

## Gastrointestinal Tract Development

Endoderm → cell sheet → tubular gut

Lateral folding

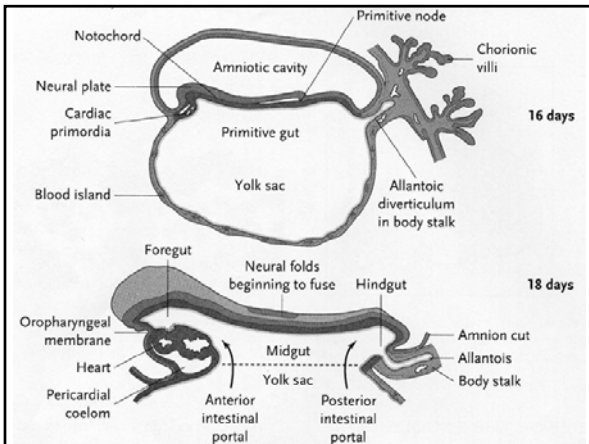
Ventral bending cranially → Head fold

Ventral bending caudally → Tail fold

Yolk sac is connected to the gut in the middle

Yolk stalk, omphalomesenteric duct, or vitelline duct

Yolk stalk is progressively delineated.



## Embryonic Gut

Regions:

Foregut → Lateral fold and head fold

Hindgut → Lateral fold and tail fold

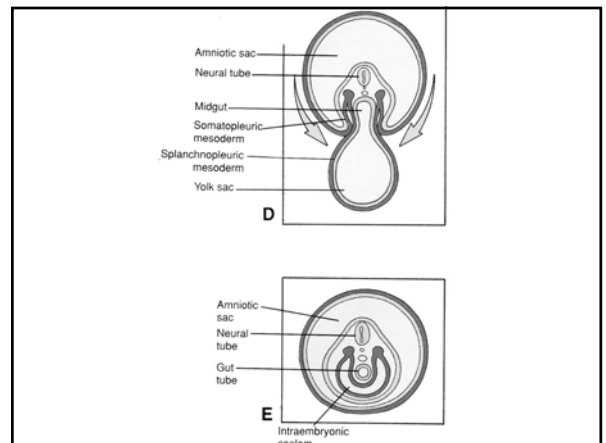
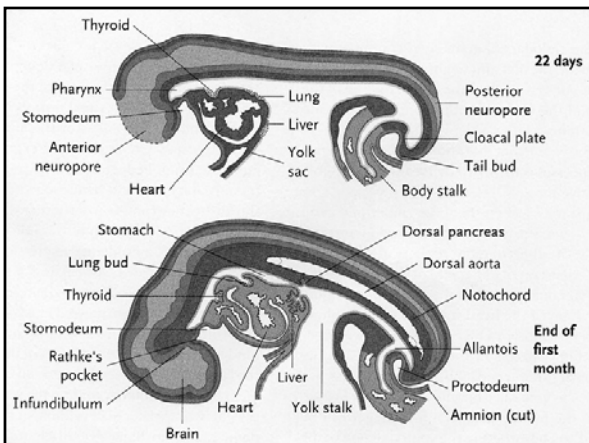
Midgut → Yolk Stalk Region

Anterior intestinal portal – foregut / midgut transition

Posterior intestinal portal - midgut / hindgut transition

Oropharyngeal membrane = ectoderm-endoderm bilayer separating stomodeum, future mouth – ectoderm lined, from the future pharynx – endoderm lined.

Cloacal plate or Proctodeal membrane = ectoderm-endoderm bilayer, separates the ectoderm lined proctodeum from the gut endoderm.



## Embryonic Gut

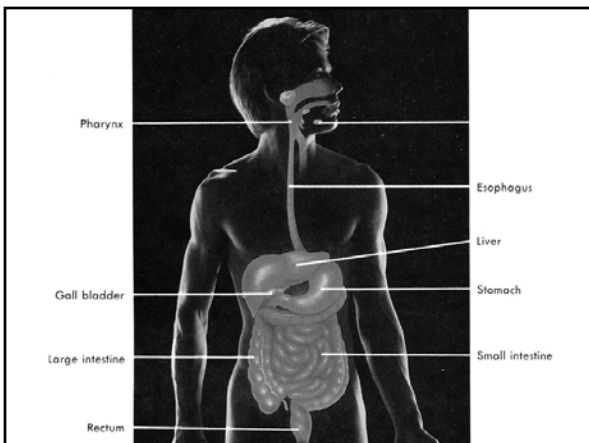
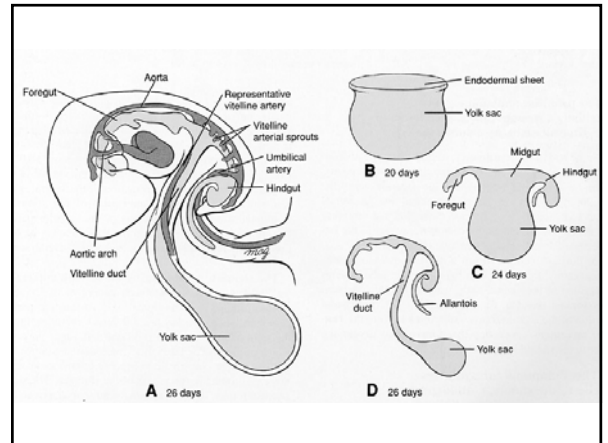
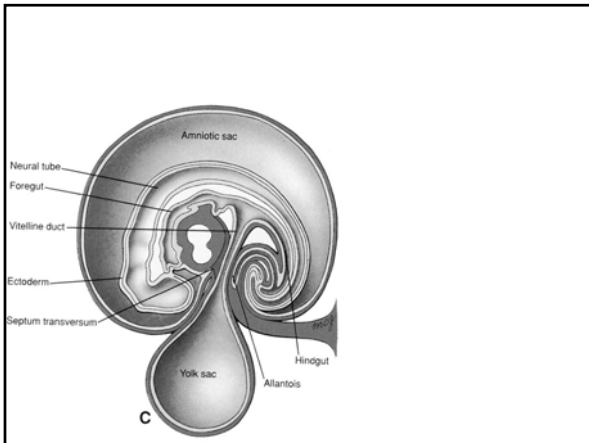
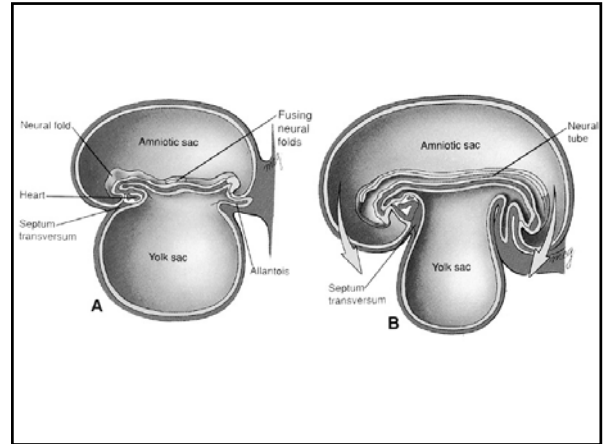
Straight tube suspended by the dorsal mesentery

Only ventral connection is the transverse septum level of stomach and cranial duodenum.

Transverse septum - mesoderm initially between developing heart and the cranial margin of the embryonic disc

Cranial flexure displaces the transverse septum between the heart and the yolk sac –  
Forming the initial partition separating the thoracic and abdominal cavities → part of the diaphragm

Hindgut – evagination is the allantois



## Foregut Derivatives

Oropharyngeal membrane (cranial end)

Pharynx (derivatives of the pharyngeal pouches, tongue, thyroid gland)

Thoracic esophagus (lung buds)

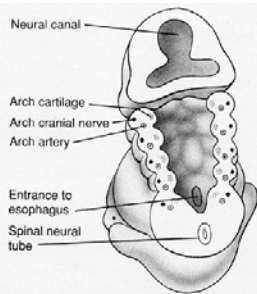
Abdominal esophagus

Stomach

Cranial half of duodenum (liver, gallbladder, pancreas)

Caudal end = Ampulla of Vater (common bile and pancreatic ducts drain into gut)

## Pharynx



Pharyngeal:

Pouches (endoderm); Grooves (ectoderm); Arches (mesoderm)

## Pharyngeal Pouches

Pharyngeal Pouch #1 – Caudal to Arch #1

**Auditory tube** (Eustachian tube), **tympnic cavity**

Pharyngeal Pouch #2 – Caudal to Arch #2

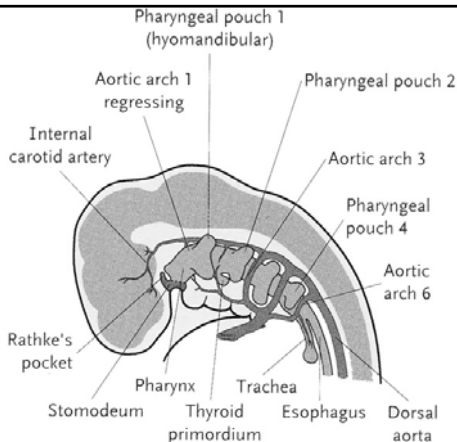
Supratonsillar fossae associated with **Palatine tonsils**

Pharyngeal Pouch #3 – Caudal to Arch #3

Inferior parathyroid, Thymus

Pharyngeal Pouch #4 – Caudal to Arch #4

Superior parathyroids, Postbranchial body



## Tongue

Lateral Lingual Swellings – paired lateral swellings from the 1<sup>st</sup> pharyngeal arch (ventral)

2 unpaired medial swellings from the ventral midline of the pharynx

Tuberculum impar

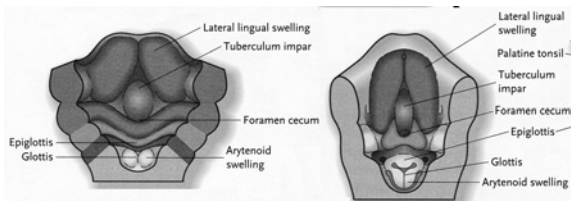
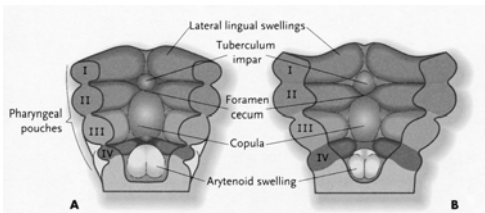
Copula

Contribution from the 3<sup>rd</sup> and 4<sup>th</sup> pharyngeal arches

Oral Tongue (anterior 2/3) forms from the expansion of lateral swellings and the tuberculum impar - median sulcus of the tongue is the site of midline fusion

Base of the tongue is formed from the copula with contribution from the 3<sup>rd</sup> and 4<sup>th</sup> pharyngeal arches

The epiglottis forms from a swelling caudal to the copula



## Thyroid Gland

Thyroid Diverticulum

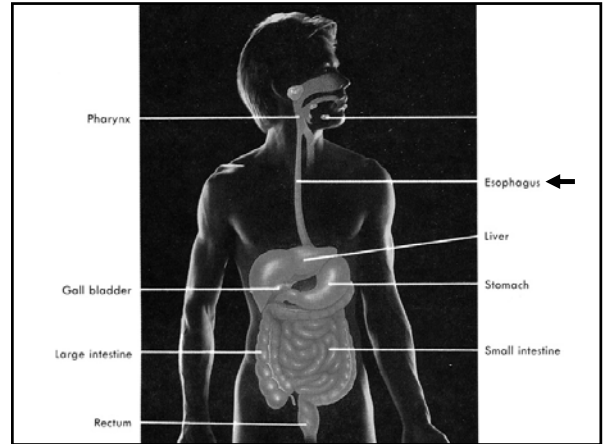
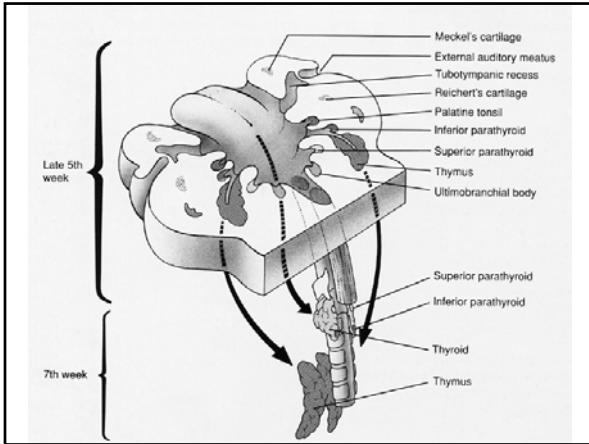
Midventral thickening, between Pharyngeal Pouch 1 and 2 (base of the tongue)

Single outgrowth elongates in a caudal direction

Bifurcates to form the bi-lobed Thyroid gland

The connection – thyroglossal duct regresses about week 7

The site of the thyroid diverticulum persists as the foramen cecum – between the tuberculum impar and the copula



## Esophagus

Thoracic Esophagus buds off the lung buds → Respiratory Tract

Abdominal Esophagus – abruptly narrows – extends to the Stomach

Differentiation of Epithelium:

7<sup>th</sup> – 8<sup>th</sup> Week – epithelium is stratified columnar,

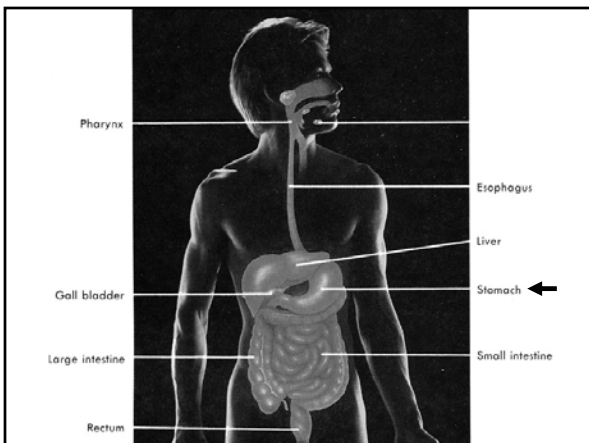
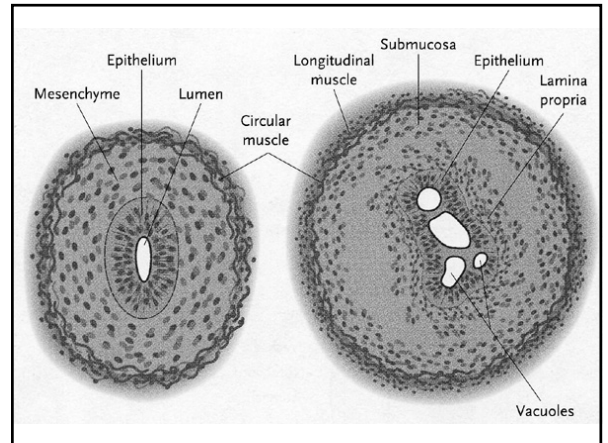
Lumen becomes partially occluded

Appearance of large vacuoles

Vacuoles coalesce – recanalization

12<sup>th</sup> Week - Epithelium is multilayered and ciliated

16<sup>th</sup> Week – Stratified squamous epithelium



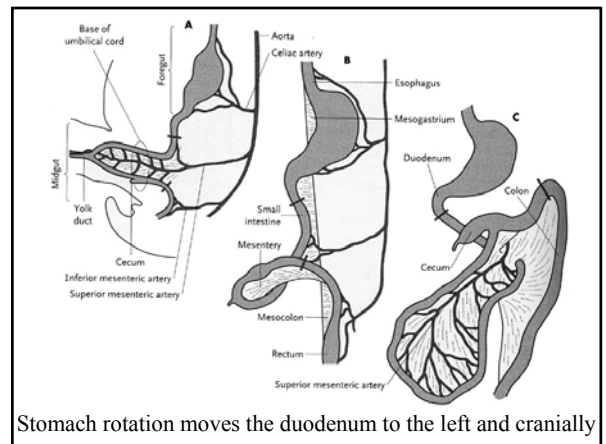
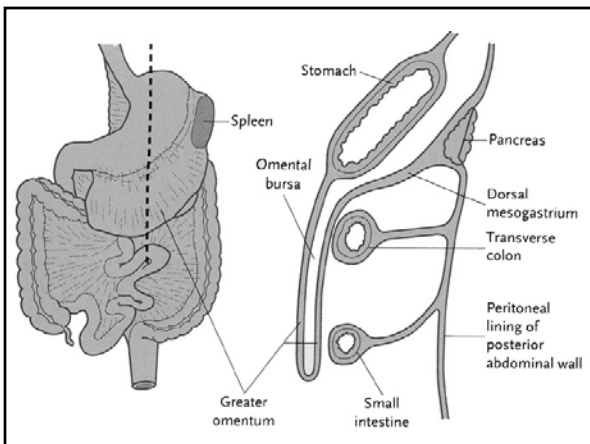
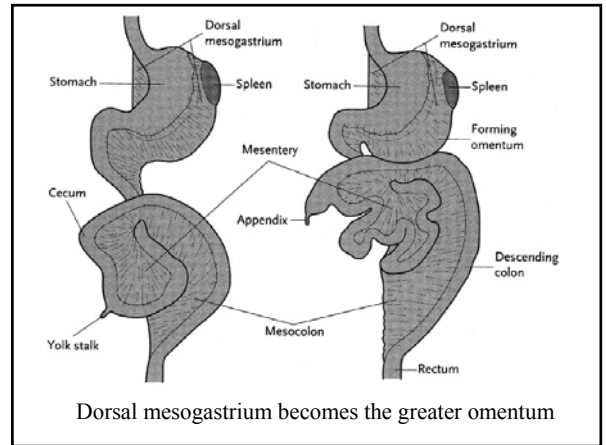
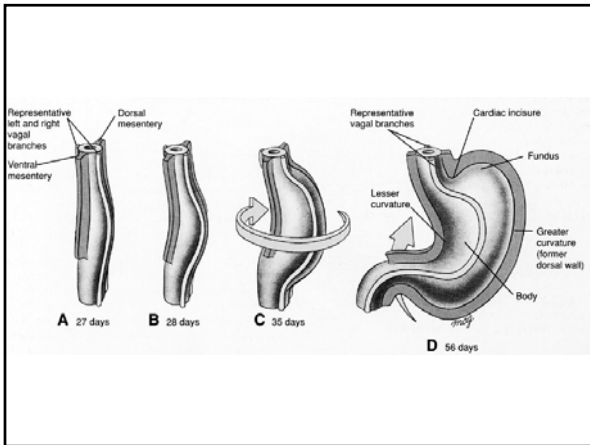
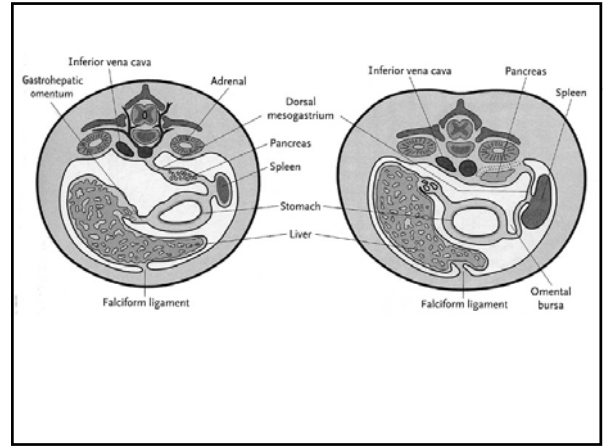
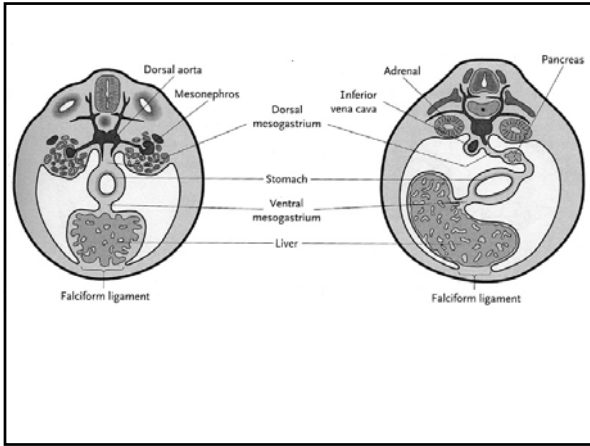
## Stomach

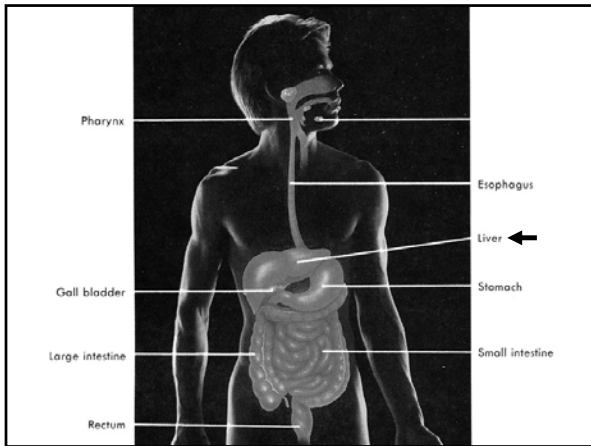
Stomach - initially symmetrical and fusiform (spindle)

Differential growth - dorsal > ventral - creates the Greater curvature of the stomach (dorsal side) and Lesser curvature (ventral side)

90° rotation of the stomach around craniocaudal axis  
greater curvature is to the left and caudal  
lesser curvature is to the right and cranial

Dorsal mesogastrum (dorsal mesentery) – differential growth is responsible for the rotation. Dorsal mesogastrum becomes the greater omentum





## Liver is Derived from the Duodenum

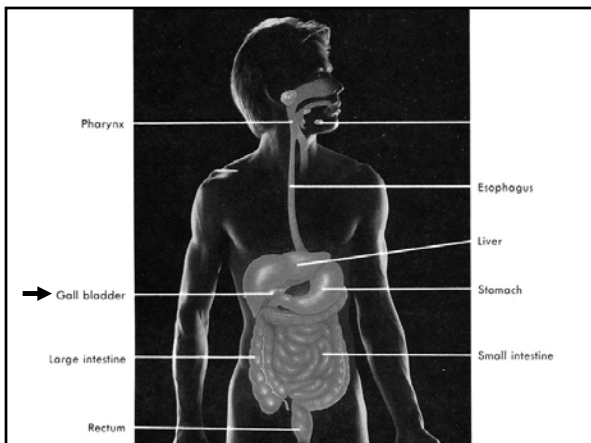
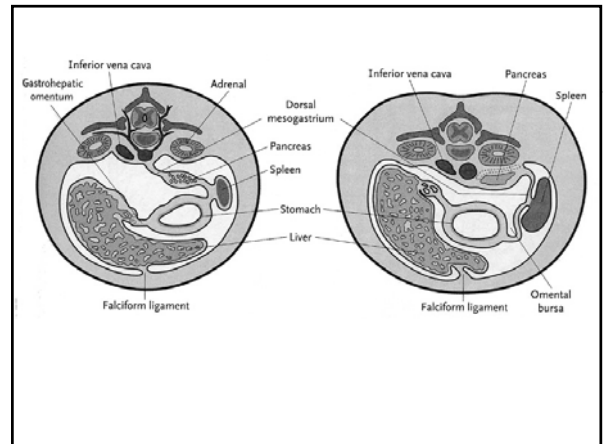
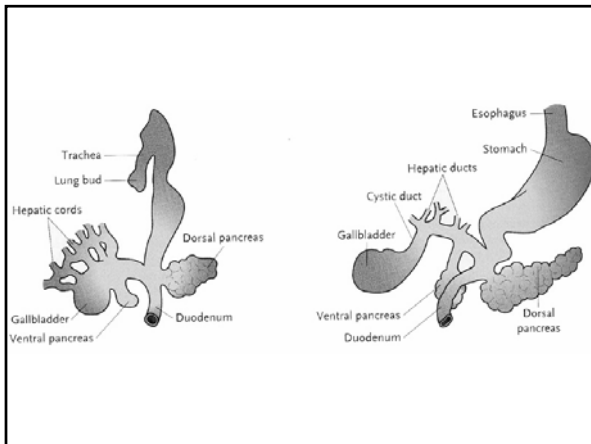
Endodermal thickening – ventral side of Duodenum

Hepatic diverticulum - grows ventrally into the transverse septum

Hepatic diverticulum branches into many Hepatic cords that form hepatocytes and the drainage ducts (bile canaliculi, hepatic ducts).

Gastrohepatic omentum – connection to the stomach – becomes the lesser omentum

Falciform ligament – ventral mesentery connection to the body wall

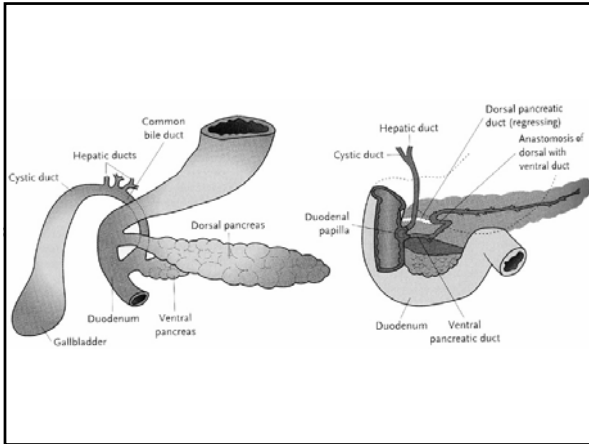


## Gallbladder / Cystic Duct

Cystic diverticulum arises from a ventral endodermal thickening just posterior to the hepatic diverticulum

The cystic diverticulum gives rise to the gallbladder and cystic duct.

Hepatic duct and cystic duct merge to form the common bile duct



## Pancreas

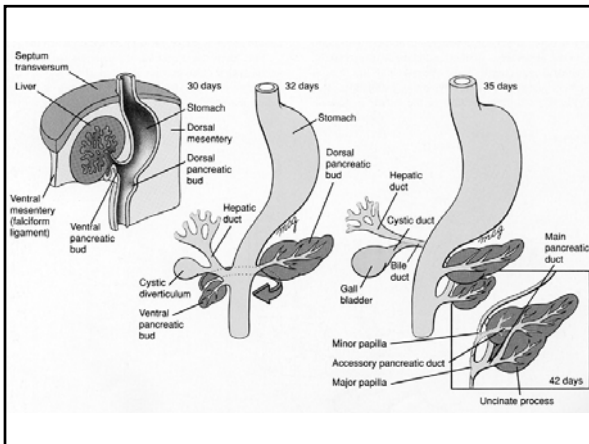
Pancreas forms from two distinct outgrowths from the duodenum

Dorsal pancreatic bud grows into the dorsal mesentery

Ventral pancreatic bud sprouts from the hepatic diverticulum into the ventral mesentery caudal to the forming gallbladder

The main duct of the ventral pancreas bud merges at the proximal end of the common bile duct

The mouth of the common bile duct is displaced to the dorsal mesentery



## Pancreas

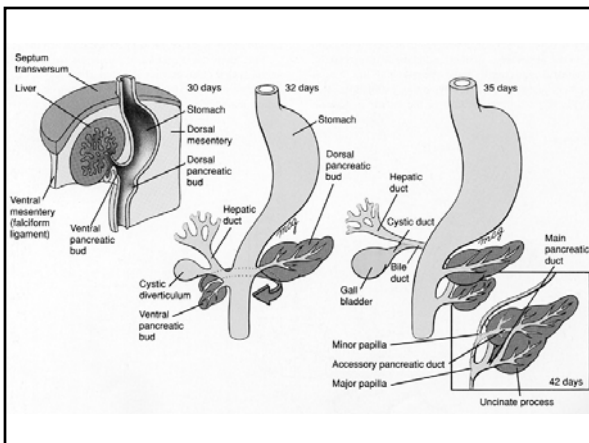
The dorsal and ventral pancreatic rudiments fuse

The dorsal duct degenerates and the dorsal and ventral parts merge their duct systems. The ventral duct becomes the main pancreatic duct (Duct of Wirsung)

Where the common bile duct and pancreatic ducts empty into the duodenum is called the Ampulla of Vater

Exocrine function - acinar cells - production of digestive enzymes

Endocrine function - islets of Langerhans - production of insulin and glucagon ( $\beta$  cells and  $\alpha$  cells)



## Spleen

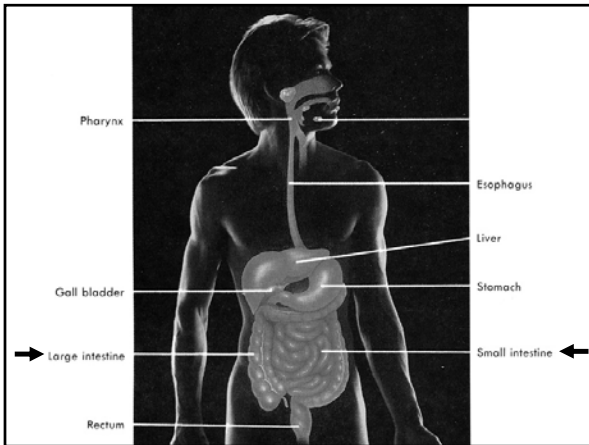
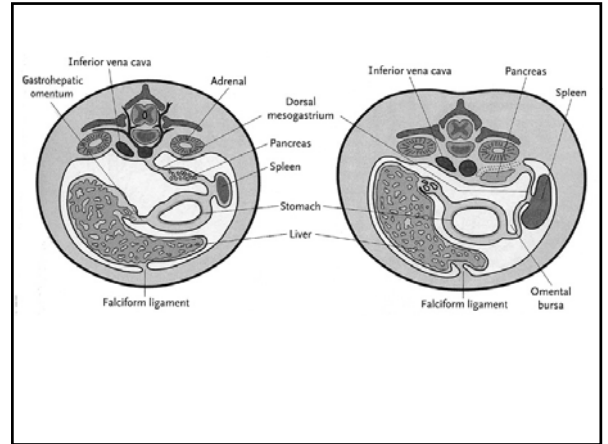
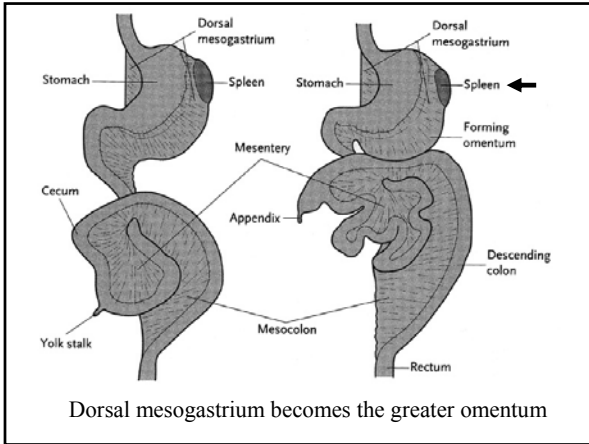
The Spleen is an intra-abdominal organ that is not an endodermal derivative

The Spleen is mesodermal and develops in the dorsal mesogastrium

The Spleen is a vascular lymphatic organ

The Spleen moves to the left side of the abdominal cavity with the rotation of the stomach.

Initially a hematopoietic organ, later gets colonized by T-lymphocyte precursor cells



## Formation of the Intestine

Midgut derivatives:  
 Caudal half of duodenum  
 Jejunum  
 Ileum  
 Cecum  
 Appendix  
 Ascending colon  
 Right 2/3 of transverse colon

Hindgut derivatives:  
 Left 1/3 of transverse colon  
 Descending colon  
 Sigmoid colon  
 Rectum  
 Cloacal membrane at caudal end

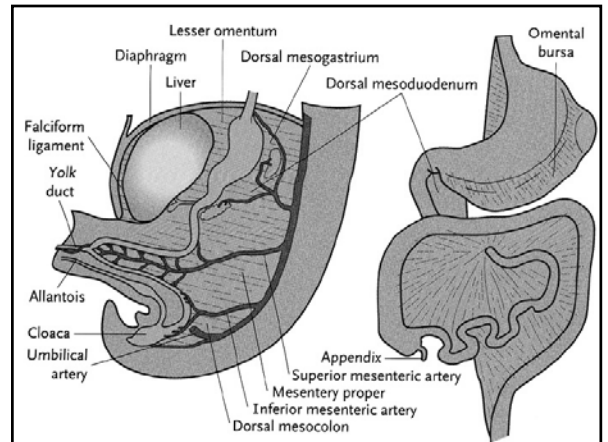
## Primary Intestinal Loop

The intestine is essentially a long straight tube, but its development is complicated by its length.

Two important points of reference:  
 Yolk Stalk – near border of small and large intestine  
 Superior Mesenteric Artery – branch of Dorsal Aorta

Ileum – elongates too rapidly for the size of the abdominal cavity causing a herniation into the umbilicus

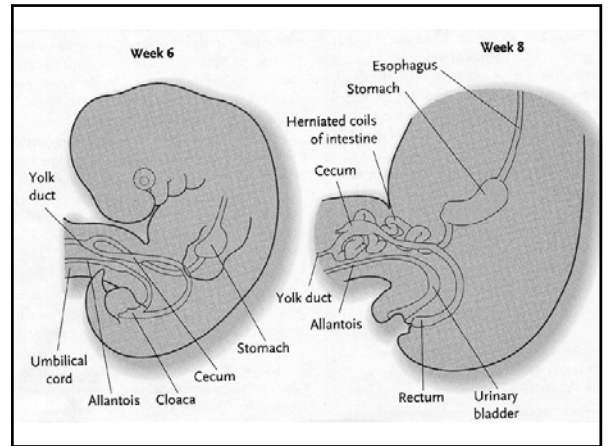
Dorsal-ventral hairpin - called the primary intestinal loop.





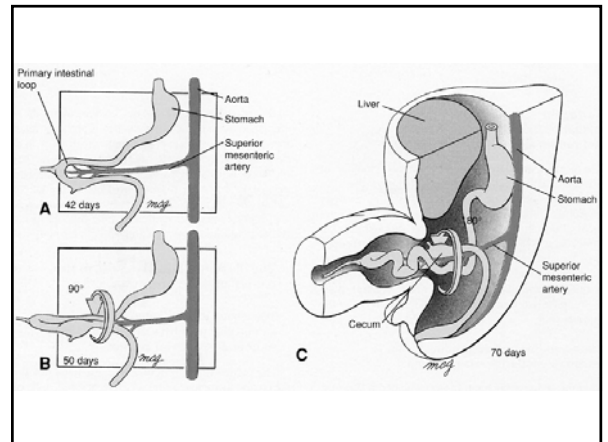
## Intestine Development

- Cranial part of loop gives rise to most of the ileum
- Caudal loop becomes part of ileum, the ascending colon and 2/3 of the transverse colon
- Initially - the loop does a 90° counterclockwise rotation (viewed from the front) - cranial loop → right, caudal loop → left
- Jejunum and Ileum lengthens resulting in a series of folds called the jejunal-ileal loops



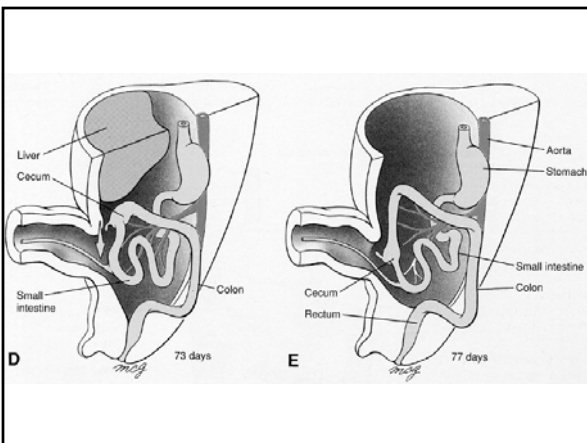
## Retraction

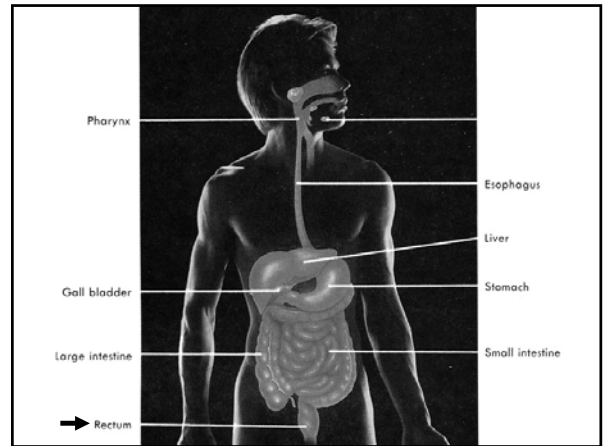
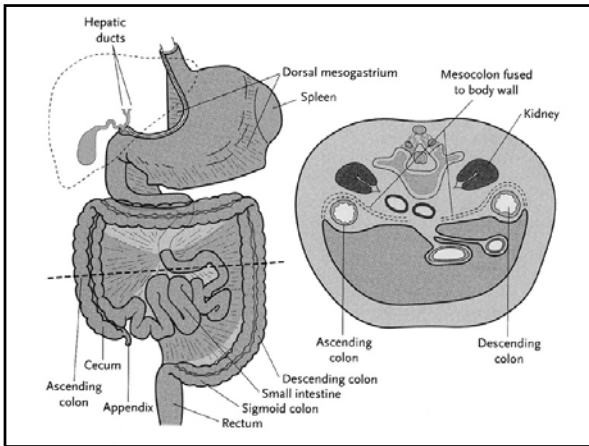
- Cecum defines junction between small and large intestines – producing the appendix
- Retraction of the loop into the abdomen
- Associated with a 180° rotation - total rotation is 270°
- Cecum lies just inferior to the liver
- The cecum moves in a cranial to caudal direction to lie in the lower left abdomen



## Ascending and Descending Colon

- Dorsal mesentery associated with the ascending and descending colon shortens and disappears
- These regions adhere directly to the dorsal body wall
- Transverse colon does not become fixed





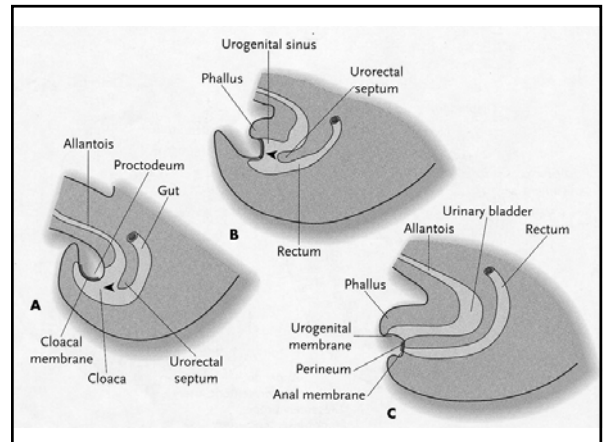
## Cloaca

Cloaca (latin = sewer) - where allantois and gastrointestinal tract merge

Cloaca is partitioned into the rectum (posterior) and the primitive urogenital sinus (anterior) - by the growth of the urorectal septum

Urorectal septum is the composite of two septal system - Tourneux fold (central) and Rathke folds (lateral)

Urorectal septum fuses with cloacal membrane - forming the urogenital membrane and the anal membrane



## Anorectal Canal

Anorectal canal - between rectum and anus

Superior 2/3 is endodermal from hindgut

Inferior 1/3 is derived from the proctodeum - ectodermal

The Ectodermal-Endodermal boundary in adult is marked by an irregular folding of mucosa in the anorectal canal called the Pectinate line

## Canalization and Histogenesis

The developing digestive tract lumen becomes occluded and secondary lumina form and coalesce during recanalization

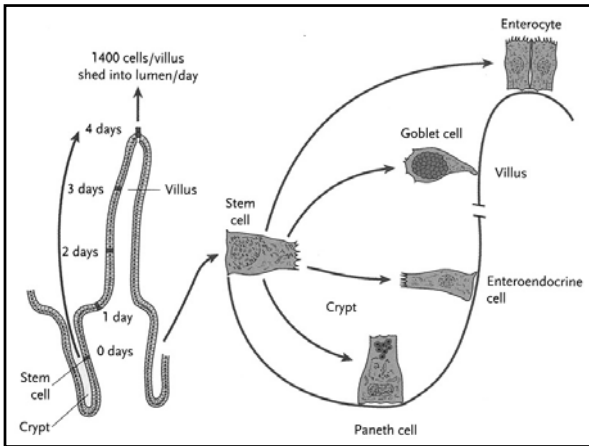
Stomach - Gastric mucosa - folds called rugae, pits called gastric pits, HCl secretion begins postnatal

Intestine - Intestinal Villi form by mesodermal growth during recanalization

Intestinal Crypts form at the base of the intestinal villi

Each crypts contains a clone of Epithelial Stem Cells that produce intestinal cells throughout adult life

Intestinal epithelial cells have a 4 day life span



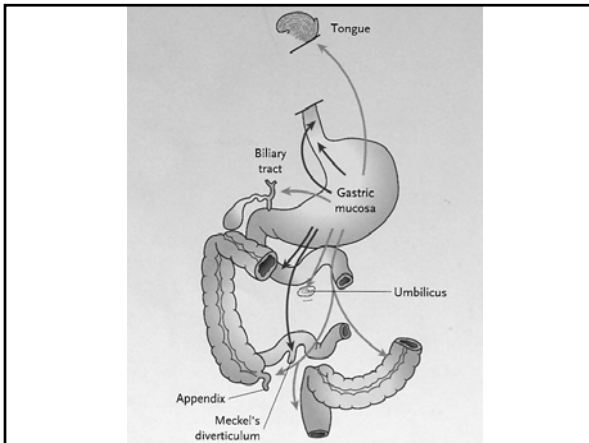
## Anomalies - Foregut

### Esophagus:

- Esophageal stenosis (narrowing) – abnormal recanalization – impaired swallowing
- Esophageal atresia (abnormal opening) – abnormal branching of the respiratory tract – impaired swallowing

### Stomach:

- Pyloric stenosis – hypertrophy of smooth muscle, projectile vomiting
- Heterotopic gastric mucosa – Misplaced gastric mucosa cells



## Anomalies - Foregut

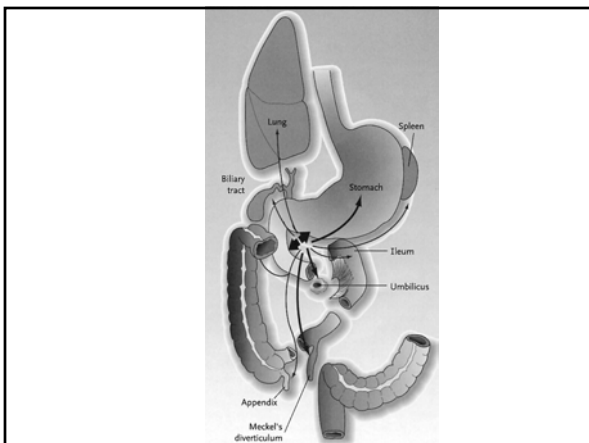
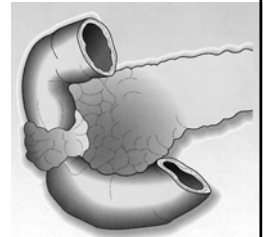
### Liver:

- Biliary atresia – abnormal hepatic duct formation – varying severity postnatal jaundice

### Pancreas:

- Annular pancreas – Pancreatic tissue encircling the duodenum sometimes causing obstruction

- Heterotopic pancreatic tissue
- Misplaced pancreatic cells



## Anomalies - Midgut

- Duodenal stenosis and atresia – abnormal recanalization

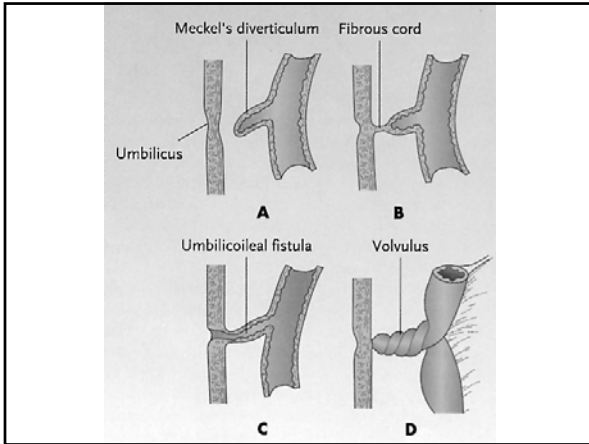
### Persistent vitelline duct –

- Meckel's diverticulum - (2-4% of population) – blind pouch

- Fibrous cord – connection to umbilicus

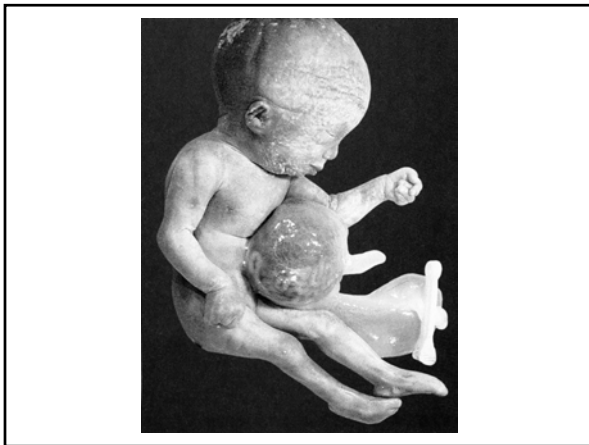
- Volvulus – intestinal rotation → bowel strangulation

- Umbilicoil fistula – direct opening



## Anomalies – Midgut Omphalocele

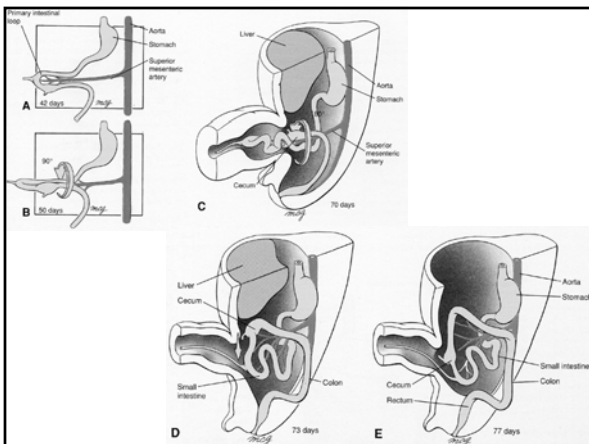
- Failure of the umbilicus to close - newborn with organs protruding from the abdominal wall
- Organs protruding into a thin sac of amniotic tissue from normal herniation - incomplete retraction
- Organs in a sac of peritoneum and amniotic tissue - indicates normal herniation and retraction, but a secondary herniation resulting from the failure of the ventral abdominal wall to close



## Anomalies - Midgut Abnormal Rotation and Fixation

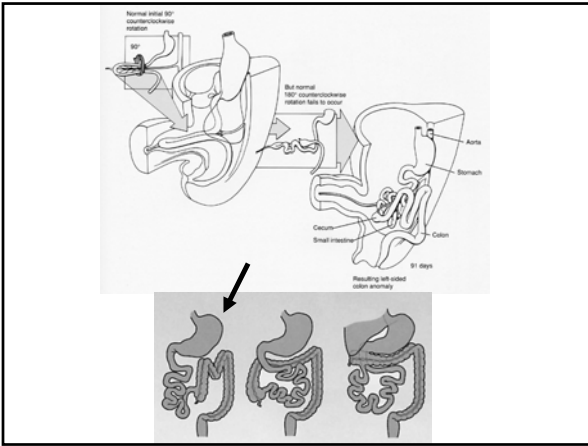
Spectrum of abnormalities

- Non-rotation
- Reverse rotation
- Mixed rotation
- Subhepatic cecum



## Non-Rotation

- Called left-sided colon
- 1<sup>st</sup> rotation is Normal
- 2<sup>nd</sup> rotation is Absent
- Cranial loop ends up on the right side
- Caudal loop on the left side
- Some organs may or may not get fixed to the body wall



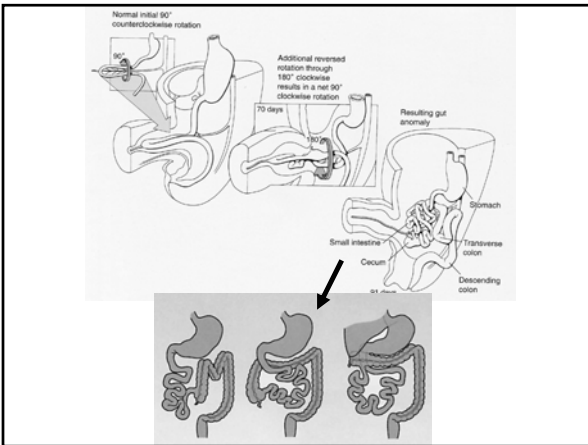
## Reverse Rotation

Normal 1<sup>st</sup> rotation

2<sup>nd</sup> rotation is clockwise instead of counter clockwise

Net rotation is 90° clockwise

This is equivalent to a 270° counter clockwise rotation except the duodenum is ventral to the transverse colon and does not get fixed to dorsal wall, transverse colon does get fixed



## Mixed Rotation

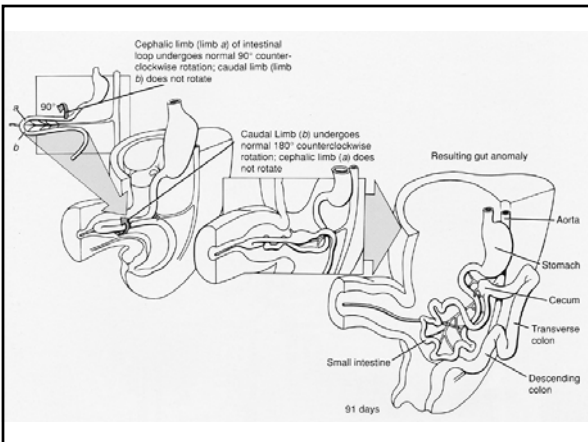
Cranial and caudal loops behave independently

Cranial loop rotates only the 1<sup>st</sup> 90°

Caudal loop only rotates the 2<sup>nd</sup> 180°

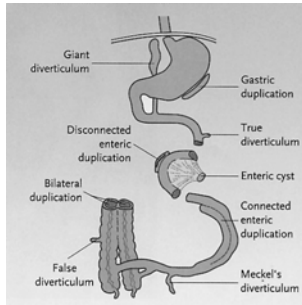
Results in misplaced organs - abnormal fixation

Typical outcome from abnormal rotations - obstructions of the gastrointestinal tract, compression of intestinal vasculature - resulting in intestinal ischemia; compression of lymphatic vessels - resulting in gastrointestinal bleeding



## Anomalies – Midgut Subhepatic Cecum

## Intestinal Duplication, Diverticula, and Atresia



Unknown Causes

## Anomalies - Hindgut

Hirschsprung's Disease – Dilation of the colon – defective neural crest migration → absence of parasympathetic ganglia in the colon wall  
 Imperforate anus – absence of anal opening



## Hindgut Fistula

Often connecting the hindgut to the urogenital system

