Lecture - Gastrointestinal Development

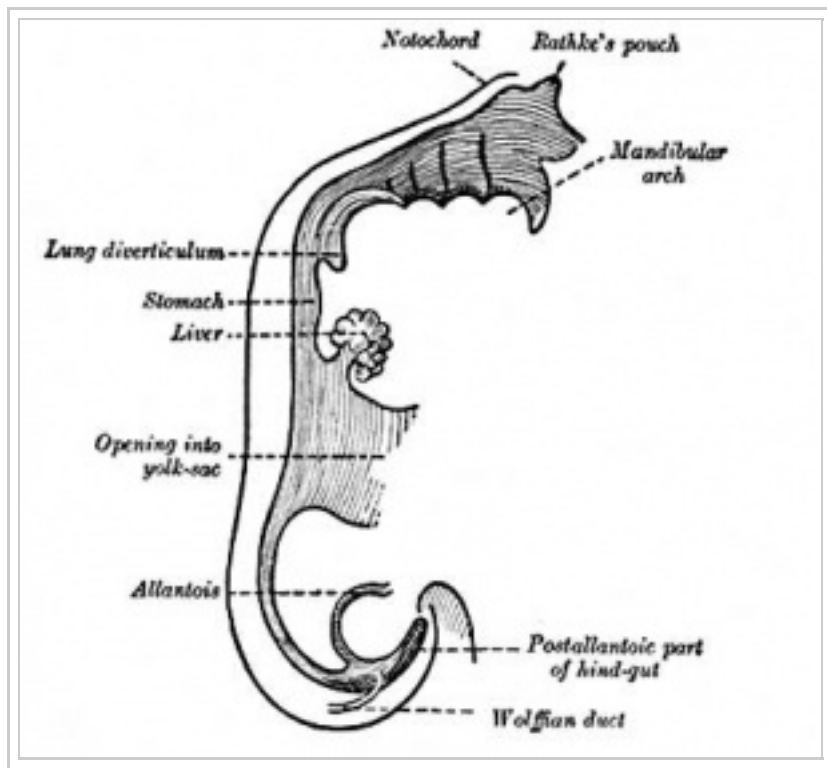
From Embryology

Embryology - 31 Aug 2015 Translate **[Expand]**

Endoderm Development

Introduction

This lecture will cover the early development of the endoderm layer of the trilaminar embryo as it contributes to the lining, glands and organs of the gastrointestinal tract (**GIT**).



The early developing gastrointestinal tract

Gastrulation, or gut formation, was historically the easiest observable feature of frog development. In human development, during the 4th week the 3 distinct portions (fore-, mid- and hind-gut) extend the length of the embryo and will contribute different structures.

The oral cavity (mouth) is formed following breakdown of the buccopharyngeal membrane (= oropharyngeal or oral) and the opening means that it contains amniotic fluid, which is also swallowed later in development.

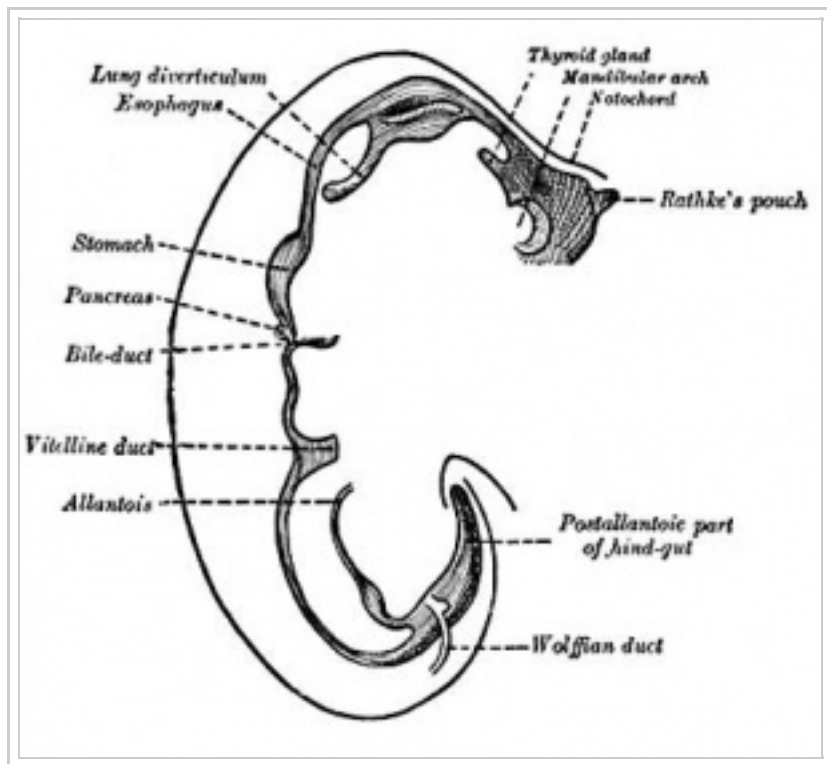
The large mid-gut is generated by lateral embryonic folding which "pinches off" a pocket of the yolk sac, the 2 compartments continue to communicate through the vitelline duct.

The hindgut (cloaca) will later be divided into separate urogenital and rectal regions that end at the cloacal membrane.

Note that we will be returning in the laboratory and later (head, endocrine, neural crest) to discuss the gastrointestinal tract, associated organs and physical growth changes.

Lecture Objectives

- Understanding of germ layer contributions to the early gastrointestinal tract (GIT)
- Understanding of the folding of the GIT
- Understanding of three main GIT embryonic divisions
- Understanding of associated organ development (liver, pancreas, spleen)
- Brief understanding of mechanical changes (rotations) during GIT development
- Brief understanding of gastrointestinal abnormalities



The later developing gastrointestinal tract

Lecture Resources

Movies[Expand]

References [Collapse]	
Hill, M.A. (2015). *UNSW Embryology* (15th ed.) Retrieved August 31, 2015, from https://embryology.med.unsw.edu.au	**GIT Links**: Introduction | Medicine Lecture | **Science Lecture** | Endoderm | Stomach | Liver | Gall Bladder | Pancreas | Intestine | Tongue | Taste | Enteric Nervous System | Stage 13 | Stage 22 | Abnormalities | Movies | Postnatal | Milk | Tooth | Tongue | BGD Lecture | BGD Practical | Category:Gastrointestinal Tract **GIT Histology Links**: Upper GIT | Salivary Gland | Smooth Muscle Histology | Liver | Gall Bladder | Pancreas | Colon | Histology Stains | Histology | GIT Development **Historic Embryology[Expand]** ▪ Lecture Archive: 2014 (https://embryology.med.unsw.edu.au/embryology/index.php?title=Lecture_-_Gastrointestinal_Development&oldid=195582) | 2014 Lecture 9 PDF
Moore, K.L., Persaud, T.V.N. & Torchia, M.G. (2011). *The developing human: clinically oriented embryology* (9th ed.). Philadelphia: Saunders.	The following chapter links only work with a UNSW connection. ▪ Alimentary System (http://www.unsw.eblib.com.wwwproxy0.library.unsw.edu.au/patron/Read.aspx?p=1430154&pg=235)
Schoenwolf, G.C., Bleyl, S.B., Brauer, P.R. & Francis-West, P.H. (2009). *Larsen's human embryology* (4th ed.). New York; Edinburgh: Churchill Livingstone.	The following chapter links only work with a UNSW connection. ▪ Chapter 14 - Development of the Gastrointestinal Tract

Germ Layer Contributions

- **Endoderm** - epithelium and associated glands.
- **Mesoderm** (splanchnic) - mesentry, connective tissues, smooth muscle, blood vessels.
- **Ectoderm** (neural crest) - enteric nervous system.

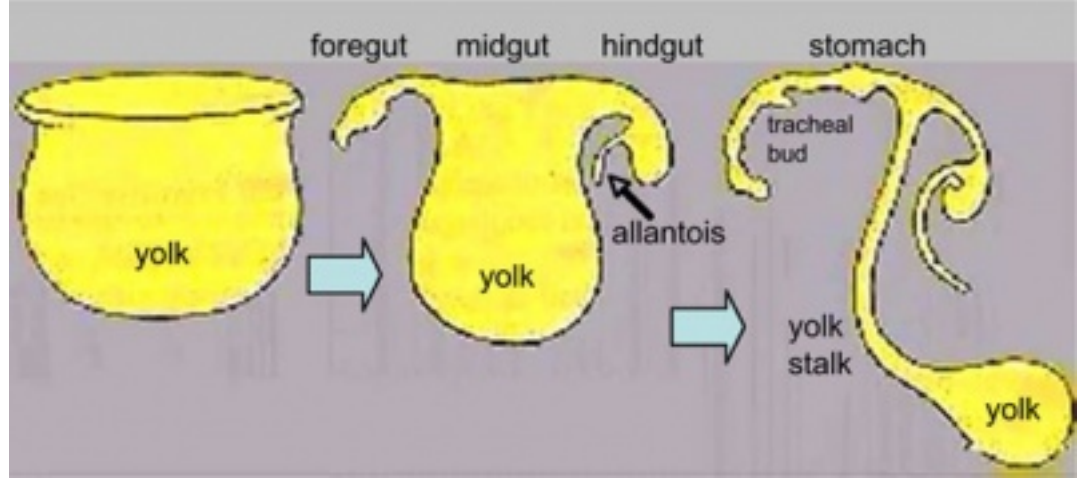
Both endoderm and mesoderm will contribute to associated organs.

Folding of the embryonic disc occurs ventrally around the notochord, which forms a rod-like region running rostro-caudally in the midline.

In relation to the notochord:

- **Laterally** (either side of the notochord) lies mesoderm.
- **Rostrally** (above the notochord end) lies the buccopharyngeal membrane, above this again is the mesoderm region forming the heart.
- **Caudally** (below the notochord end) lies the primitive streak (where gastrulation occurred), below this again is the cloacal membrane.
- **Dorsally** (above the notochord) lies the neural tube then ectoderm.
- **Ventrally** (beneath the notochord) lies the mesoderm then endoderm.

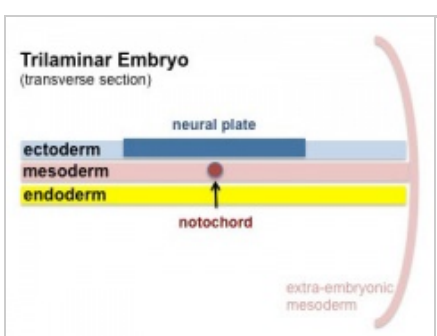
The ventral endoderm (shown yellow) has grown to line a space called the yolk sac. Folding of the embryonic disc "pinches off" part of this yolk sac forming the first primative GIT.



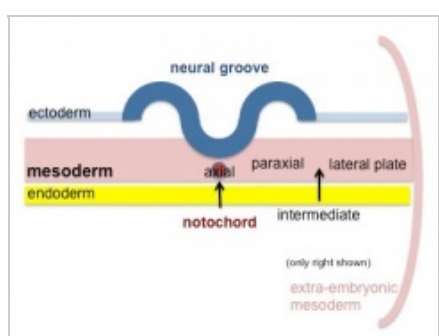
Coelomic Cavity

- The mesoderm initially undergoes segmentation to form paraxial, intermediate mesoderm and **lateral plate mesoderm**.
- Paraxial mesoderm segments into somites and lateral plate mesoderm divides into somatic and **splanchnic mesoderm**.
- The space forming between them is the **coelomic cavity**, that will form the 3 major body cavities (pericardial, pleural, **peritoneal**)
- Most of the gastrointestinal tract will eventually lie within the peritoneal cavity.

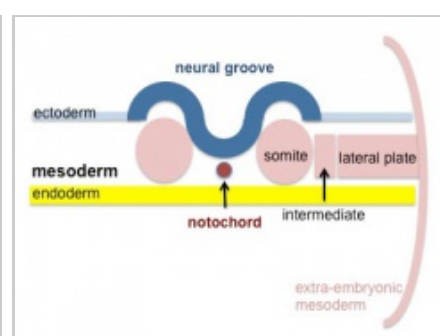
Mesoderm and Ectoderm Cartoons



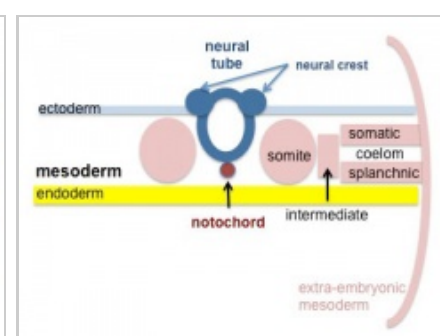
Trilaminar Embryo



Paraxial and Lateral Plate



Somites

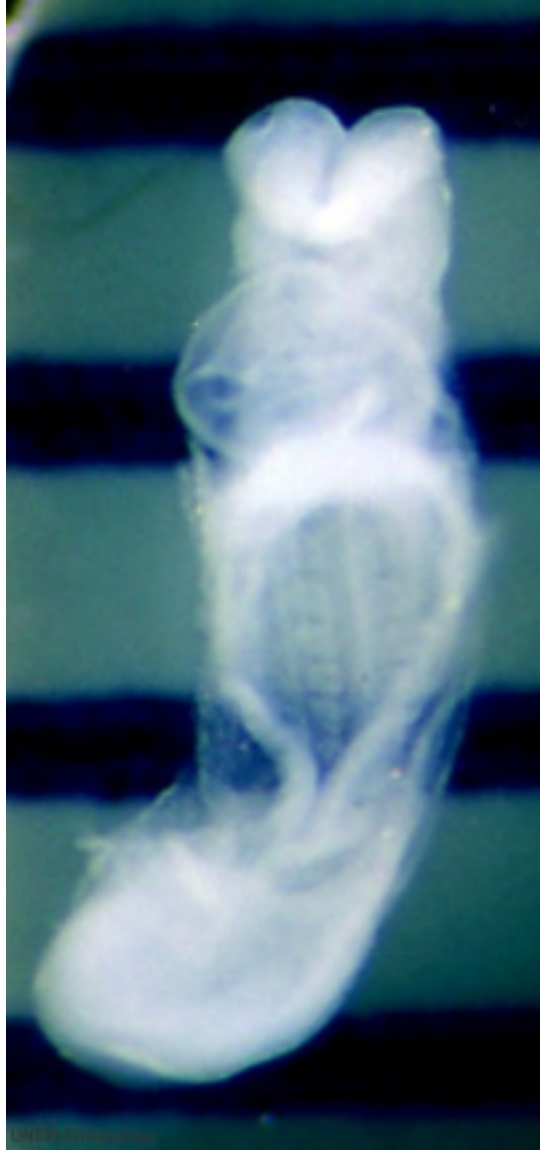


Somatic and Splanchnic

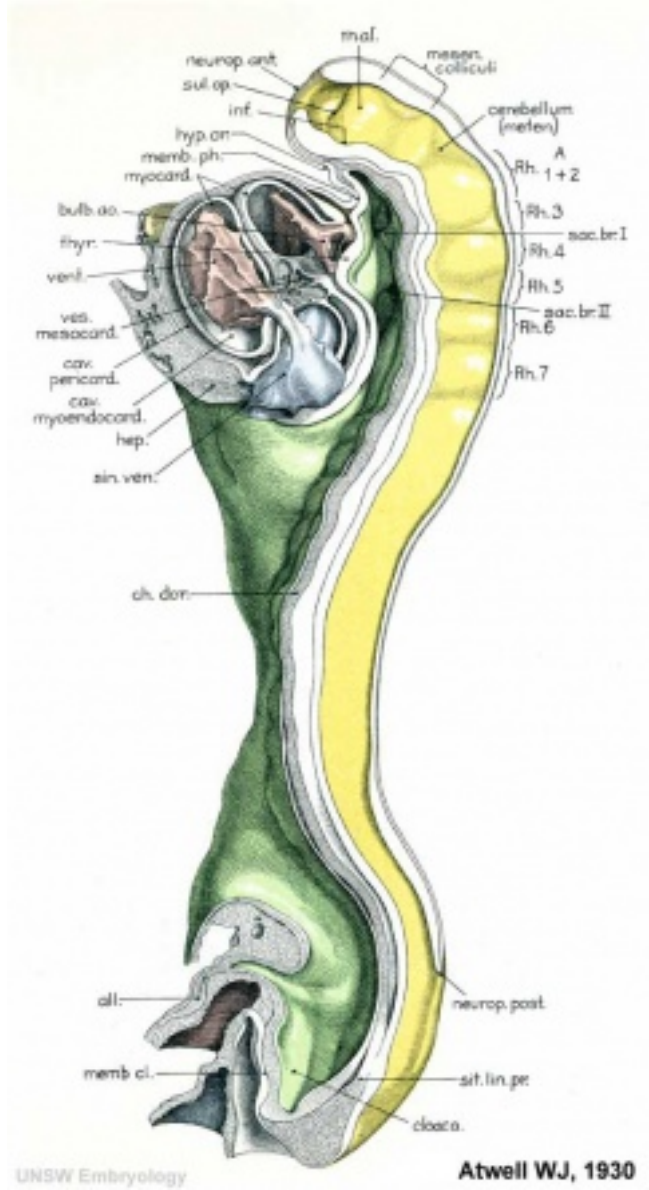
(Note only the righhand side is shown, lefthand side would be identical.)

Week 4

(Gestational age **GA** 6 weeks) Carnegie stage 11

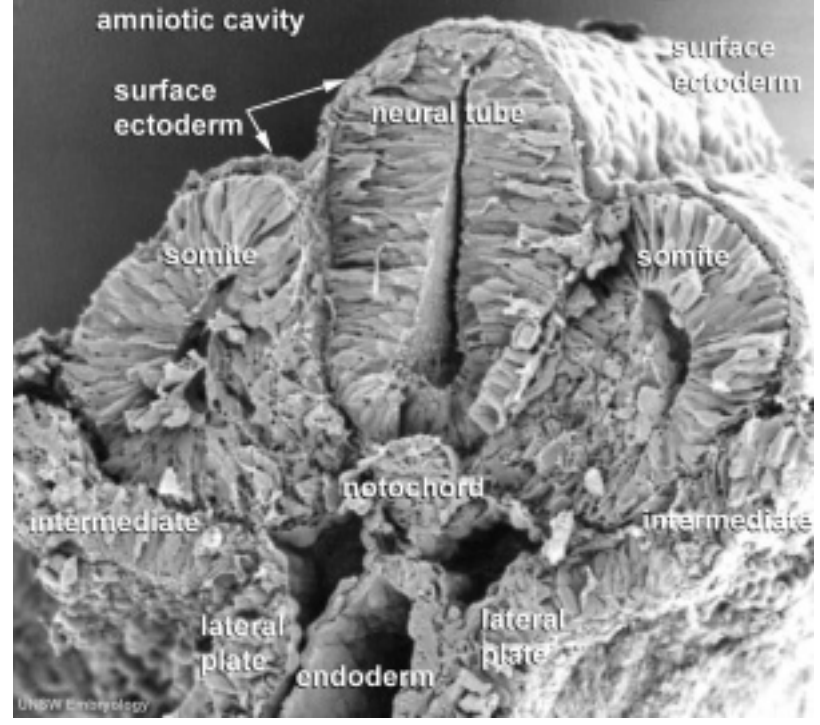


Embryo (stage 11 ventral view)

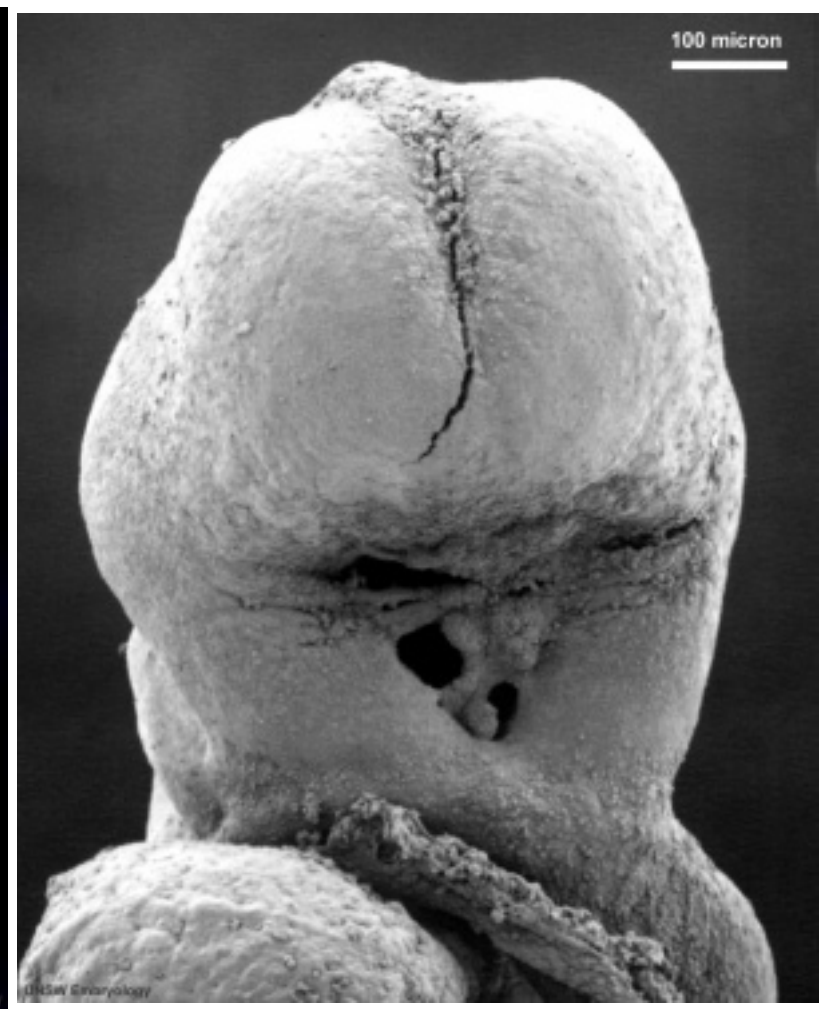


Atwell WJ, 1930

Embryo (midline section)

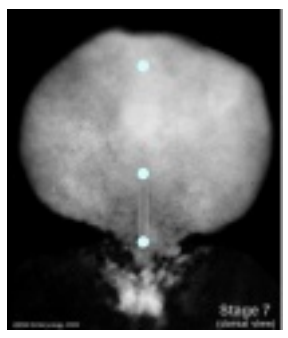


Embryo (EM section) endoderm, splanchnic mesoderm, Intraembryonic coelom



Stomodeum

Buccopharyngeal membrane



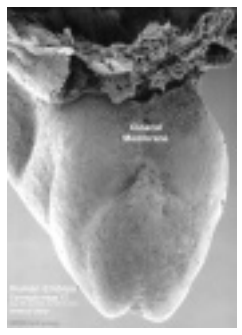
Stage 7 Membranes

Stage 11 25 days, Low power ventral view of the Buccopharyngeal Membrane

Higher power ventrolateral view of the Buccopharyngeal Membrane

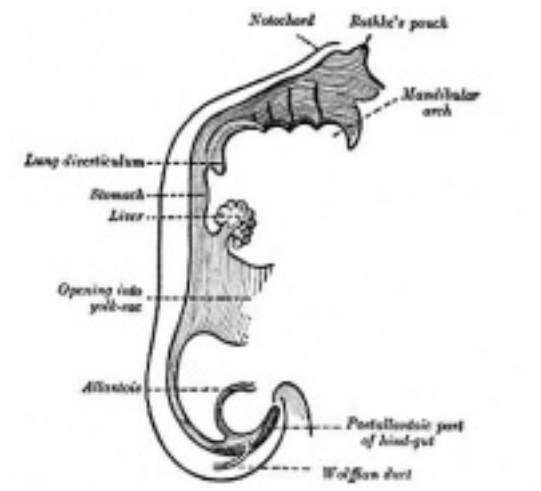
Close up view of the degenerating Buccopharyngeal Membrane

Stage 12 Week 4, 26 days



Stage 12 Cloacal membrane

Liver Development

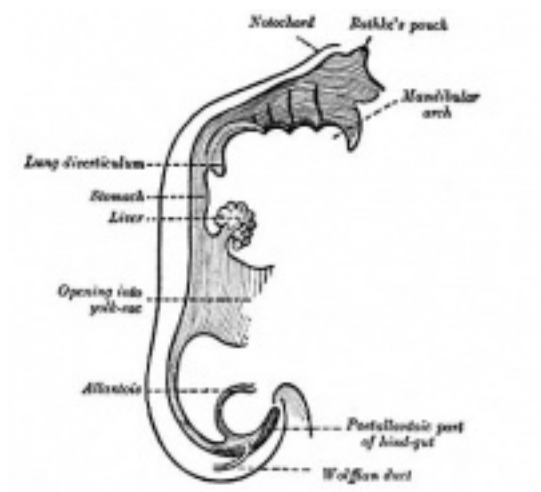


Endoderm and splanchnic mesoderm at the level of the transverse septum (week 4)

- Stage 11 - hepatic diverticulum development
- Stage 12 - cell differentiation, septum transversum forming liver stroma, hepatic diverticulum forming hepatic trabeculae
- Stage 13 - epithelial cord proliferation enmeshing stromal capillaries

The liver initially occupies the entire anterior body. All blood vessels enter the liver (placental, vitelline) and leave to enter the heart.

Stomach



Stomach Rotation

Page | Play

- During week 4 at the level where the stomach will form the tube begins to dilate, forming an **enlarged lumen**.
- The dorsal border grows more rapidly than ventral first rotation (of 90 degrees), which establishes the greater curvature of the stomach.
- A second rotation (of 90 degrees) occurs on the longitudinal axis establishing the adult orientation of the stomach.

Week 5

(**GA** 7 weeks)

Canalization

Tract Growth

Page | Play

- Beginning at week 5 endoderm in the GIT wall proliferates
- By week 6 totally blocking (occluding)
- over the next two weeks this tissue degenerates reforming a hollow gut tube.
- By the end of week 8 the GIT endoderm tube is a tube once more.
- The process is called recanalization (hollow, then solid, then hollow again)
- Abnormalities in this process can lead to abnormalities such as atresia, stenosis or duplications.

Mesentery Development

Greater Omentum

Page | Play

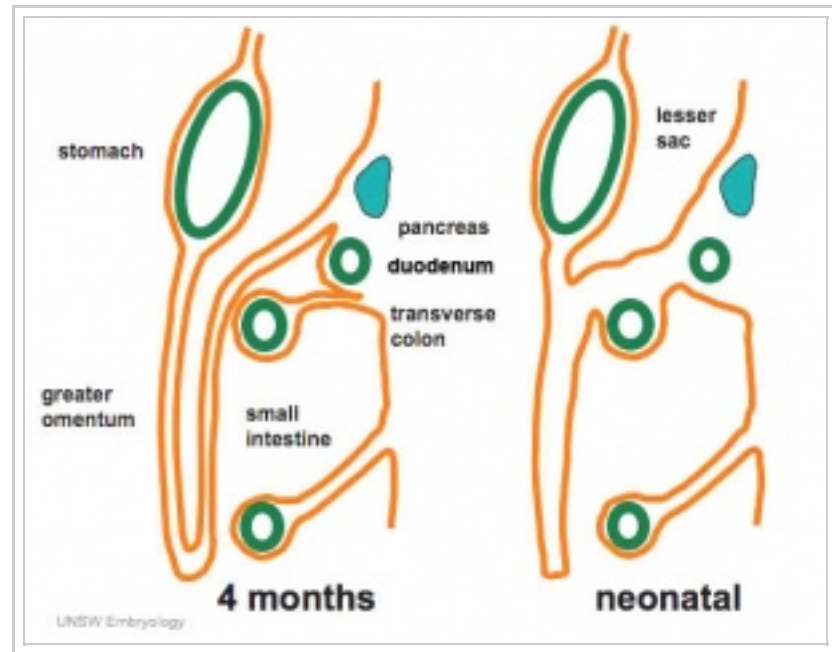
Lesser sac

Page | Play

- Ventral mesentery lost except at level of stomach and liver.
  - contributing the lesser omentum and falciform ligament.
- Dorsal mesentery forms the adult structure along the length of the tract and allows blood vessel, lymph and neural connection.
- At the level of the stomach the dorsal mesogastrium extends as a fold forming the greater omentum
  - continues to grow and extend down into the peritoneal cavity and eventually lies anterior to the small intestines.
  - This fold of mesentery will also fuse to form a single sheet.

Spleen

- Mesoderm within the dorsal mesogastrium (week 5) form a long strip of cells adjacent to the forming stomach above the developing pancreas.
- Vascular and immune organ, no direct GIT function.

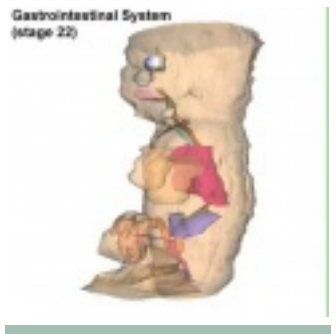


Greater Omentum

Week 8 - 10

(**GA** 10-12 weeks)

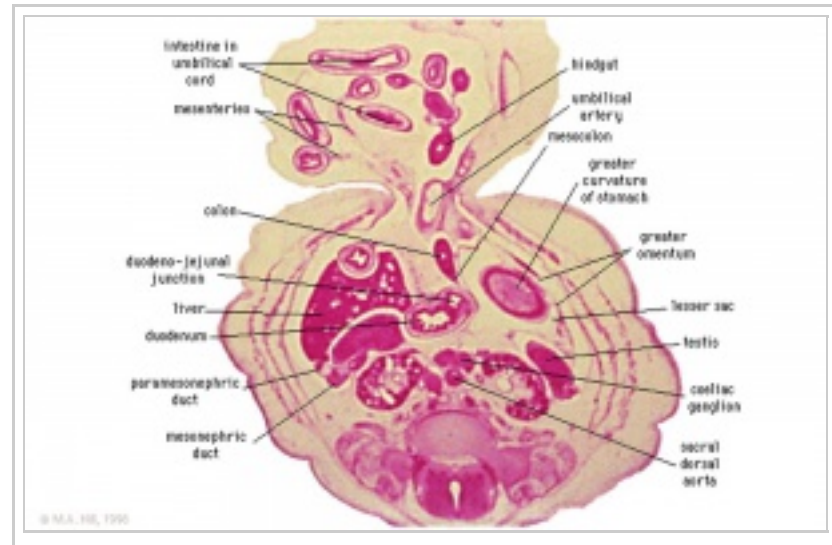
Intestine Herniation



Gastrointestinal

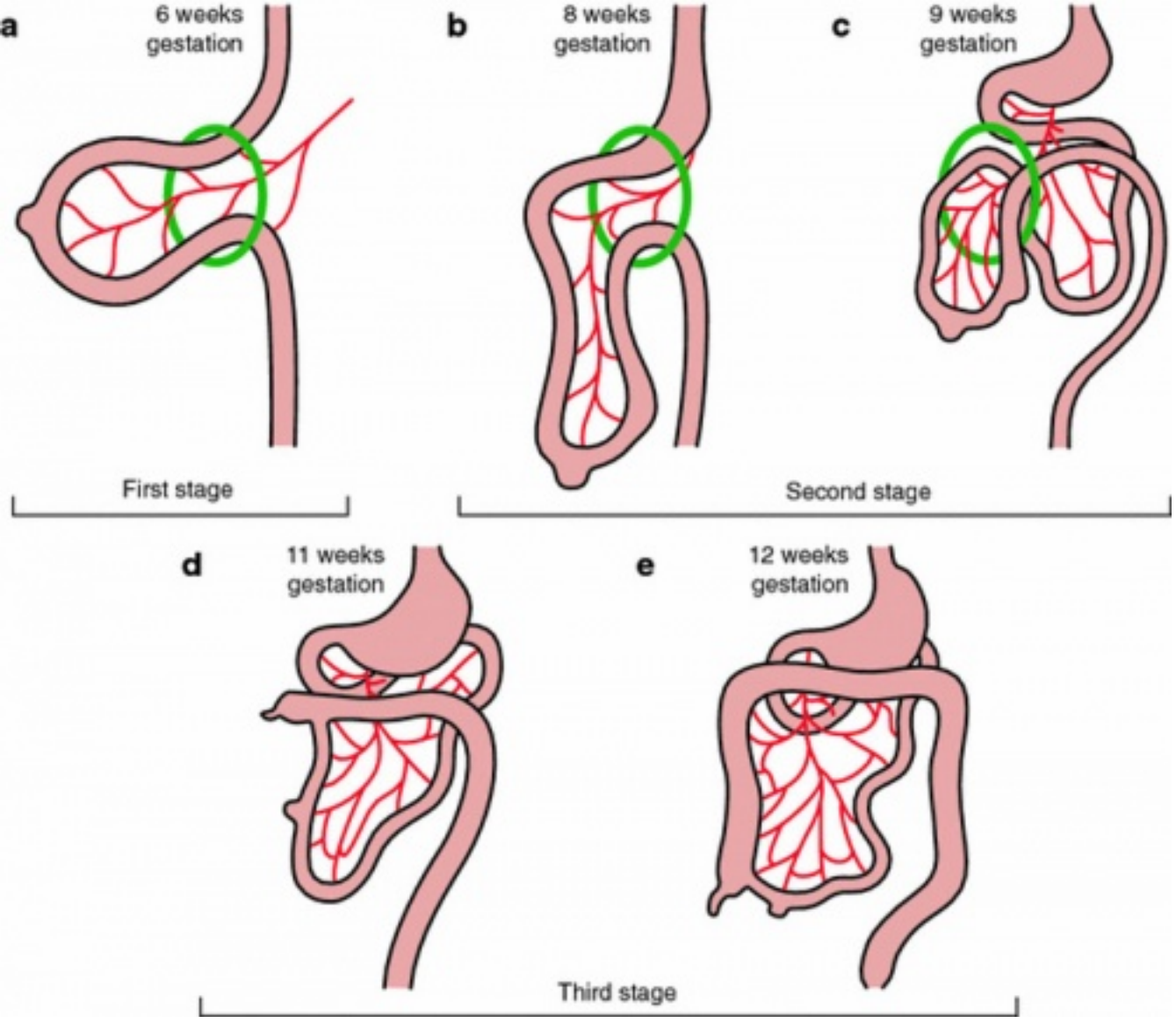
Page | Play

- **neural crest** migration into the wall forms enteric nervous system (peristalsis, secretion)
- midgut grows in length as a loop extending ventrally, returning as hindgut
- connected by dorsal mesentery
- rotates to form adult anatomical position (abnormalities of rotation)
- continued body growth "engulfs" the intestine by about week 11.



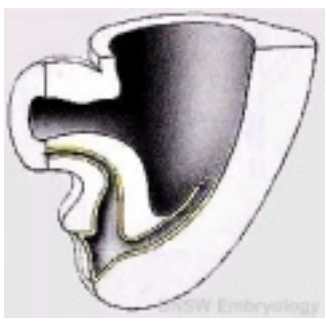
Week 8 herniated midgut

Intestine Rotation



Normal intestinal rotation (note these are gestational age **GA** weeks)[1]

Hindgut



Urogenital Septum

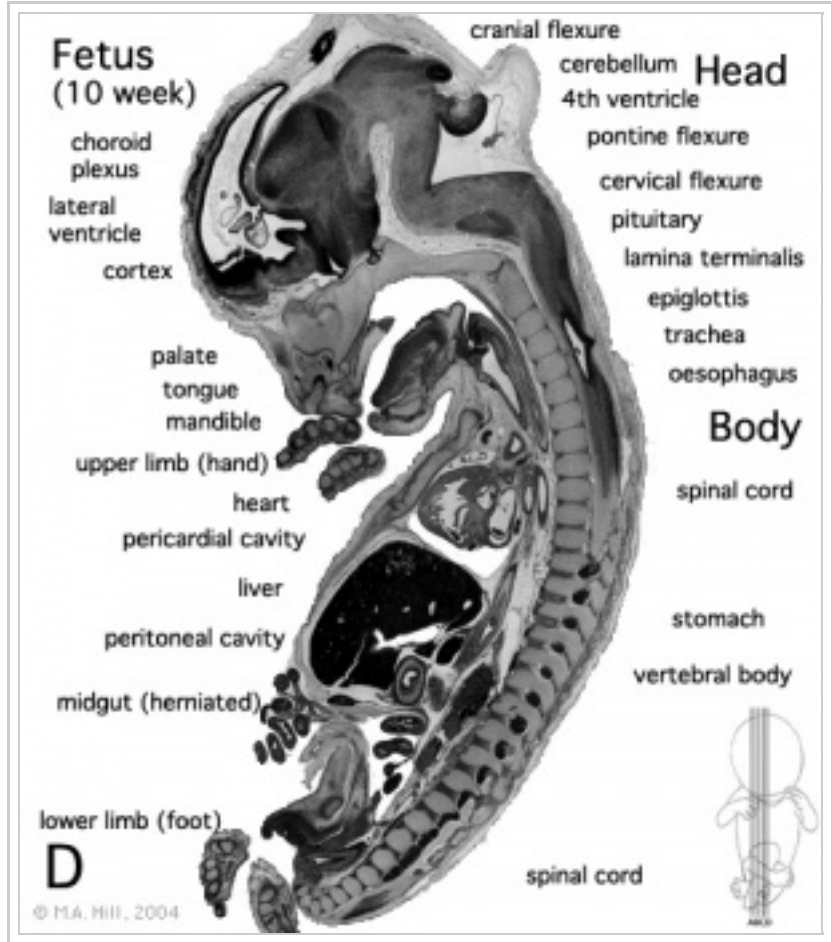
Page | Play

- Initially the **cloaca** forms a common urinary, genital, GIT space
- This is divided by formation of a **septum** into anterior urinary and dorsal rectal (superior Tourneux fold; lateral Rathke folds)
- hindgut - distal third transverse colon, descending and sigmoid colon, rectum.
- anal pit - distal third of anorectal canal (ectodermal)

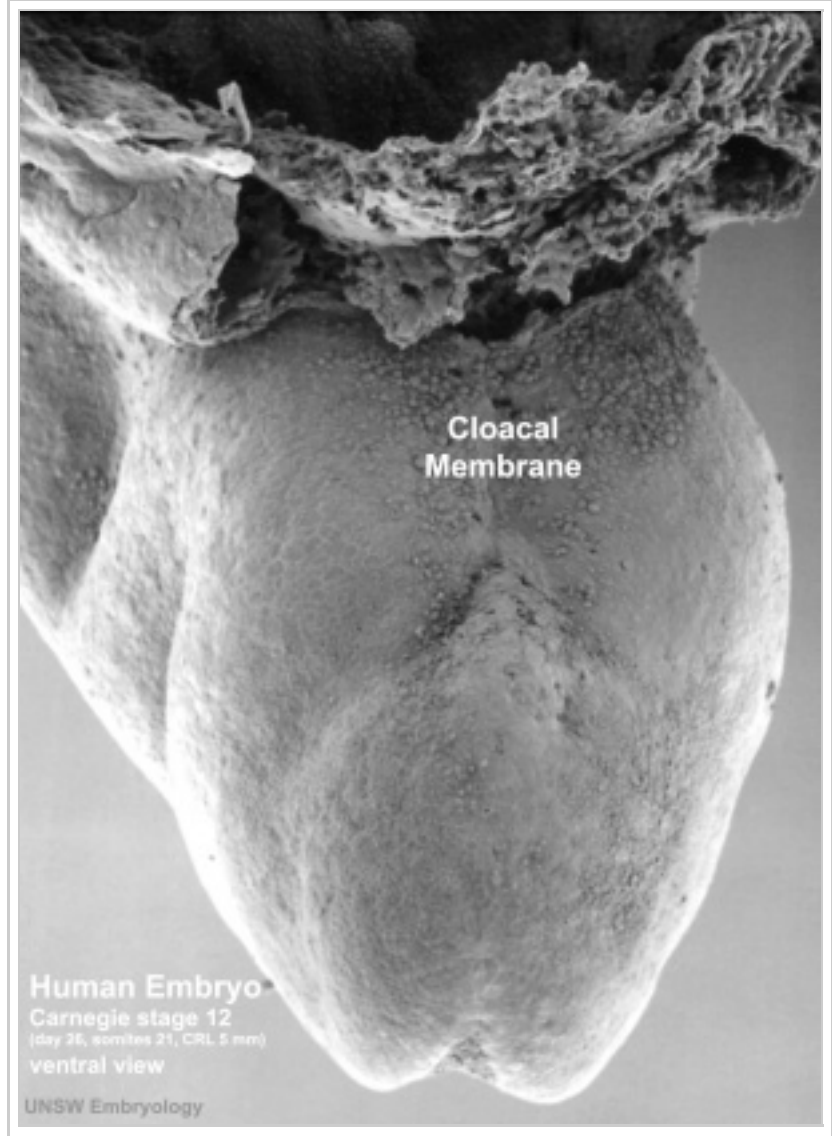
Gastrointestinal Tract Divisions

During the 4th week the 3 distinct portions (fore-, mid- and hind-gut) extend the length of the embryo and will contribute different components of the GIT. These 3 divisions are also later defined by the vascular (artery) supply to each of theses divisions.

1. **Foregut** - celiac artery (Adult: pharynx, esophagus, stomach, upper duodenum, respiratory tract, liver, gallbladder pancreas)
2. **Midgut** - superior mesenteric artery (Adult: lower duodenum,



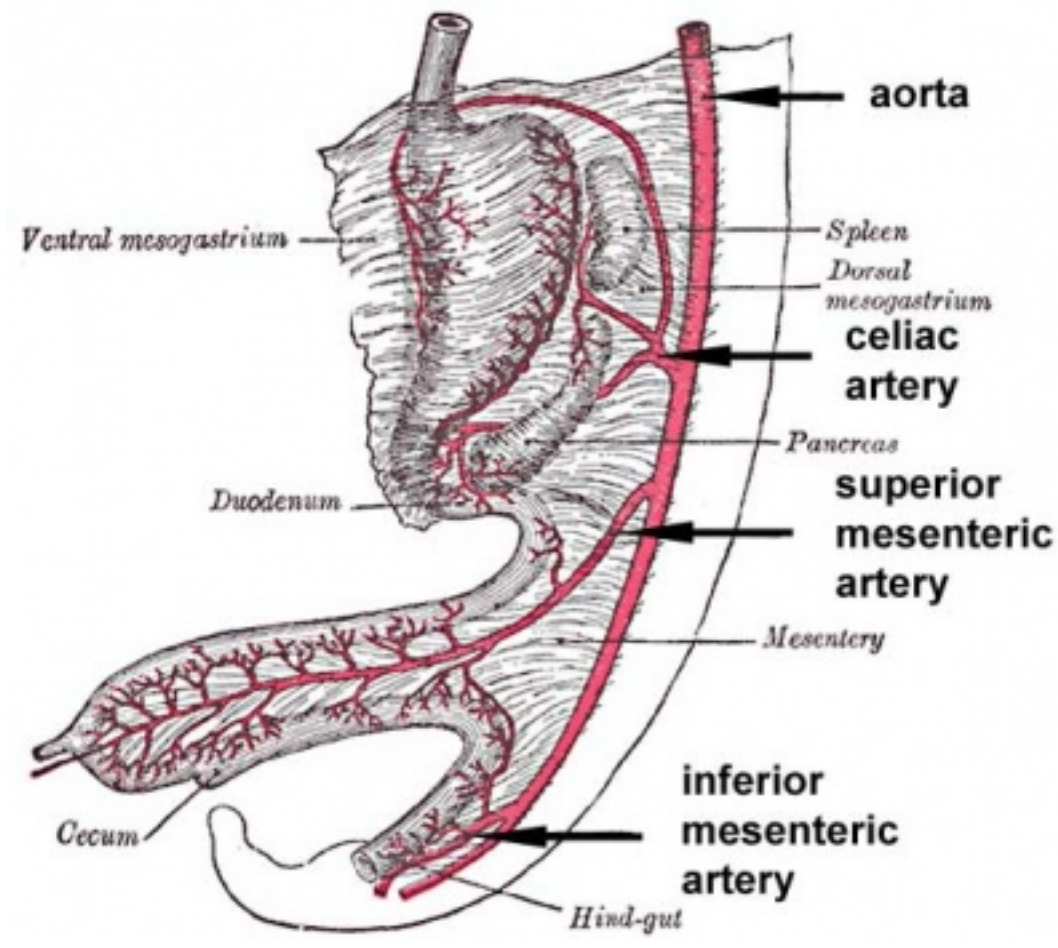
Week 10



Cloacal membrane (Week 4, Stage 12)

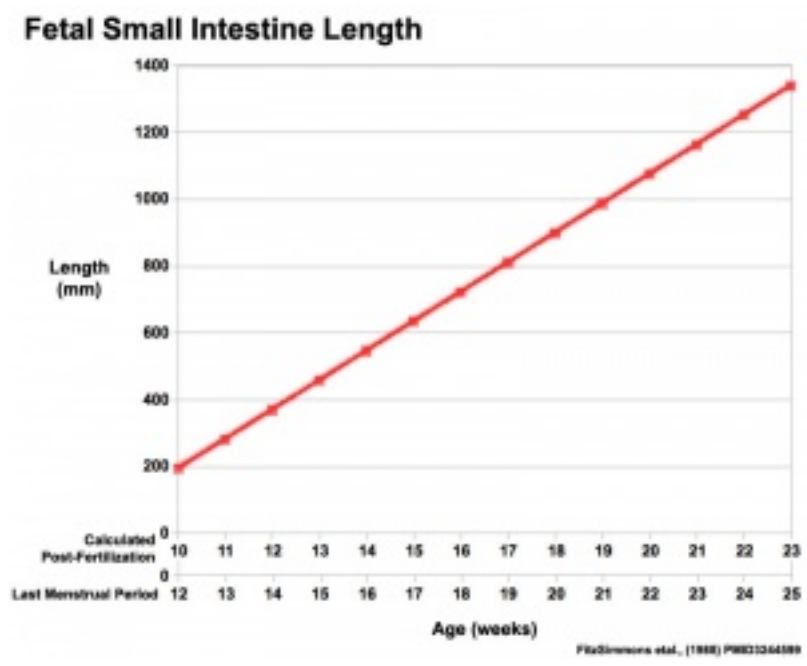
jejunum, ileum, cecum, appendix, ascending colon, half transverse colon)

3. **Hindgut** - inferior mesenteric artery (Adult: half transverse colon, descending colon, rectum, superior part anal canal)

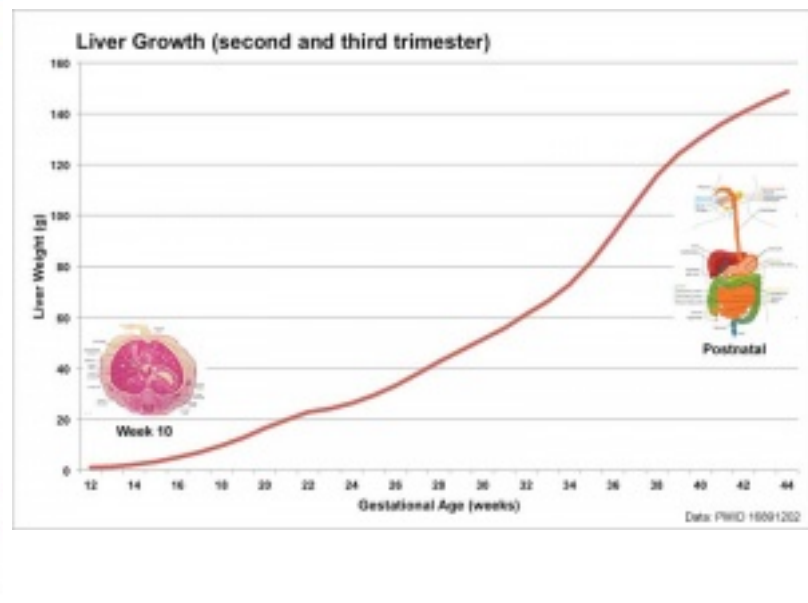


Gastrointestinal Tract Blood Supply

Fetal



Small Intestine length (mm)



Liver Growth (weight grams)
1 to 124 grams (birth)

Liver

- Differentiates to form the hepatic diverticulum and hepatic primordium, generates the gall bladder then divides into right and left hepatic (liver) buds.
- Hepatic Buds - form hepatocytes, produce bile from week 13 (forms meconium of newborn)
  - Left Hepatic Bud - left lobe, quadrate, caudate (both q and c anatomically Left) caudate lobe of human liver consists of 3 anatomical parts: Spiegel's lobe, caudate process, and paracaval portion.
  - Right Hepatic Bud - right lobe
- Bile duct - 3 connecting stalks (cystic duct, hepatic ducts) which fuse.
- Early liver also involved in blood formation, after the yolk sac and blood islands acting as a primary site.

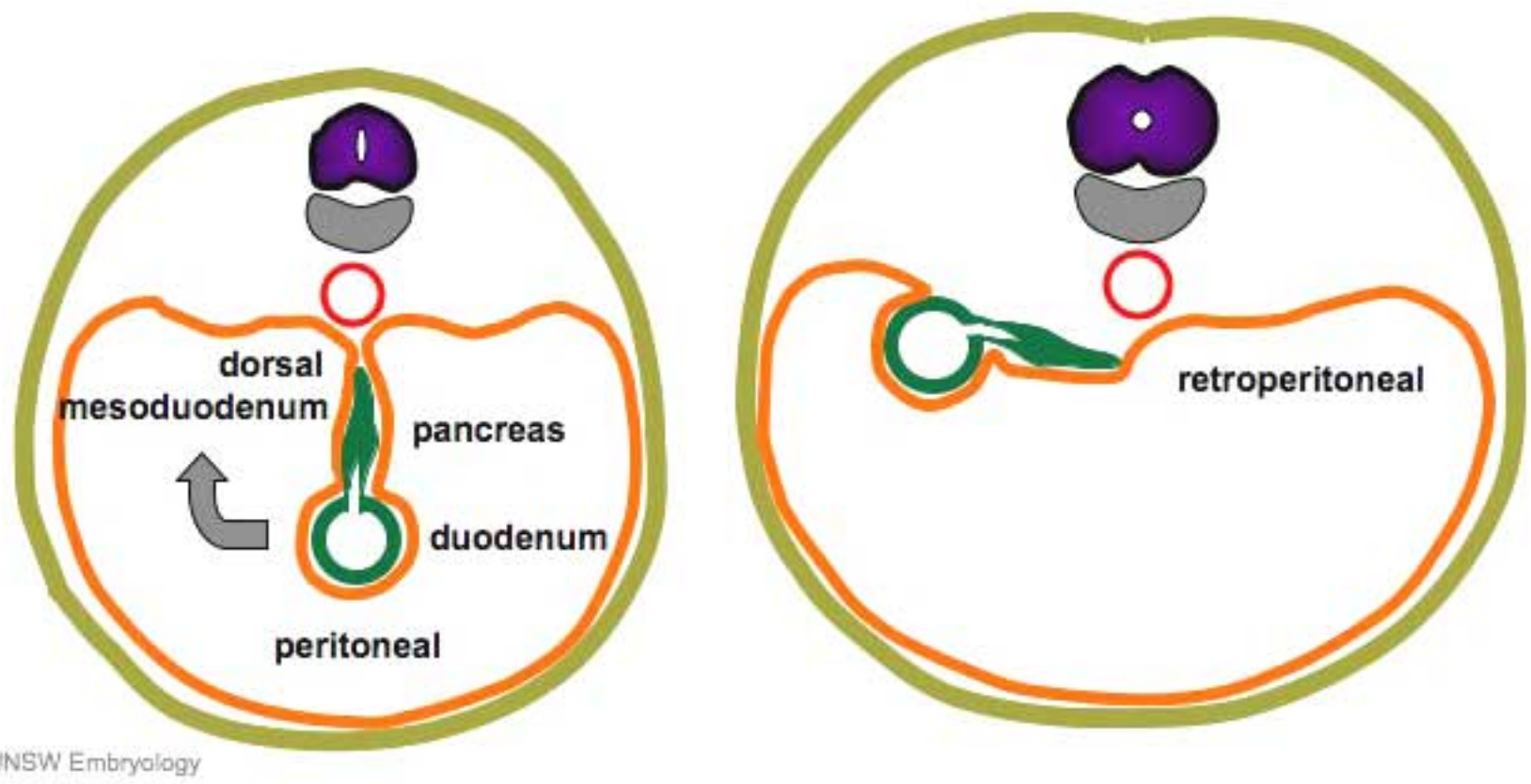
Liver Development

Pancreas

- Pancreatic buds - endoderm, covered in splanchnic mesoderm

- Pancreatic bud formation – duodenal level endoderm, splanchnic mesoderm forms dorsal and ventral mesentery, **dorsal bud** (larger, first), **ventral bud** (smaller, later)
- Duodenum growth/rotation – brings ventral and dorsal buds together, fusion of buds, exocrine function (postnatal function)
- Pancreatic duct – ventral bud duct and distal part of dorsal bud
- Pancreatic islets - endocrine function (**week 10** onwards)

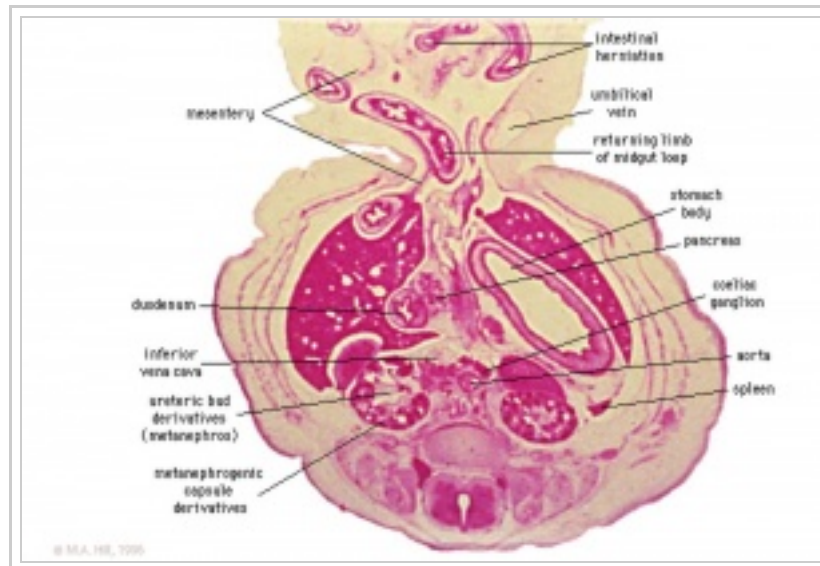
Pancreas (week 8)



Pancreas Development

Spleen

- Mesoderm within the dorsal mesogastrium form a long strip of cells adjacent to the forming stomach above the developing pancreas.
- The spleen is located on the left side of the abdomen and has a role initially in blood and then immune system development.
- The spleen's haematopoietic function (blood cell formation) is lost with embryo development and lymphoid precursor cells migrate into the developing organ.
- Vascularization of the spleen arises initially by branches from the dorsal aorta.

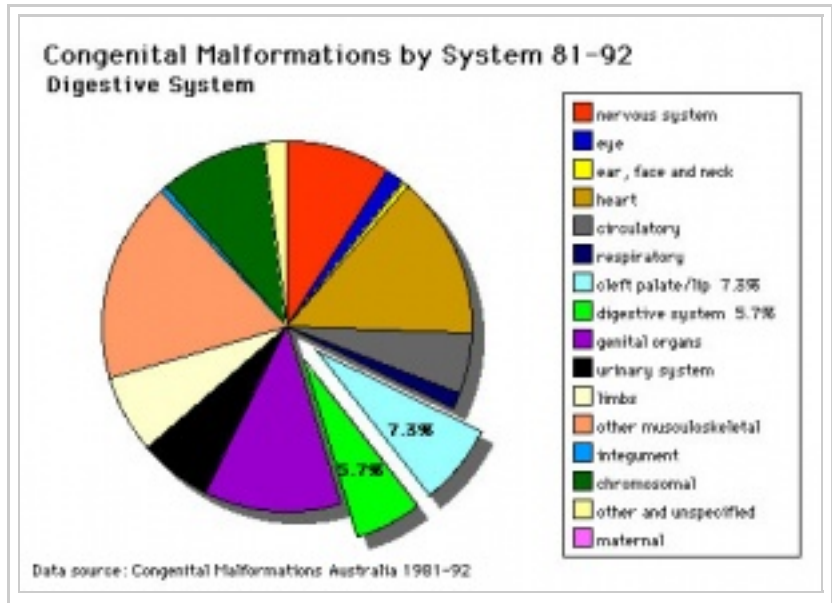


Spleen week 8 stage 22 embryo

Gastrointestinal Tract Abnormalities

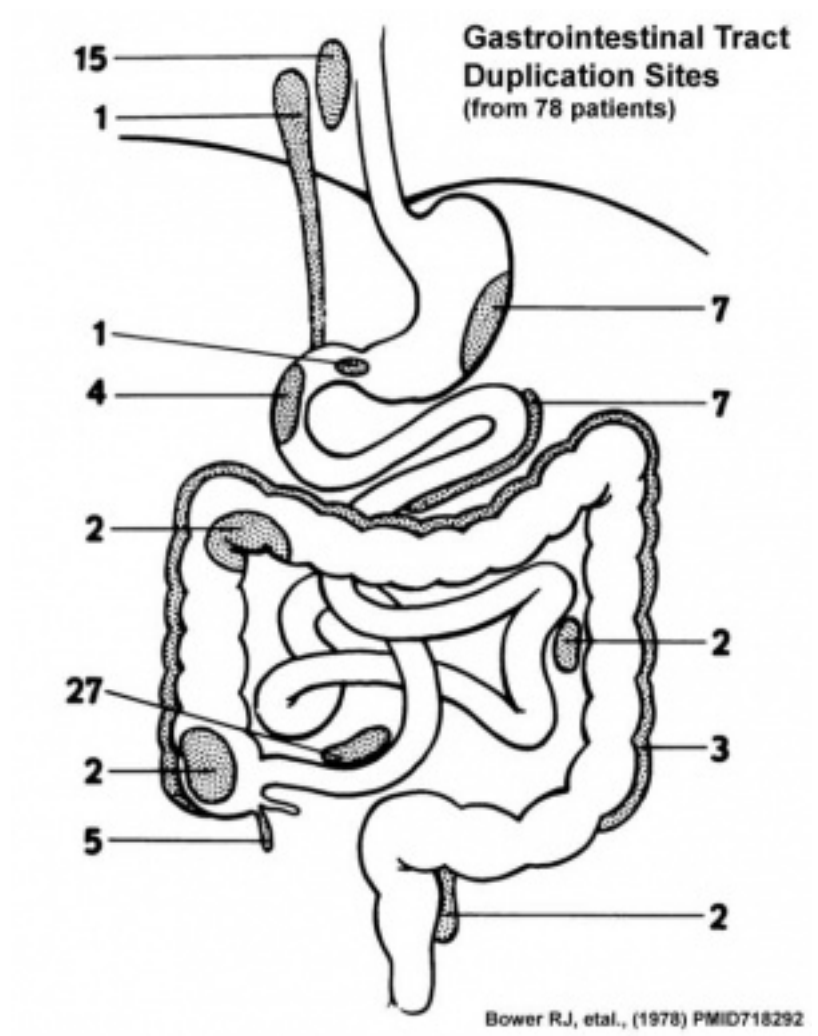
USA Statistics[Expand]

Lumen Abnormalities



Australian Statistics Gastrointestinal Tract - Abnormalities

There are several types of abnormalities that impact upon the continuity of the gastrointestinal tract lumen.



Atresia

- Interuption of the lumen (esophageal atresia, duodenal atresia, extrahepatic biliary atresia, anorectal atresia)

Stenosis

- Narrowing of the lumen (duodenal stenosis, pyloric stenosis)

Duplication

- Incomplete recanalization resulting in parallel lumens, this is really a specialized form of stenosis.

Meckel's Diverticulum

- This abnormality is a very common (incidence of 1–2% in the general population) and results from improper closure and absorption of the vitelline duct during early development.
  - vitelline duct (omphalomesenteric duct, yolk stalk) is a transient developmental duct that connects the yolk to the primitive GIT.

Meckel's Diverticulum

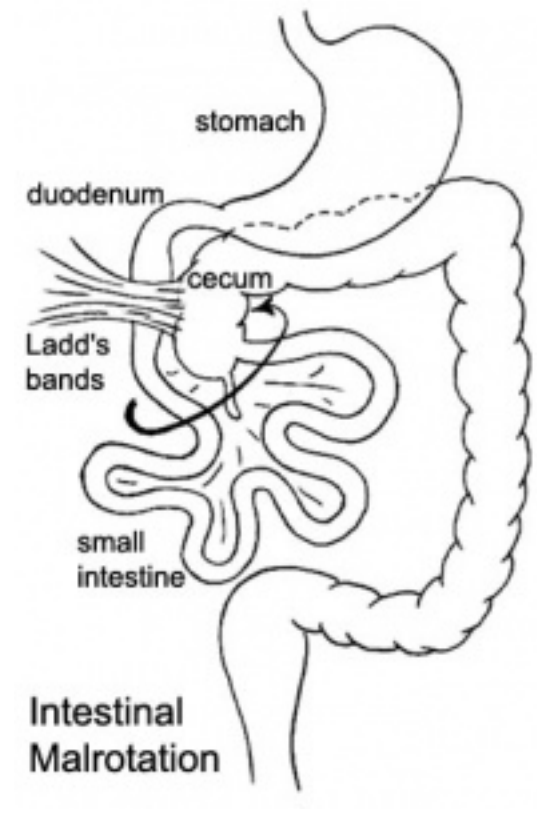
Intestinal Malrotation

Presents clinically in symptomatic malrotation as:

- Neonates - bilious vomiting and bloody stools.
- Newborn - bilious vomiting and failure to thrive.
- Infants - recurrent abdominal pain, intestinal obstruction, malabsorption/diarrhea, peritonitis/septic shock, solid food intolerance, common bile duct obstruction, abdominal distention, and failure to thrive.

Ladd's Bands - are a series of bands crossing the duodenum which can cause duodenal obstruction.

Links: Intestinal Malrotation

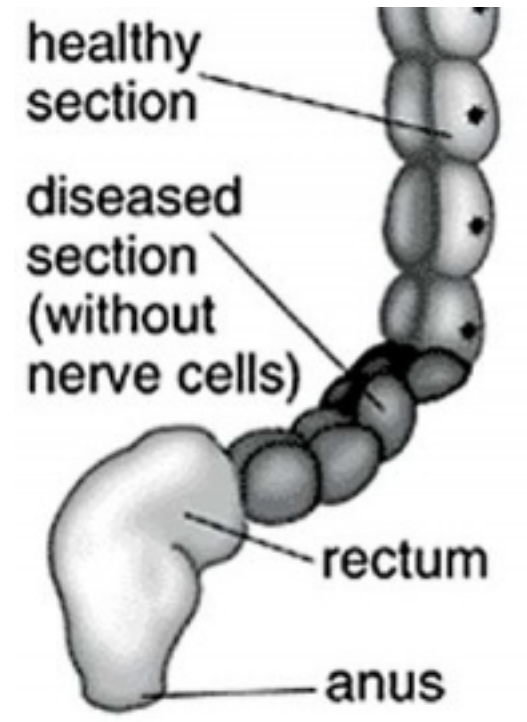


Intestinal malrotation

Intestinal Aganglionosis

(intestinal aganglionosis, Hirschsprung's disease, aganglionic colon, megacolon, congenital aganglionic megacolon, congenital megacolon)

- A condition caused by the lack of enteric nervous system (neural ganglia) in the intestinal tract responsible for gastric motility (peristalsis).
- Neural crest cells
  - migrate initially into the cranial end of the GIT.
  - migrate during embryonic development caudally down the GIT.
- Aganglionosis typically at the anal end of GIT.
  - increased severity as it extends cranially.



Gastroschisis

Gastroschisis (omphalocele, paraomphalocele, laparoschisis, abdominoschisis, abdominal hernia) is a congenital abdominal wall defect which results in herniation of fetal abdominal viscera (intestines and/or organs) into the amniotic cavity.

Incidence of gastroschisis has been reported at 1.66/10,000, occuring more frequently in young mothers (less than 20 years old).

By definition, it is a body wall defect, not a gastrointestinal tract defect, which in turn impacts upon GIT development.

This indirect developmental effect (one system impacting upon another) occurs in several other systems.

- **Omphalocele** - appears similar to gastroschisis, herniation of the bowel, liver and other organs into the intact umbilical cord, the tissues being **covered by membranes** unless the latter are ruptured.

Gastroschisis

Final Thoughts- After Birth

Remember that the GIT does not function until after birth consider:

- metabolic disorders discovered by neonatal diagnosis
- Neonatal feeding difficulties due to cleft lip and cleft palate.

Links: Gastrointestinal Tract - Abnormalities

1. ↑ Vicki Martin, Charles Shaw-Smith **Review of genetic factors in intestinal malrotation.** Pediatr. Surg. Int.: 2010, 26(8);769-81 PubMed 20549505 | PMC2908440 (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2908440)

2. ↑ R J Bower, W K Sieber, W B Kiesewetter **Alimentary tract duplications in children.** Ann. Surg.: 1978, 188(5);669-74 PubMed 718292

Terms

Gastrointestinal Tract Development

- **allantois** - An extraembryonic membrane, endoderm in origin extension from the early hindgut, then cloaca into the connecting stalk of placental animals, connected to the superior end of developing bladder. In reptiles and birds, acts as a reservoir for wastes and mediates gas exchange. In mammals is associated/incorporated with connecting stalk/placental cord fetal-maternal interface.
- **amnion** - An extraembryonic membrane]ectoderm and extraembryonic mesoderm in origin and forms the innermost fetal membrane, produces amniotic fluid. This fluid-filled sac initially lies above the trilaminar embryonic disc and with embryoic disc folding this sac is drawn ventrally to enclose (cover) the entire embryo, then fetus. The presence of this membane led to the description of reptiles, bird, and mammals as amniotes.
- **amniotic fluid** - The fluid that fills amniotic cavity totally encloses and cushions the embryo. Amniotic fluid enters both the gastrointestinal and respiratory tract following rupture of the buccopharyngeal membrane. The late fetus swallows amniotic fluid.
- **buccal** - (Latin, *bucca* = cheek) A term used to relate to the mouth (oral cavity).
- **buccopharyngeal membrane** - (oral membrane) (Latin, *bucca* = cheek) A membrane which forms the external upper membrane limit (cranial end) of the early gastrointestinal tract (GIT). This membrane develops during gastrulation by ectoderm and endoderm without a middle (intervening) layer of mesoderm. The membrane lies at the floor of the ventral depression (stomodeum) where the oral cavity will open and will breakdown to form the initial "oral opening" of the gastrointestinal tract. The equivilent membrane at the lower end of the gastrointestinal tract is the cloacal membrane.
- **cloacal membrane** - Forms the external lower membrane limit (caudal end) of the early gastrointestinal tract (GIT). This membrane is formed during gastrulation by ectoderm and endoderm without a middle (intervening) layer of mesoderm. The membrane breaks down to form the initial "anal opening" of the gastrointestinal tract.
- **coelom** - Term used to describe a space. There are extraembryonic and intraembryonic coeloms that form during vertebrate development. The single intraembryonic coelom will form the 3 major body cavities: pleural, pericardial and peritoneal.
- **foregut** - The first of the three part/division (**foregut** - midgut - hindgut) of the early forming gastrointestinal tract. The foregut runs from the buccopharyngeal membrane to the midgut and forms all the tract (esophagus and stomach) from the oral cavity to beneath the stomach. In addition, a ventral bifurcation of the foregut will also form the respiratory tract epithelium.
- **gastrula** - (Greek, *gastrula* = little stomach) A stage of an animal embryo in which the three germ layers ([E#endoderm|endoderm]/mesoderm/ectoderm) have just formed.
- **gastrulation** - The process of differentiation forming a gastrula. Term means literally means "to form a gut" but is more in development, as this process converts the bilaminar embryo (epiblast/hypoblast) into the trilaminar embryo (E#endoderm endoderm/mesoderm/ectoderm) establishing the 3 germ layers that will form all the future tissues of the entire embryo. This process also establishes the the initial body axes.
- **hindgut** - The last of the three part/division foregut - midgut - **hindgut**) of the early forming gastrointestinal tract. The hindgut forms all the tract from the distral transverse colon to the cloacal membrane and extends into the connecting stalk (placental cord) as the allantois. In addition, a ventral of the hindgut will also form the urinary tract (bladder, urethra) epithelium.
- **intraembryonic coelom** - The "horseshoe-shaped" space (cavity) that forms initially in the third week of development in the lateral plate mesoderm that will eventually form the 3 main body cavities: pericardial, pleural, peritoneal. The intraembryonic coelom communicates transiently with the extraembryonic coelom.
- **neuralation** - The general term used to describe the early formation of the nervous system. It is often used to describe the early events of differentiation of the central ectoderm region to form the neural plate, then neural groove, then neural tube. The nervous system includes the central nervous system (brain and spinal cord) from the neural tube and the peripheral nervous system (peripheral sensory and sympathetic ganglia) from neural crest. In humans, early neuralation begins in week 3 and continues through week 4.
- **neural crest** - region of cells at the edge of the neural plate that migrates throughout the embryo and contributes to many different tissues. In the gastrointestinal tract it contributes mainly the enteric nervous system within the wall of the gut responsible for peristalsis and secretion.
- **pharynx** - uppermost end of gastrointestinal and respiratory tract, in the embryo beginning at the buccopharyngeal membrane and forms a major arched cavity within the phrayngeal arches.
- **somitogenesis** The process of segmentation of the paraxial mesoderm within the trilaminar embryo body to form pairs of somites, or balls of mesoderm. A somite is added either side of the notochord (axial mesoderm) to form a somite pair. The segmentation does not occur in the head region, and begins cranially (head end) and extends caudally (tailward) adding a somite pair at regular time intervals. The process is sequential and therefore used to stage the age of many different species embryos based upon the number visible somite pairs. In humans, the first somite pair appears at day 20 and adds caudally at 1 somite pair/4 hours (mouse 1 pair/90 min) until on average 44 pairs eventually form.
- **splanchnic mesoderm** - Gastrointestinal tract (endoderm) associated mesoderm formed by the separation of the lateral plate mesoderm into two separate components by a cavity, the intraembryonic coelom. Splanchnic mesoderm is the embryonic origin of the gastrointestinal tract connective tissue, smooth muscle, blood vessels and contribute to organ development (pancreas, spleen, liver). The intraembryonic coelom will form the three major body cavities including the space surrounding the gut, the peritoneal cavity. The other half of the lateral plate mesoderm (somatic mesoderm) is associated with the ectoderm of the body wall.
- **stomodeum** - (stomadeum, stomatodeum) A ventral surface depression on the early embryo head surrounding the buccopharyngeal membrane, which lies at the floor of this depression. This surface depression lies between the maxillary and mandibular components of the first pharyngeal arch.

Glossary Links

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