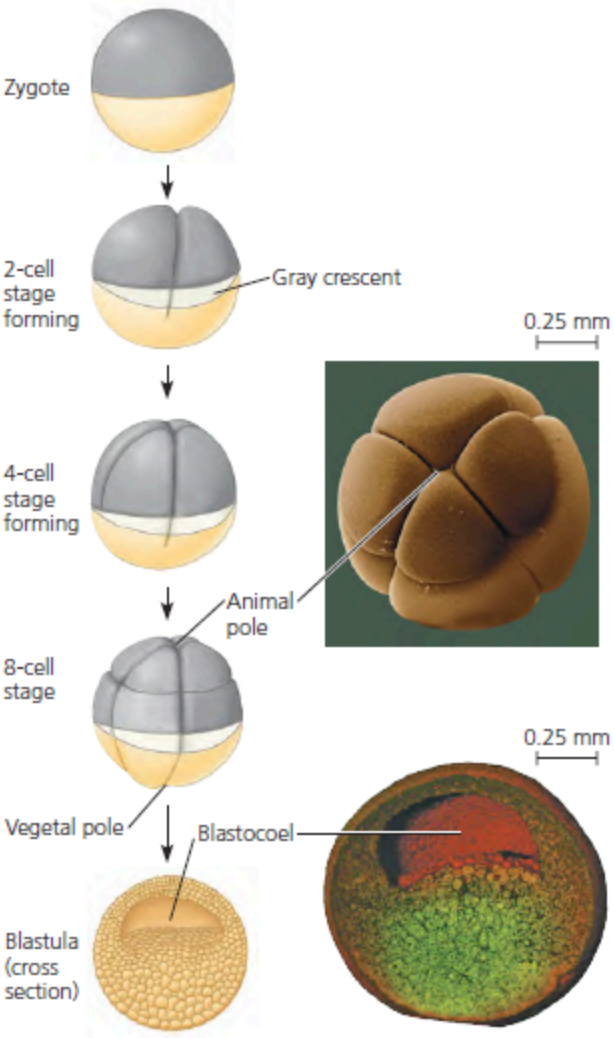
Cheat Sheet



8-cell stage (viewed from the animal pole). The large amount of yolk displaces the third cleavage toward the animal pole, forming two tiers of cells. The four cells near the animal pole (closer, in this view) are smaller than the other four cells (colorized SEM).

Blastula (at least 128 cells). As cleavage continues, a fluid-filled cavity, the blastocoel, forms within the embryo. Because of unequal cell division, the blastocoel is located in the animal hemisphere. Both the drawing and the micrograph (assembled from fluorescence images) show cross sections of a blastula with about 4,000 cells.

▲ **Figure 47.7 Cleavage in a frog embryo.** The cleavage planes in the first and second divisions extend from the animal pole to the vegetal pole, but the third cleavage is perpendicular to the polar axis. In some species, the first division bisects the gray crescent, a lighter-colored region that appears opposite the site of sperm entry.

ECTODERM (outer layer of embryo)

- Epidermis of skin and its derivatives (including sweat glands, hair follicles)
- Nervous and sensory systems
- Pituitary gland, adrenal medulla
- Jaws and teeth
- Germ cells

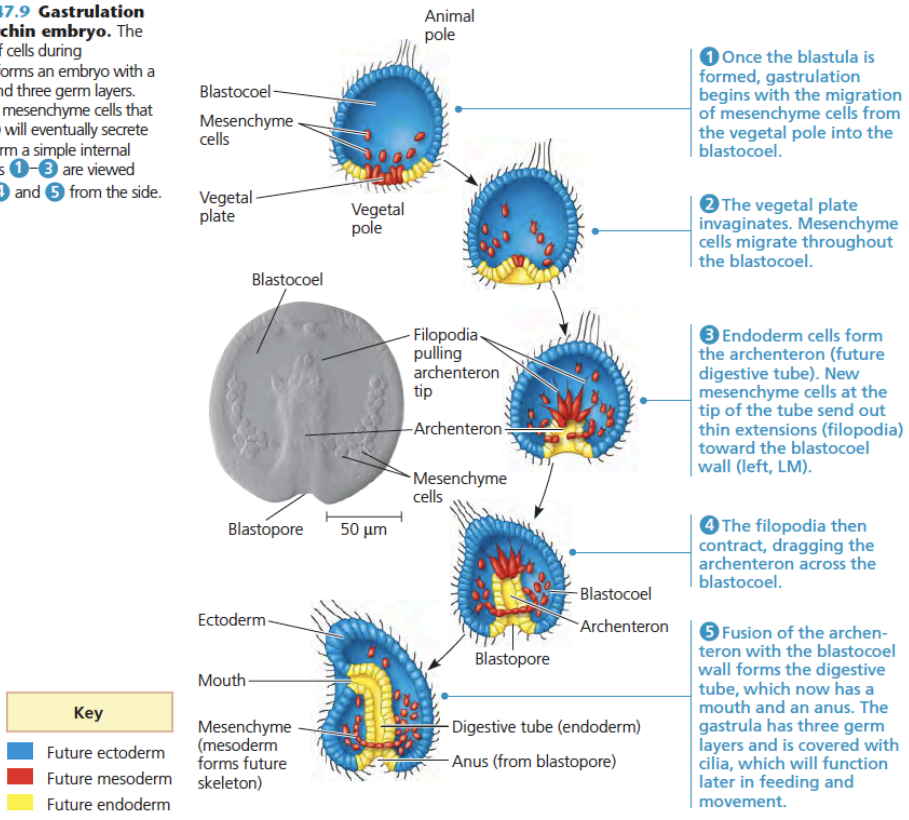
MESODERM (middle layer of embryo)

- Skeletal and muscular systems
- Circulatory and lymphatic systems
- Excretory and reproductive systems (except germ cells)
- Dermis of skin
- Adrenal cortex

ENDODERM (inner layer of embryo)

- Epithelial lining of digestive tract and associated organs (liver, pancreas)
- Epithelial lining of respiratory, excretory, and reproductive tracts and ducts
- Thymus, thyroid, and parathyroid glands

▶ **Figure 47.9 Gastrulation in a sea urchin embryo.** The movement of cells during gastrulation forms an embryo with a primitive digestive tube and three germ layers. Some of the mesodermal mesenchyme cells that migrate inward (step 1) will eventually secrete calcium carbonate and form a simple internal skeleton. Embryos in steps 1–3 are viewed from the front, those in 4 and 5 from the side.



Chapter 47 Questions

1. **What are model organisms?**
2. **What is fertilization?**
3. **What is polyspermy?**
4. **Why is it easy for researchers to study fertilization in sea urchins?**
5. **Describe how the sperm fuses with the egg in sea urchins.**
6. **What causes the fast block to polyspermy in sea urchins?**
7. **Describe the slow block to polyspermy in sea urchins.**
8. **In what way does the sperm activate the egg?**
9. **What triggers the activation of the egg?**
10. **In what state is the sea urchin egg when it is released?**
11. **What is capacitation?**
12. **Describe fertilization in mammals.**
13. **How does the length of fertilization in mammals differ from that of sea urchins?**
14. **What is cleavage?**
15. **What is the result of cleavage?**
16. **What is yolk and how is it organized in many animal eggs?**
17. **What is a cleavage furrow?**
18. **Describe the cleavage pattern in frogs.**
19. **What is holoblastic cleavage?**
20. **What is meroblastic cleavage?**
21. **What occurs in the cleavage of *Drosophila* and other insects.**
22. **What is morphogenesis?**
23. **What is gastrulation?**
24. **What is organogenesis?**
25. **What is a gastrula?**
26. **What are germ layers?**
27. **What is ectoderm?**
28. **What is endoderm?**
29. **What is mesoderm?**
30. **What are diploblasts and triploblasts?**
31. **Name the major derivatives of each of the three germ layers.**
32. **What is the dorsal lip?**
33. **What are mesenchyme cells?**
34. **Describe sea urchin gastrulation.**
35. **Describe gastrulation in frogs.**
36. **Where do the cell movements that begin gastrulation occur?**
37. **Describe the state of a chick embryo just before gastrulation.**
38. **What occurs during gastrulation in chicks?**
39. **What is the result of cleavage in humans?**
40. **How does implantation occur in humans?**

41. **What occurs after implantation of human embryo?**
42. **What makes up the placenta?**
43. **What are the 4 extraembryonic membranes?**
44. **What are amniotes?**
45. **What is neurulation?**
46. **What is the first step of neurulation?**
47. **How does the neural plate form?**
48. **What is induction?**
49. **What are neural folds?**
50. **What is the neural tube?**
51. **What happens to the notochord just before birth?**
52. **What is spina bifida?**
53. **What is the neural crest?**
54. **What are somites?**
55. **Describe organogenesis in invertebrates.**
56. **How does invagination of cell layers occur during gastrulation?**
57. **What is convergent extension?**
58. **How do cells migrate during organogenesis?**
59. **What is apoptosis?**
60. **What is cell fate?**
61. **What is determination?**
62. **What is differentiation?**
63. **What are fate maps?**
64. **Describe the cell determination of *C. elegans*.**
65. **What are germ cells?**
66. **What are P granules?**
67. **Describe cell death in normal *C. elegans* development.**
68. **How is the position of the anterior-posterior axis determined in frogs?**
69. **How is the dorsal-ventral axis determined in frogs?**
70. **Describe axis formation in mammals, birds, insects, and fish.**
71. **What is the grey crescent?**
72. **What is developmental potential?**
73. **What does totipotent mean?**
74. **Until what stage are cells totipotent in mammals and frogs?**
75. **What occurs after the 16-cell stage in humans in terms of potential?**
76. **What are monozygotic twins?**
77. **When are the tissue-specific fates of cells fixed?**
78. **What functions as an organizer of the embryo's body plan?**
79. **What is *Spemann's organizer*?**
80. **What is pattern formation?**
81. **What is positional information?**
82. **Describe pattern formation of vertebrate limbs.**
83. **What is the apical ectodermal ridge (AER)?**

84. What is the zone of polarizing activity (ZPA)?
85. What are monocilia?
86. What do mutations in monocilia formation cause?
87. How do monocilia function in development?
88. What is Kartagener's syndrome?
89. How is left-right asymmetry established?

Chapter 47 Answers

1. Species chosen for ease with which they can be studied in the laboratory
2. Formation of diploid zygote from haploid egg/sperm
3. Entry of multiple sperm nuclei into egg, would cause polyploidy
4. Gametes easy to collect and fertilization occurs outside body
5. Jelly coat of egg exudes soluble molecules that attract sperm. When sperm head hits egg, molecules in jelly coat trigger acrosomal reaction in sperm (specialized vesicle at tip of sperm, acrosome, discharges hydrolytic enzymes that digest jelly coat, acrosomal process forms, elongates, and penetrates coat, tip of process bind to receptor proteins in egg plasma membrane). Recognition triggers fusion of plasma membranes.
6. Ion channels open in egg's plasma membrane when sperm fuses, causing sodium ions to diffuse into egg and cause depolarization, prevents additional sperm from fusing
7. Cortical granules (vesicles in outer rim of cytoplasm) fuse with egg plasma membrane after sperm binds egg. Contents released between plasma membrane and surrounding vitelline layer (formed by egg's ECM). Granule contents trigger cortical reaction, lifting vitelline layer away from egg and hardens it into protective fertilization envelope. Formation requires high concentration of Ca^{2+} ions, so binding of sperm causes STP that causes ER to release Ca^{2+} into cytosol, which causes cortical granules to fuse with plasma membrane (occurs in vertebrates as well)
8. Increase in rates of cellular respiration and protein synthesis and nuclei fuse and cell cycle begins.
9. Rise in Ca^{2+} concentration, proteins/;mRNAs required for activation already present in cytoplasm of unfertilized egg
10. It has completed meiosis
11. first 6 hours in female tract cause changes in sperm
12. Internal, support cells surround egg. Sperm travels through follicle layer before reaching zona pellucida (ECM of egg), acrosomal reaction occurs, cortical reaction occurs, zona pellucida changes in response to cortical reaction and acts as slow block to polyspermy. No fast block known
13. First cell division - Mammals 12-36 hrs, 1.5 in sea urchins
14. Series of rapid cell divisions during early development, restores balance between cell's size and DNA content, cell cycle consists primarily of S and M phases.
15. Smaller cells called blastomeres, first 5-7 divisions form blastula (hollow ball of 128 or more cells) surrounding blastocoel (fluid-filled cavity)
16. Stored nutrients, concentrated toward one pole (vegetal pole), opposite of animal pole.
17. Indentation that forms when animal cell divides
18. First two cleavage furrows parallel to meridian (line between poles), dense yolk slows cytokinesis, second cell division occurs while first is in progress, eventually four blastomeres of equal size from animal pole to vegetal pole. In third division, division is equatorial, produces eight-cell embryo, yolk displaces mitotic apparatus so furrow closer to animal pole. Blastocoel completely in animal hemisphere. See picture

19. Cleavage where furrows pass entirely through egg, seen in echinoderms, mammals, and annelids
20. Incomplete cleavage of yolk-rich egg (in birds and other reptiles, fish, and insects)
21. Yolk found throughout egg, multiple rounds of mitosis without cytokinesis. First several hundred nuclei spread throughout yolk, migrate to edge of embryo later. Plasma membrane forms around each nucleus to form blastula (single layer of 6000 cells surrounding yolk)
22. Cellular and tissue-based processes by which animal body takes shape
23. Set of cells at or near surface of blastula moves to interior location, cell layers established, primitive digestive tube formed, only in animals
24. Formation of organs
25. Two-layered or three-layered embryo
26. Layers that are produced by gastrulation
27. Outer germ layer
28. Lining of digestive tract
29. Third germ layer forming between ectoderm/endoderm
30. Diploblastic = endo and ecto, triplo = endo/ecto/meso
31. See picture
32. Part above the blastopore during beginning of gastrulation
33. Cells that detach from blastocoel wall and form mesoderm
34. See picture
35. Sheet of cells from animal hemisphere rolls over dorsal lip (involution) and moves into interior (will form mesoderm and endoderm). Cells at pole spread over outer surface. Invagination forms archenteron, blastopore filled with plug of yolk-filled cells, blastocoel shrinks and disappears
36. Dorsal side, opposite of sperm entry, gray crescent = dorsal side
37. Upper and lower layer of cells (epiblast and hypoblast) lie atop yolk mass. All cells that become embryo come from epiblast.
38. Epiblast cells move toward midline, detach, and move inward towards yolk, producing primitive streak (thickening at midline). Some cells move downward to form endoderm by pushing away hypoblast cells. Others migrate sideways to form mesoderm. Surface cells become ectoderm, hypoblast cells segregate and form sac around yolk.
39. 100 cell embryo around central cavity in uterus. Called blastocyst (mammalian blastula). Inner cell mass at one end of blastocyst cavity (will develop into embryo proper, cells are source of embryonic stem cell lines)
40. Trophoblast (outer epithelium of blastocyst) secretes enzymes that break down molecules of endometrium, allowing invasion of blastocyst. Trophoblast extends finger-like projections that cause capillaries in endometrium to spill blood that trophoblast captures. Inner cell mass forms flat disk with an inner layer of cells (epiblast) and outer layer (hypoblast)
41. Trophoblast continues to expand into endometrium, extraembryonic membranes appear from embryo (enclose structures outside embryo). Gastrulation then begins like in chick
42. Cells of invading trophoblast, epiblast, and adjacent endometrial tissue

43. Chorion (gas exchange), allantois (waste disposal, incorporated into umbilical cord), amnion (fluid protection), and yolk sac (encloses yolk in reptiles, in mammals site of early blood cell formation and migrates to embryo proper)
44. Mammals and reptiles (embryos are surrounded by fluid within amnion (sac))
45. Early steps in formation of brain and spinal cord in vertebrates
46. Cells from dorsal mesoderm form notochord (rod that extends along dorsal side of chordate embryo)
47. Signaling molecules secreted by notochord and other tissues causes ectoderm above notochord to thicken/form neural plate
48. Process in which group of cells or tissues influences the development of another group through close range interactions
49. Ridges forming the lateral edges of the neural plate
50. Cells of neural plate change shape, curving structure inward, rolling itself into tube (runs anterior-posterior axis of embryo. Will become brain in head and spinal cord along rest of body
51. Disappears, parts persist as inner portions of disks in adult spine (can herniate or rupture to cause back pain)
52. most common disabling birth defect, occurs when portion of neural tube fails to develop or close properly. (can be repaired after birth, but nerve dmg permanent)
53. Set of cells that develop along borders where neural tube pinches off from ectoderm, migrate to many parts of embryo, form variety of tissues that include peripheral nerves as well as parts of teeth/skull bone
54. Groups of mesodermal cells lateral to notochord separate into blocks, organize segmented structure of body. Parts dissociate into mesenchyme cells, some form vertebrae, others form muscles associated with vertebral column/ribs.
55. tissues of nervous system form on ventral not dorsal side. Anterior-posterior axis rolls into tube inside embryo like in vertebrates, similar molecular signaling pathways
56. Crosswise microfilaments at the apical end of each cell contract to give cells a wedge shape. Microtubules oriented from dorsal to ventral help lengthen cells along that axis
57. Rearrangement that causes a sheet of cells to become narrower while it becomes longer, occurs in formation of primitive streak in chick egg and elongation of archenteron in sea urchin, involution in frog gastrula
58. Crawl by using cytoskeletal fibers to extend/retract cellular protrusions. Cell adhesion molecules (transmembrane glycoproteins promote interaction between pairs of cells). ECM helps guide cells, cells that line pathways regulate movement of migrators by secreting molecules into ECM
59. Programmed cell death, common feature of animal development
60. Where a cell resides, how it appears, and what it does
61. Process by which cell or group of cells becomes committed to particular fate
62. Specialization in structure and function
63. Diagrams showing the structures arising from each region in the embryo
64. 959 somatics cells, intestine derived from one of first four cells of zygote
65. Specialized cells that give rise to eggs or sperm

66. Complexes of RNA and protein that direct particular cells to become germ cells, distribute towards posterior end, continually partitioned asymmetrically
67. 131 cells die, mutation in one gene allows all to live
68. Dark melanin granules in cortex of animal hemisphere, yellow yolk in vegetal hemisphere (animal-vegetal asymmetry determines axis, but animal-vegetal axis is different), determined during oogenesis
69. Randomly. Wherever sperm enters determines where axis forms. After sperm/egg fusion, egg surface(with melanin) rotates with respect to cytoplasm (cortical rotation since plasma membrane + cortex rotate toward sperm entry), exposes gray crescent
70. Mammals, sperm entry influences location of first cleavage plane.
    Chicks, anterior-posterior axis established by pull of gravity while egg travels down oviduct
    Insect - gradients of active transcription factors establish anterior/posterior and dorsal/ventral axes
    Zebrafish - signals within embryo establish anterior posterior axis over course of day
71. Lighter-colored cytoplasmic region exposed when pigmented cortex slides over underlying cytoplasm in frogs, marker of future dorsal side
72. Range of structures to which a cell can give rise.
73. Can develop into all different cell types of the species
74. Mammals - eight-cell stage, more than many other animals
    Frogs - first two blastomeres
75. Cells determined to form trophoblast or inner cell mass, limited dev potential but nuclei are totipotent
76. Identical, cells or group of cells from single embryo separated, if occurs before differentiation of trophoblast/inner cell mass, embryos grow with separate chorion and amnion (⅓ of twins). Rest, two embryos share chorion, in rare cases of later separation share amnion
77. In late gastrula, but not always in early gastrula
78. Dorsal lip, triggers gastrulation of surrounding tissue, induces formation of organs
79. cluster of cells that control induction of gastrulation, seems to inactivate growth factor bone morphogenetic protein 4 (BMP-4) on dorsal side of embryo
80. Process governing arrangement of organs and tissues in their characteristic places in 3d space.
81. Molecular cues that control pattern formation, tell a cell where it is with respect to body axes, helps determine how cell/descendants will respond to molecular signaling
82. Begin as limb buds (bumps of mesodermal tissues covered by layer of ectoderm). Each component of limb develops with precise location/orientation relative to proximal-distal (shoulder-fingertip), anterior-posterior (thumb-little finger), and dorsal-ventral (knuckle-palm) axes.
83. Thickened area of ectoderm at tip of limb bud, removal blocks outgrowth of limb along proximal distal axis. Secretes protein signal called fibroblast growth factor (FGF), promotes limb-bud outgrowth

84. Limb-bud regulatory region, specialized block of mesodermal tissue, regulates development along anterior-posterior axis. Cells near ZPA form posterior structures, cells farthest form anterior structures. Secretes Sonic hedgehog protein. Production of sonic hedgehog in ectopic place can result in extra toes
85. Stationary primary cilia, single juts from surface of most cells.
86. Severe kidney disease in mice after altering gene important for material transport in cilia, cystic kidney disease in human if mutation function of monocilia
87. Act as antennae, receive signals from signaling proteins
88. Male infertility due to immotile sperm, infections of nasal sinuses and bronchi in males and females, situs inversus (reversal of normal left-right asymmetry of organs). Caused by defect that makes cilia immotile. Sperm tails cannot beat, airway cells cannot sweep mucus/microbes out of airway.
89. Cilia generates leftward fluid flow, without flow asymmetry arises randomly