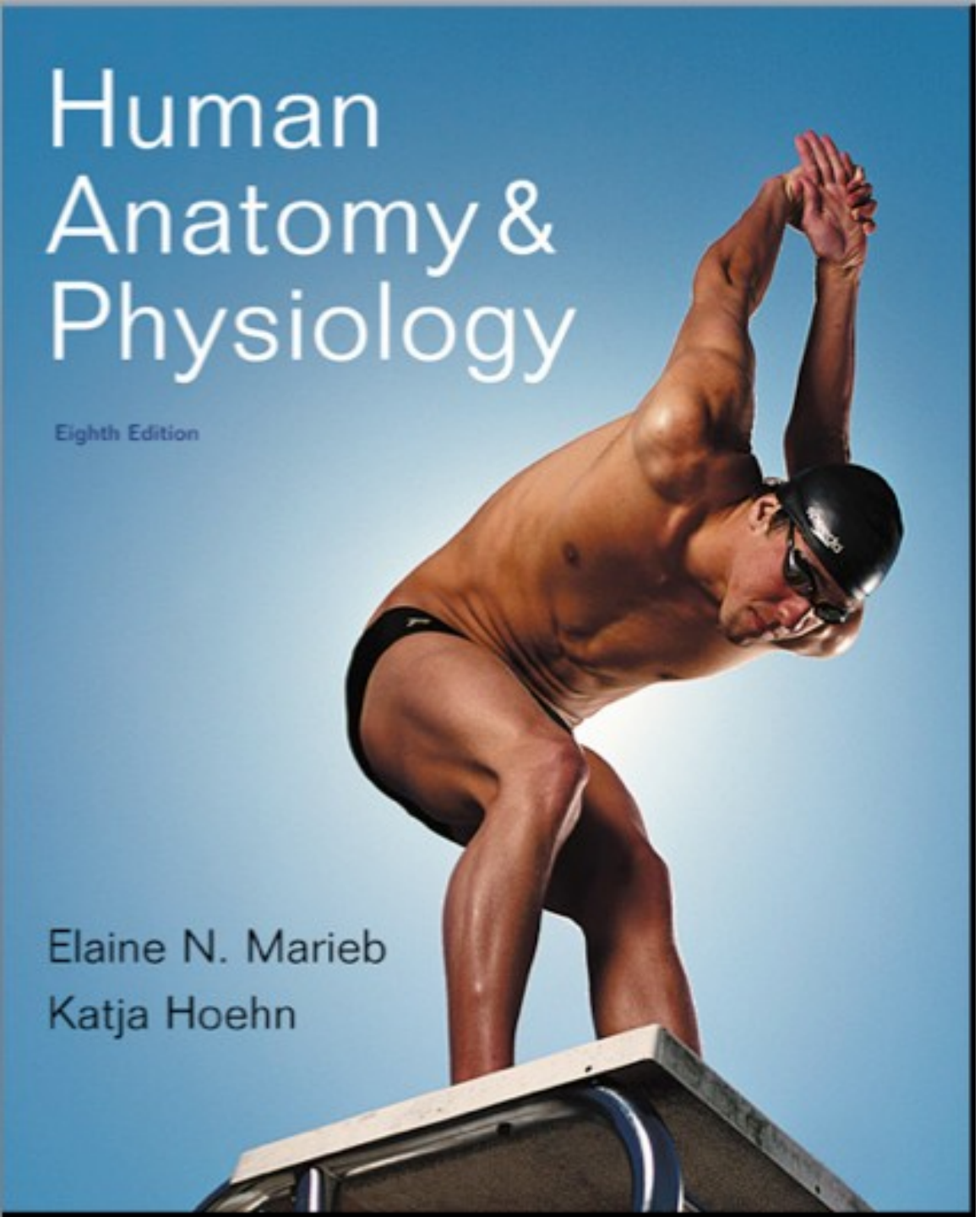


Chapter 28

Pregnancy & Human Development

Pregnancy

- Pregnancy: events that occur from fertilization until the infant is born
- Conceptus: the developing offspring
- Gestation period: time from the last menstrual period until birth (~280 days)
- Embryo: conceptus from fertilization through week 8
- Fetus: conceptus from week 9 through birth

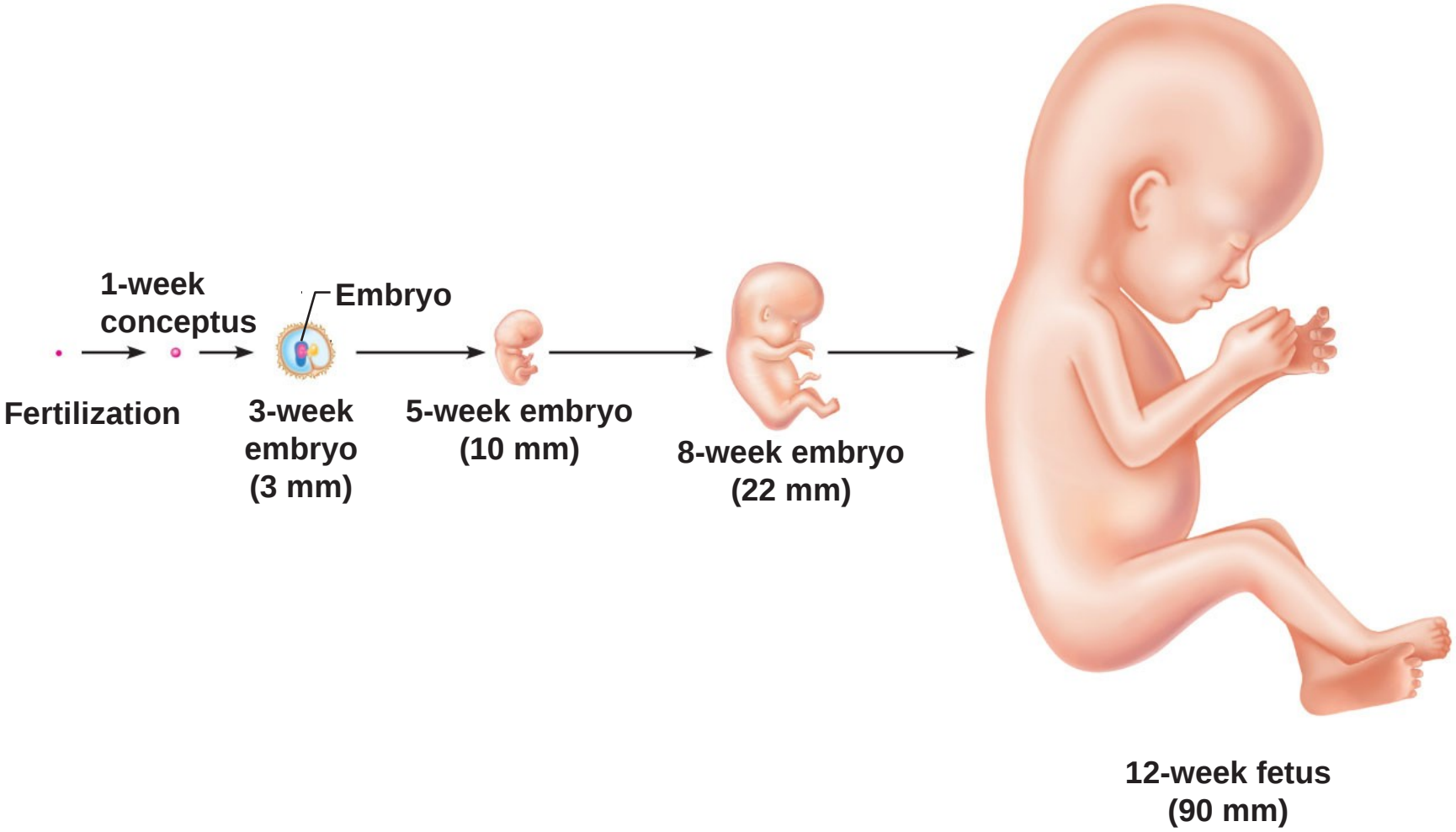

1-week
conceptus
Embryo
Fertilization
3-week
embryo
(3 mm)
5-week embryo
(10 mm)
8-week embryo
(22 mm)
12-week fetus
(90 mm)

Figure 28.1

From Egg to Zygote

- The oocyte is viable for 12 to 24 hours
- Sperm is viable 24 to 48 hours after ejaculation

From Egg to Zygote

- For fertilization to occur, coitus must occur no more than
  - Two days before ovulation
  - 24 hours after ovulation
- Fertilization: when the sperm's chromosomes combine with those of a secondary oocyte to form a fertilized egg (zygote)

Accomplishing Fertilization

- Ejaculated sperm
  - Leak out of the vagina immediately after deposition
  - Are destroyed by the acidic vaginal environment
  - Fail to make it through the cervix
  - Are dispersed in the uterine cavity or destroyed by phagocytes
  - Few (100 to a few thousand) reach the uterine tubes

Accomplishing Fertilization

- Sperm must become motile
- Sperm must be activated before they can penetrate the oocyte
  - Secretions of the female tract weaken acrosome membrane

Acrosomal Reaction and Sperm Penetration

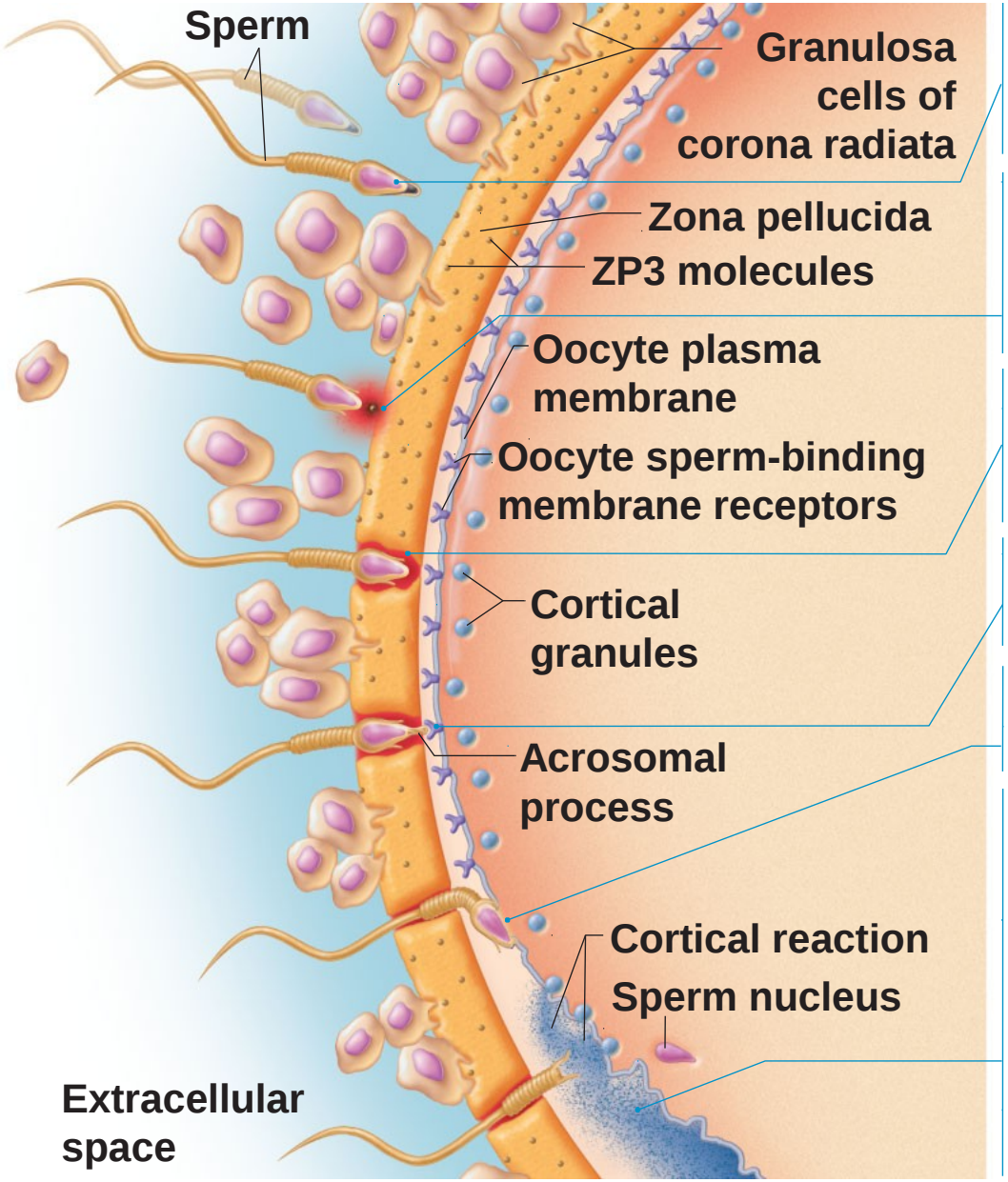
- Sperm must breach oocyte coverings
  - Corona radiata and zona pellucida
- Sperm binds to the zona pellucida and undergoes the acrosomal reaction
  - Enzymes are released to digest holes in the zona pellucida
  - Hundreds of acrosomes release their enzymes to digest the zona pellucida

Acrosomal Reaction and Sperm Penetration

- Sperm head approaches the oocyte
- An acrosomal process forms and binds to receptors
- Oocyte and sperm membranes fuse
- Only one sperm is allowed to penetrate the oocyte (monospermy)

Blocks to Polyspermy

- Upon entry of a sperm, Ca^{2+} surge from the ER causes the cortical reaction
  - Cortical granules release enzymes (zonal inhibiting proteins, or ZIPs)
  - ZIPs destroy sperm receptors
  - Spilled fluid binds water and swells, detaching other sperm (slow block to polyspermy)



1. Aided by surface hyaluronidase enzymes, a sperm cell weaves its way past granulosa cells of the corona radiata.
2. Binding of the sperm to ZP3 molecules in the zona pellucida causes a rise in Ca^{2+} level within the sperm, triggering the acrosomal reaction.
3. Acrosomal enzymes digest holes through the zona pellucida, clearing a path to the oocyte membrane.
4. The sperm forms an acrosomal process, which binds to the oocyte's sperm-binding receptors.
5. The sperm and oocyte plasma membranes fuse, allowing sperm contents to enter the oocyte.
6. Entry of sperm contents (tail and plasma membrane remain behind) causes a rise in the Ca^{2+} level in the oocyte's cytoplasm, triggering the cortical reaction (exocytosis of cortical granules). The result is hardening of the zona pellucida and clipping off of sperm receptors (slow block to polyspermy).

Figure 28.2

Completion of Meiosis II and Fertilization

- As sperm nucleus moves toward the oocyte nucleus it swells to form the male pronucleus
- The Ca^{2+} surge triggers completion of meiosis II $\rightarrow$ ovum + second polar body
- Ovum nucleus swells to become a female pronucleus
- Membranes of the two pronuclei rupture and the chromosomes combine

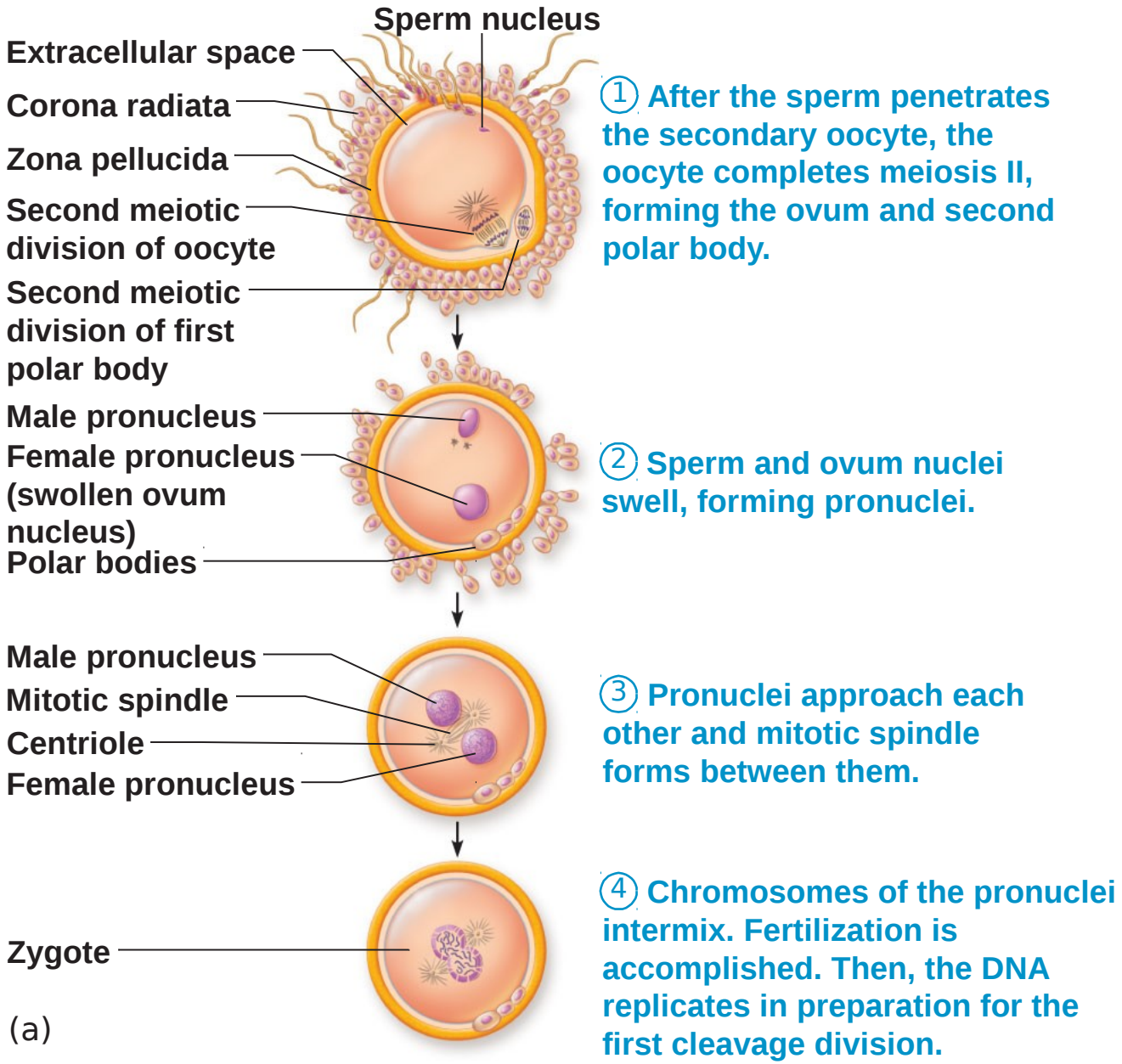

Sperm nucleus
Extracellular space
Corona radiata
Zona pellucida
Second meiotic division of oocyte
Second meiotic division of first polar body
Male pronucleus
Female pronucleus (swollen ovum nucleus)
Polar bodies
Male pronucleus
Mitotic spindle
Centriole
Female pronucleus
Zygote
(a)
1 After the sperm penetrates the secondary oocyte, the oocyte completes meiosis II, forming the ovum and second polar body.
2 Sperm and ovum nuclei swell, forming pronuclei.
3 Pronuclei approach each other and mitotic spindle forms between them.
4 Chromosomes of the pronuclei intermix. Fertilization is accomplished. Then, the DNA replicates in preparation for the first cleavage division.

Figure 28.3a

Embryonic Development

- Cleavage
  - Mitotic divisions of zygote
  - First cleavage at 36 hours $\rightarrow$ two daughter cells (blastomeres)
  - At 72 hours $\rightarrow$ morula (16 or more cells)
- At day 3 or 4, the embryo of ~100 cells (blastocyst) has reached the uterus

Embryonic Development

- Blastocyst: fluid-filled hollow sphere
- Trophoblast cells
  - Display factors that are immunosuppressive
  - Participate in placenta formation
- Inner cell mass
  - Becomes the embryonic disc ($\rightarrow$ embryo and three of the embryonic membranes)

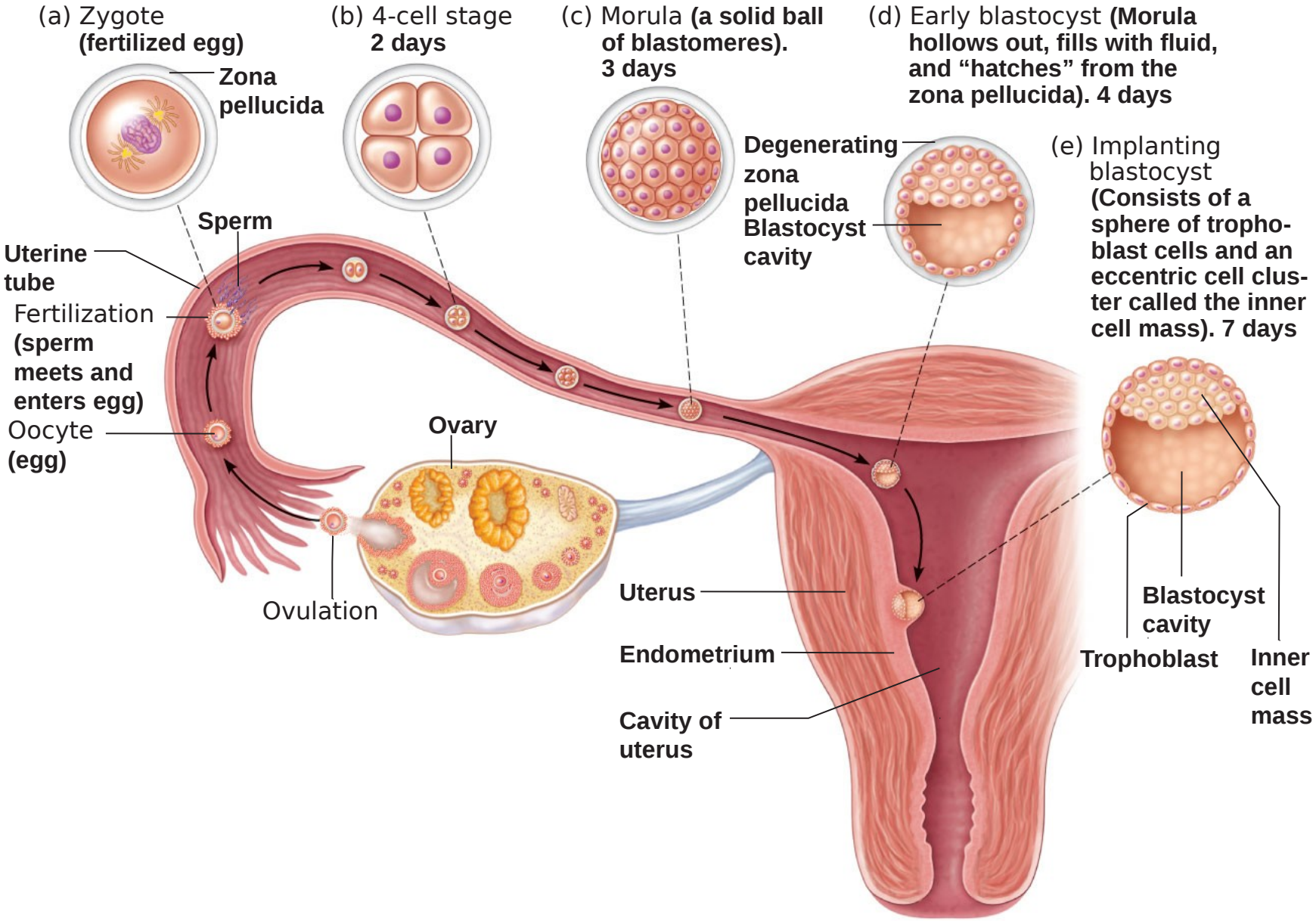

(a) Zygote (fertilized egg)
Zona pellucida
(b) 4-cell stage 2 days
(c) Morula (a solid ball of blastomeres). 3 days
(d) Early blastocyst (Morula hollows out, fills with fluid, and "hatches" from the zona pellucida). 4 days
Degenerating zona pellucida
Blastocyst cavity
(e) Implanting blastocyst (Consists of a sphere of trophoblast cells and an eccentric cell cluster called the inner cell mass). 7 days
Sperm
Uterine tube
Fertilization (sperm meets and enters egg)
Oocyte (egg)
Ovary
Ovulation
Uterus
Endometrium
Cavity of uterus
Blastocyst cavity
Trophoblast
Inner cell mass

Figure 28.4

Implantation

- Blastocyst floats for 2–3 days
- Implantation begins 6–7 days after ovulation
  - Trophoblast adheres to a site with the proper receptors and chemical signals
  - Inflammatory-like response occurs in the endometrium

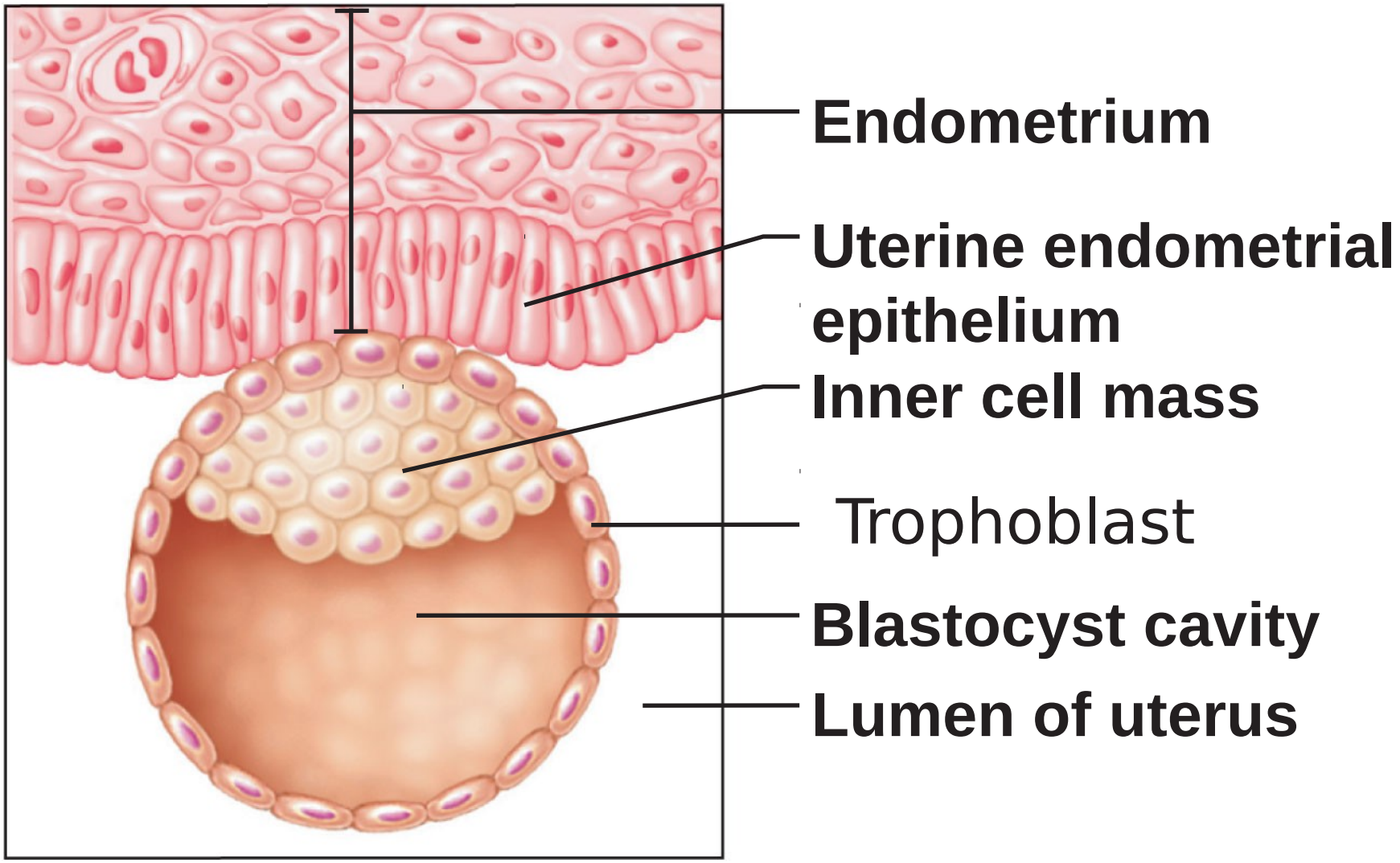

Endometrium
Uterine endometrial epithelium
Inner cell mass
Trophoblast
Blastocyst cavity
Lumen of uterus
(a)

Figure 28.5a

Implantation

- Trophoblasts proliferate and form two distinct layers
  1. Cytotrophoblast (cellular trophoblast): inner layer of cells
  2. Syncytiotrophoblast: cells in the outer layer lose their plasma membranes, invade and digest the endometrium

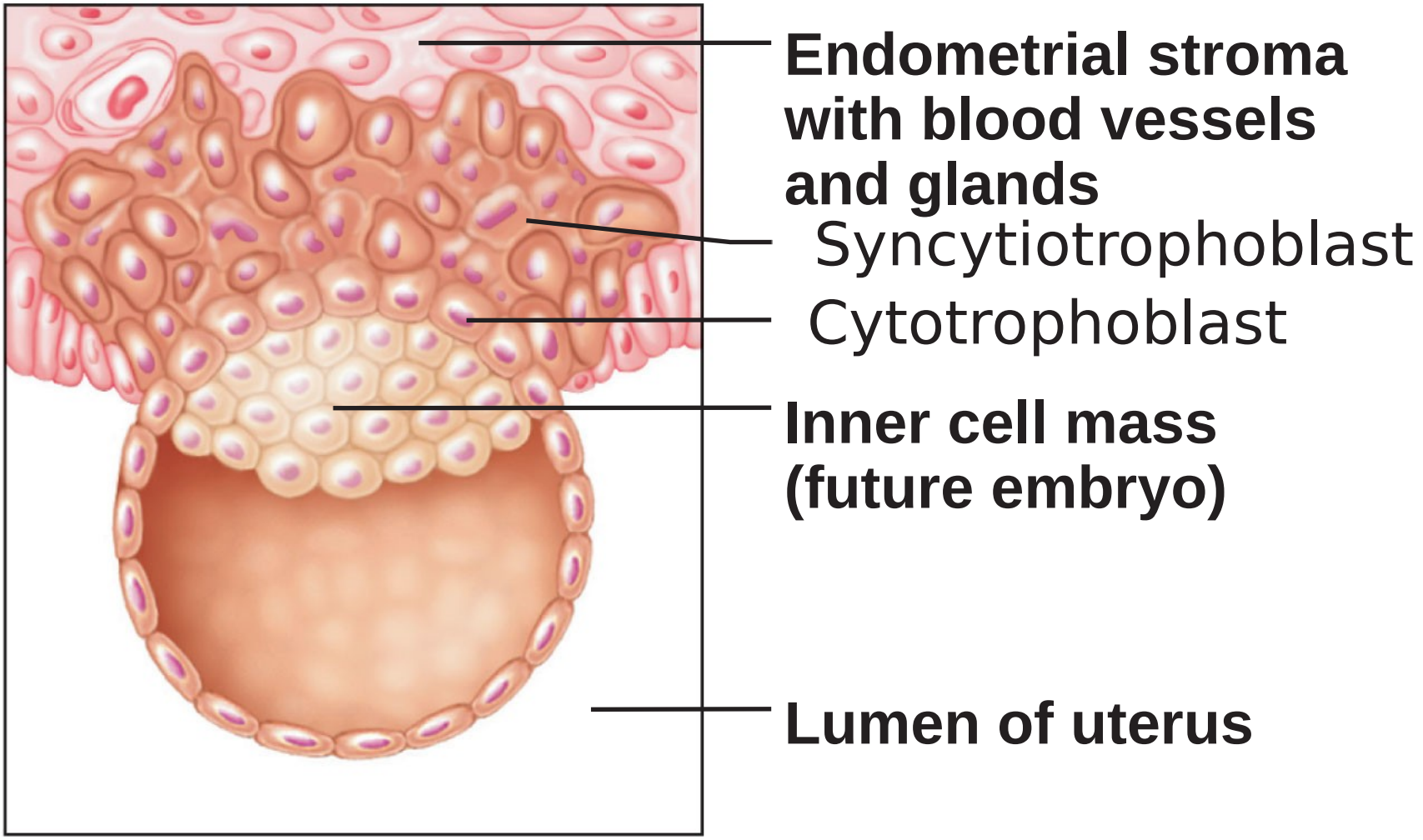

Endometrial stroma with blood vessels and glands
Syncytiotrophoblast
Cytotrophoblast
Inner cell mass (future embryo)
Lumen of uterus
(c)

Figure 28.5c

Implantation

- The implanted blastocyst is covered over by endometrial cells
- Implantation is completed by the twelfth day after ovulation

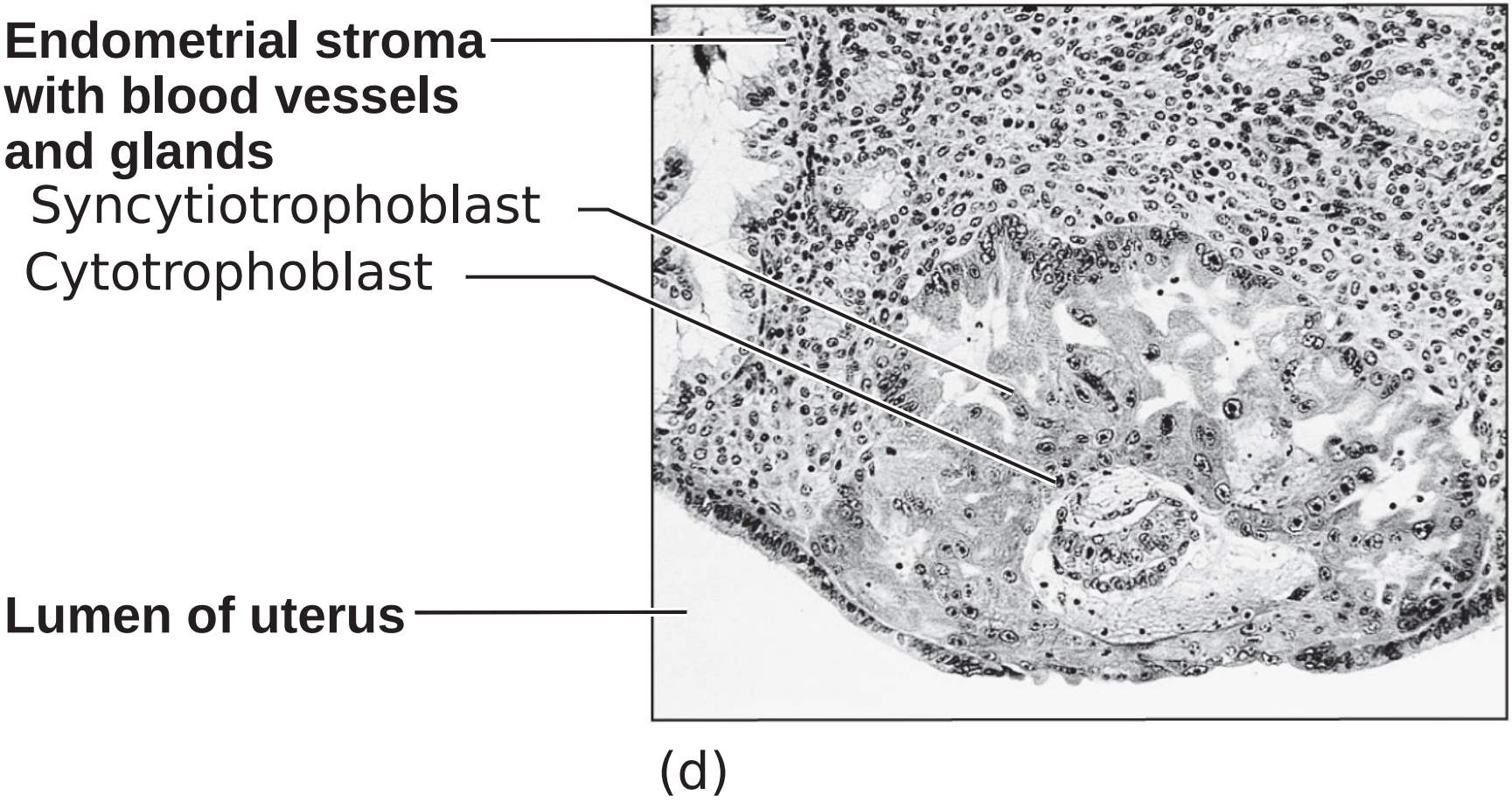

Endometrial stroma with blood vessels and glands
Syncytiotrophoblast
Cytotrophoblast
Lumen of uterus
(d)

Figure 28.5d

Hormonal Changes During Pregnancy

- Human chorionic gonadotropin (hCG)
  - Secreted by trophoblast cells, later the chorion
  - Prompts corpus luteum to continue secretion of progesterone and estrogen
  - hCG levels rise until the end of the second month, then decline as the placenta begins to secrete progesterone and estrogen

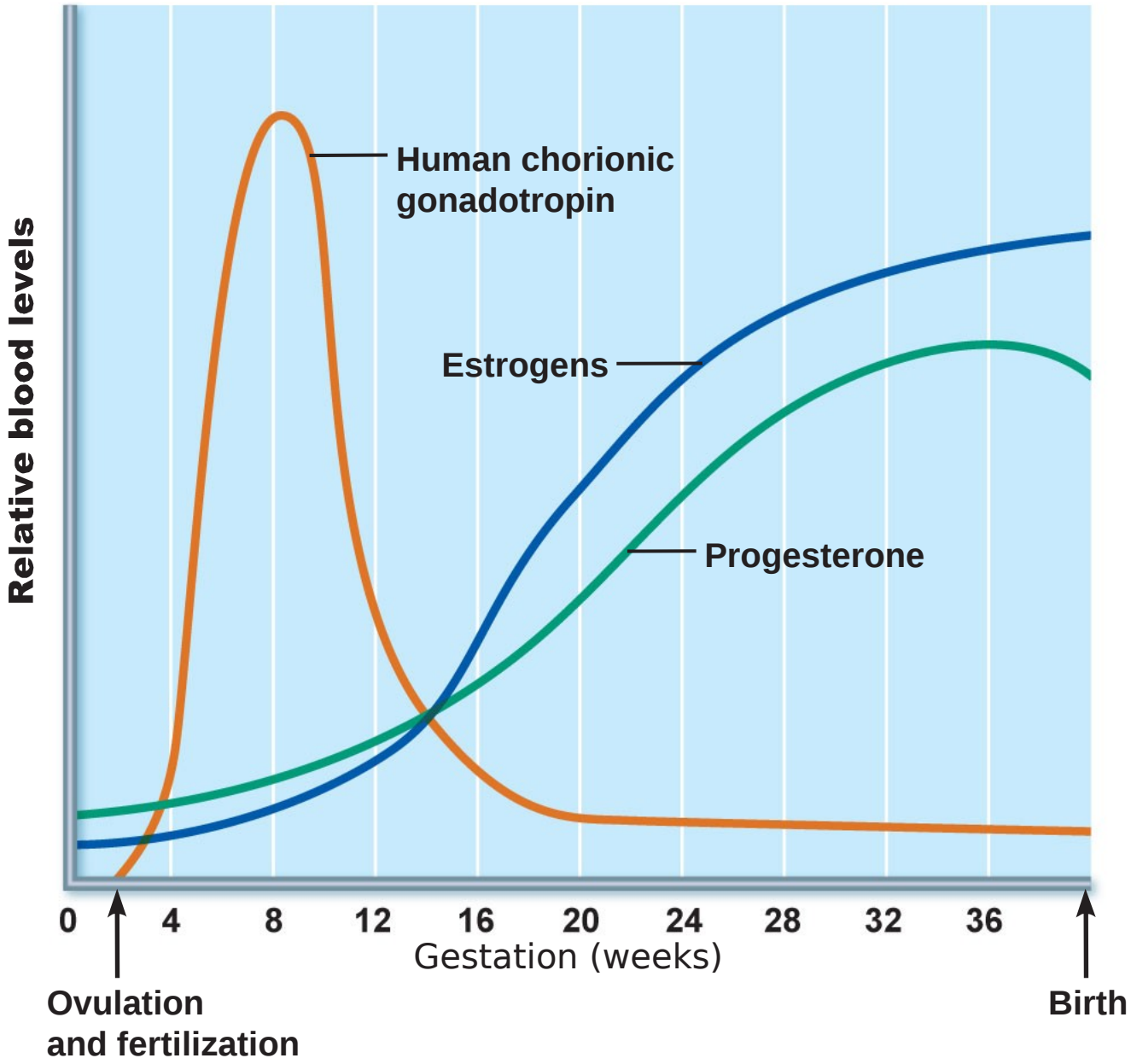
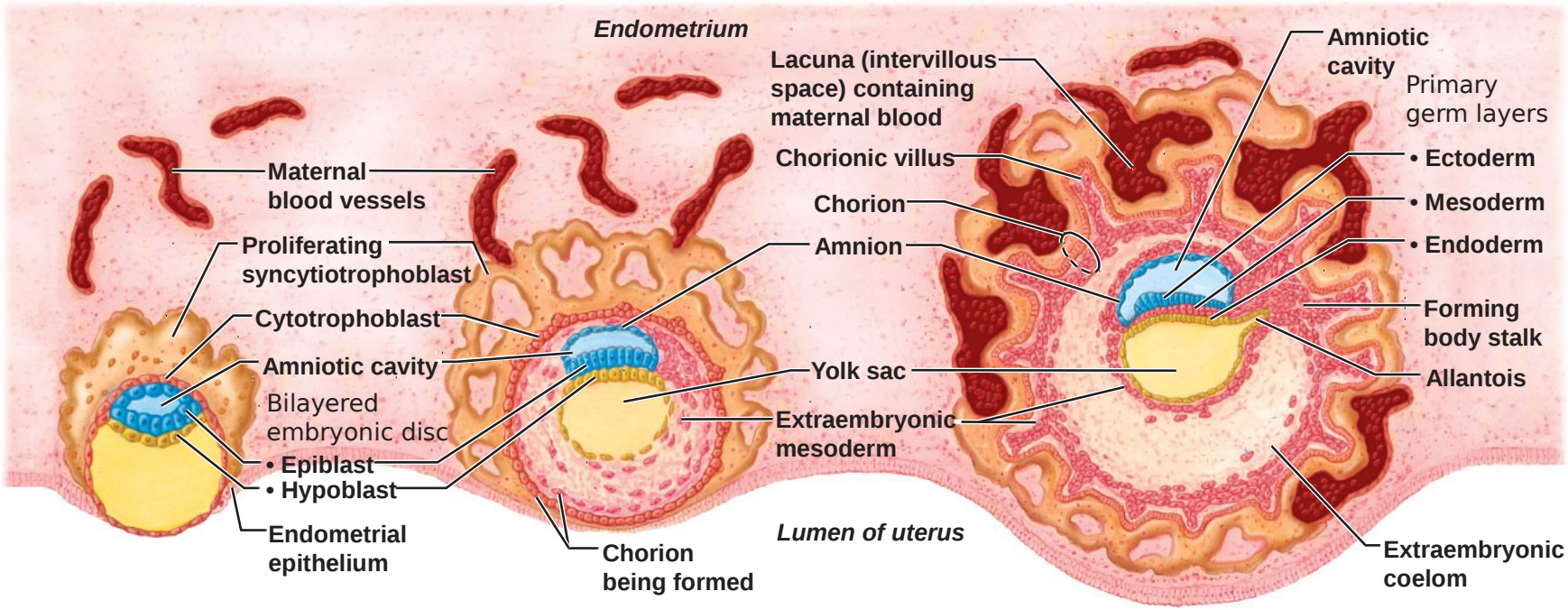

Relative blood levels
Human chorionic gonadotropin
Estrogens
Progesterone
0
4
8
12
16
20
24
28
32
36
Gestation (weeks)
Ovulation and fertilization
Birth

Figure 28.6

Placentation

- Formation of the placenta from embryonic and maternal tissues
  1. Embryonic tissues
     - Mesoderm cells develop from the inner cell mass and line the trophoblast
     - Together these form the chorion and chorionic villi



(a) Implanting 7½-day blastocyst. **The syncytiotrophoblast is eroding the endometrium. Cells of the embryonic disc are now separated from the amnion by a fluid-filled space.**

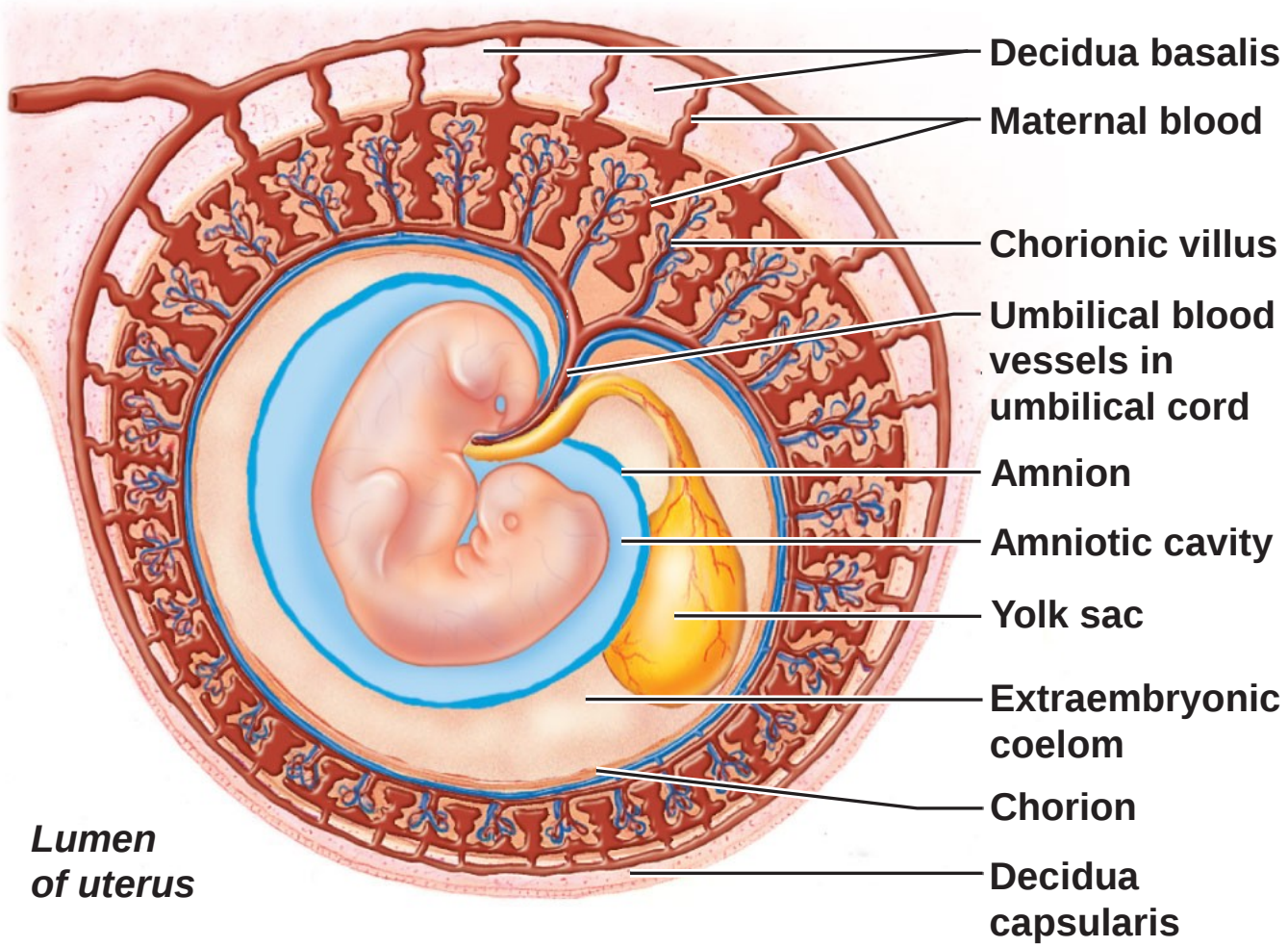
(b) 12-day blastocyst. **Implantation is complete. Extraembryonic mesoderm is forming a discrete layer beneath the cytotrophoblast.**

(c) 16-day embryo. **Cytotrophoblast and associated mesoderm have become the chorion, and chorionic villi are elaborating. The embryo exhibits all three germ layers, a yolk sac and an allantois, which forms the basis of the umbilical cord.**

Figure 28.7 (a-c)

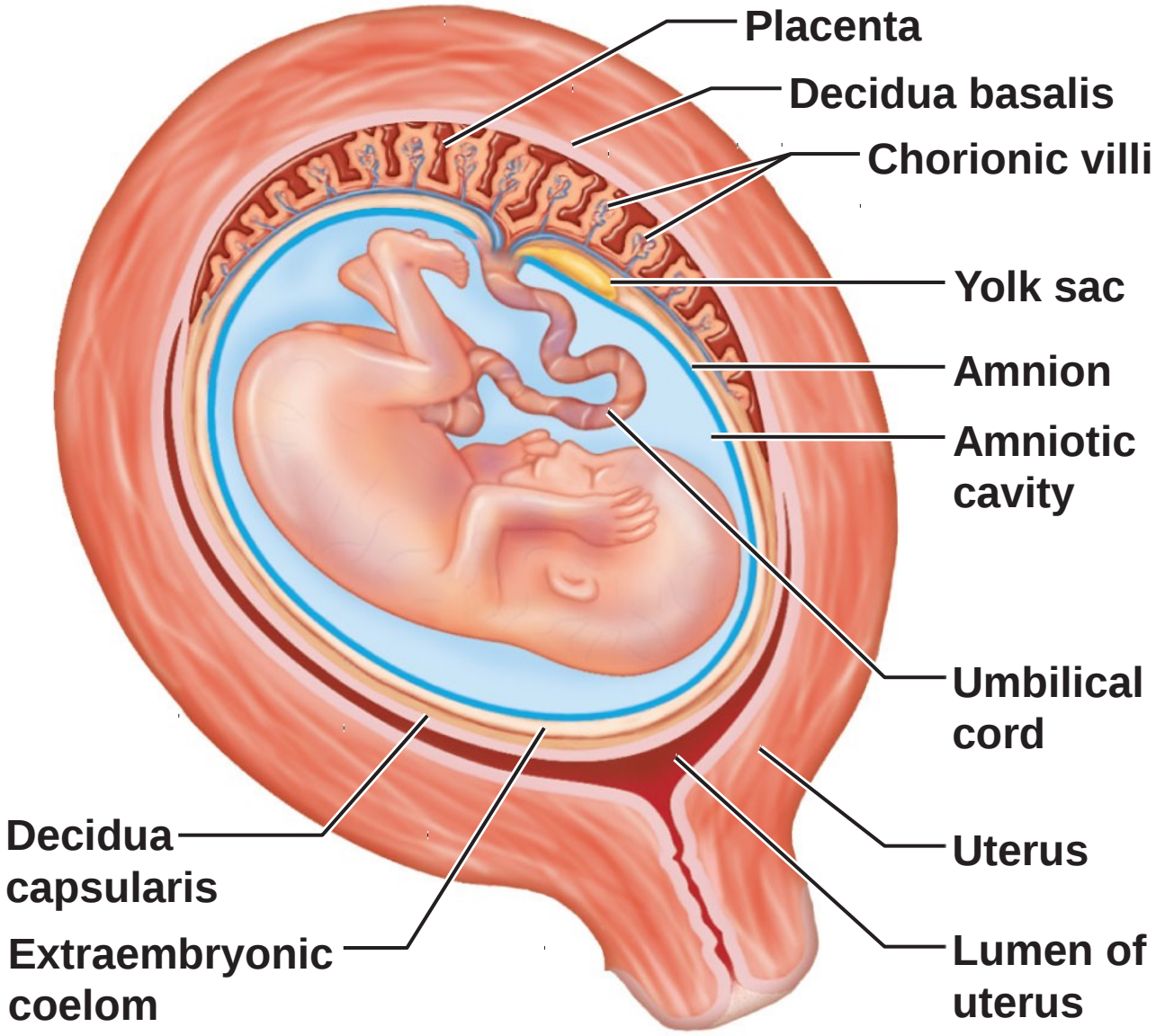
Placentation

- Development of the placenta
- Forms from both embryonic cells and maternal cells



(d) $4\frac{1}{2}$-week embryo. **The decidua capsularis, decidua basalis, amnion, and yolk sac are well formed. The chorionic villi lie in blood-filled intervillous spaces within the endometrium. The embryo is now receiving its nutrition via the umbilical vessels that connect it (through the umbilical cord) to the placenta.**

Figure 28.7d



(e) 13-week fetus.

Figure 28.7e

Placenta

- Maternal and embryonic blood supplies do not intermix
- Embryonic and maternal blood vessels lie side-by-side.
- However, some embryonic cells may cross into mother's blood stream
- Embryonic placental barriers include:
  - Membranes of the chorionic villi
  - Endothelium of embryonic capillaries

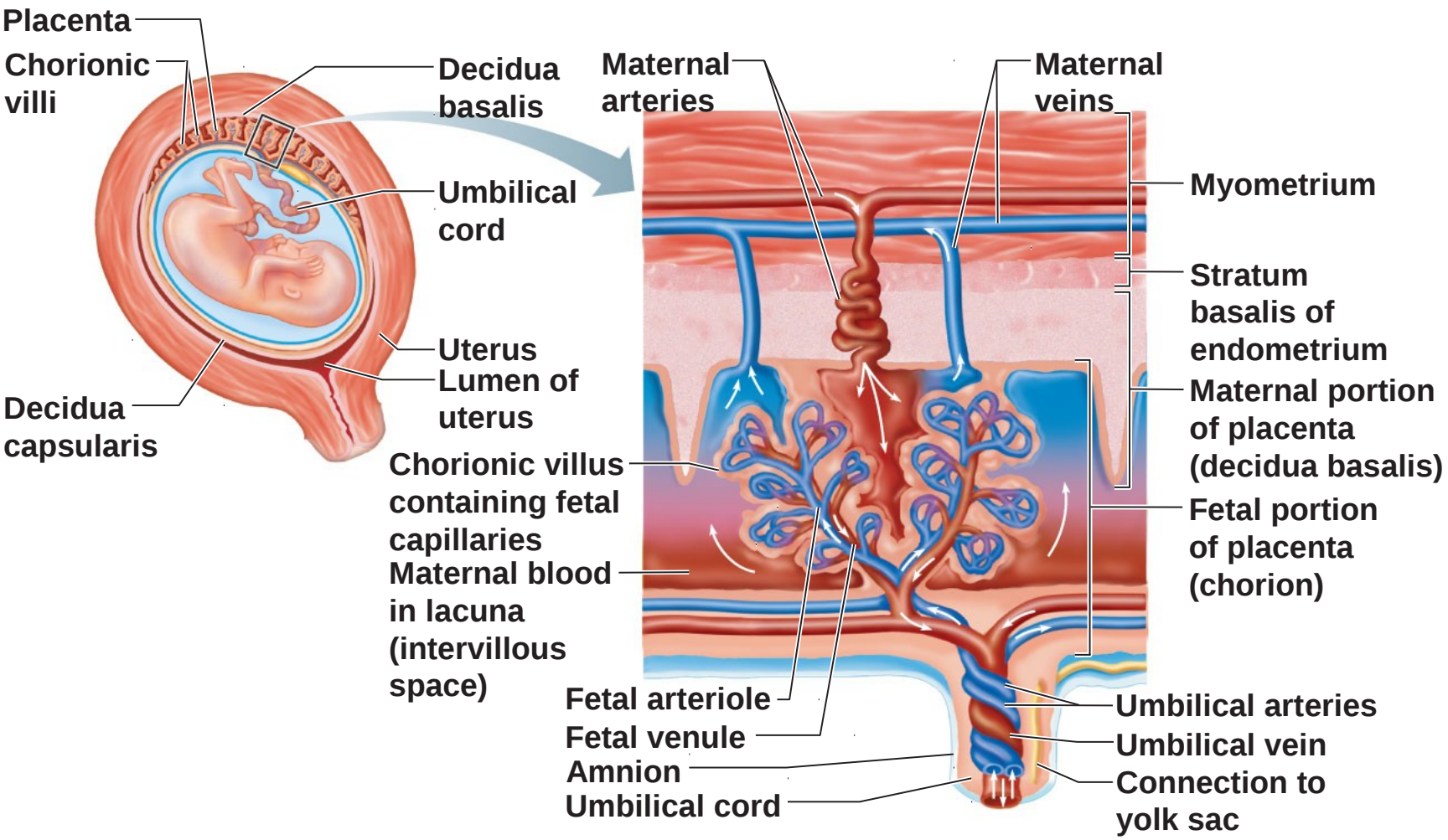

Placenta
Chorionic villi
Decidua basalis
Umbilical cord
Uterus
Lumen of uterus
Decidua capsularis
Maternal arteries
Maternal veins
Myometrium
Stratum basalis of endometrium
Maternal portion of placenta (decidua basalis)
Fetal portion of placenta (chorion)
Chorionic villus containing fetal capillaries
Maternal blood in lacuna (intervillous space)
Fetal arteriole
Fetal venule
Amnion
Umbilical cord
Umbilical arteries
Umbilical vein
Connection to yolk sac

Figure 28.8

Embryonic Development: Gastrula to Fetus

- Germ Layers
  - During implantation, the blastocyst starts to convert to a gastrula
  - Inner cell mass develops into the embryonic disc (subdivides into epiblast and hypoblast)
  - The three primary germ layers and the extraembryonic membranes develop

Extraembryonic Membranes

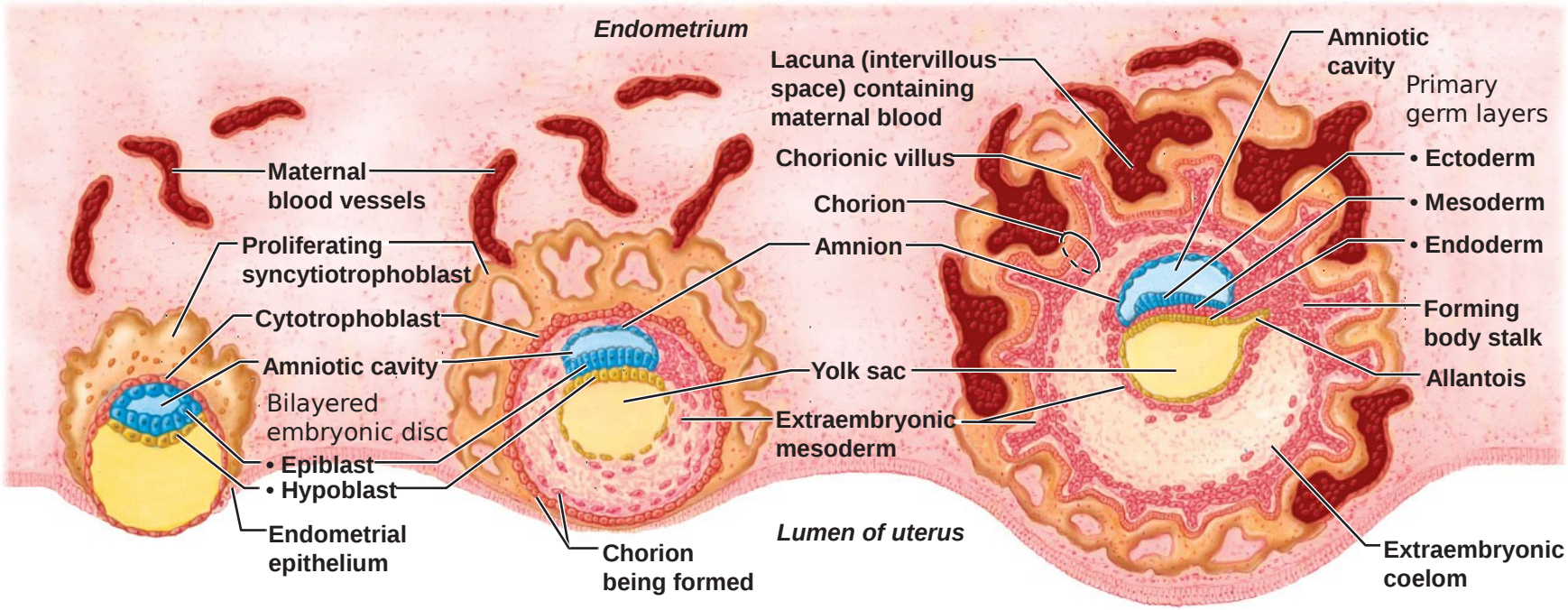
1. Amnion: epiblast cells form a transparent sac filled with amniotic fluid
   - Provides a buoyant environment that protects the embryo
   - Helps maintain a constant homeostatic temperature
   - Allows freedom of movement and prevents parts from fusing together
   - Amniotic fluid comes from maternal blood, and later, fetal urine

Extraembryonic Membranes

2. Yolk sac: a sac that hangs from the ventral surface of the embryo
   - Forms part of the digestive tube
   - Source of the earliest blood cells and blood vessels

Extraembryonic Membranes

3. Allantois: a small outpocketing at the caudal end of the yolk sac
   - Structural base for the umbilical cord
   - Becomes part of the urinary bladder
4. Chorion: helps form the placenta
   - Encloses the embryonic body and all other membranes

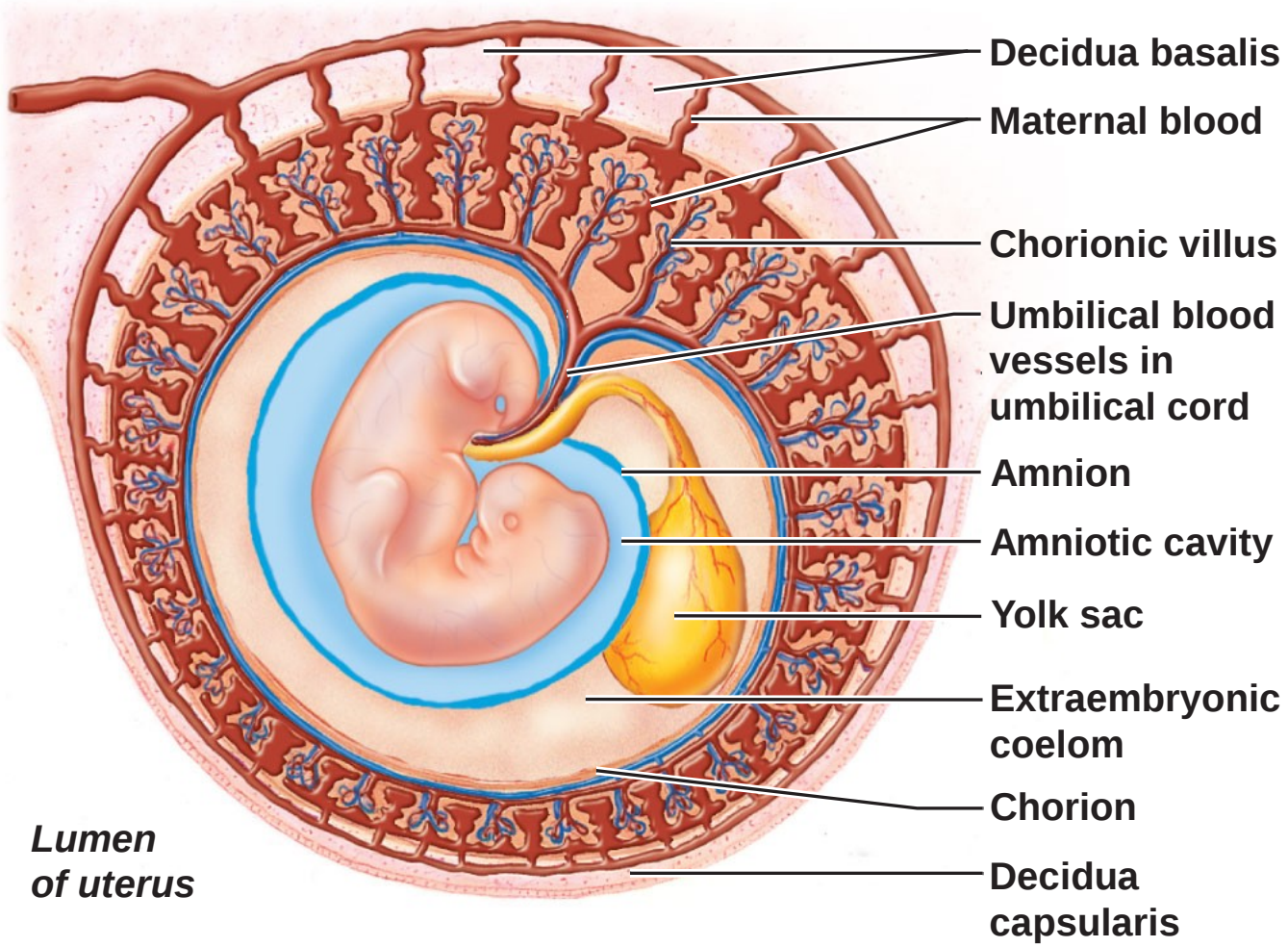


(a) Implanting 7½-day blastocyst. **The syncytiotrophoblast is eroding the endometrium. Cells of the embryonic disc are now separated from the amnion by a fluid-filled space.**

(b) 12-day blastocyst. **Implantation is complete. Extraembryonic mesoderm is forming a discrete layer beneath the cytotrophoblast.**

(c) 16-day embryo. **Cytotrophoblast and associated mesoderm have become the chorion, and chorionic villi are elaborating. The embryo exhibits all three germ layers, a yolk sac and an allantois, which forms the basis of the umbilical cord.**

Figure 28.7 (a-c)



(d) $4\frac{1}{2}$-week embryo. **The decidua capsularis, decidua basalis, amnion, and yolk sac are well formed. The chorionic villi lie in blood-filled intervillous spaces within the endometrium. The embryo is now receiving its nutrition via the umbilical vessels that connect it (through the umbilical cord) to the placenta.**

Figure 28.7d

Gastrulation

- Occurs in week 3, in which the embryonic disc becomes a three-layered embryo with ectoderm, mesoderm, and endoderm
- Begins with appearance of primitive streak, a raised dorsal groove that establishes the longitudinal axis of the embryo

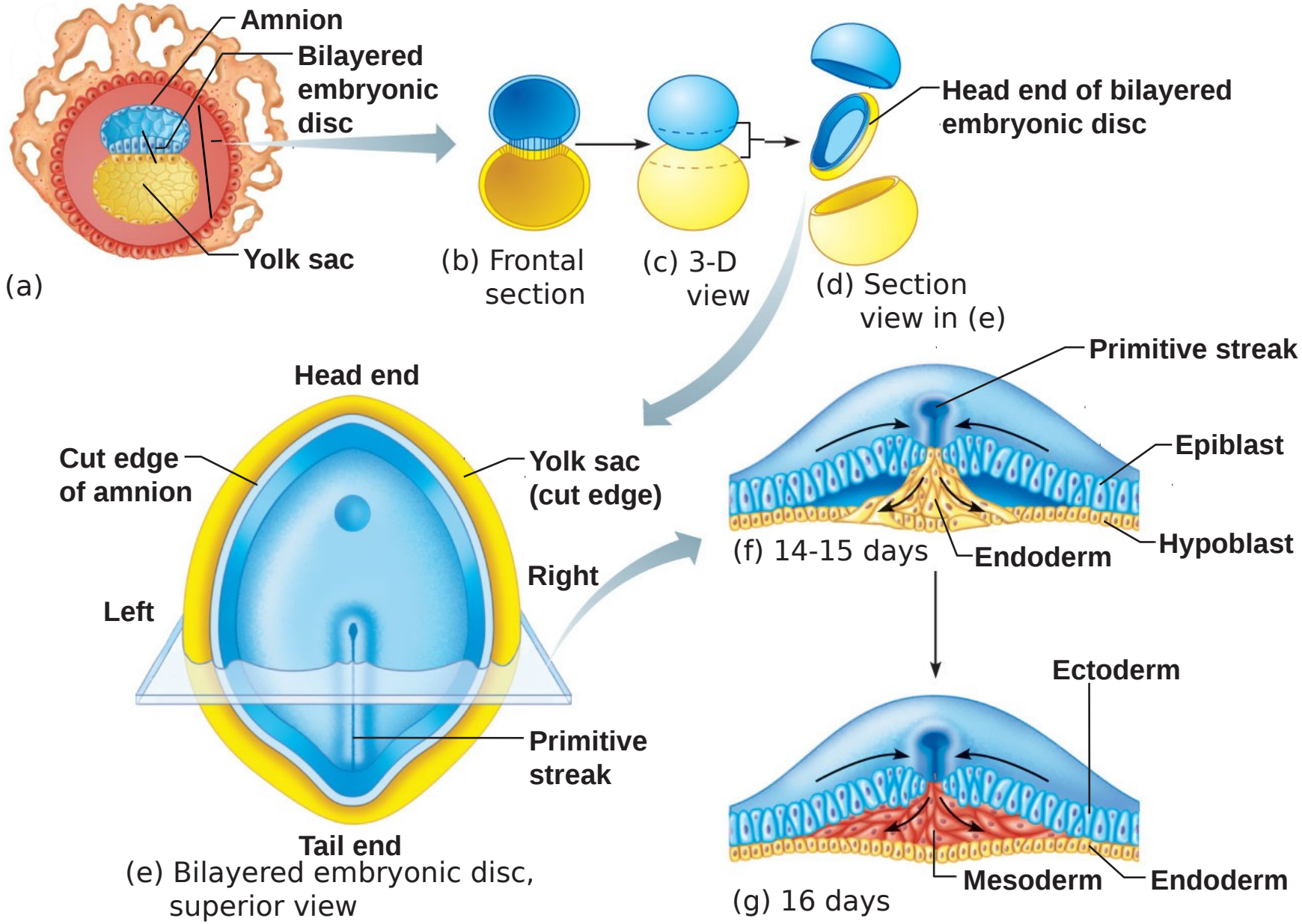

Amnion
Bilayered embryonic disc
Yolk sac
(a)
(b) Frontal section
(c) 3-D view
Head end of bilayered embryonic disc
(d) Section view in (e)
Head end
Cut edge of amnion
Yolk sac (cut edge)
Right
Left
Primitive streak
Tail end
(e) Bilayered embryonic disc, superior view
Primitive streak
Epiblast
Hypoblast
Endoderm
(f) 14-15 days
Ectoderm
Mesoderm
Endoderm
(g) 16 days

Figure 28.9

Gastrulation

- Cells begin to migrate into the groove
  - The first cells form the endoderm
  - Cells that follow push laterally, forming the mesoderm
  - Cells that remain on the embryo’s dorsal surface form the ectoderm
- Notochord: rod of mesodermal cells that serves as axial support

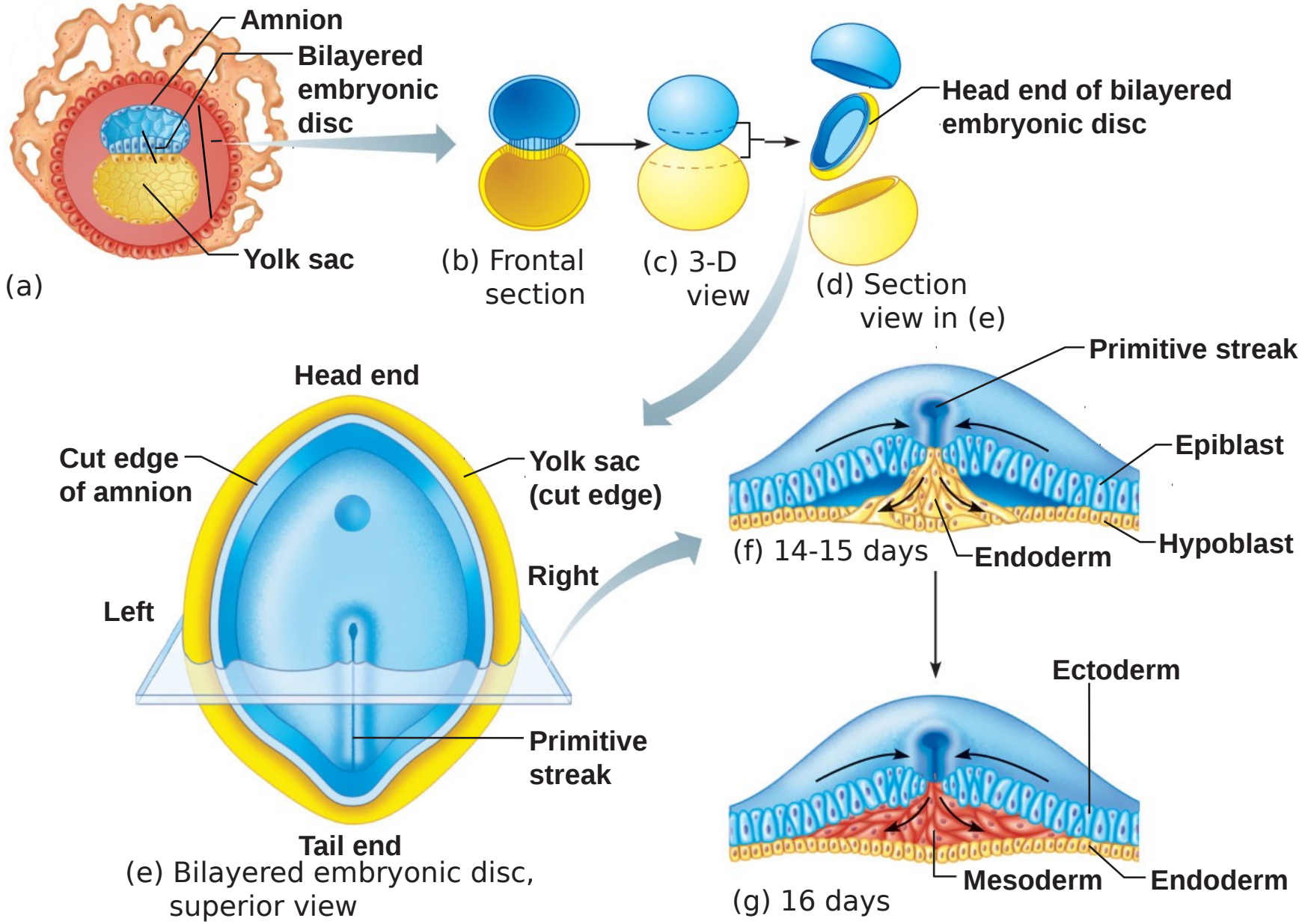

Amnion
Bilayered embryonic disc
Yolk sac
(a)
(b) Frontal section
(c) 3-D view
Head end of bilayered embryonic disc
(d) Section view in (e)
Head end
Cut edge of amnion
Yolk sac (cut edge)
Right
Left
Primitive streak
Tail end
(e) Bilayered embryonic disc, superior view
Primitive streak
Epiblast
Hypoblast
Endoderm
(f) 14-15 days
Ectoderm
Mesoderm
Endoderm
(g) 16 days

Figure 28.9

Primary Germ Layers

- The primitive tissues from which all body organs derive
- Ectoderm $\rightarrow$ nervous system and skin epidermis
- Endoderm $\rightarrow$ epithelial linings of the digestive, respiratory, and urogenital systems
- Mesoderm $\rightarrow$ forms all other tissues
- Endoderm and ectoderm are considered epithelia

Organogenesis

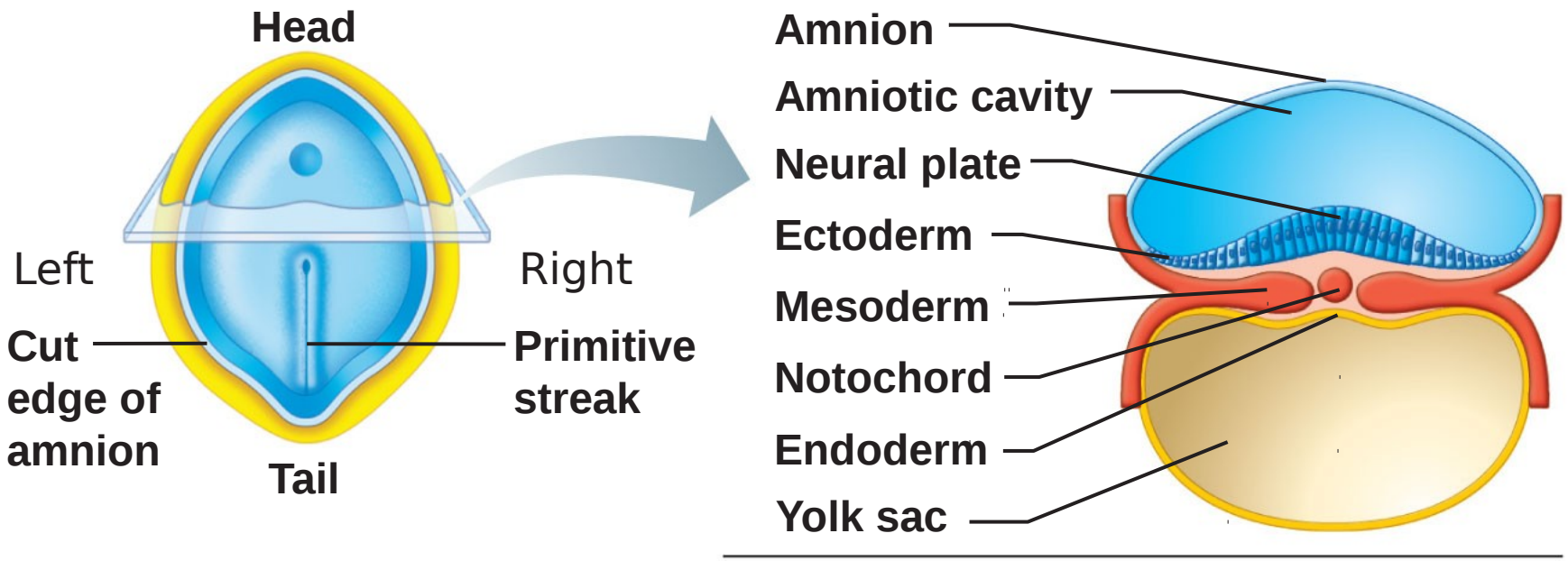
- Gastrulation sets the stage for organogenesis: formation of body organs and systems
- At eighth week
  - All organ systems are recognizable
  - End of the embryonic period

Specialization of Ectoderm

- Neurulation
  - First major event of organogenesis
  - Gives rise to brain and spinal cord
  - Ectoderm over the notochord forms the neural plate
  - Neural plate folds inward as a neural groove with neural folds

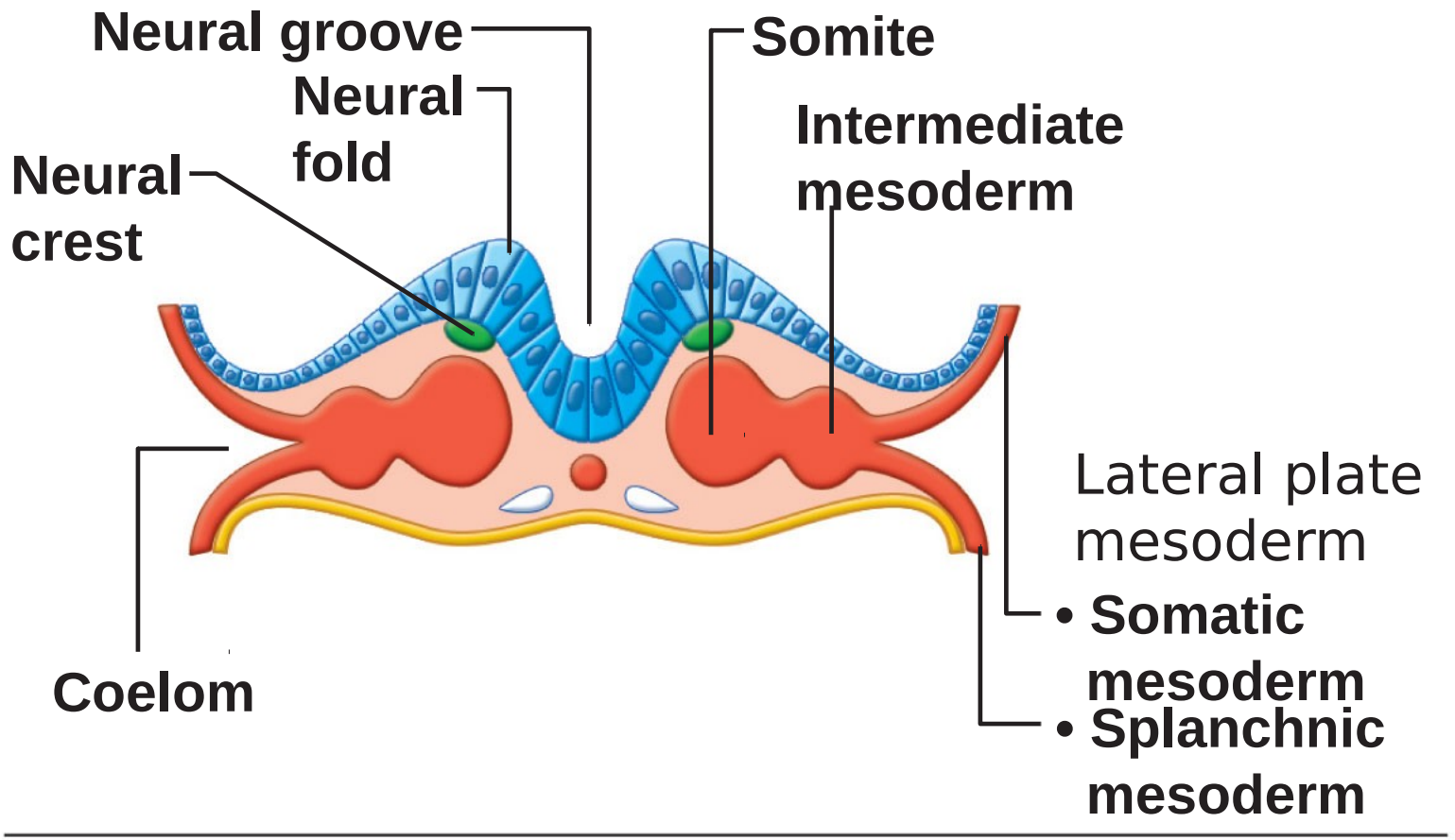
Specialization of Ectoderm

- By the 22nd day, neural folds fuse into a neural tube
  - Anterior end $\rightarrow$ brain; the rest $\rightarrow$ spinal cord
- Neural crest cells $\rightarrow$ cranial, spinal, and sympathetic ganglia, and adrenal medulla



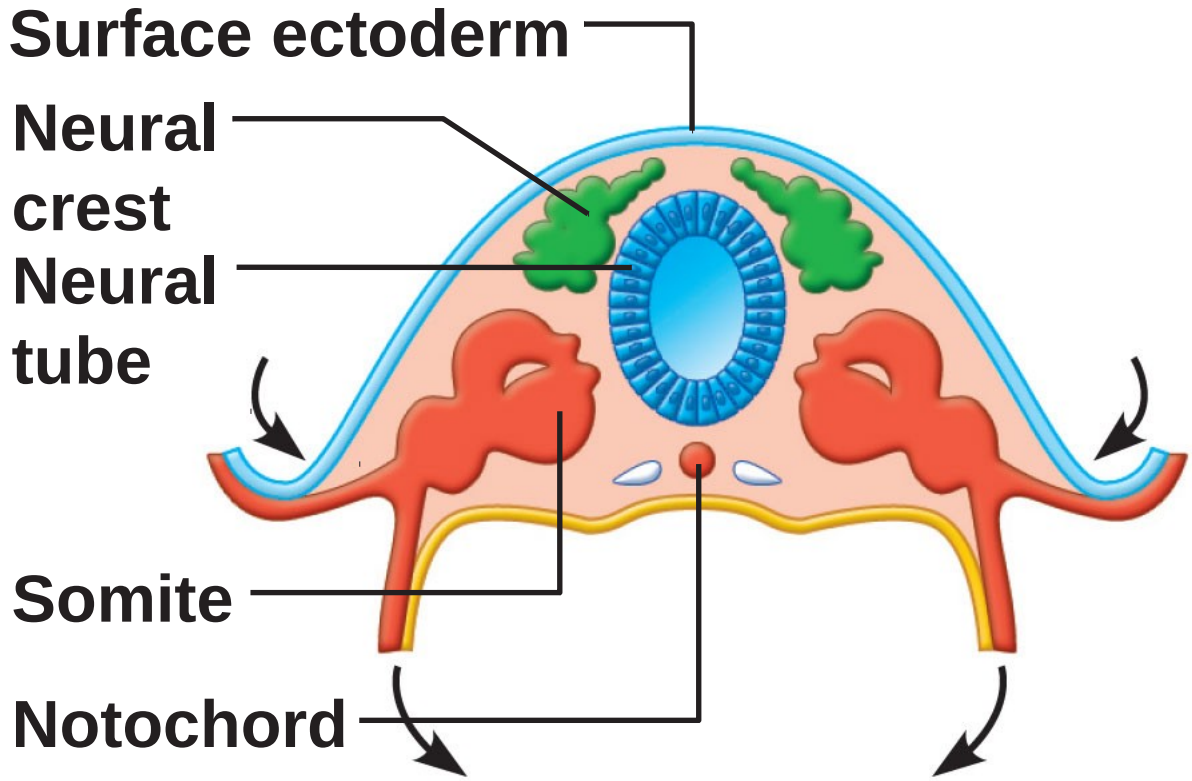
(a) 17 days. **The flat three-layered embryo has completed gastrulation. Notochord and neural plate are present.**

Figure 28.10a



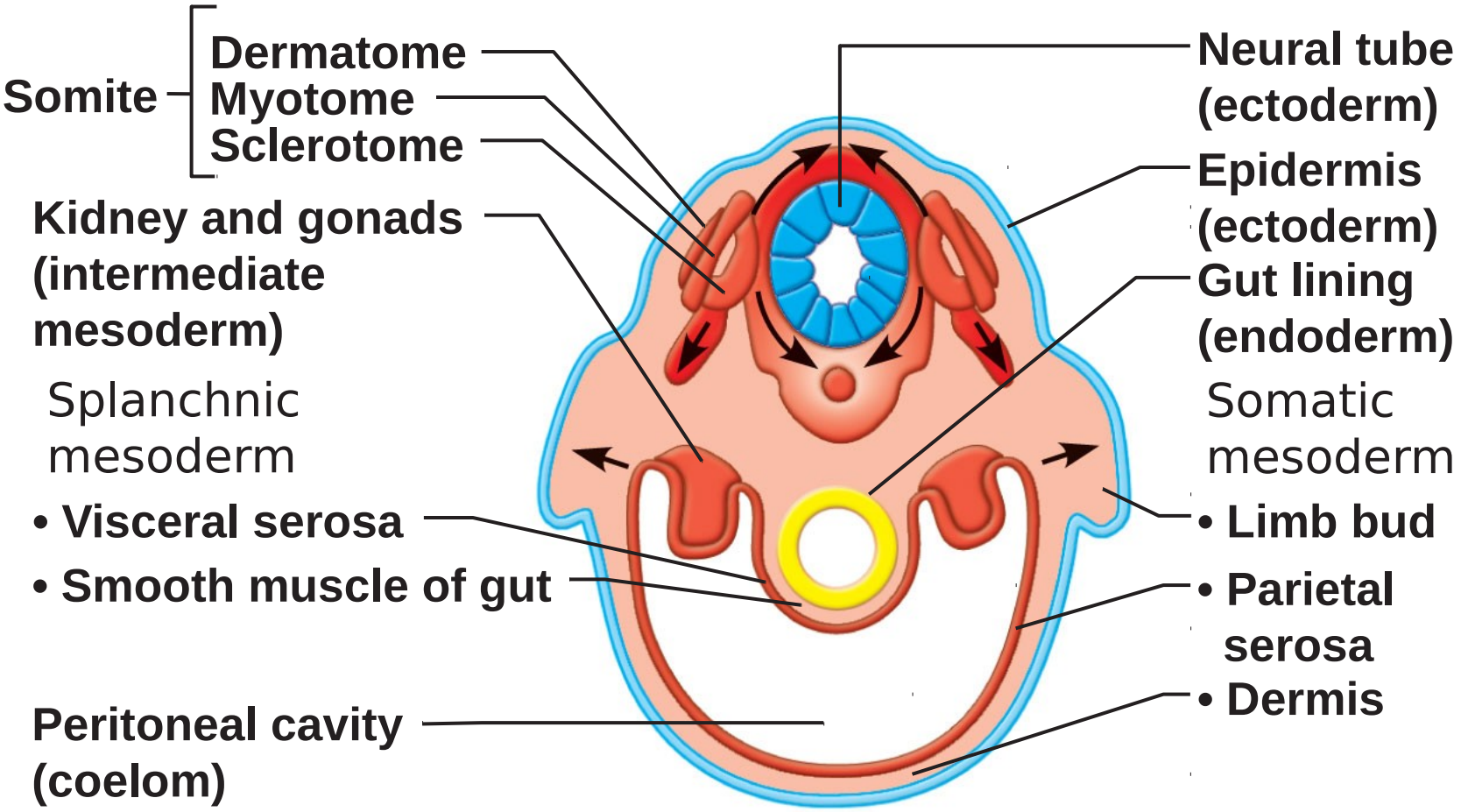
(b) 20 days. **The neural folds form by folding of the neural plate, which then deepens, producing the neural groove. Three mesodermal aggregates form on each side of the notochord (somite, intermediate mesoderm, and lateral plate mesoderm).**

Figure 28.10b



(c) 22 days. **The neural folds have closed, forming the neural tube which has detached from the surface ectoderm and lies between the surface ectoderm and the notochord. Embryonic body is beginning to undercut.**

Figure 28.10c



(d) End of week 4. **Embryo undercutting is complete. Somites have subdivided into sclerotome, myotome, and dermatome, which form the vertebrae, skeletal muscles, and dermis respectively. Body coelom present.**

Figure 28.10d

Specialization of Endoderm

- Embryonic folding begins with lateral folds
- Next, head and tail folds appear
- Endoderm tube forms epithelial lining of the GI tract
- Organs of the GI tract become apparent, and oral and anal openings perforate
- Mucosal lining of respiratory tract forms from pharyngeal endoderm

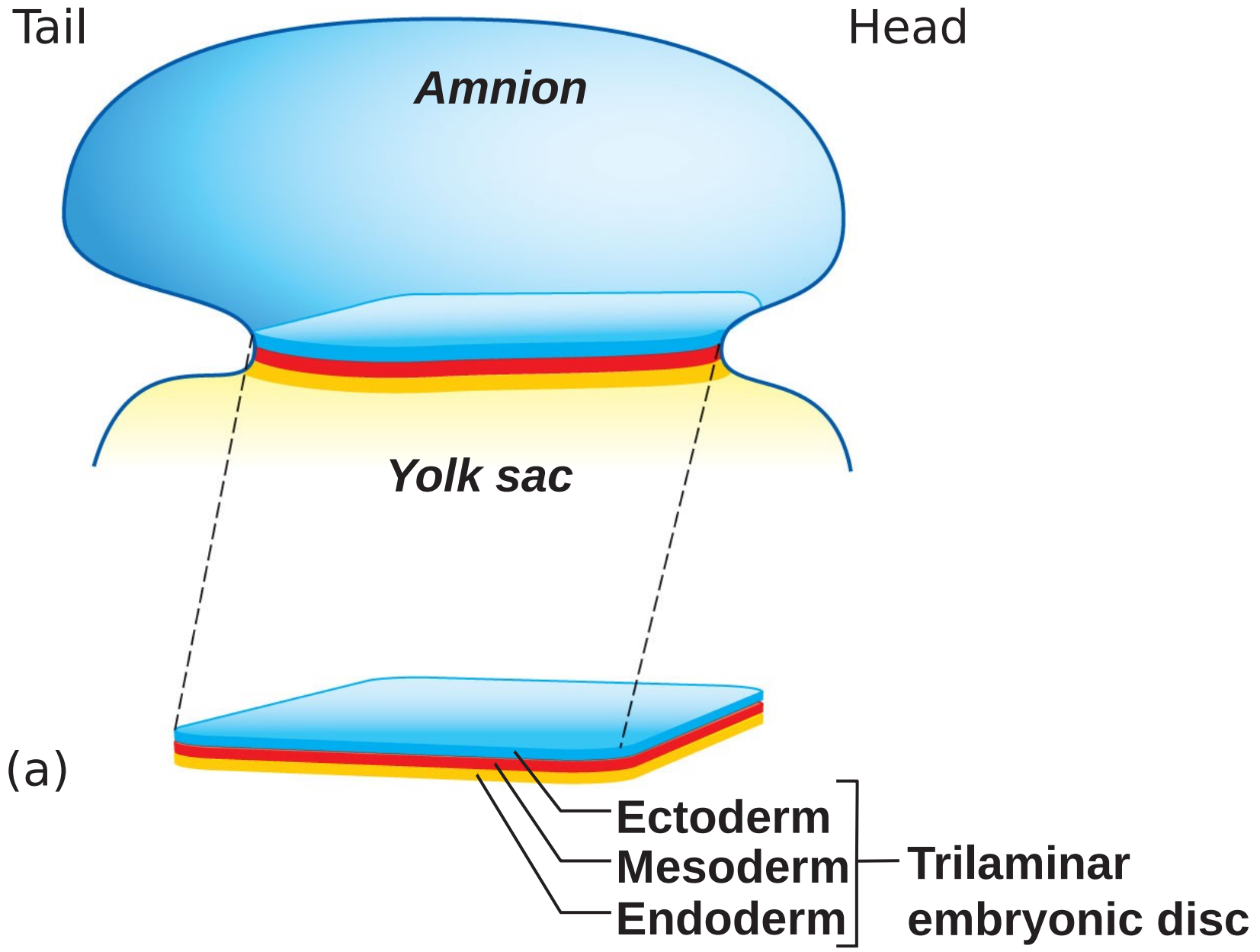


Figure 28.11a

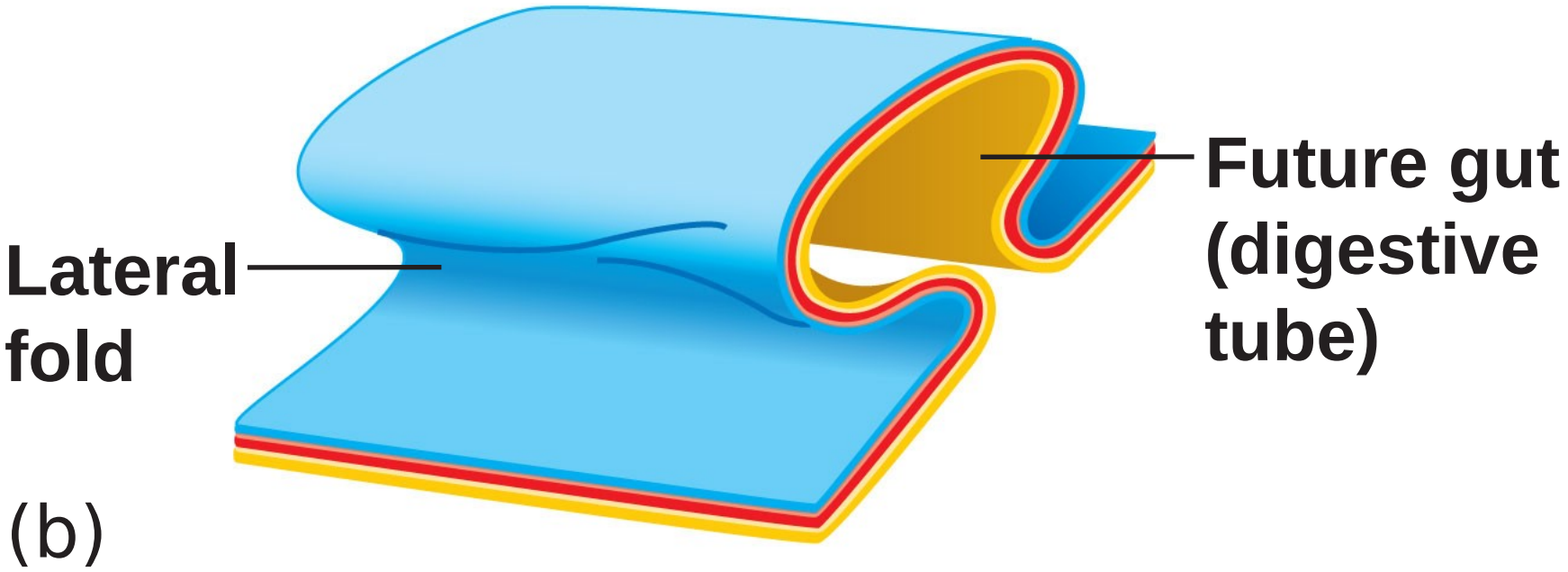


Figure 28.11b

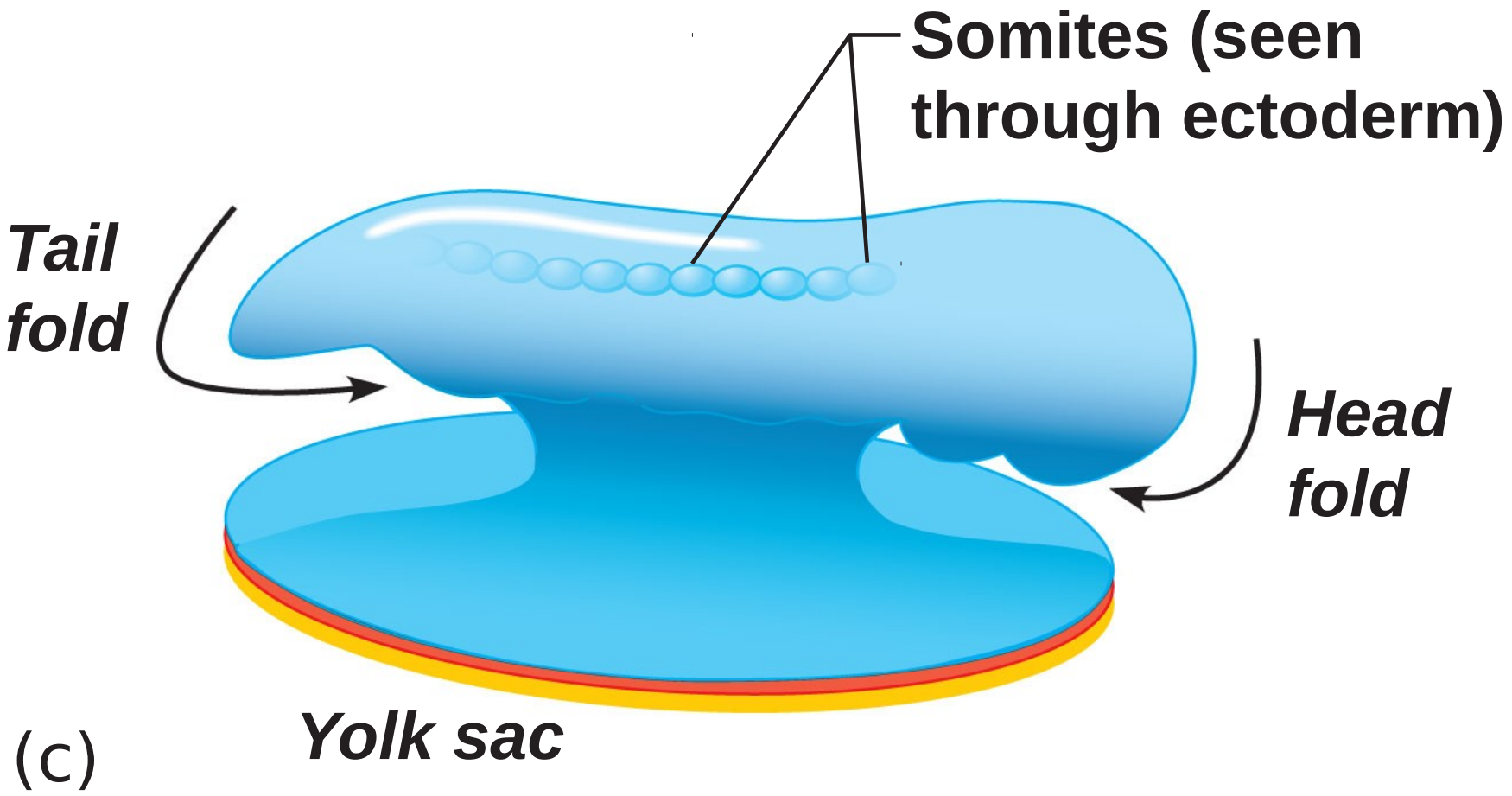


Figure 28.11c

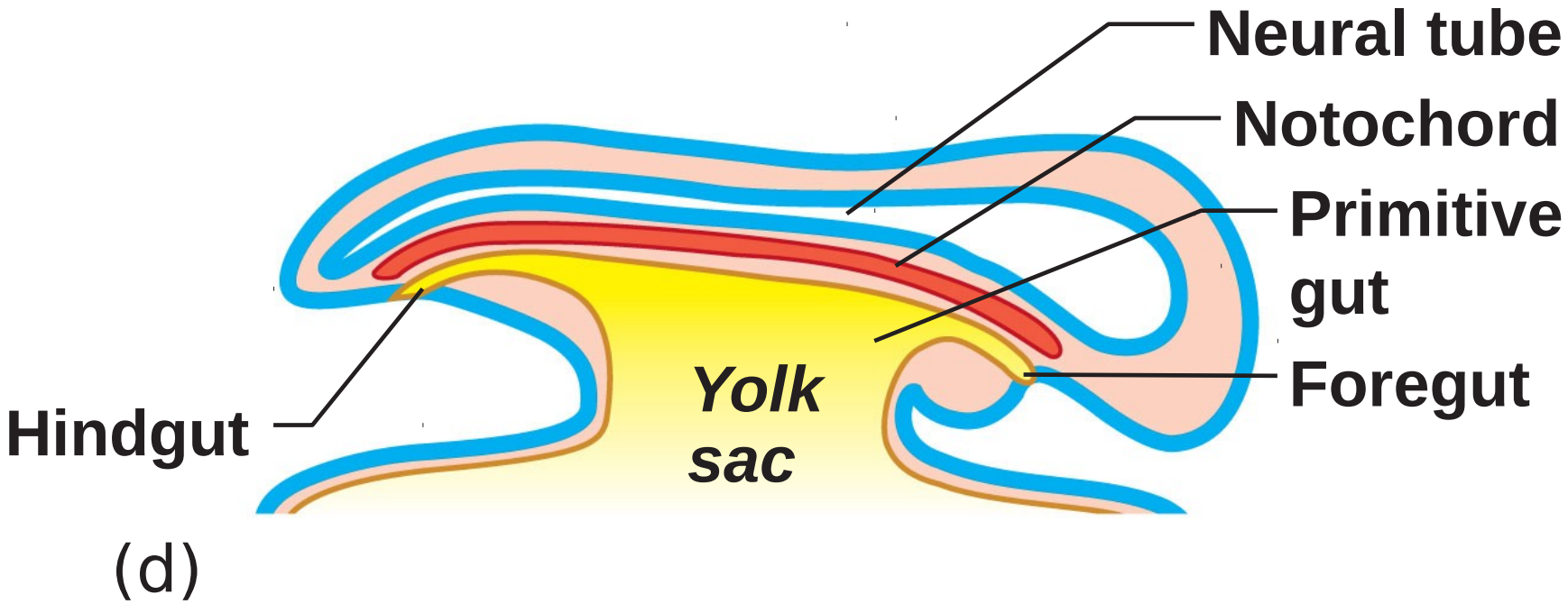


Figure 28.11d

TABLE 28.1 Developmental Events of the Fetal Period

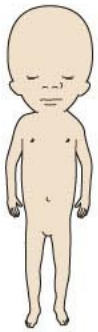
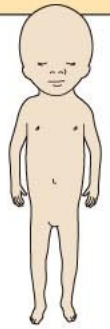
TIME		CHANGES AND ACCOMPLISHMENTS
8 weeks (end of embryonic period)	 8 weeks	Head nearly as large as body; all major brain regions present; first brain waves in brain stem Liver disproportionately large and begins to form blood cells Limbs present; digits are initially webbed, but fingers and toes are free by the end of this interval Ossification just begun; weak, spontaneous muscle contractions occur Cardiovascular system fully functional (heart has been pumping blood since the fourth week) All body systems present in at least rudimentary form Approximate crown-to-rump length: 22 mm (0.9 inch); weight: 2 grams (0.06 ounce)
9–12 weeks (month 3)	 12 weeks	Head still dominant, but body elongating; brain continues to enlarge, shows its general structural features; cervical and lumbar enlargements apparent in spinal cord; retina of eye is present Skin epidermis and dermis obvious; facial features present in crude form Liver prominent and bile being secreted; palate is fusing; most glands of endodermal origin are developed; walls of hollow visceral organs gaining smooth muscle Blood cell formation begins in bone marrow Notochord degenerating and ossification accelerating; limbs well molded Sex readily detected from the genitals Approximate crown-to-rump length at end of interval: 90 mm

TABLE 28.1 Developmental Events of the Fetal Period *(continued)*

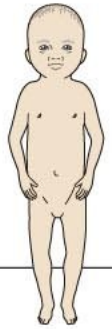
TIME	CHANGES AND ACCOMPLISHMENTS
13–16 weeks (month 4)	Cerebellum becoming prominent; general sensory organs differentiated; eyes and ears assume characteristic position and shape; blinking of eyes and sucking motions of lips occur Face looks human and growth of the body beginning to outpace that of the head Glands developed in GI tract; meconium is collecting Kidneys attain typical structure Most bones are now distinct and joint cavities are apparent Approximate crown-to-rump length at end of interval: 140 mm
17–20 weeks (month 5)	Vernix caseosa (fatty secretions of sebaceous glands) covers body; lanugo (silklike hair) covers skin Fetal position (body flexed anteriorly) assumed because of space restrictions Limbs reach near-final proportions Quickening occurs (mother feels spontaneous muscular activity of fetus) Approximate crown-to-rump length at end of interval: 190 mm



16 weeks

TABLE 28.1 Developmental Events of the Fetal Period

TIME	CHANGES AND ACCOMPLISHMENTS
21–30 weeks (months 6 and 7)	Period of substantial increase in weight (may survive if born prematurely at 27–28 weeks, but hypothalamic temperature regulation and lung production of surfactant are still inadequate) Myelination of spinal cord begins; eyes are open Distal limb bones are beginning to ossify Skin is wrinkled and red; fingernails and toenails are present; tooth enamel is forming on deciduous teeth Body is lean and well proportioned Bone marrow becomes sole site of blood cell formation Testes reach scrotum in seventh month (in males) Approximate crown-to-rump length at end of interval: 280 mm
30–40 weeks (term) (months 8 and 9)	Skin whitish pink; fat laid down in subcutaneous tissue (hypodermis) Approximate crown-to-rump length at end of interval: 360 mm (14 inches); weight: 3.2 kg (7 lb)



At birth

Table 28.1 (3 of 3)

Effects of Pregnancy: Anatomical Changes

- The uterus expands, occupying most of the abdominal cavity
- Lordosis occurs with the change in the center of gravity
- Weight gain of ~13 kg (28 lb)
- Relaxin causes pelvic ligaments and the pubic symphysis to relax to ease birth passage

Effects of Pregnancy: Physiological Changes

- GI tract
  - Morning sickness due to elevated levels of estrogen and progesterone
  - Heartburn and constipation are common
- Urinary system
  - ↑ Urine production due to ↑ metabolism and fetal wastes
  - Stress incontinence may occur as bladder is compressed

Effects of Pregnancy: Physiological Changes

- Respiratory system
  - Estrogens may cause nasal edema and congestion
  - Tidal volume increases
  - Dyspnea (difficult breathing) may occur later in pregnancy

Effects of Pregnancy: Physiological Changes

- Cardiovascular system
  - Blood volume increases 25–40%
  - Blood pressure and pulse rise
  - Venous return from lower limbs may be impaired, resulting in varicose veins

Parturition

- Parturition giving birth to the baby
- Labor events that expel the infant from the uterus

Initiation of Labor

- During the last few weeks of pregnancy
  - Fetal secretion of cortisol stimulates the placenta to secrete more estrogen
    - Causes production of oxytocin receptors by myometrium
    - Antagonizes calming effects of progesterone, leading to Braxton Hicks contractions in uterus

Lactation

- Production of milk by the mammary glands
- Toward the end of pregnancy
  - Placental estrogens, progesterone, and lactogen lead to release of prolactin.

Lactation

- Colostrum
  - Yellowish secretion rich in vitamin A, protein, minerals, and IgA antibodies
  - Released the first 2–3 days
  - Followed by true milk production
- Suckling initiates a positive feedback mechanism
- Oxytocin causes the letdown reflex

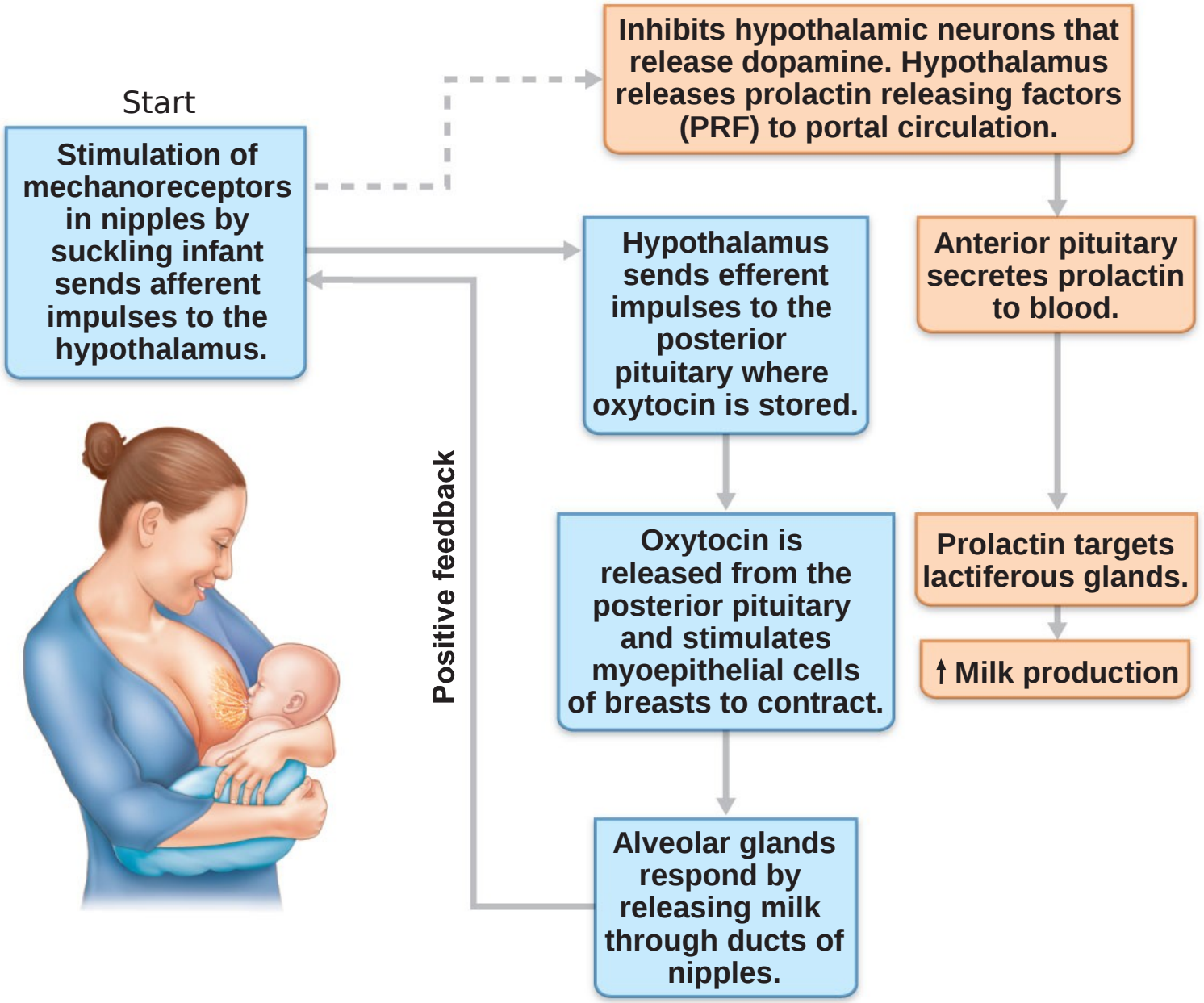

Start
Stimulation of mechanoreceptors in nipples by suckling infant sends afferent impulses to the hypothalamus.
Inhibits hypothalamic neurons that release dopamine. Hypothalamus releases prolactin releasing factors (PRF) to portal circulation.
Anterior pituitary secretes prolactin to blood.
Hypothalamus sends efferent impulses to the posterior pituitary where oxytocin is stored.
Oxytocin is released from the posterior pituitary and stimulates myoepithelial cells of breasts to contract.
Alveolar glands respond by releasing milk through ducts of nipples.
Prolactin targets lactiferous glands.
↑ Milk production
Positive feedback

Figure 28.19

Advantages of Breast Milk

- Fats and iron are easily absorbed; amino acids more easily metabolized, compared with cow’s milk
- Beneficial chemicals: IgA, complement, lysozyme, interferon, and lactoperoxidase
- Interleukins and prostaglandins prevent overzealous inflammatory responses

Advantages of Breast Milk

- Natural laxative effect helps eliminate bile-rich meconium, helping to prevent physiological jaundice
- Encourages bacterial colonization of the large intestine