Embryology

Goal 8. Introduce embryology, including the study of pregnancy, placental structure and function, and the embryological development of each of the body systems.

A. Early Embryology Goal 8.01
1. Fertilization
2. Early Development

B. Extraembryonic Development Goal 8.02
1. Extraembryonic Membranes
2. Implantation
3. Functions of Placenta

C. Twinning Goal 8.03
1. Definition
2. Monozygotic
3. Dizygotic

D. Processes Goal 8.04
1. Differentiation
2. Induction
3. Cell Migration
4. Invagination
5. Evagination
6. Folding & Fusion

E. Cardiovascular Development Goal 8.05
1. Early differentiation
2. Development of 4 chambered heart
3. Unique features of fetal circulation
4. Placental membrane

F. Nervous System Goal 8.06
1. Neurulation at beginning of third week
2. Brain development begins by week four
3. Development of cranial & spinal nerves
4. Development of the eye
5. Development of pituitary gland

G. GI/Respiratory Tract Development Goal 8.07
1. Formation of Foregut
2. Formation of the Hindgut
3. Midgut

H. Urogenital = Urinary + Reproductive Systems Goal 8.08
1. Urinary tract
2. Reproductive tract
3. External genitalia

Goal 8.01 define fertilization (activation and amphimixis), zygote, cleavage, blastula, blastocoel, gastrula, archenteron, mesoderm, ectoderm, endoderm. Briefly describe the early sequence of embryonic development.

A. Early embryology

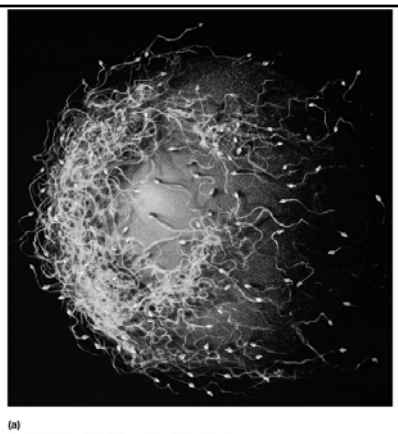
1. Fertilization

a. Activation Sperm penetration triggers meiosis II, and the extra set of chromosomes is thrown out

b. Amphimixis (= syngamy) = union of sperm nucleus & ovum nucleus, restoring the diploid condition

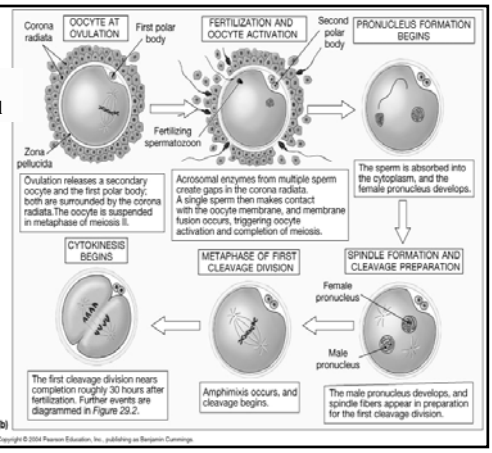
c. Zygote
= the ultimate stem cell. It is totipotent (it can produce all types of human body cells for the embyro), and it produces the life support system (extra-embryonic membranes)

Fig. 29.01
Martini



(a)

Fig. 29.01
Continued



(b)

As you read your text, look for and/or think about the answers to these questions.

What is capacitation?

Which two enzymes are found in the acrosome?

What is polyspermy? What prevents this?

What is the cortical reaction?

What is a fertilization membrane & how is it created?

2. Early Development –of embryo This happens in the uterine tube

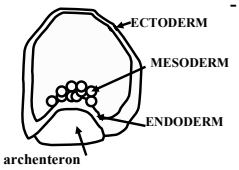
a. Cleavage

= repeated mitosis without cell growth. Reduces size of cells to that of adult.

b. Blastula = blastocyst of human

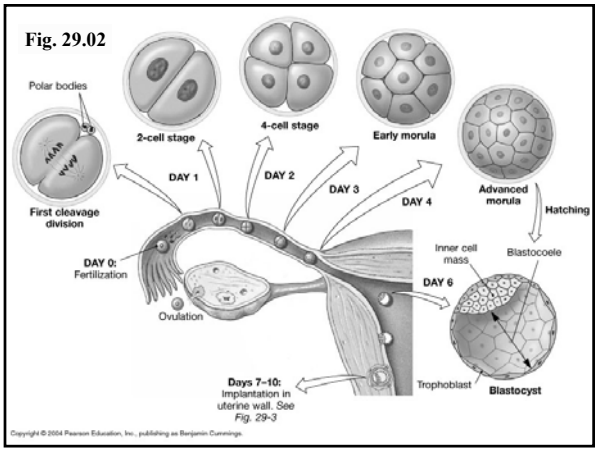
= hollow ball of cells; in humans, a mass of cells called the embryoblast lies at one side

c. Gastrulation & Development of germ layers(LAB EXAMPLE - animal model)



- **archenteron**
  = "primitive gut", first GI development
- **ectoderm**
  = "outer skin", first embryonic tissue
- **endoderm**
  = "inner skin", another embryonic tissue

Fig. 29.02



d. Primitive streak & the mesoderm (HUMAN DEVELOPMENT)

Primitive streak = a line of cells invaginating along one side of the embryo. A third embryonic tissue, mesoderm, forms from this.

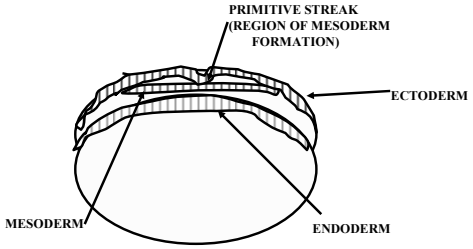
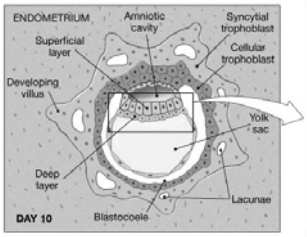
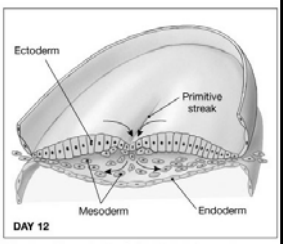


Fig. 29.04



The inner cell mass begins as two layers: a superficial layer, facing the amniotic cavity, and a deep layer, exposed to the blastocoele. Migration of cells around the amniotic cavity is the first step in the formation of the amnion. Migration of cells around the edges of the blastocoele is the first step in yolk sac formation.



Migration of superficial cells into the interior creates a third layer. From the time this process (gastrulation) begins, the superficial layer is called *ectoderm*, the deep layer *endoderm*, and the migrating cells *mesoderm*.

Goal 8.02 Describe formation of the extraembryonic membranes and implantation, with the structure & function of the placenta.

B. Extraembryonic Development

1. **Extraembryonic Membranes** = tissues derived from division of the fertilized ovum, but which are not a part of the embryo, and only function in the prenatal period. There are 4 types:

a. Amnion

= thin membrane enclosing a fluid-filled cavity.

- cushions embryo
- prevents adhesion of embryo & uterine wall

b. Chorion

Trophoblast cells + mesoderm unite to form chorion,
2 types: Smooth chorion fuses to amnion
Villous chorion → placental tissue

c. Allantois

A tube forming in the body stalk – it induces formation of umbilical vessels within umbilical cord

d. Yolk sac

A bag forming off the embryonic gut: it makes blood cells and gametes of the embryo

2. **Implantation**

a. Attachment to endometrium

Occurs about the 6th day after fertilization.

b. Erosion into endometrium

Secretion of enzyme (hyaluronidase) by trophoblast.
The enzyme dissolves endometrial tissue.

c. Fetal placenta development

Trophoblast opens blood-filled spaces in endometrium

Chorion forms villi that hang in the blood pools

Blood vessels arise in villi & grow to join umbilical vessels

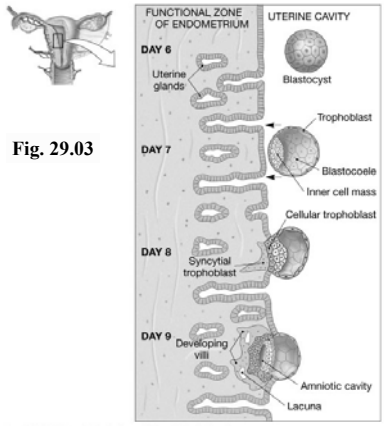
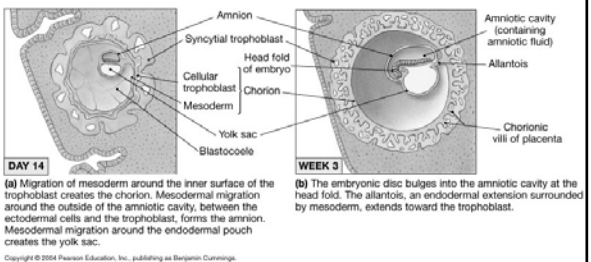


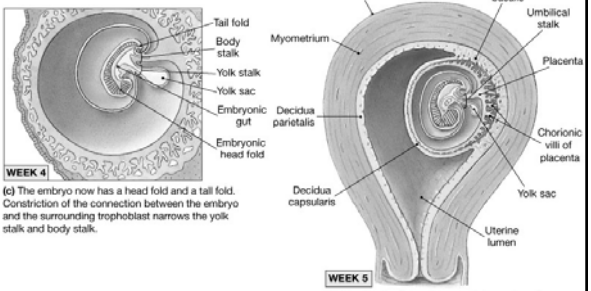
Fig. 29.03

Fig. 29.05



(a) Migration of mesoderm around the inner surface of the trophoblast creates the chorion. Mesodermal migration around the outside of the amniotic cavity, between the ectodermal cells and the trophoblast, forms the amnion. Mesodermal migration around the endodermal pouch creates the yolk sac.

(b) The embryonic disc bulges into the amniotic cavity at the head fold. The allantois, an endodermal extension surrounded by mesoderm, extends toward the trophoblast.

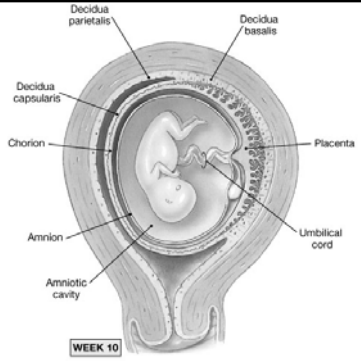


(c) The embryo now has a head fold and a tail fold. Constriction of the connection between the embryo and the surrounding trophoblast narrows the yolk stalk and body stalk.

(d) The developing embryo and extraembryonic membranes bulge into the uterine cavity. The trophoblast pushing out into the uterine lumen remains covered by endometrium but no longer participates in nutrient absorption and embryo support. The embryo moves away from the placenta, and the body stalk and yolk stalk fuse to form an umbilical stalk.

Fig. 29.05, Continued

Fig. 29.05 Concluded



(e) The amnion has expanded greatly, filling the uterine cavity. The fetus is connected to the placenta by an elongated umbilical cord that contains a portion of the allantois, blood vessels, and the remnants of the yolk stalk.

d. Maternal placenta development

Area deep to implanted embryo (decidua basalis of endometrium)

blood pools (placental sinuses) enlarge, become contained by **septae** (walls)

Pools fed by maternal spiral arteries, drained by maternal veins

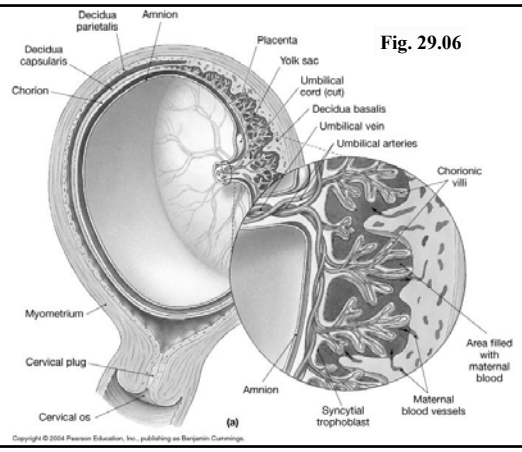


Fig. 29.06

3. Functions of the Placenta

= exchanges between maternal & fetal blood through the placental membrane

a. Nutrient function

Food, water, minerals, & vitamins diffuse through the placental membrane

b. Respiratory function

Fetal Hb has a greater affinity for O_2 than adult Hb, so O_2 moves from mother → fetus & CO_2 is removed

c. Excretory function

Fetal metabolic wastes diffuse into maternal blood

d. Endocrine function

Placental tissue secretes a number of hormones

HCG = human chorionic gonadotropin → Maintains health of corpus luteum. Pregnancy tests detect this substance.

HCS (human chorionic somatomammotropin) → development of mammary glands

Progesterone → maintains secretory phase of endometrium

Estrogen → one signal for initiation of labor (increases irritability of myometrium)

Relaxin → softens cartilage in pubic symphysis

e. Immune function – placenta allows maternal antibodies (IgG) to pass into fetus

Goal 8.03 explain how fraternal twins and identical twins are formed.

C. Twinning

1. Definition = **Multiple** embryo formation, can refer to twins (2), triplets (3), quadruplets (4), quintuplets (5), sextuplets (6), or septuplets (7)

2. Identical or Monozygous twins

a. Develop from a single zygote

= those formed from union of 1sperm + 1 ovum, genetically identical

b. Single or double placentas present (depends on time of separation)

3. Fraternal or dizygotic twins

a. Develop from two zygotes

2 or more ova released, each fertilized by a different sperm; genetically as related as brothers & sisters from different pregnancies with the same parents

b. Always have 2 placentas (or more)

Goal 8.04 List and briefly describe the basic processes in the development of shape and form of an embryo, including induction, cell migration, invagination, evagination, folding, and fusion.

List the systems and tissues derived from ectoderm, endoderm, and mesoderm.

D. Processes

1. **Differentiation**

= specialization of cells in both anatomy & function, forming different types (= committed cell lines)
Starts at beginning of third week of development

2. **Induction** = stimulation of development of a tissue by secretion of chemicals from another tissue

Notocord → nervous tissue; optic cup → lens

3. **Cell migration** = movement of cells from their site of origin to their final location in the embryo

Lateral heart tubes → central location in thorax

4. **Invagination** = pockets that sink into a structure

Formation of archenteron

5. **Evagination** = buds that arise out of a structure

Laryngotracheal bud from pharynx; optic cups from forebrain

6. **Folding & fusion** = action in which structures bend, touch & join

Formation of gut; formation of neural tube

c. Development of three germ layers & derivative structures

Germ layer = embryonic tissue that will form other tissues.
3 types:

1) **Ectoderm**

Produces **nervous tissue, epidermis**, hair, nails, glands of skin, pharyngeal cartilages & throat muscles, & endocrine tissues that are nervous type (adrenal medulla, posterior pituitary)

2) **Endoderm**

Produces **mucosa of GI tract, respiratory tract** & urinary bladder, with **liver & pancreas**; thyroid, thymus & anterior pituitary glands; **& gametes**

3) **Mesoderm**

Everything else: **bones, muscles, connective tissue, blood & vessels, reproductive system, serous membranes, kidneys**

Goal 8.05 Name the time of development of the cardiovascular system, and the origin of the heart and blood cells. Describe the unique features of fetal circulation, including the foramen ovale, ductus arteriosus, ductus venosus, umbilical arteries, umbilical vein, and placental membrane.

E. Cardiovascular Development

1. Early differentiation

a. **Extraembryonic**

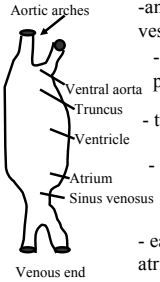
-hemangioblasts on surface of yolk sac differentiate to become **angioblasts** → blood vessels

- **hemocytoblasts** → blood cells both are mesodermal

-vessels grow towards the embryo to join with the vitelline vessels developing in the embryo

-angioblasts in mesoderm of chorion form vessels that connect to the vessels of the allantois to form **umbilical** vessels

b. **Embryonic circulation**



-angioblasts of the mesoderm clump & begin to form vessels

-layers of mesoderm fold anteriorly bringing heart primordia together to form a tubular heart

- tube elongates & bulges out to the side

- heart starts to beat at 3 weeks

- early blood flow involves: sinus venosus → single atrium → single ventricle → bulbus arteriosus → truncus arteriosus → ventral aorta

2. **Development of 4 chambered heart**

a. partitioning of **atria**

= formation of septa that separate right from left

2-step process that leaves an opening, the foramen ovale, with a one-way flutter valve so blood flows R→L

b. fate of **sinus venosus:** Forms **vena cavae**

c. Endocardial cushion

Source of tissue forming interventricular septum

d. partitioning of **ventricles**

Tissue grows inward from periphery & unites to separate R & L ventricles

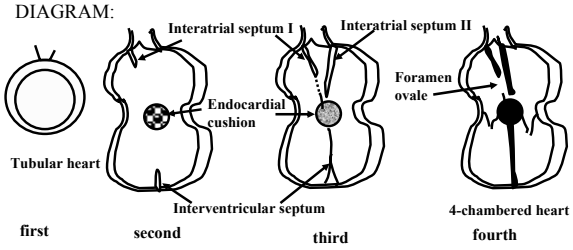
e. fate of **truncus arteriosus**

Divides by a spiral partition into the **aorta** & **pulmonary arteries** ; produces the crossed anatomy of the adult vessels

f. development of valves & chordae tendineae

= last step in the process

DIAGRAM:



3. Unique features of fetal circulation

a. Foramen ovale = opening between R & L atria; bypasses pulmonary circuit

b. Ductus arteriosus

= connection between pulmonary trunk & aorta; bypasses pulmonary circuit

c. Ductus venosus

= connection between umbilical vein & inferior vena cava; bypasses sinusoids & lobules of liver

d. one umbilical vein

= vessel from placenta to fetus; brings oxygen-rich, nutrient-rich blood

e. two umbilical arteries

= vessels from fetus to placenta; brings waste to placenta for exchange into maternal circulation

3. Unique features of fetal circulation

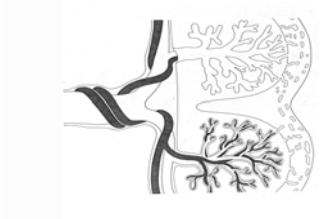
f. placental vessels

From umbilical arteries into chorionic villi of placental capillaries, then out to umbilical vein

4. Placental membrane

= wall of tissue separating maternal from fetal blood; formed of chorionic villi + capillary walls

Fetal blood enters maternal circulation only during the final stage of labor.



Goal 8.06 Briefly describe formation of the nervous system (neurulation) including formation of the neural plate, neural fold, neural tube, neural crest, and nerves. Outline the embryonic development of the three-part brain and the five-part brain, with the origin of the eye and pituitary gland.

F. Nervous System

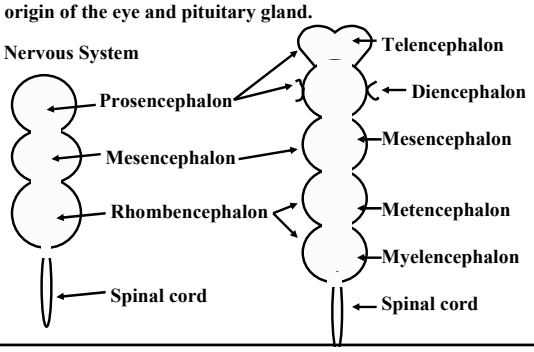


Table 14.1

TABLE 14-1 DEVELOPMENT OF THE BRAIN

Primary Brain Vesicles (3 weeks)	Secondary Brain Vesicles (6 weeks)	Brain Regions at Birth
Prosencephalon	Telencephalon	Cerebrum
	Diencephalon	Diencephalon
Mesencephalon	Mesencephalon	Mesencephalon
Rhombencephalon	Metencephalon	Cerebellum and Pons
	Myelencephalon	Medulla oblongata

1. Neurulation at beginning of third week
= formation of nerve tissue

a. Notocord
= mesodermal rod that secretes compounds **inducing** formation of nervous tissue by the ectoderm

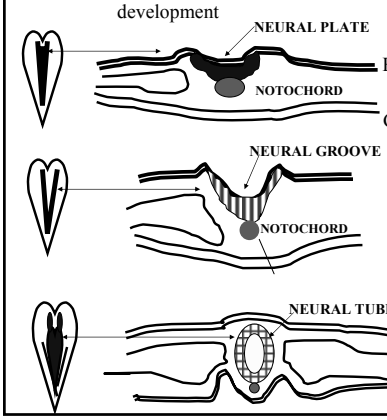
b. Neural plate = thickened, flattened mass of ectoderm

c. Neural groove & neural folds
= formation of a valley (groove) as ridges(folds) rise up

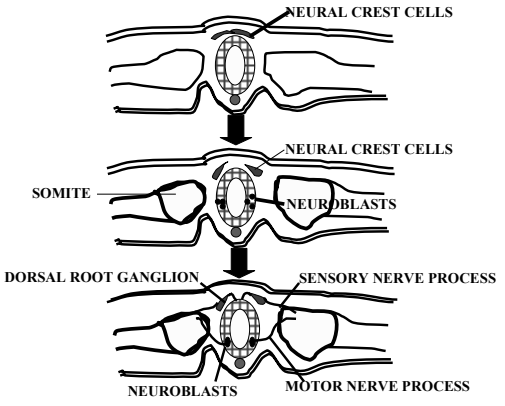
d. Neural tube
Fusion of ridges forms a cylinder (tube), develops into brain & spinal cord

e. Neural Crest Cells
From the folds, these masses become ganglia & peripheral nerves

DIAGRAM: Cross-sections of embryos at successive stages of neural development



Blue = Ectoderm
Red = Mesoderm
Green = Endoderm

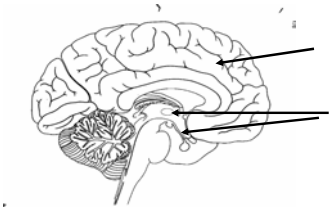


2. Brain development begins by week four

a. Forebrain (Prosencephalon) → telencephalon & diencephalon

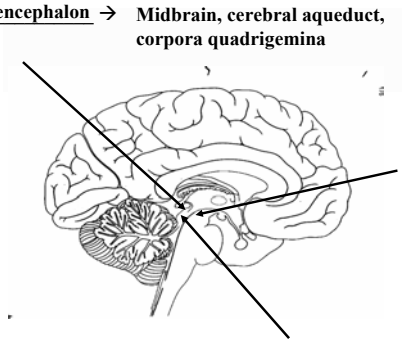
- telencephalon → cerebral hemispheres & lateral ventricles

- diencephalon → thalamus, hypothalamus, 3rd ventricle, pineal gland, optic vesicles



b. Midbrain (Mesencephalon) → mesencephalon

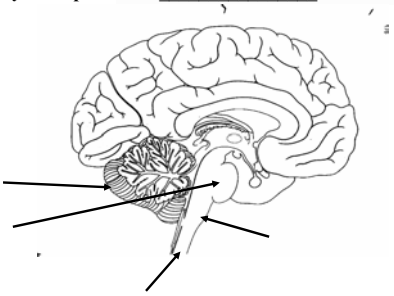
- Mesencephalon → Midbrain, cerebral aqueduct, corpora quadrigemina



c. Hindbrain (Rhombencephalon) → metencephalon & myelencephalon

- metencephalon → cerebellum, pons, & 4th ventricle

- myelencephalon → medulla



d. Neural tube → spinal cord with central canal

3. Development of cranial & spinal nerves

a. Neural crest cells

→ Spinal nerves, sensory neurons, cranial nerves, autonomic chain, autonomic nerves

b. Mantle layer (of neural tube)

→ Grey matter of spinal cord, motor neurons

4. Development of the eye

a. Optic vesicles at four weeks

Begin as buds evaginating from forebrain (ectoderm)

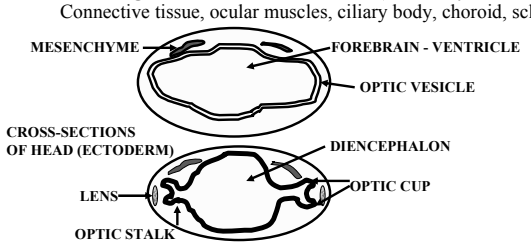
b. Optic cup at five weeks

Retina & optic nerve form from diencephalon of forebrain

c. Lens Optic cup **induces** formation of lens in the skin over the cup

d. Remaining structures from mesoderm (mesenchyme tissue)

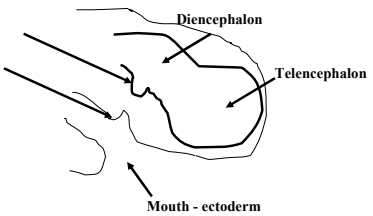
Connective tissue, ocular muscles, ciliary body, choroid, sclera



5. Development of pituitary gland:

a. Posterior pituitary with infundibulum, evaginates from hypothalamus of diencephalon (= nerve tissue, ectoderm)

b. Anterior pituitary Evagination of ectoderm of roof of mouth (glandular epithelium)



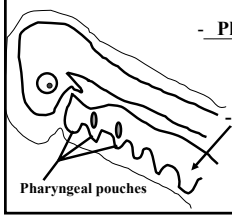
Goal 8.07 Briefly describe formation of the gut, and list the organs derived from the gut. Include the pharyngeal pouches, respiratory tree, foregut, midgut, and hindgut.

G. Development of the GI Tract

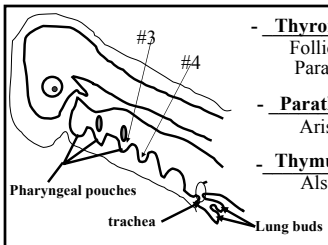
1. Formation of **foregut**

a. Lifting of embryo off the embryonic disc and undercutting and folding of the germ layers result in the formation of the foregut

b. **Pharynx** Evagination of endoderm produces pockets (pouches)



- **Pharyngeal pouches**
  - #1 → middle ear + auditory tubes
  - #2 → palatine tonsils
- **Laryngotracheal groove**
  - From posterior pharynx, produces respiratory tree



- **Thyroid**
  - Follicles from pouches #3 & #4
  - Parafollicular cells from #4
- **Parathyroid**
  - Arise from pouches #3 & #4
- **Thymus**
  - Also from pouches #3 & #4

c. Esophagus & stomach

Separate from trachea at posterior pharynx.

Stomach forms by dilation of lower foregut.

2. Formation of the hindgut

a. Lifting of caudal end of embryo, undercutting and folding of the germ layers result in the formation of the hindgut

Initially = a **cloaca** (Latin for "sewer"), where 3 systems empty: GI, urinary, & reproductive

b. Hindgut differentiates

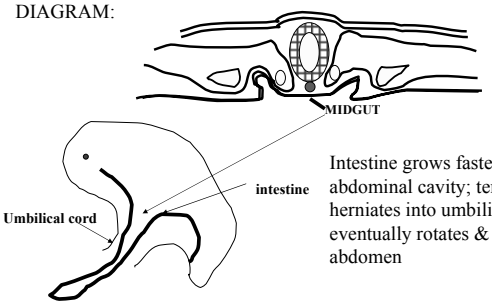
- forms half of colon + rectum & anus
- **anal plate** = partition separating the colon from a urogenital sinus
- **allantoic stalk**
  - opens to the hindgut. The bladder develops from the inner part of the allantois.

3. **Midgut**

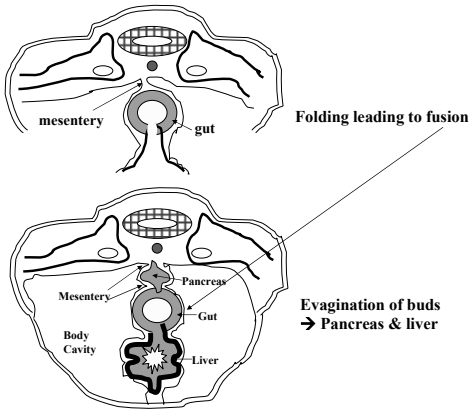
a. This is the portion of gut that remains open until later in development. Forms small intestine + half of colon.

b. Eventual closure of foregut and hindgut obliterate the midgut.

DIAGRAM:



Intestine grows faster than abdominal cavity; temporarily herniates into umbilical cord; eventually rotates & returns to abdomen



Goal 8.08 Describe the embryonic urogenital system at the indifferent stage, and name the differences in development that lead to the establishment of the urinary system and the internal and external reproductive organs of the male and female.

H. **Urogenital** = Urinary + Reproductive Systems

1. Urinary tract → 3-stage development process

a. Pronephros = "forekidney", nonfunctional, regresses

Ducts of this structure → paramesonephric ducts

b. Mesonephros

= "midkidney"; functions for a time, then regresses

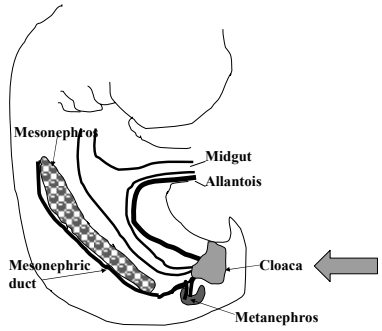
Mesonephric ducts remain

c. Metanephros

= "hind kidney"; functional, permanent kidney.

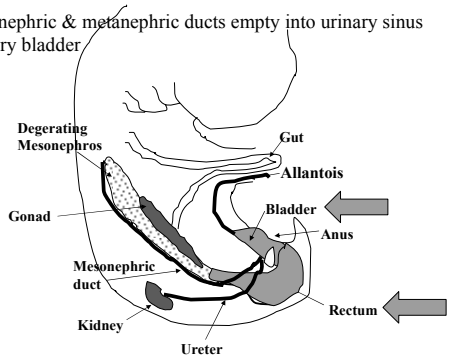
Helps regulate volume of amniotic fluid, which is swallowed, absorbed, & excreted by the fetus

As the kidneys & ducts develop, all empty into the cloaca (common chamber) at first:



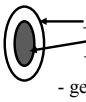
d. Division of hindgut into dorsal **rectum** & ventral urinary **sinus** continuous with the allantois

e. Mesonephric & metanephric ducts empty into urinary sinus → urinary bladder



2. Reproductive tract

a. Early internal changes



Cortex develops in females → follicle formation

Medulla develops in males → seminiferous tubules

- genetic sex determined at conception, (XX or XY)

- **Gonads** developed in medial border of mesonephros

- **Germ cells** develop in yolk sac & migrate to gonad

= oogonia & spermatogonia

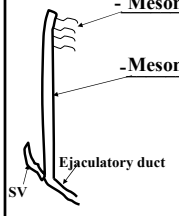
- gonads descend into pelvic cavity, eventually

Posterior to uterine tubes in females

Into scrotum in male, near the time of birth

b. Development of duct systems

1) Male



- **Mesonephric** tubules → Efferent ducts between rete testis & epididymis

- **Mesonephric** ducts → Epididymis & vas deferens, ejaculatory ducts & seminal vesicles

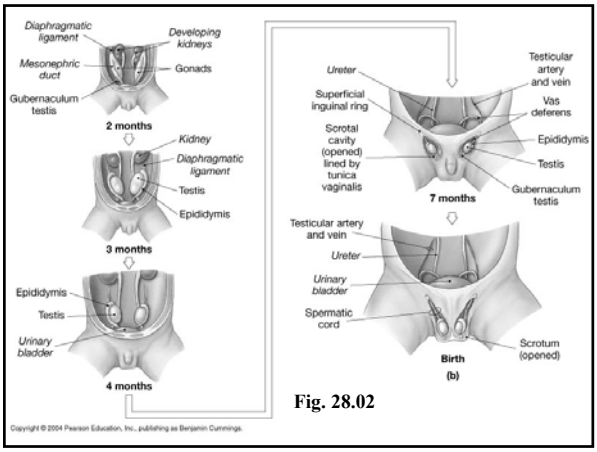
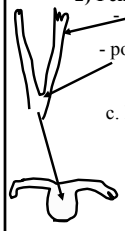


Fig. 28.02

2) Female



- anterior part of **paramesonephric** ducts → **Uterine tubes**

- posterior part of **paramesonephric** ducts
  Fuse & enlarge → **uterus**

c. Influences on development

1) Both sexes have both duct systems developed

2) Further development is determined by genotype

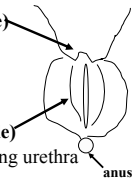
3) Effect of **testosterone** Secretion begins in ~ 7th week
→ Formation of **male** system. Absence of testosterone → **female** development.

Testosterone programs brain for continuous, low-level release of FSH & LH

Estrogen programs brain to release FSH & LH in pulses

3. External **genitalia** In both sexes, these are identical initially
("→" means "becomes the" in the notes following:

a. Indifferent stage= at 7 weeks, 4 external structures present

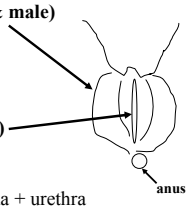


- **genital tubercle (female & male)**
  In male → glans, erectile tissues
  In female → glans, erectile tissues

- **urethral folds (female & male)**
  In males → body of penis, enclosing urethra
  In females → labia minora

- **Labioscrotal swellings (female & male)**
  In males → scrotum
  In females → labia majora

- **Urogenital sinus (female & male)**
  In males → urethra
  In females → separates into vagina + urethra

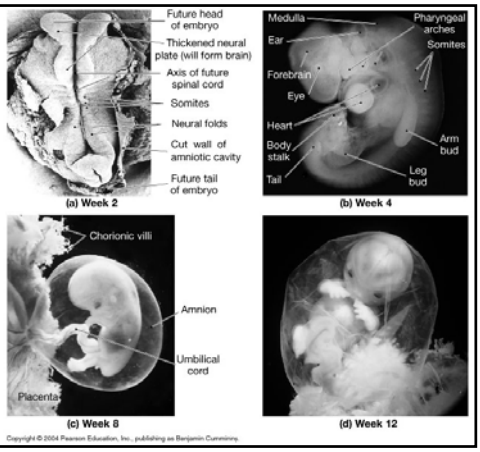


What happens if the partition between **urogenital sinus & rectum** fails to develop in a fetus?

What happens if the partition that separates **urethra from vagina** fails to develop?

What happens if the external genitalia are **influenced by abnormal levels of testosterone** in a genetically female fetus?

What happens if the **receptors for testosterone** fail to function in the cells of a genetically male fetus?



Teratogenic Influences

These are physical & chemical factors that cause damage to a genetically normal embryo & fetus during intrauterine development.

Prenatal death results from damage occurring in the first 2 weeks of development.

In the following summary chart, major morphological deformities are indicated by **X,** physiological defects &/or minor morphological deformities are indicated by **-**.

Weeks 3	4	5	6	7	8	12	16	20-36
CNS XXXX	XXXX	XXXX	-------	-------	-------	-------	-------	-------
HEART XXXX	XXXX	XXXX	XX---	-------	-------			
ARMS LEGS	XX	XXXX	XXXX	XXXX	-----			
EARS	XXXX	XXXX	XXXX	XXXX	XXXX	XXX--	-------	
EYES	XX	XXXX	XXXX	XXXX	XX----	-------	--------	-------
TEETH			X	XXXX	XXXX	-------	--------	
EXT. GENIT-ALIA				XXX	XXXX	XXXX	-------	--------

Chart modified & updated from Fig. 8-12 in The Developing Human, Clinically Oriented Embryology by Keith Moore, W.B. Saunders (1973).