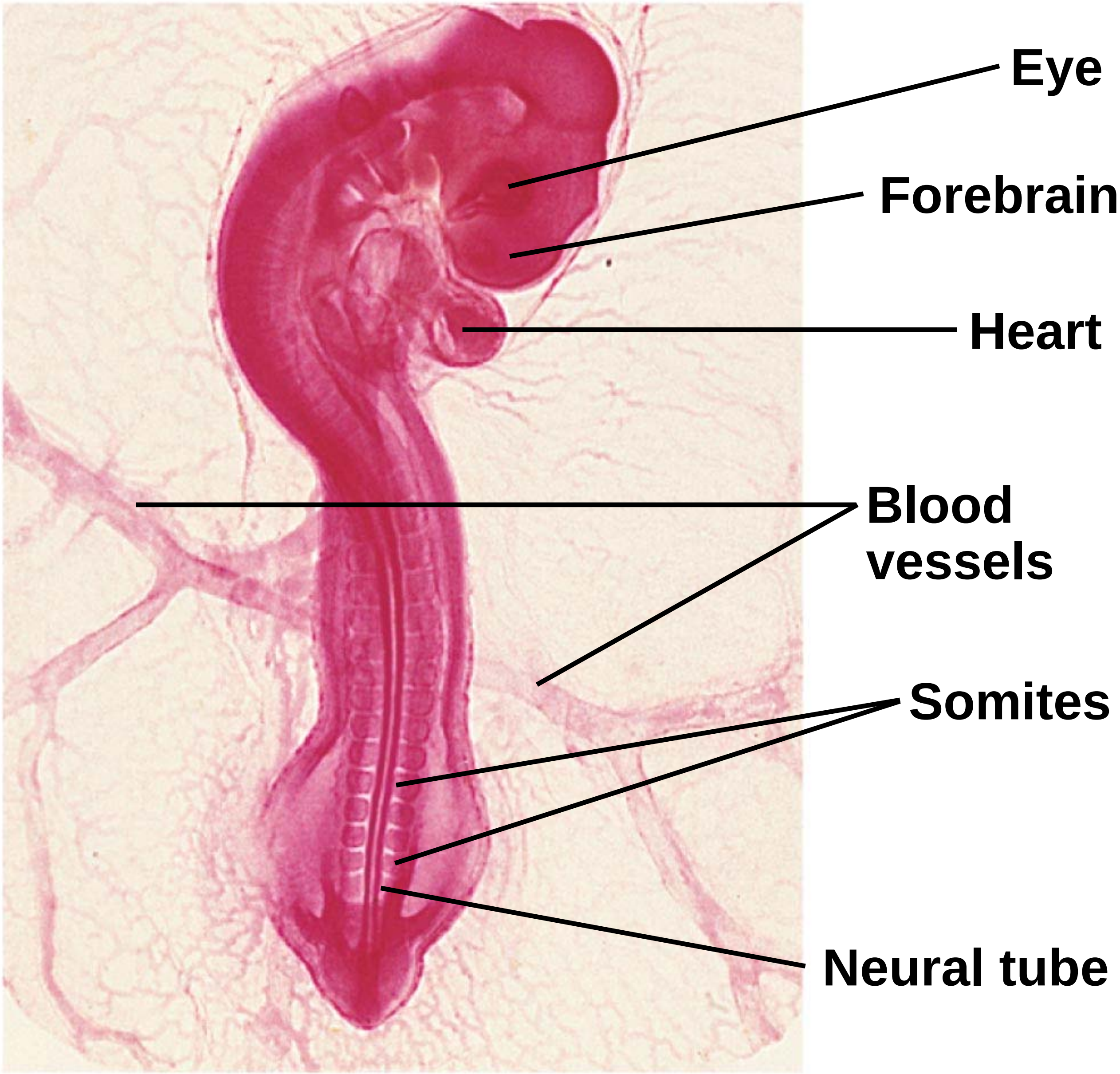
(b) Late organogenesis

Fig. 47-13a



(a) Early organogenesis

Fig. 47-13b



(b) Late organogenesis

- The mechanisms of organogenesis in invertebrates are similar, but the body plan is very different

Fig. 47-14

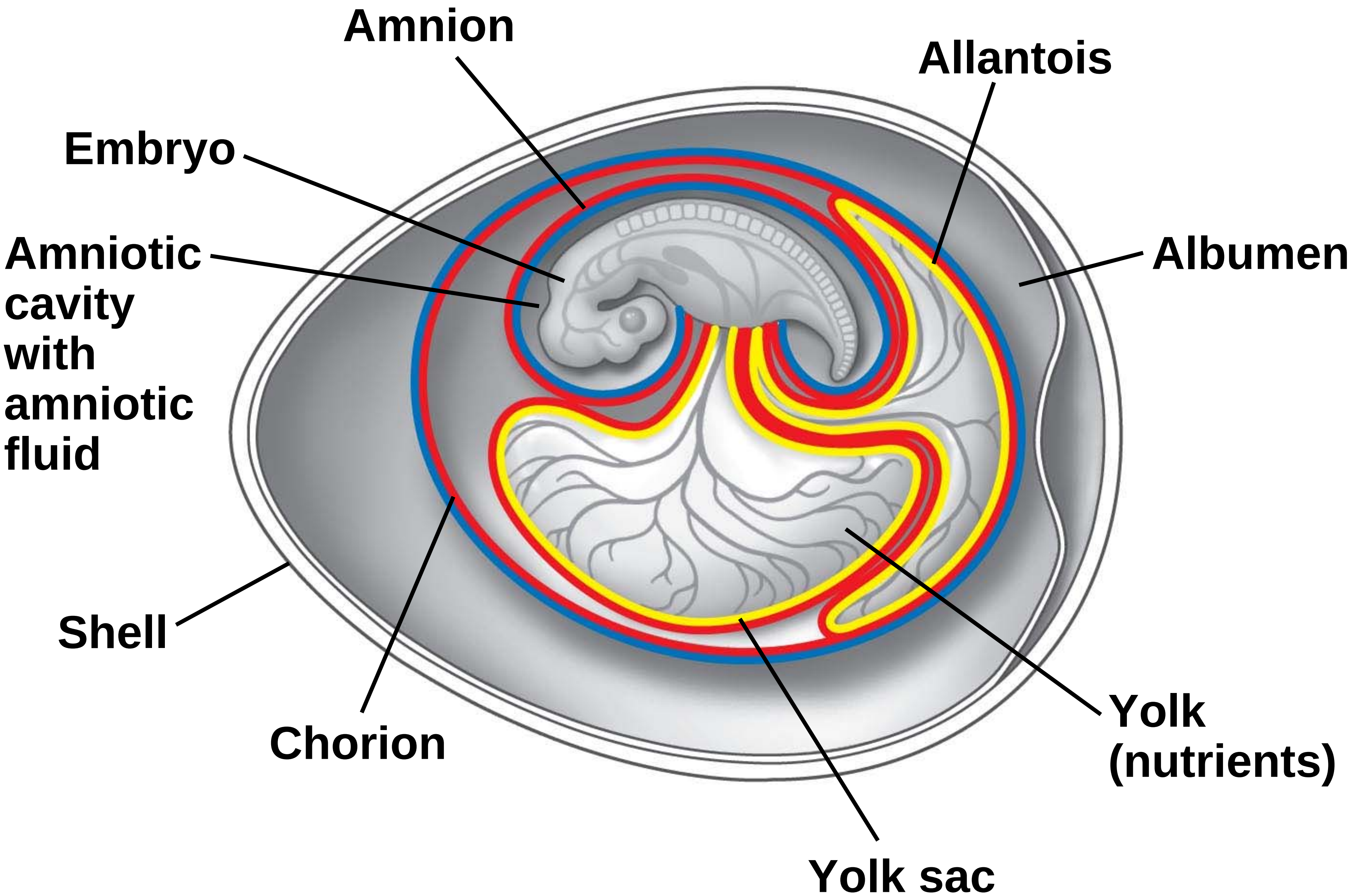
ECTODERM	MESODERM	ENDODERM
• Epidermis of skin and its derivatives (including sweat glands, hair follicles) • Epithelial lining of mouth and anus • Cornea and lens of eye • Nervous system • Sensory receptors in epidermis • Adrenal medulla • Tooth enamel • Epithelium of pineal and pituitary glands	• Notochord • Skeletal system • Muscular system • Muscular layer of stomach and intestine • 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

Developmental Adaptations of Amniotes

- Embryos of birds, other reptiles, and mammals develop in a fluid-filled sac in a shell or the uterus
- Organisms with these adaptations are called **amniotes**

- During amniote development, four **extraembryonic membranes** form around the embryo:
  - The **chorion** functions in gas exchange
  - The **amnion** encloses the amniotic fluid
  - The **yolk sac** encloses the yolk
  - The **allantois** disposes of waste products and contributes to gas exchange

Fig. 47-15


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

Mammalian Development

- The eggs of placental mammals
  - Are small and store few nutrients
  - Exhibit holoblastic cleavage
  - Show no obvious polarity
- Gastrulation and organogenesis resemble the processes in birds and other reptiles
- Early cleavage is relatively slow in humans and other mammals

- At completion of cleavage, the **blastocyst** forms
- A group of cells called the **inner cell mass** develops into the embryo and forms the extraembryonic membranes
- The **trophoblast**, the outer epithelium of the blastocyst, initiates implantation in the uterus, and the inner cell mass of the blastocyst forms a flat disk of cells
- As implantation is completed, gastrulation begins

Fig. 47-16-1

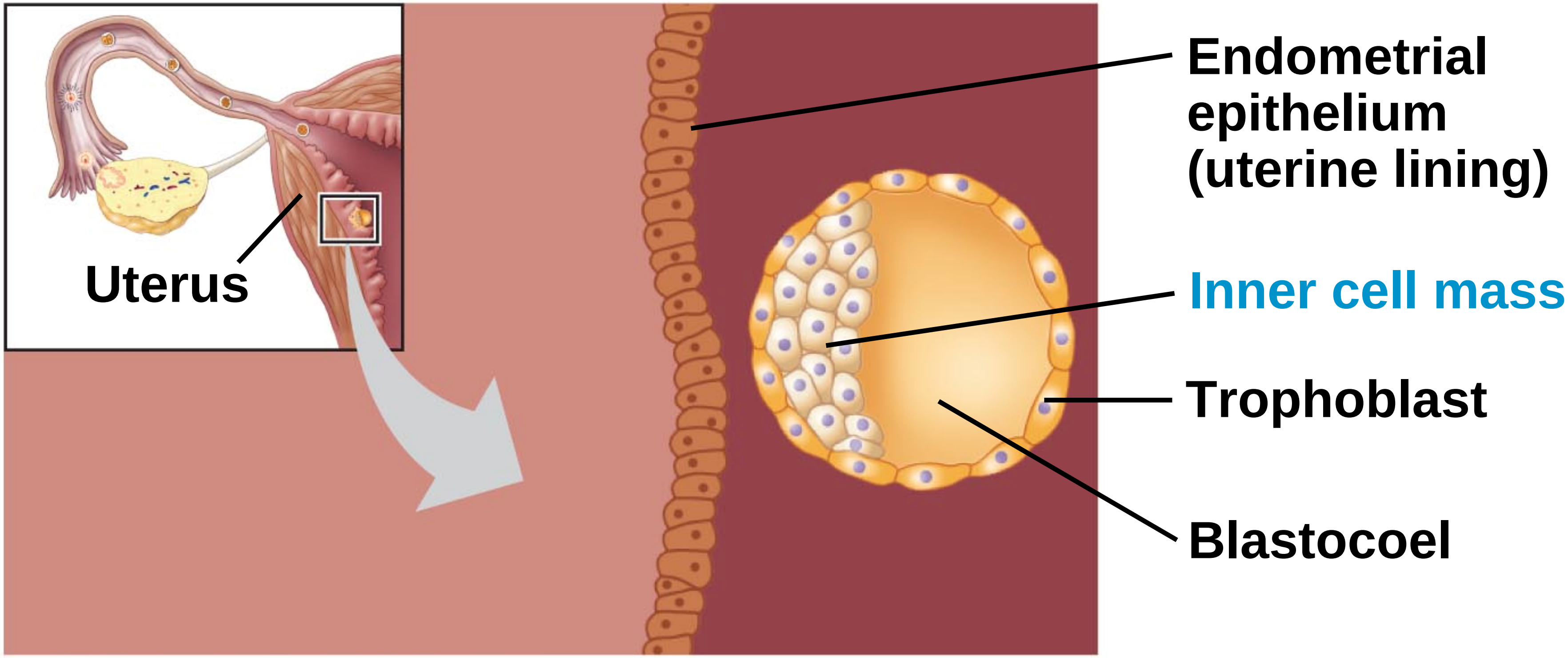
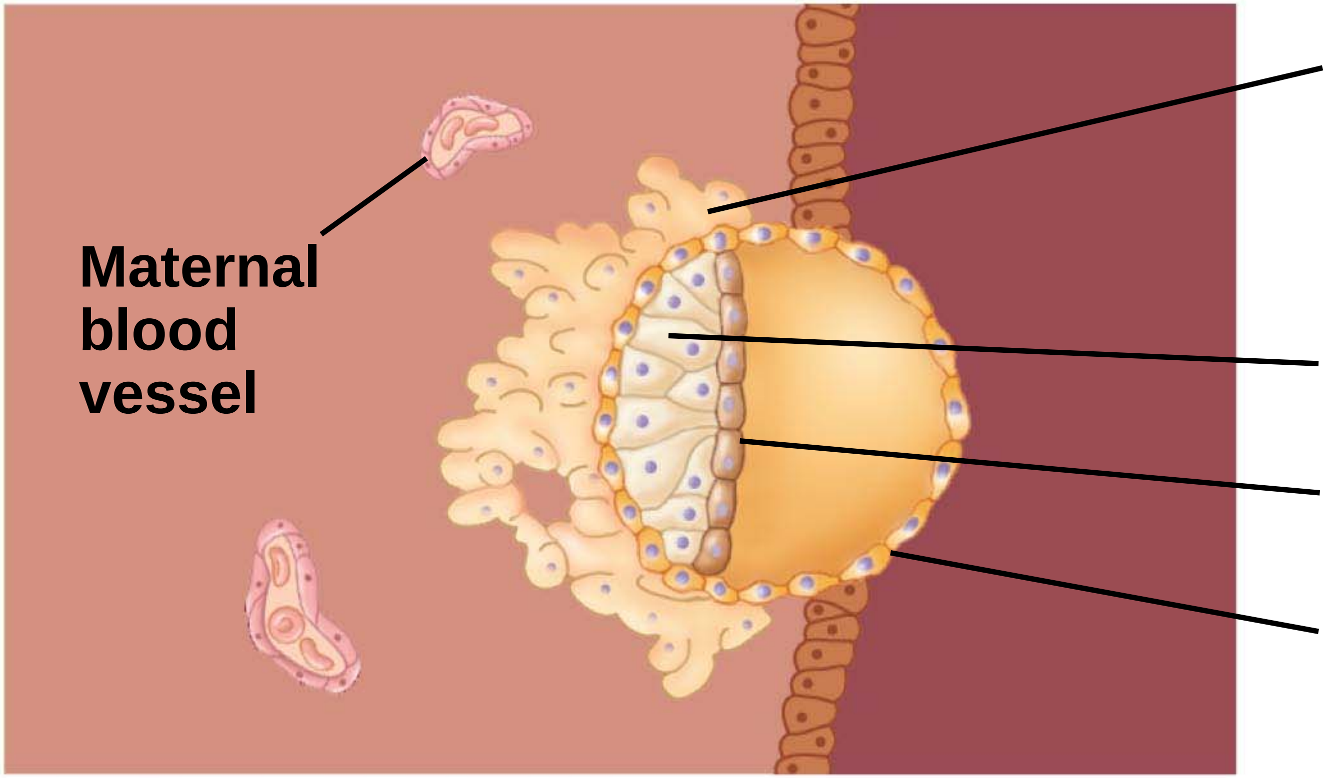

Uterus
Endometrial epithelium (uterine lining)
Inner cell mass
Trophoblast
Blastocoel

Fig. 47-16-2


Expanding region of trophoblast
Maternal blood vessel
Epiblast
Hypoblast
Trophoblast

- The epiblast cells invaginate through a primitive streak to form mesoderm and endoderm
- The placenta is formed from the trophoblast, mesodermal cells from the epiblast, and adjacent endometrial tissue
- The placenta allows for the exchange of materials between the mother and embryo
- By the end of gastrulation, the embryonic germ layers have formed

Fig. 47-16-3

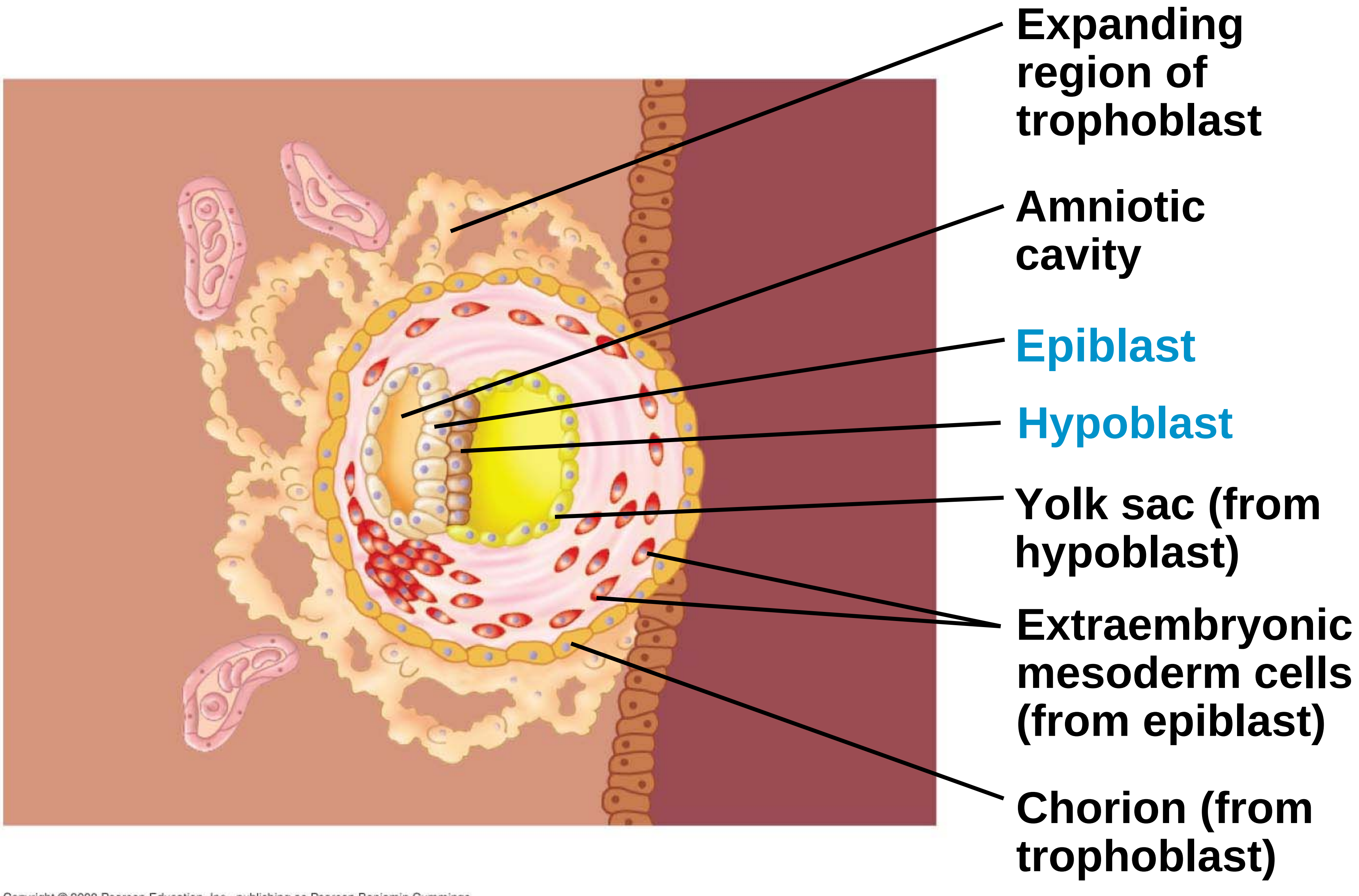

Expanding region of trophoblast
Amniotic cavity
Epiblast
Hypoblast
Yolk sac (from hypoblast)
Extraembryonic mesoderm cells (from epiblast)
Chorion (from trophoblast)

Fig. 47-16-4

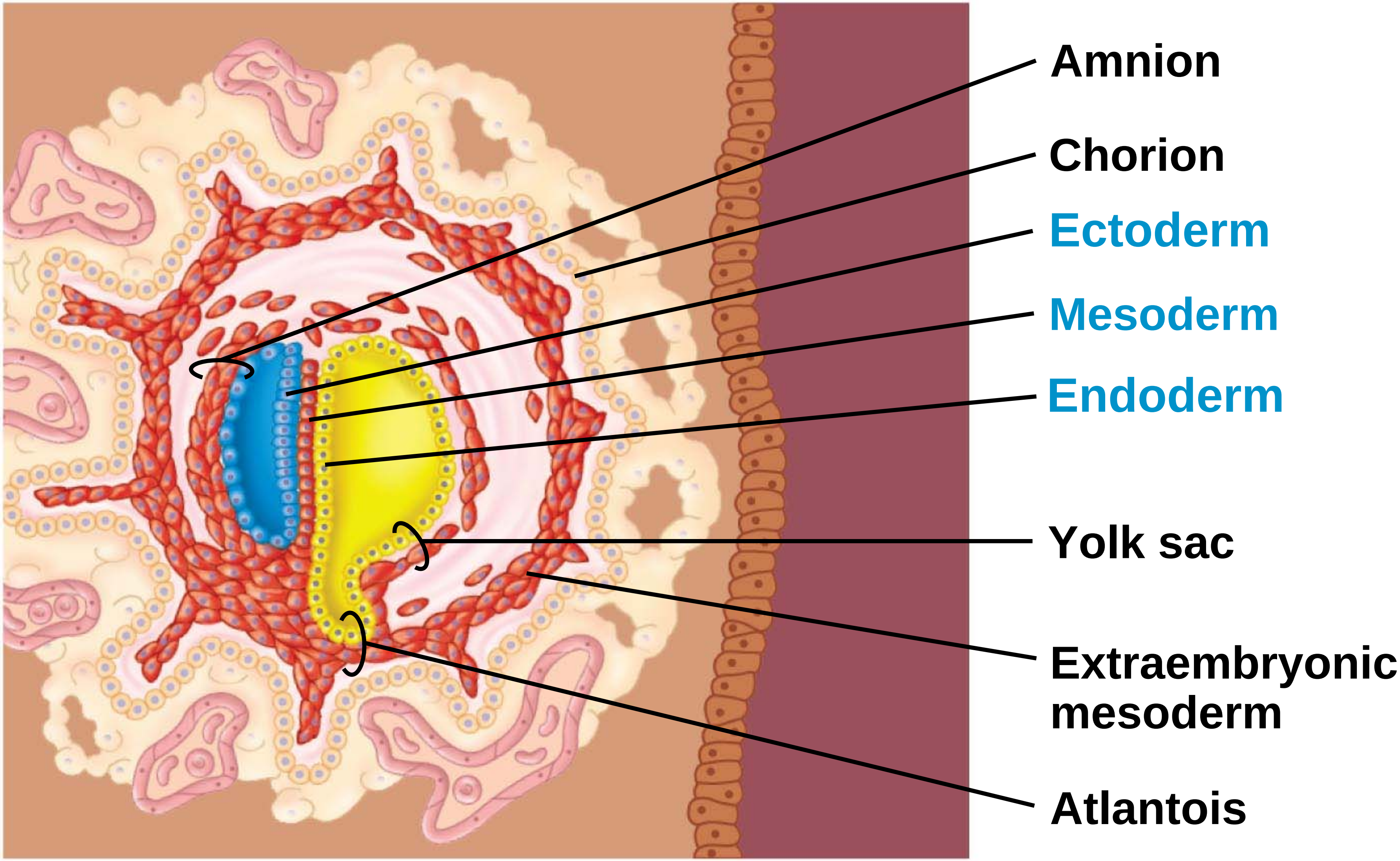
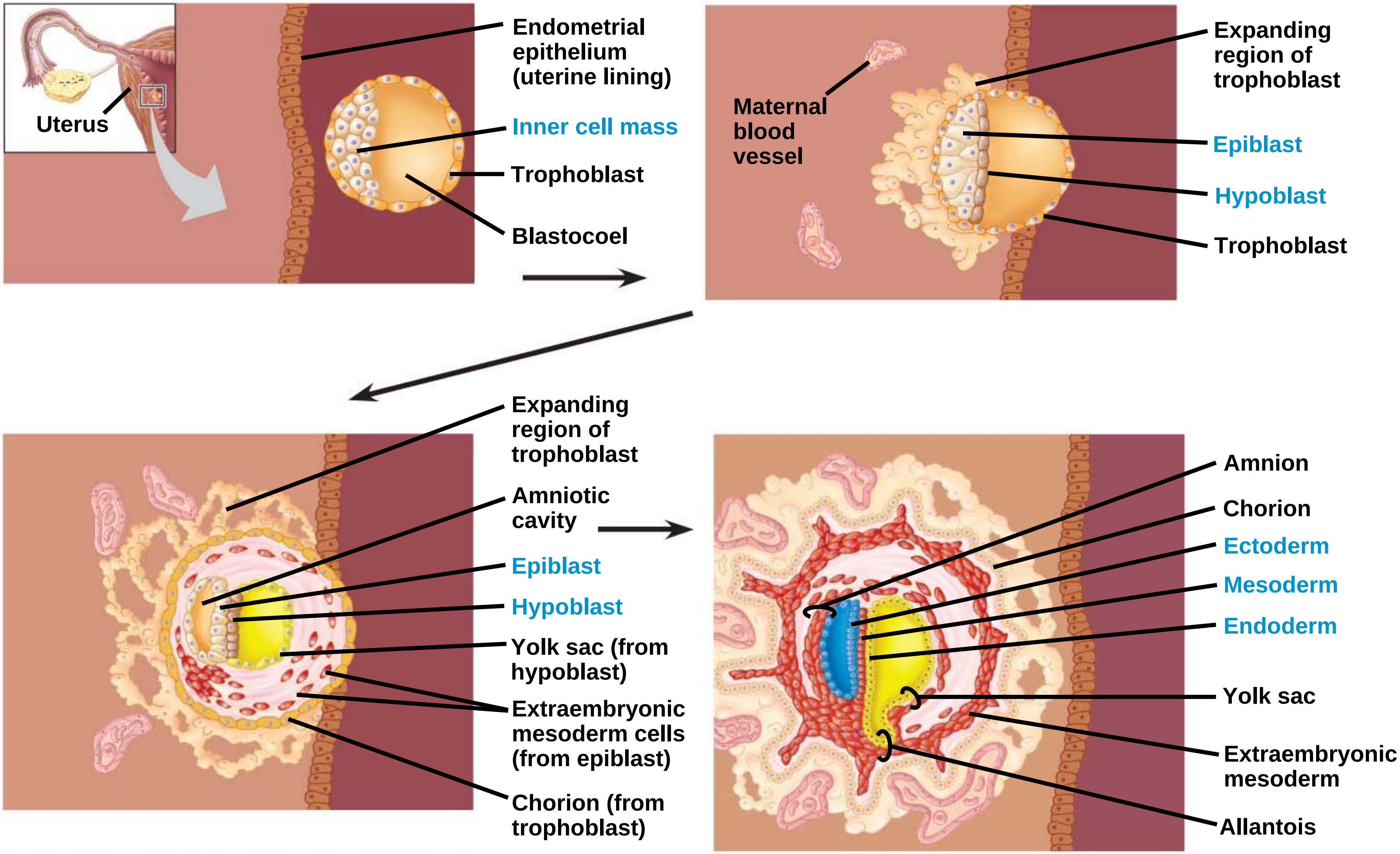

Amnion
Chorion
Ectoderm
Mesoderm
Endoderm
Yolk sac
Extraembryonic mesoderm
Atlantois

Fig. 47-16-5



Uterus
Endometrial epithelium (uterine lining)
Inner cell mass
Trophoblast
Blastocoel
Maternal blood vessel
Expanding region of trophoblast
Epiblast
Hypoblast
Trophoblast
Expanding region of trophoblast
Amniotic cavity
Epiblast
Hypoblast
Yolk sac (from hypoblast)
Extraembryonic mesoderm cells (from epiblast)
Chorion (from trophoblast)
Amnion
Chorion
Ectoderm
Mesoderm
Endoderm
Yolk sac
Extraembryonic mesoderm
Allantois

- The extraembryonic membranes in mammals are homologous to those of birds and other reptiles and develop in a similar way

Concept 47.2: Morphogenesis in animals involves specific changes in cell shape, position, and adhesion

- Morphogenesis is a major aspect of development in plants and animals
- Only in animals does it involve the *movement* of cells

The Cytoskeleton, Cell Motility, and Convergent Extension

- Changes in cell shape usually involve reorganization of the cytoskeleton
- Microtubules and microfilaments affect formation of the neural tube

Fig. 47-17-1

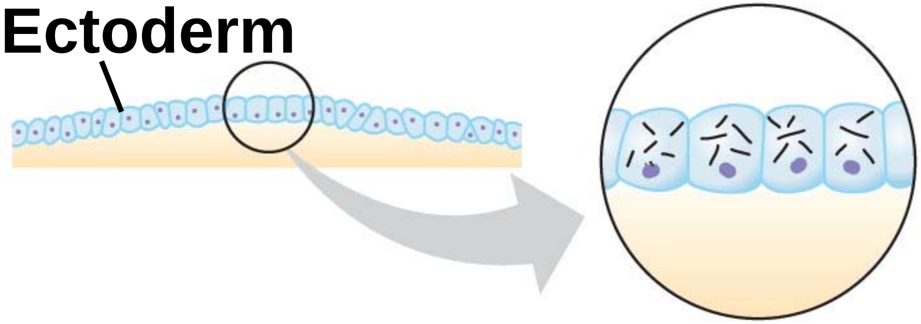


Fig. 47-17-2

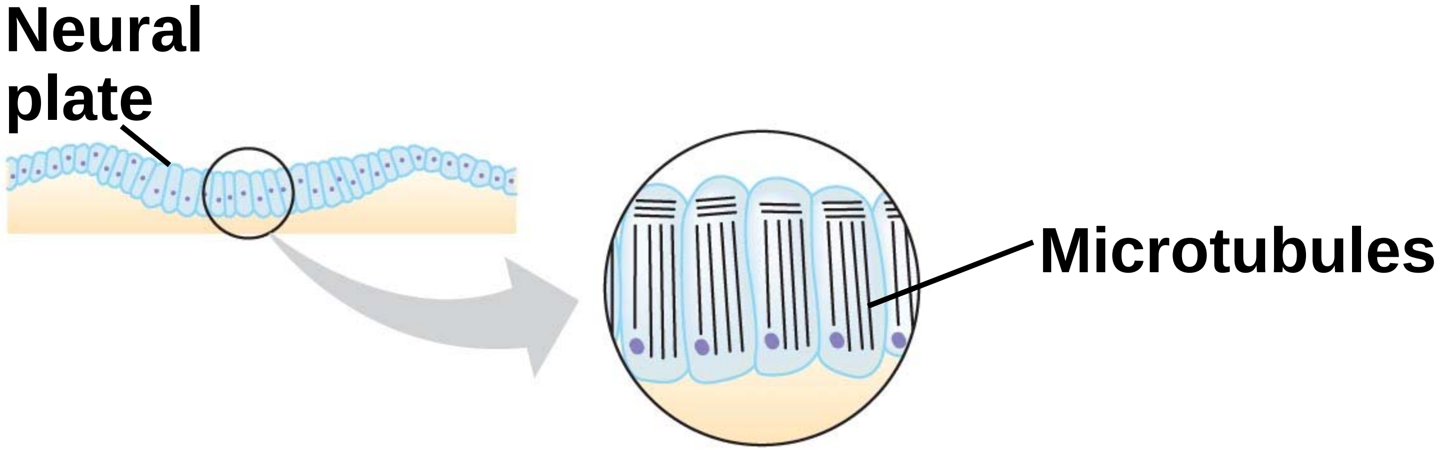


Fig. 47-17-3

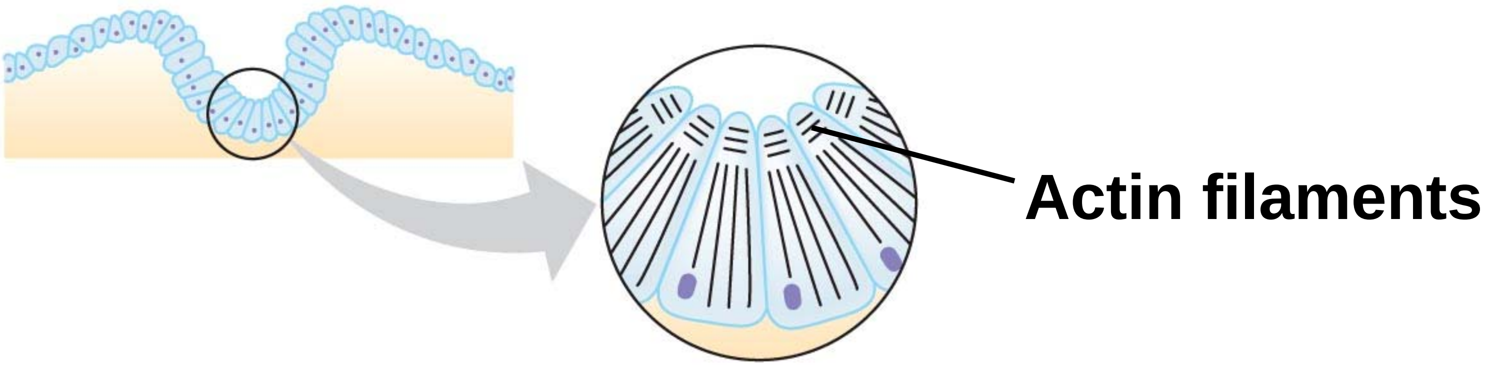


Fig. 47-17-4

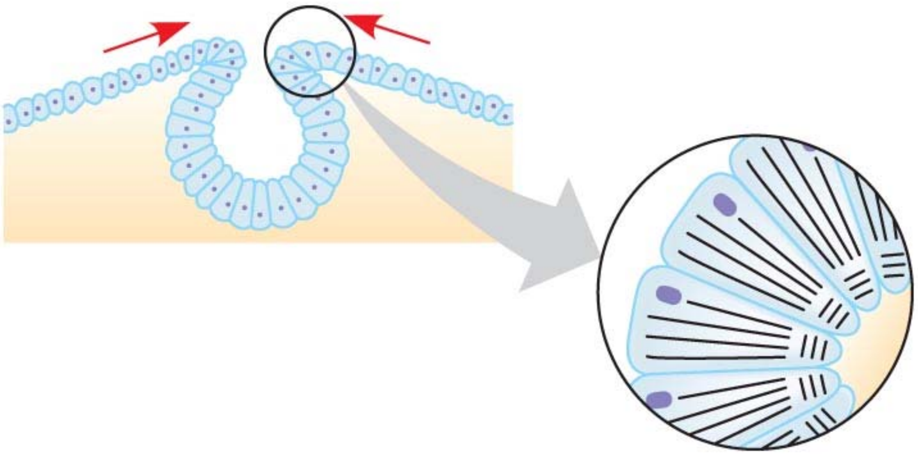


Fig. 47-17-5

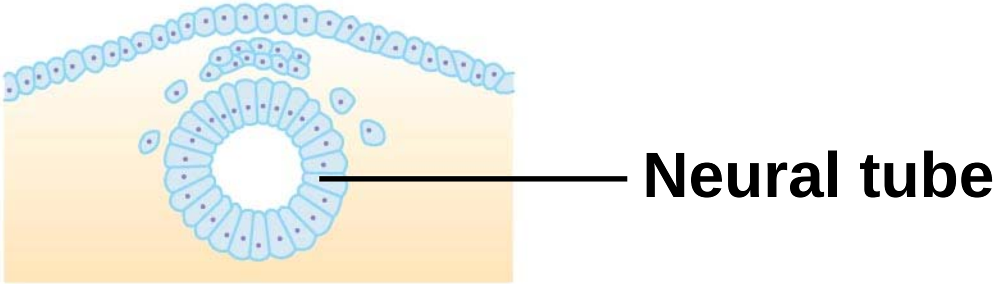
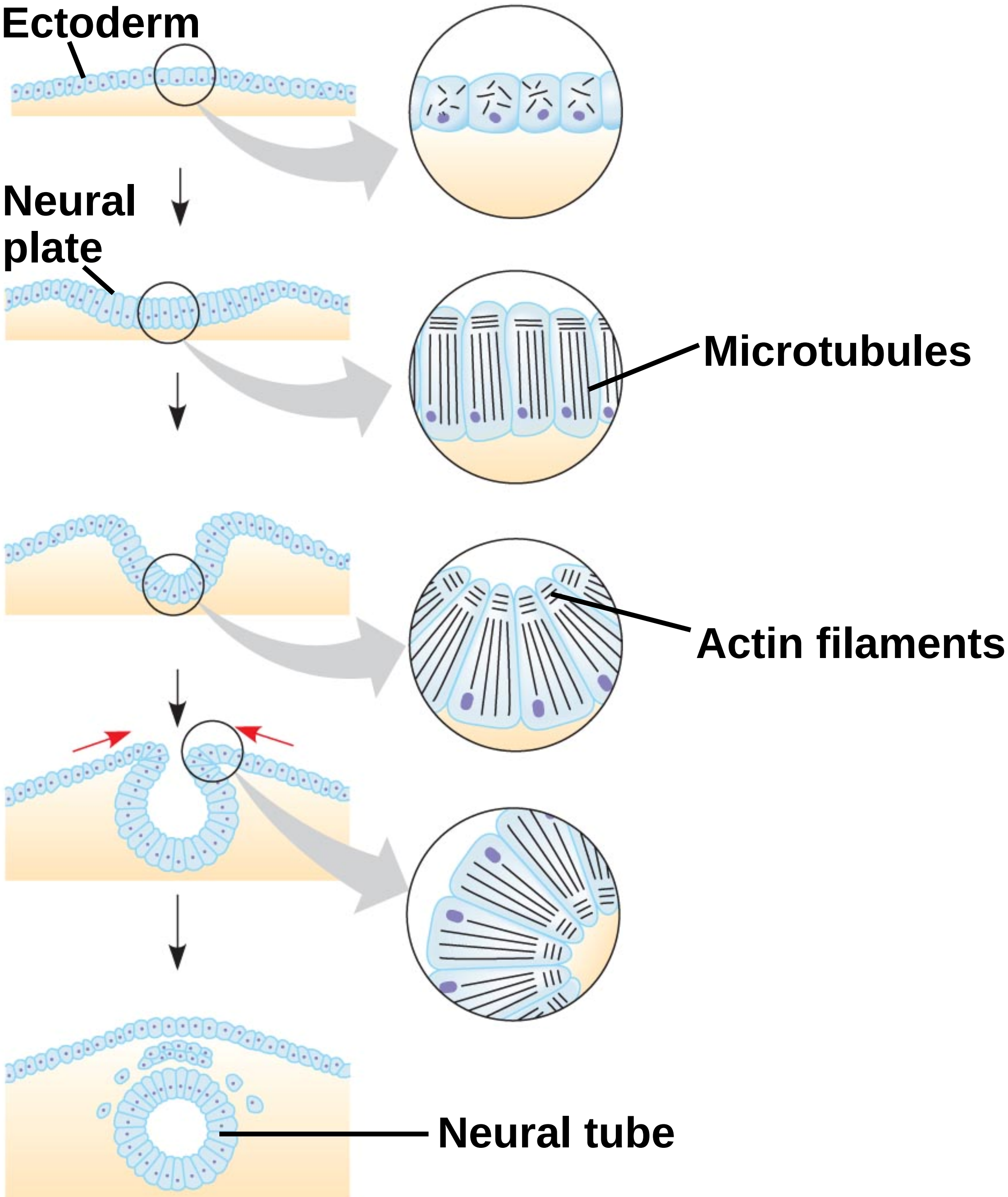


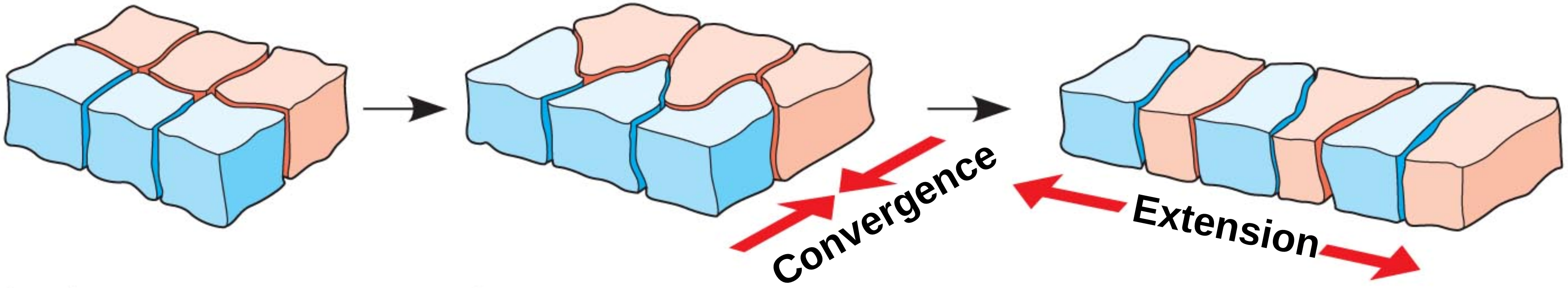
Fig. 47-17-6



Ectoderm
Neural plate
Microtubules
Actin filaments
Neural tube

- The cytoskeleton also drives cell migration, or cell crawling, the active movement of cells
- In gastrulation, tissue invagination is caused by changes in cell shape and migration
- Cell crawling is involved in **convergent extension**, a morphogenetic movement in which cells of a tissue become narrower and longer

Fig. 47-18

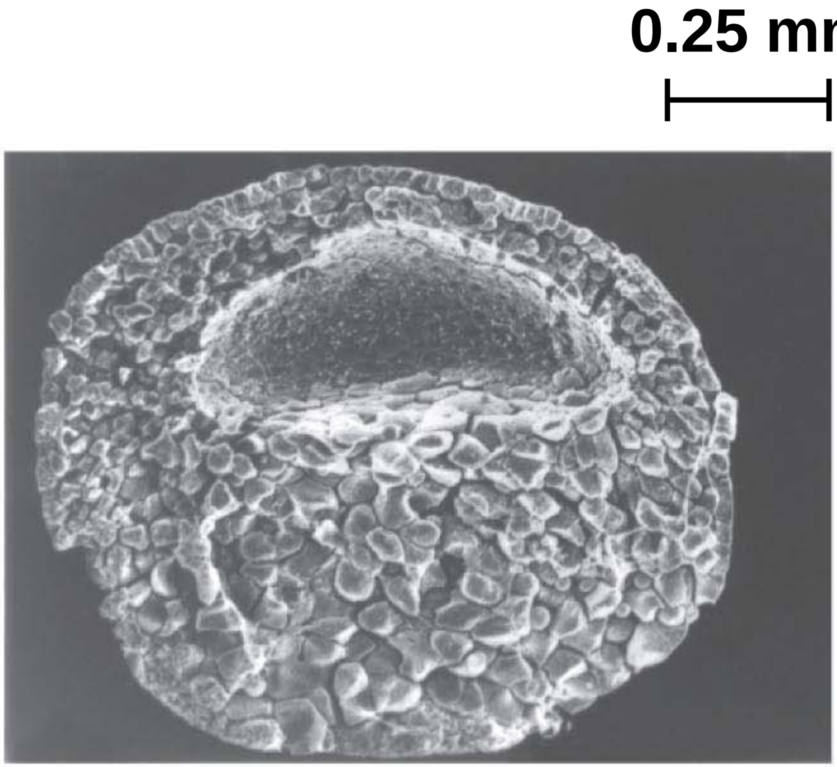


Role of Cell Adhesion Molecules and the Extracellular Matrix

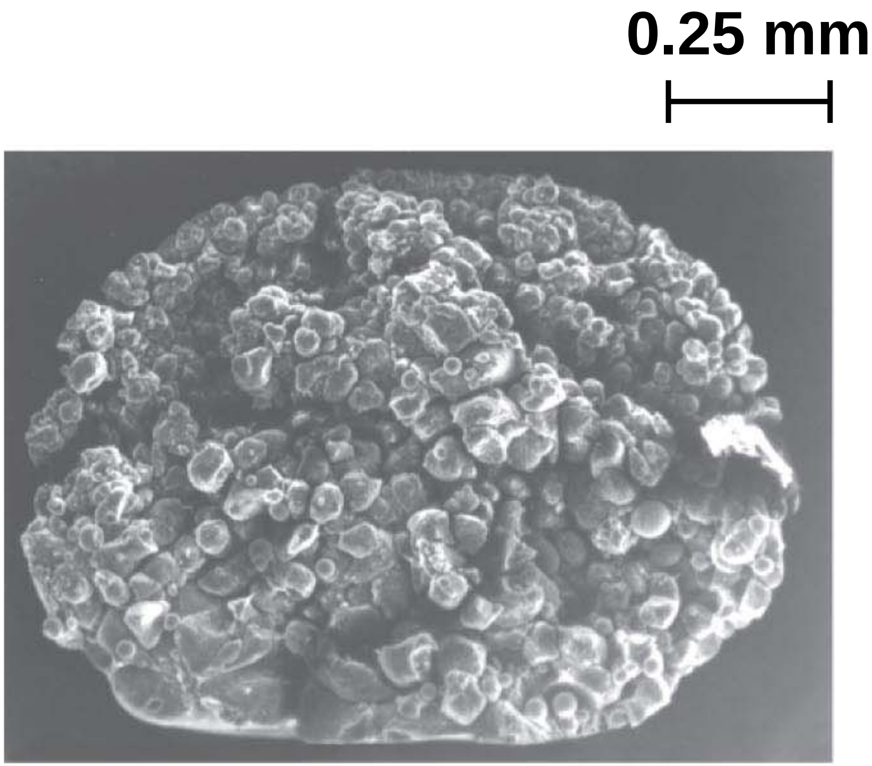
- **Cell adhesion molecules** located on cell surfaces contribute to cell migration and stable tissue structure
- One class of cell-to-cell adhesion molecule is the **cadherins**, which are important in formation of the frog blastula

Fig. 47-19

RESULTS



Control embryo



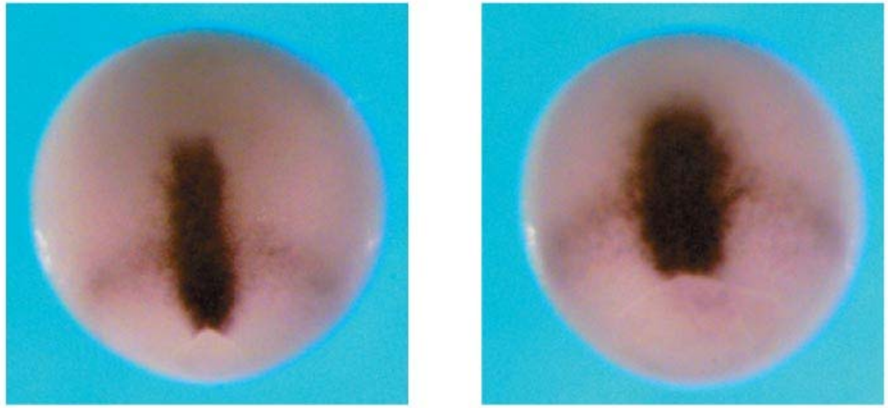
Embryo without EP cadherin

- Fibers of the extracellular matrix may function as tracks, directing migrating cells along routes
- Several kinds of glycoproteins, including fibronectin, promote cell migration by providing molecular anchorage for moving cells

Fig. 47-20

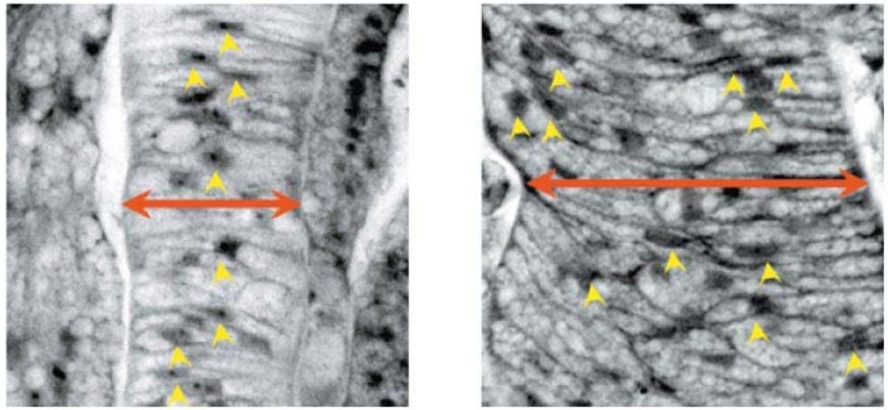
RESULTS

Experiment 1



Control Matrix blocked

Experiment 2

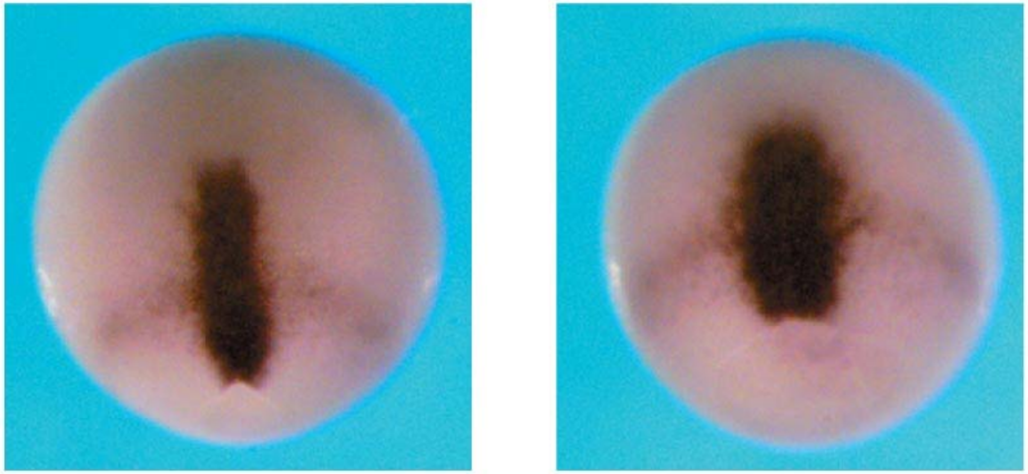


Control Matrix blocked

Fig. 47-20-1

RESULTS

Experiment 1

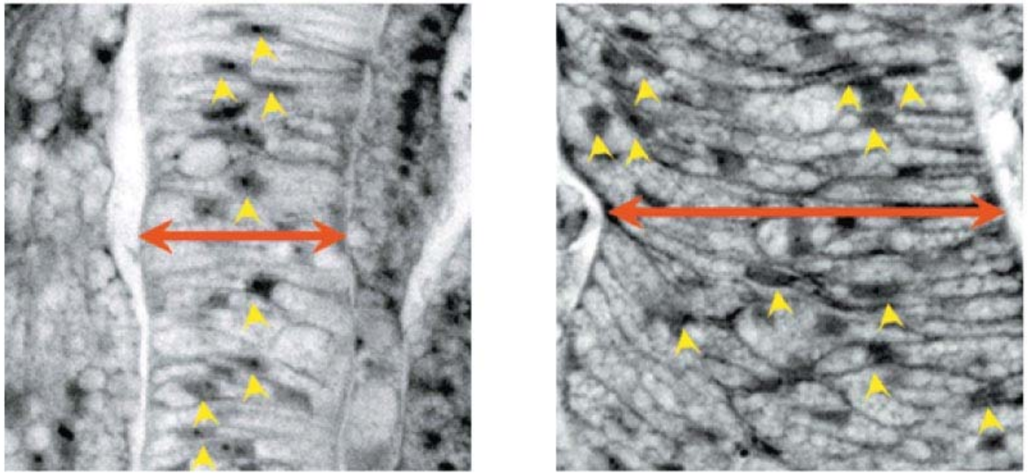


Control **Matrix blocked**

Fig. 47-20-2

RESULTS

Experiment 2



Control

Matrix blocked

Concept 47.3: The developmental fate of cells depends on their history and on inductive signals

- Cells in a multicellular organism share the same genome
- Differences in cell types is the result of differentiation, the expression of different genes

- Two general principles underlie differentiation:

1. During early cleavage divisions, embryonic cells must become different from one another
   - If the egg's cytoplasm is heterogenous, dividing cells vary in the cytoplasmic determinants they contain

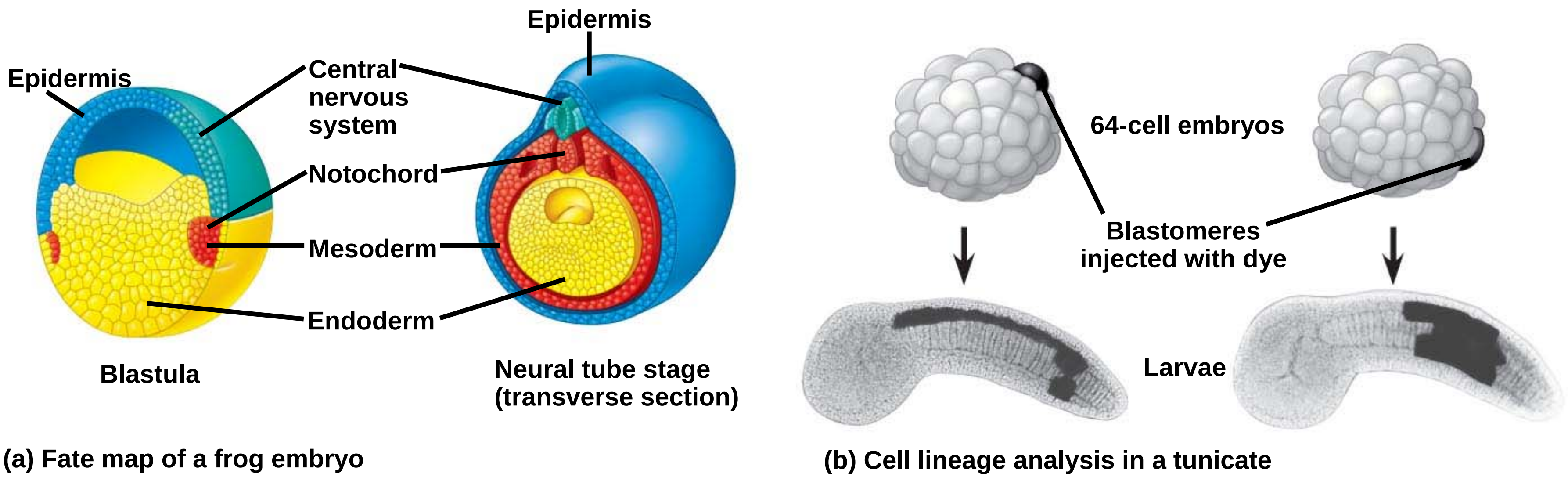
2. After cell asymmetries are set up, interactions among embryonic cells influence their fate, usually causing changes in gene expression

   – This mechanism is called **induction**, and is mediated by diffusible chemicals or cell-cell interactions

Fate Mapping

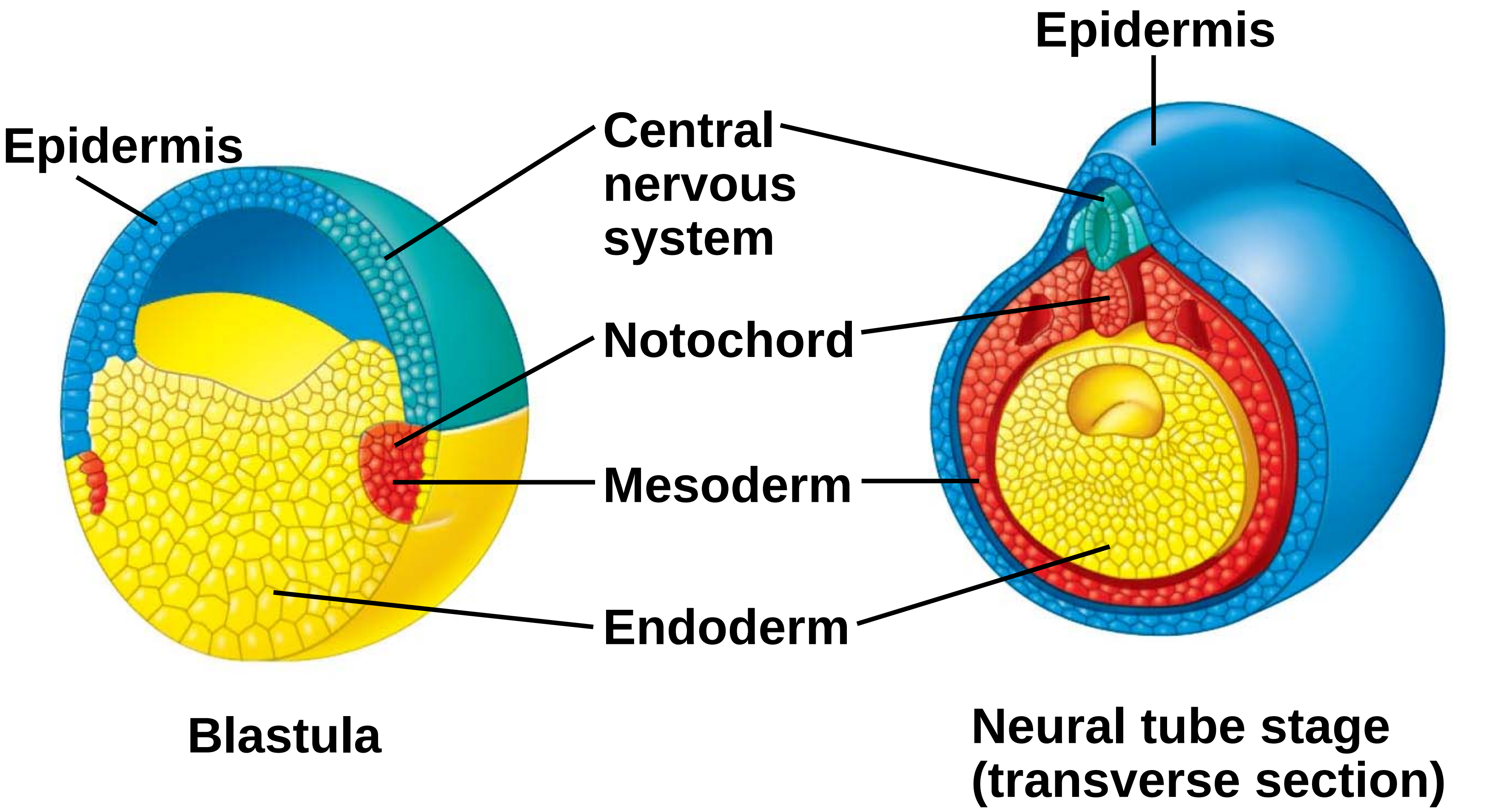
- **Fate maps** are general territorial diagrams of embryonic development
- Classic studies using frogs indicated that cell lineage in germ layers is traceable to blastula cells

Fig. 47-21



Epidermis
Epidermis
Central nervous system
Notochord
Mesoderm
Endoderm
Blastula
Neural tube stage (transverse section)
(a) Fate map of a frog embryo
64-cell embryos
Blastomeres injected with dye
Larvae
(b) Cell lineage analysis in a tunicate

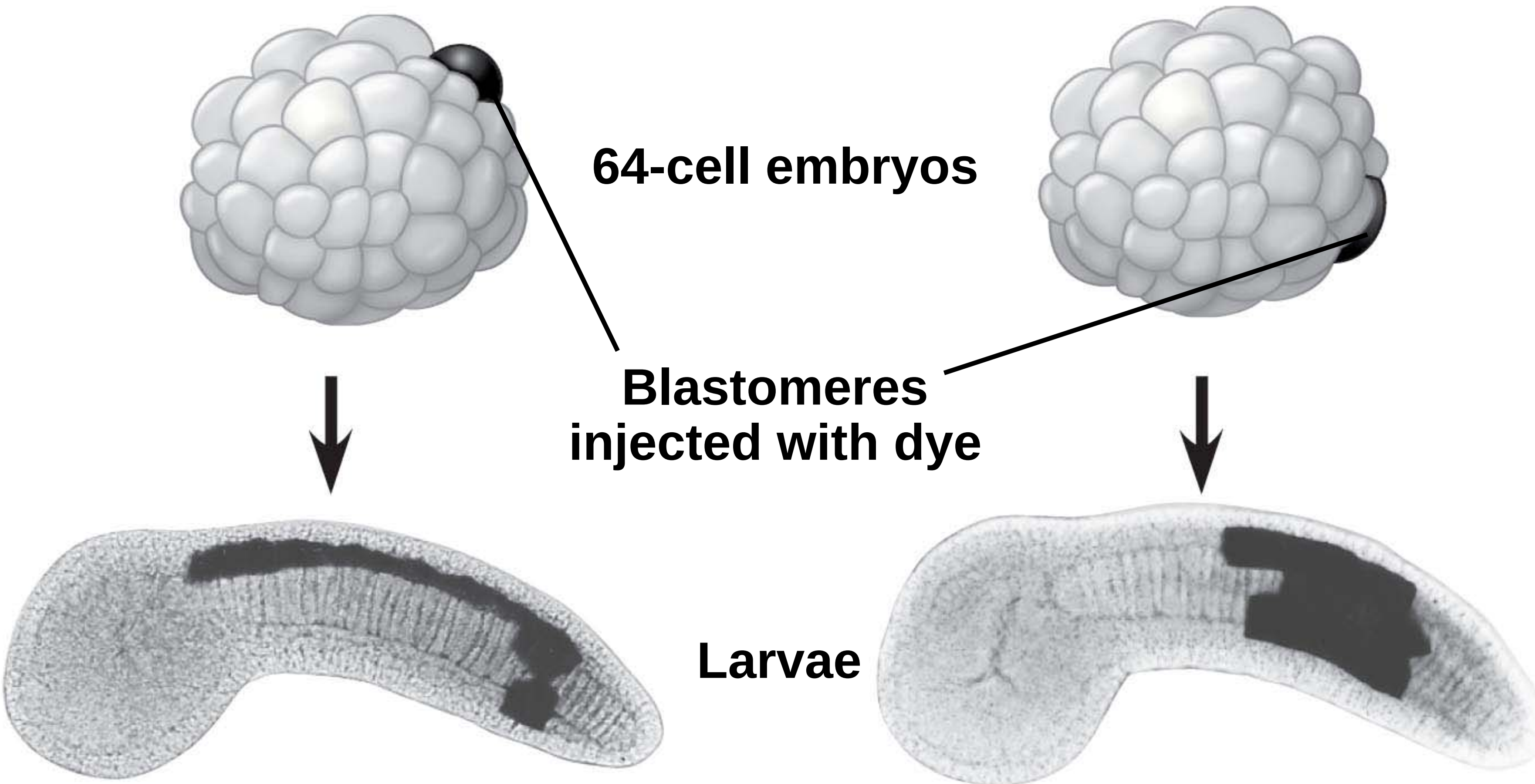
Fig. 47-21a



(a) Fate map of a frog embryo

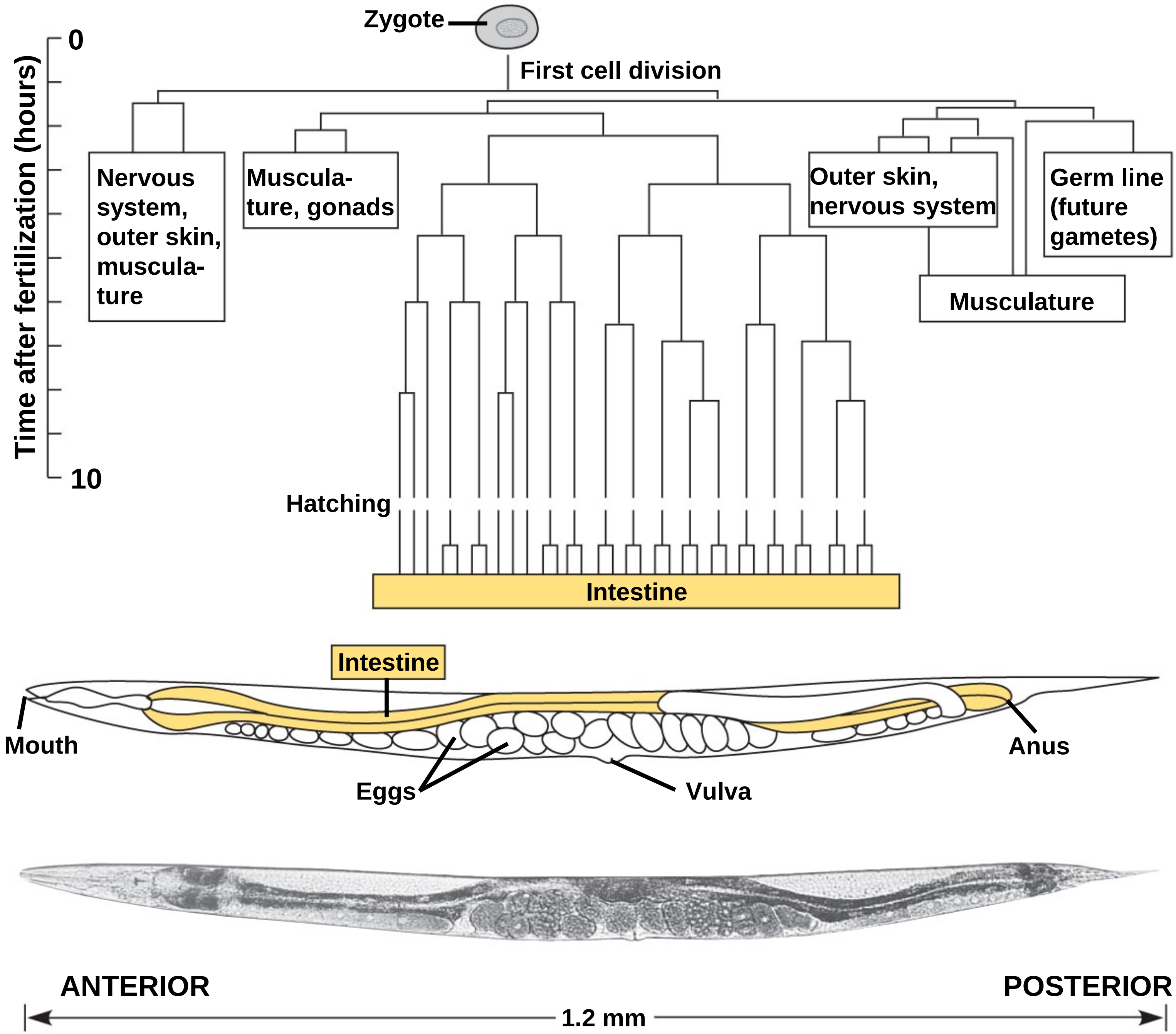
- Techniques in later studies marked an individual blastomere during cleavage and followed it through development

Fig. 47-21b



(b) Cell lineage analysis in a tunicate

Fig. 47-22


Zygote
First cell division
Time after fertilization (hours)
0
10
Nervous system, outer skin, muscula-ture
Muscula-ture, gonads
Outer skin, nervous system
Germ line (future gametes)
Musculature
Hatching
Intestine
Intestine
Mouth
Eggs
Vulva
Anus
ANTERIOR
POSTERIOR
1.2 mm

Establishing Cellular Asymmetries

- To understand how embryonic cells acquire their fates, think about how basic axes of the embryo are established

The Axes of the Basic Body Plan

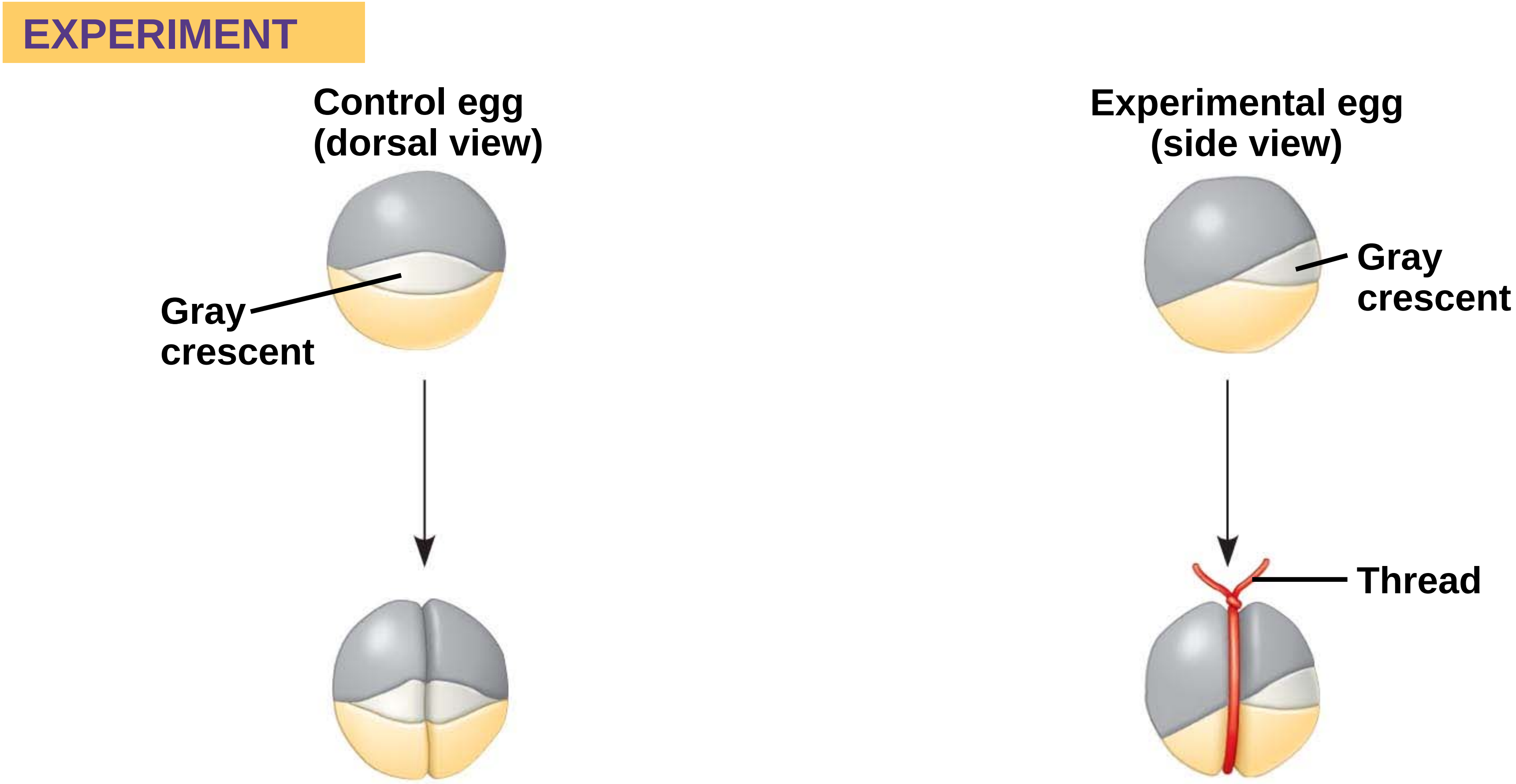
- In nonamniotic vertebrates, basic instructions for establishing the body axes are set down early during oogenesis, or fertilization
- In amniotes, local environmental differences play the major role in establishing initial differences between cells and the body axes

Restriction of the Developmental Potential of Cells

- In many species that have cytoplasmic determinants, only the zygote is **totipotent**
- That is, only the zygote can develop into all the cell types in the adult

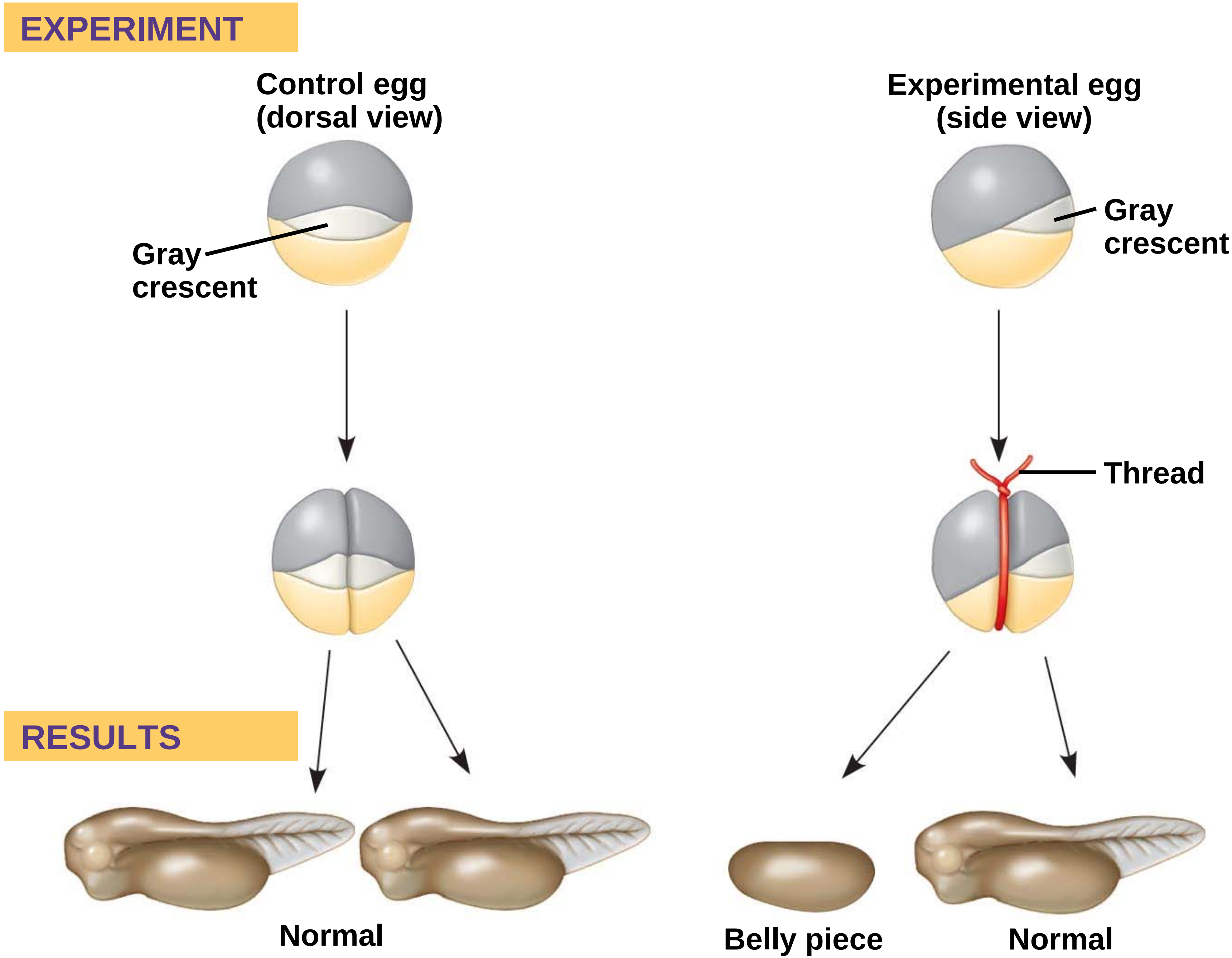
- Unevenly distributed cytoplasmic determinants in the egg cell help establish the body axes
- These determinants set up differences in blastomeres resulting from cleavage

Fig. 47-23a



EXPERIMENT
Control egg
(dorsal view)
Gray
crescent
Experimental egg
(side view)
Gray
crescent
Thread

Fig. 47-23b


EXPERIMENT
Control egg
(dorsal view)
Gray
crescent
Experimental egg
(side view)
Gray
crescent
Thread
RESULTS
Normal
Belly piece
Normal

- As embryonic development proceeds, potency of cells becomes more limited

Cell Fate Determination and Pattern Formation by Inductive Signals

- After embryonic cell division creates cells that differ from each other, the cells begin to influence each other's fates by induction

The "Organizer" of Spemann and Mangold

- Based on their famous experiment, Hans Spemann and Hilde Mangold concluded that the blastopore's dorsal lip is an organizer of the embryo
- The Spemann organizer initiates inductions that result in formation of the notochord, neural tube, and other organs

Fig. 47-24

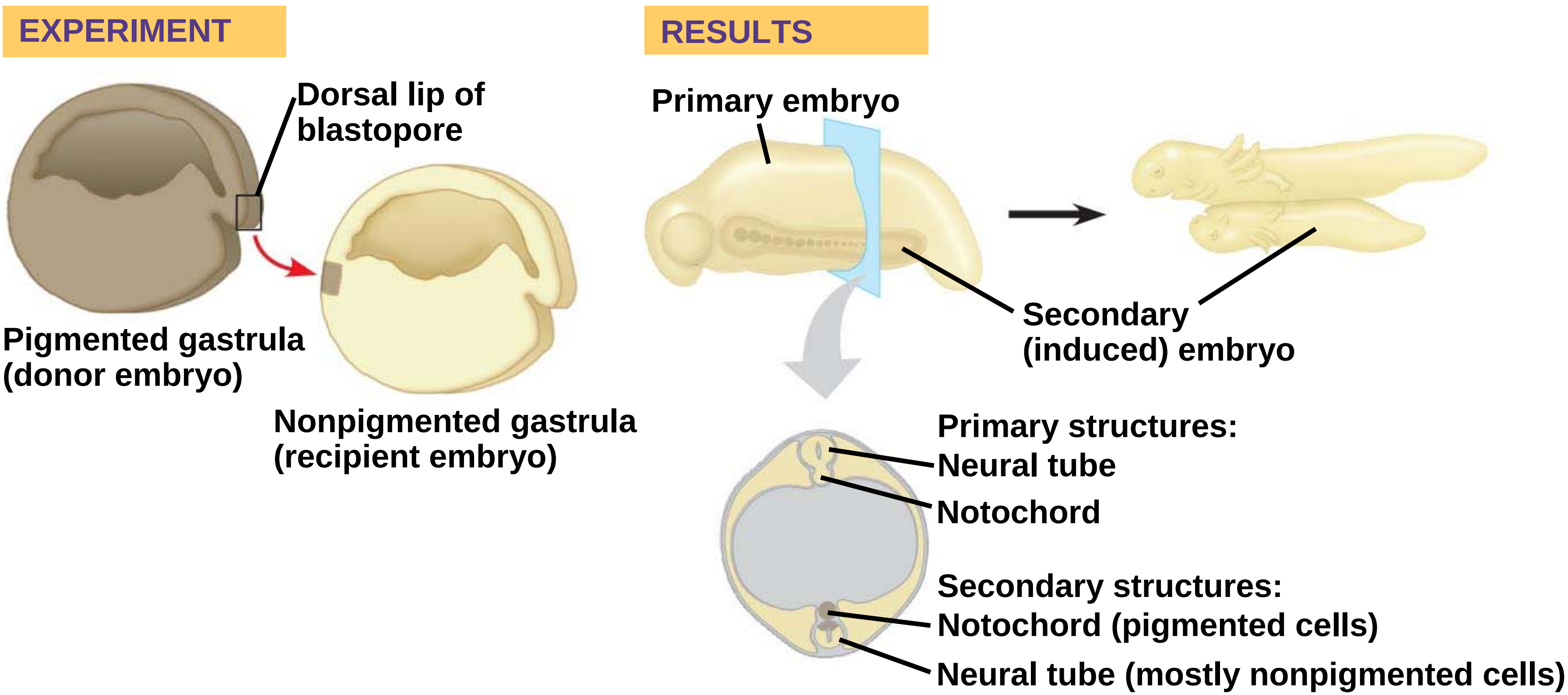

EXPERIMENT
Dorsal lip of blastopore
Pigmented gastrula (donor embryo)
Nonpigmented gastrula (recipient embryo)
RESULTS
Primary embryo
Secondary (induced) embryo
Primary structures:
Neural tube
Notochord
Secondary structures:
Notochord (pigmented cells)
Neural tube (mostly nonpigmented cells)

Fig. 47-24a

EXPERIMENT

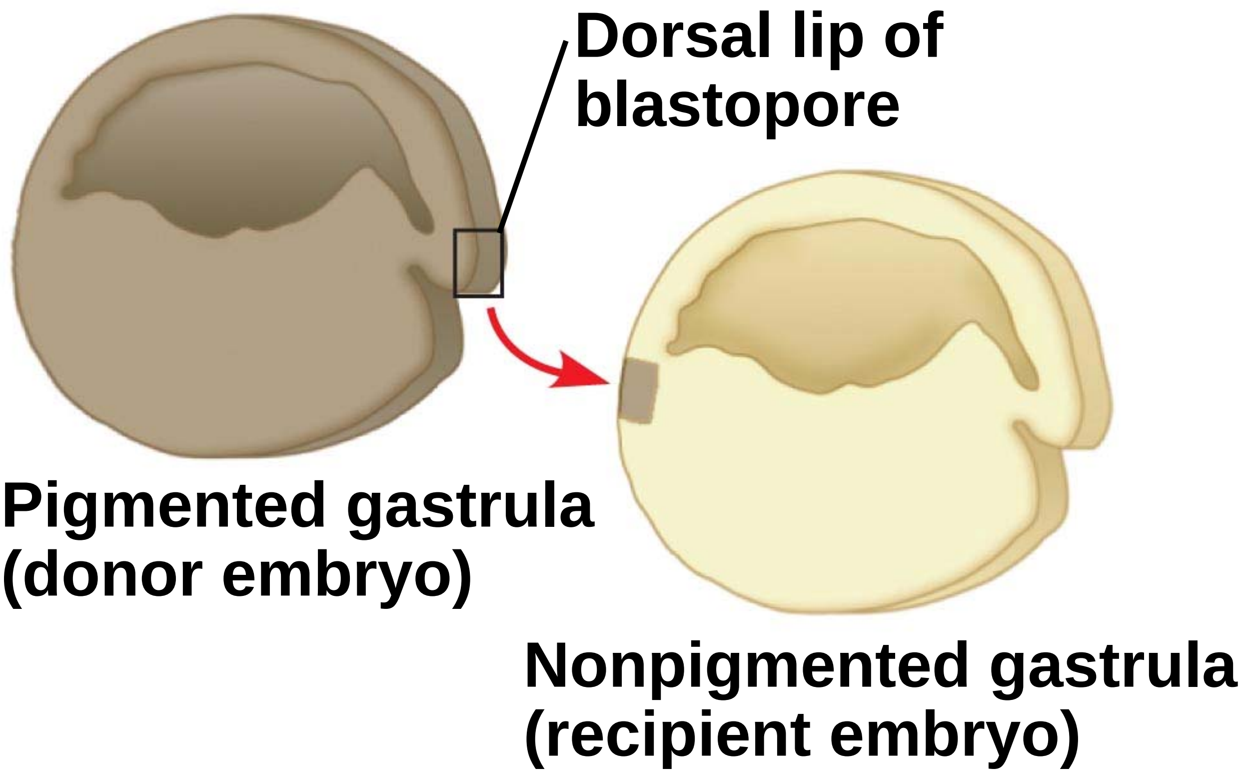
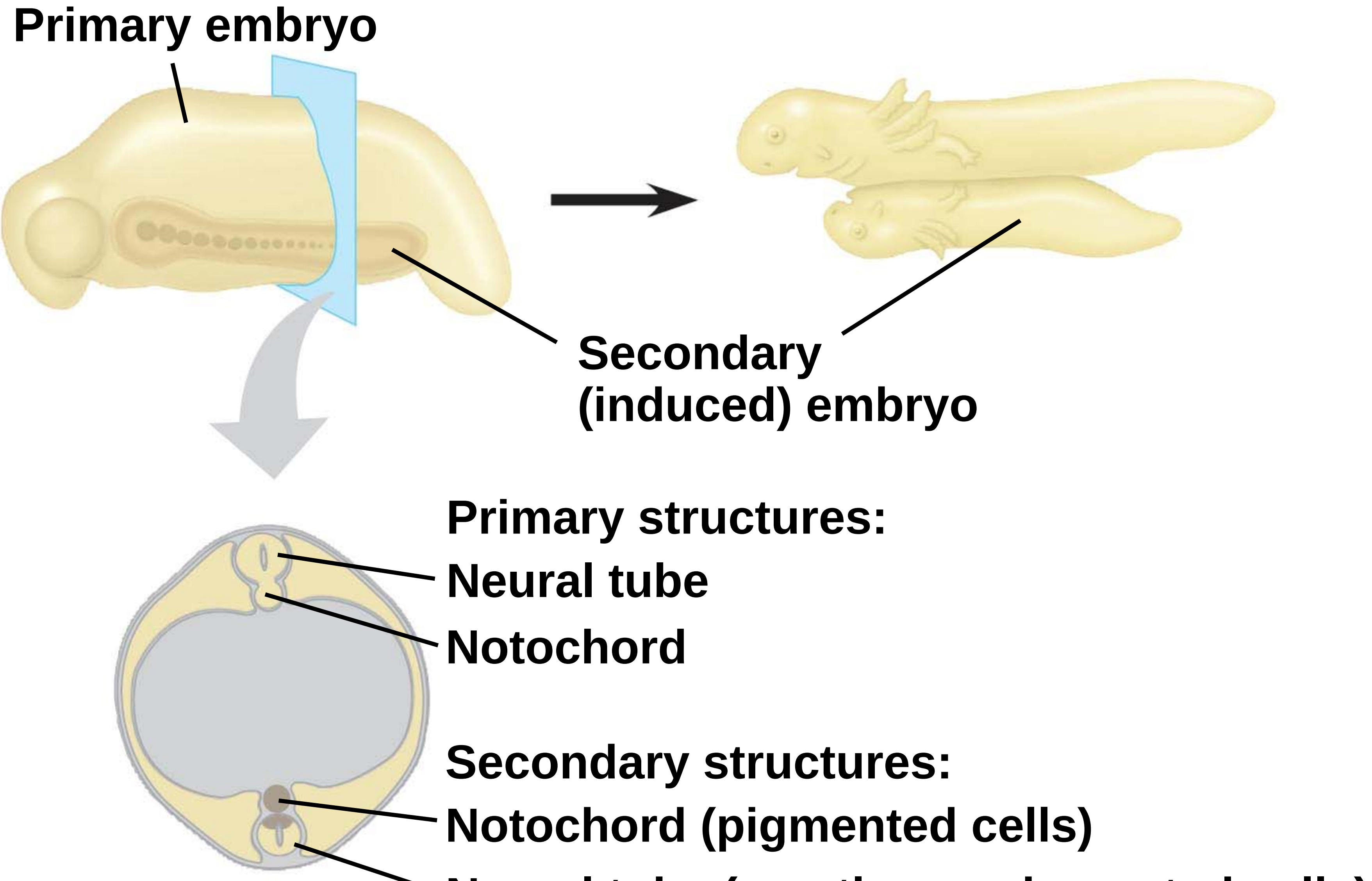


Fig. 47-24b

RESULTS

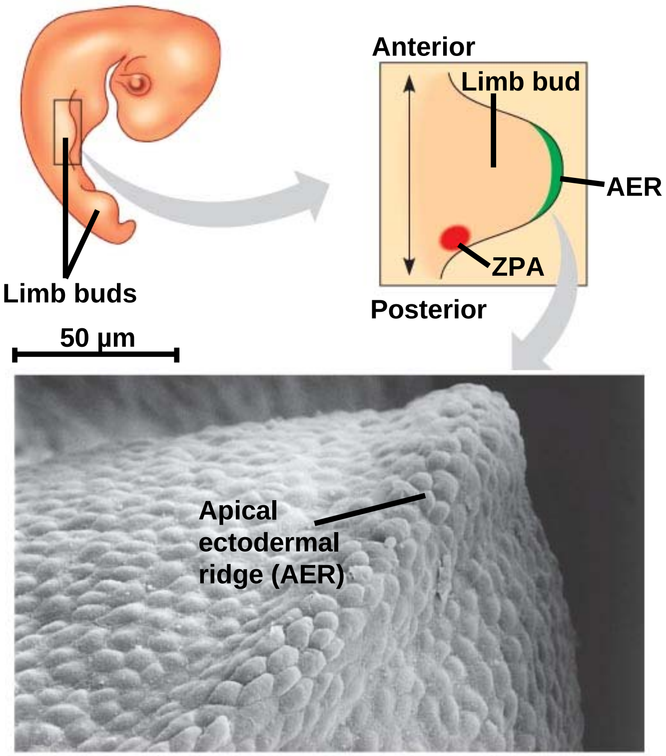


Formation of the Vertebrate Limb

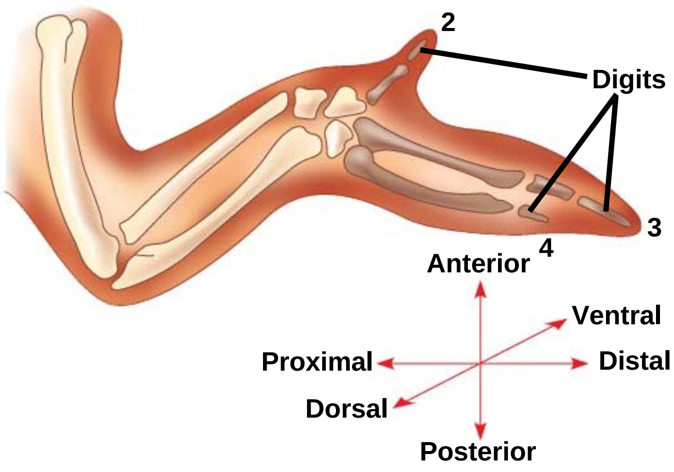
- Inductive signals play a major role in **pattern formation**, development of spatial organization
- The molecular cues that control pattern formation are called **positional information**
- This information tells a cell where it is with respect to the body axes
- It determines how the cell and its descendents respond to future molecular signals

- The wings and legs of chicks, like all vertebrate limbs, begin as bumps of tissue called limb buds

Fig. 47-25

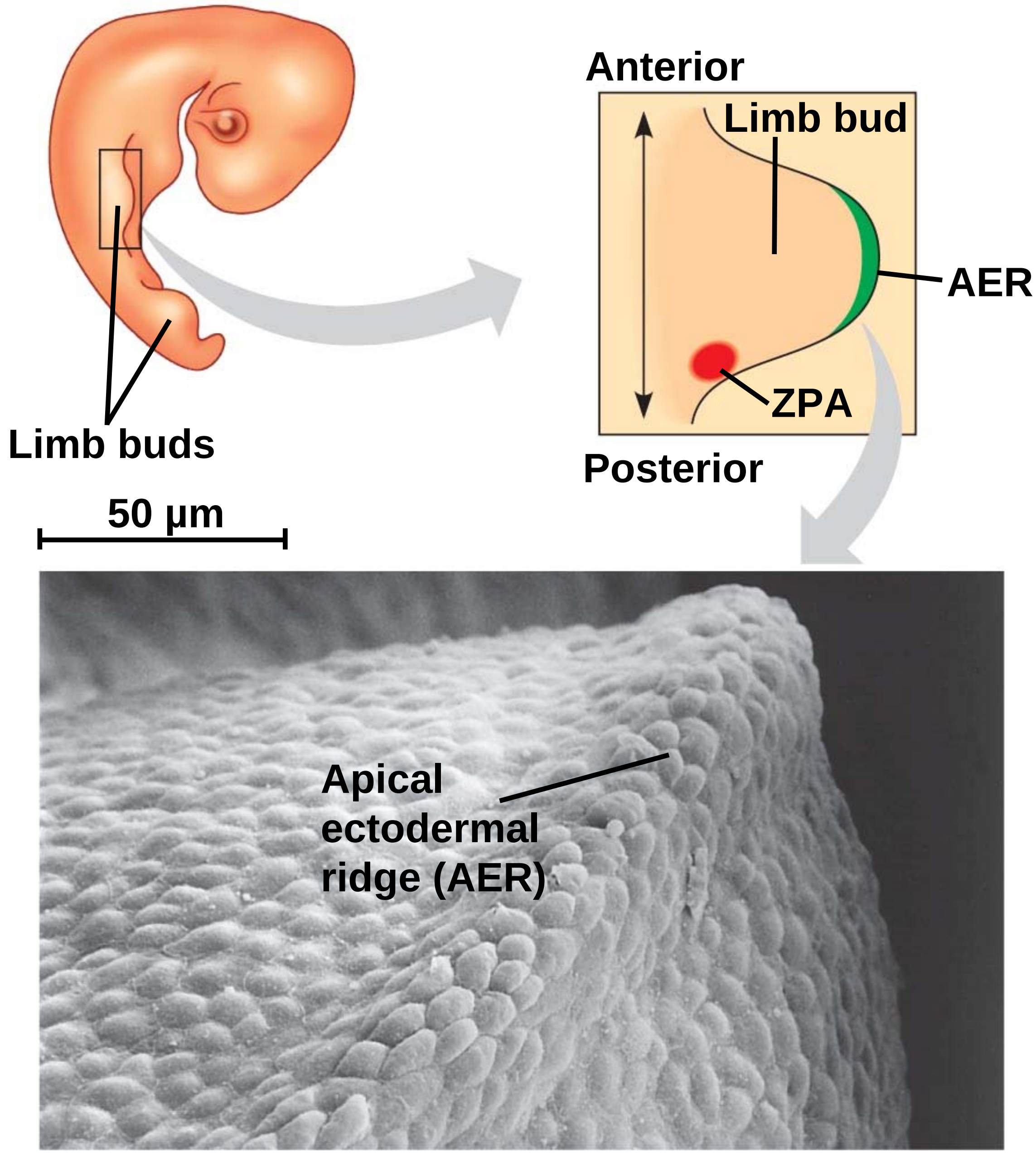


(a) Organizer regions



(b) Wing of chick embryo

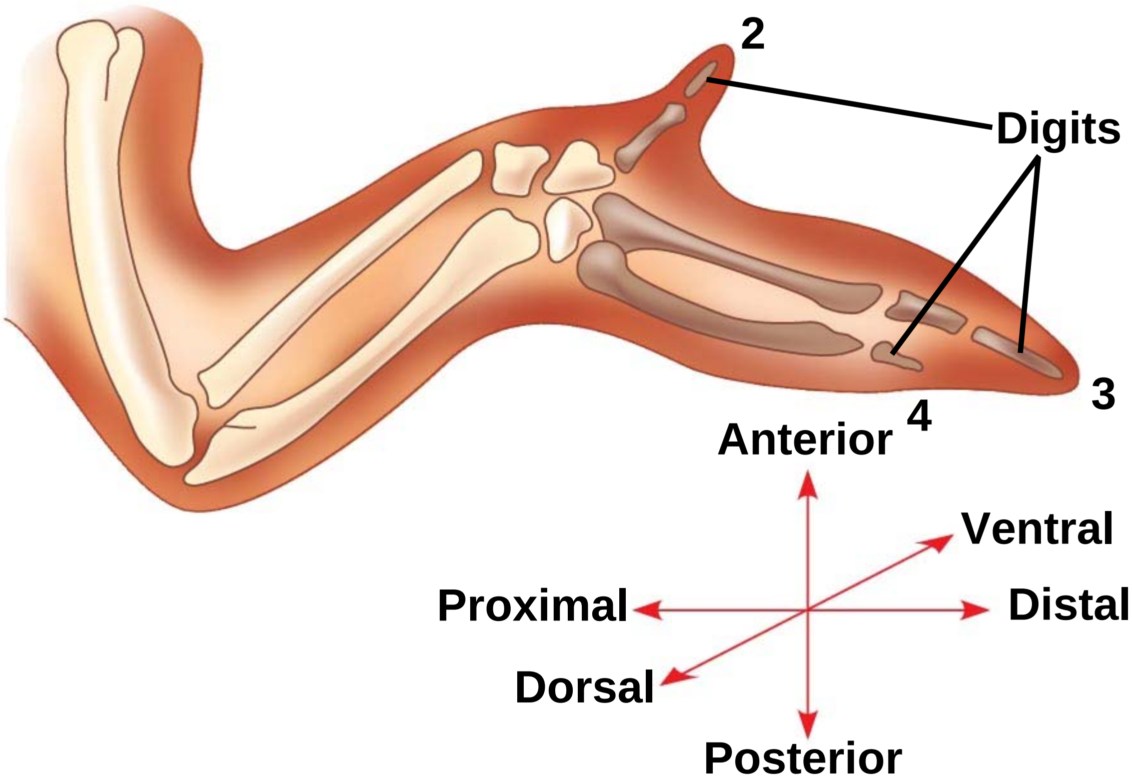
Fig. 47-25a



(a) Organizer regions

- The embryonic cells in a limb bud respond to positional information indicating location along three axes
  - Proximal-distal axis
  - Anterior-posterior axis
  - Dorsal-ventral axis

Fig. 47-25b



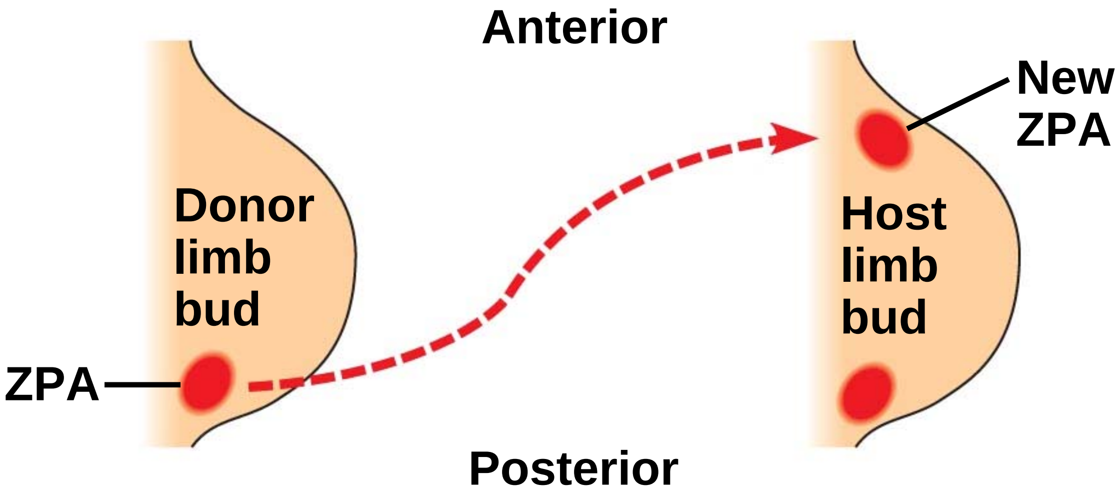
(b) Wing of chick embryo

- One limb-bud organizer region is the **apical ectodermal ridge (AER)**
- The AER is thickened ectoderm at the bud's tip
- The second region is the **zone of polarizing activity (ZPA)**
- The ZPA is mesodermal tissue under the ectoderm where the posterior side of the bud is attached to the body

- Tissue transplantation experiments support the hypothesis that the ZPA produces an inductive signal that conveys positional information indicating “posterior”

Fig. 47-26

EXPERIMENT



RESULTS

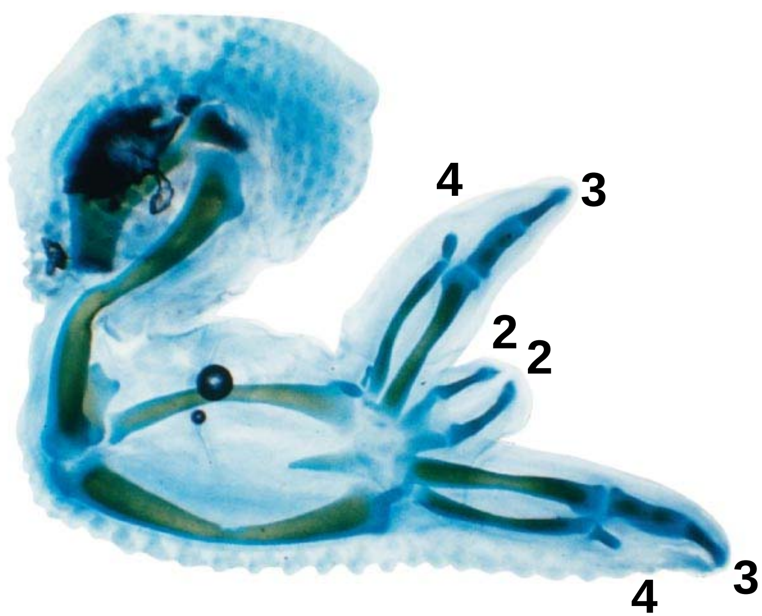


Fig. 47-26a

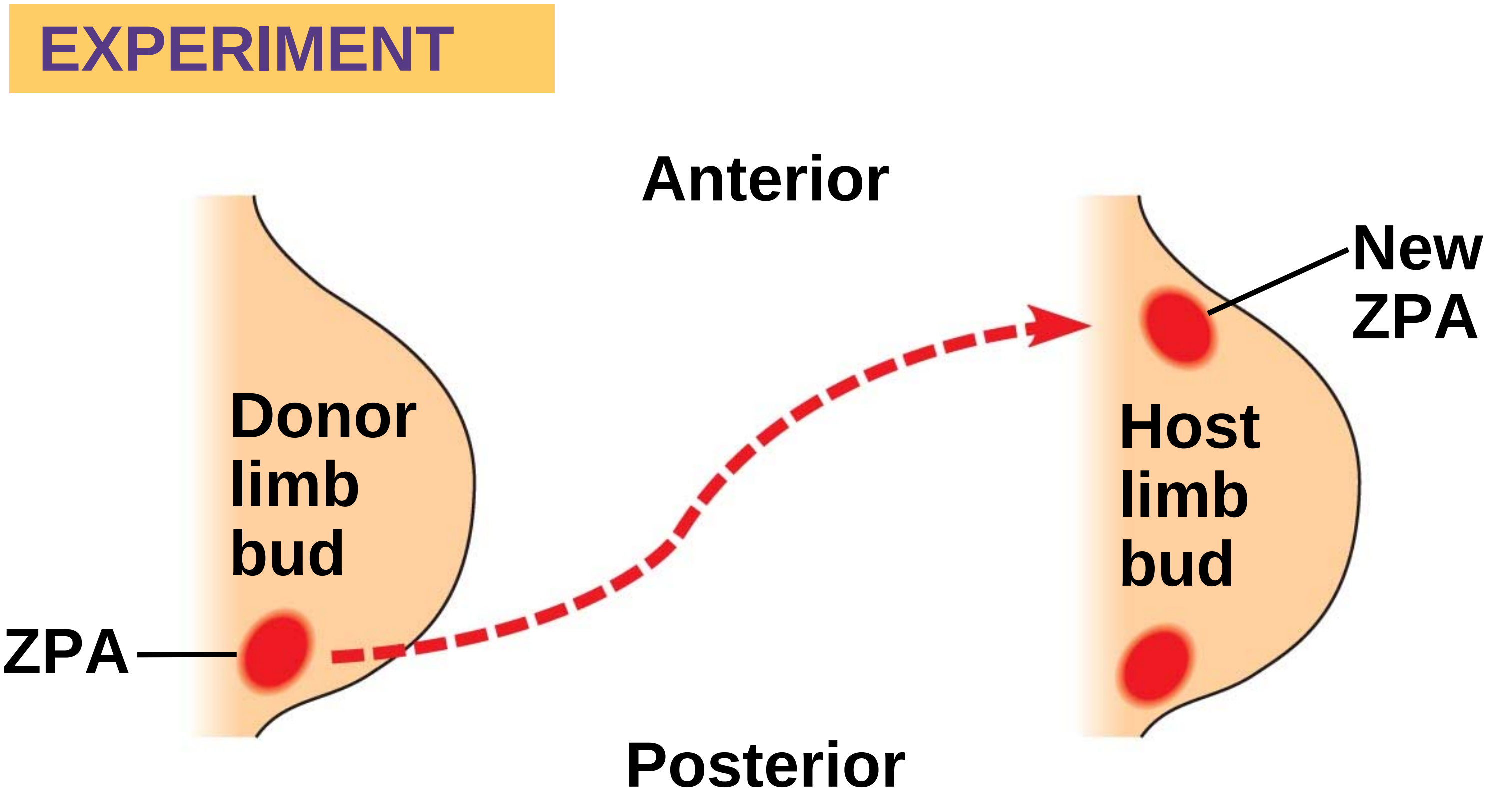
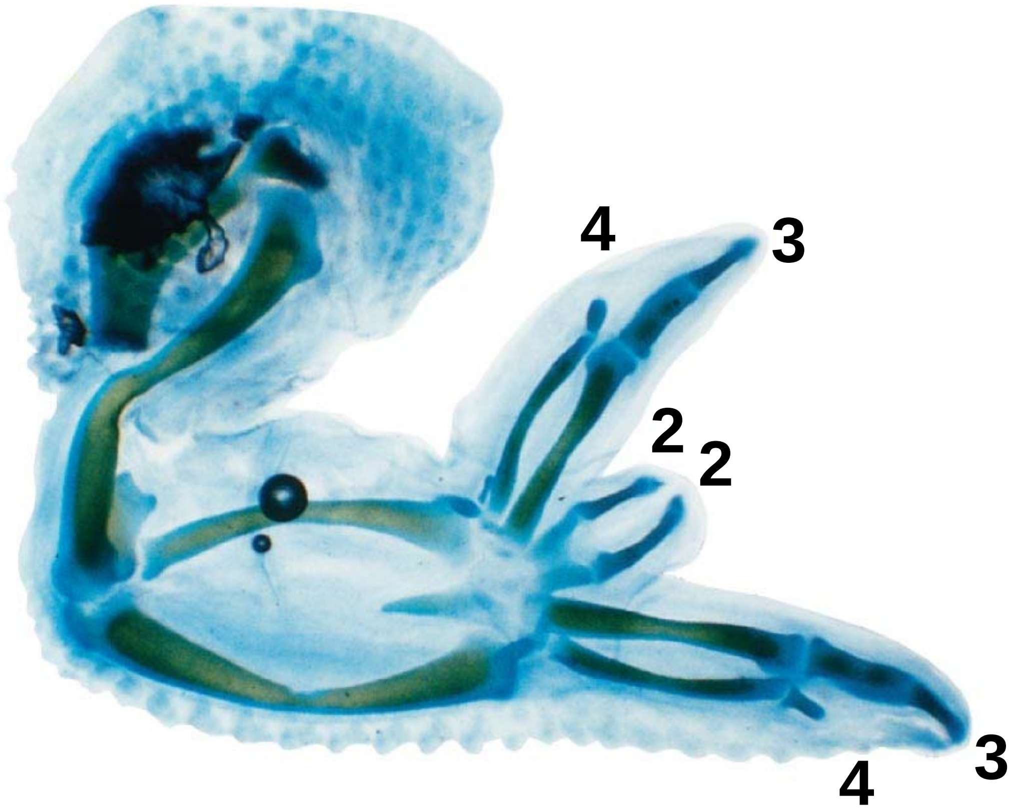

EXPERIMENT
Anterior
New
ZPA
Donor
limb
bud
Host
limb
bud
ZPA
Posterior

Fig. 47-26b

RESULTS



- Signal molecules produced by inducing cells influence gene expression in cells receiving them

- Signal molecules lead to differentiation and the development of particular structures

- *Hox* genes also play roles during limb pattern formation

Fig. 47-27

Fig. 47-UN1

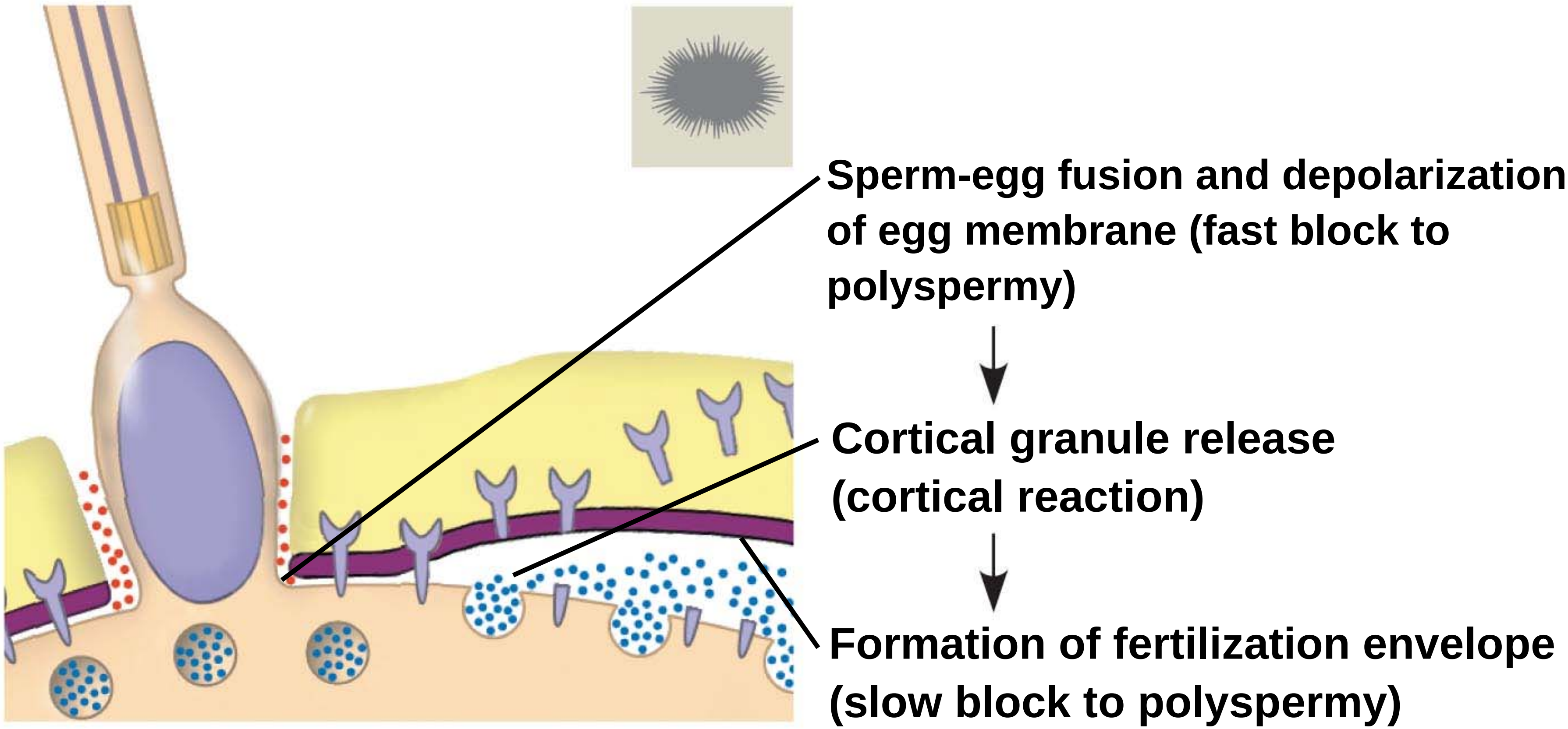

Sperm-egg fusion and depolarization of egg membrane (fast block to polyspermy)
Cortical granule release (cortical reaction)
Formation of fertilization envelope (slow block to polyspermy)

Fig. 47-UN2

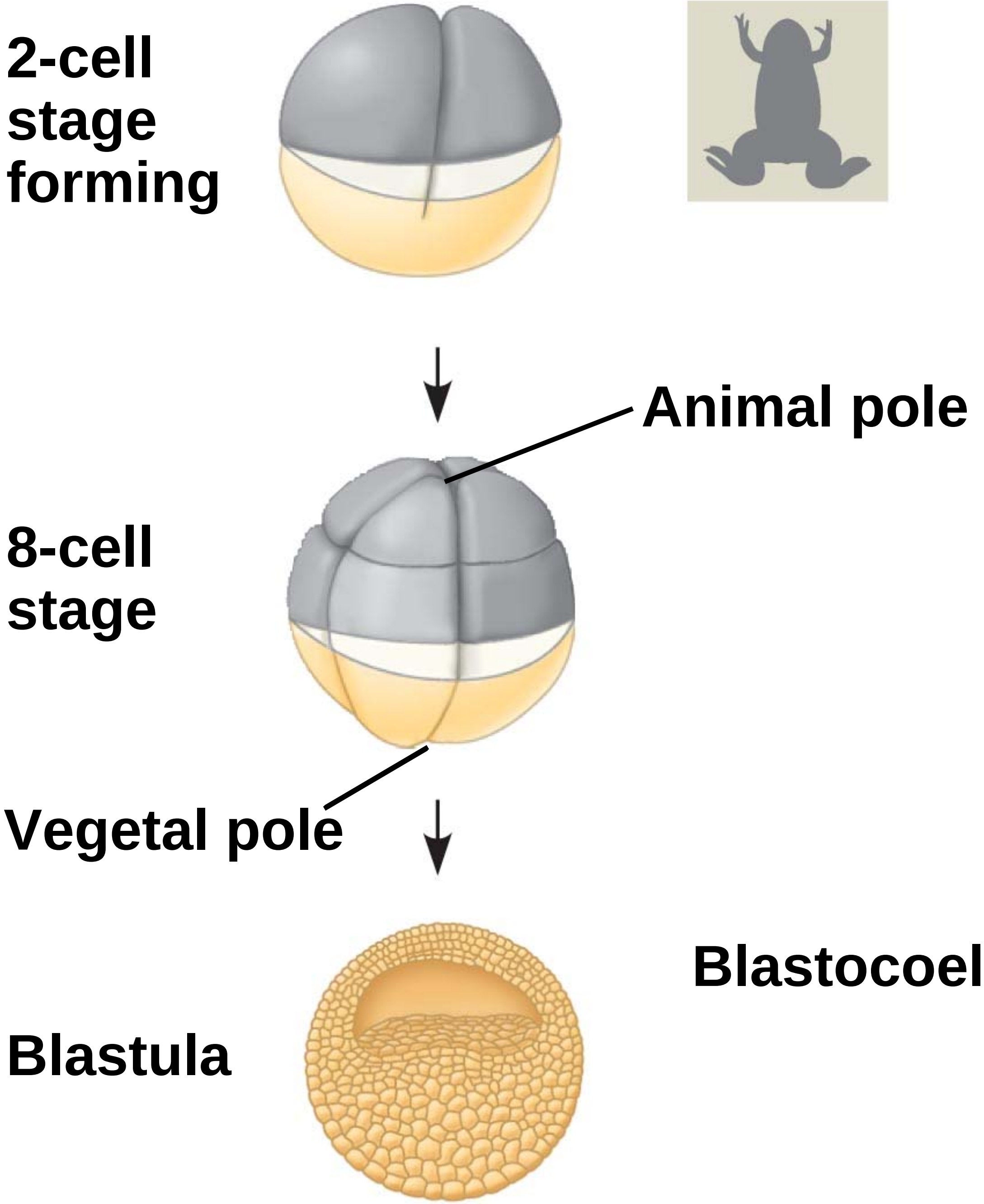

2-cell stage forming
Animal pole
8-cell stage
Vegetal pole
Blastocoel
Blastula

Fig. 47-UN3

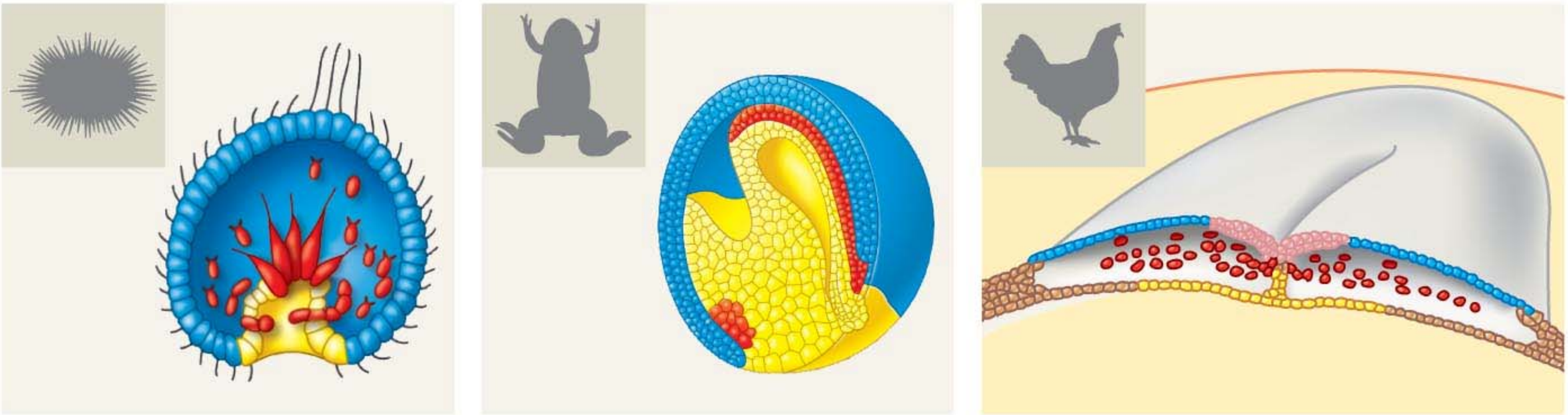


Fig. 47-UN4

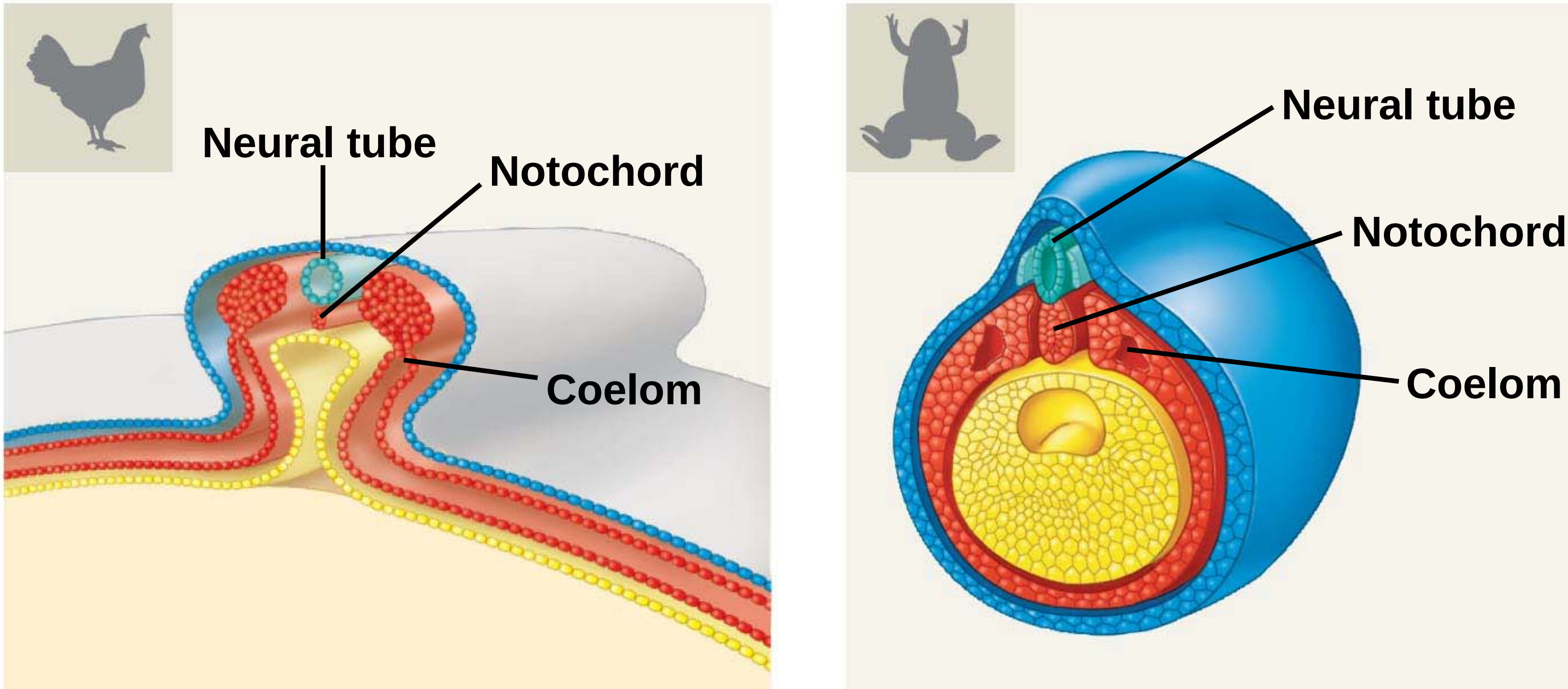
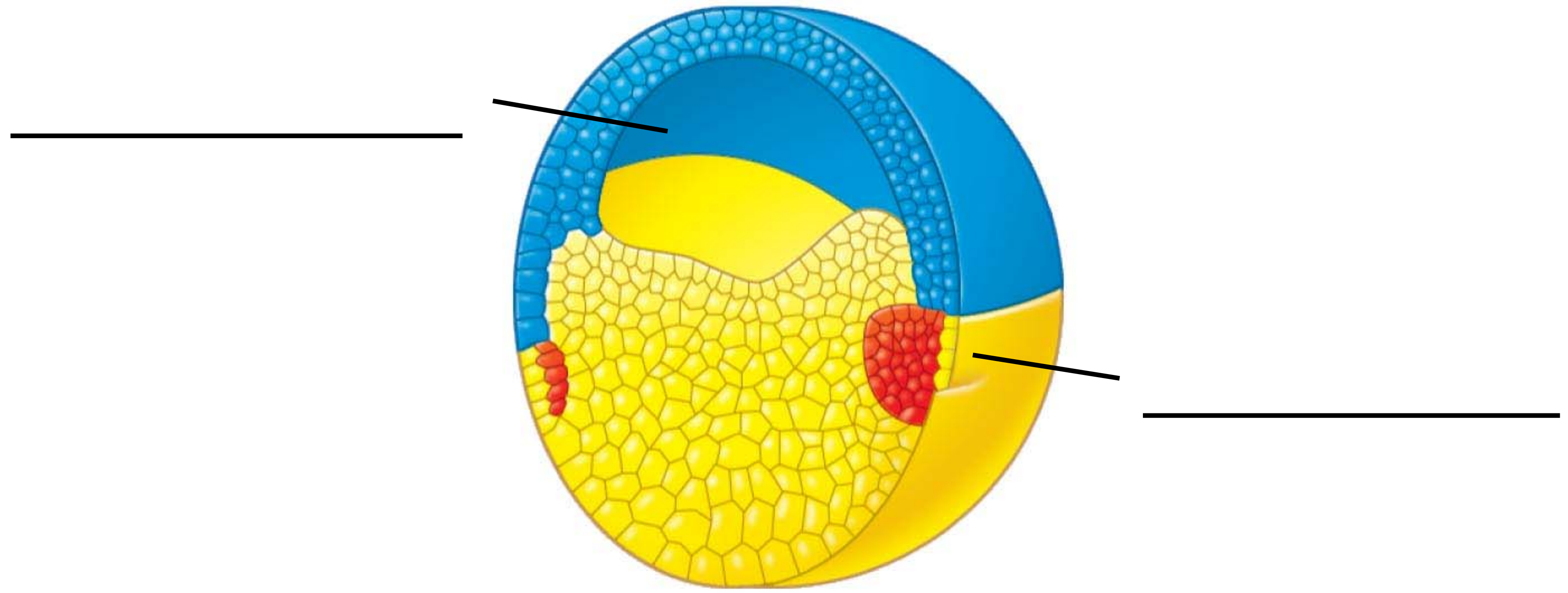

Neural tube
Notochord
Coelom
Neural tube
Notochord
Coelom

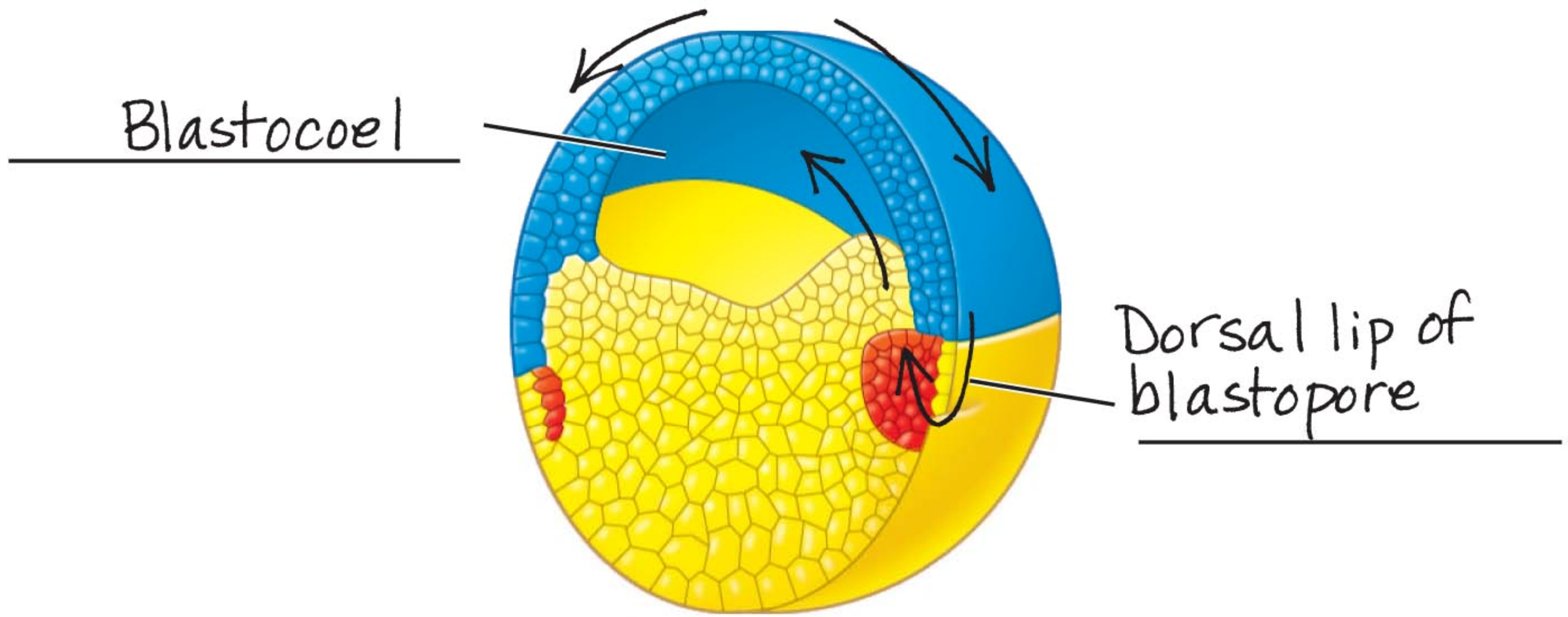
Fig. 47-UN5



Species: ____________________

Stage: ____________________

Fig. 47-UN6



Species: Frog

Stage: Early gastrula

You should now be able to:

1. Describe the acrosomal reaction
2. Describe the cortical reaction
3. Distinguish among meroblastic cleavage and holoblastic cleavage
4. Compare the formation of a blastula and gastrulation in a sea urchin, a frog, and a chick
5. List and explain the functions of the extraembryonic membranes

6. Describe the process of convergent extension
7. Describe the role of the extracellular matrix in embryonic development
8. Describe two general principles that integrate our knowledge of the genetic and cellular mechanisms underlying differentiation
9. Explain the significance of Spemann’s organizer in amphibian development

10. Explain pattern formation in a developing chick limb, including the roles of the apical ectodermal ridge and the zone of polarizing activity