Chapter 47

Animal Development

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Key concepts

Development transforms the zygote into a fully matured organism by the specific signaling events.

Fig. 47-1

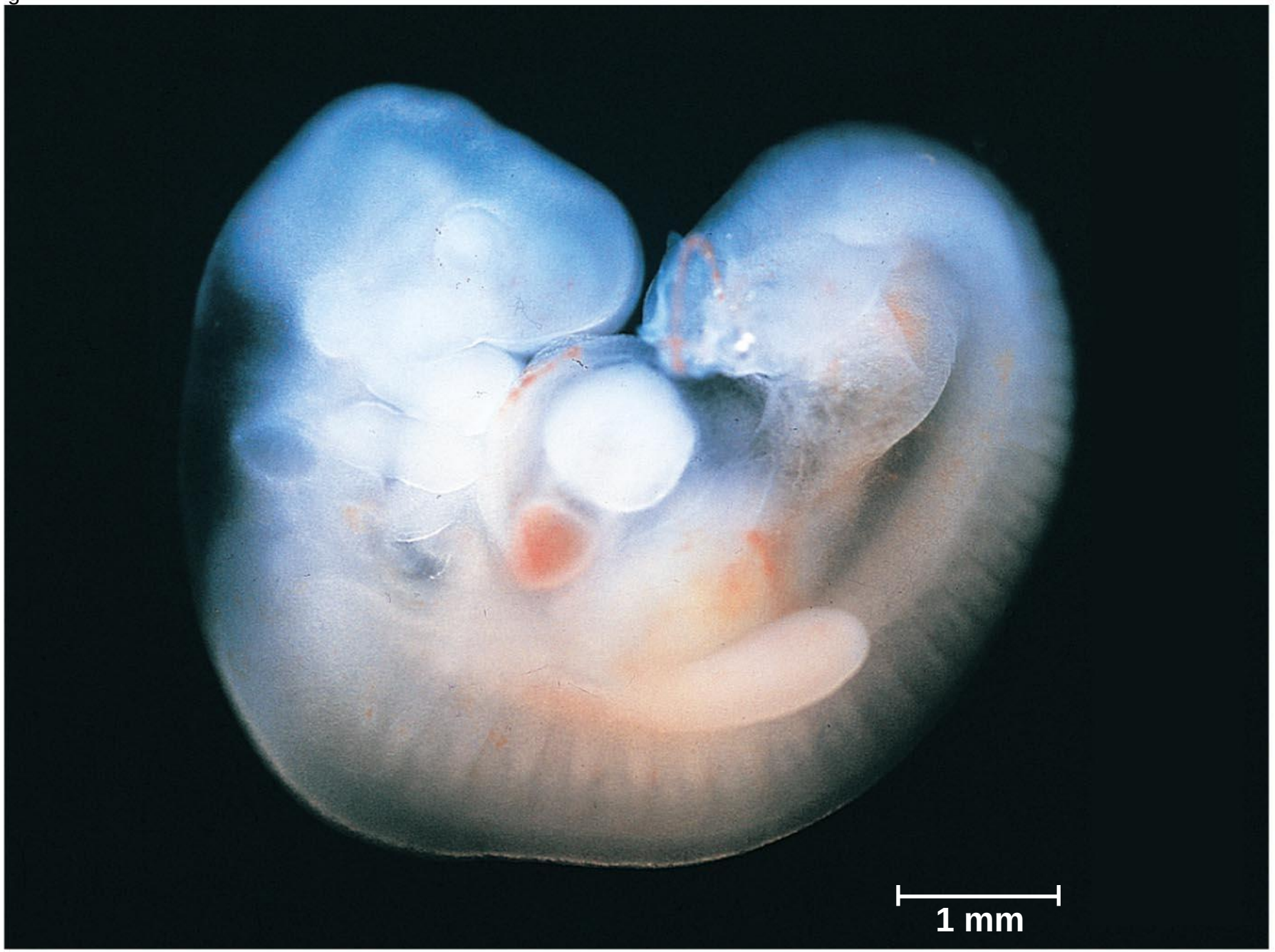
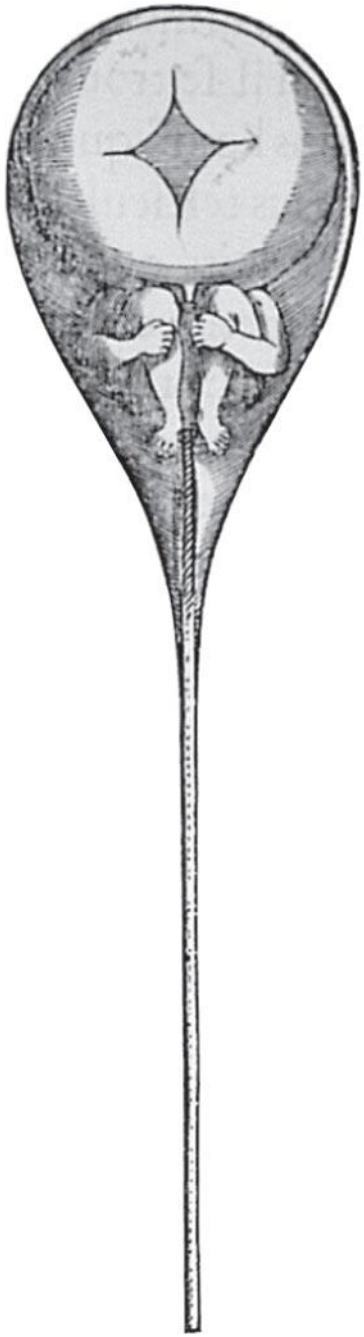


Fig. 47-2



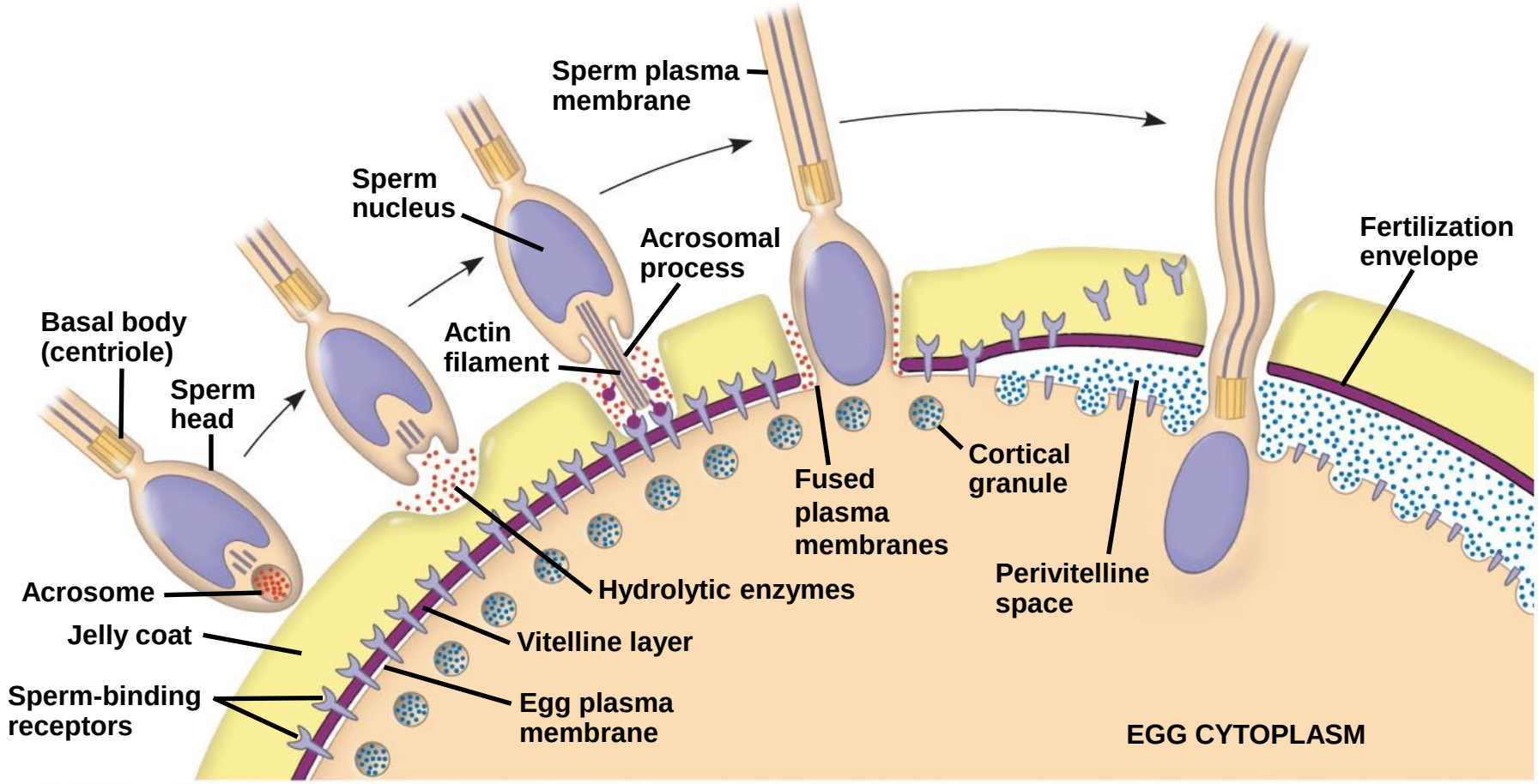
Preformation is the idea that the egg or sperm contains a miniature infant, or "homunculus," which becomes larger during development

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

Fig. 47-3-5

The acrosomal and cortical reactions during sea urchin fertilization



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

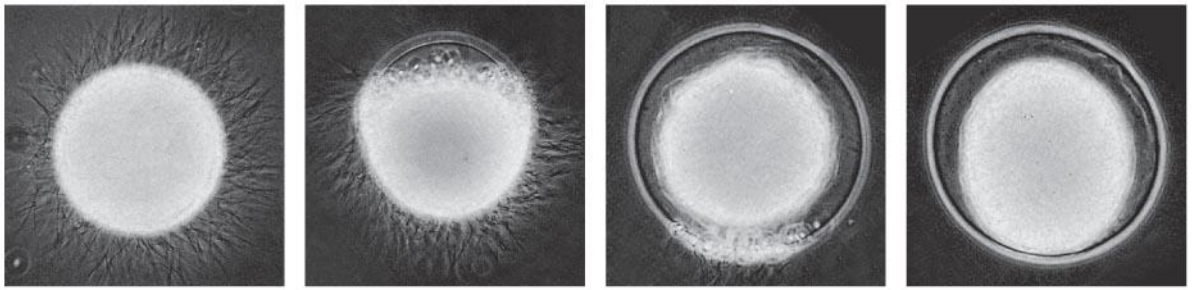
The Cortical Reaction

- 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

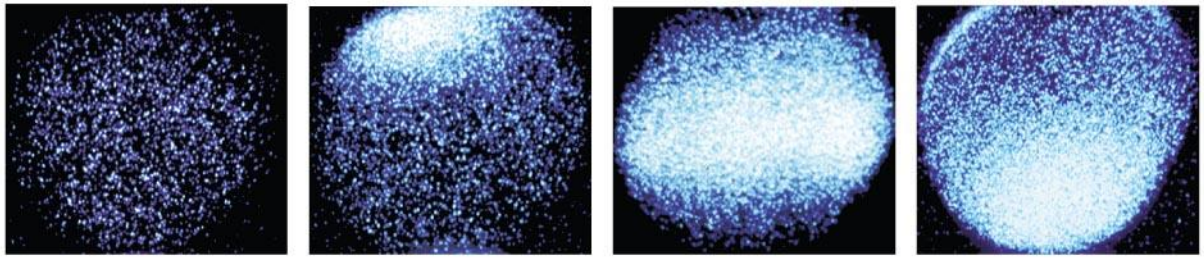
EXPERIMENT

Is the distribution of Ca^{2+} in an egg correlated with formation of the fertilization envelope?



10 sec after fertilization | 25 sec | 35 sec | 1 min | 500 µm

RESULTS



1 sec before fertilization | 10 sec after fertilization | 20 sec | 30 sec | 500 µm

CONCLUSION

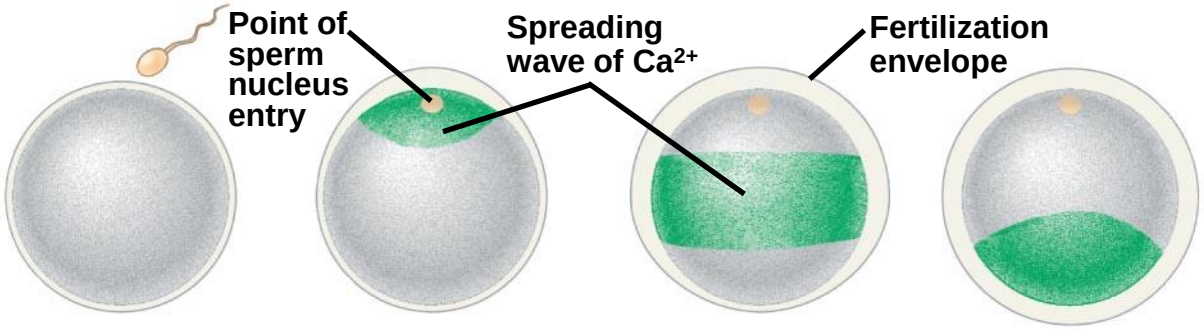
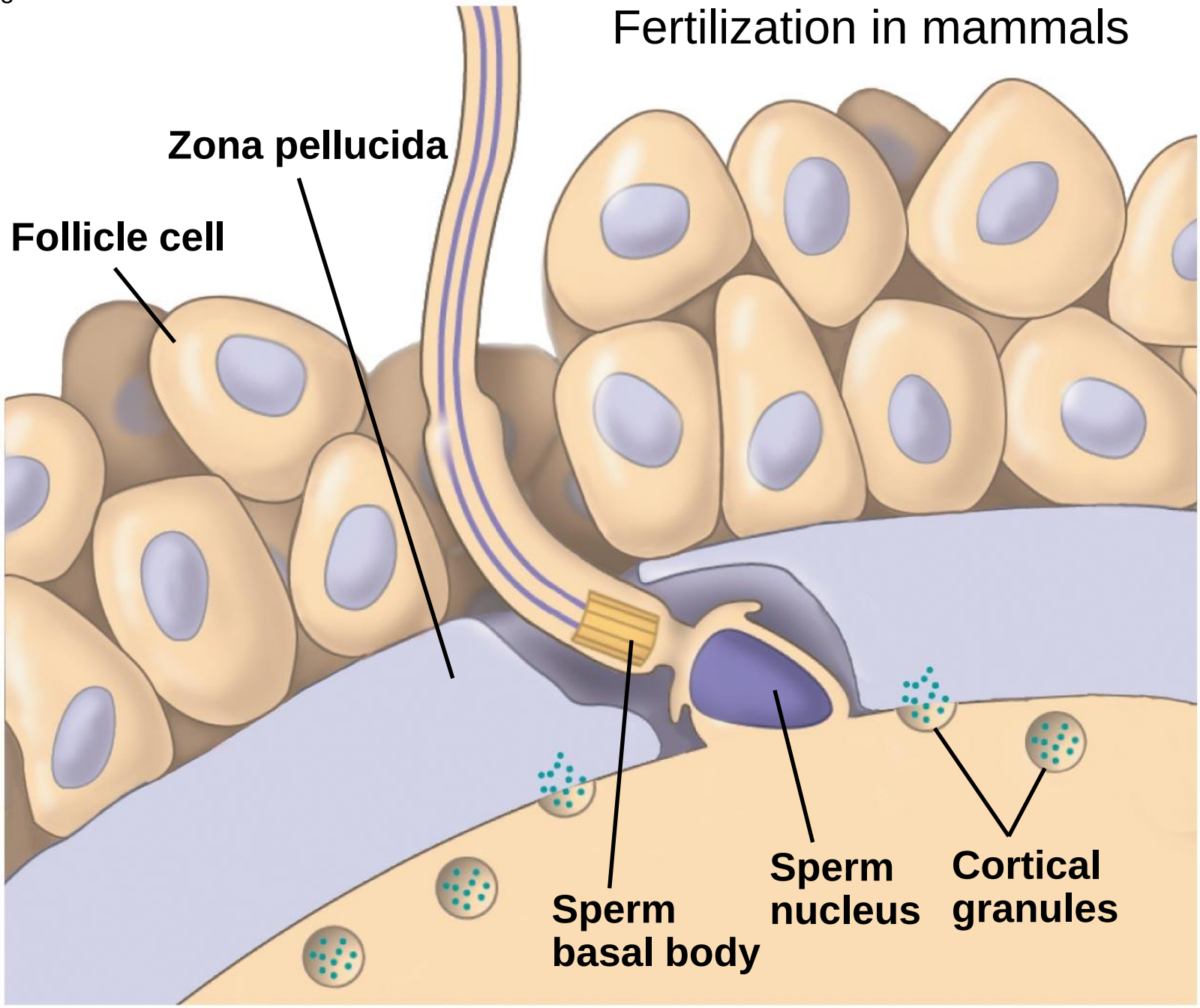


Fig. 47-5

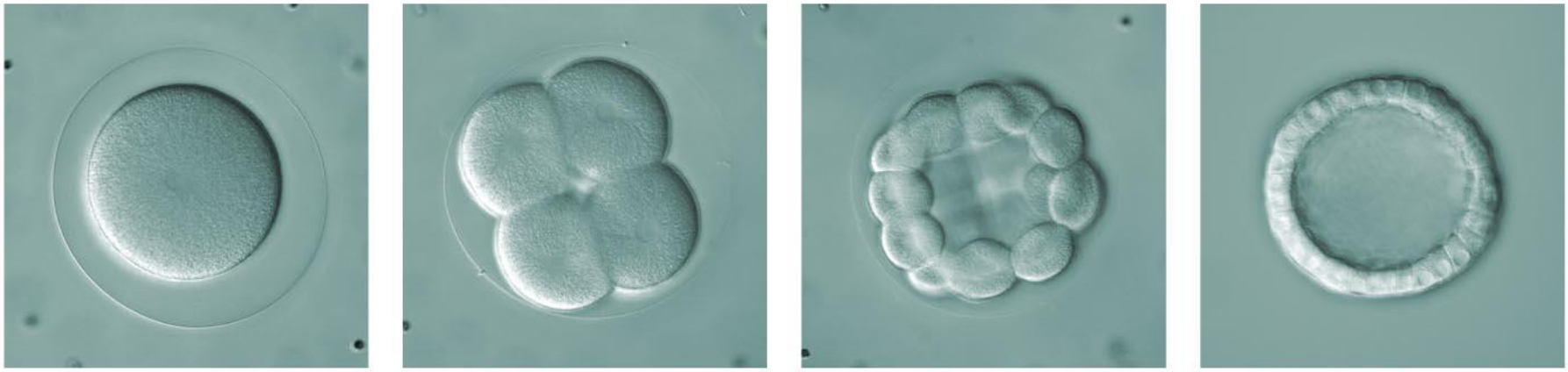


Cleavage

- 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

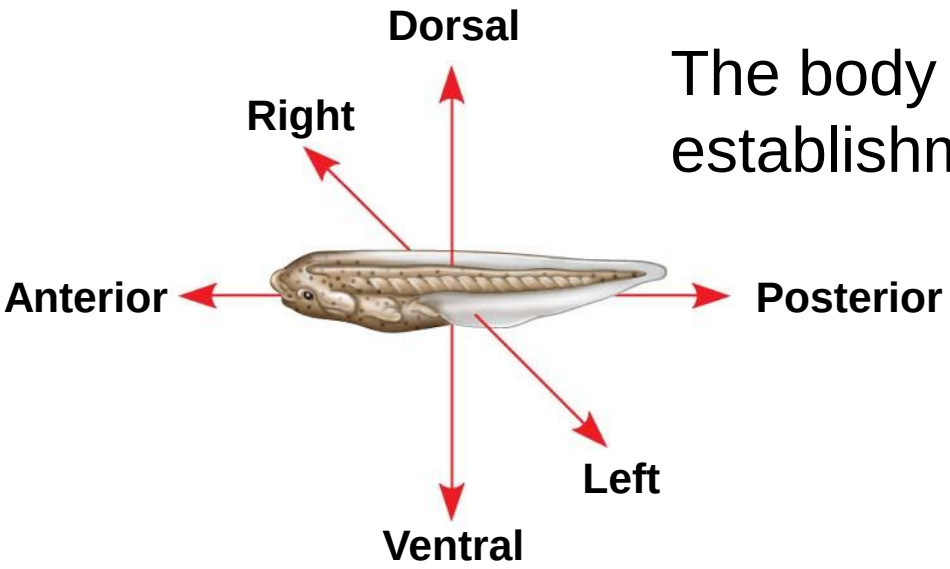
Cleavage in an echinoderm embryo



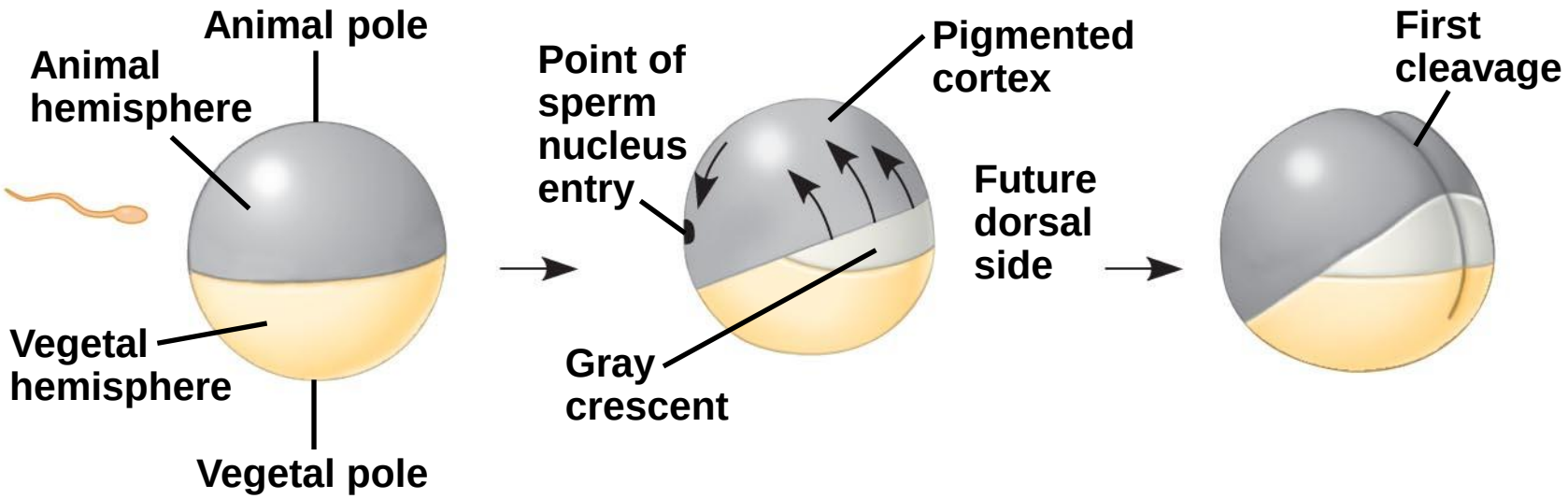
(a) Fertilized egg **(b) Four-cell stage** **(c) Early blastula** **(d) Later blastula**

Fig. 47-7

The body axes and their establishment in an amphibian



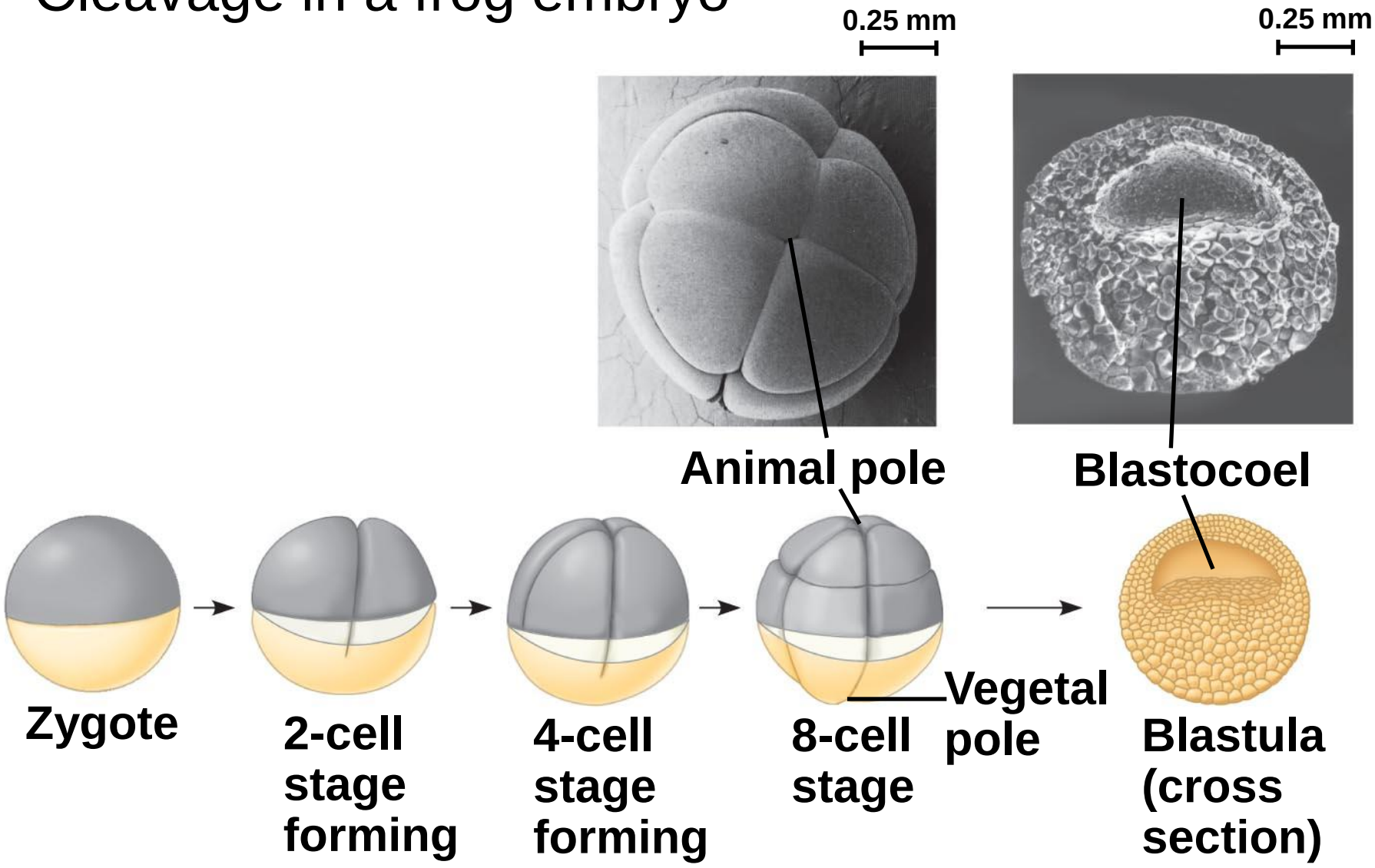
(a) The three axes of the fully developed embryo



(b) Establishing the axes

Fig. 47-8-6

Cleavage in a frog embryo



- **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

- 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

Fig. 47-9-6

Gastrulation in a sea urchin embryo

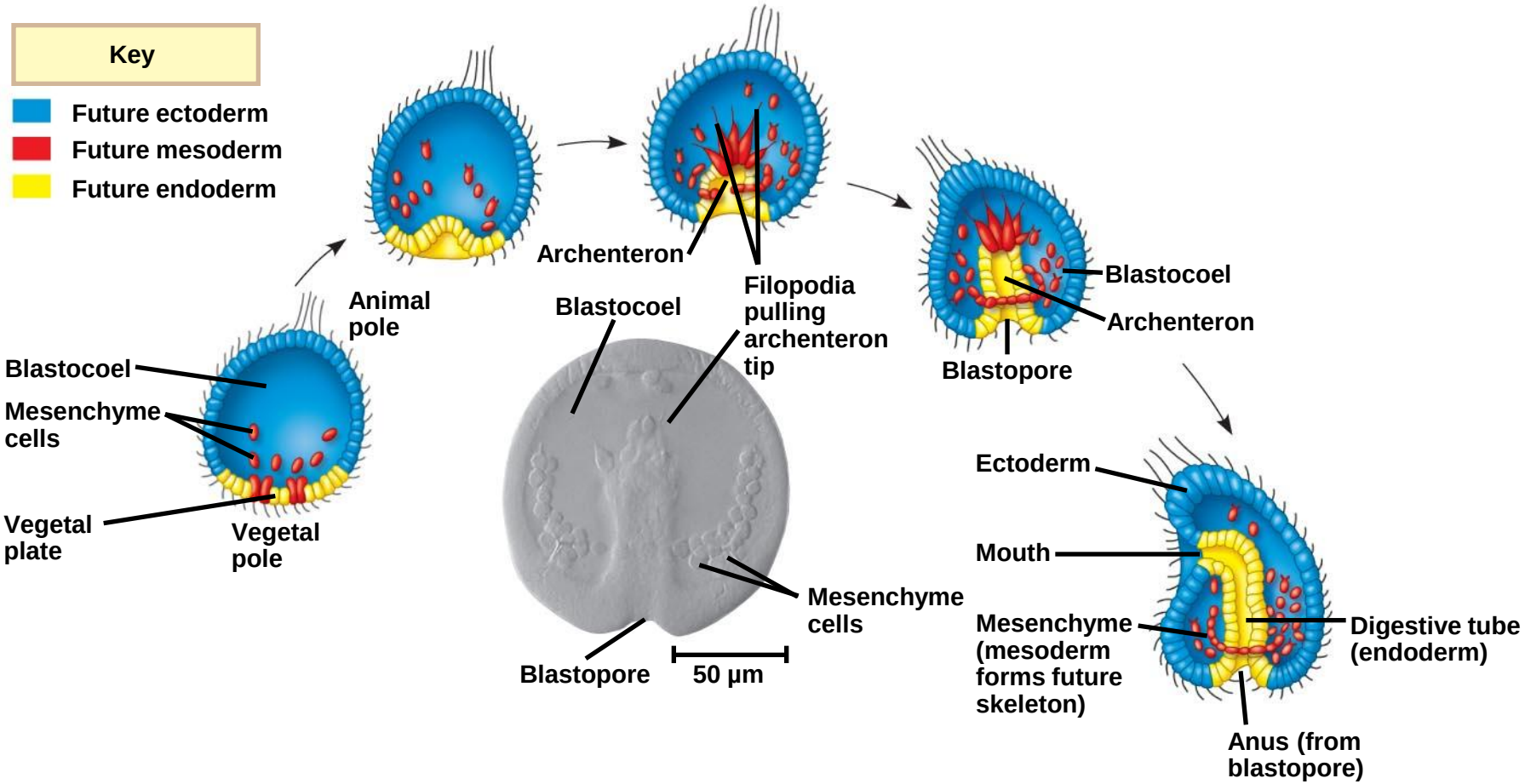


Fig. 47-10-4

Gastrulation in a frog embryo

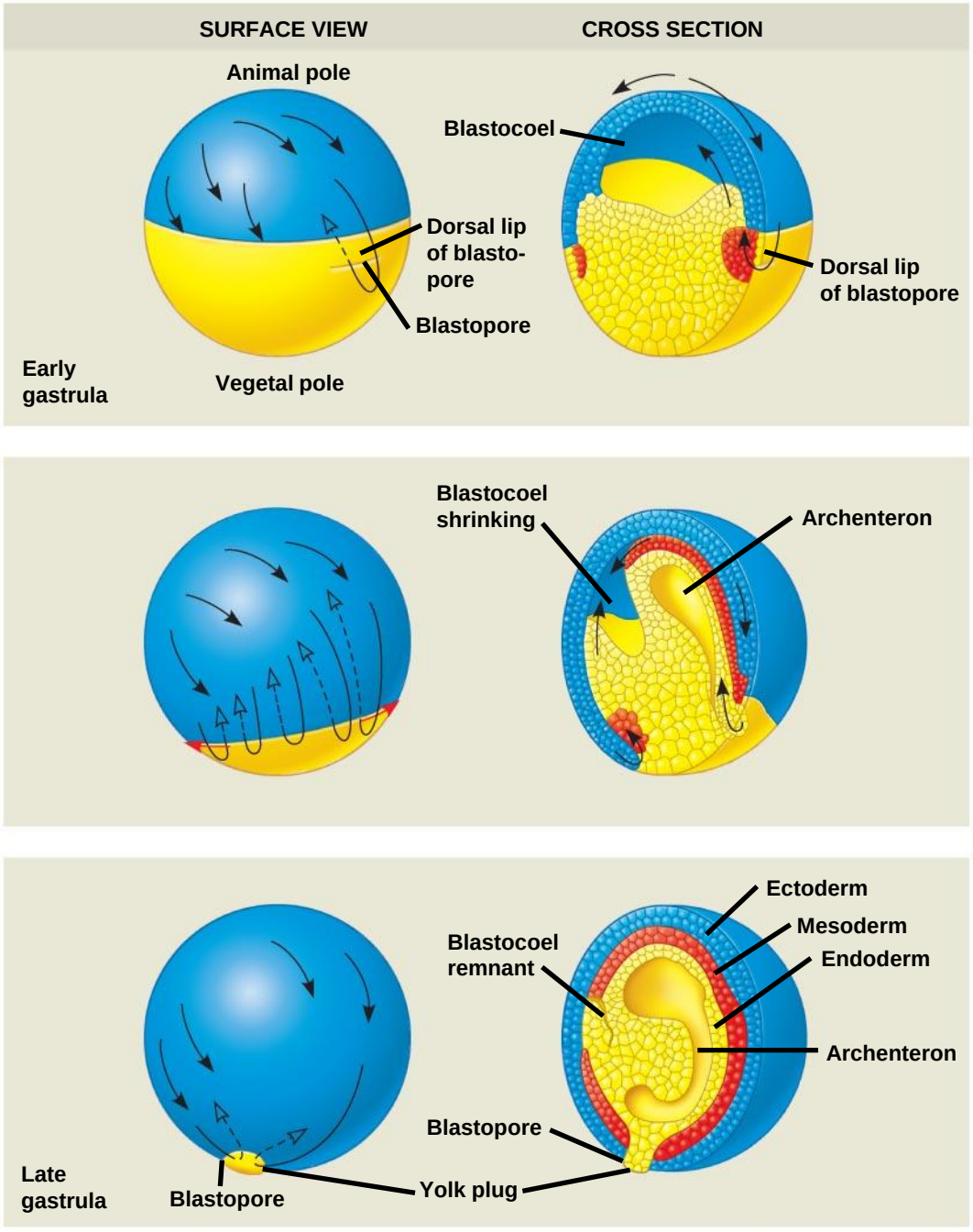


Fig. 47-11

Gastrulation in a chick embryo

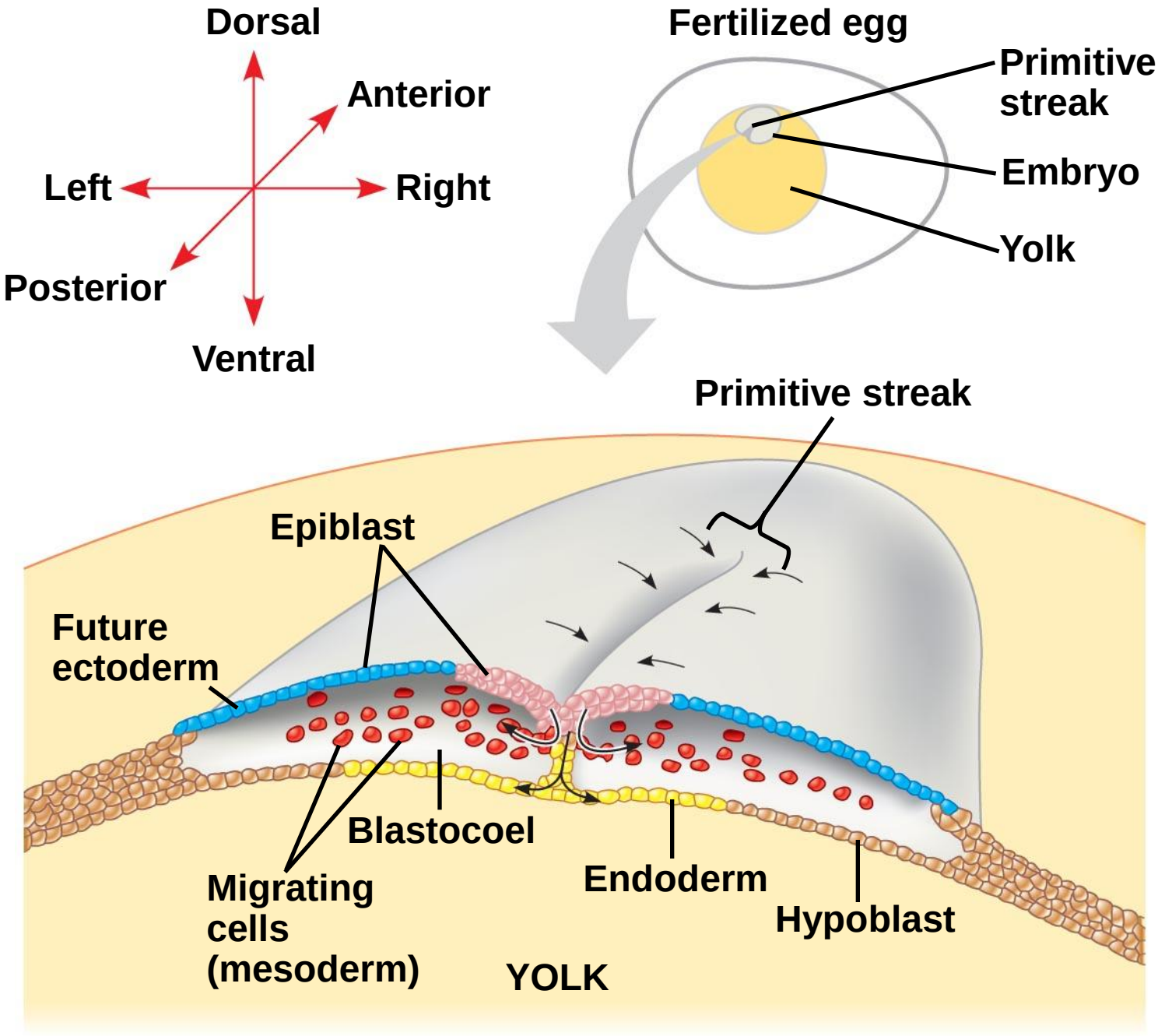
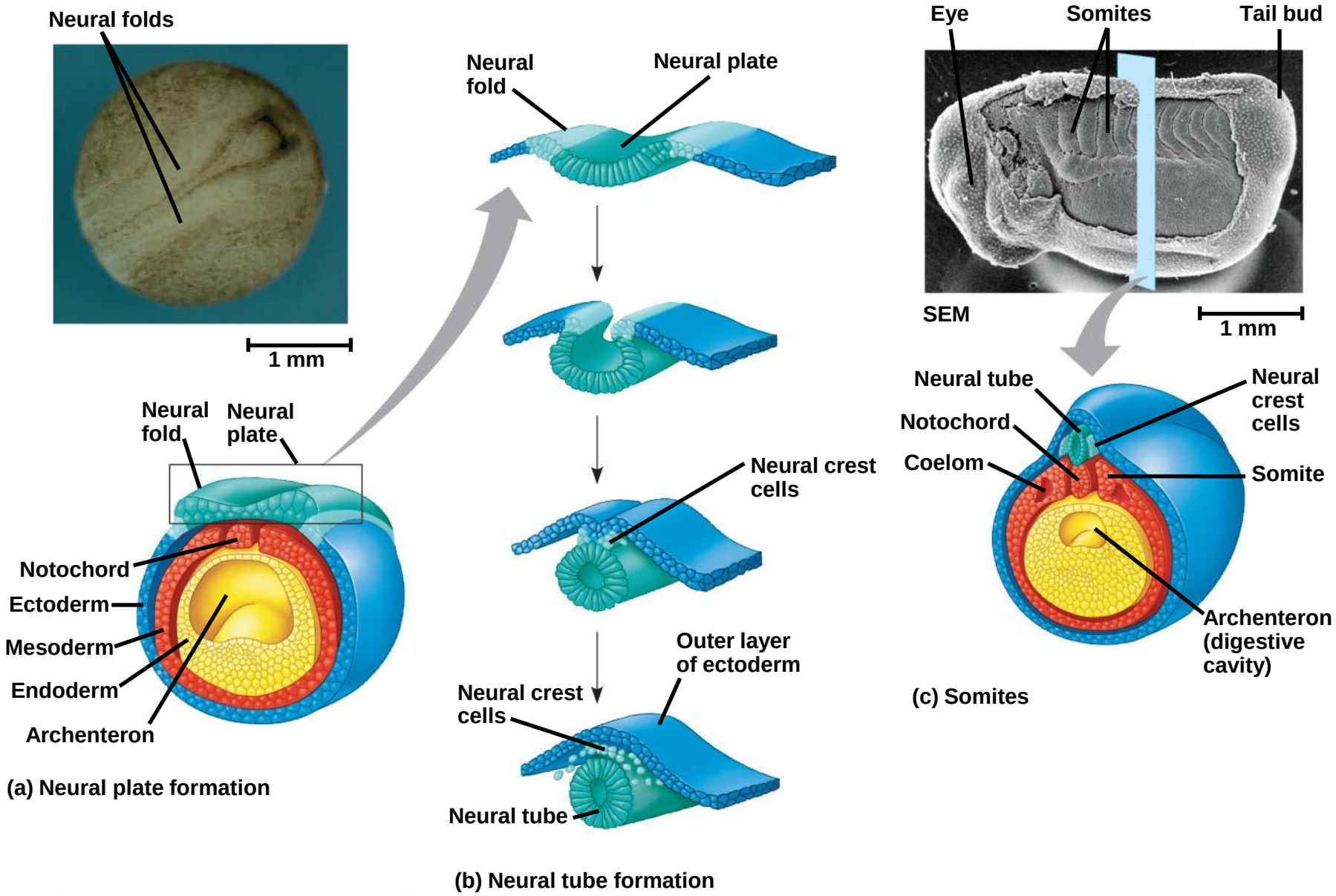


Fig. 47-12

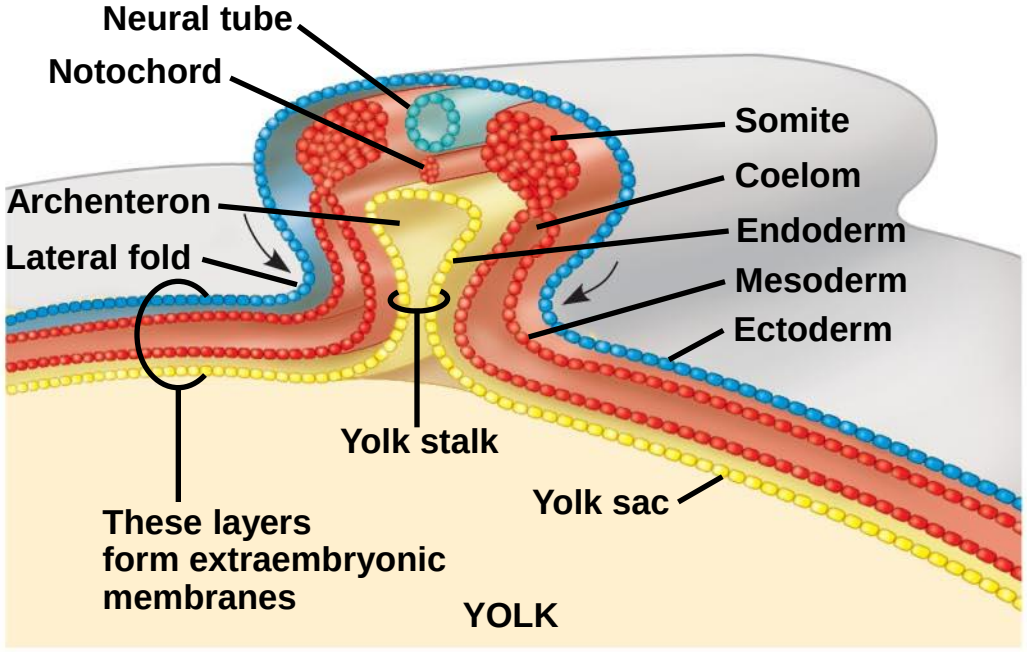
Early organogenesis in a frog embryo



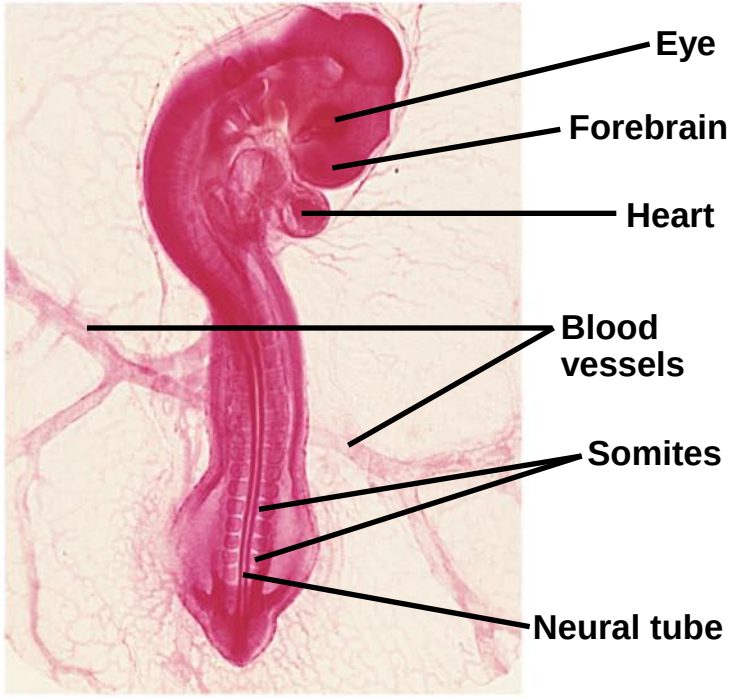
- **Neural crest cells** develop along the neural tube of vertebrates and form various parts of the embryo (nerves, parts of teeth, skull bones, and so on)
- Mesoderm lateral to the notochord forms blocks called **somites**
- Lateral to the somites, the mesoderm splits to form the coelom

Fig. 47-13

Organogenesis in a chick embryo



(a) Early organogenesis



(b) Late organogenesis

Fig. 47-14

Adult derivatives of the three embryonic germ layers in vertebrates

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

Extraembryonic membranes in birds and other reptiles

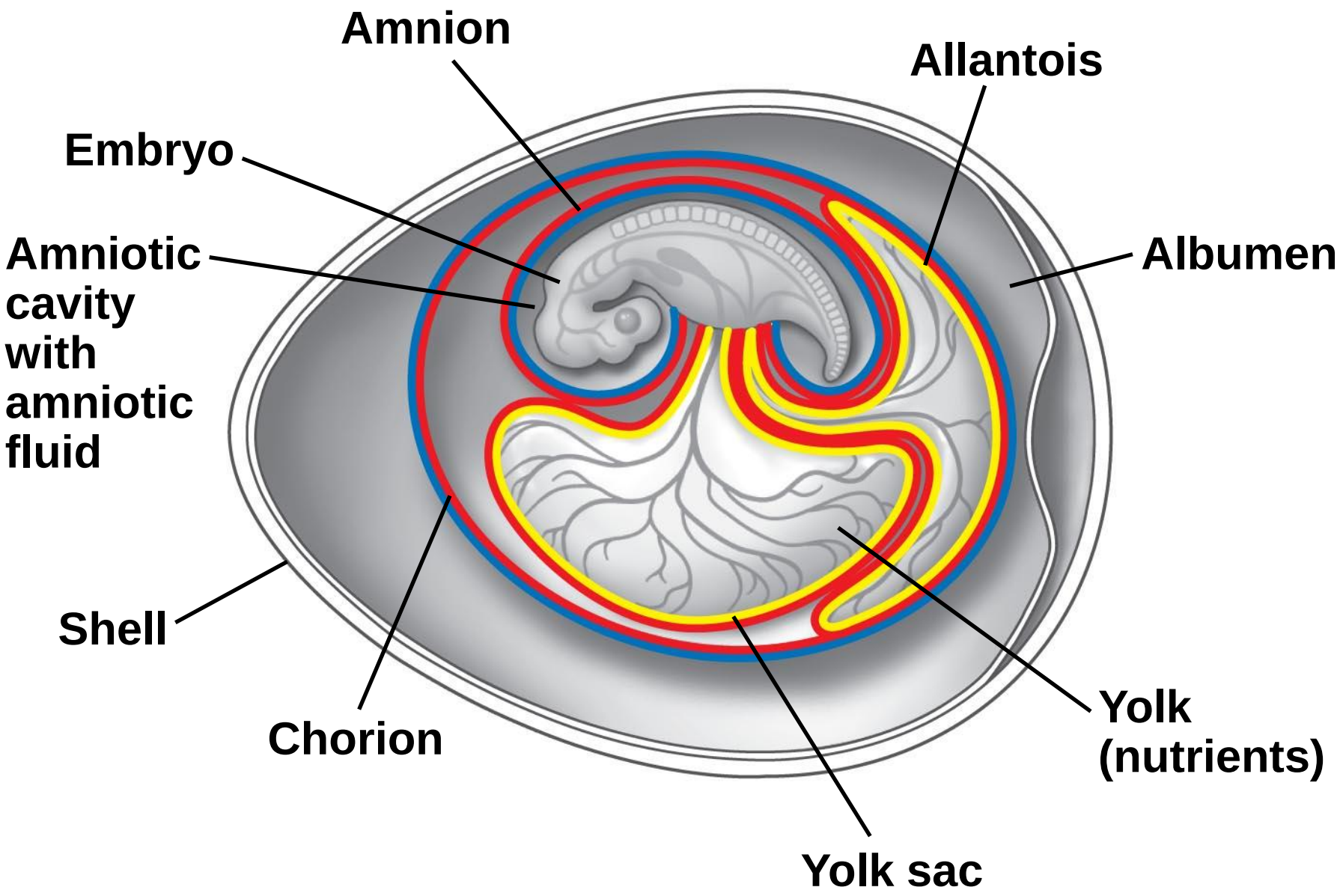


Fig. 47-16-5

Four stages in early embryonic development of a human

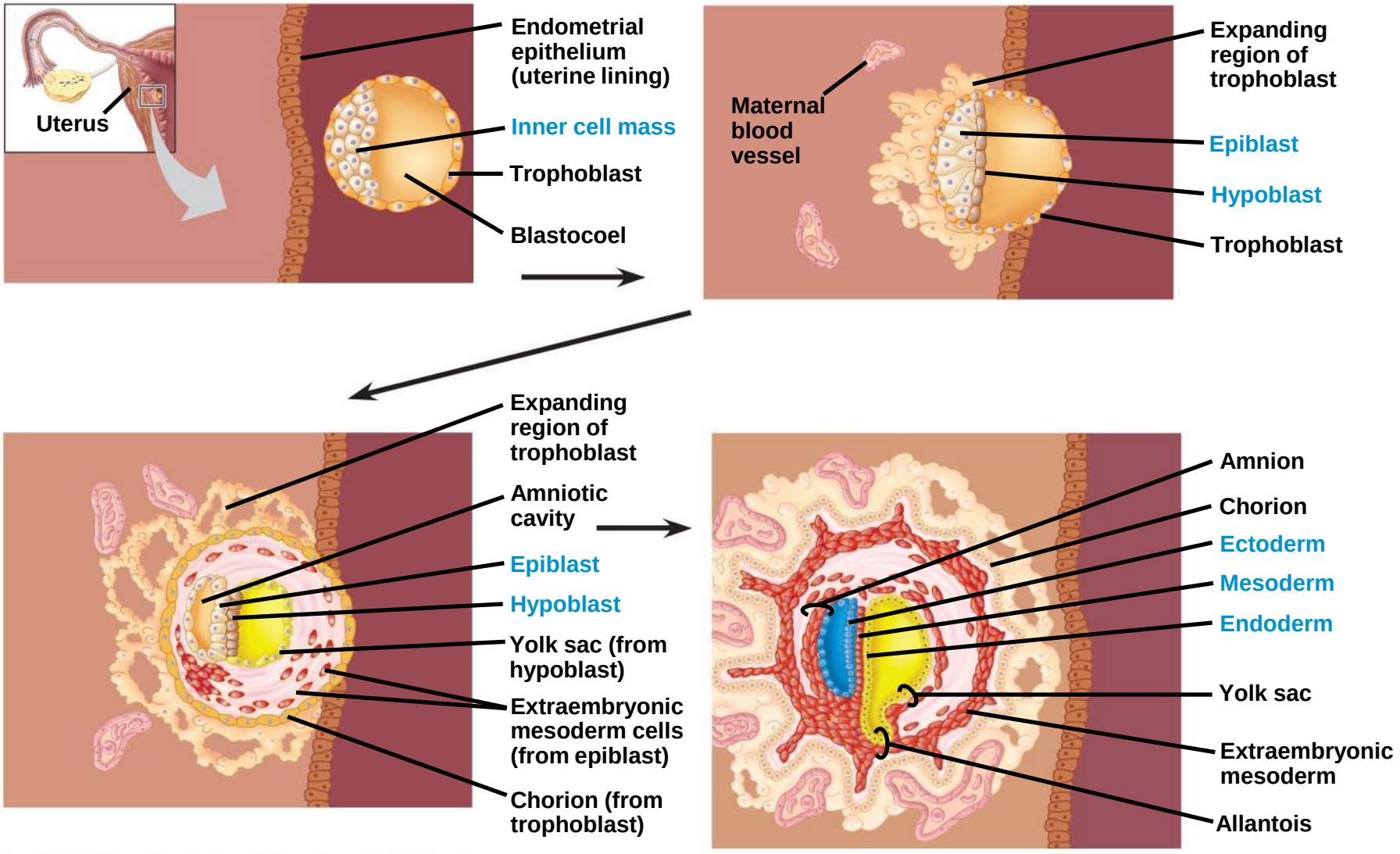
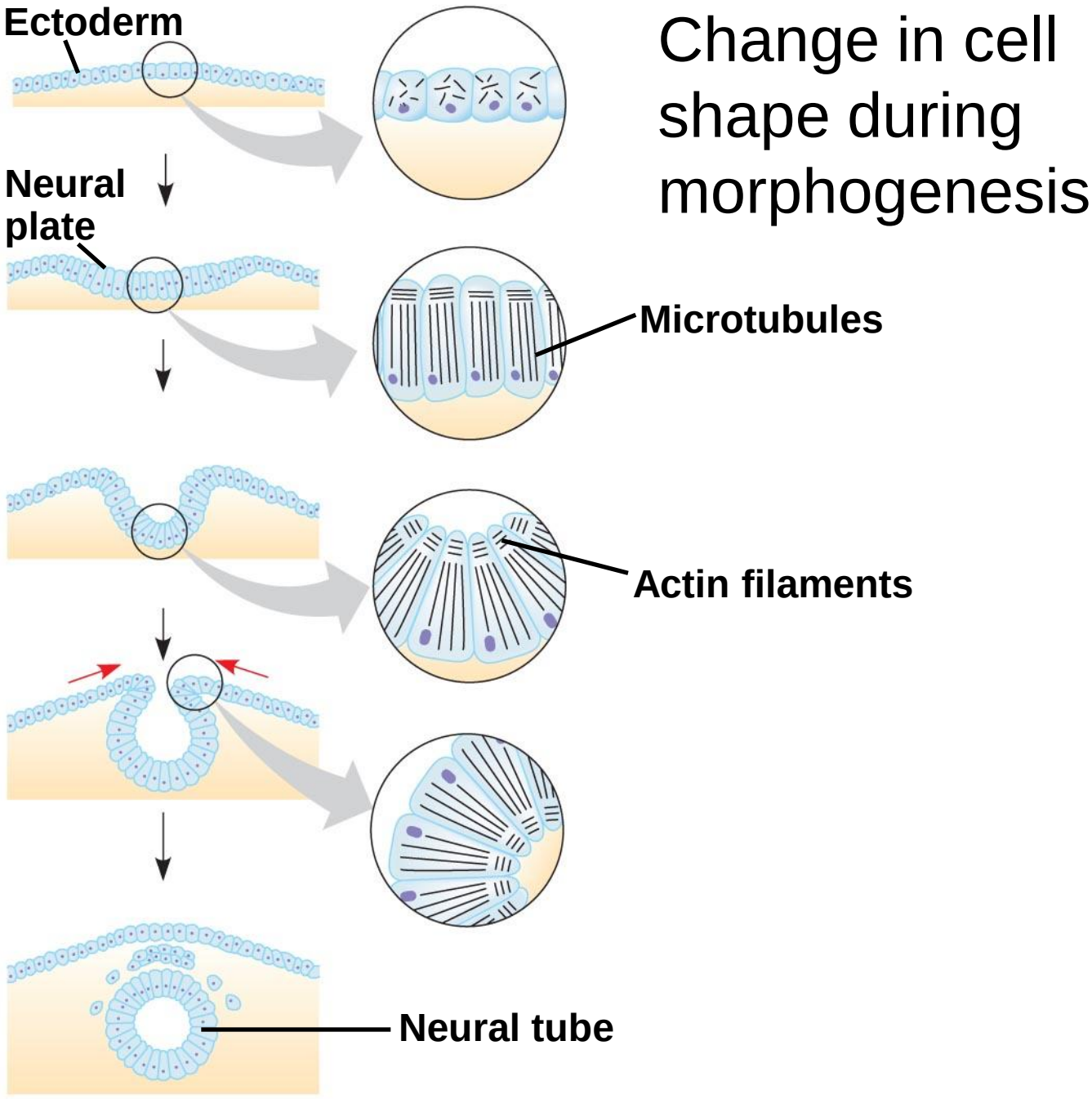


Fig. 47-17-6



Change in cell shape during morphogenesis

Fig. 47-18

convergent extension, a morphogenetic movement in which cells of a tissue become narrower and longer

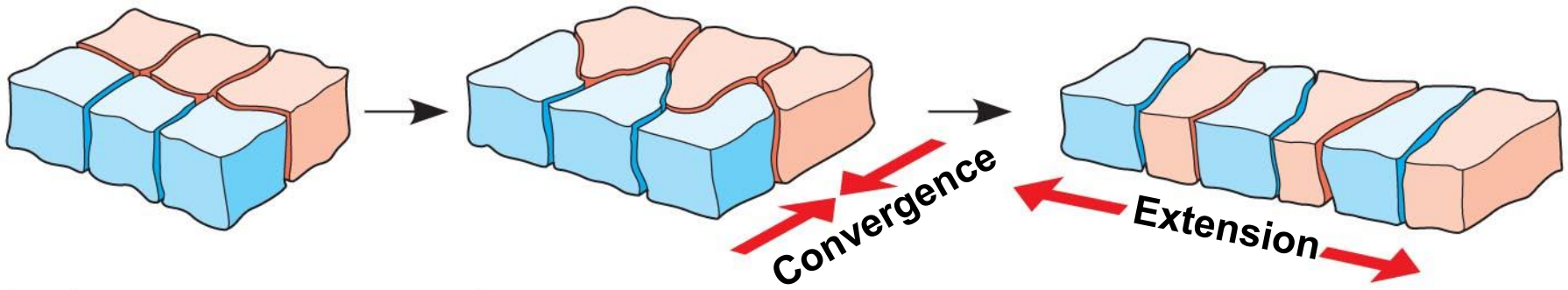
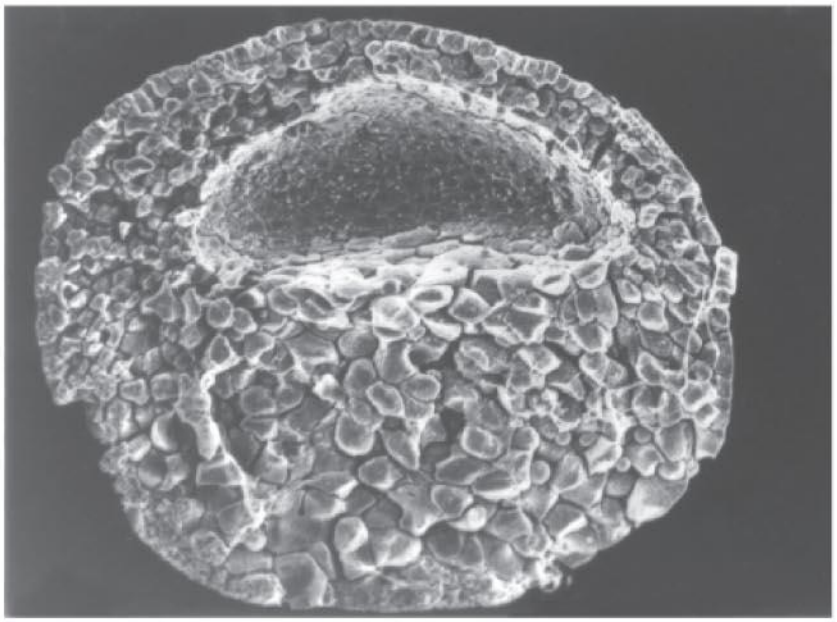


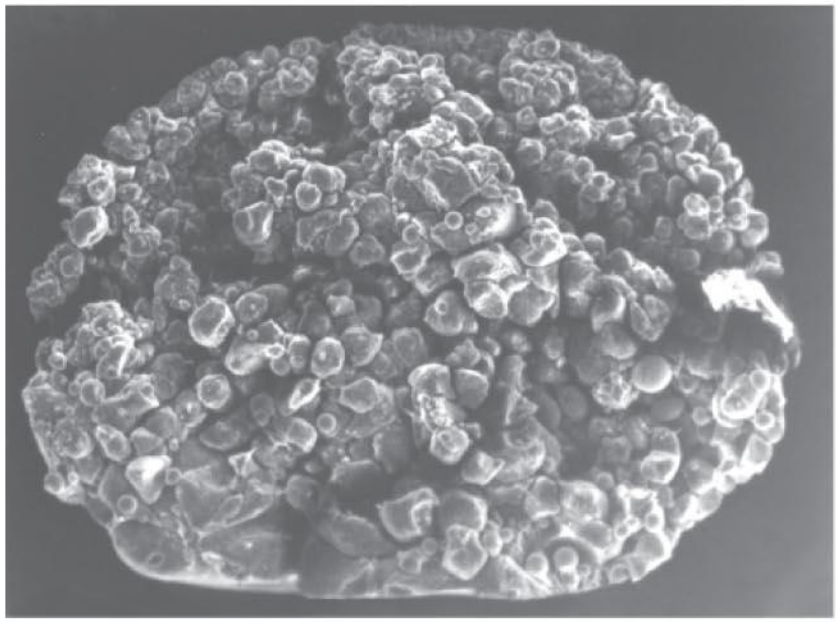
Fig. 47-19

Is cadherin required for development of the blastula?

RESULTS



Control embryo



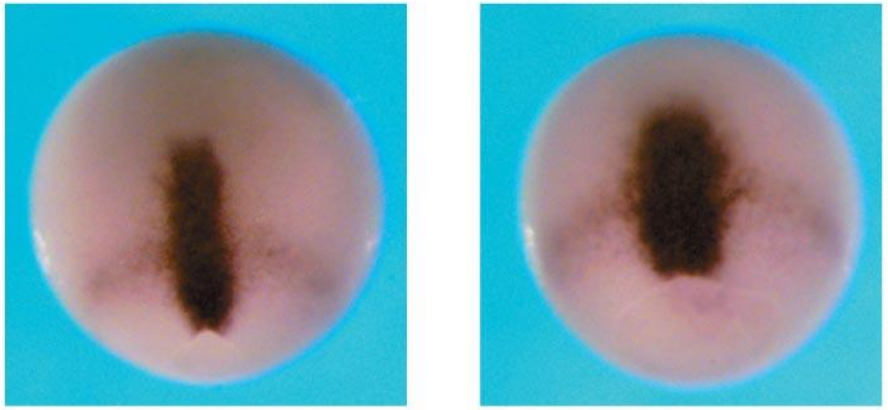
Embryo without EP cadherin

Fig. 47-20

RESULTS

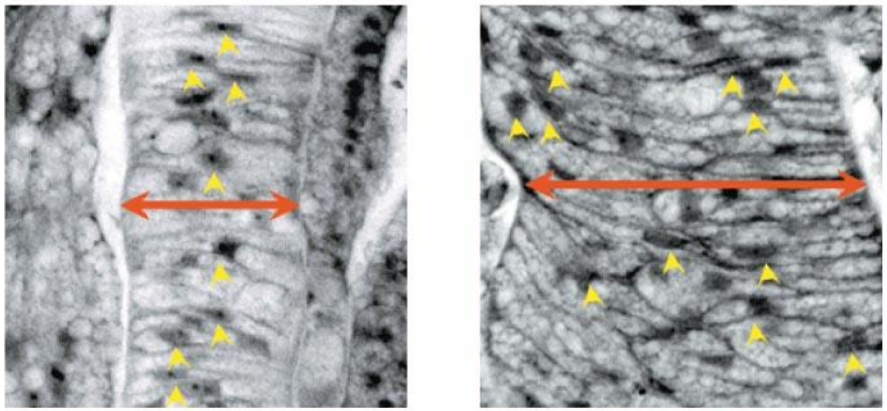
Is an organized fibronectin matrix required for convergent extension?

Experiment 1



Control | Matrix blocked

Experiment 2



Control | Matrix blocked

- Two general principles underlie differentiation:

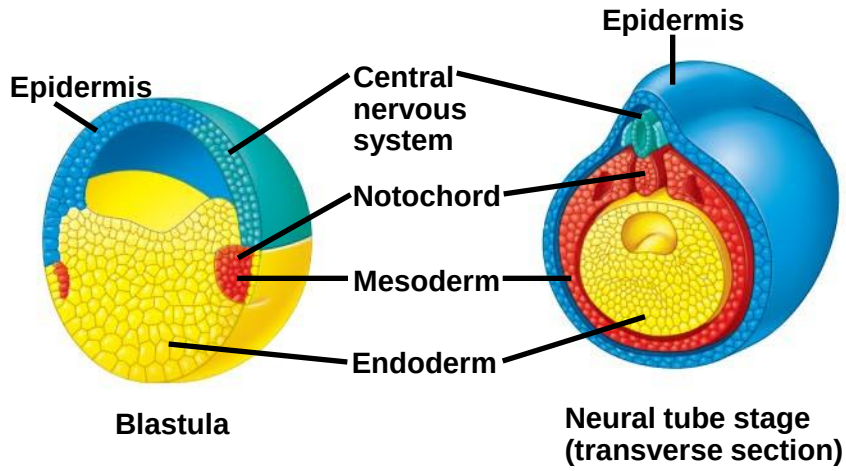
1. During early cleavage divisions, embryonic cells must become different from one another
   - If the egg's cytoplasm is heterogenous, dividing cells vary in the cytoplasmic determinants they contain

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

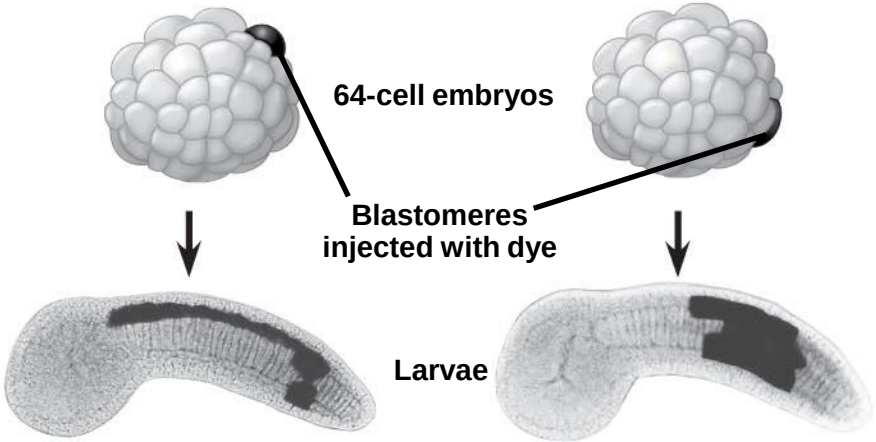
   - This mechanism is called **induction**, and is mediated by diffusible chemicals or cell-cell interactions

Fig. 47-21

Fate mapping for two chordates



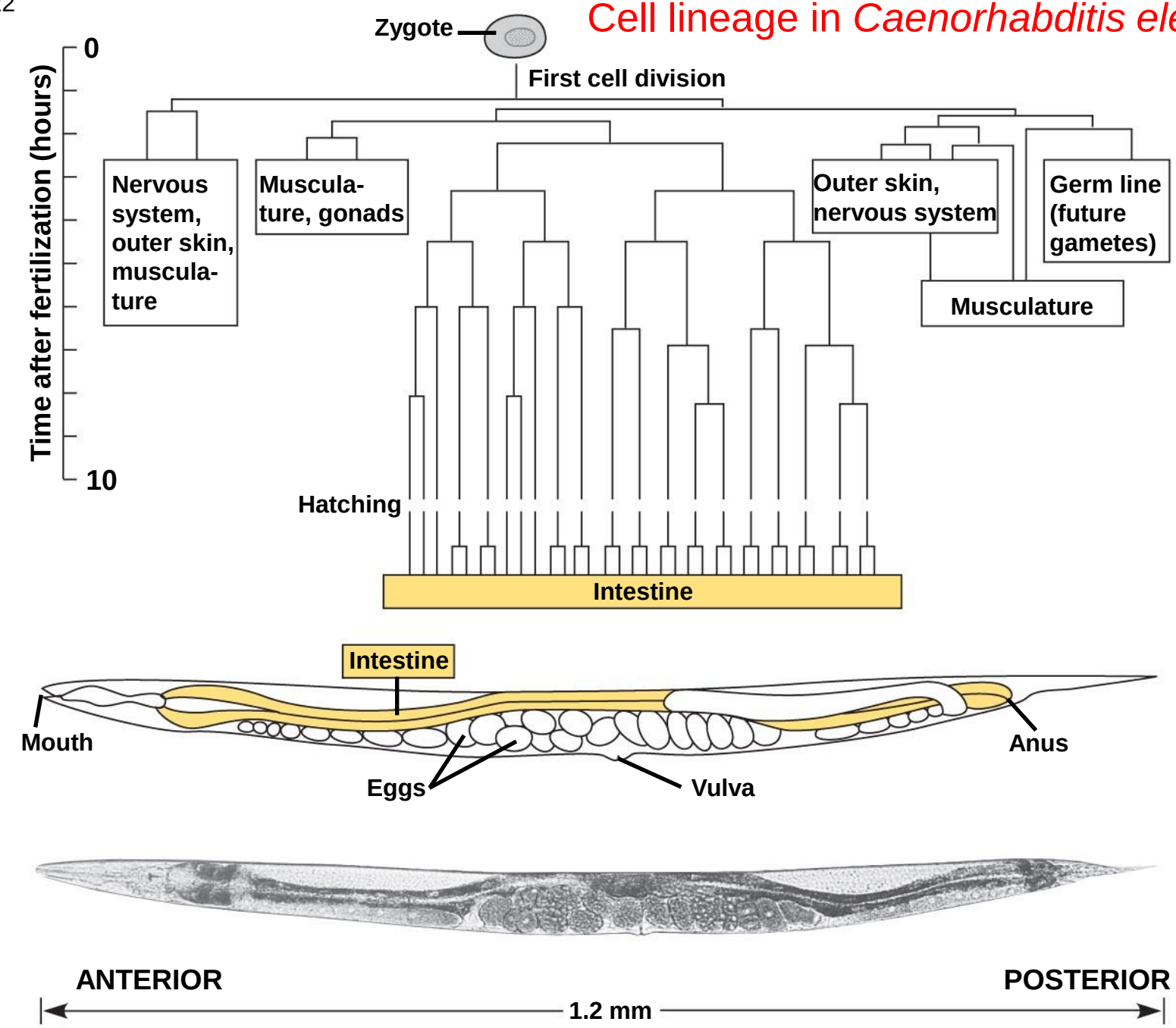
(a) Fate map of a frog embryo



(b) Cell lineage analysis in a tunicate

Fig. 47-22

Cell lineage in *Caenorhabditis elegans*



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

Fig. 47-23b

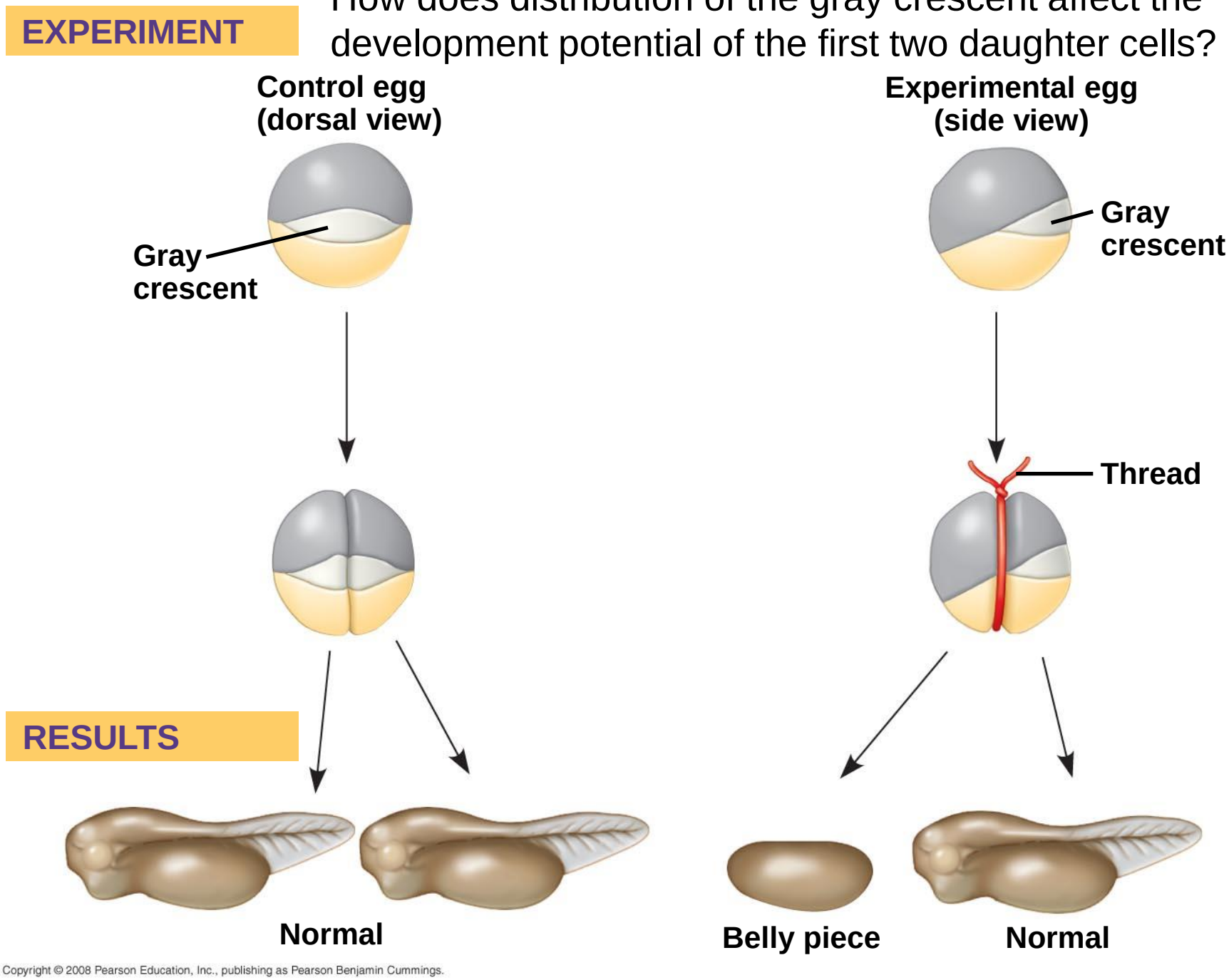
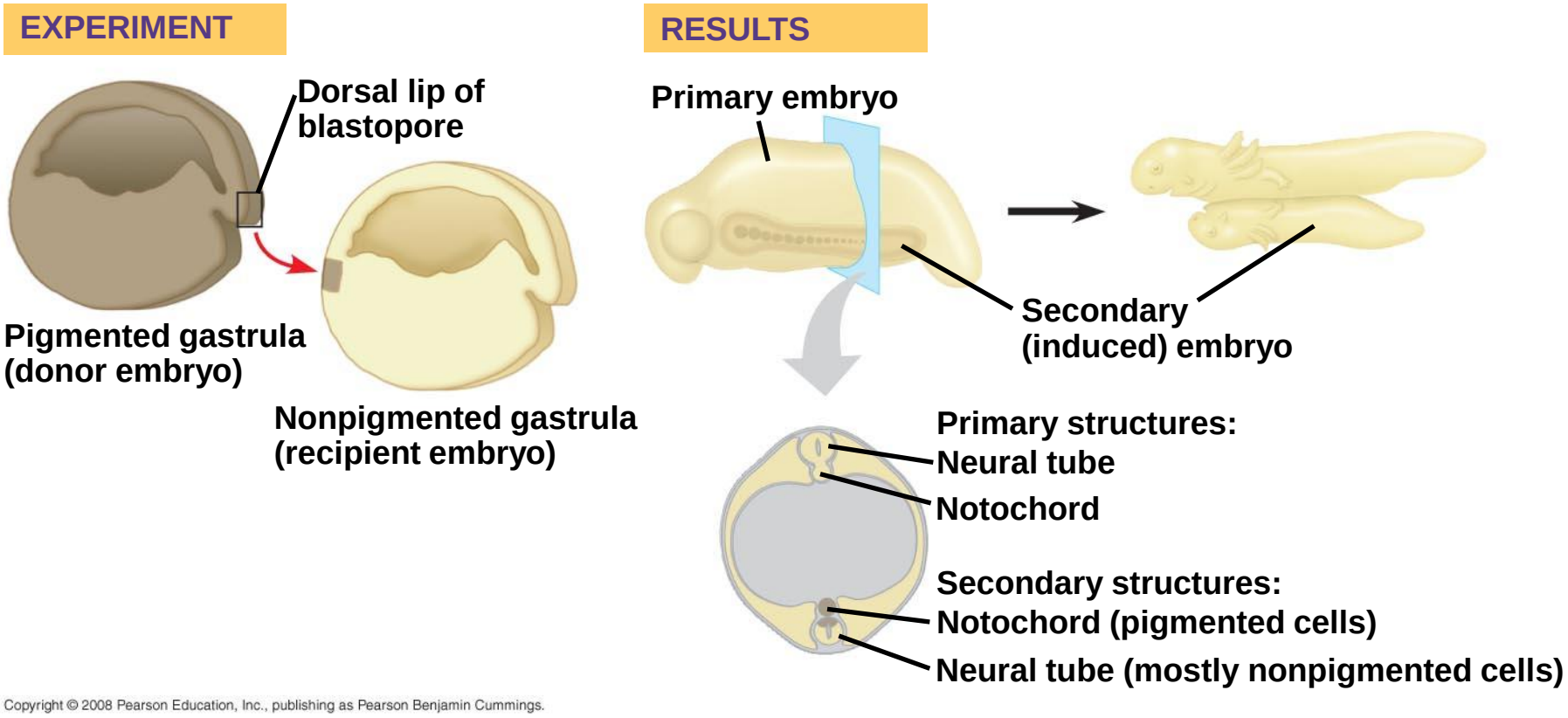


Fig. 47-24

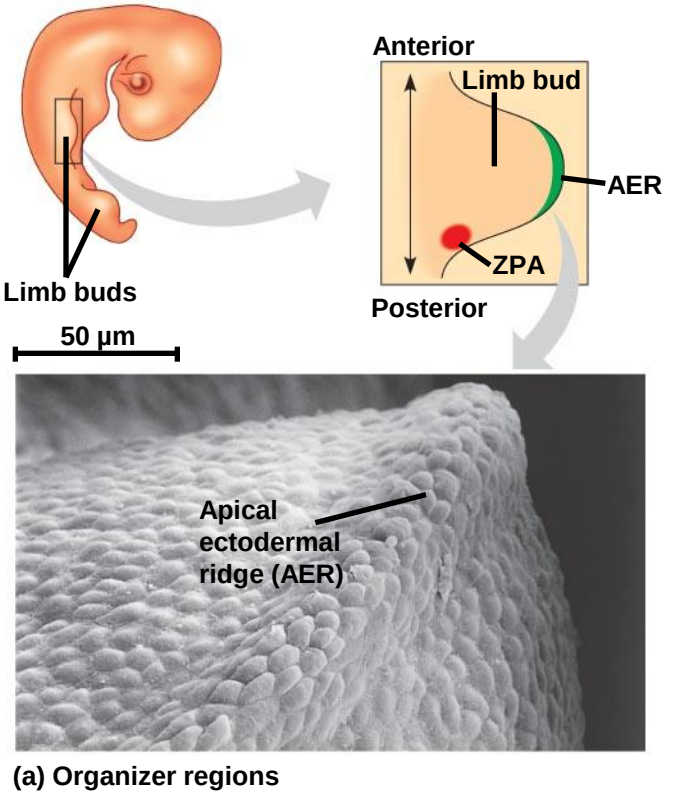
Can the dorsal lip of the blastopore induce cells in another part of the amphibian embryo to change their developmental fate?



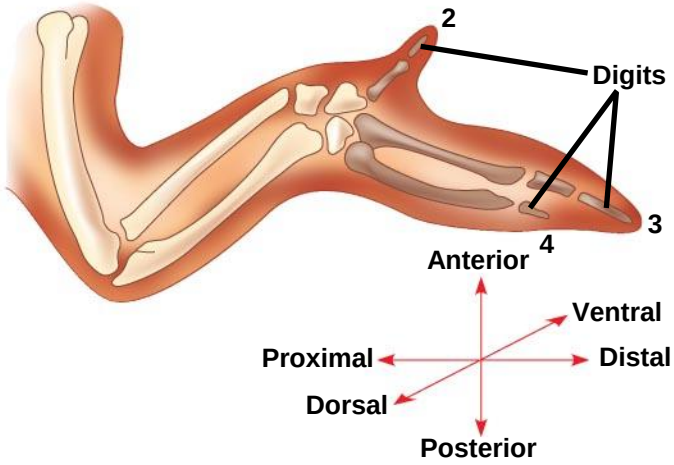
Based on their famous experiment, Hans Spemann and Hilde Mangold concluded that the blastopore's dorsal lip is an organizer of the embryo

- 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. 47-25



(a) Organizer regions



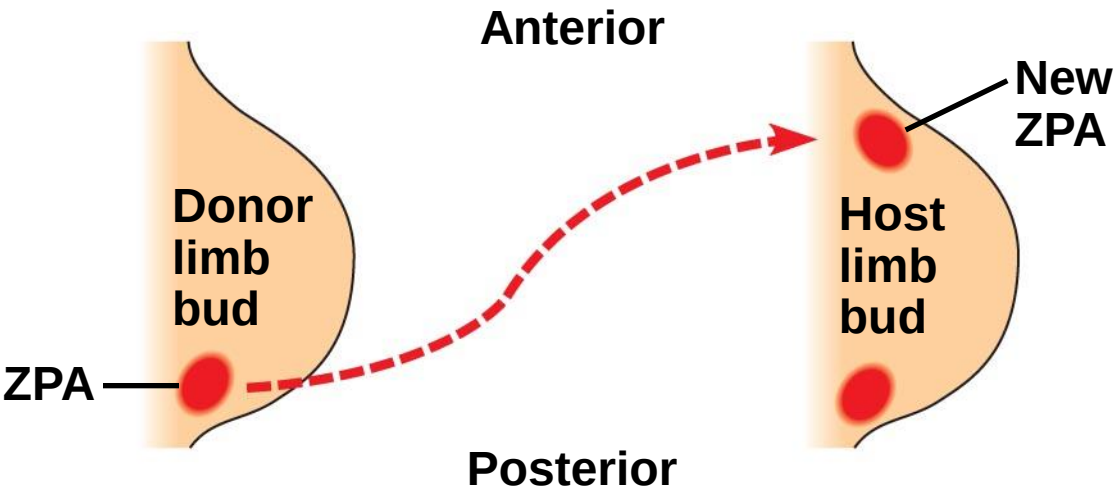
(b) Wing of chick embryo

Vertebrate limb development

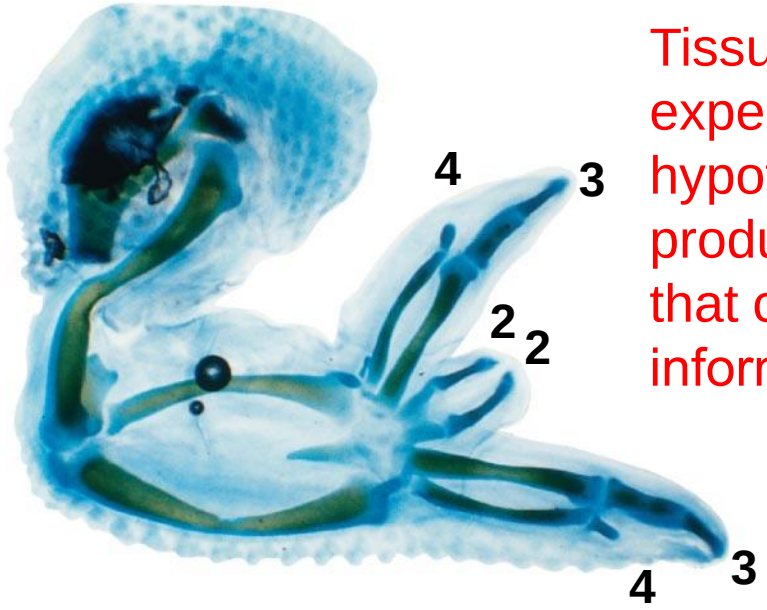
- One limb-bud organizer region is the **apical ectodermal ridge (AER)**
- The AER is thickened ectoderm at the bud's tip
- The second region is the **zone of polarizing activity (ZPA)**
- The ZPA is mesodermal tissue under the ectoderm where the posterior side of the bud is attached to the body

Fig. 47-26

EXPERIMENT



RESULTS



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

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

Fig. 47-27

Human polysyndactyly due to a homozygous mutation in a *Hox* gene

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