

Development of Ectodermal Organs

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Neurulation- Development of the Nervous System

Development of the: Neural Tube & Neural Crest

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Neural Tube

- The nervous system develops when the **notochord** induces its overlying ectoderm to become **neuroectoderm** and to develop into the **neural plate**.
- The neural plate folds along its central axis to form a **neural groove** lined on each side by a **neural fold**.
- The two neural folds fuse together and pinch off to become the **neural tube**.
- Fusion of the neural folds begins in the middle of the embryo and moves cranially and caudally.
- The **cranial** open end of the tube is the **anterior (rostral) neuropore**, and the **caudal** open end of the tube is the **posterior (caudal) neuropore**.
- The anterior neuropore closes on or before **day 26** and the caudal neuropore closes before the **end of the fourth week**.

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Neural Crest

Some cells from the **neural folds** give rise to pleuripotent **neural crest** cells that migrate widely in the embryo and give rise to many nervous structures:

- Spinal ganglia (dorsal root ganglia)
- Ganglia of the autonomic nervous system
- Ganglia of some cranial nerves
- Sheaths of peripheral nerves
- Meninges of brain and spinal cord
- Pigment cells
- Suprarenal medulla
- Skeletal and muscular components in the head

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Development of the Central Nervous System

Development of the: Brain & Spinal Cord

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Development of the Brain

Three primary transverse segments of brain	Five secondary transverse segments of brain	Adult derivatives (and their cavities)
Prosencephalon (forebrain)	Telencephalon (endbrain)	Cerebral hemispheres (lateral ventricles)
Mesencephalon (midbrain)	Diencephalon	Thalamus, subthalamus, hypothalamus, epithalamus, (third ventricle)
Rhombencephalon (hindbrain)	Mesencephalon (midbrain)	Midbrain (aqueduct)
Spinal cord (myelion)	Metencephalon	Pons (cranial half of fourth ventricle)
	Myelencephalon	Medulla oblongata (caudal half of fourth ventricle)
	Spinal cord	Spinal cord (central canal)

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The diagrams show the progression of the embryonic brain:

- A: 3½ weeks:** Shows the Prosencephalon, Mesencephalon, Rhombencephalon, Auditory vesicle, and Spinal cord.
- B: 4½ weeks:** Shows the Midbrain, Diencephalon, Trigeminal ganglion, Optic vesicle, and Telencephalic vesicle.
- C: 7 weeks:** Shows the Midbrain, Diencephalon, Metencephalon, Myelencephalon, Vagus, and Hypoglossus.
- D: 11 weeks:** Shows the Cerebral hemisphere (rudimentary), Superior colliculus, Inferior colliculus, Cerebellum, Modulla, Lower cranial nerves, Olfactory bulb, and Spinal cord.

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Primary vesicles	Secondary Structures	Adult structures	
Forebrain vesicle	(prosencephalon)	Telencephalon	Cerebral hemispheres, consisting of the cortex and medullary center, basal ganglia, lamina terminalis, hippocampus, the corpus striatum, and the olfactory system
		Diencephalon	Thalamus, epithalamus, hypothalamus, subthalamus, neurohypophysis, pineal gland, retina, optic nerve, mamillary
Midbrain vesicle	(mesencephalon)	Midbrain	
Hindbrain vesicle	Metencephalon Myelencephalon	Pons and cerebellum Medulla	

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Structure of embryonic brain

The diagram illustrates the structure of the embryonic brain, divided into three main regions:

- Forebrain:** Diencephalon, Telencephalon (cerebral vesicles).
- Midbrain:** Mesencephalon.
- Hindbrain:** Metencephalon, Myelencephalon.

Other labeled structures include the Optic stalk, Pontine flexure, and Spinal cord.

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Development of the Spinal Cord

- The neural tube consists of three cellular layers from inner to outer: the **ventricular zone** (ependymal layer), the **intermediate zone** (mantle layer), and the **marginal zone** (marginal layer).
- The **ventricular zone** gives rise to **neuroblasts** (future nerve cells) and **glioblasts** (future supporting cells) which **migrate** into the intermediate zone form two collections of cells (the **alar plate** and the **basal plate**) separated by a groove called the **sulcus limitans**.
- Cells in the **alar plate** become **afferent (sensory) neurons** and form the **dorsal (posterior) horn** of the spinal cord. Cells in the **basal plate** become **efferent (motor) neurons** and form the **ventral (anterior) horn** of the spinal cord.
- The two ventral horns bulge ventrally to create **ventral median fissure**.
- The dorsal horns merge to create the **dorsal median septum**.
- The lumen of the neural tube becomes the **central canal** of the spinal cord.
- The spinal cord extends the entire length of the vertebral canal at **week 8** of development.
- At **birth**, the conus medullaris extends to the **L3** vertebra.
- In the **adult**, the conus medullaris extends to the **L1** vertebra.
- Spinal lumbar punctures** must be performed caudally to the conus medullaris to avoid damaging the spinal cord.

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Development of the Spinal Nerves and Ganglia

- The cells of these rudiments then send out processes (axons) in two directions:
 - Toward the periphery, where they will synapse on sensory receptors in skin, muscles and visceral organs and
 - Toward the dorsal neural tube, where they synapse on cell bodies of the mantle layer.
 - These neurons, which have their cell bodies in the dorsal root ganglia, are sensory neurons; they carry impulses from receptors to the spinal cord.

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Fate of the Epidermis

- Most of the epidermis of the embryo becomes the epidermis of the skin, which overlies the dermis (which is derived from the mesoderm).
- The epidermis gives rise to skin glands, hair, feathers, scales, etc.
- The epidermis also gives rise to some organs.
- These first appear as plate-shaped thickenings in the skin called, **placodes**. Organs which form from epidermal placodes are ganglia of some cranial nerves, lens rudiment, which form the lens and the olfactory sacs, which form the nasal sensory organs.
- The auditory placode, which forms the ear vesicle, which is the rudiment of the internal ear and the lateral line sense organs of fish

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Development of Mesodermal Organs

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URINARY SYSTEM

- The urogenital system arises during the fourth week of development from **urogenital ridges** in the **intermediate mesoderm** on each side of the primitive aorta.
- The **nephrogenic ridge** is the part of the urogenital ridge that forms the urinary system.
- Three sets of kidneys develop sequentially in the embryo:
 - The **pronephros** is rudimentary and nonfunctional, and **regresses completely**.
 - The **mesonephros** is functional for only a short period of time, and remains as the **mesonephric (Wolffian) duct**.
 - The **metanephros** remains as the permanent adult kidney. It develops from the **uteric bud**, an outgrowth of the mesonephric duct, and the **metanephric mesoderm**, derived from the caudal part of the nephrogenic ridge.
- Urine excreted into the amniotic cavity by the fetus forms a major component of the amniotic fluid.
- The **kidneys develop in the pelvis and ascend** during development to their adult anatomical location at **T12-L3**.
- This normally happens by the **ninth week**.

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Development of the Cardiovascular System

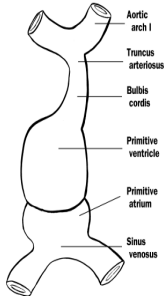
Development of the:

- The Heart
- Blood Vessels
- Blood production

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Development of Heart

- Two **endocardial heart tubes** arise from **cardiogenic mesoderm**.
- As lateral folding occurs, these fuse to form the **primitive heart tube**, which develops into **the endocardium**. The **myocardium and epicardium** develop from **mesoderm** surrounding the primitive heart tube.
- Several contractions and dilations soon appear in the heart tube, all of which have adult remnants.



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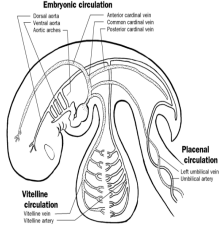
Development of Blood Vessels

- Blood vessel formation (**angiogenesis**) starts at the beginning of the third week.
- Blood vessels first start to develop in the extraembryonic mesoderm of the yolk sac, connecting stalk, and chorion.
- Blood vessels begin to develop in the embryo about two days later.

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Production of Blood

- Production of blood (**hemopoiesis** or **hematopoiesis**) begins first in the **yolk sac wall** about the third week of development. **Erythrocytes produced in the yolk sac have nuclei**. Blood formation does not begin inside the embryo until about the **fifth week**. **Erythrocytes produced in the embryo do not have nuclei** (eunucleated). Hematopoiesis inside in the embryo occurs first in the **liver**, then later in the **spleen, thymus, and bone marrow**.



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Development of the Reproductive System

Development of the:

- Determination of Gender
- Development of External genitalia
- Development of Genital Ducts
- Descent of the Ovaries and Testes

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Determination of Gender

- Although genetic sex (XX or XY) is determined at fertilization, the embryo's gender is not distinguishable for the first six weeks of development; this is known as the **indifferent period of development**.
- Characteristics of either male or female genitalia can often be recognized by week twelve of development.

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Development of External Genitalia

- In both sexes about the fourth week of development an indifferent **genital tubercle** develops near the cloaca and elongates to form a **phallus**.
- In a male embryo, androgens secreted by the testes cause the phallus to elongate into the **penis** and the **urogenital folds** to fuse and form the **spongy urethra**.
- Without influence of androgens, the phallus becomes the **clitoris**, the **urogenital folds** become the **labia minora**, and the **labioscrotal swellings** become the **labia majora**.
- The external genital organs are not fully differentiated until about the **twelfth week** of development.

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Development of Genital Ducts

- During indifferent development both pairs of genital ducts are present.
- In **female** embryos the **paramesonephric ducts (müllerian ducts)** develop into most of the female genital tract, including the **uterine tubes, uterus, and part of the vaginal canal**.
- In **male** embryos the testes secrete **müllerian inhibiting substance**, which suppresses development of the paramesonephric ducts.
- Instead the **mesonephric ducts** develops into the **epididymis, ductus deferens, and ejaculatory duct**.

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Descent of the Ovaries and Testes

- The ovaries and testes develop in the abdomen and descend to their adult anatomical positions before birth.
- In the male the **testes descend** from the abdomen into the scrotum about the **twenty-eighth week** of development.

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Development of Paired Limbs

- Towards the end of the fourth week the limbs begin to develop from **limb buds** made up of mesenchyme (**somatic mesoderm**) covered with **surface ectoderm**.
- The **apical ectodermal ridge** at the tip of each limb bud induces the mesenchyme beneath it to elongate.
- At the end of each limb the hand or foot first develops as a single flat outgrowth, then programmed death of selective cells (apoptosis) causes it to divide into distinct digits.
 - Movement of Limbs
 - Skeletal Elements

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Movement of Limbs

- Initially the limbs develop high on the trunk where they are supplied by the ventral rami of adjacent spinal nerves.
- Spinal roots **C5 – T1** supply the upper limb bud and **L2 – S3** supply the lower limb bud.
- During weeks six through eight the limbs descend to their adult height taking their nerve supply with them.
- To attain adult anatomical position, the upper and lower limbs rotate in opposite directions and to different degrees, with the result that the adult elbow points posteriorly and the adult knee points anteriorly.

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Skeletal Elements

- Cartilaginous bones begin to develop from **chondrification centers** early in the fifth week.
- Ossification of the long bones (**osteogenesis**) begins from **primary ossification centers**, which appear in the middle of the long bones in the seventh week.
- Ossification of the carpal (wrist) bones does not begin until approximately the first year after birth.
- The skeletal muscle of the limbs is derived from myotomal cells that migrate into the limbs, followed by the branches of their associated spinal nerves.

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Development of Endodermal Organs

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DEVELOPMENT OF THE DIGESTIVE SYSTEM

- Primitive Gut Tube
- Proctodeum and Stomodeum
- Stomach
- Duodenum
- Pancreas
- Liver and Biliary Apparatus
- Spleen
- Midgut

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Primitive Gut Tube

- The **primitive gut tube** is derived from the dorsal part of the **yolk sac**, which is incorporated into the body of the embryo during folding of the embryo during the fourth week.
- The primitive gut tube is divided into three sections.
- The **epithelium** of and the **parenchyma of glands** associated with the digestive tract (e.g., liver and pancreas) are derived from **endoderm**.
- The **muscular walls** of the digestive tract (lamina propria, muscularis mucosae, submucosa, muscularis externa, adventitia and/or serosa) are derived from **splanchnic mesoderm**.
- During the **solid stage** of development the endoderm of the gut tube proliferates until the gut is a solid tube.
- A process of **recanalization** restores the lumen.

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Proctodeum and Stomodeum

- The proctodeum (anal pit) is the **primordial anus**, and the stomodeum is the **primordial mouth**.
- In both of these areas ectoderm is in direct contact with endoderm without intervening mesoderm, eventually leading to degeneration of both tissue layers. **Foregut, Esophagus.**
- The **tracheoesophageal septum** divides the foregut into the esophagus and trachea. information.

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Stomach

- The primordium of the **primitive stomach** is visible about the end of the fourth week.
- It is initially oriented in the median plane and suspended from the dorsal wall of the abdominal cavity by the **dorsal mesentery** or **mesogastrium**.
- During development the stomach rotates 90 degrees in a clockwise direction along its longitudinal axis, placing the **left vagus nerve** along its anterior side and the **right vagus nerve** along its posterior side.
- Rotation of the stomach creates the **omental bursa** or **lesser peritoneal sac**.

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Duodenum

- The duodenum acquires its C-shaped loop as the stomach rotates.
- Because of its location at the junction of the foregut and the midgut, branches of both the **celiac trunk** and the **superior mesenteric artery** supply the duodenum.

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Pancreas

- The pancreas develops from two outgrowths of the endodermal epithelium, the **dorsal pancreatic bud** and the **ventral pancreatic bud**.
- During rotation of the gut these primordial come together to form a single pancreas.
- The ventral pancreatic bud forms the uncinat process and part of the head, while the dorsal pancreatic bud forms the remainder of the head, body, and tail of the pancreas.
- The ducts of the pancreatic buds join together to form the **main pancreatic duct**, but the proximal part of the duct of the dorsal pancreatic bud may persist as an **accessory pancreatic duct**.

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Liver and Biliary Apparatus

- The liver develops from endodermal cells that form the **hepatic diverticulum**.
- The liver grows in close association with the **septum transversum**, which later forms part of the diaphragm.
- As it grows the hepatic diverticulum divides into a **cranial part**, which forms the **parenchyma** of the liver, and the **caudal part**, which gives rise to the **gallbladder** and **cystic duct**.
- The **hemopoietic cells**, **Kupffer cells**, and **connective tissue** of the liver are derived from **mesenchyme** in the septum transversum.
- The embryonic liver is large and fills much of the abdominal cavity during the seventh through ninth weeks of development.
- Blood formation (hemopoiesis) begins in the liver during the sixth week of development, and bile formation begins in the twelfth week.

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Spleen

- The spleen develops from **mesenchymal cells** located between layers of the dorsal mesogastrium.

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Midgut

- The midgut communicates with the yolk sac via the **yolk stalk**.
- As the midgut forms, it elongates into a U-shaped loop (**midgut loop**) that temporarily projects into the umbilical cord (**physiological umbilical herniation**).
- The cranial limb of the midgut elongates rapidly during development and forms the **jejunum** and **cranial portion of the ileum**.
- The caudal limb forms the **cecum, appendix**,

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RESPIRATORY SYSTEM

- **Lower Respiratory System**
- **Larynx**
- **Trachea**
- **Bronchi**

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RESPIRATORY SYSTEM

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Lower Respiratory System

- The primordium of the lower respiratory system develops in about the fourth week.
- The **laryngotracheal diverticulum** arises from endoderm on the ventral wall of the foregut.
- **Tracheoesophageal folds** develop on either side and join to form a **tracheoesophageal septum** that separates it from the rest of the foregut.
- This divides the foregut into the **laryngotracheal tube** (ventral) and the **esophagus** (dorsal).
- The caudal end of the laryngotracheal diverticulum enlarges to form the **lung bud**, which is surrounded by **splanchnic mesenchyme**.

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Lower Respiratory System

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Larynx

- The opening of the laryngotracheal tube becomes the **inlet of the larynx**.
- The **laryngeal cartilages** are derived from the **fourth and sixth pharyngeal arches**.

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Larynx

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Trachea

- The **epithelium and glands** of the trachea develop from **the endoderm of the laryngotracheal tube**.
- The **cartilage, connective tissue, and smooth muscle** are derived from the surrounding **splanchnic mesenchyme**.

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Trachea

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Bronchi

- At the end of the fourth week the lung bud divides into two **bronchial buds**, which enlarge to form the **primary bronchi**.
- The **right bronchus** is **larger** and **more vertically oriented** than the left one, and this relationship persists throughout life.
- In the fifth week, each bronchial bud divides into **secondary bronchi**.
- In the eighth week the secondary bronchi divide to form the **segmental bronchi** (tertiary bronchi), ten in the right lung and eight in the left.
- Each segmental bronchus becomes a bronchopulmonary segment (segment in a lung).
- The **smooth muscle, connective tissue, and cartilaginous plates** in the bronchi are derived from **splanchnic mesenchyme**.

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Bronchi

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BODY CAVITIES

- **Intraembryonic Coelom**
- **Diaphragm**

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BODY CAVITIES

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Intraembryonic Coelom

- The **primitive intraembryonic coelom** forms in the **lateral and cardiogenic mesoderm** about the fourth week of development.
- The embryo undergoes two foldings and this cavity is eventually divided into the **pericardial, pleural, and peritoneal** embryonic body cavities.
- During the fourth week the **septum transversum** grows to separate the pericardial cavity from the pleural cavities.
- During the sixth week the **pleuroperitoneal membranes** grow to separate the pleural cavities from the peritoneal cavity.
- During the seventh week the **pleuropericardial membranes** separate the pericardial cavity from the pleural cavities. In the adult the pleuropericardial membranes form the **fibrous pericardium of the heart**.

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Intraembryonic Coelom

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Diaphragm

- The diaphragm separates the thoracic and abdominal cavities. It arises from tissue from four sources:
 - The **septum transversum**, which forms the **central tendon of the diaphragm**.
 - The **pleuroperitoneal membranes**, which contribute only a small amount to the adult diaphragm
 - The **dorsal mesentery of the esophagus**, which forms the **crura** and median portion of the diaphragm
 - The **body wall**, which forms the periphery of the diaphragm
- The diaphragm develops initially at the level of **cervical somites 3-5** and it "descends" to the level of **L1** as the embryo grows.
- As it moves it takes along its innervation, which explains why the **phrenic nerve** arises from **cervical roots three, four, and five** ("C3-4-5 keeps a man alive.")

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Diaphragm

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SENSE ORGANS-EYE

- About the fourth week, **optic sulci** (optic grooves) develop in the **diencephalon**.
- The optic sulci evaginate to form **optic vesicles**.
- The optic vesicles enlarge and form **hollow optic stalks**.
- The optic vesicles **induce the surface ectoderm** of the head to form **lens placodes**.
- The optic vesicles then invaginate to form double-walled optic cups, and the ventral surfaces of the optic stalks invaginate to form **optic fissures**.
- Mesenchyme within each optic cup forms the **hyaloid artery** and **hyaloid vein**.
- In the meantime, the lens placodes have sunk in to form **lens pits**.
- The pits detach from the surface ectoderm to form **lens vesicles**.
- The retina is derived from the walls of the optic cups.
- The proximal parts of the hyaloid vessels form the **central artery and vein of the retina**.
- The distal parts of the hyaloid vessels **disappear before birth**.

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SENSE ORGANS-EYE

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