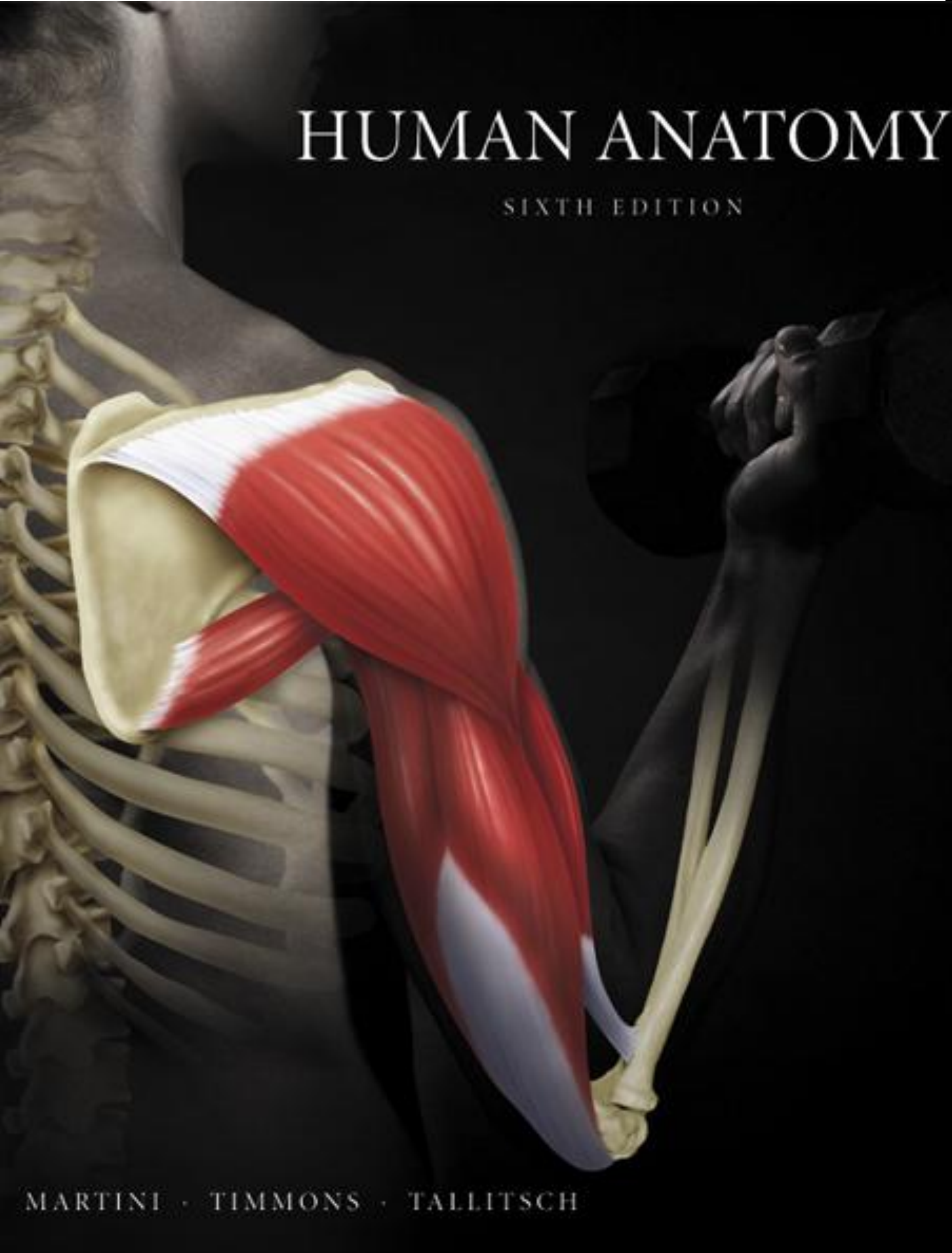

Chapter

28

Embryology and Human Development

PowerPoint® Lecture Slides prepared by Jason LaPres
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Introduction

- ***Development*** is the gradual modification of anatomical structures during the period from conception to maturity.
  - The formation of specialized cell types during development is called ***differentiation***.
  - Differentiation occurs through selective changes in genetic activity.
  - A basic appreciation of human development provides a framework for enhancing the understanding of anatomical structures.

An Overview of Development

- Development involves:
  - The division and differentiation of cells
  - Reorganization of those cell types to produce or modify anatomical structures
- Development produces a mature individual capable of reproduction.
  - The process is a continuum that begins at **fertilization**, or ***conception***, and can be separated into periods characterized by specific anatomical changes.

An Overview of Development

- ***Prenatal development*** occurs in the period from conception to delivery.
  - The term **embryology** refers to the study of the developmental events that occur during prenatal development.
  - The period of prenatal development can be further subdivided.
    - **Pre-embryonic development** begins at fertilization and continues through cleavage and implantation.
    - Pre-embryonic development is followed by **embryonic development**, which extends from implantation to the end of the eighth developmental week.
    - **Fetal development** begins at the start of the ninth developmental week and continues up to the time of birth.

An Overview of Development

- ***Postnatal development*** commences at birth and continues to maturity.
  - The **neonatal period** immediately follows delivery.

Fertilization

- Fusion of egg and sperm and the mixing of their DNA
- Usually occurs in the uterine tube
- Sperm penetration stimulates the secondary oocyte to finish meiosis.
- After ejection of the second polar body, the haploid nuclei fuse.
  - **Amphymixis**

Fertilization

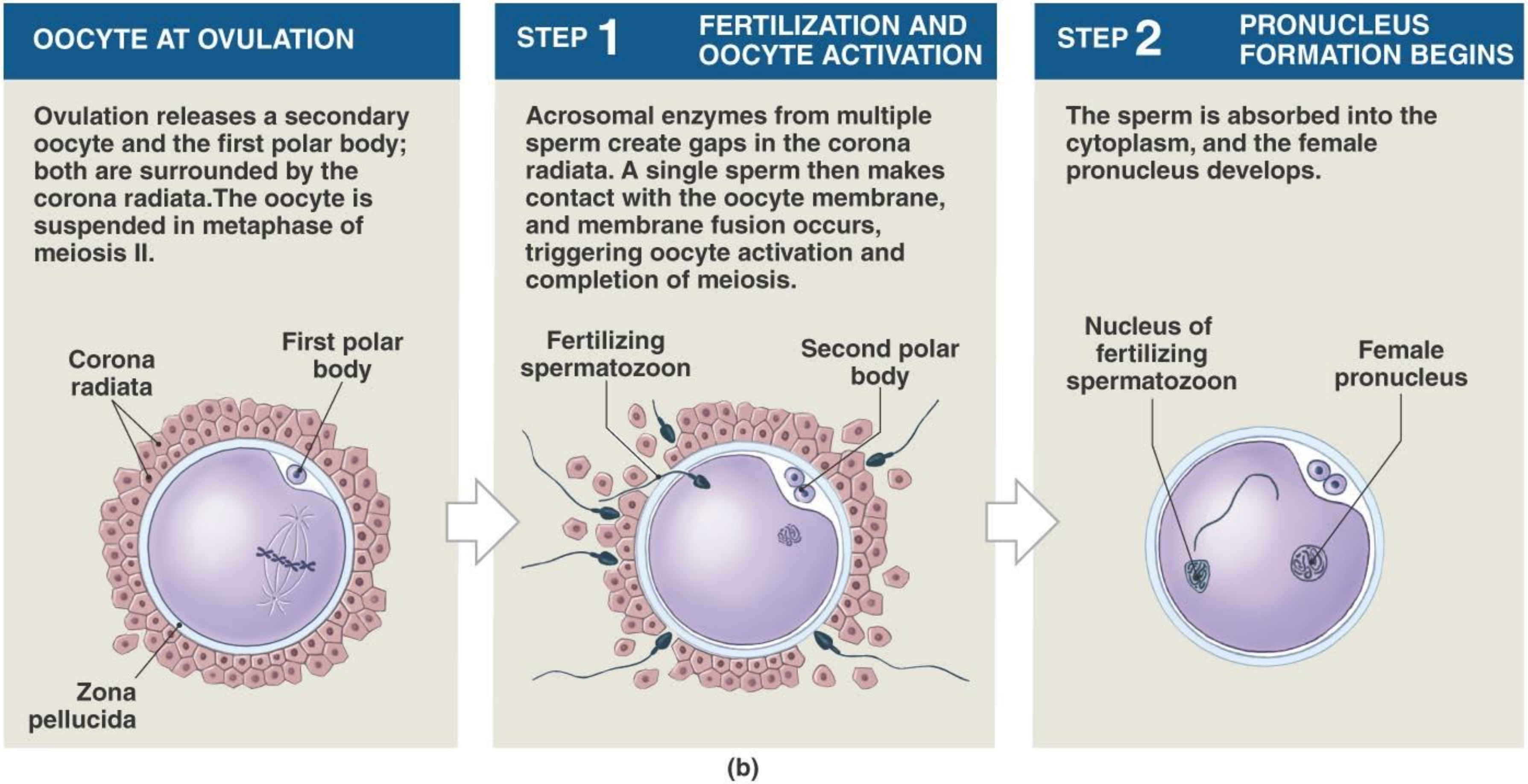


Figure 28.1 Fertilization and Preparation for Cleavage

Fertilization

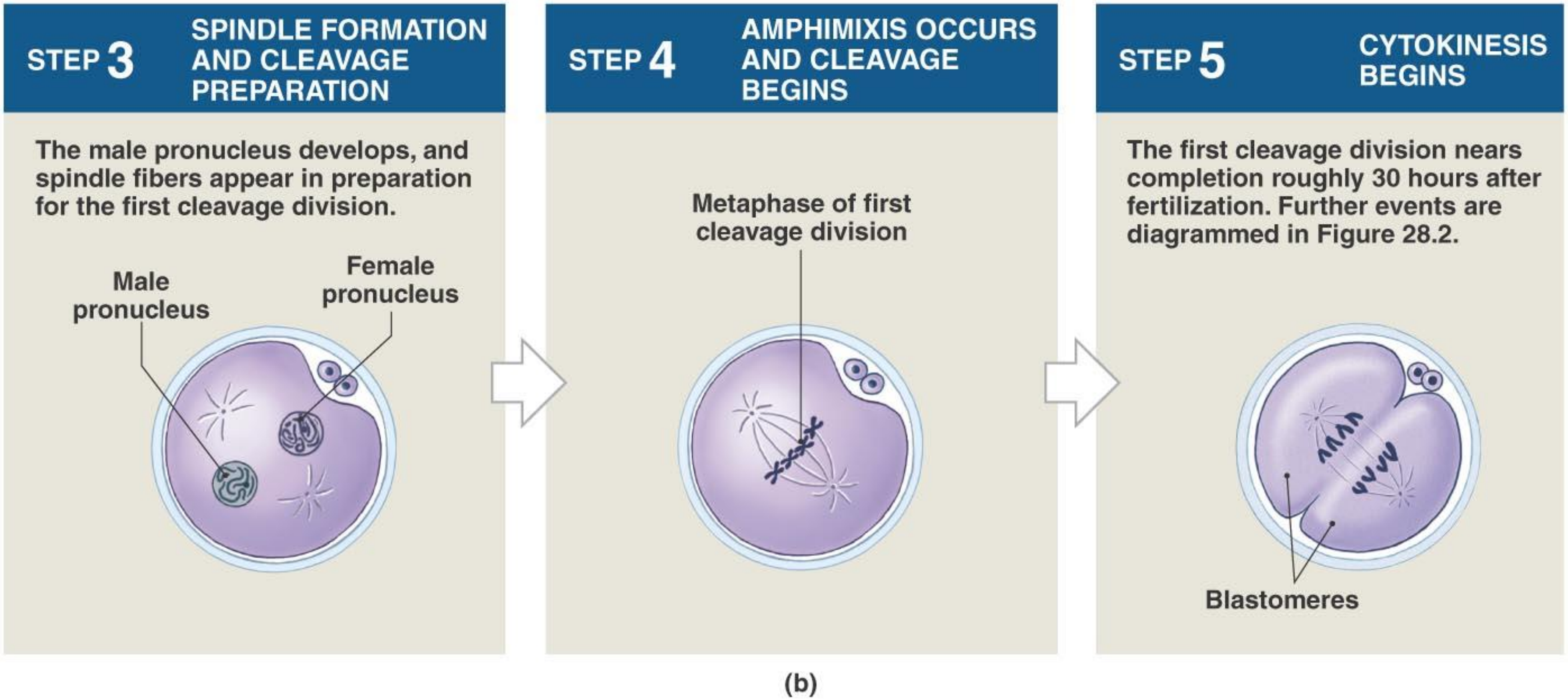


Figure 28.1 Fertilization and Preparation for Cleavage

Prenatal Development

- The **gestation period** consists of three trimesters, each 3 months in duration:
  - First trimester
    - Cleavage
    - Implantation
    - Placentation
    - Embryogenesis
  - Second trimester
    - Most organs finish development
  - Third trimester
    - Rapid growth

Prenatal Development

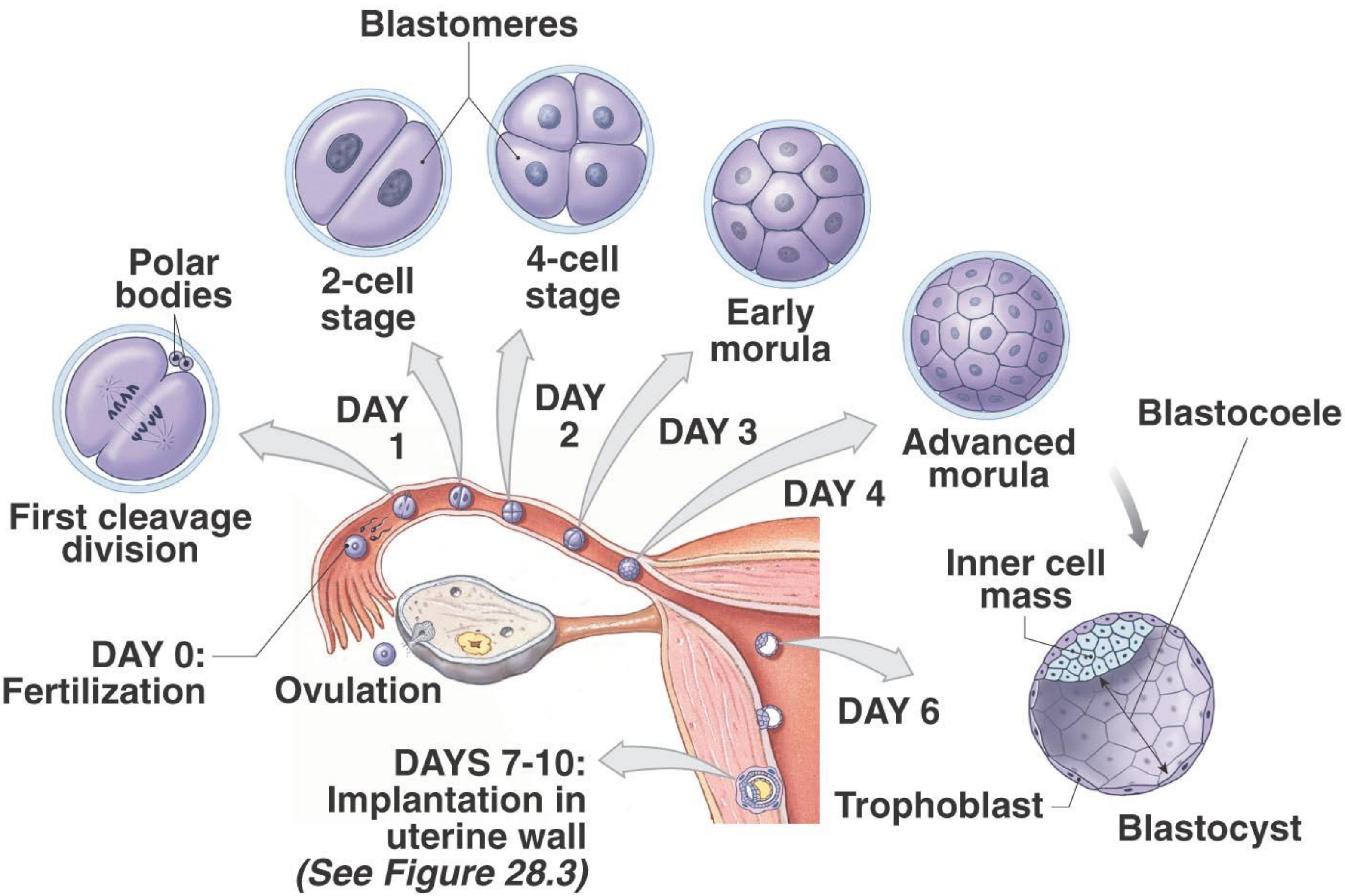


Figure 28.2 Cleavage and Blastocyst Formation

Prenatal Development

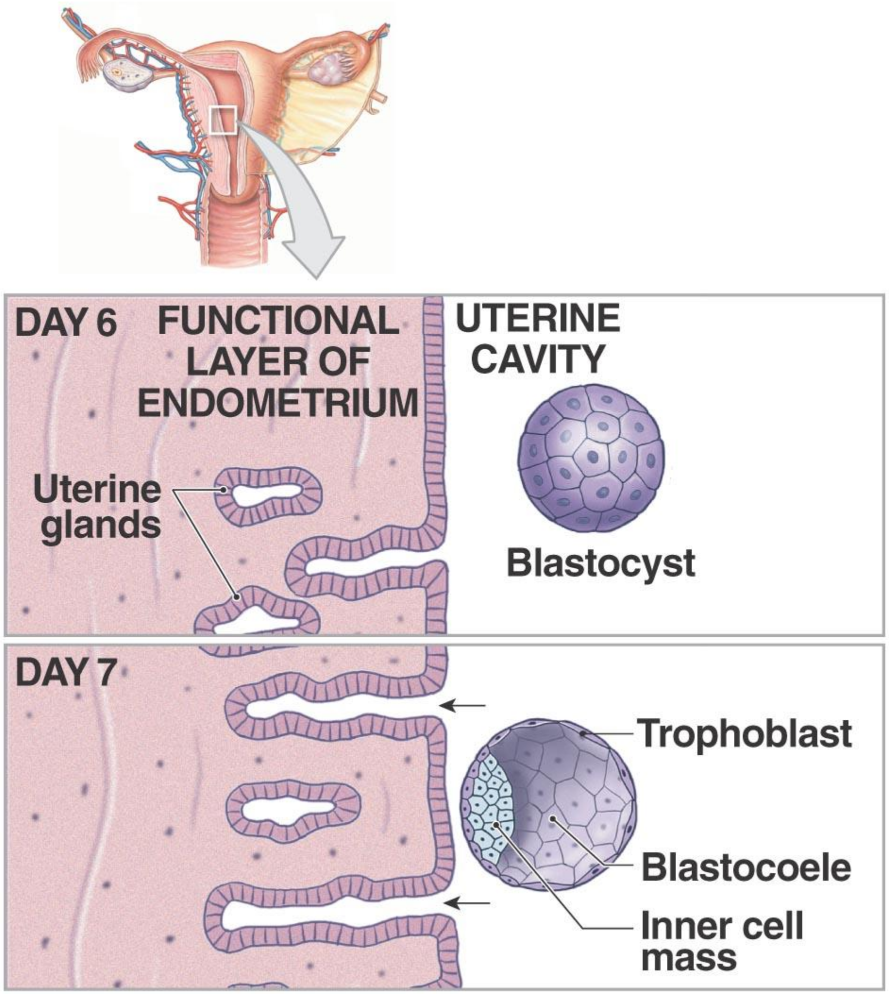


Figure 28.3 Stages in the Implantation Process

Prenatal Development

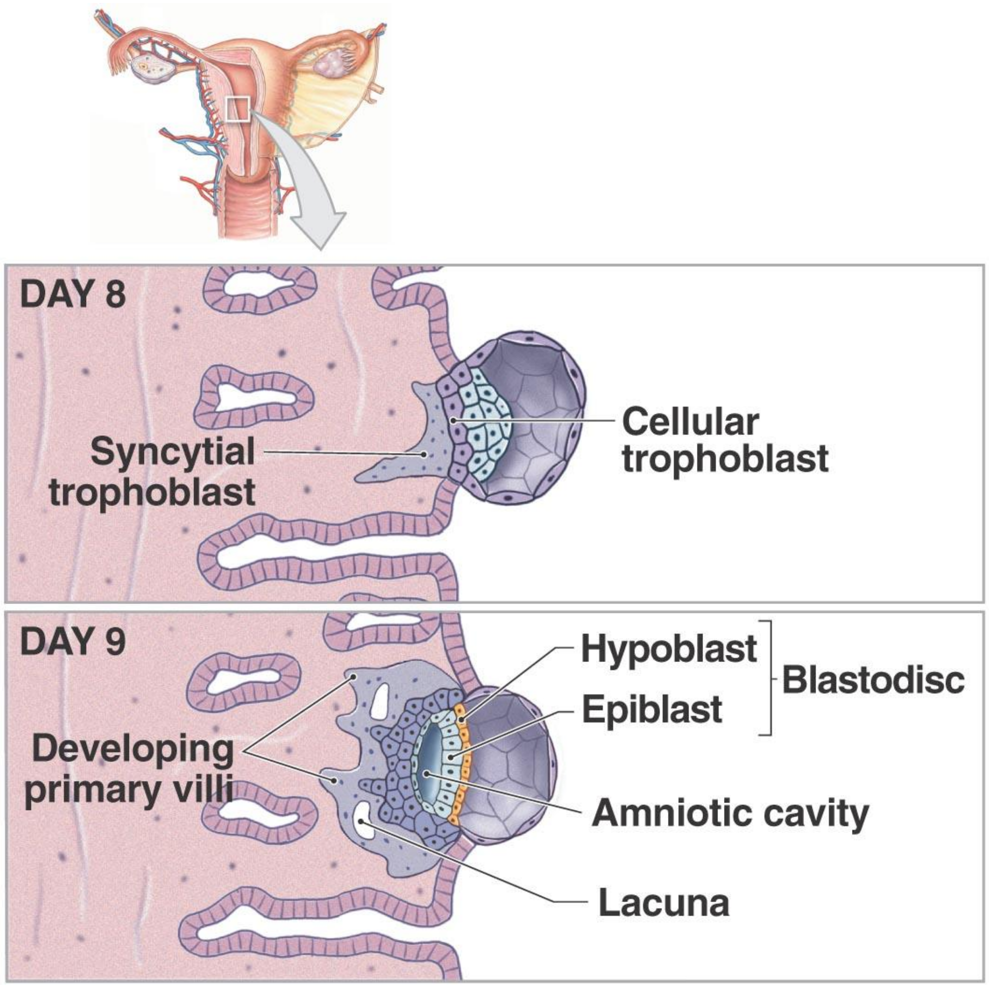
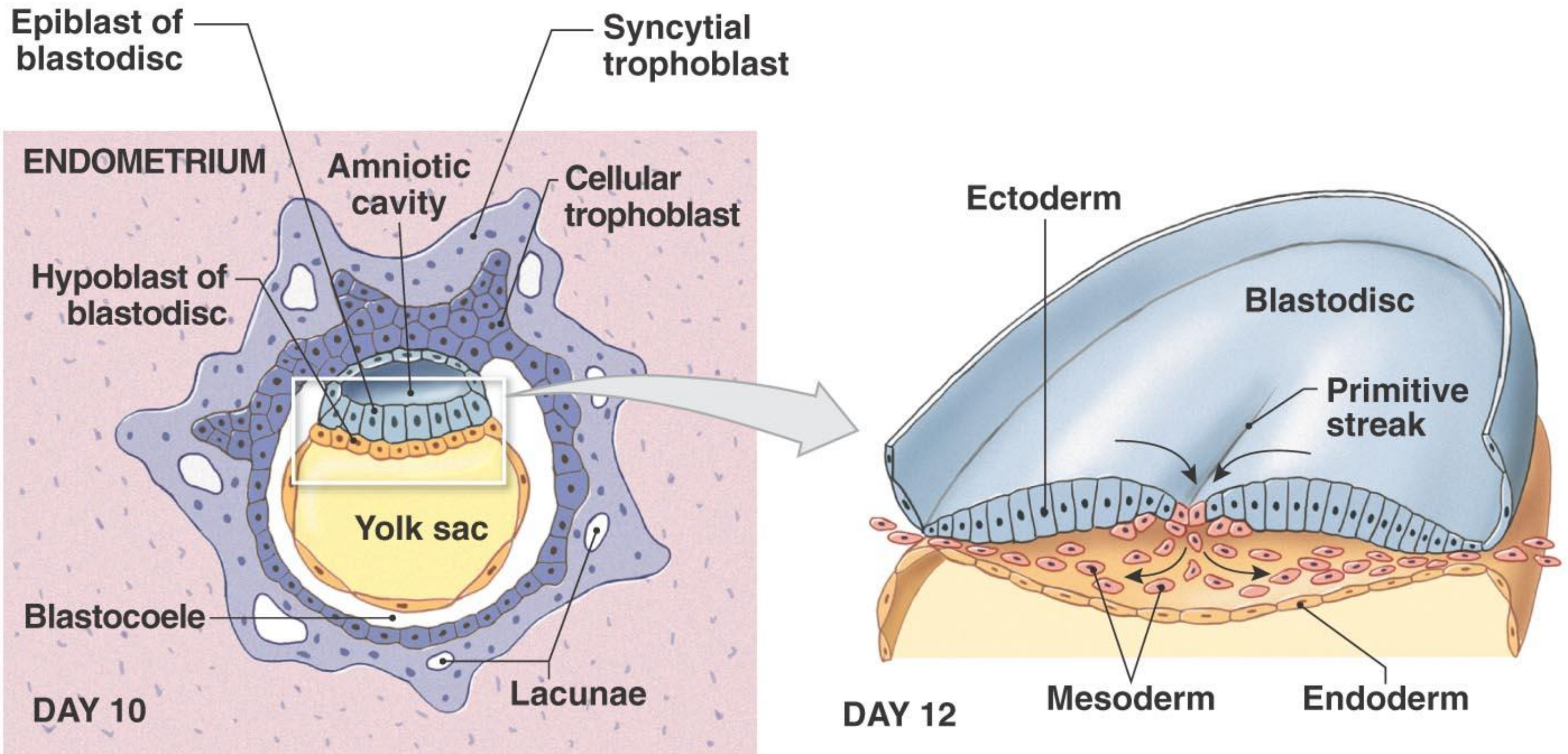


Figure 28.3 Stages in the Implantation Process

Prenatal Development



The blastodisc begins as two layers: the *epiblast*, facing the amniotic cavity, and the *hypoblast*, exposed to the blastocoele. Migration of epiblast cells around the amniotic cavity is the first step in the formation of the amnion. Migration of hypoblast cells creates a sac that hangs below the blastodisc. This is the first step in yolk sac formation.

Migration of epiblast cells into the region between epiblast and hypoblast gives the blastodisc a third layer. From the time this process (gastrulation) begins, the epiblast is called *ectoderm*, the hypoblast *endoderm*, and the migrating cells *mesoderm*.

Figure 28.4 Blastodisc Organization and Gastrulation

Prenatal Development

TABLE 28.1 The Fates of the Primary Germ Layers

Ectodermal Contributions

Integumentary system: epidermis, hair follicles and hairs, nails, and glands communicating with the skin (apocrine and merocrine sweat glands, mammary glands, and sebaceous glands)

Skeletal system: pharyngeal cartilages and their derivatives in the adult (portion of sphenoid, the auditory ossicles, the styloid processes of the temporal bones, the horns and superior rim of the hyoid bone)*

Nervous system: all neural tissue, including brain and spinal cord

Endocrine system: pituitary gland and suprarenal medullae

Respiratory system: mucous epithelium of nasal passageways

Digestive system: mucous epithelium of mouth and anus, salivary glands

Mesodermal Contributions

Integumentary system: dermis, except for epidermal derivatives

Skeletal system: all components except some pharyngeal derivatives

Muscular system: all components

Endocrine system: suprarenal cortex and endocrine tissues of heart, kidneys, and gonads

Cardiovascular system: all components, including bone marrow

Lymphoid system: all components

Urinary system: the kidneys, including the nephrons and the initial portions of the collecting system

Reproductive system: the gonads and the adjacent portions of the duct systems

Miscellaneous: the lining of the body cavities (thoracic, pericardial, peritoneal) and the connective tissues supporting all organ systems

Endodermal Contributions

Endocrine system: thymus, thyroid, and pancreas

Respiratory system: respiratory epithelium (except nasal passageways) and associated mucous glands

Digestive system: mucous epithelium (except mouth and anus); exocrine glands (except salivary glands); liver, and pancreas

Urinary system: urinary bladder and distal portions of the duct system

Reproductive system: distal portions of the duct system; stem cells that produce gametes

*The neural crest is derived from ectoderm and contributes to the formation of the skull and the skeletal derivatives ofthe embryonic pharyngeal arches.

TABLE 28.1 The Fates of the Primary Germ Layers

Prenatal Development

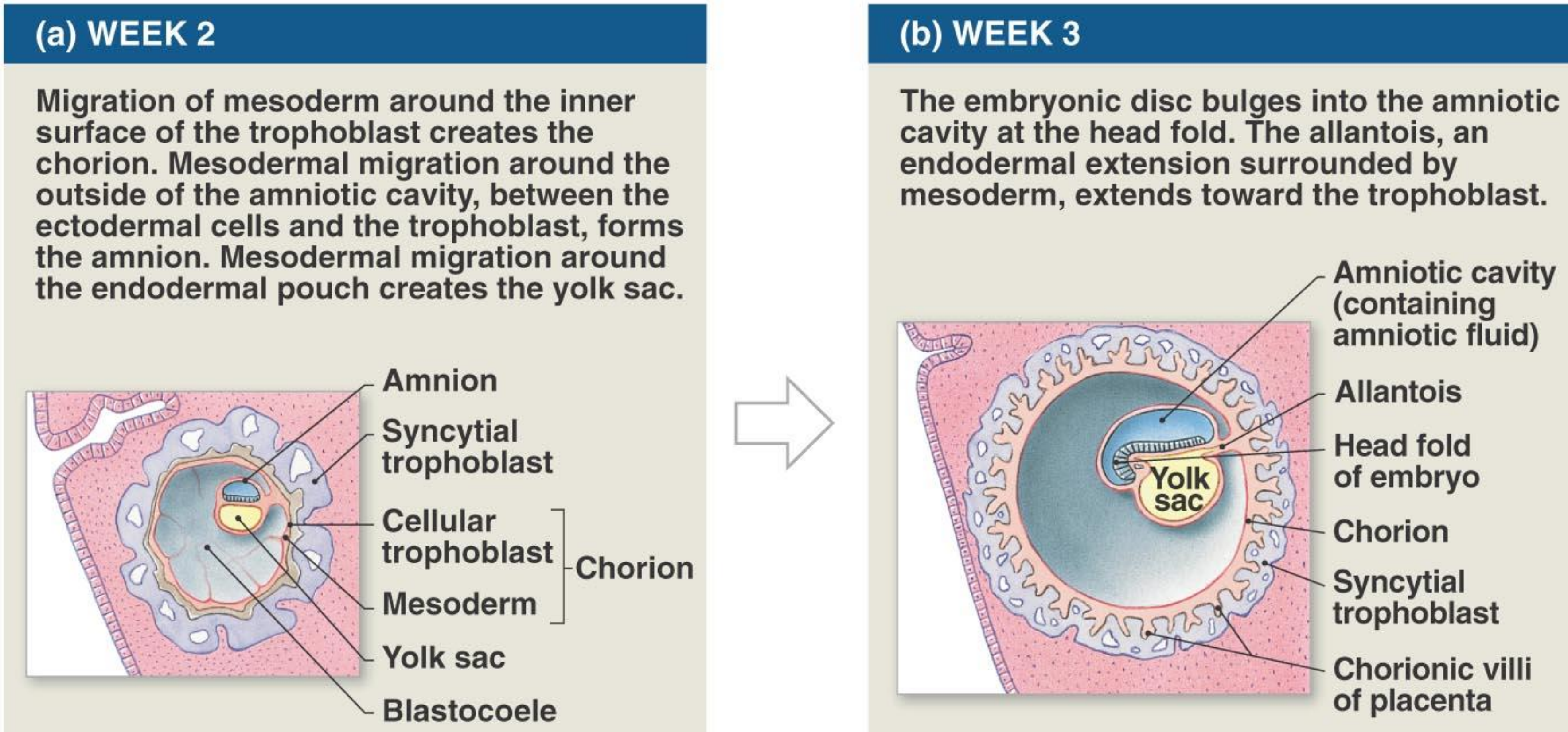
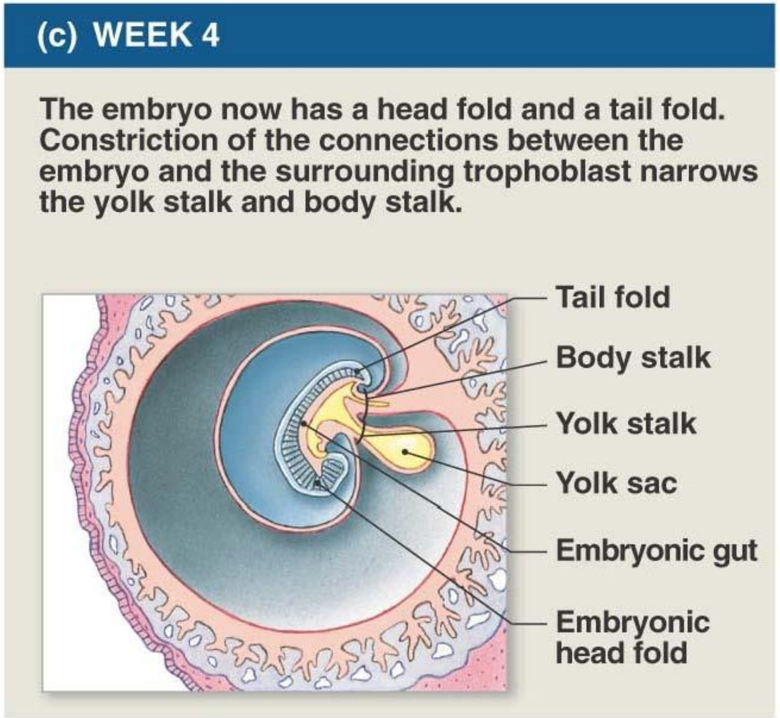


Figure 28.5 The Embryonic Membranes and Placenta Formation

Prenatal Development



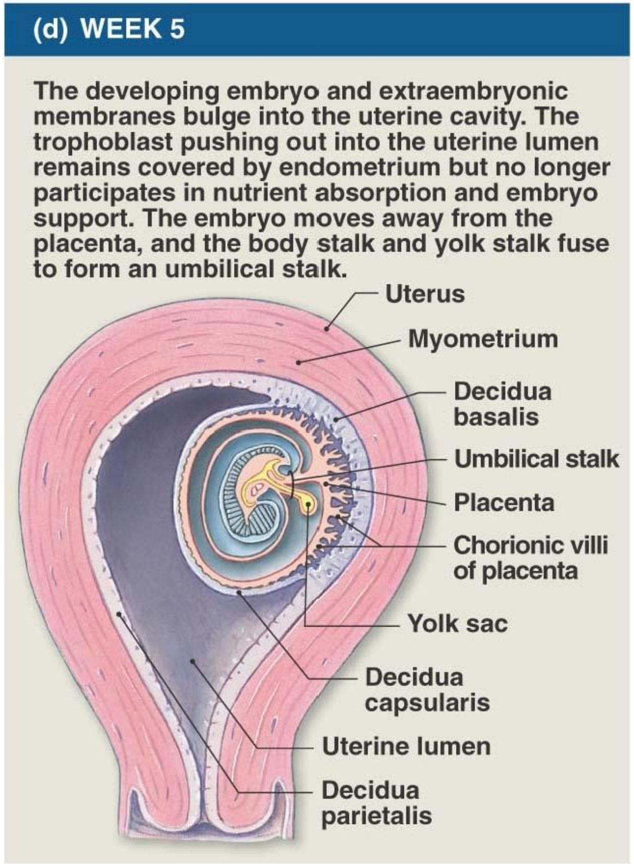


Figure 28.5 The Embryonic Membranes and Placenta Formation

Prenatal Development

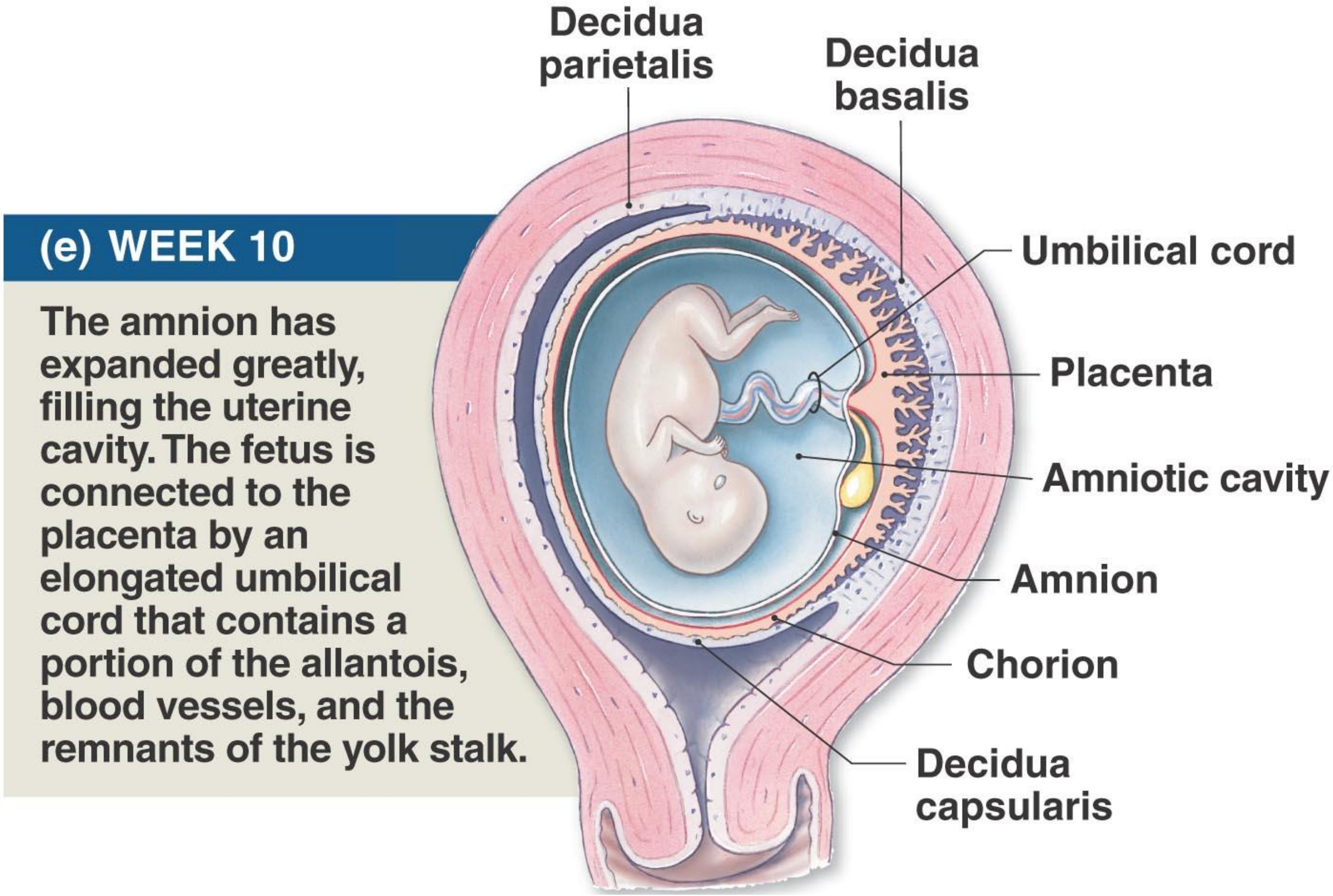


Figure 28.5 The Embryonic Membranes and Placenta Formation

Prenatal Development

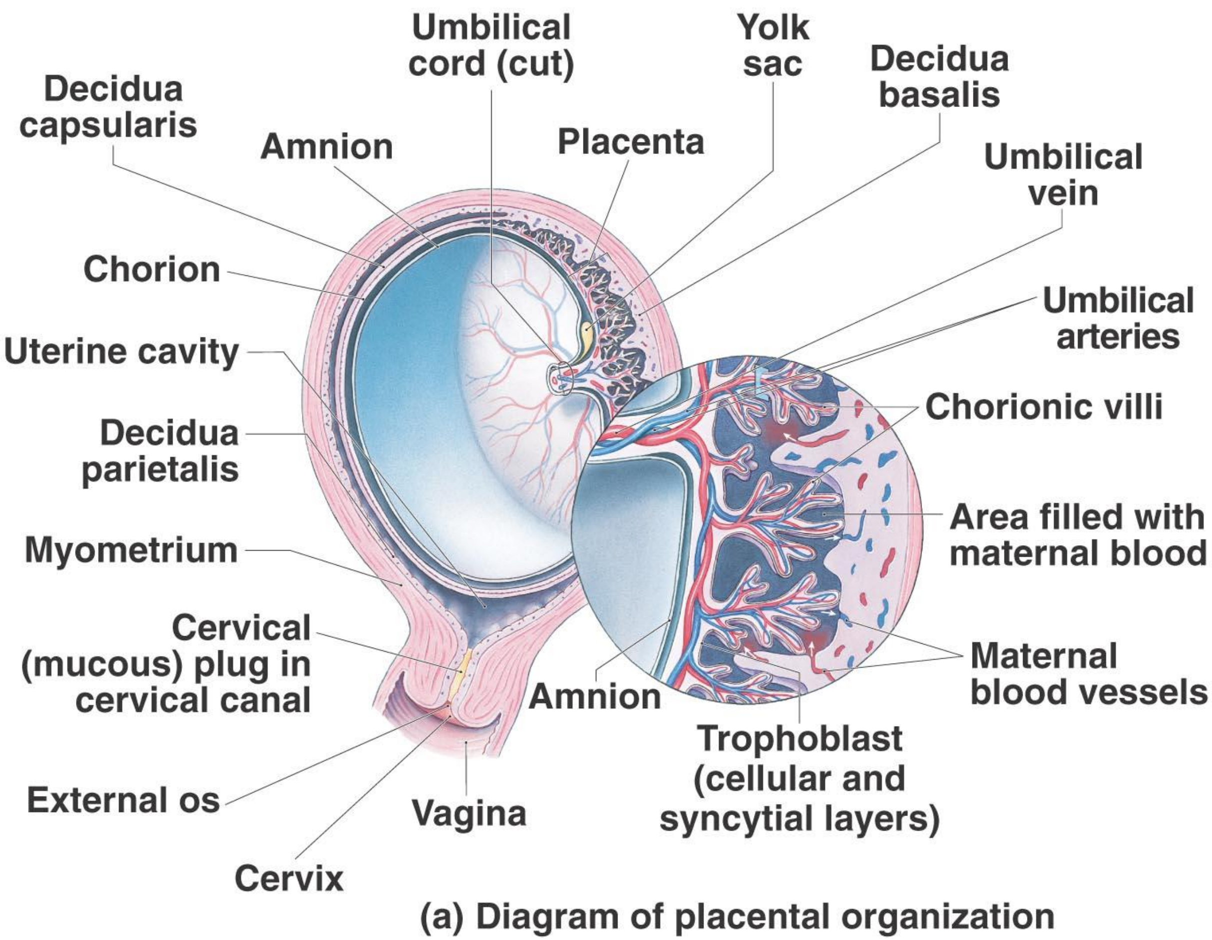


Figure 28.6a A Three-Dimensional View of Placental Structure: (a) Diagram of Placental Organization

Prenatal Development

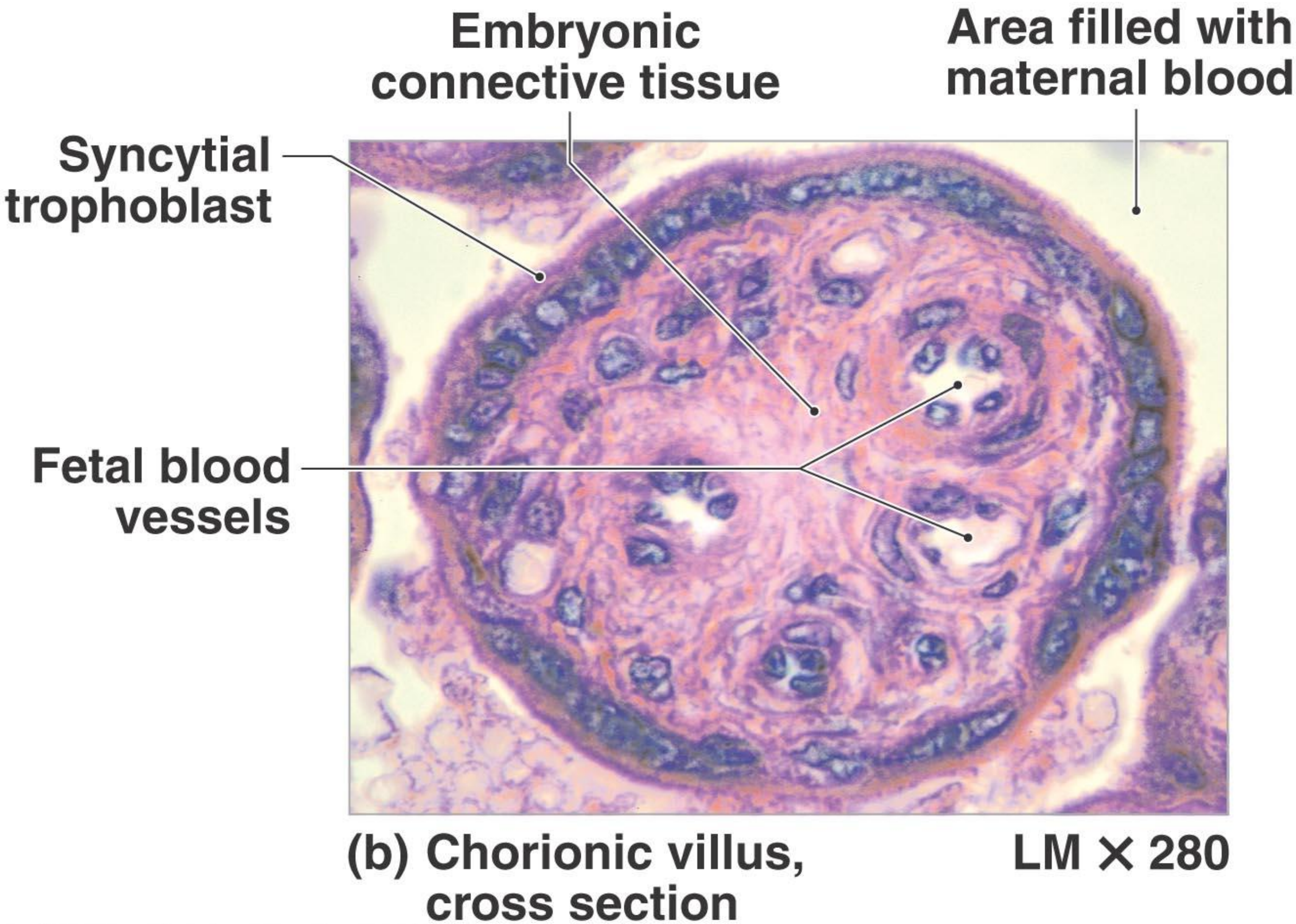


Figure 28.6b A Three-Dimensional View of Placental Structure: (b) Chorionic Villus, Cross Section

Prenatal Development

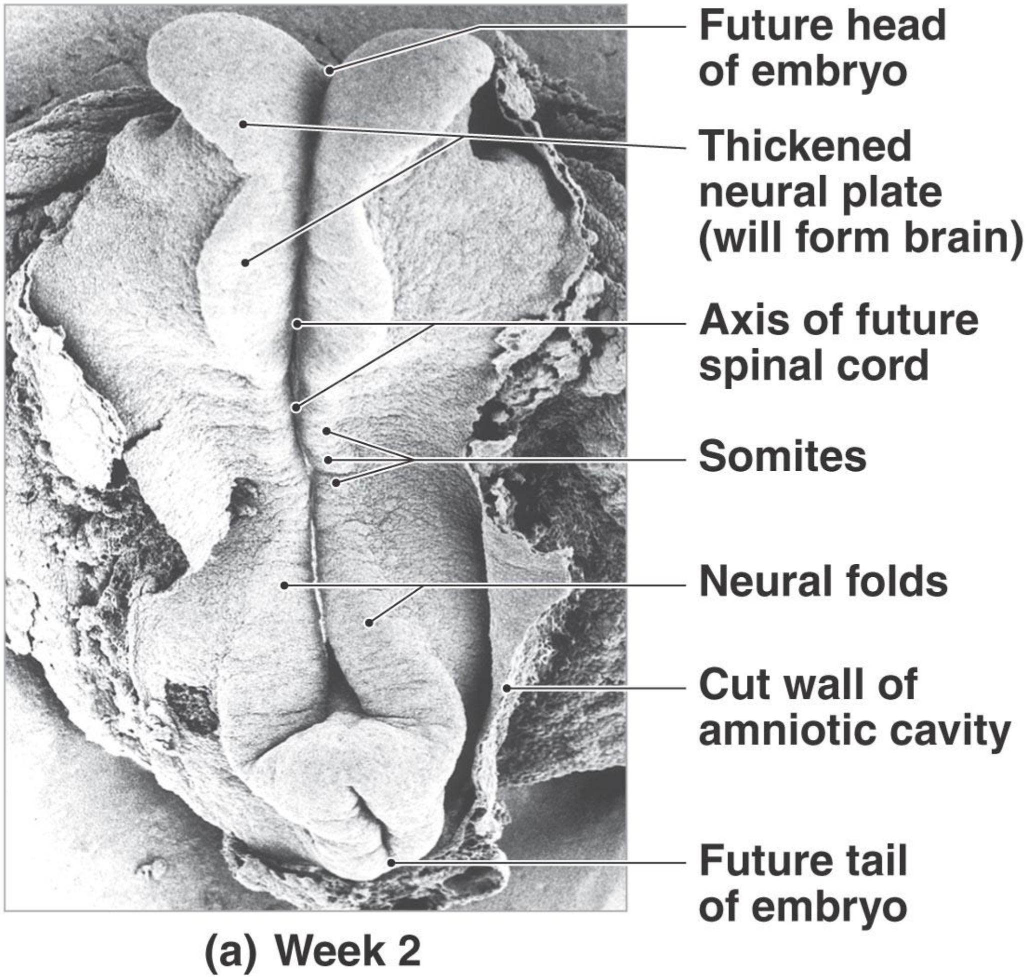


Figure 28.7 The First Trimester

Prenatal Development

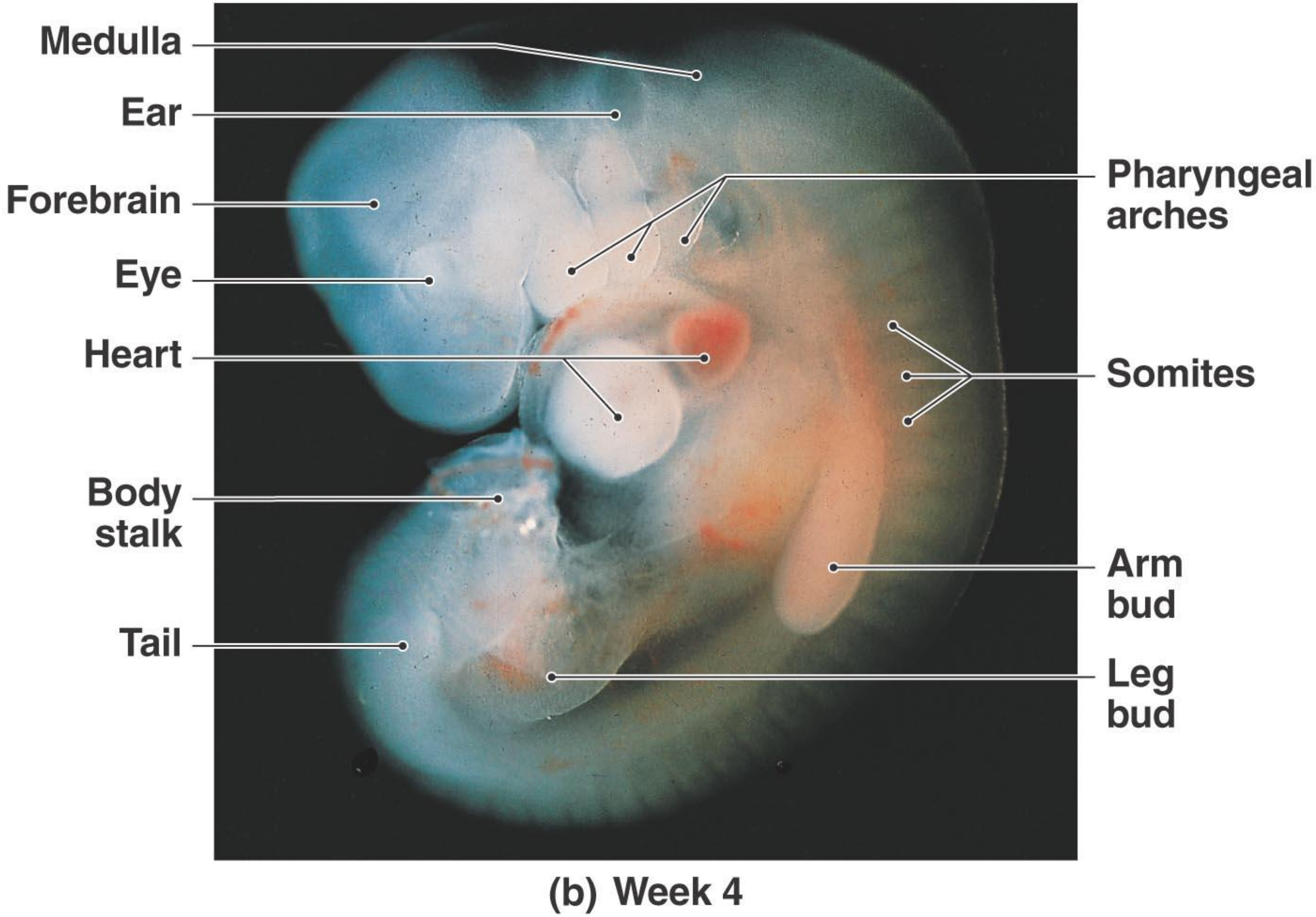


Figure 28.7 The First Trimester

Prenatal Development

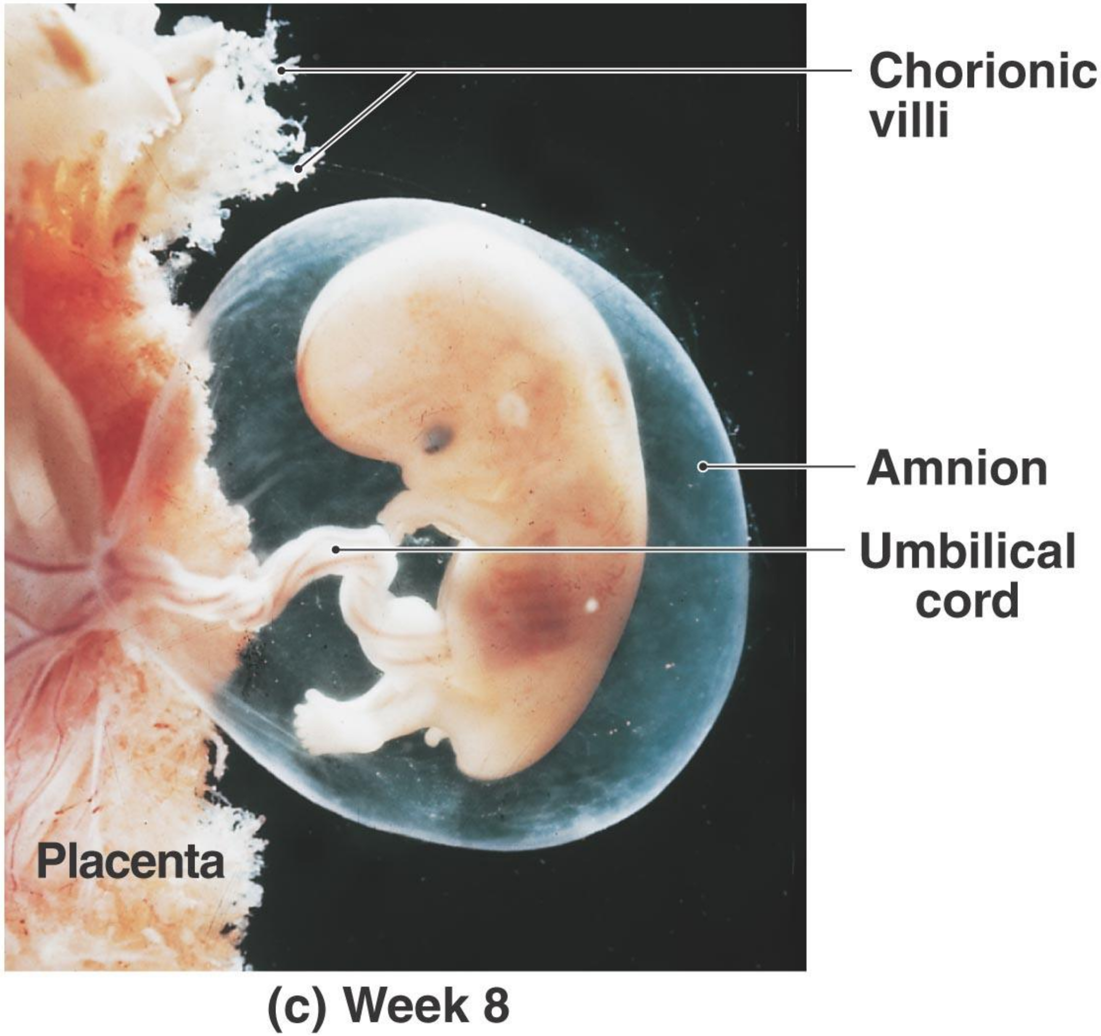
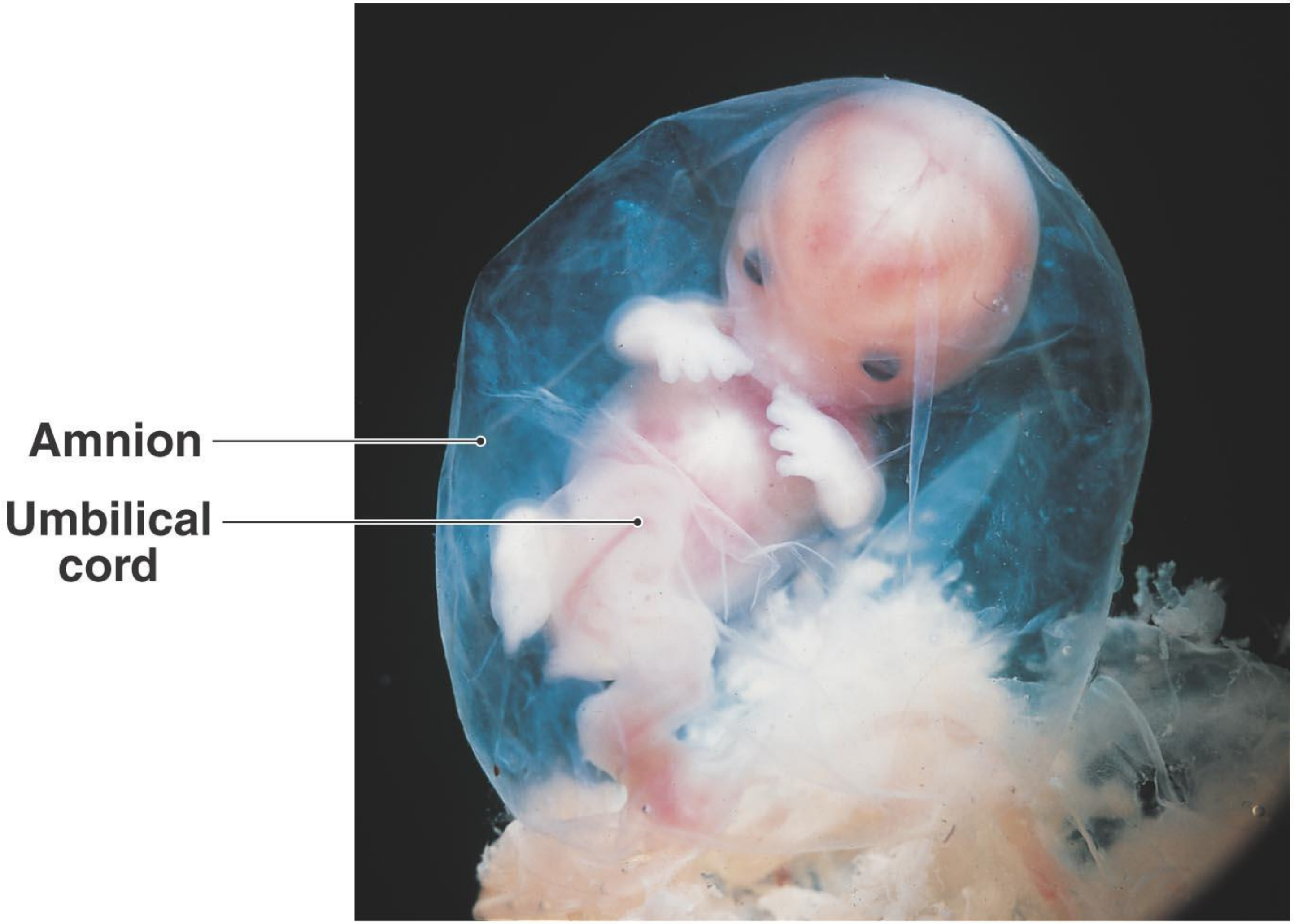


Figure 28.7 The First Trimester

Prenatal Development



(d) Week 12

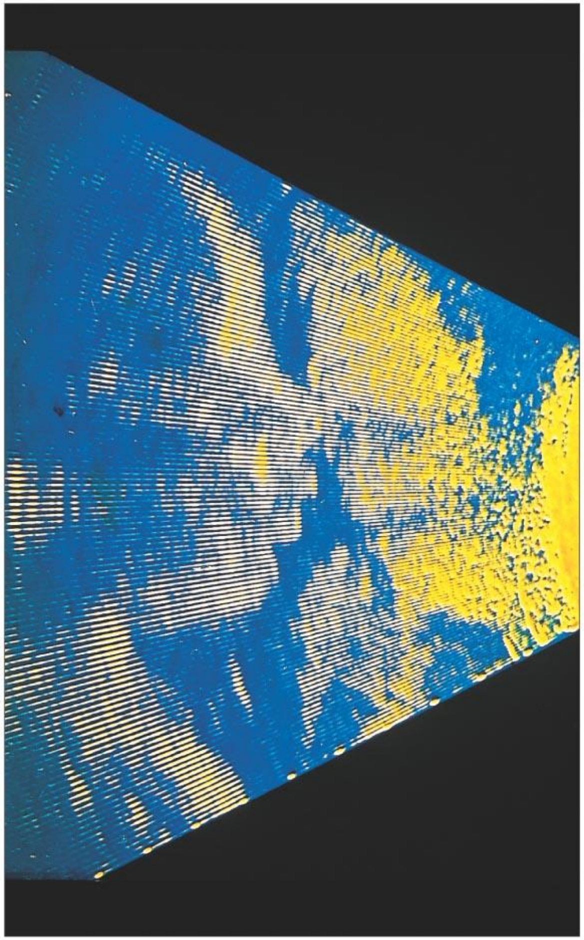
Figure 28.7 The First Trimester

Prenatal Development

(a) Four-month fetus (endoscopic view)

Figure 28.8 The Second and Third Trimesters

Prenatal Development



(b) Six-month fetus
(ultrasound image)

Figure 28.8 The Second and Third Trimesters

Prenatal Development

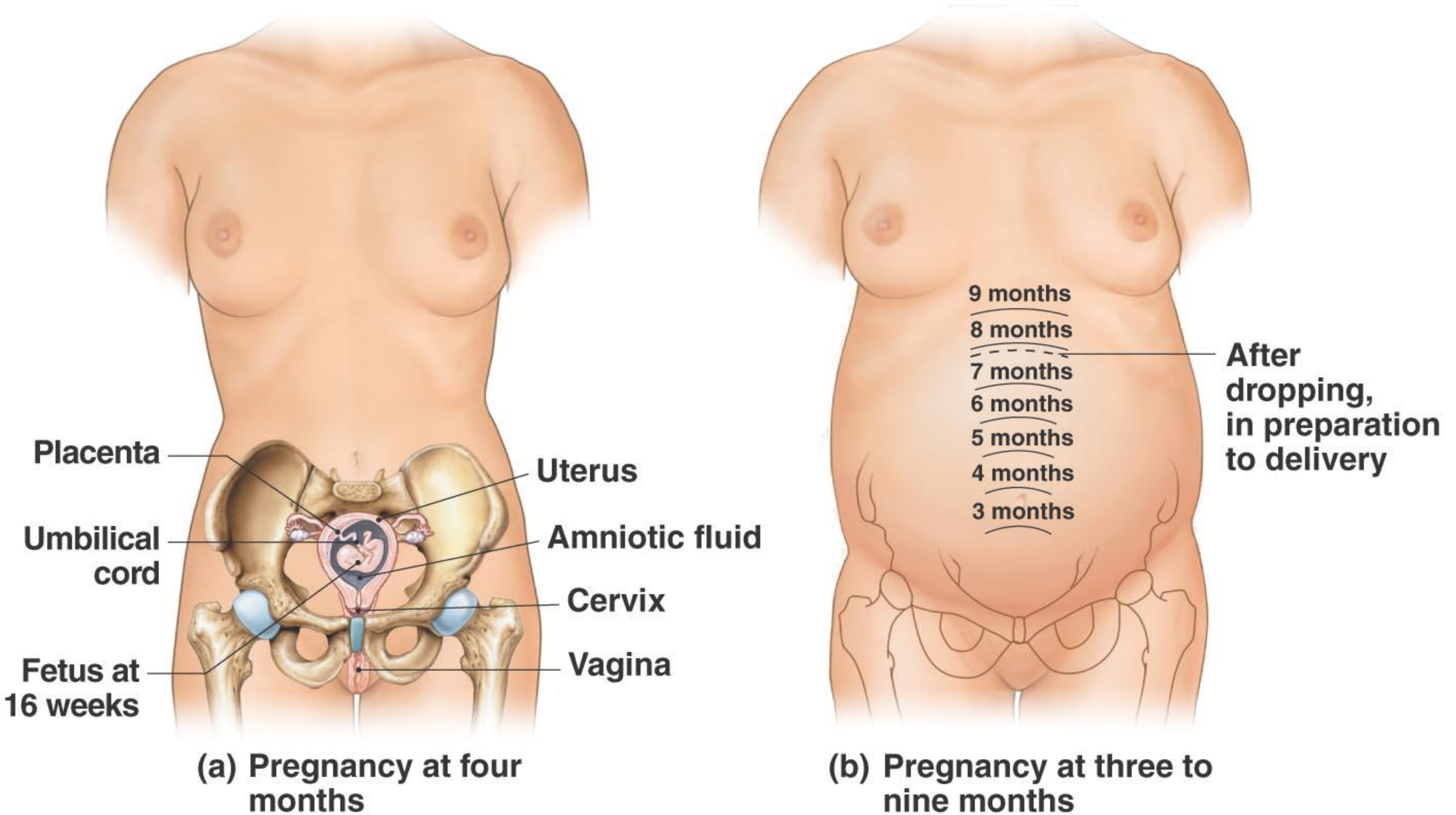


Figure 28.9a, b The Growth of the Uterus and Fetus

Prenatal Development

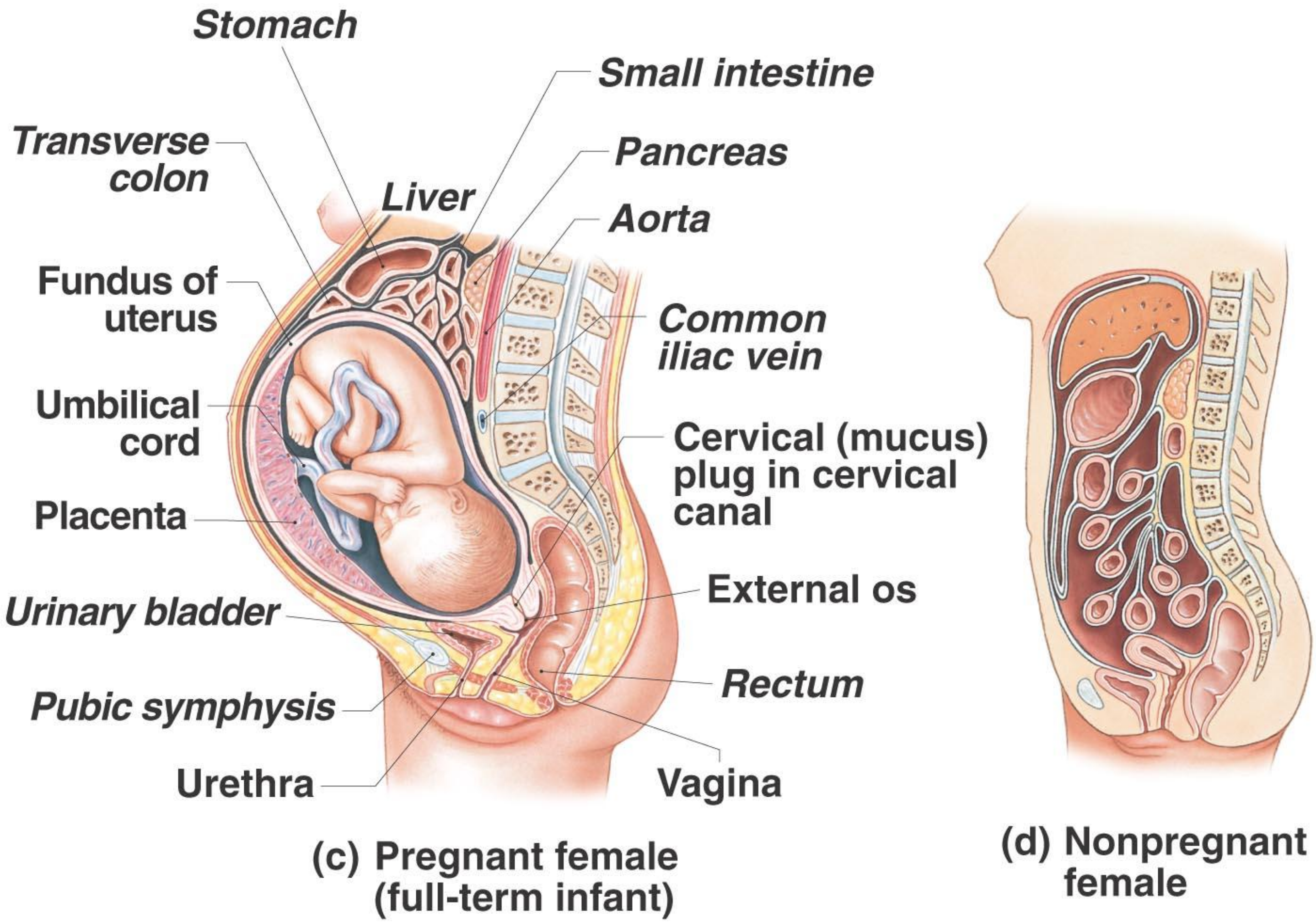


Figure 28.9c, d The Growth of the Uterus and Fetus

Prenatal Development

TABLE 28.2 An Overview of Prenatal Development

Background Material in Chapter 3:
Formation of Tissues (p.79)
Development of Epithelia (p.80)
Origins of Connective Tissues (p.81)
Development of Organ Systems (pp.82–83)





Gestational Age (months)	Size and Weight	Integumentary System	Skeletal System	Muscular System	Nervous System	Special Sense Organs
1	5 mm 0.02 g		(b) Somite formation	(b) Somite formation	(b) Neural tube formation	(b) Eye and ear formation
2	28 mm 2.7 g	(b) Formation of nail beds, hair follicles, sweat glands	(b) Formation of axial and appendicular cartilages	(c) Rudiments of axial musculature	(b) CNS, PNS organization, growth of cerebrum	(b) Formation of taste buds, olfactory epithelium
3	78 mm 26 g	(b) Epidermal layers appear	(b) Ossification centers spreading	(c) Rudiments of appendicular musculature	(c) Basic spinal cord and brain structure	
4	133 mm 150 g	(b) Formation of hair, sebaceous glands (c) Sweat glands	(b) Articulations (c) Facial and palatal organization	Fetus starts moving	(b) Rapid expansion of cerebrum	(c) Basic eye and ear structure (b) Peripheral receptor formation
5	185 mm 460 g	(b) Keratin production, nail production			(b) Myelination of spinal cord	
6	230 mm 823 g			(c) Perineal muscles	(b) CNS tract formation (c) Layering of cortex	

Note: (b) = begin formation; (c) = complete formation.

TABLE 28.2 An Overview of Prenatal Development

Prenatal Development

TABLE 28.2 An Overview of Prenatal Development (*Continued*)

Endocrine System	Cardiovascular and Lymphoid Systems	Respiratory System	Digestive System	Urinary System	Reproductive System
	(b) Heartbeat	(b) Trachea and lung formation	(b) Formation of intestinal tract, liver, pancreas (c) Yolk sac	(c) Allantois	
(b) Formation of thymus, thyroid, pituitary, suprarenal glands	(c) Basic heart structure, major blood vessels, lymph nodes and ducts (b) Blood formation in liver	(b) Extensive bronchial branching into mediastinum (c) Diaphragm	(b) Formation of intestinal subdivisions, villi, salivary glands	(b) Kidney formation (adult form)	(b) Formation of mammary glands
(c) Thymus, thyroid gland	(b) Tonsils,blood formation in bone marrow		(c) Gallbladder, pancreas		(b) Formation of definitive gonads, ducts, genitalia
	(b) Migration of lymphocytes to lymphoid organs, blood formation in spleen			(b) Degeneration of embryonic kidneys	
	(c) Tonsils	(c) Nostrils open	(c) Intestinal subdivisions		
(c) Suprarenal glands	(c) Spleen, liver, bone marrow	(b) Alveolar formation	(c) Epithelial organization, glands		

Note: (b) = begin formation; (c) = complete formation.

TABLE 28.2 An Overview of Prenatal Development

Prenatal Development

TABLE 28.2 An Overview of Prenatal Development (*Continued*)

Background Material in Chapter 3:
Formation of Tissues (p. 79)
Development of Epithelia (p. 80)
Origins of Connective Tissues (p. 81)
Development of Organ Systems (pp. 82–83)





Gestational Age (months)	Size and Weight	Integumentary System	Skeletal System	Muscular System	Nervous System	Special Sense Organs
7	270 mm 1492 g	(b) Keratinization, nail formation, hair formation				(c) Eyelids open, retina sensitive to light
8	310 mm 2274 g		(b) Epiphyseal cartilage formation			(c) Taste receptors functional
9	346 mm 2912 g					
Postnatal development		Hair changes in consistency and distribution	Formation and growth of epiphyseal cartilages continue	Muscle mass and control increase	Myelination, layering, CNS tract formation continue	
Embryological Summaries by System		Development of the Integumentary System (pp. 764–765)	Development of the Skull (pp. 766–767) Development of the Vertebral Column (pp. 768–769) Development of the Appendicular Skeleton (pp. 770–771)	Development of the Muscular System (pp. 772–773)	Introduction to the Development of the Nervous System (p. 774) Development of the Spinal Cord and Spinal Nerves (pp. 775–776) Development of the Brain and Cranial Nerves (pp. 777–778)	Development of Special Sense Organs (pp. 779–780)

Note: (b) = begin formation;(c) = complete formation.

TABLE 28.2 An Overview of Prenatal Development

Prenatal Development

TABLE 28.2 An Overview of Prenatal Development (*Continued*)

Endocrine System	Cardiovascular and Lymphoid Systems	Respiratory System	Digestive System	Urinary System	Reproductive System
(c) Pituitary gland			(c) Intestinal plicae		(b) Descent of testes
		Complete pulmonary branching and alveolar formation		Complete nephron formation at birth	Descent of testes complete at or near time of birth
	Cardiovascular changes at birth; lymphoid system gradually becomes fully operational				
Development of the Endocrine System (pp. 781–782)	Development of the Heart (p. 783) Development of the Cardiovascular System (pp. 784–785) Development of the Lymphoid System (p. 786)	Development of the Respiratory System (pp. 787–788)	Development of the Digestive System (pp. 789–790)	Development of the Urinary System (pp. 791–792)	Development of the Reproductive System (pp. 793–795)

Note: (b) = begin formation; (c) = complete formation.

TABLE 28.2 An Overview of Prenatal Development

Labor and Delivery

- *Parturition*— expulsion of the fetus, birth
- Stages of labor
  - *Dilation stage*— the cervix dilates; usually lasts 8 or more hours
  - *Expulsion stage*— involves delivery of fetus
  - *Placental stage*— ejection of the placenta
- Premature labor occurs when true labor begins before fetus has completed normal development.
- A premature delivery produces a baby weighing over 1 kg.

Labor and Delivery

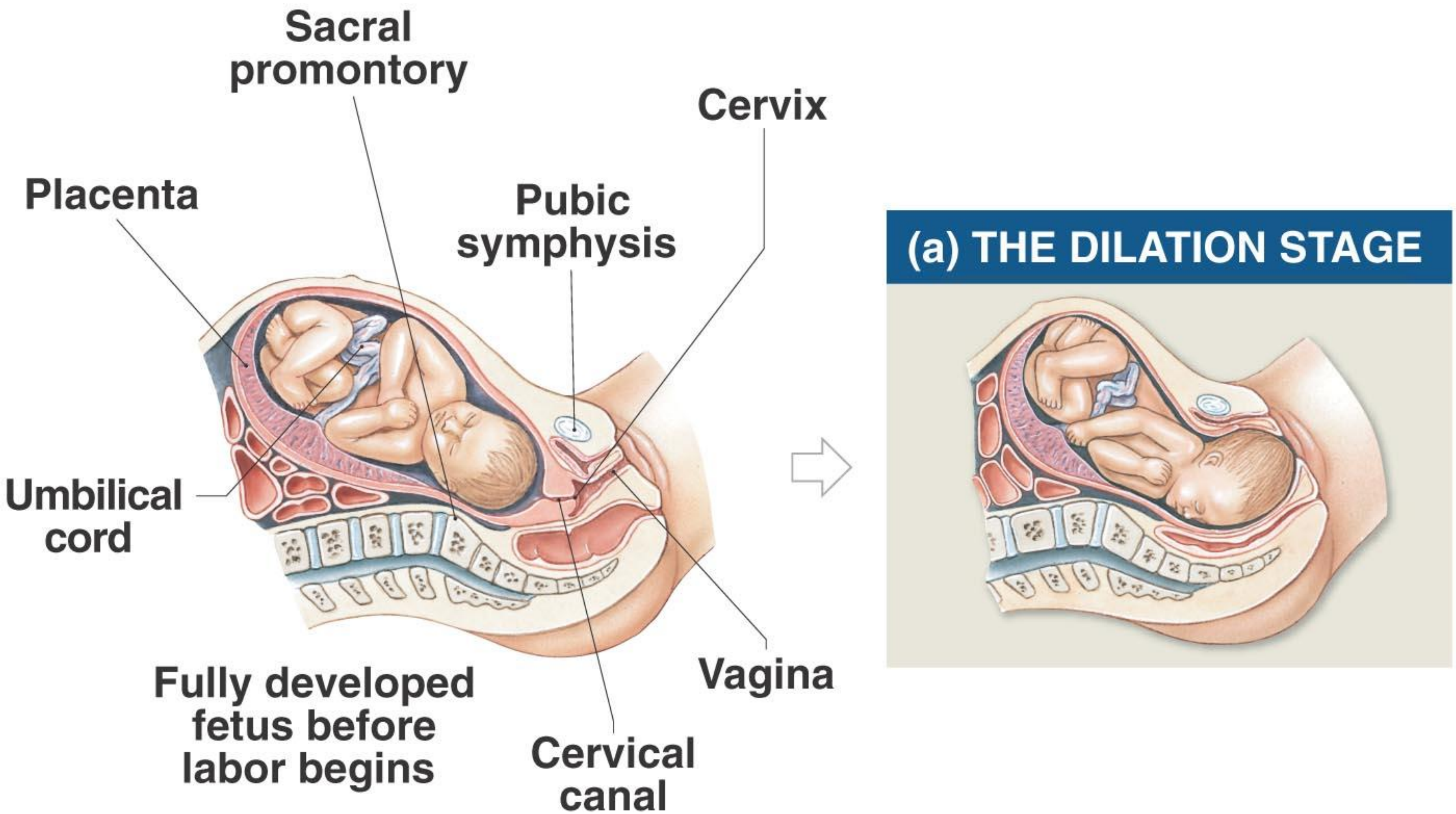


Figure 28.10 The Stages of Labor

Labor and Delivery

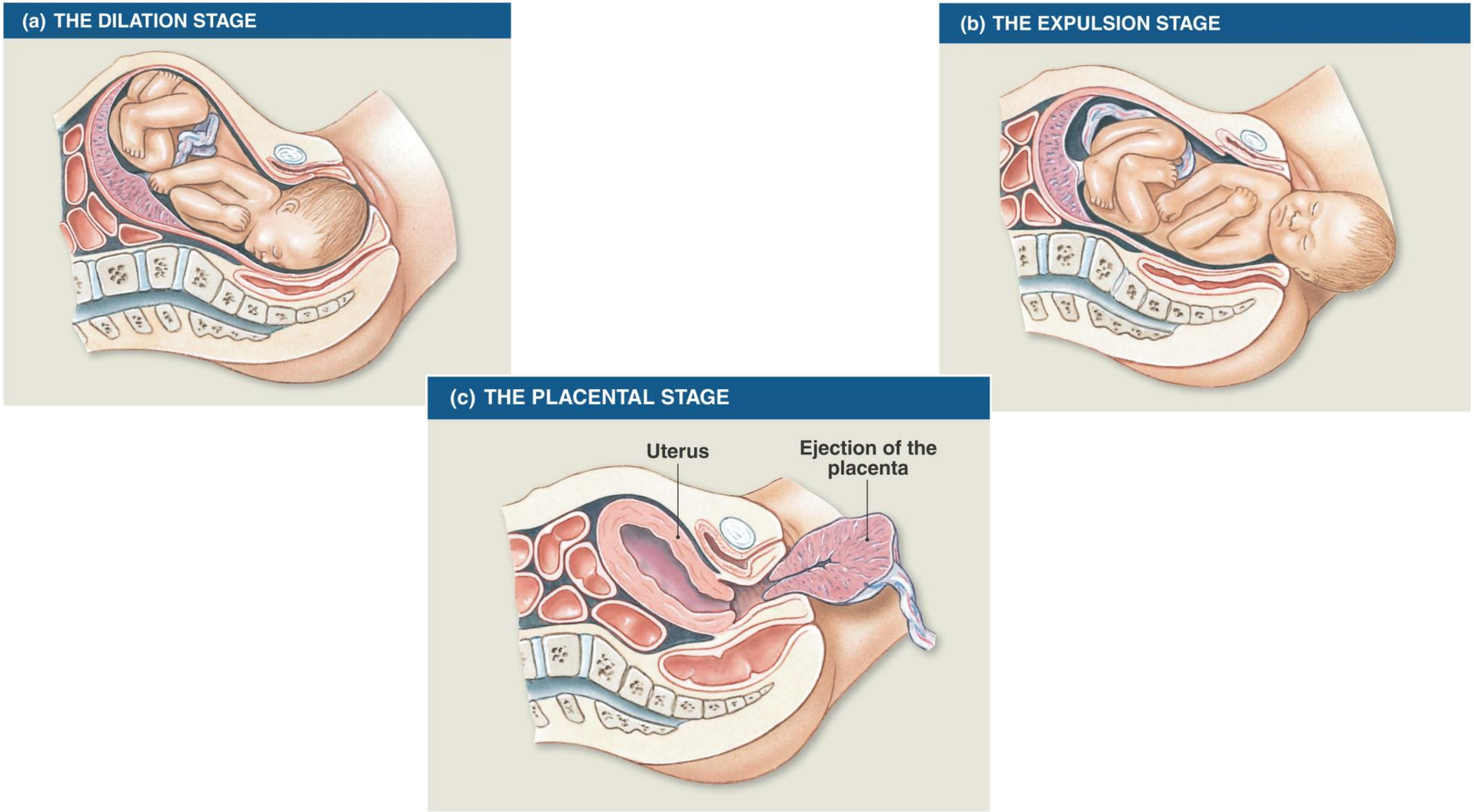
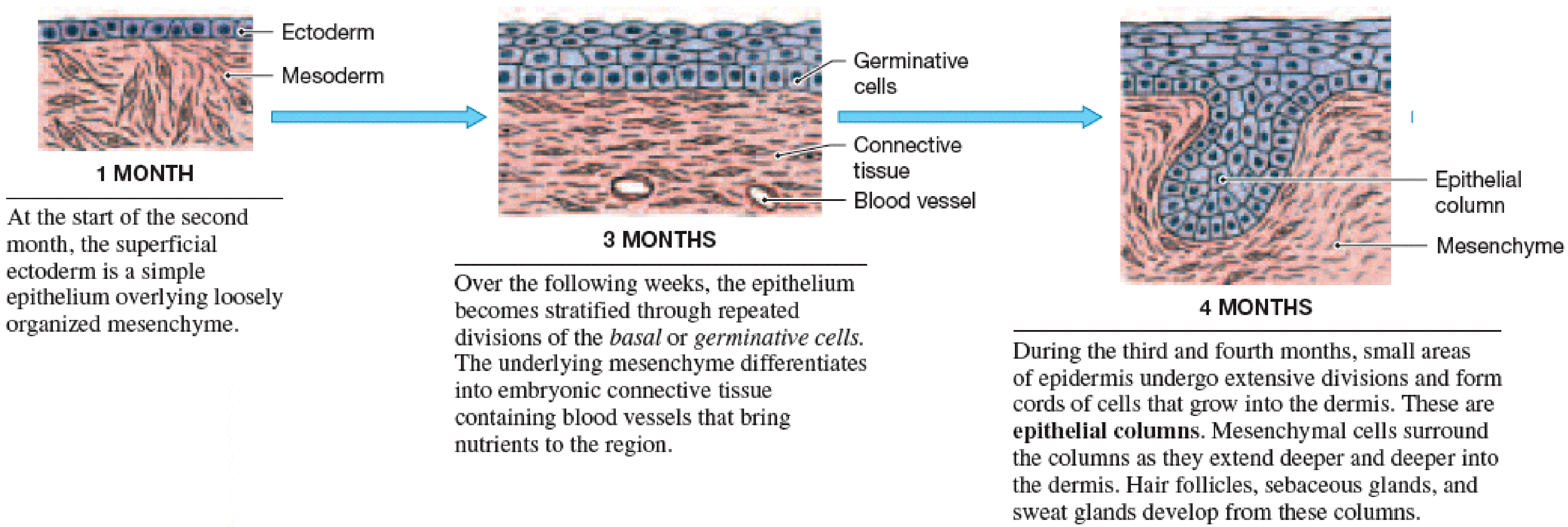


Figure 28.10 The Stages of Labor

The Neonatal Period

- Transition from Fetus to Neonate (Newborn)
  - The lungs at birth are collapsed and filled with fluid, and filling them with air involves a massive and powerful inhalation.
  - The pattern of cardiovascular circulation changes because of alterations in blood pressure and flow rates.
  - Typical heart rates of 120–140 beats per minute and respiratory rates of 30 breaths per minute in neonates are normal.
  - The digestive system remains excrete debris, then begins to nurse.
  - Glomerular filtration is normal, but the urine cannot be concentrated to any significant degree.
  - The neonate has little ability to control body temperature.

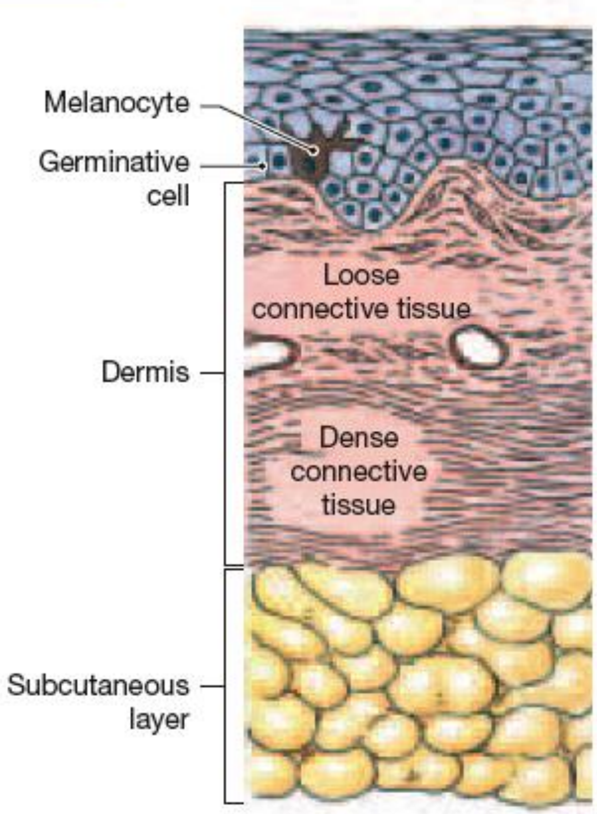
Embryology Summary



The Development of the Integumentary System

Embryology Summary

SKIN



4 MONTHS

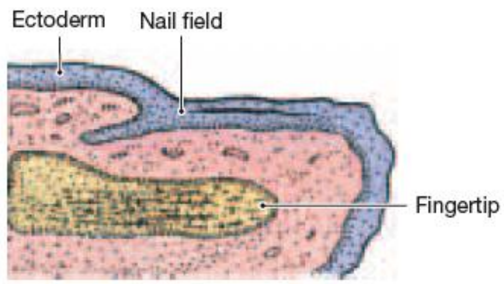
As basal cell divisions continue, the epithelial layer thickens and the basal lamina is thrown into irregular folds. Pigment cells called *melanocytes* migrate into the area and squeeze between the germinative cells. The epithelium now resembles the *epidermis* of the adult.

The embryonic connective tissue differentiates into the *dermis*. Fibroblasts and other connective tissue cells form from mesenchymal cells or migrate into the area. The density of fibers increases. Loose connective tissue extends into the ridges, but a deeper, less vascular region is dominated by a dense, irregular collagen fiber network. Below the dermis the embryonic connective tissue develops into the *subcutaneous layer*, a layer of loose connective tissue.

The Development of the Integumentary System

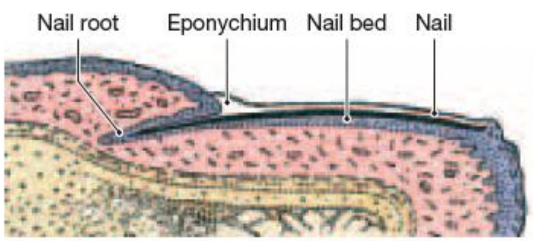
Embryology Summary

NAILS



4 MONTHS

Nails begin as thickenings of the epidermis near the tips of the fingers and toes. These thickenings settle into the dermis, and the borderline with the general epidermis becomes distinct. Initially, nail production involves all of the germinative cells of the *nail field*.

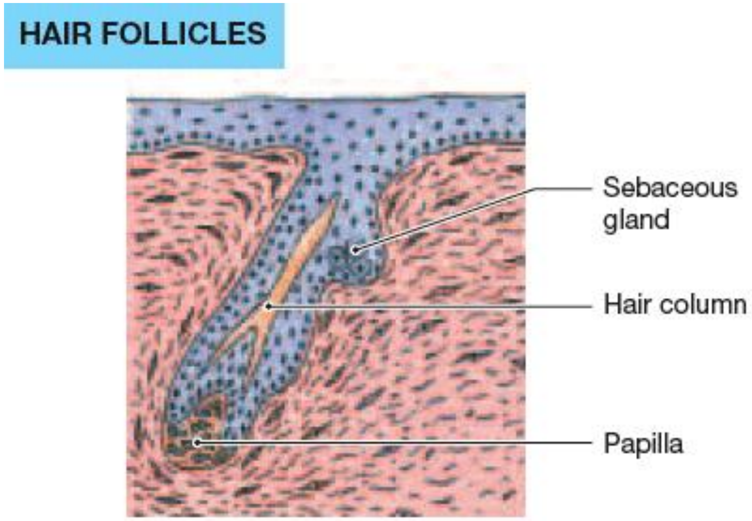


BIRTH

By the time of birth, nail production is restricted to the *nail root*.

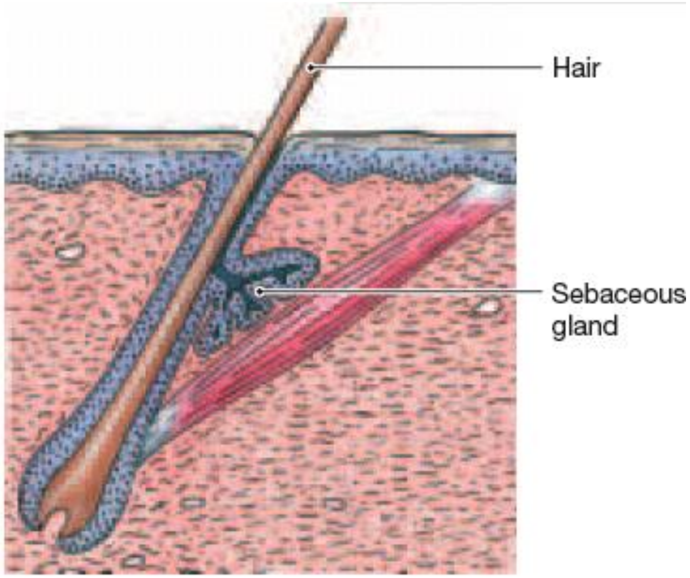
The Development of the Integumentary System

Embryology Summary



5 MONTHS

A hair follicle develops as a deep column surrounds a *papilla*, a small mass of connective tissue. Hair growth will occur in the epithelium covering the papilla. An outgrowth from the epithelial column forms a *sebaceous gland*.

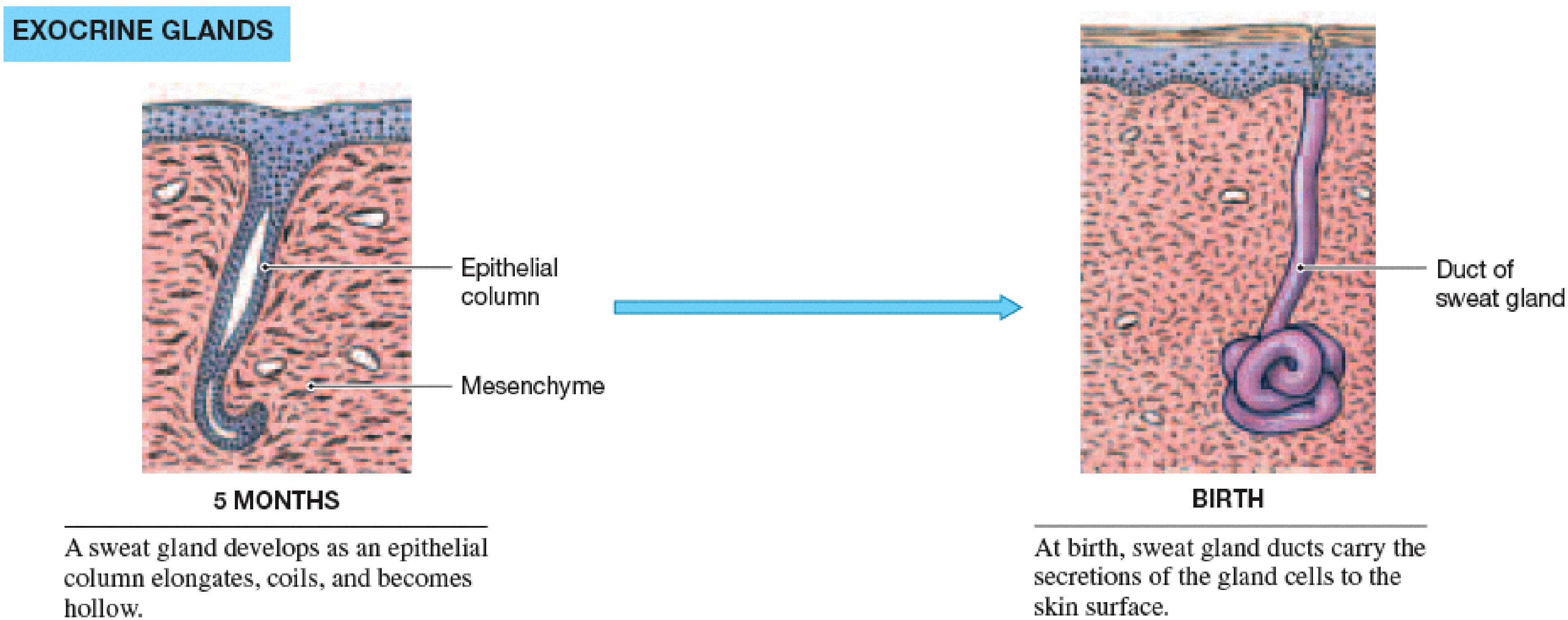


BIRTH

At birth a hair projects from the follicle, and the secretions of the sebaceous gland lubricate the hair shaft.

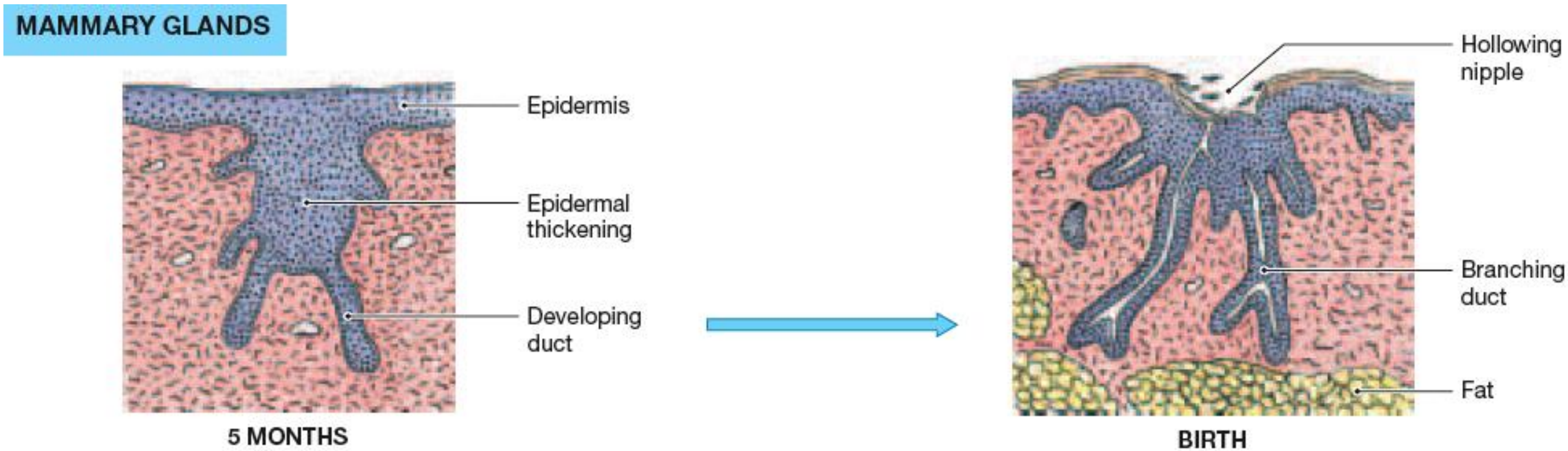
The Development of the Integumentary System

Embryology Summary



The Development of the Integumentary System

Embryology Summary

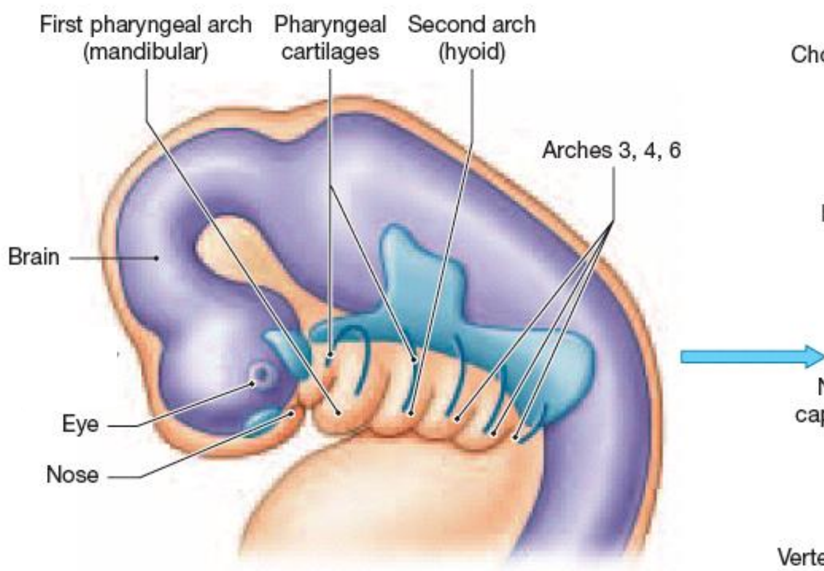


Mammary glands develop in a comparable fashion, but the epidermal thickenings are much broader and extensive branching occurs.

At birth, the mammary glands have not completed their development. In females, further elaboration of the duct and gland system occurs at puberty, but functional maturity does not occur until late in pregnancy.

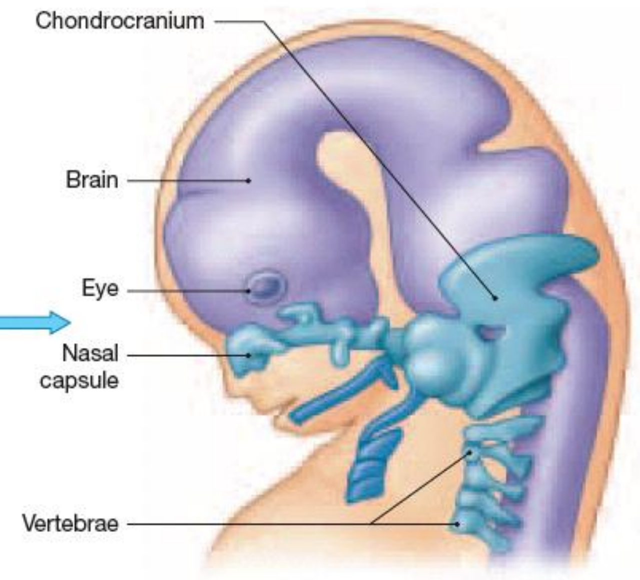
The Development of the Integumentary System

Embryology Summary



5 WEEKS

After 5 weeks of development, the central nervous system is a hollow tube that runs the length of the body. A series of cartilages appears in the mesenchyme of the head beneath and alongside the expanding brain and around the developing nose, eyes, and ears. These cartilages are shown in light blue. Five additional pairs of cartilages develop in the walls of the pharynx. These cartilages, shown in dark blue, are located within the **pharyngeal**, or **branchial, arches**. (*Branchial* refers to gills—in fish the caudal arches develop into skeletal supports for the gills.) The first arch, or **mandibular arch**, is the largest.

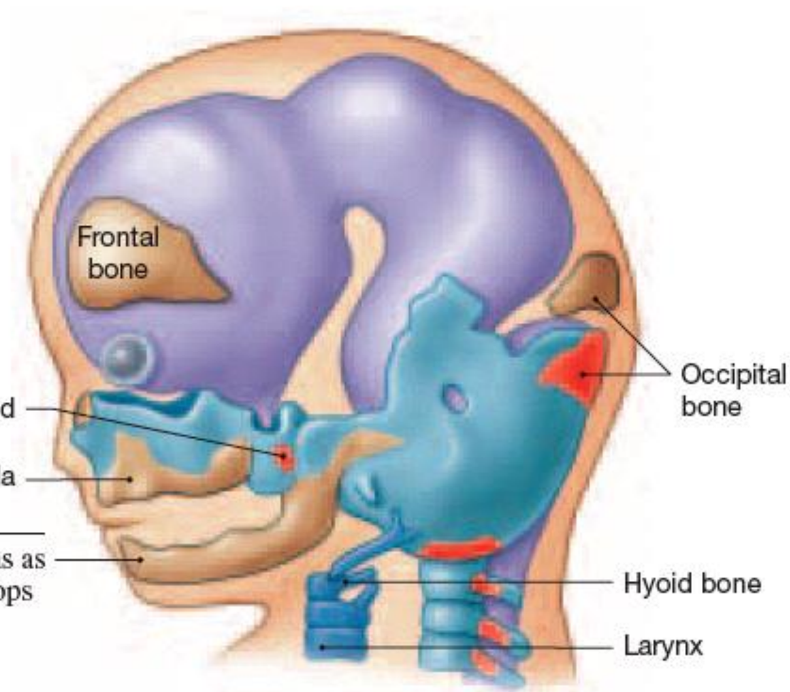


8 WEEKS

The cartilages associated with the brain enlarge and fuse, forming a cartilaginous **chondrocranium** (kon-drō-KRĀ-nē-um; *chondros*, cartilage + *cranium*, skull) that cradles the brain and sense organs. At 8 weeks its walls and floor are incomplete, and there is no roof.

The Development of the Skull

Embryology Summary



The mandible forms as dermal bone develops around the inferior portion of the mandibular arch.

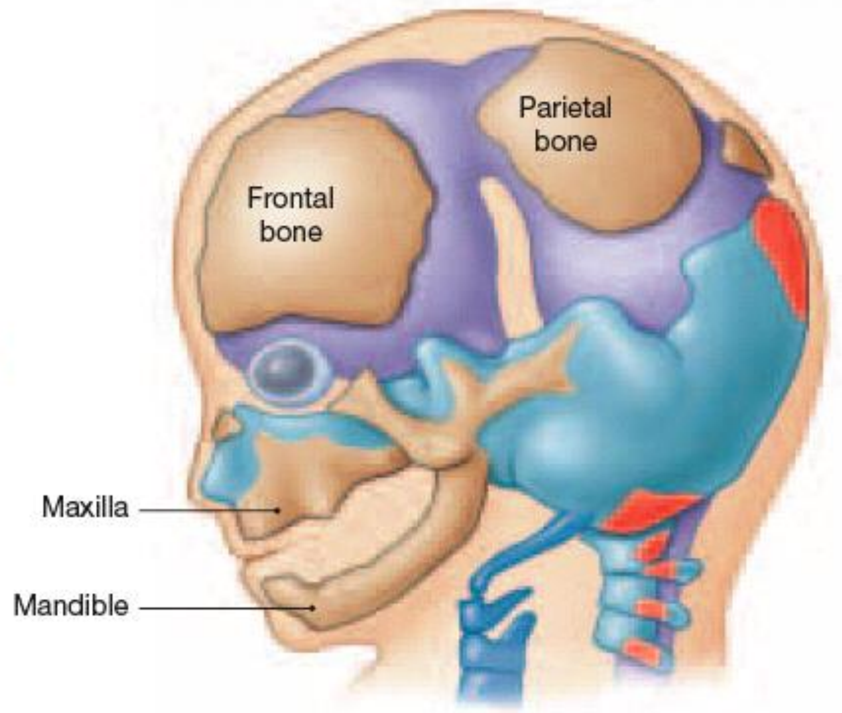
9 WEEKS

During the ninth week, numerous centers of endochondral ossification appear within the chondrocranium. These centers are shown in red. Gradually, the frontal and parietal bones of the cranial roof appear as intramembranous ossification begins in the overlying dermis. As these centers (beige) enlarge and expand, extensive fusions occur.

The Development of the Skull

Embryology Summary

The dorsal portion of the mandibular arch fuses with the chondrocranium. The fused cartilages do not ossify; instead, osteoblasts begin sheathing them in dermal bone. On each side this sheath fuses with a bone developing at the entrance to the nasal cavity, producing the two maxillae. Ossification centers in the roof of the mouth spread to form the palatine processes and later fuse with the maxillae.



10 WEEKS

The Development of the Skull

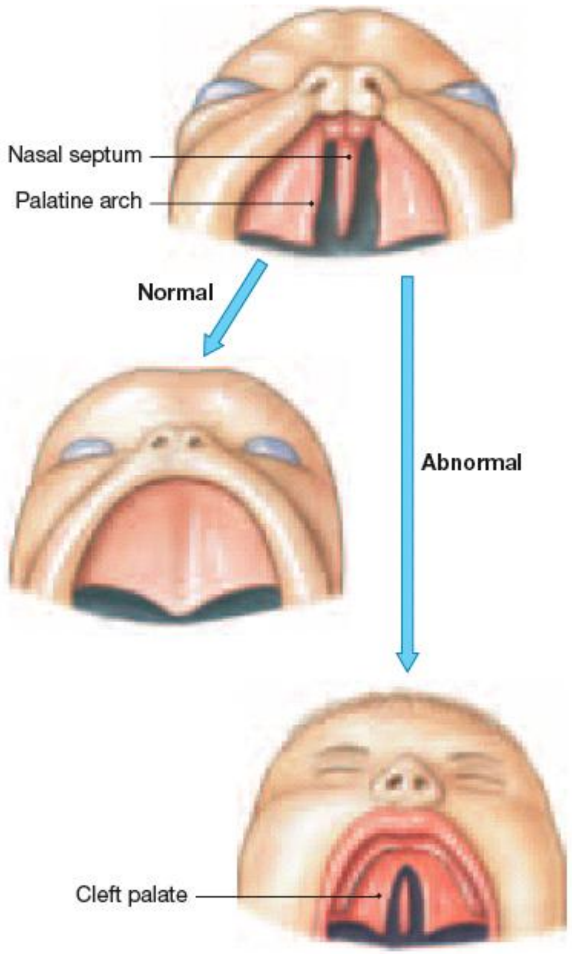
Embryology Summary

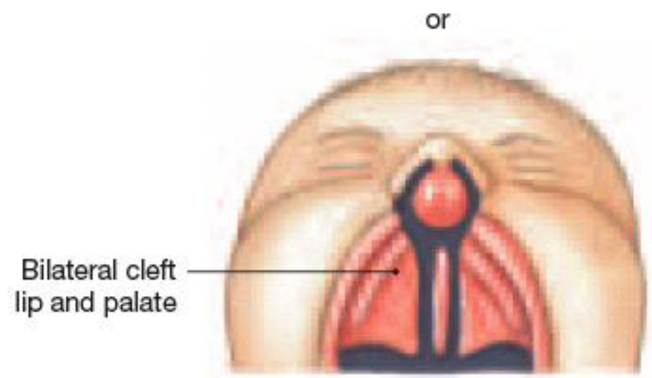
10 WEEKS

The second arch, or **hyoid arch**, forms near the temporal bones. Fusion of the superior tips of the hyoid with the temporals forms the styloid processes. The ventral portion of the hyoid arch ossifies as the hyoid bone. The third arch fuses with the hyoid, and the fourth and sixth arches form laryngeal cartilages.

The Development of the Skull

Embryology Summary

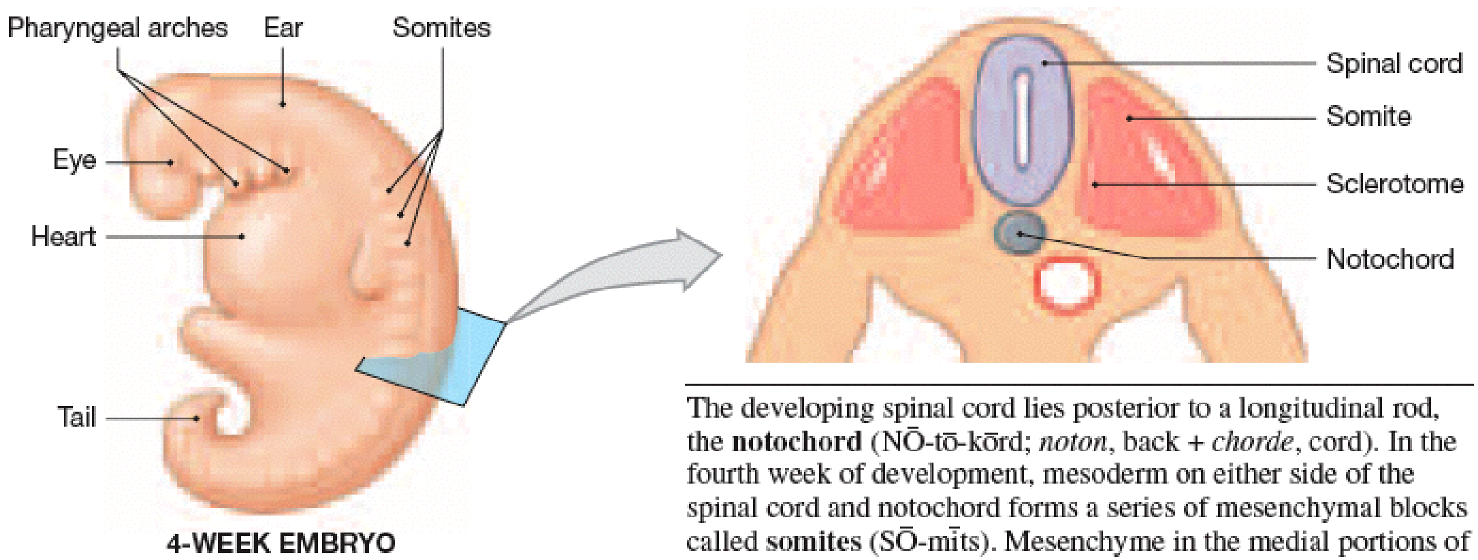




If the overlying skin does not fuse normally, the result is a **cleft lip**. Cleft lips affect roughly one birth in a thousand. A split extending into the orbit and palate is called a **cleft palate**. Cleft palates are half as common as cleft lips. Both conditions can be corrected surgically.

The Development of the Skull

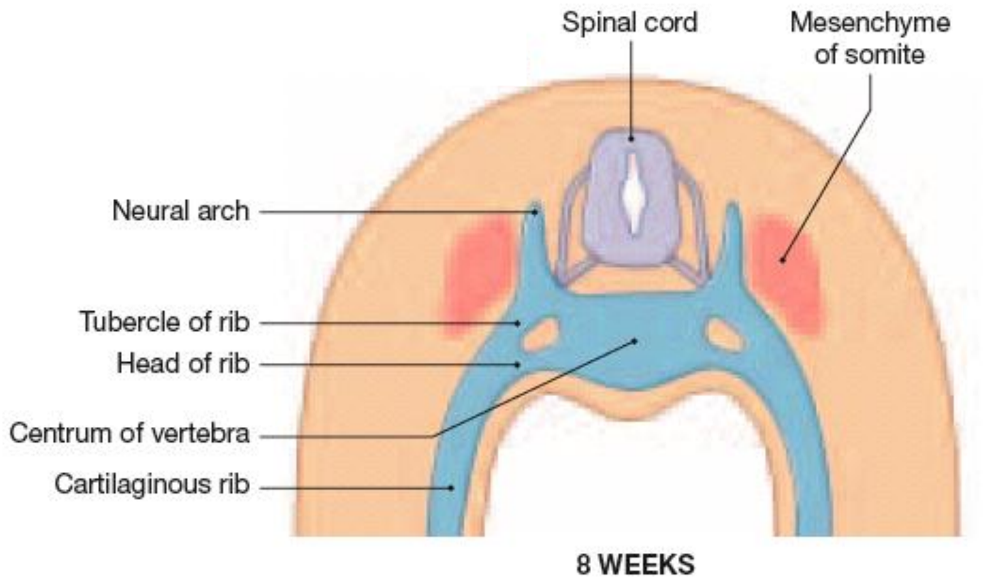
Embryology Summary



The developing spinal cord lies posterior to a longitudinal rod, the **notochord** (NŌ-tō-kōrd; *noton*, back + *chorde*, cord). In the fourth week of development, mesoderm on either side of the spinal cord and notochord forms a series of mesenchymal blocks called **somites** (SŌ-mīts). Mesenchyme in the medial portions of each somite, a region known as the **sclerotome** (SKLER-ō-tōme; *skleros*, hard), will produce the vertebral column and contribute to the floor of the cranium.

The Development of the Vertebral Column

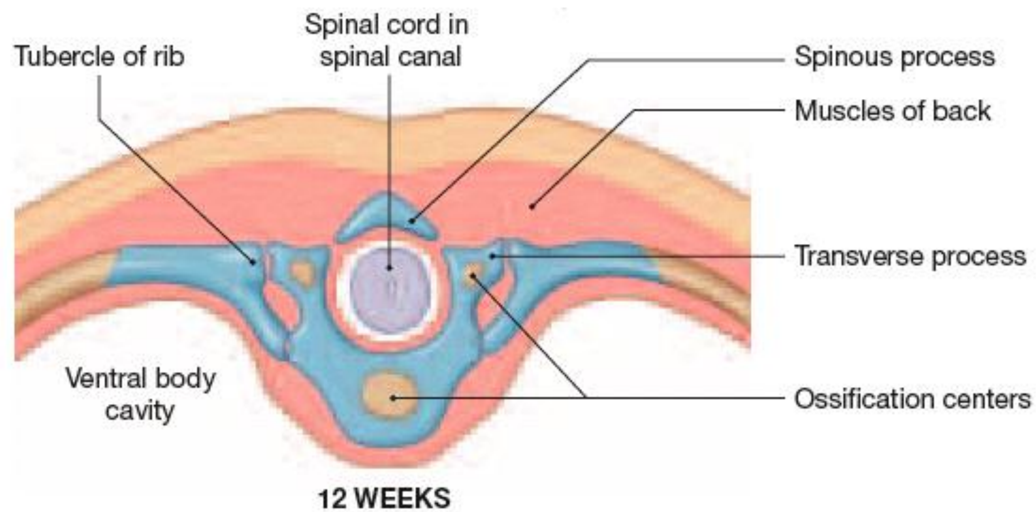
Embryology Summary



The cartilages of the vertebral centra grow around the spinal cord, creating a model of the complete vertebra. In the cervical, thoracic, and lumbar regions, articulations develop where adjacent cartilaginous blocks come into contact. In the sacrum and coccyx, the cartilages fuse together.

The Development of the Vertebral Column

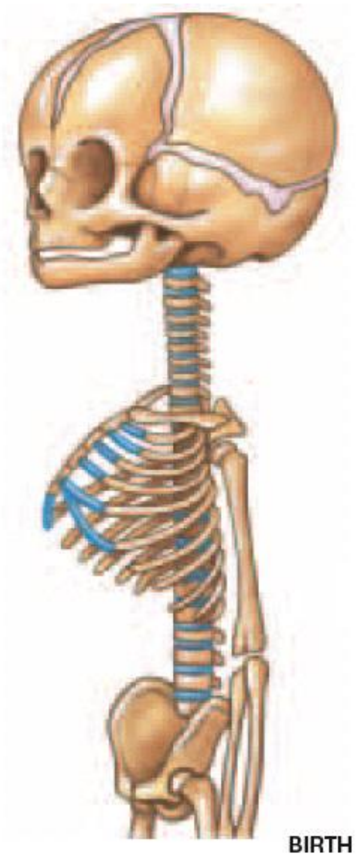
Embryology Summary



About the time the ribs separate from the vertebrae, ossification begins. Only the shortest ribs undergo complete ossification. In the rest, the distal portions remain cartilaginous, forming the costal cartilages. Several ossification centers appear in the sternum, but fusion gradually reduces the number.

The Development of the Vertebral Column

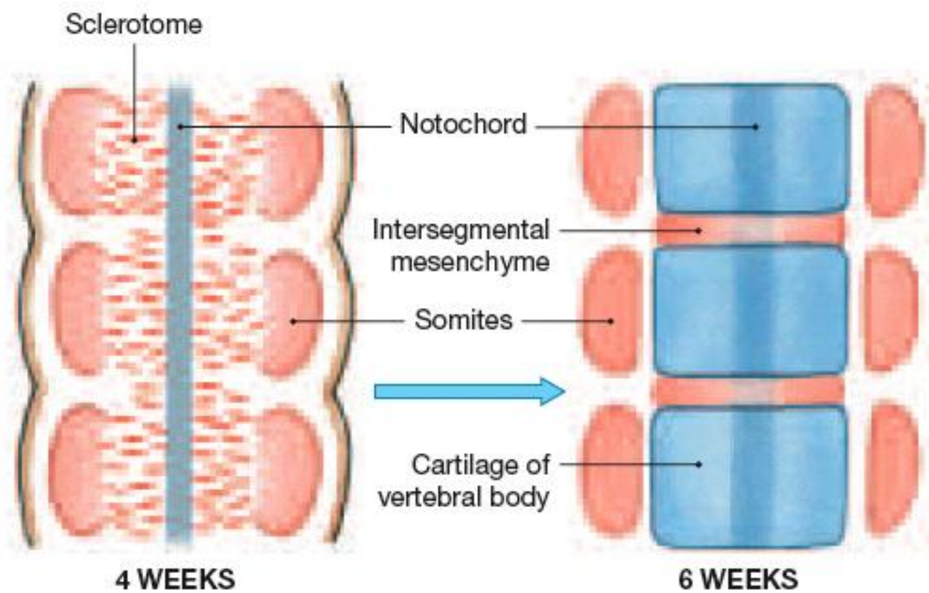
Embryology Summary



At birth, the vertebrae and ribs are ossified, but many cartilaginous areas remain. For example, the anterior portions of the ribs remain cartilaginous. Additional growth will occur for many years; in vertebrae, the bases of the neural arches enlarge until ages 3–6, and the spinal processes and vertebral bodies grow until ages 18–25.

The Development of the Vertebral Column

Embryology Summary

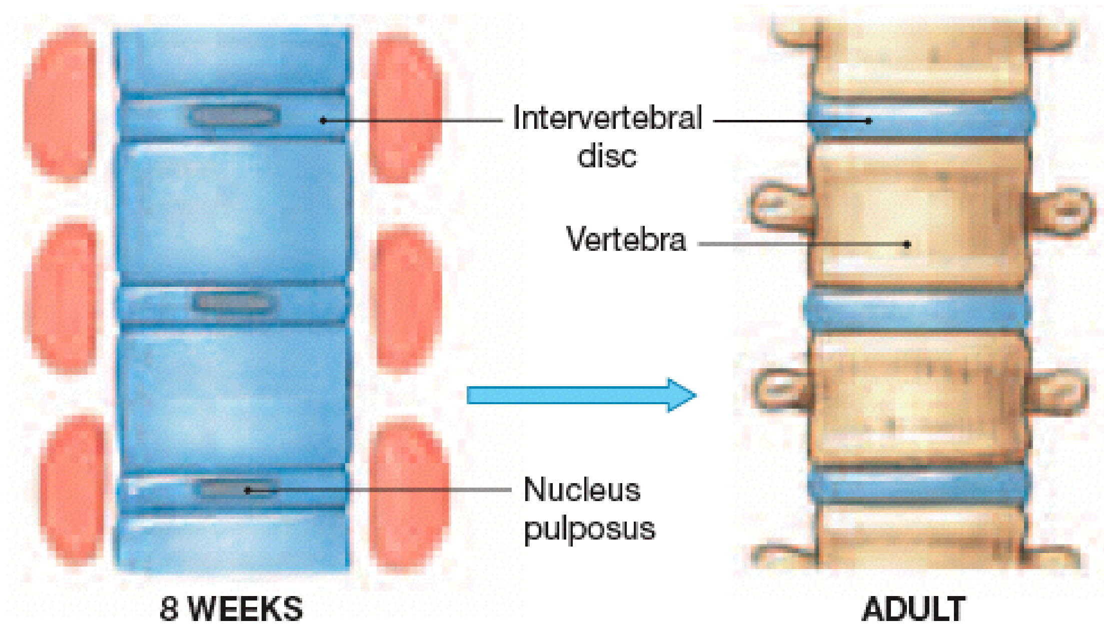


Cells of the sclerotomal segments migrate away from the somites and cluster around the notochord.

The migrating cells differentiate into chondroblasts and produce a series of cartilaginous blocks that surround the notochord. These cartilages, which will develop into the vertebral centra, are separated by patches of mesenchyme.

The Development of the Vertebral Column

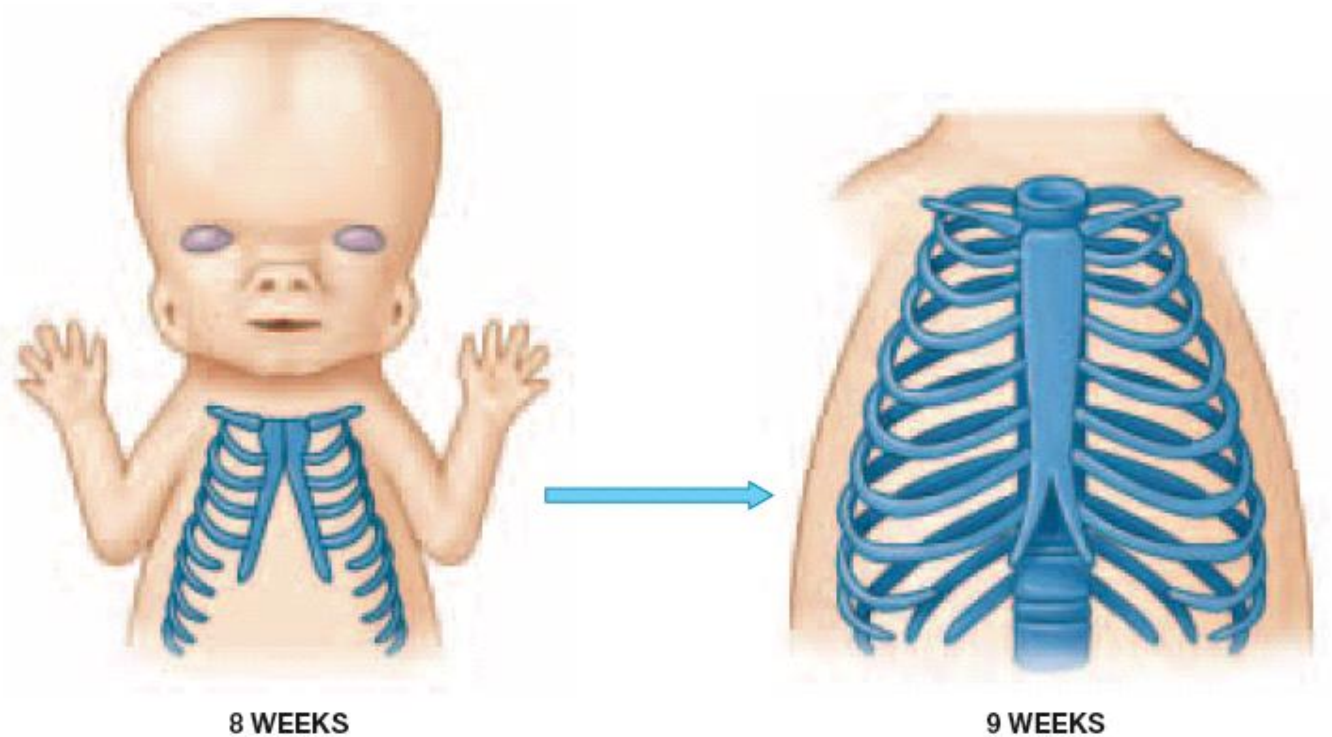
Embryology Summary



Expansion of the vertebral centra eventually eliminates the notochord, but it remains intact between adjacent vertebrae, forming the *nucleus pulposus* of the intervertebral discs. Later, surrounding mesenchymal cells differentiate into chondroblasts and produce the fibrous cartilage of the *anulus fibrosus*.

The Development of the Vertebral Column

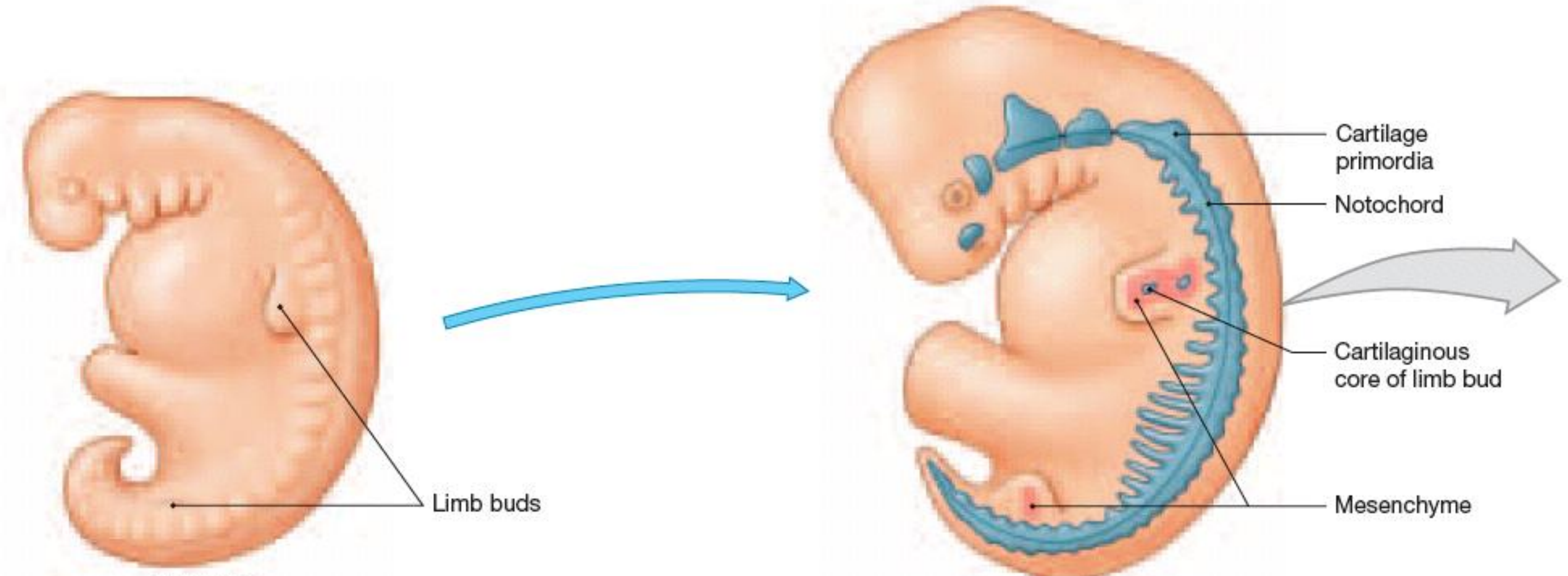
Embryology Summary



Rib cartilages expand away from the developing transverse processes of the vertebrae. At first they are continuous, but by week 8 the ribs have separated from the vertebrae. Ribs form at every vertebra, but in the cervical, lumbar, sacral, and coccygeal regions they remain small and later fuse with the growing vertebrae. The ribs of the thoracic vertebrae continue to enlarge, following the curvature of the body wall. When they reach the ventral midline, they fuse with the cartilages of the sternum.

The Development of the Vertebral Column

Embryology Summary



4 WEEKS

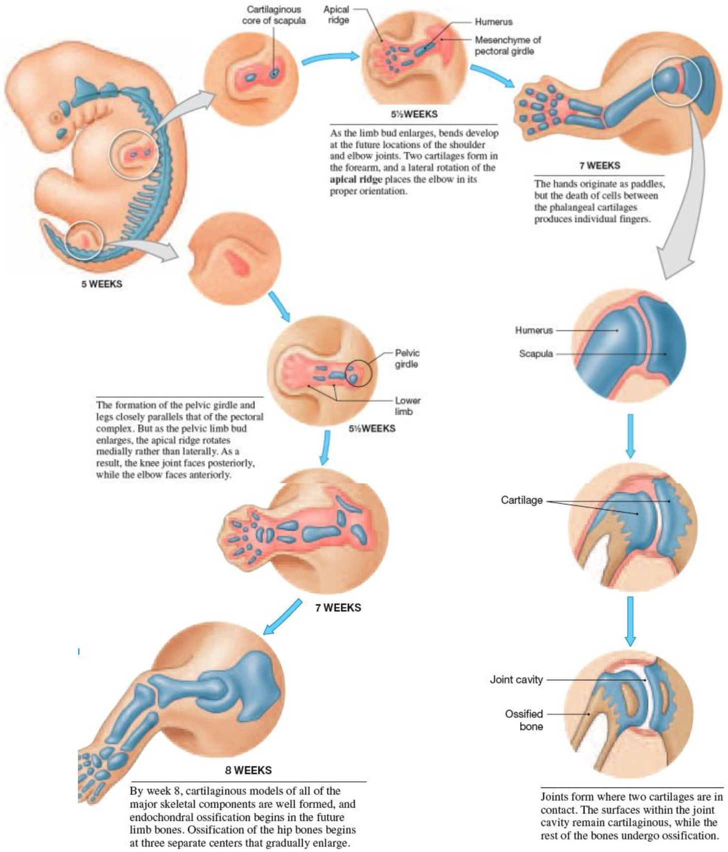
In the fourth week of development, ridges appear along the flanks of the embryo, extending from just behind the throat to just before the anus. These ridges form as mesodermal cells congregate beneath the ectoderm of the flank. Mesoderm gradually accumulates at the end of each ridge, forming two pairs of limb buds.

5 WEEKS

After 5 weeks of development, the pectoral limb buds have a cartilaginous core and scapular cartilages are developing in the mesenchyme of the trunk.

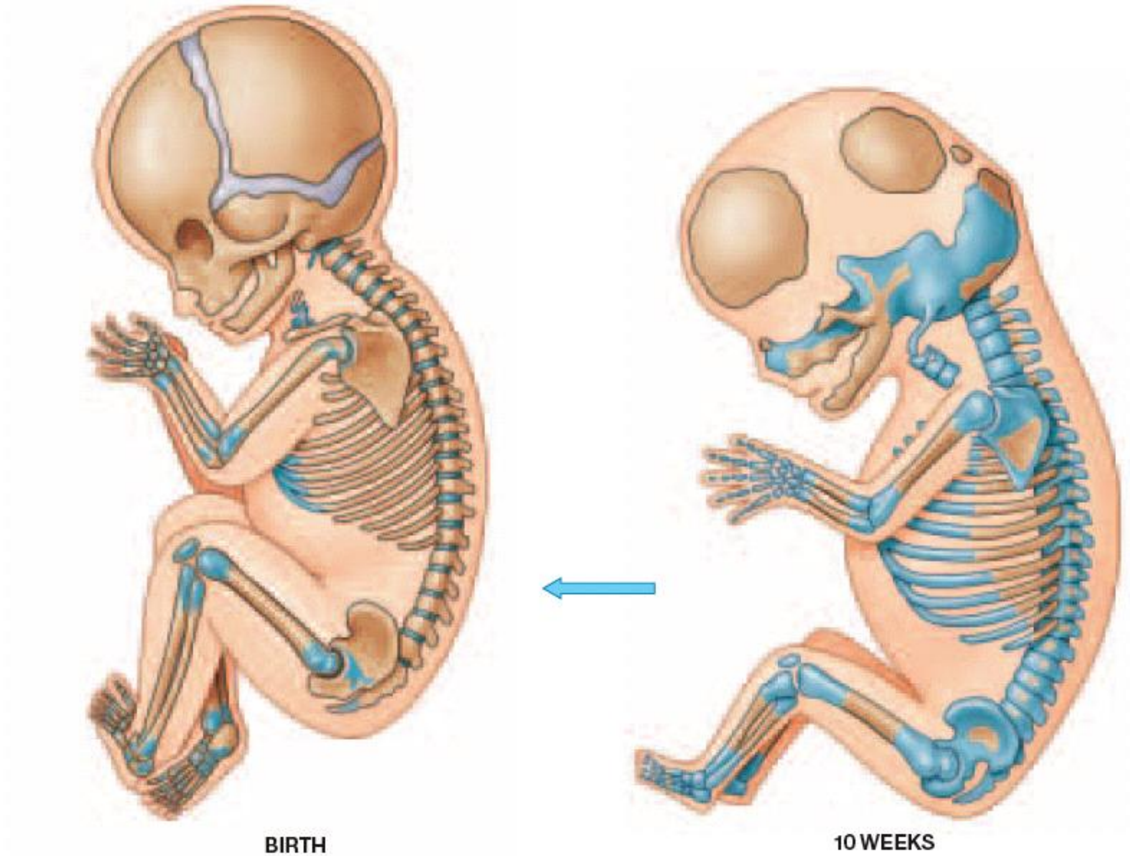
The Development of the Appendicular Skeleton

Embryology Summary



The Development of the Appendicular Skeleton

Embryology Summary

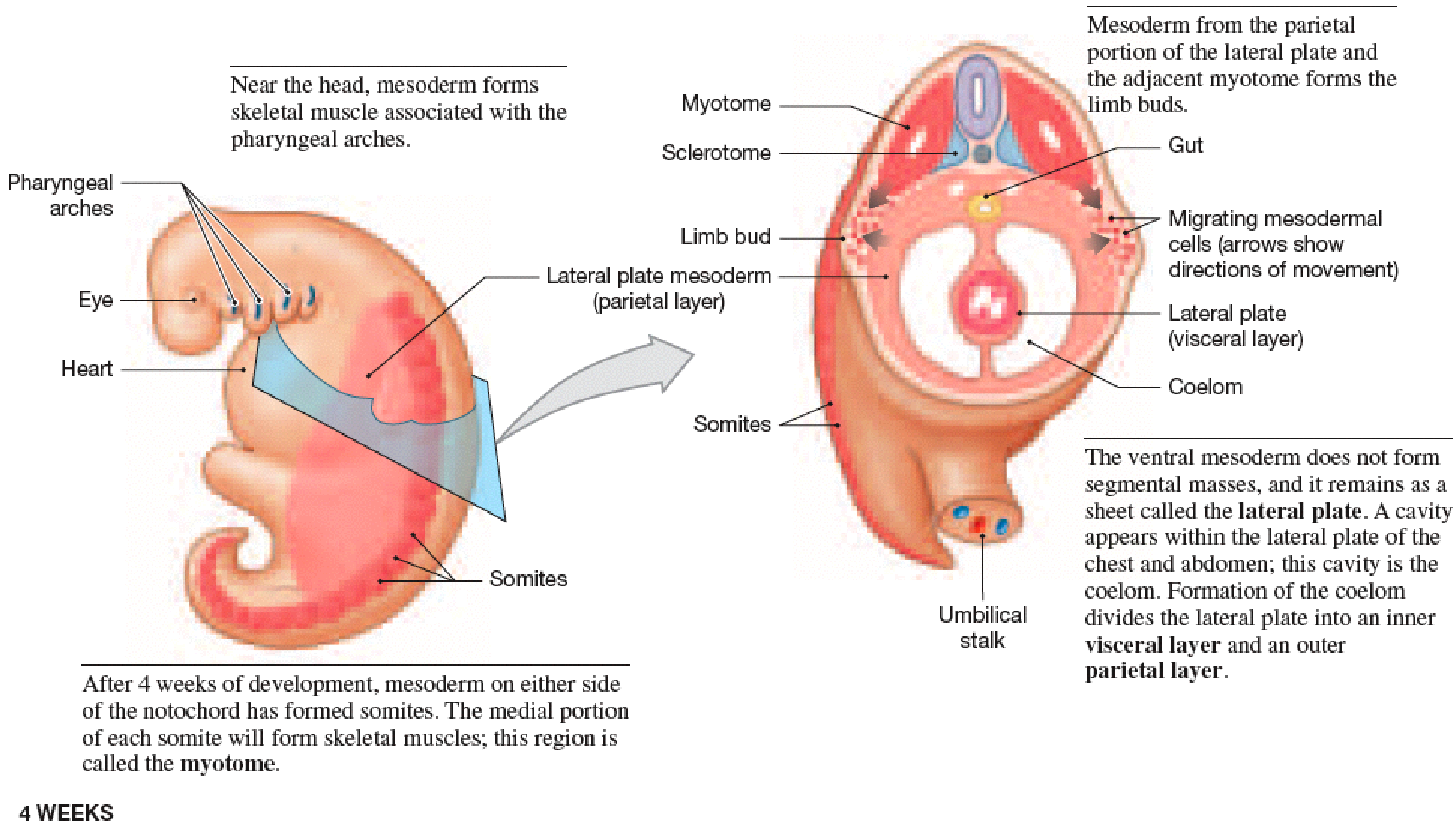


The skeleton of a newborn infant. Note the extensive areas of cartilage (blue) in the humeral head, in the wrist, between the bones of the palm and fingers, and in the hips. Notice the appearance of the axial skeleton, with reference to the two previous Embryology Summaries.

Ossification in the embryonic skeleton after approximately 10 weeks of development. The shafts of the limb bones are undergoing rapid ossification, but the distal bones of the carpus and tarsus remain cartilaginous.

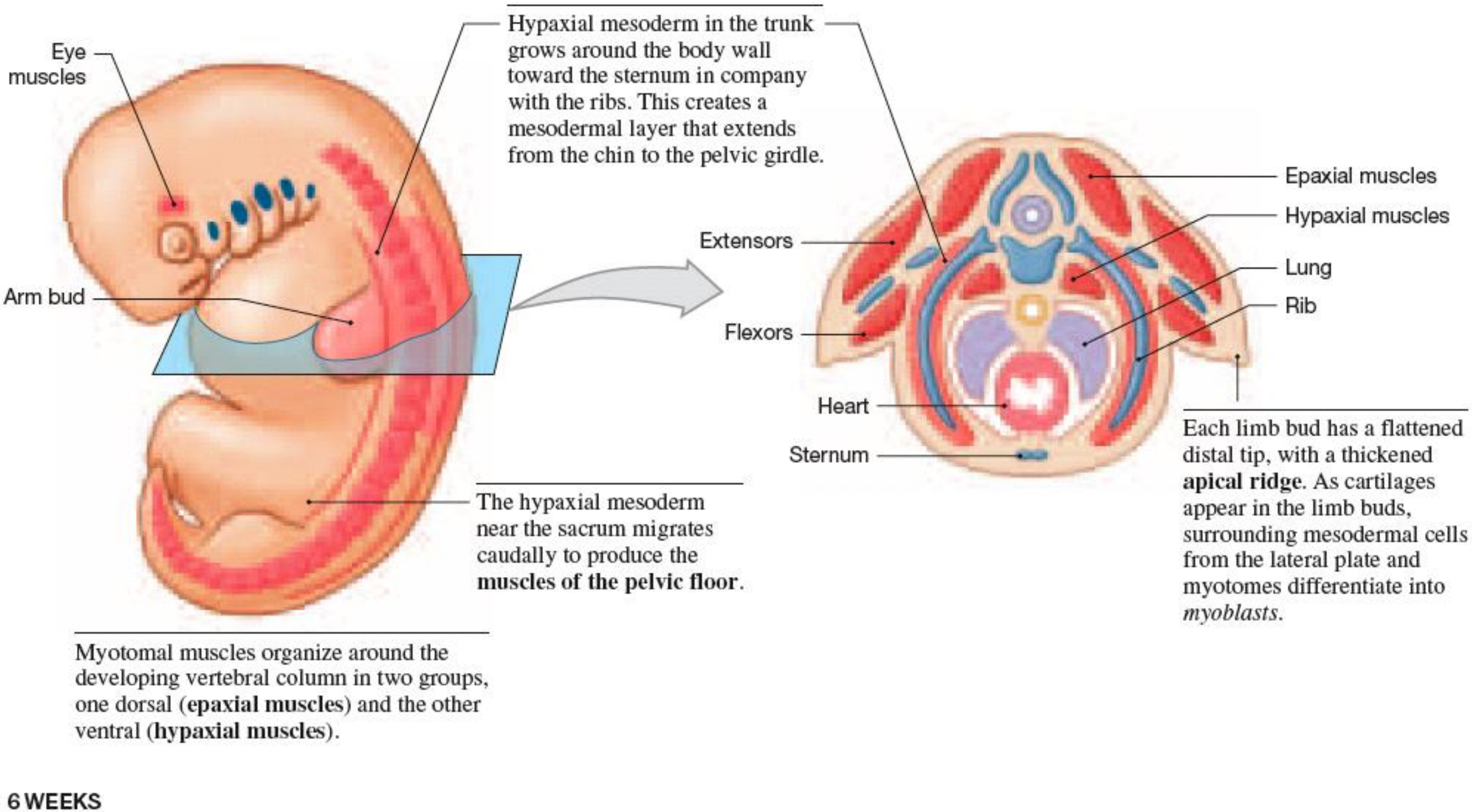
The Development of the Appendicular Skeleton

Embryology Summary



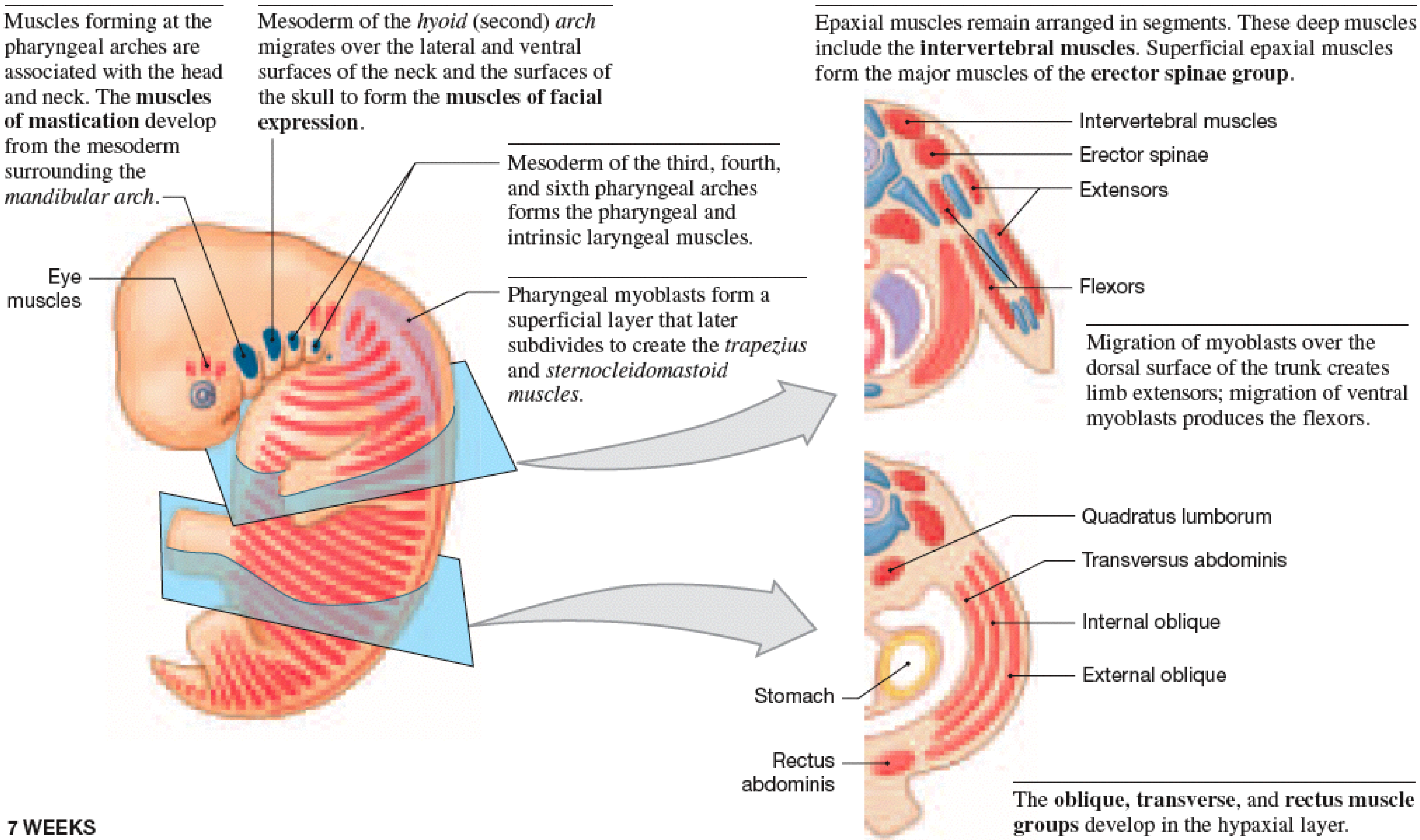
The Development of the Muscles

Embryology Summary



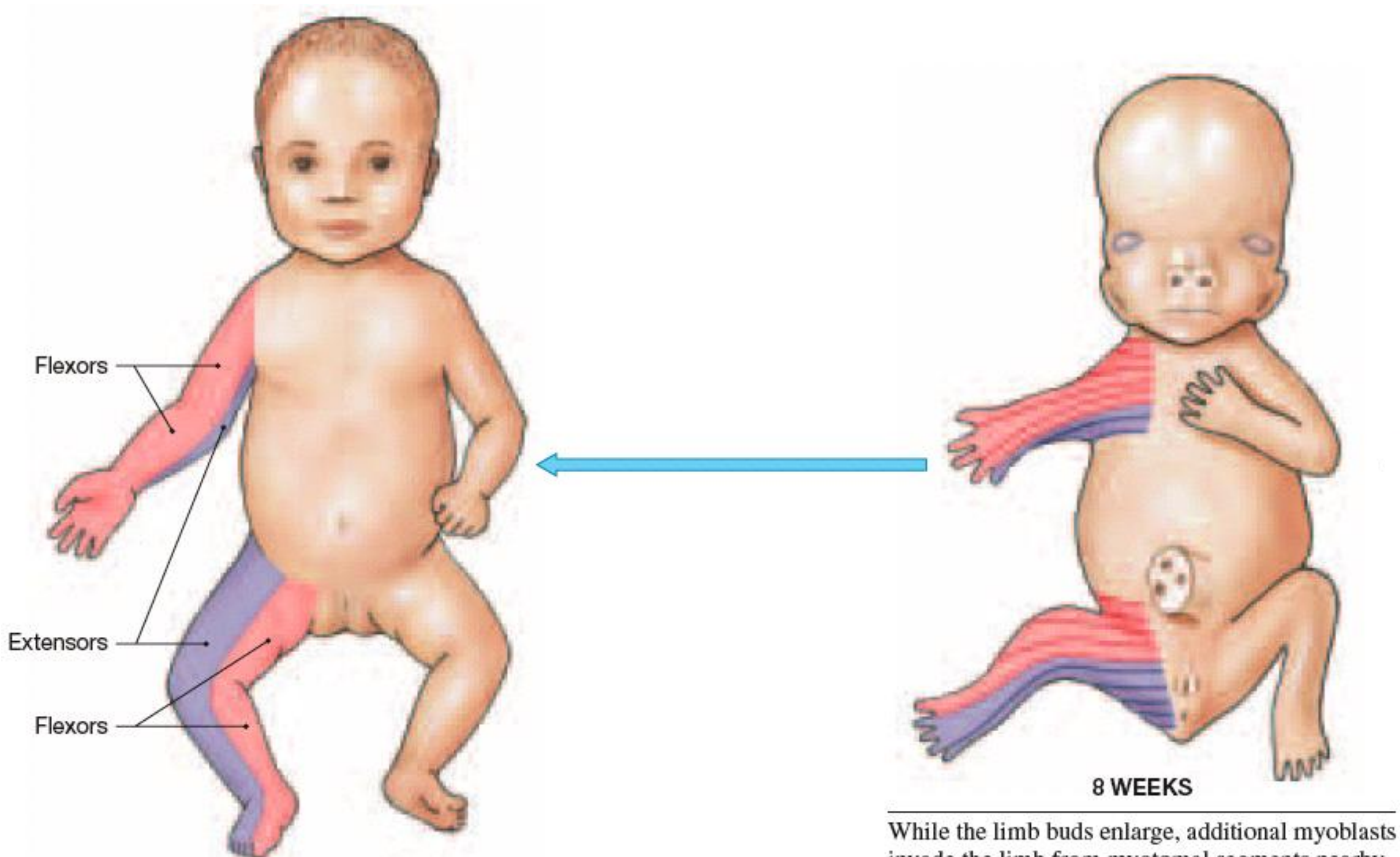
The Development of the Muscles

Embryology Summary



The Development of the Muscles

Embryology Summary



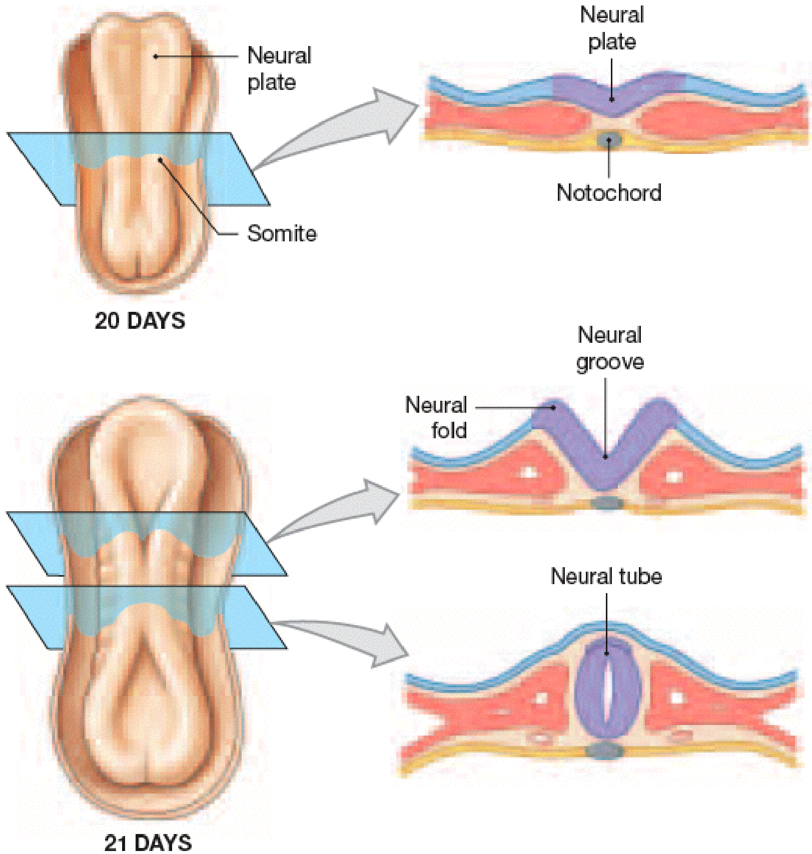
BIRTH

Rotation of the arm and leg buds produces a change in the position of these masses relative to the body axis.

While the limb buds enlarge, additional myoblasts invade the limb from myotomal segments nearby. Lines indicate the boundaries between myotomes providing myoblasts to the limb.

The Development of the Muscles

Embryology Summary



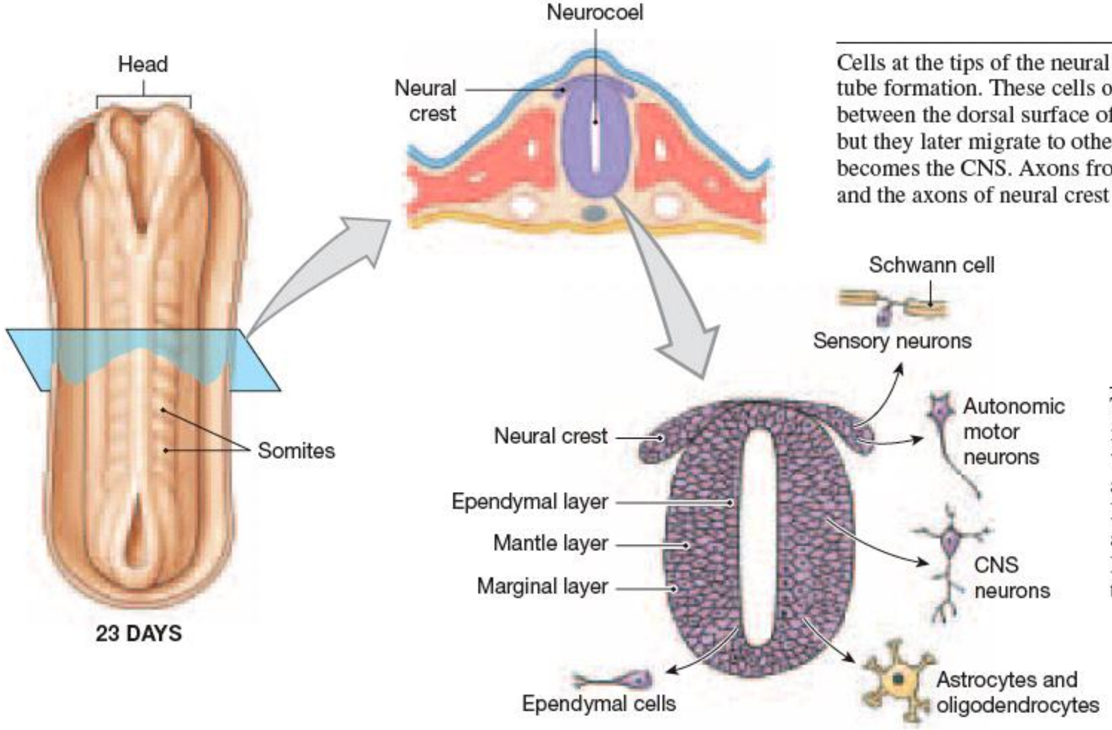
After two weeks of development, *somites* are appearing on either side of the *notochord*. The ectoderm near the midline thickens, forming an elevated neural plate. The **neural plate** is largest near the future head of the developing embryo.

A crease develops along the axis of the neural plate, creating the **neural groove**. The edges, or **neural folds**, gradually move together. They first contact one another midway along the axis of the neural plate, near the end of the third week.

Where the neural folds meet, they fuse to form a cylindrical **neural tube** that loses its connection with the superficial ectoderm. The process of neural tube formation is called **neurulation**; it is completed in less than a week. The formation of the axial skeleton and that of the musculature around the developing neural tube were described on pages 768 and 773.

The Development of the Nervous System

Embryology Summary



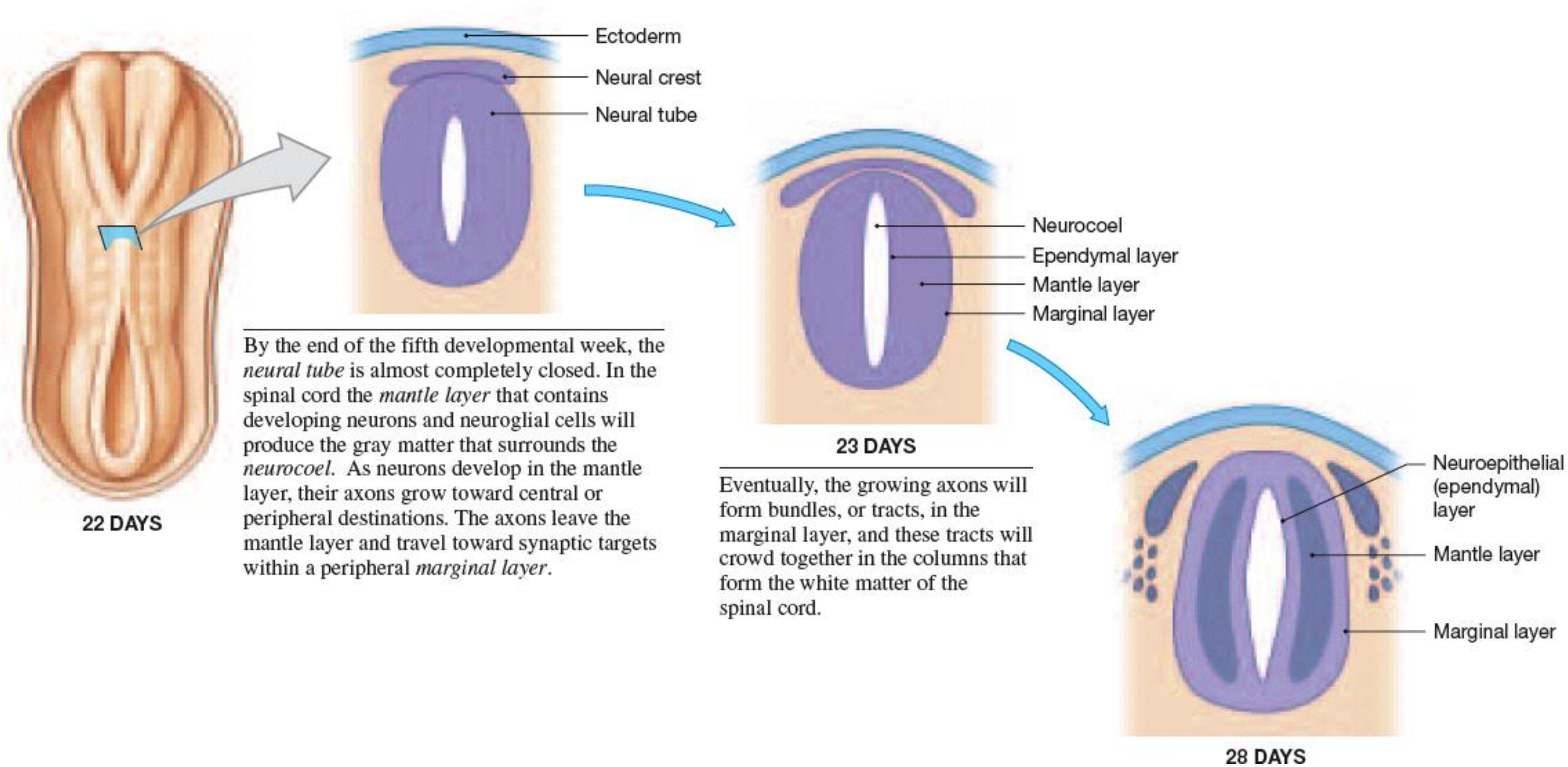
Cells at the tips of the neural folds do not participate in neural tube formation. These cells of the **neural crest** at first remain between the dorsal surface of the neural tube and the ectoderm, but they later migrate to other locations. The neural tube becomes the CNS. Axons from neurons within the neural tube and the axons of neural crest cells form the PNS.

The first cells to appear in the mantle differentiate into neurons, while the last cells to arrive become astrocytes and oligodendrocytes. Further development of the CNS and PNS will be found in the Embryology Summaries later in this chapter.

The neural tube increases in thickness as its epithelial lining undergoes repeated mitoses. By the middle of the fifth developmental week, there are three distinct layers. The **ependymal layer** lines the enclosed cavity, or **neurocoel**. The ependymal cells continue their mitotic activities, and daughter cells create the surrounding **mantle layer**. Axons from developing neurons form a superficial **marginal layer**.

The Development of the Nervous System

Embryology Summary



By the end of the fifth developmental week, the *neural tube* is almost completely closed. In the spinal cord the *mantle layer* that contains developing neurons and neuroglial cells will produce the gray matter that surrounds the *neurocoel*. As neurons develop in the mantle layer, their axons grow toward central or peripheral destinations. The axons leave the mantle layer and travel toward synaptic targets within a peripheral *marginal layer*.

Eventually, the growing axons will form bundles, or tracts, in the marginal layer, and these tracts will crowd together in the columns that form the white matter of the spinal cord.

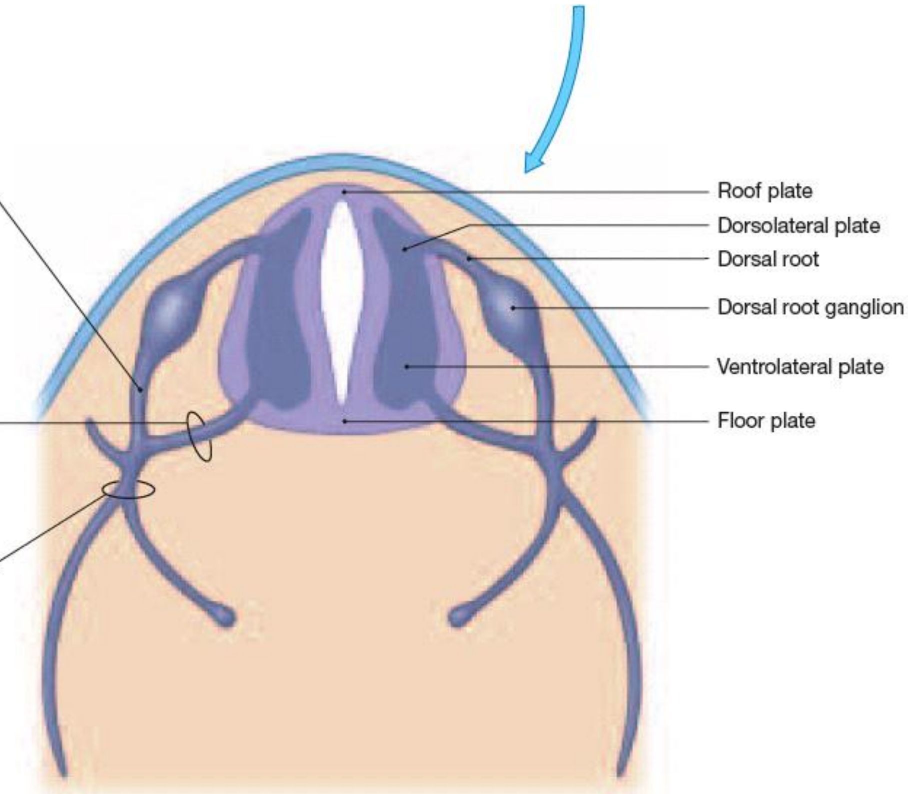
The Development of the Spinal Cord, Part I

Embryology Summary

By this time, cells of the *neural crest* have migrated to either side of the spinal cord and have formed the dorsal root ganglia. The neural crest cells become sensory neurons and glial cells (Schwann cells and satellite cells). Processes from these sensory neurons grow both into the periphery, to contact receptors, and into the CNS via the dorsal roots.

In each segment the axons of developing motor neurons form a pair of ventral roots that grow away from the spinal cord.

Distal to each dorsal root ganglion, the motor efferents of the ventral root and the sensory afferents of the dorsal root are bound together into a single spinal nerve. Along much of the spinal cord, these nerves share a stereotyped pattern of peripheral branches, and the pattern accounts for the distribution of dermatomes.



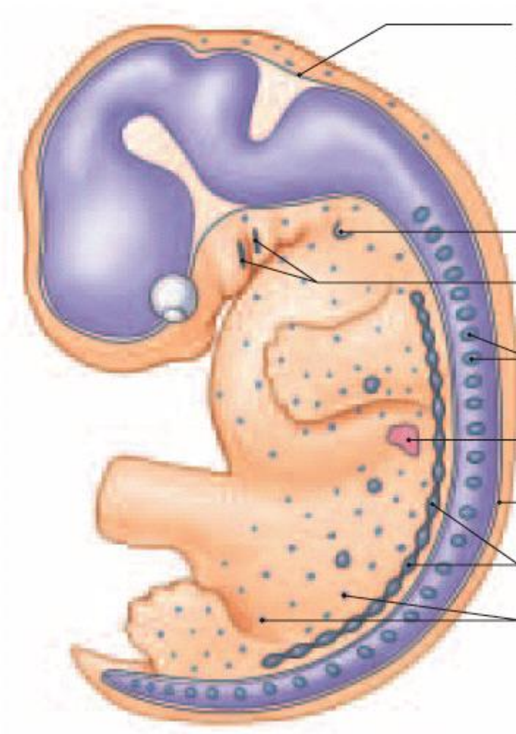
7 WEEKS

As the mantle enlarges, the neurocoel becomes laterally compressed and relatively narrow. The relatively thin **roof plate** and **floor plate** will not thicken substantially, but the **dorsolateral** and **ventrolateral plates** enlarge rapidly. Neurons developing within the dorsolateral plate will receive and relay sensory information, while those in the ventrolateral region will develop into motor neurons.

The Development of the Spinal Cord, Part I

Embryology Summary

In addition to forming dorsal root ganglia and associated glial cells, neural crest cells migrate around the central nervous system and develop into the spinal and cranial meninges.



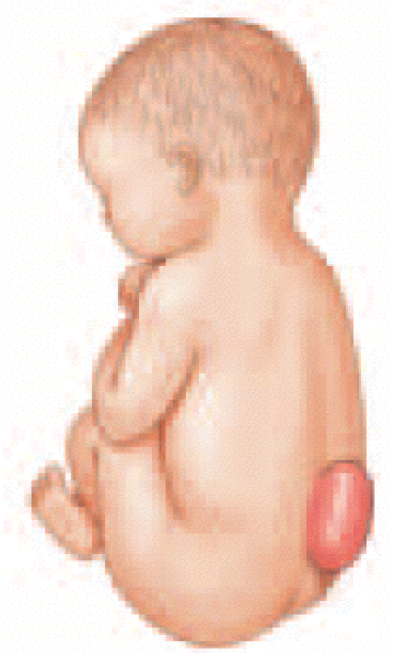
7 WEEKS
(Distribution of neural crest cells)

Neural crest cells aggregate to form autonomic ganglia near the vertebral column and in peripheral organs. Migrating neural crest cells contribute to the formation of teeth and form the laryngeal cartilages, melanocytes of the skin, the skull, connective tissues around the eye, the intrinsic muscles of the eye, Schwann cells, satellite cells, and the suprarenal medullae.

The Development of the Spinal Cord, Part II

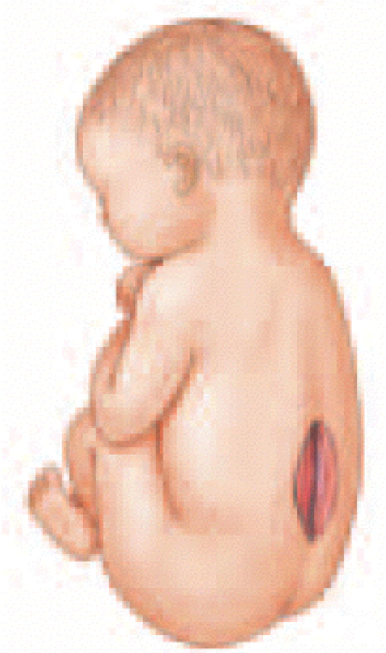
Embryology Summary

DEVELOPMENTAL ABNORMALITIES



Spina bifida

Spina bifida (BI-fi-da) results when the developing vertebral laminae fail to unite due to abnormal neural tube formation at that site. The neural arch is incomplete, and the meninges bulge outward beneath the skin of the back. The extent of the abnormality determines the severity of the defects. In mild cases, the condition may pass unnoticed; extreme cases involve much of the length of the vertebral column.



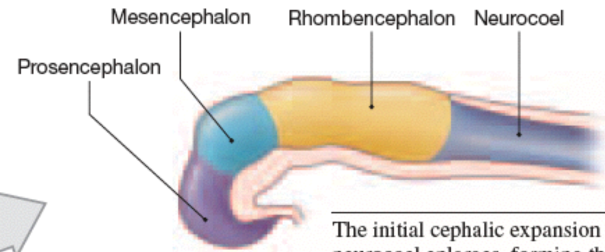
Neural tube defect

A **neural tube defect** (NTD) is a condition that is secondary to a developmental error in the formation of the spinal cord. Instead of forming a hollow tube, a portion of the spinal cord develops as a broad plate. This is often associated with spina bifida. Neural tube defects affect roughly one individual in 1000; prenatal testing can detect the existence of these defects with an 80–85 percent success rate.

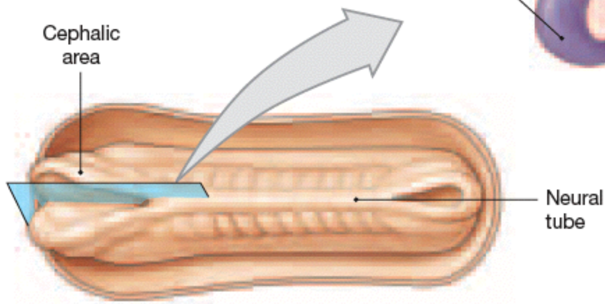
The Development of the Spinal Cord, Part II

Embryology Summary

Before proceeding, briefly review the summaries of skull formation, vertebral column development, and development of the spinal cord in the previous Embryology Summaries.



The initial cephalic expansion occurs as the neurocoel enlarges, forming three distinct **brain vesicles**: (1) the **prosencephalon** (prōs-en-SEF-a-lon) or "forebrain," (2) the **mesencephalon** or "midbrain," and (3) the **rhombencephalon** (rom-ben-SEF-a-lon) or "hindbrain." The prosencephalon and rhombencephalon will be subdivided further as development proceeds.

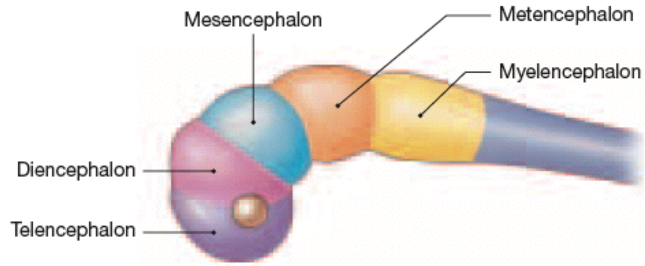


Even before **neural tube** formation has been completed, the cephalic portion begins to enlarge. Major differences in brain versus spinal cord development include (1) early breakdown of mantle (gray matter) and marginal (white matter) organization; (2) appearance of areas of neural cortex; (3) differential growth between and within specific regions; (4) appearance of characteristic bends and folds; and (5) loss of obvious segmental organization.

23 DAYS

The Development of the Brain, Part I

Embryology Summary

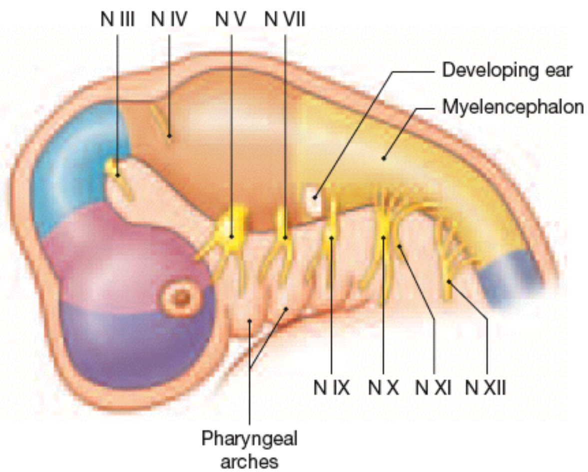


The rhombencephalon first subdivides into the **metencephalon** (met-en-SEF-a-lon; *meta*, after) and the **myelencephalon** (mī-el-en-SEF-a-lon; *myelon*, spinal cord).

The prosencephalon forms the **telecephalon** (tel-en-SEF-a-lon; *telos*, end + *enkephalos*, brain) and the **diencephalon**. The telencephalon begins as a pair of swellings near the rostral, dorsolateral border of the prosencephalon.

4 WEEKS

Cranial nerves develop as sensory ganglia and link peripheral receptors with the brain, and motor fibers grow out of developing cranial nuclei. Special sensory neurons of cranial nerves I, II, and VIII develop in association with the developing receptors. The somatic motor nerves III, IV, and VI grow to the eye muscles; the mixed nerves (V, VII, IX, and X) innervate the **pharyngeal arches** (page 766).



Development of the **mesencephalon** produces a small mass of neural tissue with a constricted neurocoel, the *aqueduct of the midbrain*.

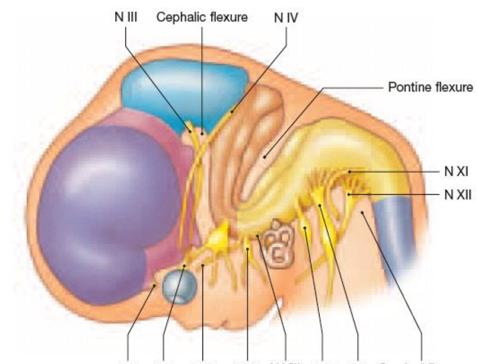
As differential growth proceeds and the position and orientation of the embryo change, a series of bends, or **flexures** (FLEK-sherz), appears along the axis of the developing brain.

5 WEEKS

The Development of the Brain, Part I

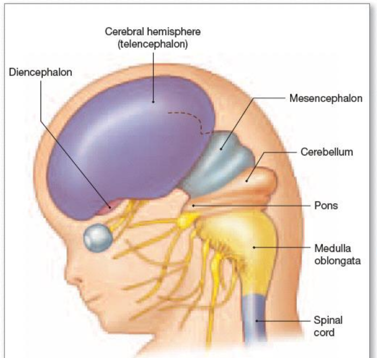
Embryology Summary

The roofs of the diencephalon and myelencephalon fail to develop, leaving a thin ependymal layer in contact with the developing meninges. Blood vessels invading these regions create areas of the **choroid plexus.**



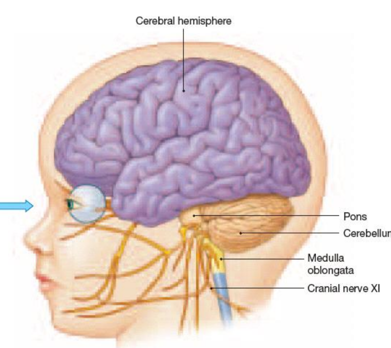
As growth continues and the pontine flexure develops, the brain becomes more compact. The expanding cerebral hemispheres now dominate the superior and lateral surfaces of the brain. Migrating neuroblasts create the cerebral cortex, and underlying masses of gray matter develop into the basal nuclei.

8 WEEKS



After 11 weeks, the expanding cerebral hemispheres have overgrown the diencephalon. At the metencephalon, cortical formation and expansion produce the cerebellum, which overlies the nuclei and tracts of the pons.

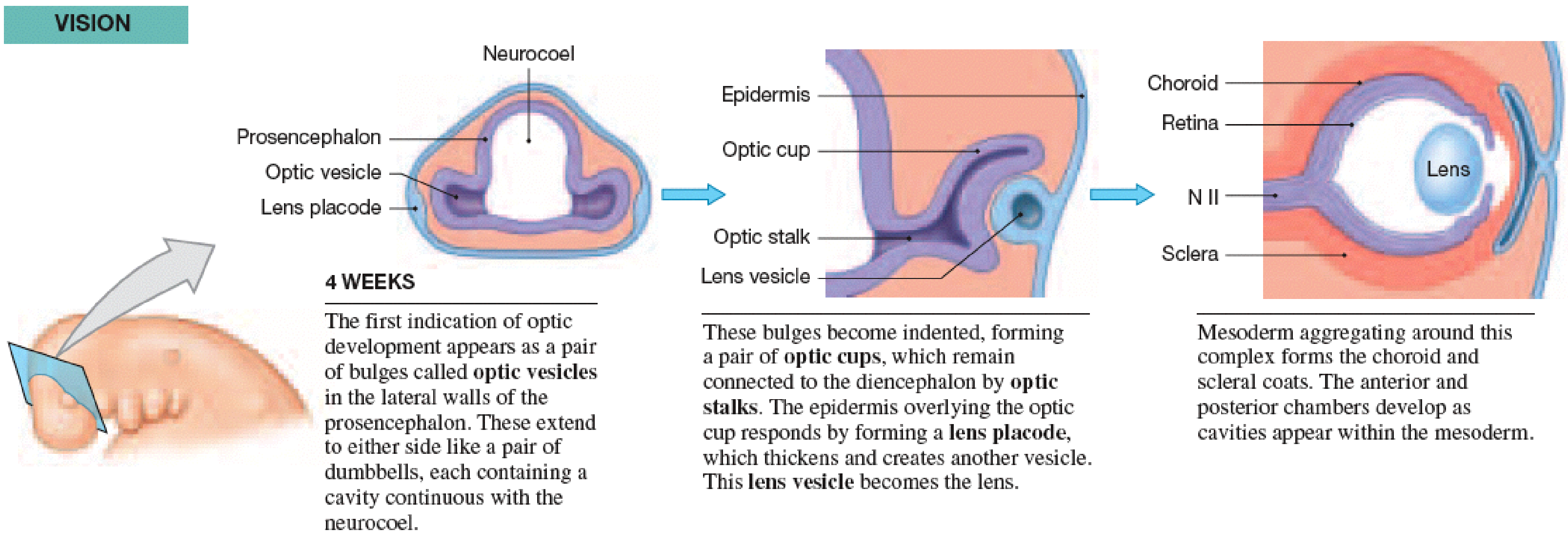
11 WEEKS



CHILD

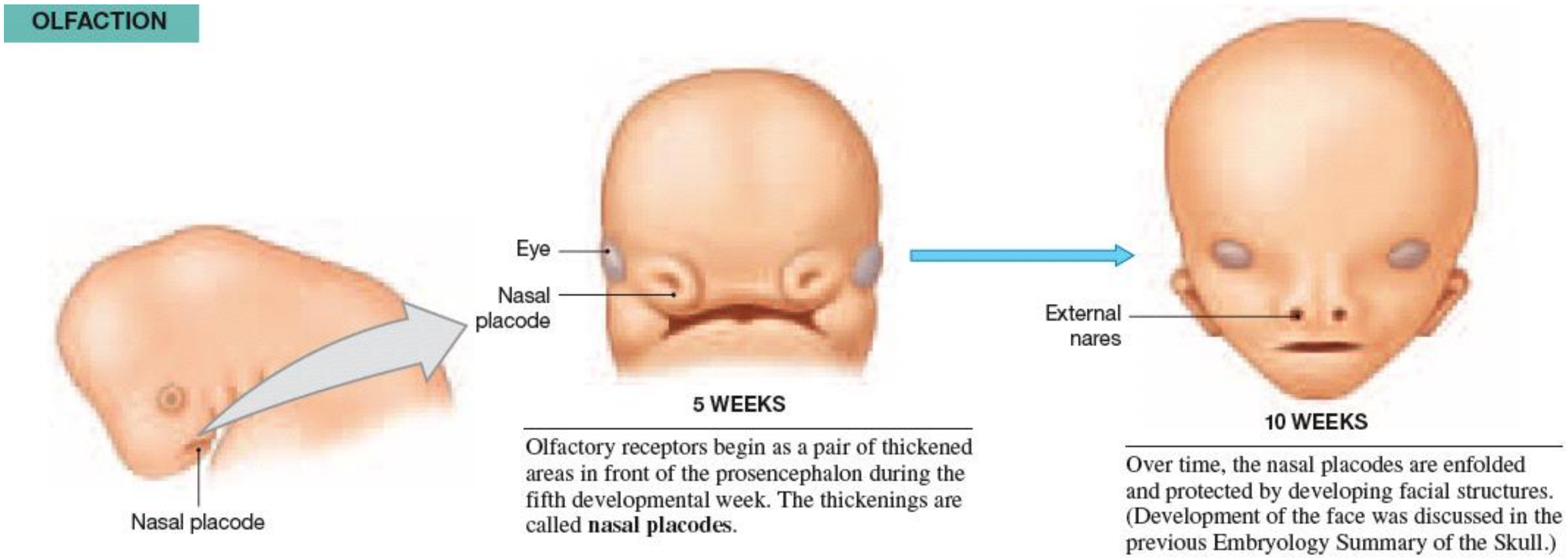
The Development of the Brain, Part II

Embryology Summary



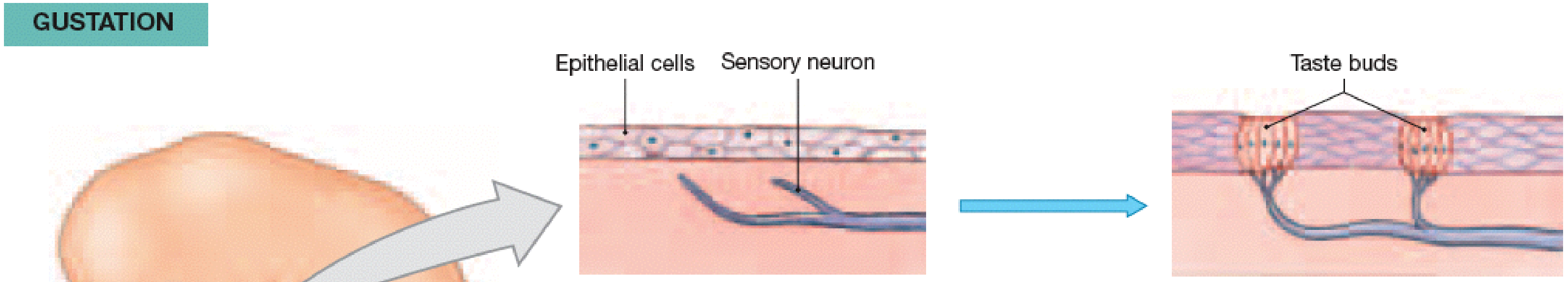
The Development of Special Sense Organs, Part I

Embryology Summary



The Development of Special Sense Organs, Part I

Embryology Summary

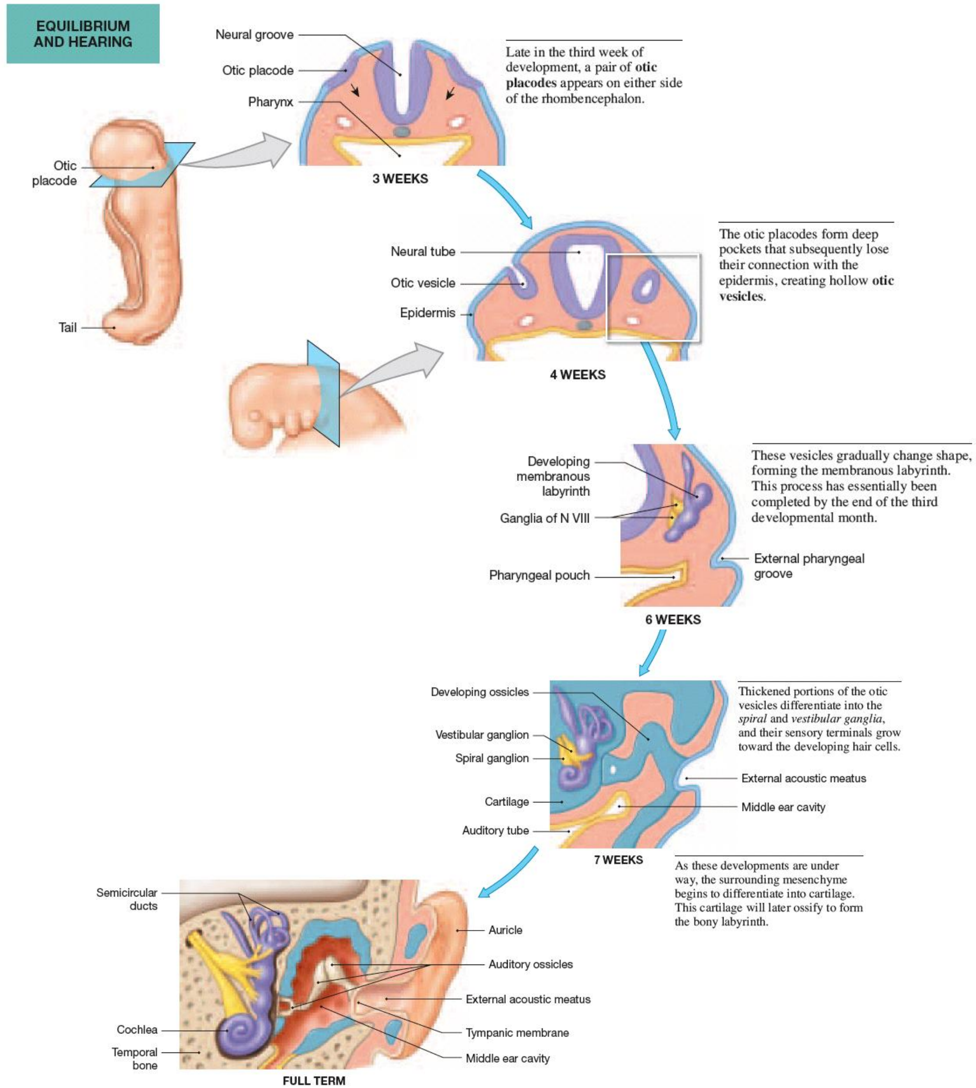


Gustatory receptors are the least specialized of any of the special sense organs. Taste buds develop as sensory fibers grow into the developing mouth and pharynx.

When the nerve endings contact epithelial cells, the epithelial cells differentiate into gustatory cells. If the sensory nerves are cut, the taste buds degenerate; if the sensory nerve is moved, it will stimulate the development of new taste buds at its new location.

The Development of Special Sense Organs, Part I

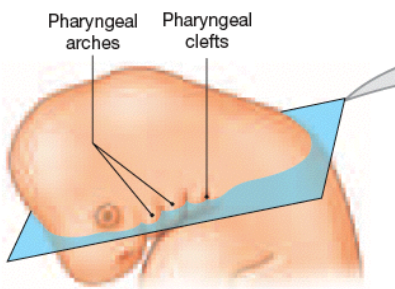
Embryology Summary



The Development of Special Sense Organs, Part II

Embryology Summary

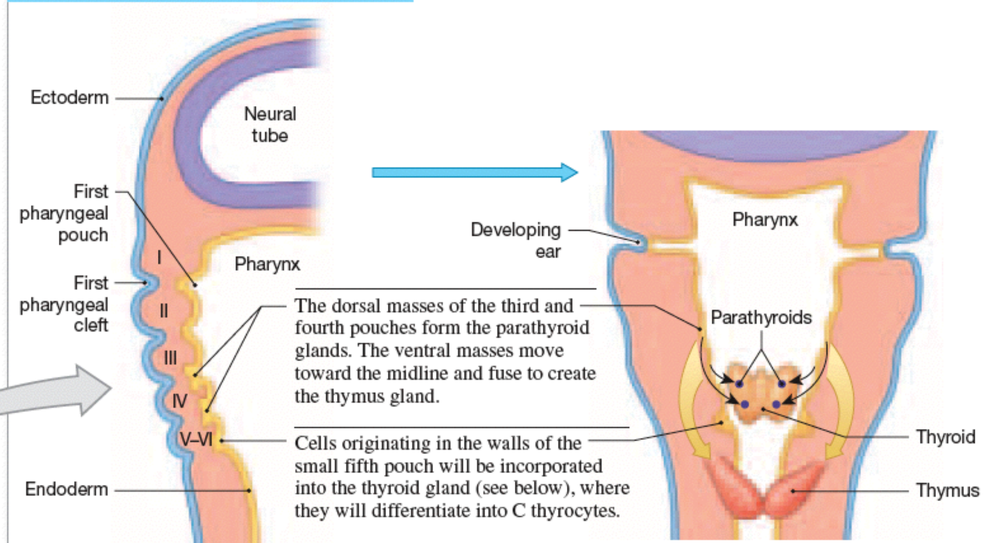
As noted in Chapter 3, all secretory glands, whether exocrine or endocrine, are derived from epithelia. Endocrine organs develop from epithelia (1) covering the outside of the embryo, (2) lining the digestive tract, and (3) lining the coelomic cavity.



WEEK 5

The pharyngeal region of the embryo plays a particularly important role in endocrine development. After 4–5 weeks of development, the *pharyngeal arches* are well formed. Human embryos develop five or six pharyngeal arches, not all visible from the exterior. (Arch 5 may not appear or may form and degenerate almost immediately.) The five major arches (I–IV, VI) are separated by *pharyngeal clefts*, deep ectodermal grooves.

PARATHYROID GLANDS AND THYMUS



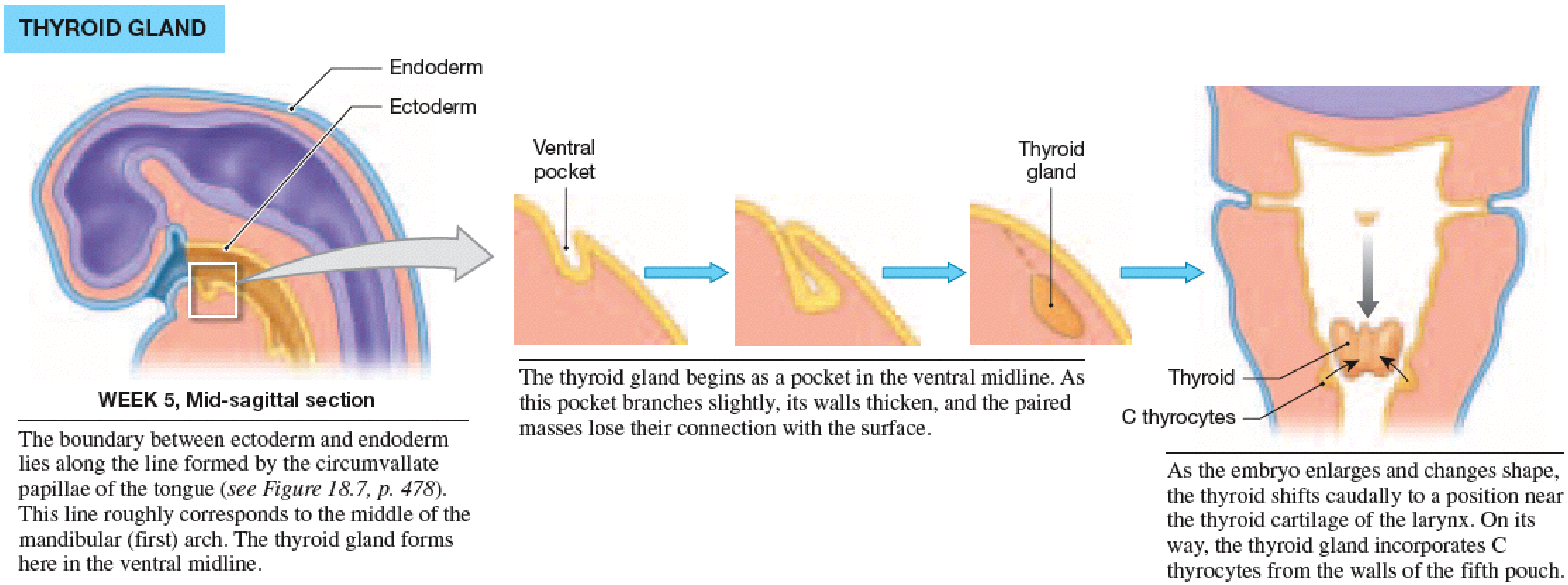
The dorsal masses of the third and fourth pouches form the parathyroid glands. The ventral masses move toward the midline and fuse to create the thymus gland.

Cells originating in the walls of the small fifth pouch will be incorporated into the thyroid gland (see below), where they will differentiate into C thyrocytes.

In sectional view, five **pharyngeal pouches** extend laterally toward the pharyngeal clefts. The first pouch lies caudal to the first (mandibular) arch. Pharyngeal pouches 5 and 6 are very small and are interconnected. Endoderm lining the third, fourth, and fifth pairs of pharyngeal pouches forms dorsal and ventral masses of cells that migrate beneath the endodermal epithelium.

The Development of the Endocrine System, Part I

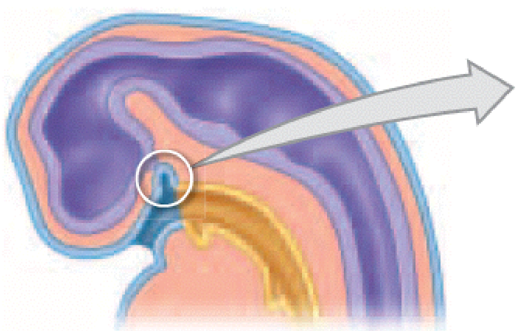
Embryology Summary



The Development of the Endocrine System, Part I

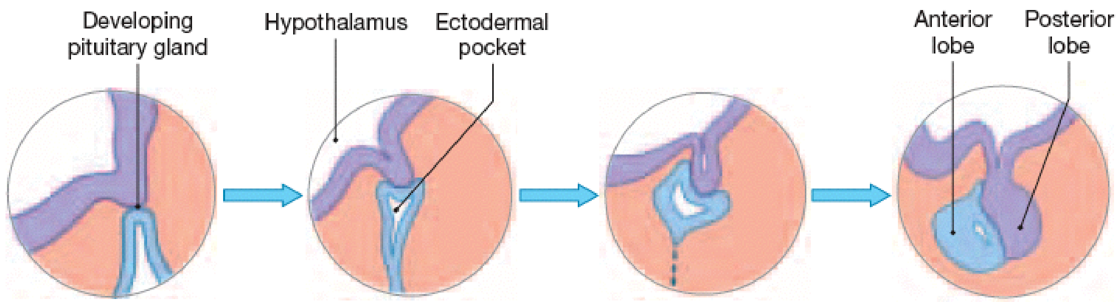
Embryology Summary

PITUITARY GLAND



WEEK 5, Mid-sagittal section

The pituitary gland forms in the dorsal midline above the forming thyroid gland.

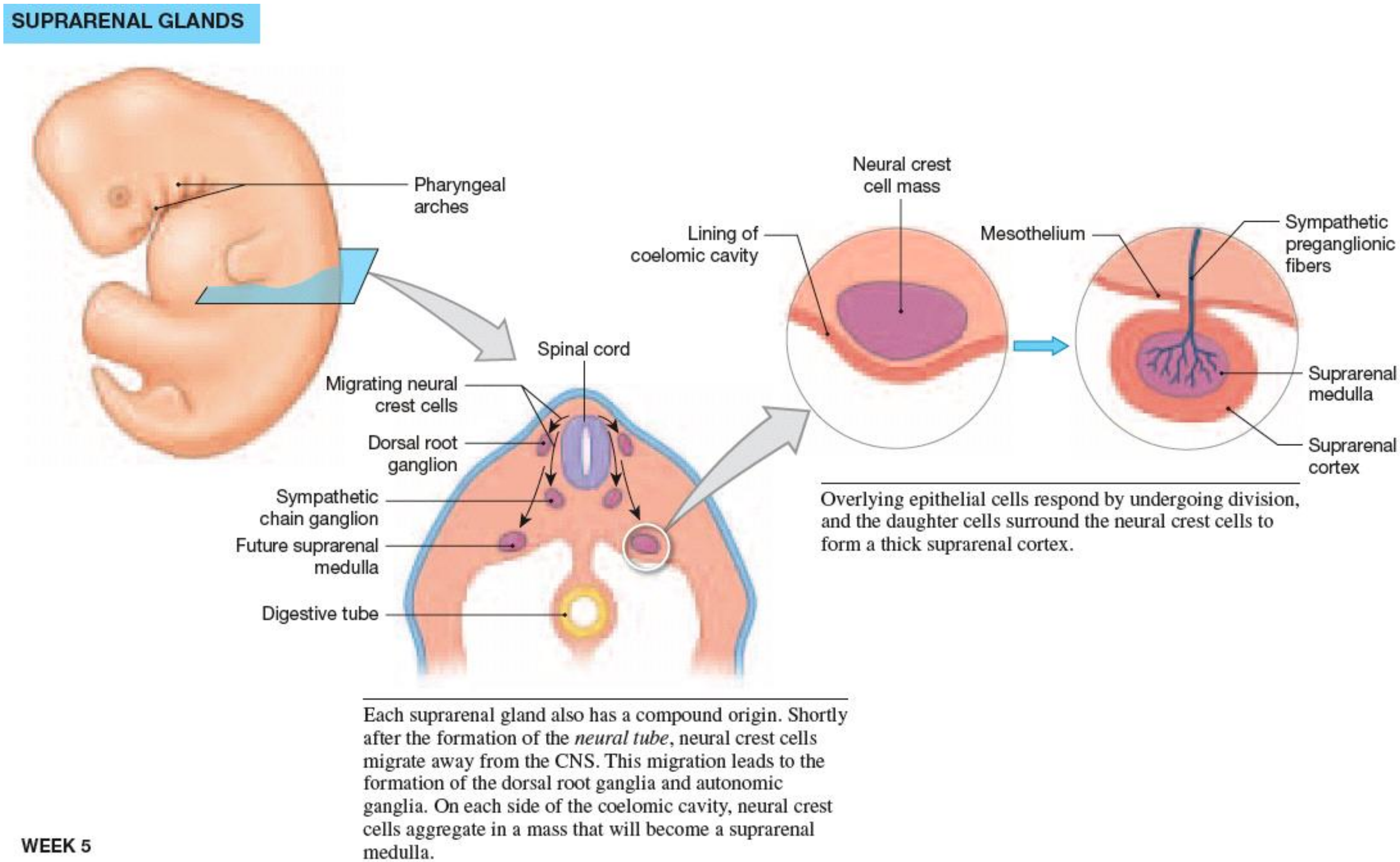


The pituitary gland has a compound origin. The first step is the formation of an ectodermal pocket in the dorsal midline of the pharynx. This pocket loses its connection to the pharynx, creating a hollow ball of cells that lies inferior to the floor of the diencephalon posterior to the optic chiasm.

As these cells undergo division, the central chamber gradually disappears. This endocrine mass will become the adenohypophysis (anterior lobe) of the pituitary gland. The neurohypophysis (posterior lobe) of the pituitary gland begins as a depression in the hypothalamic floor and grows toward the developing adenohypophysis.

The Development of the Endocrine System, Part II

Embryology Summary

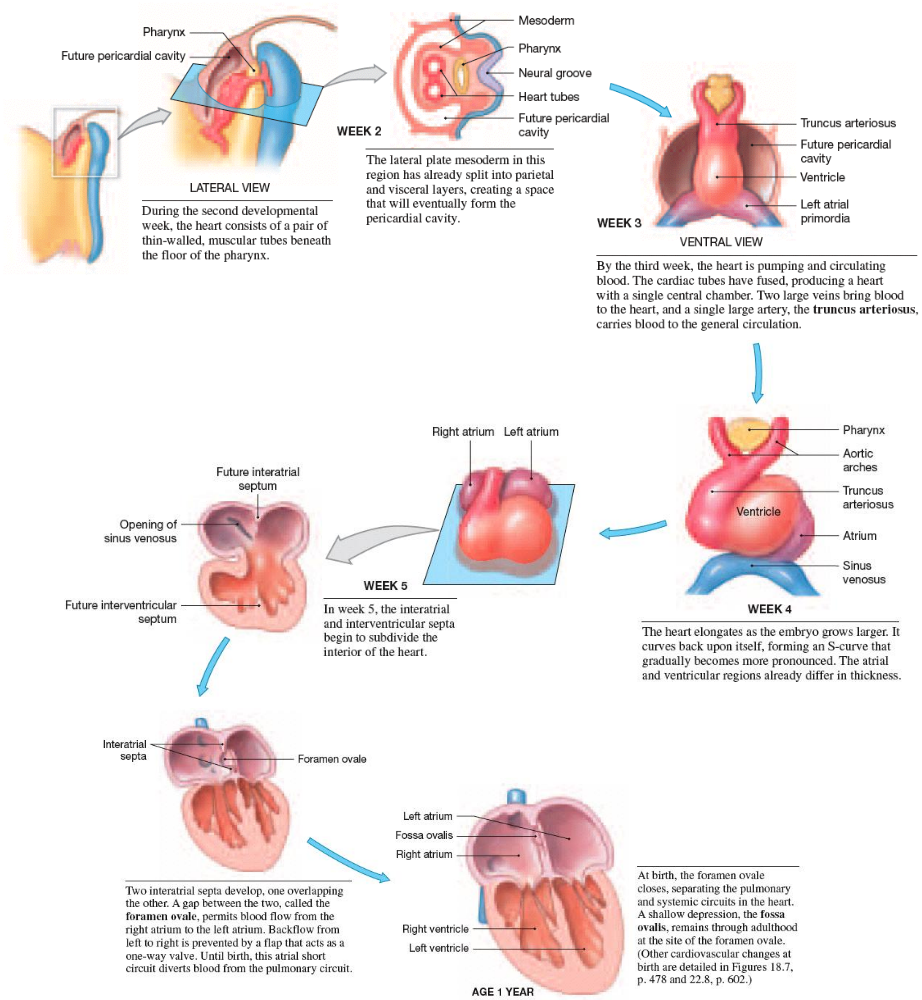


Overlying epithelial cells respond by undergoing division, and the daughter cells surround the neural crest cells to form a thick suprarenal cortex.

Each suprarenal gland also has a compound origin. Shortly after the formation of the *neural tube*, neural crest cells migrate away from the CNS. This migration leads to the formation of the dorsal root ganglia and autonomic ganglia. On each side of the coelomic cavity, neural crest cells aggregate in a mass that will become a suprarenal medulla.

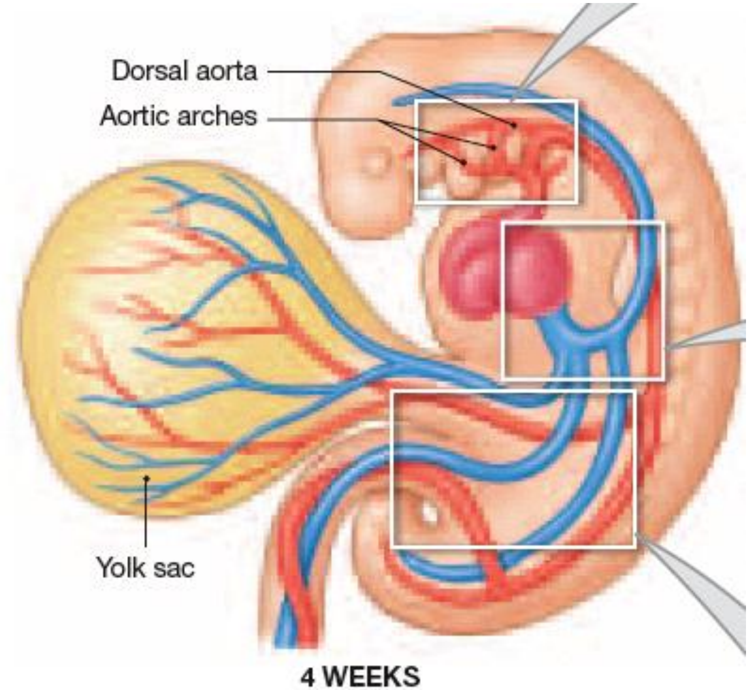
The Development of the Endocrine System, Part II

Embryology Summary



The Development of the Heart

Embryology Summary



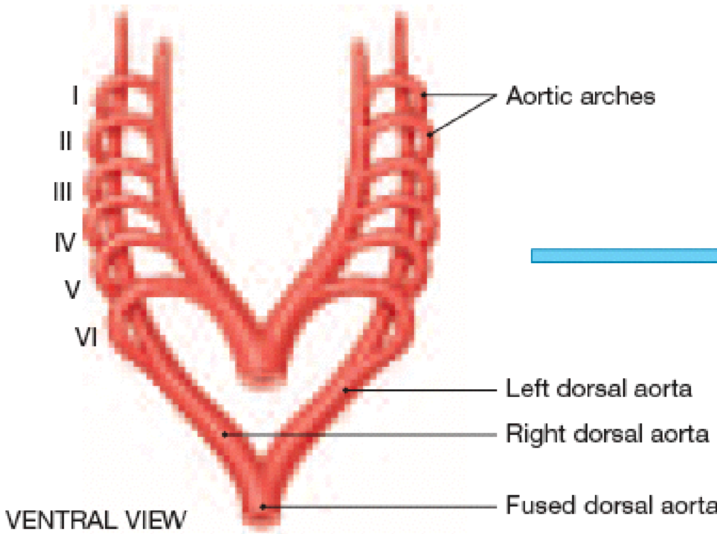
We will follow the development of three major vessel complexes: the aortic arch, the venae cavae, and the hepatic portal and umbilical systems. (Arteries are shown in red and veins in blue regardless of the oxygenation of the blood they carry.)

The Development of the Cardiovascular System

Embryology Summary

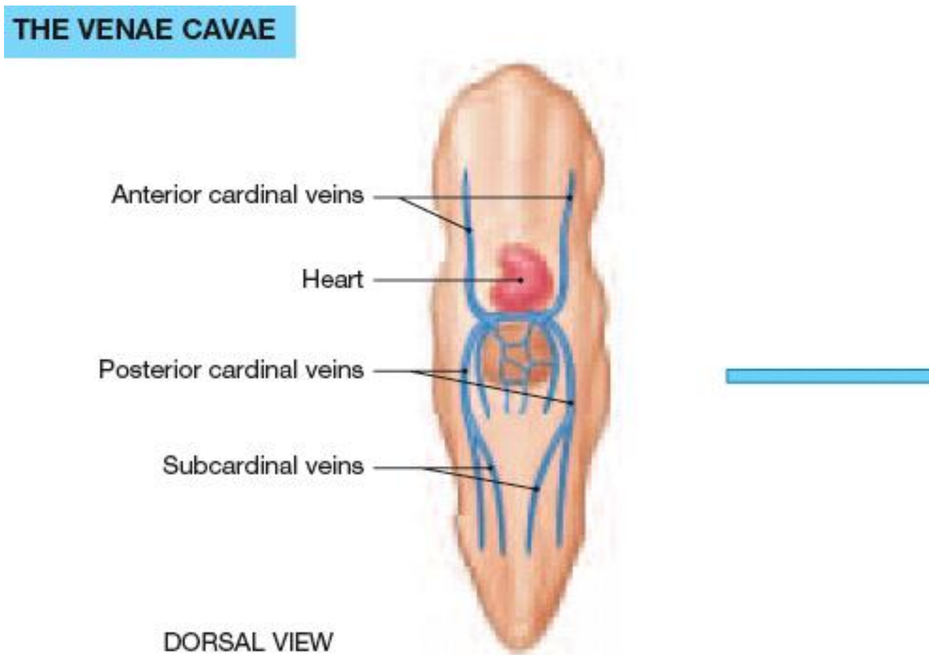
THE AORTIC ARCHES

An **aortic arch** carries arterial blood through each of the *pharyngeal arches*. In the dorsal pharyngeal wall, these vessels fuse to create the **dorsal aorta**, which distributes blood throughout the body. The arches are usually numbered from I to VI, corresponding to the pharyngeal arches.



The Development of the Cardiovascular System

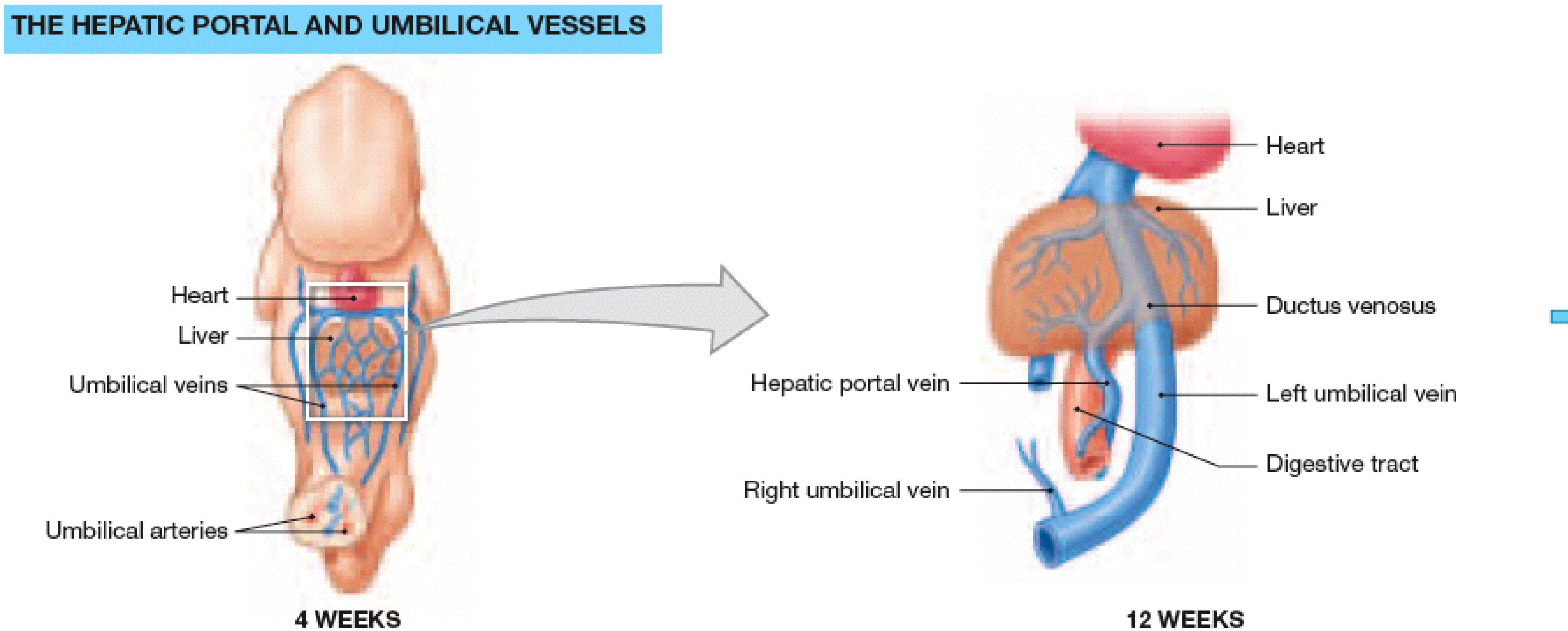
Embryology Summary



The early venous circulation draining the tissues of the body wall, limbs, and head centers around the paired **anterior cardinal veins, posterior cardinal veins**, and **subcardinal veins**.

The Development of the Cardiovascular System

Embryology Summary

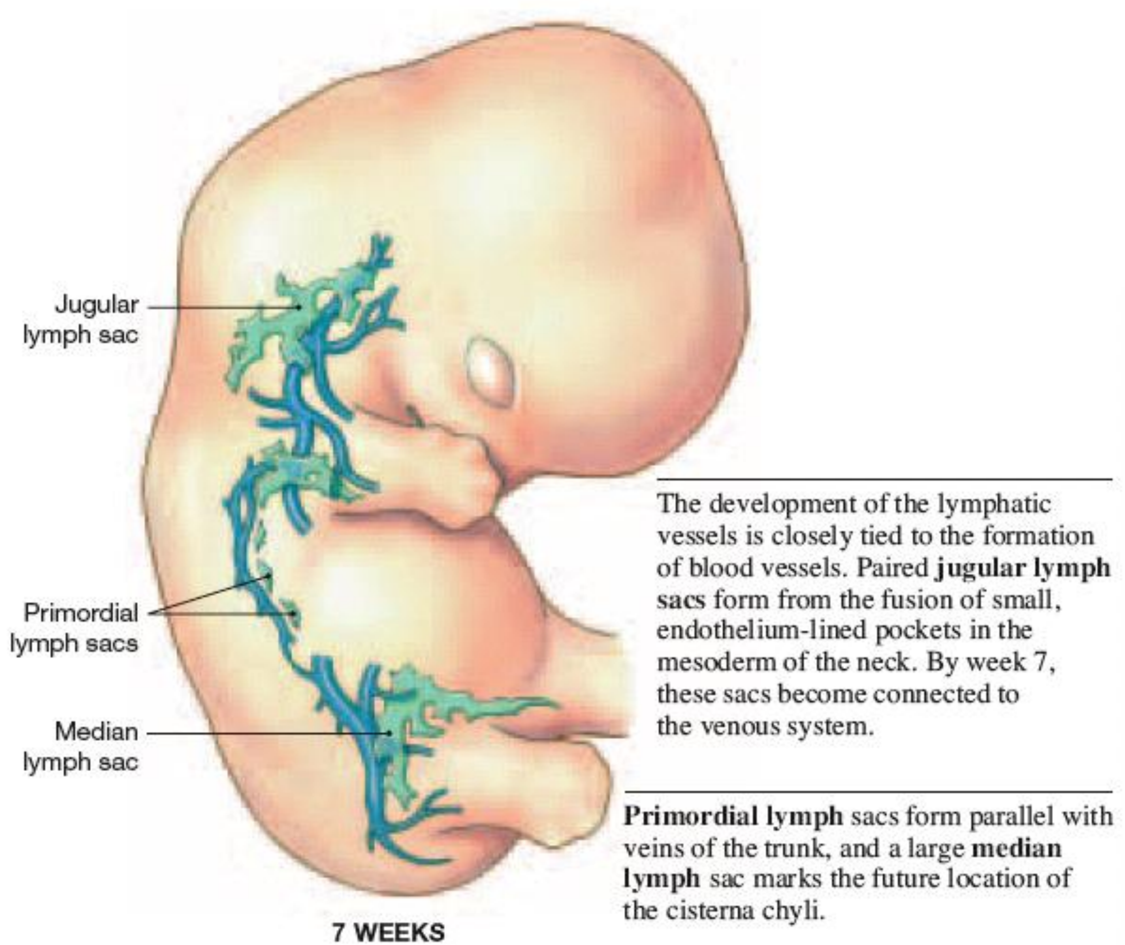


Paired **umbilical arteries** deliver blood to the placenta. At 4 weeks, paired **umbilical veins** return blood to capillary networks in the liver. Veins running along the length of the digestive tract have extensive interconnections.

By week 12, the right umbilical vein disintegrates, and the blood from the placenta travels along a single umbilical vein. The **ductus venosus** allows some venous blood to bypass the liver. The veins draining the digestive tract have fused, forming the hepatic portal vein.

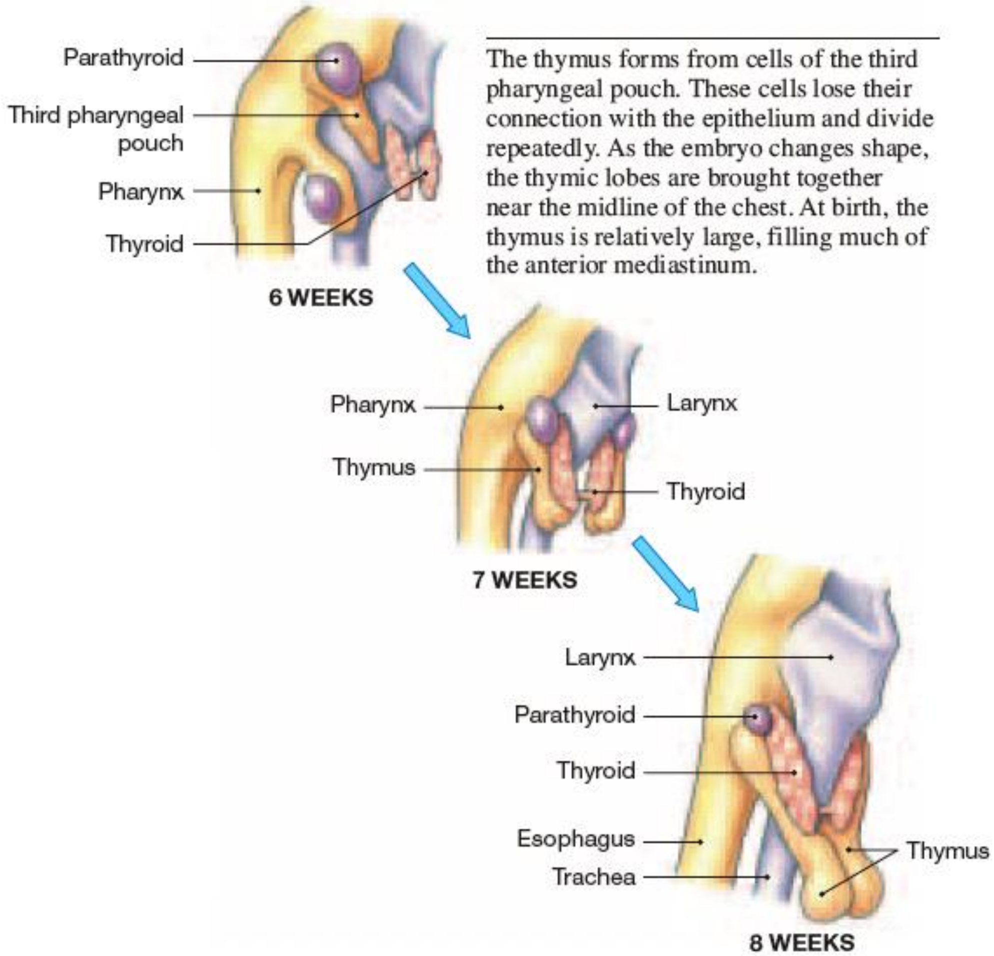
The Development of the Cardiovascular System

Embryology Summary



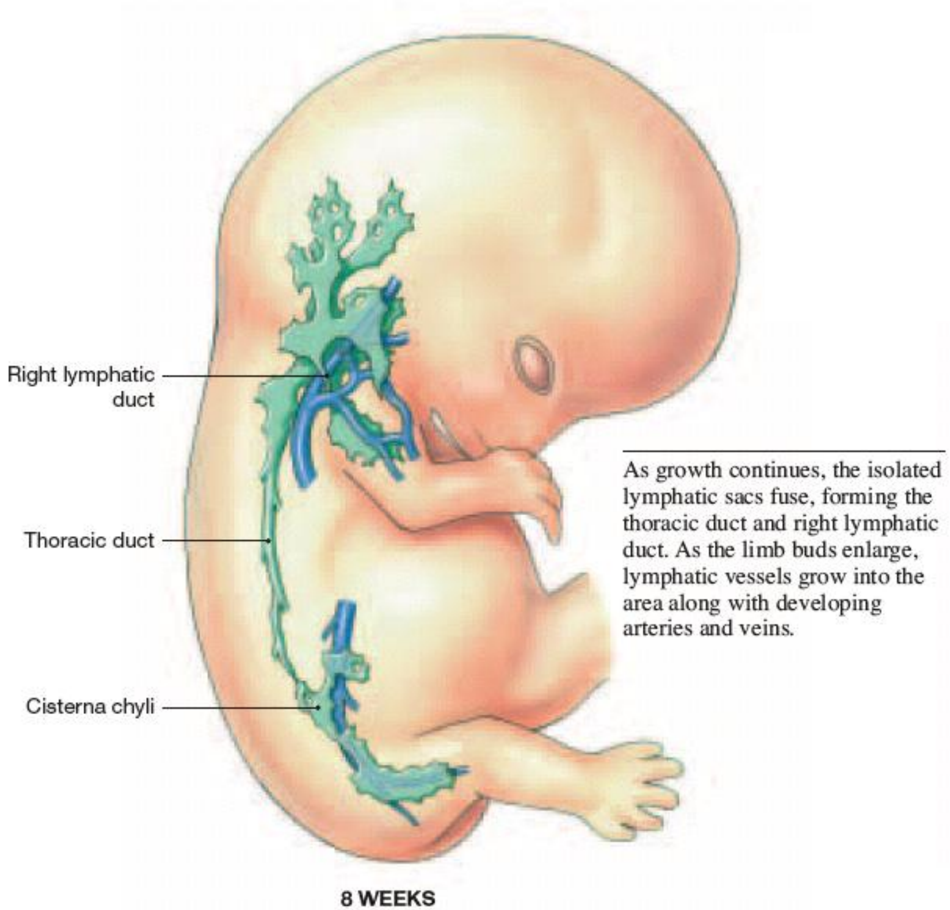
The Development of the Lymphoid System

Embryology Summary



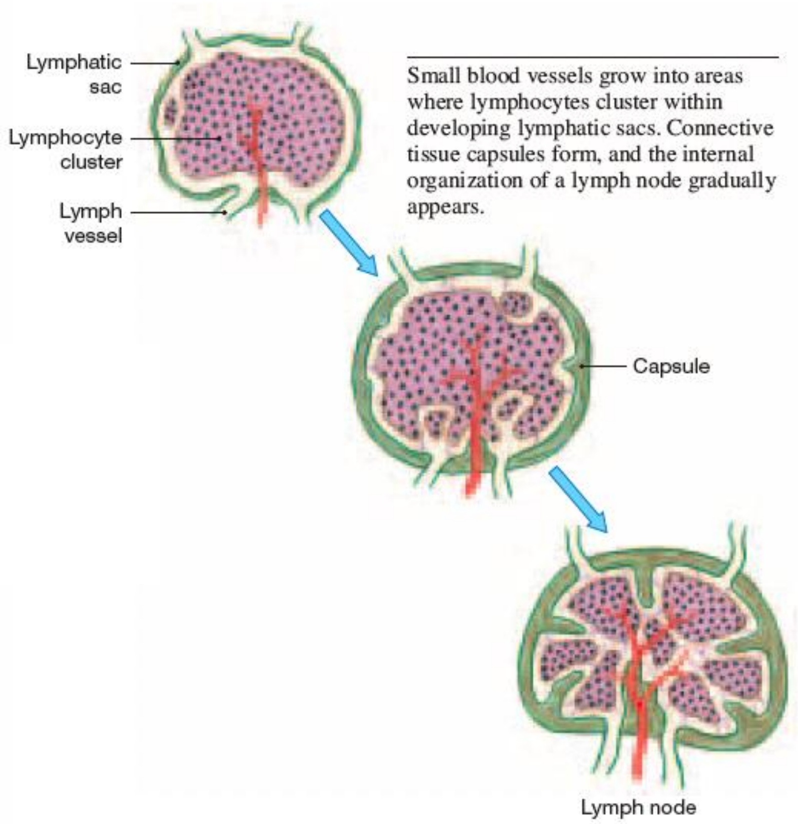
The Development of the Lymphoid System

Embryology Summary



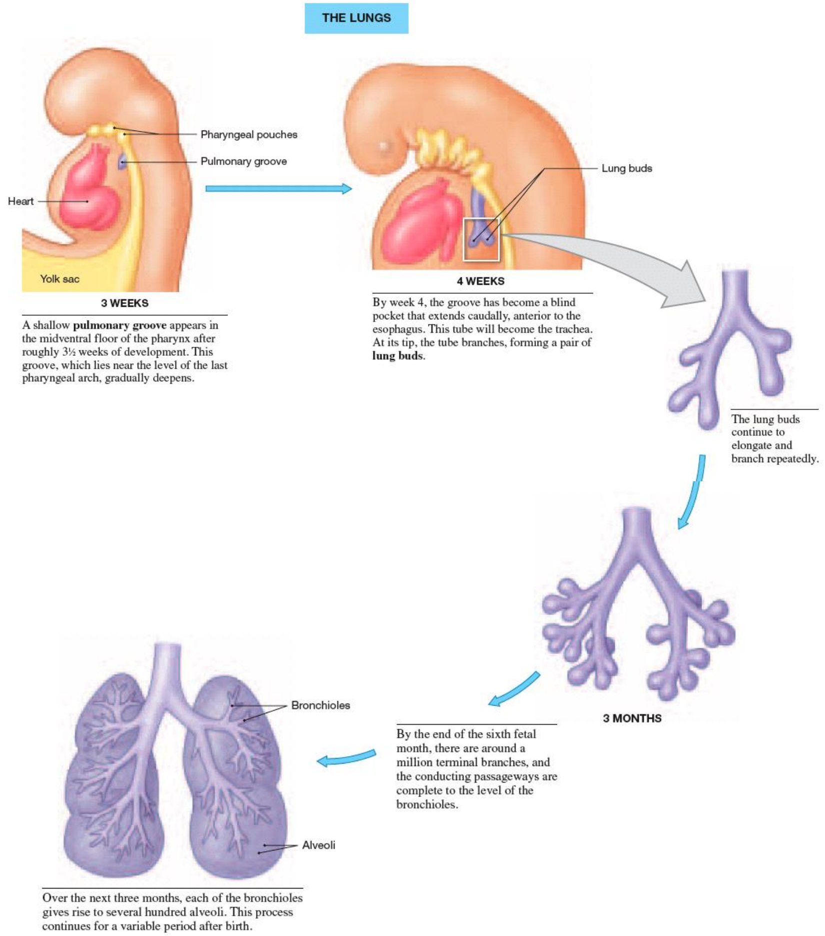
The Development of the Lymphoid System

Embryology Summary



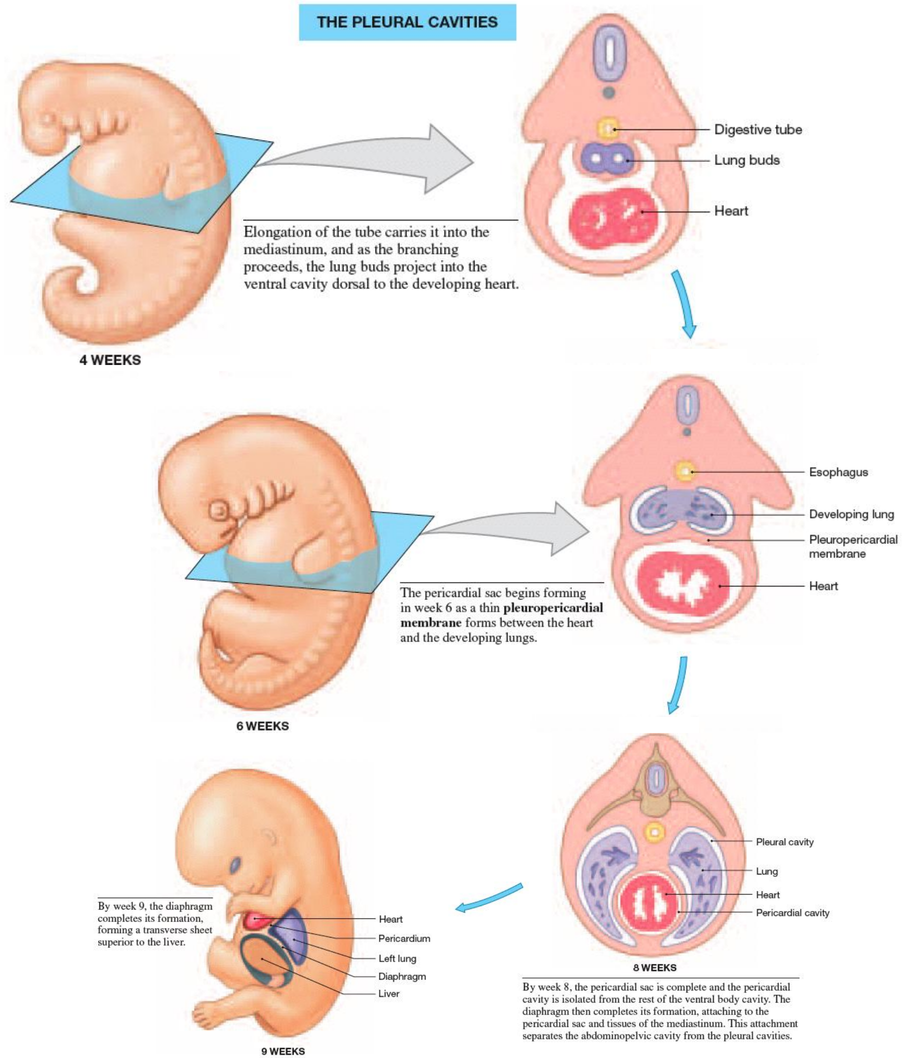
The Development of the Lymphoid System

Embryology Summary



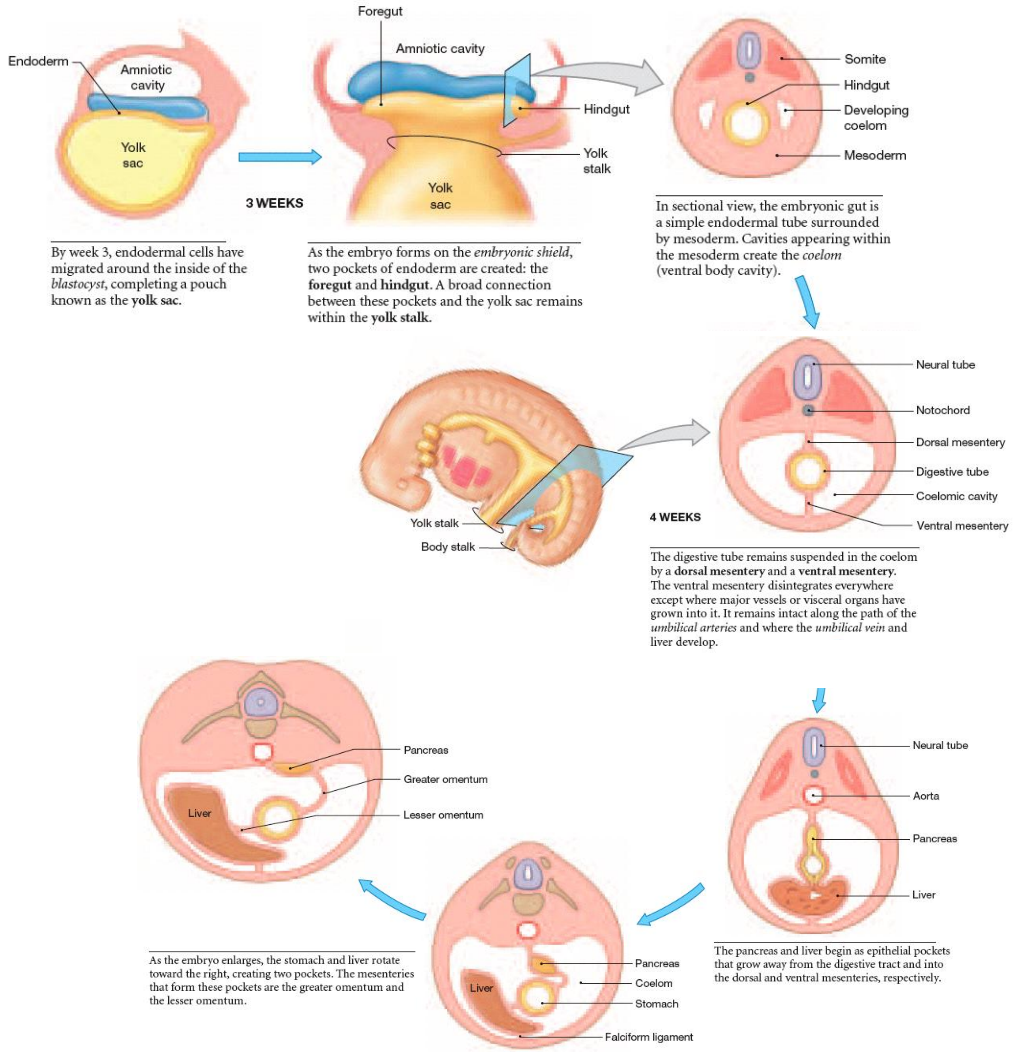
The Development of the Respiratory System, Part I

Embryology Summary



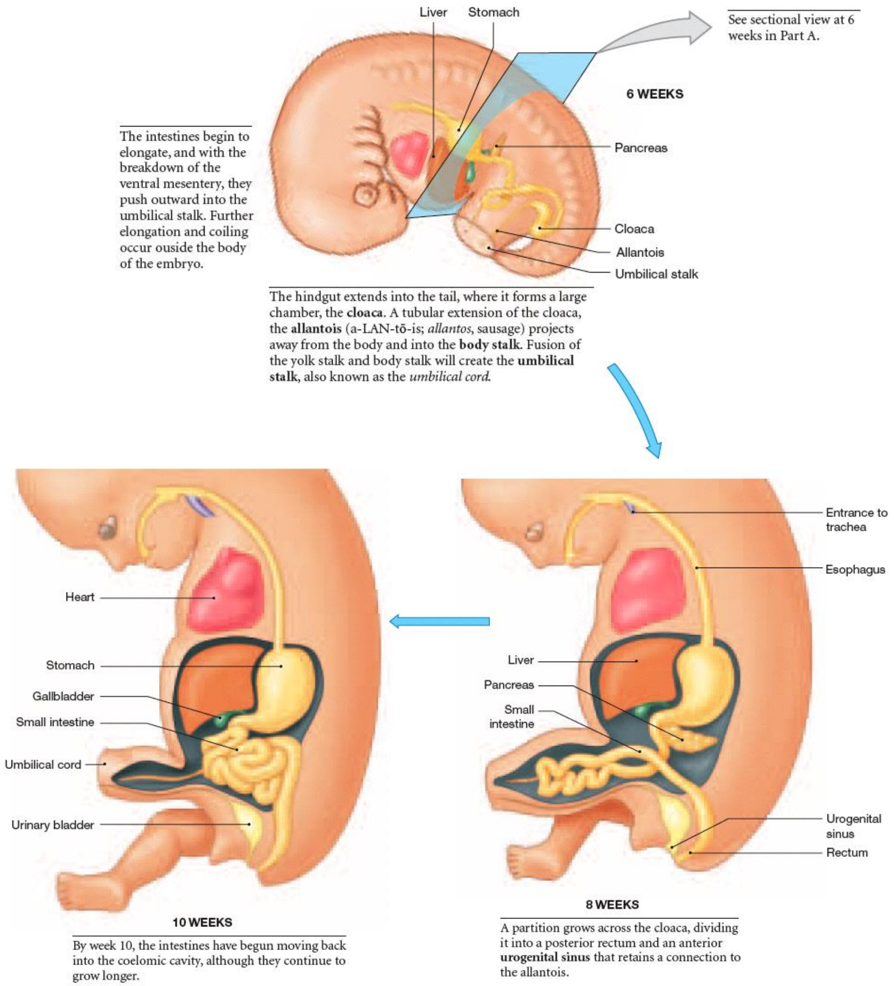
The Development of the Respiratory System, Part II

Embryology Summary



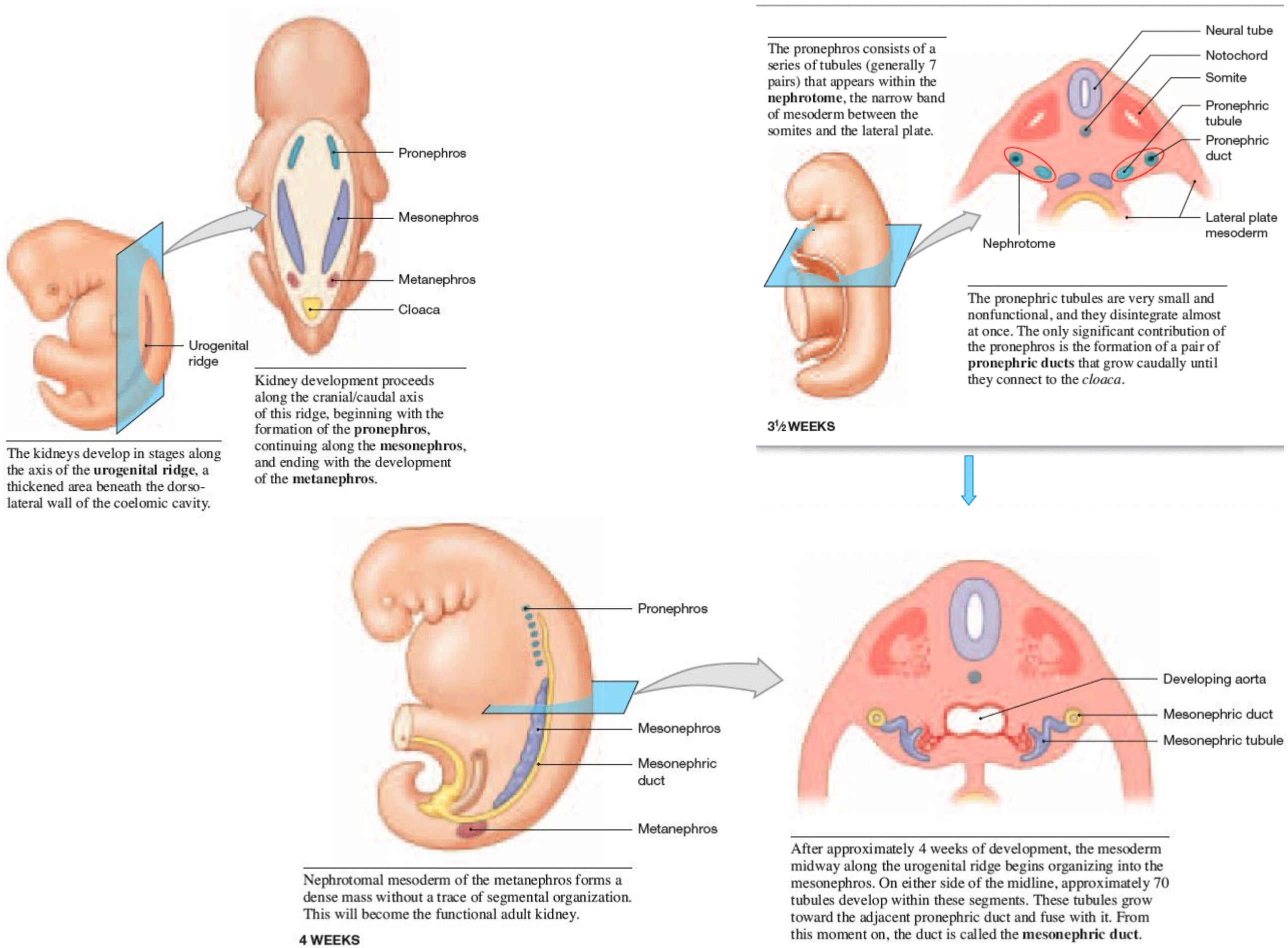
The Development of the Digestive System, Part I

Embryology Summary



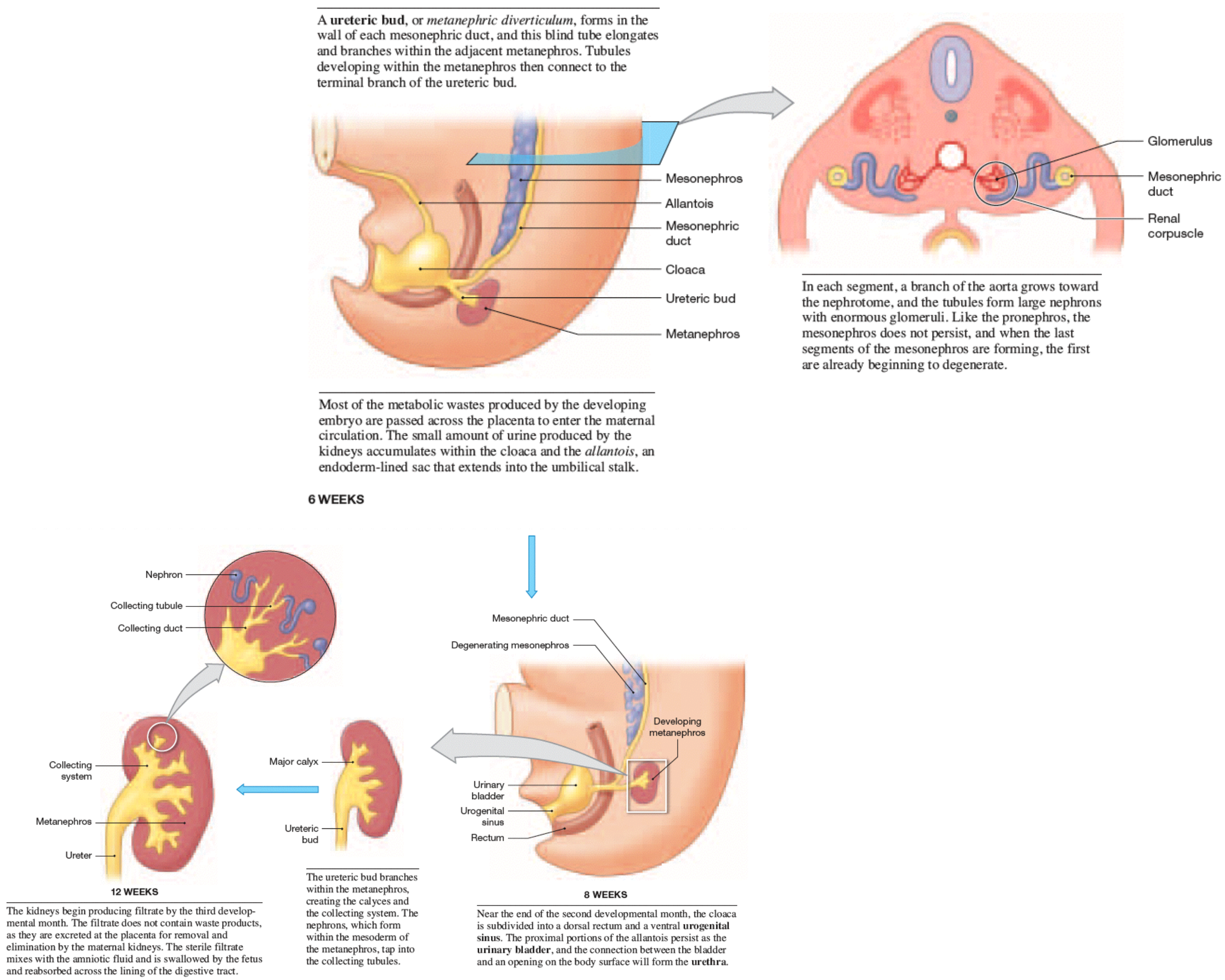
The Development of the Digestive System, Part II

Embryology Summary



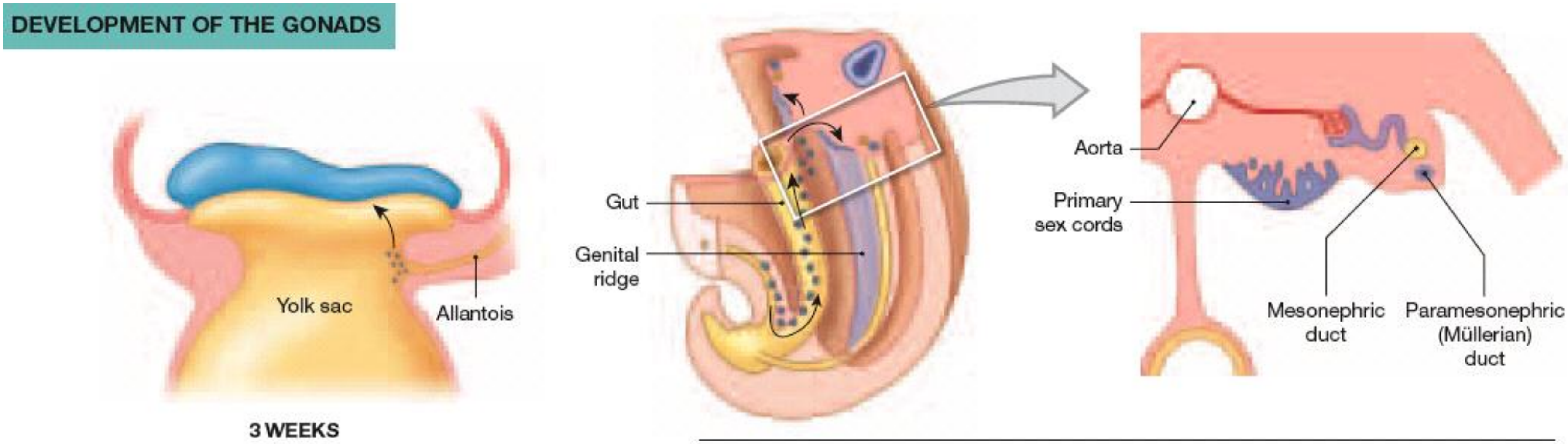
The Development of the Urinary System, Part I

Embryology Summary



The Development of the Urinary System, Part II

Embryology Summary



During the third week, endodermal cells migrate from the wall of the yolk sac near the allantois to the dorsal wall of the abdominal cavity. These primordial germ cells enter the **genital ridges** that parallel the mesonephros.

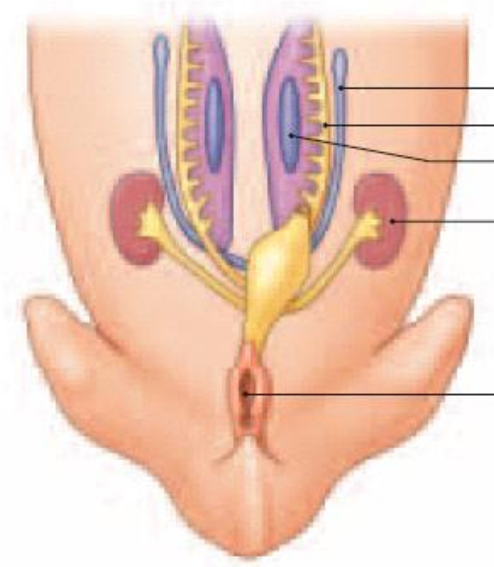
Each ridge has a thick epithelium continuous with columns of cells, the **primary sex cords**, that extend into the center (medulla) of the ridge. Anterior to each mesonephric duct, a duct forms that has no connection to the kidneys. This is the **paramesonephric** (*Müllerian*) **duct**; it extends along the genital ridge and continues toward the cloaca. At this sexually indifferent stage, male embryos cannot be distinguished from female embryos.

The Development of the Reproductive System

Embryology Summary

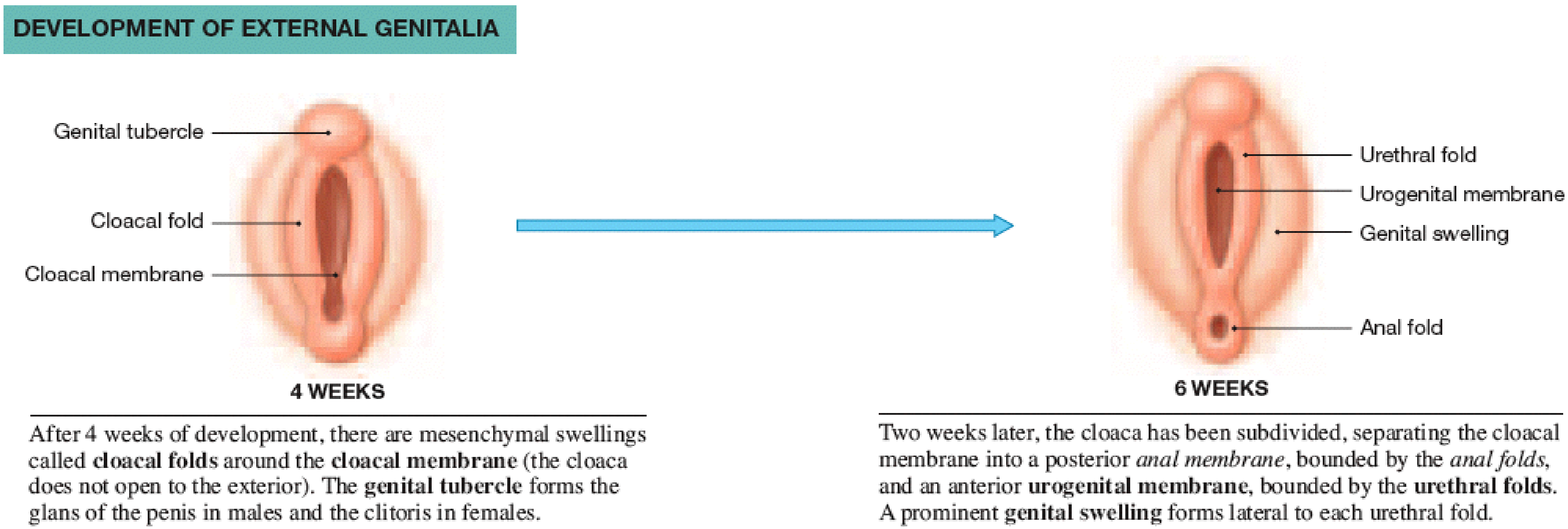
DEVELOPMENT OF DUCTS AND ACCESSORY ORGANS

Both sexes have mesonephric and paramesonephric ducts at this stage. Unless exposed to androgens, the embryo—regardless of its genetic sex—will develop into a female. In a normal male embryo, cells in the core (medulla) of the genital ridge begin producing testosterone sometime after week 6. Testosterone triggers the changes in the duct system and external genitalia that are detailed on the following page.



The Development of the Reproductive System

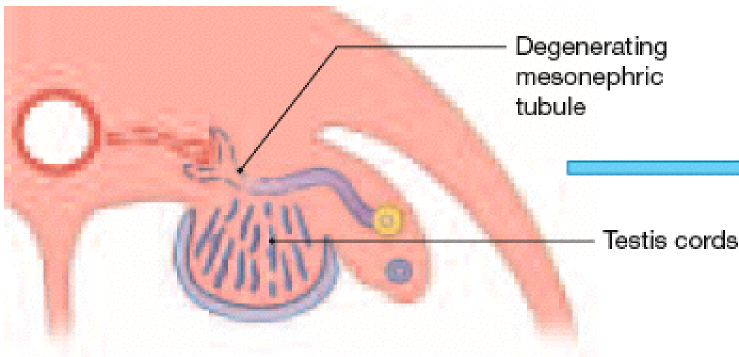
Embryology Summary



The Development of the Reproductive System

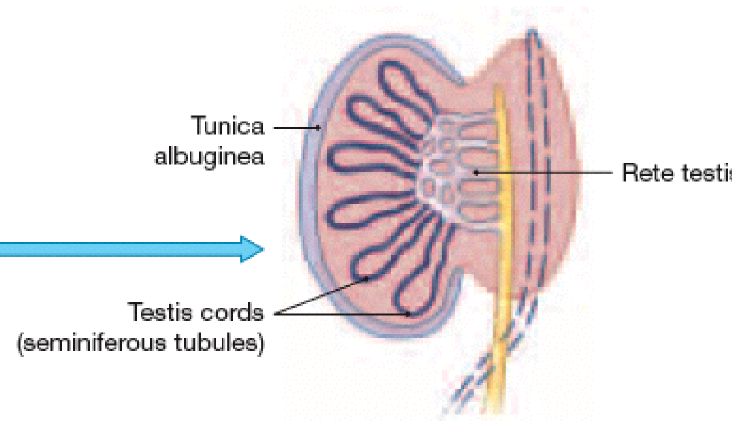
Embryology Summary

DEVELOPMENT OF THE TESTES



7 WEEKS

In the male, the primary sex cords proliferate and the germ cells migrate into the sex cords. The resulting **testis cords** will form the seminiferous tubules.

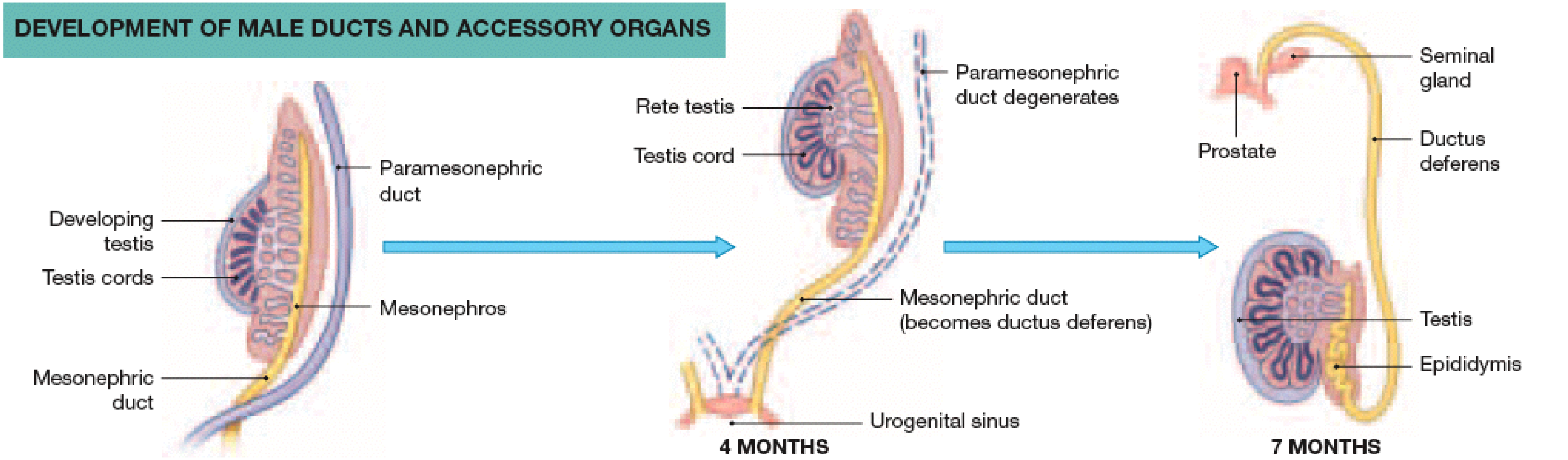


12 WEEKS

Connections form between the arching testis cords and the adjacent mesonephric nephrons. Although these nephrons later degenerate, the seminiferous tubules remain connected to the mesonephric duct.

The Development of the Reproductive System

Embryology Summary



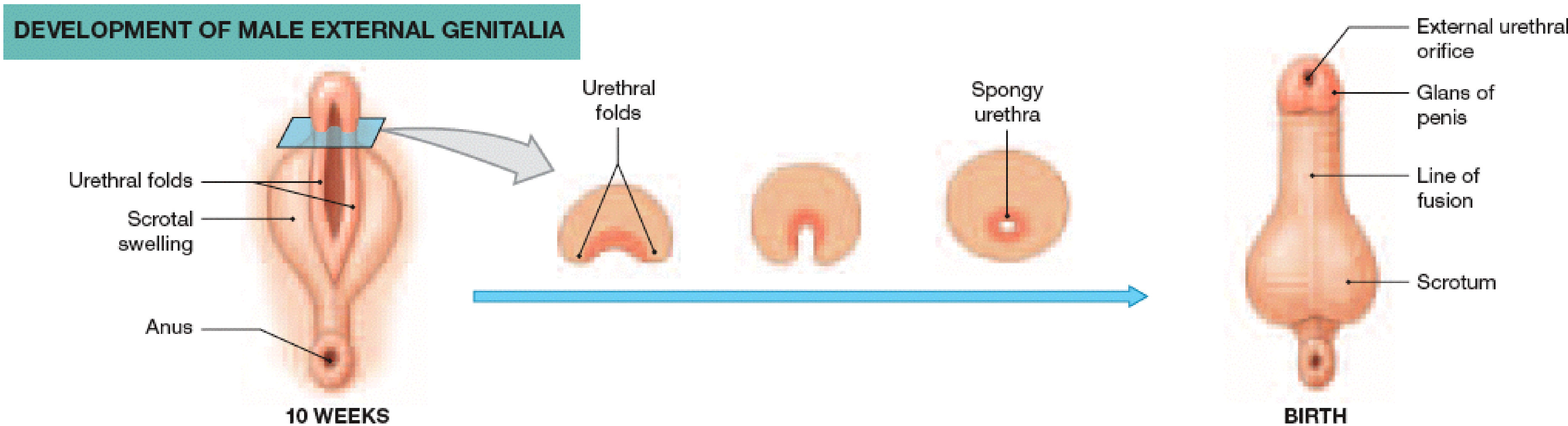
A view of the testis and ducts of the left side as seen in frontal section. Note the location and orientation of the mesonephros relative to the developing testis.

After four months of development, the testis cords are connected to the remnants of the mesonephric tubules by the rete testis. The paramesonephric (Müllerian) duct has degenerated.

Definitive organization after the testis has descended into the scrotum (*see Figure 27.2, p. 717*). Note the relationships between the definitive sex organs and the embryonic structures.

The Development of the Reproductive System

Embryology Summary

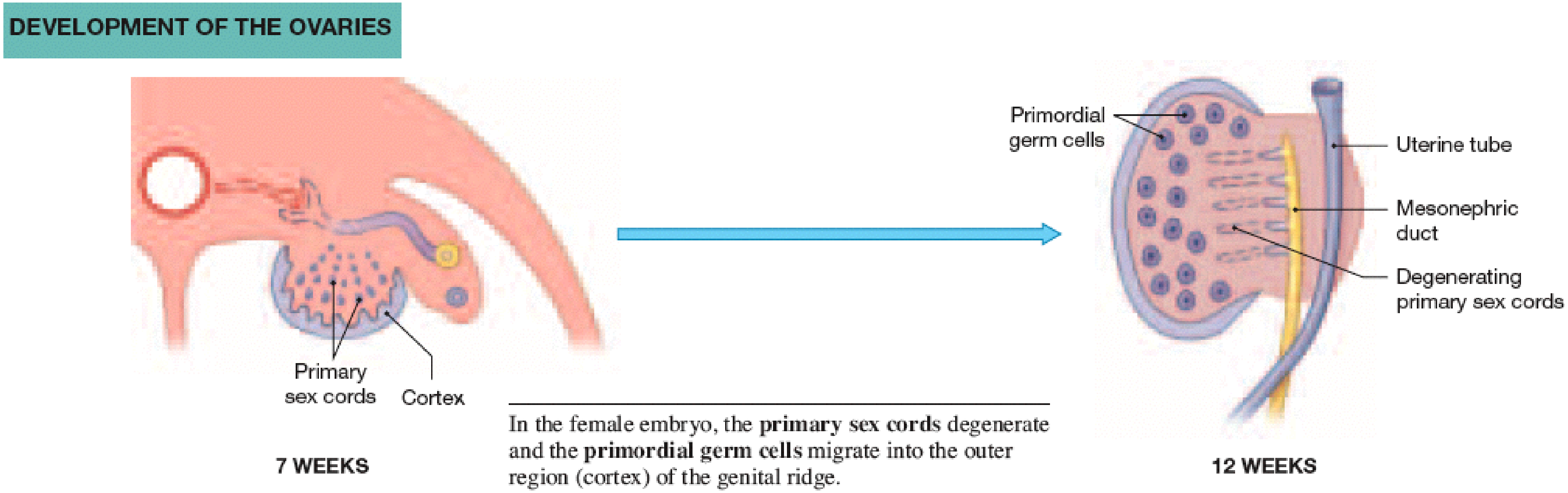


At 10 weeks, the **genital tubercle** has enlarged, the tips of the urethral folds are moving together to form the spongy urethra (see sectional views), and paired **scrotal swellings** have developed from the genital swellings.

In the newborn male, the line of fusion between the urethral folds is quite evident.

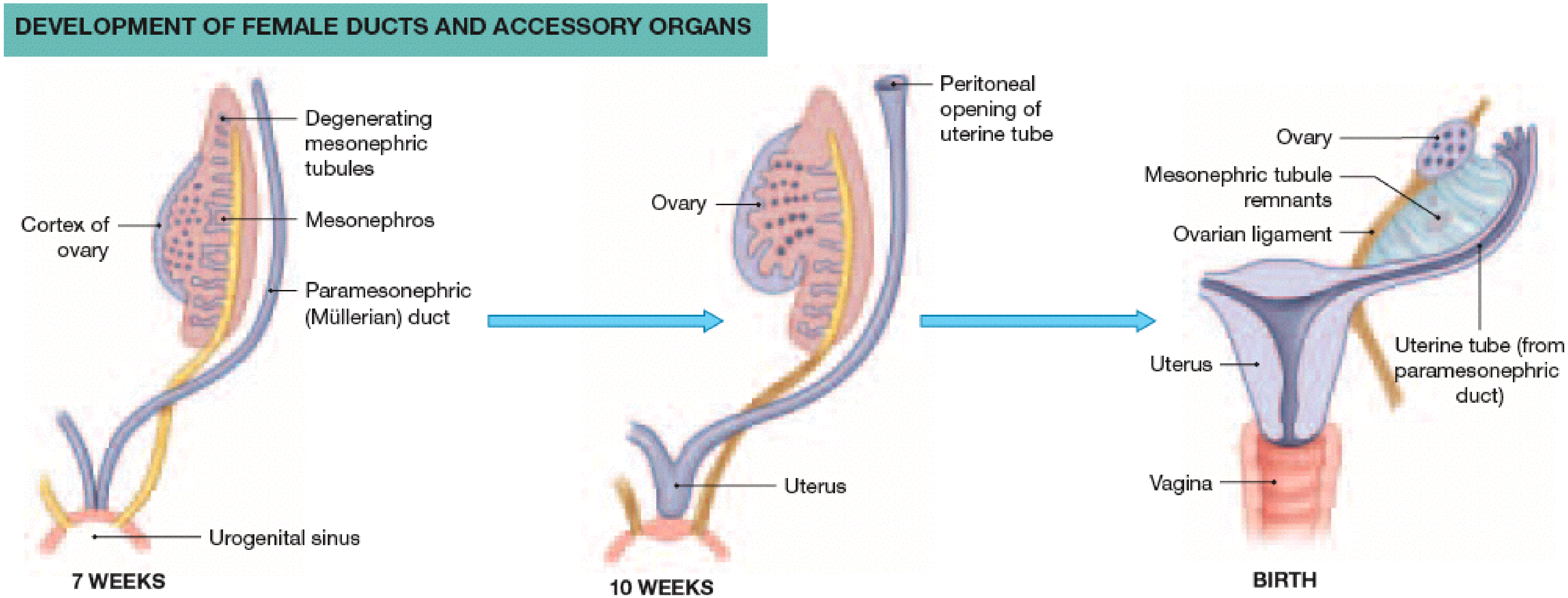
The Development of the Reproductive System

Embryology Summary



The Development of the Reproductive System

Embryology Summary

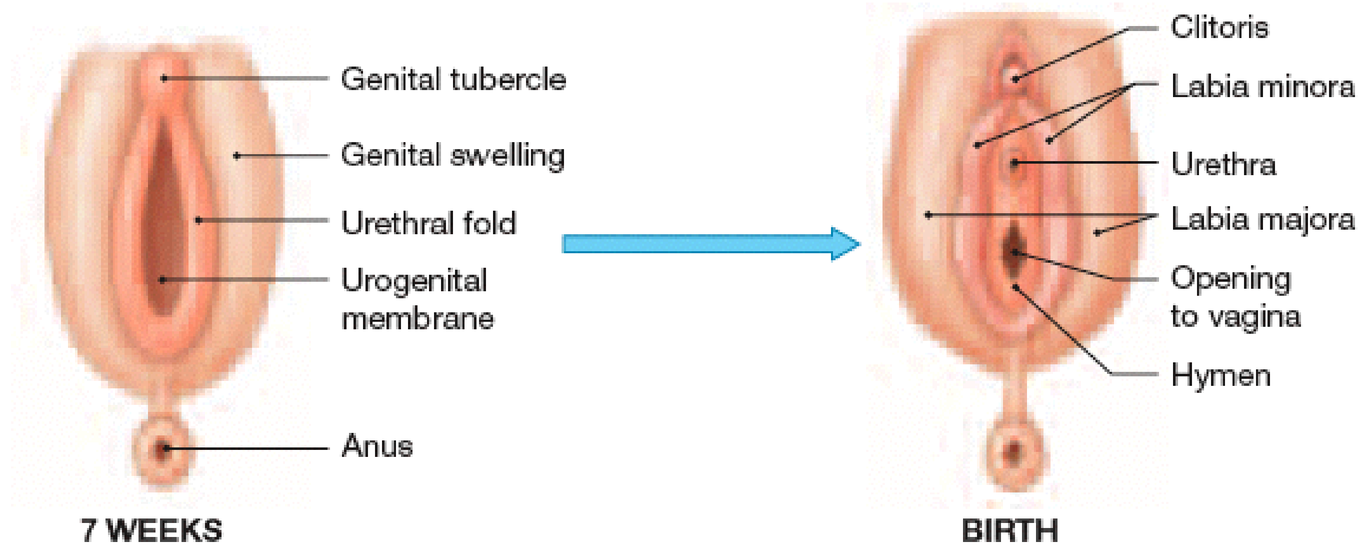


The mesonephric tubules and duct degenerate; the paramesonephric (Müllerian) duct develops a broad opening into the peritoneal cavity. Note the fusion of the ducts and the separation of the common chamber, which will form the uterus, from the urogenital sinus.

The Development of the Reproductive System

Embryology Summary

DEVELOPMENT OF FEMALE EXTERNAL GENITALIA



In the female, the urethral folds do not fuse; they develop into the labia minora. The genital swellings will form the labia majora. The genital tubercle develops into the clitoris. The urethra opens to the exterior immediately posterior to the clitoris. The hymen remains as an elaboration of the urogenital membrane.

The Development of the Reproductive System

Embryology Summary

COMPARISON OF MALE AND FEMALE EXTERNAL GENITALIA	
Males	**Females**
Penis	Clitoris
Corpora cavernosa	Erectile tissue
Corpus spongiosum	Vestibular bulbs
Proximal shaft of penis	Labia minora
Spongy urethra	Vestibule
Bulbo-urethral glands	Greater vestibular glands
Scrotum	Labia majora

The Development of the Reproductive System