Development of the Gastrointestinal Tract

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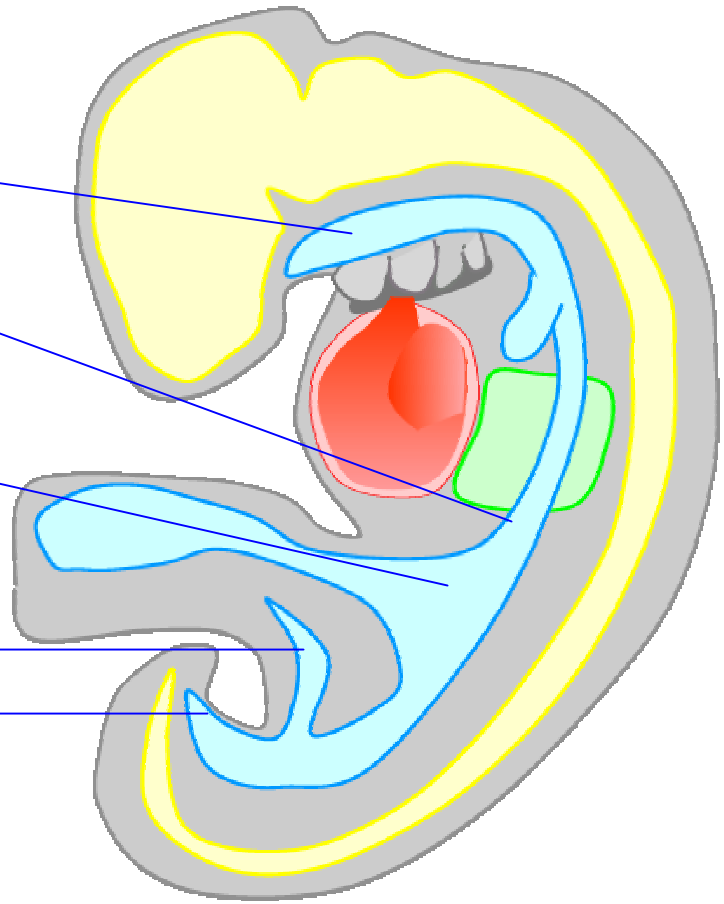
Folding of the embryo results in the formation of the gut consisting of 3 parts:

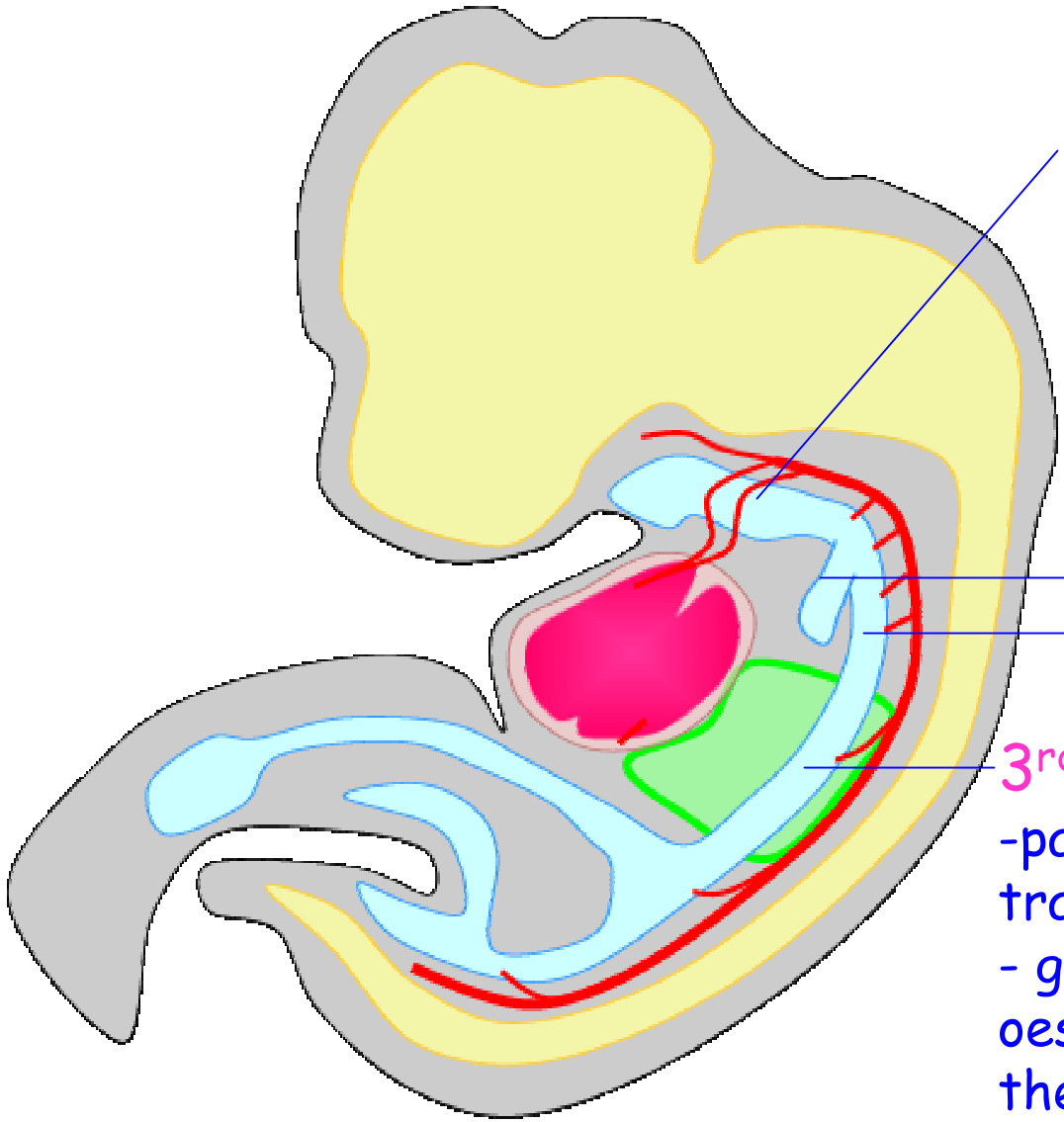
Foregut - extends from the buccopharyngeal membrane to the septum transversum

Midgut - communicates with vitelline tube and yolk sac

Hindgut - communicates with the allantoic diverticulum and extends to the cloacal membrane



The foregut is divided into 3 parts



1st part - Pharynx

- associated with paired branchial arches

2nd (Thoracic) part -

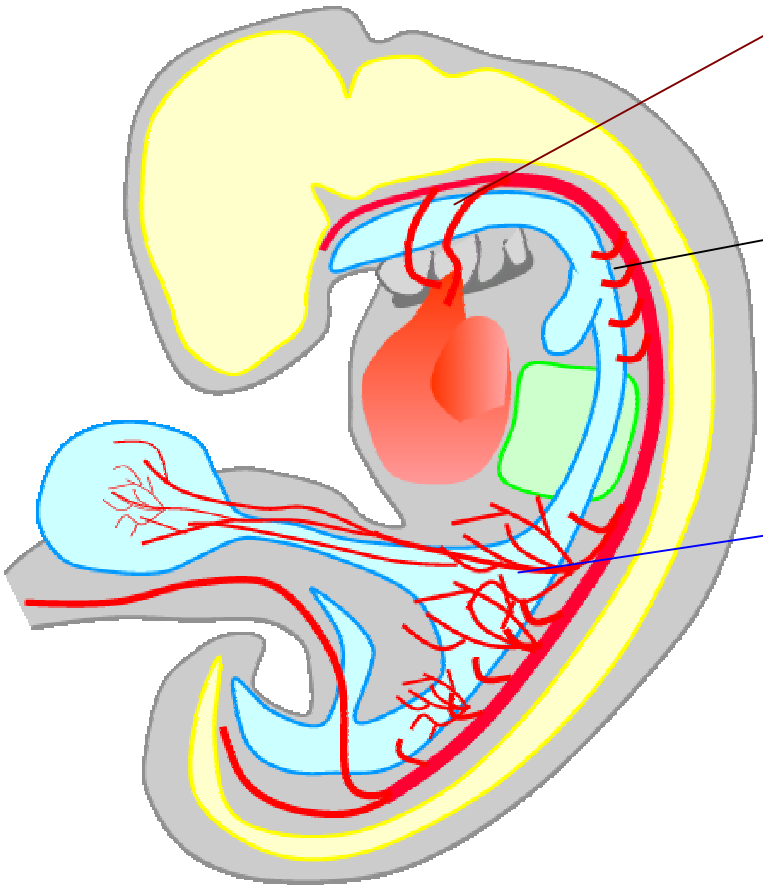
gives rise to the respiratory bud and oesophagus

3rd (abdominal) part

-passes through septum transversum

- gives rise to abdominal part of oesophagus, stomach and half of the duodenum

The dorsal aorta supplies arteries to the gut

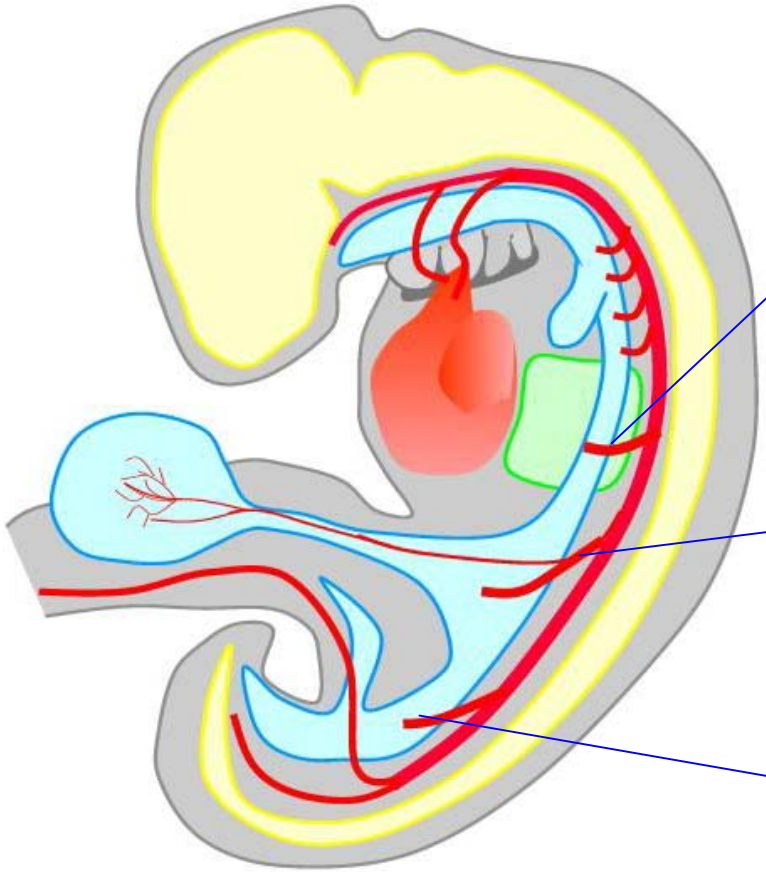


Aortic arches
- supply the pharynx

Set of 5 arteries
- supply thoracic part of oesophagus

Vitelline arteries
- initially supply the yolk sac and form a plexus around the gut. This develops into the arterial supply of the abdominal part of the gut.

Three main arteries formed from the vitelline plexus supply the foregut , midgut and hindgut



Coeliac axis
- supplies foregut in the septum transversum

Superior mesenteric artery
- supplies midgut

Inferior mesenteric artery
- supplies hindgut

The boundaries of the foregut , midgut and hindgut are determined by their respective blood supply

Stages in the Development of the Oesophagus

- Elongation occurs during the 2nd month; by the 8th week the proliferating epithelium has partly occluded the lumen.
- Recanalization occurs during the 3rd month by vacuolation in the multilayered columnar epithelium.
- Differentiation of stratified squamous epithelium occurs during the 4th month.
- Induction of muscle formation in the splanchnic mesoderm occurs during the 2nd month in response to signals from the endoderm. Initially only smooth muscle forms.
- Transdifferentiation of smooth to skeletal muscle occurs in the upper two-thirds of the oesophagus

Transdifferentiation is the direct transformation of one differentiated cell type to another.

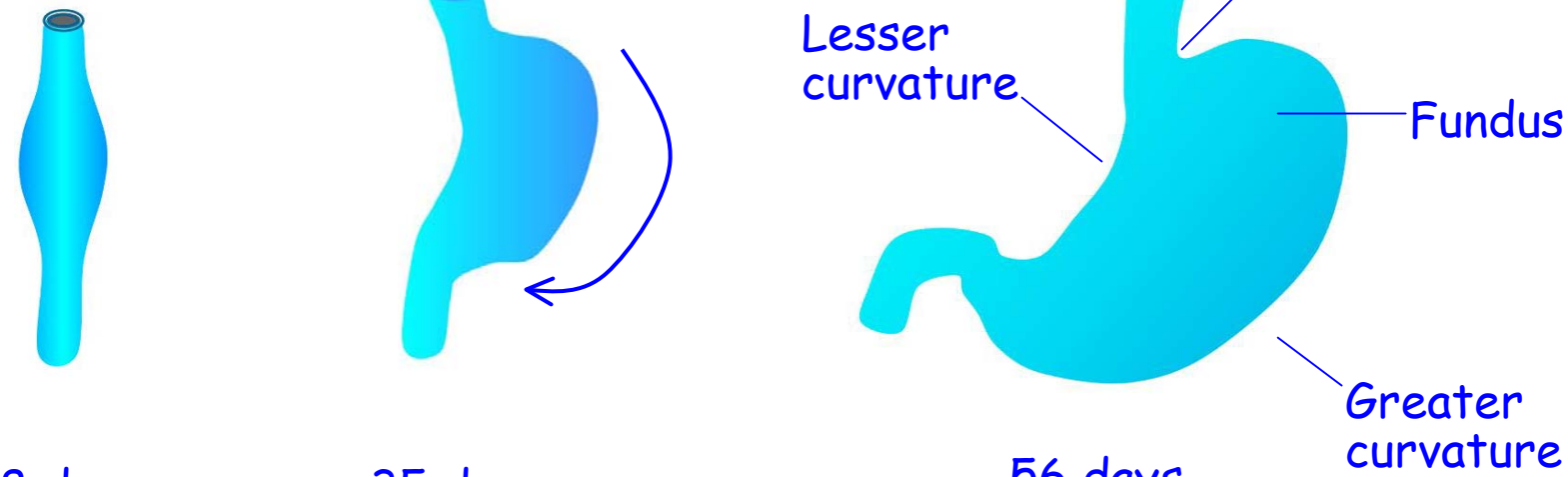
Development of the Stomach

This will be considered under 3 aspects:

- Growth
- Histological differentiation
- Position adjustment

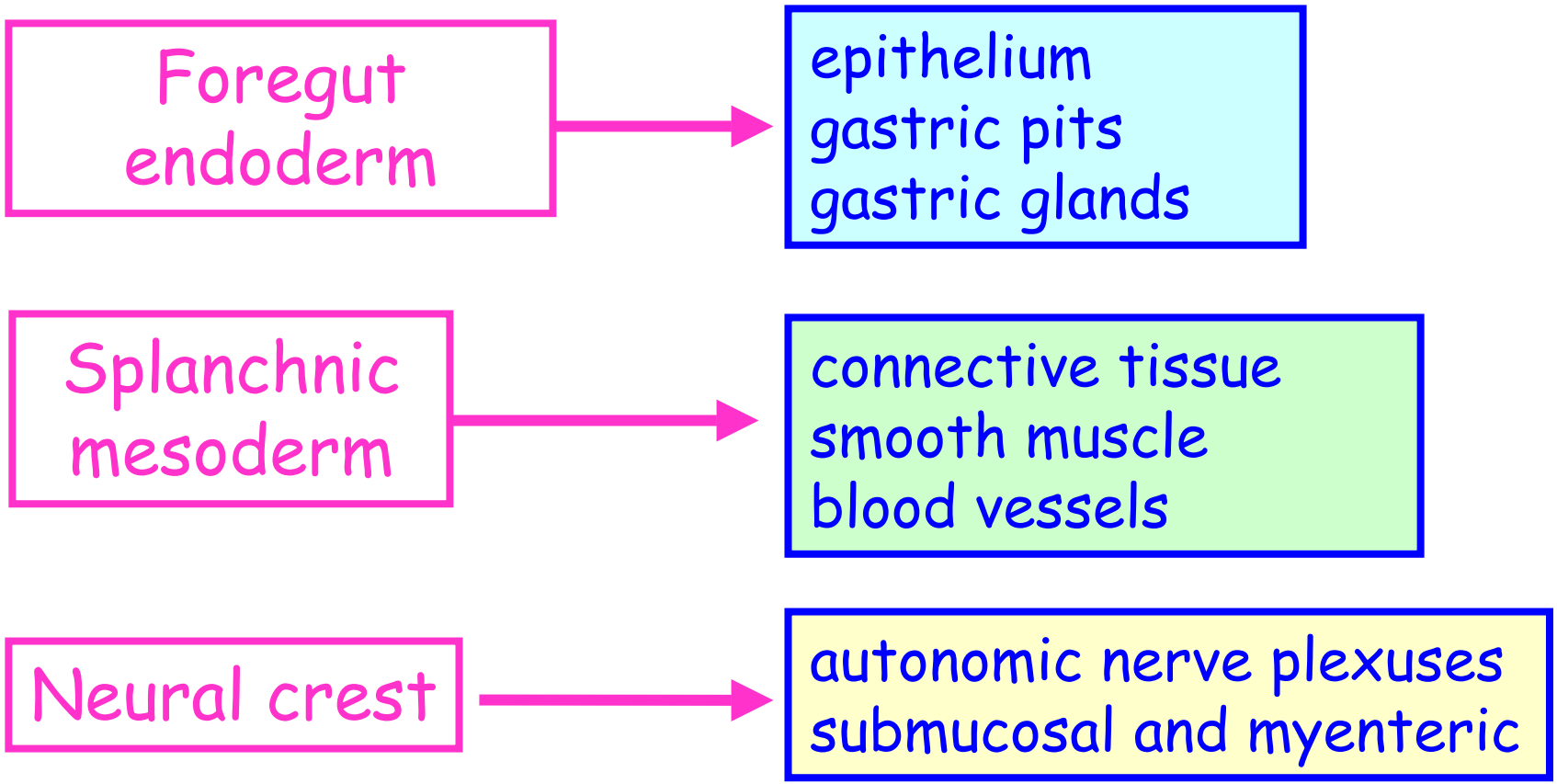
Growth of the stomach

- **4th –8th week** the developing stomach grows in all directions to become a sac-like structure
- **5th week** – the dorsal border grows faster than the ventral border giving rise to the greater and lesser curvatures, respectively
- **8th week** the stomach acquires its characteristic shape



Differential growth gives shapes to the stomach

Differentiation of the Stomach



Histological Differentiation of the Stomach

Differentiation occurs during the 2nd- 3rd months

Time frame

8 weeks → rughae, pits, smooth muscle

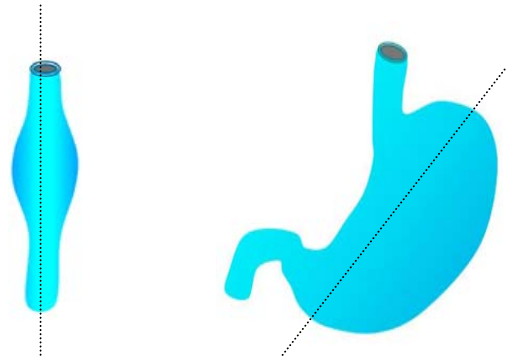
10 - 20 weeks → chief (zymogen), parietal (oxyntic) cells

8-9 months → glands become functional, secrete HCl and enzymes

Position adjustment of the stomach

a. Descent - Due to rapid elongation of the oesophagus, the cardiac end of the stomach descends from C2 at 4 weeks to T11 at 12 weeks

b. Tilting - from a vertical position at 4 weeks to an oblique position by 8 weeks. This is due to more rapid growth along the greater curvature.



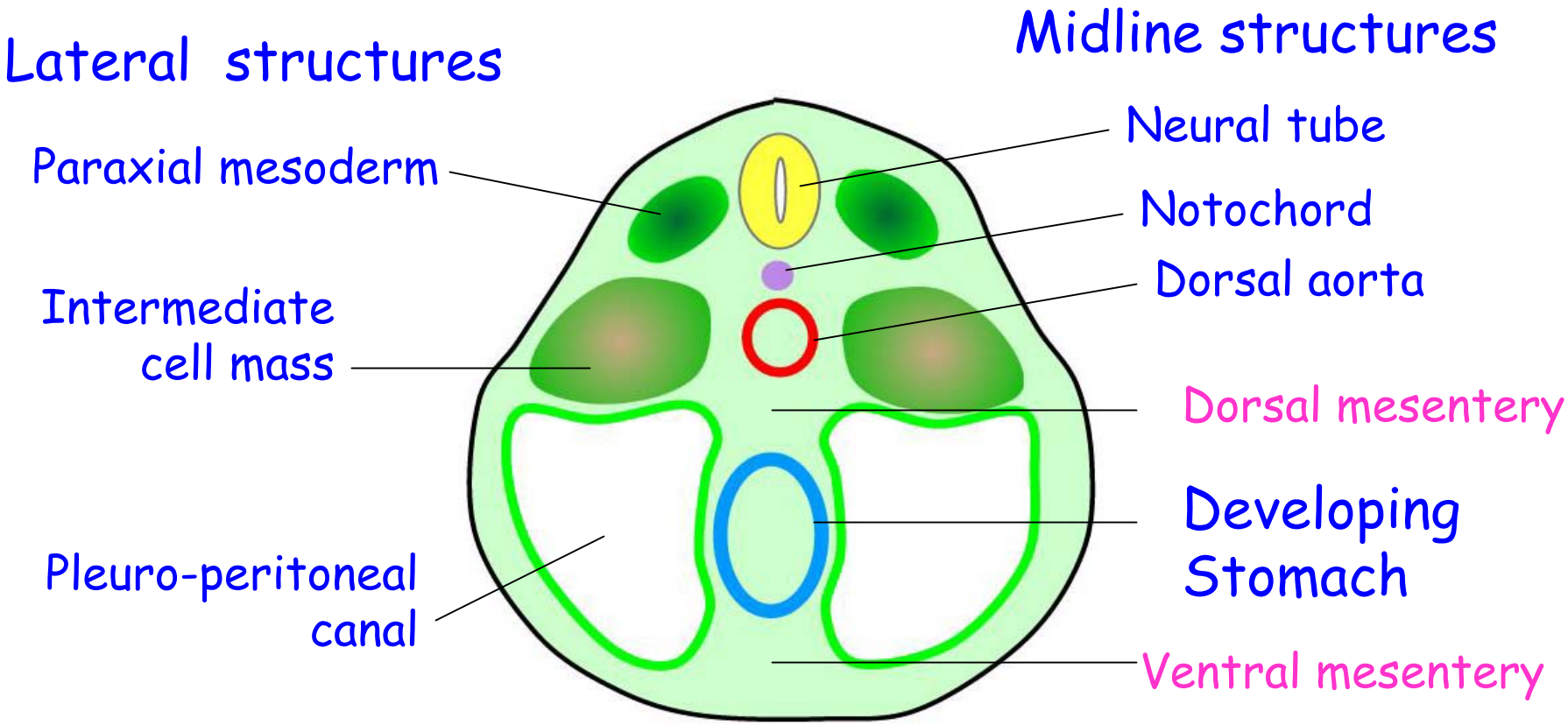
28 days 56 days

c. Rotation - 90° around a vertical axis, so that the original dorsal border (greater curvature) becomes left and the original left surface becomes ventral (anterior).

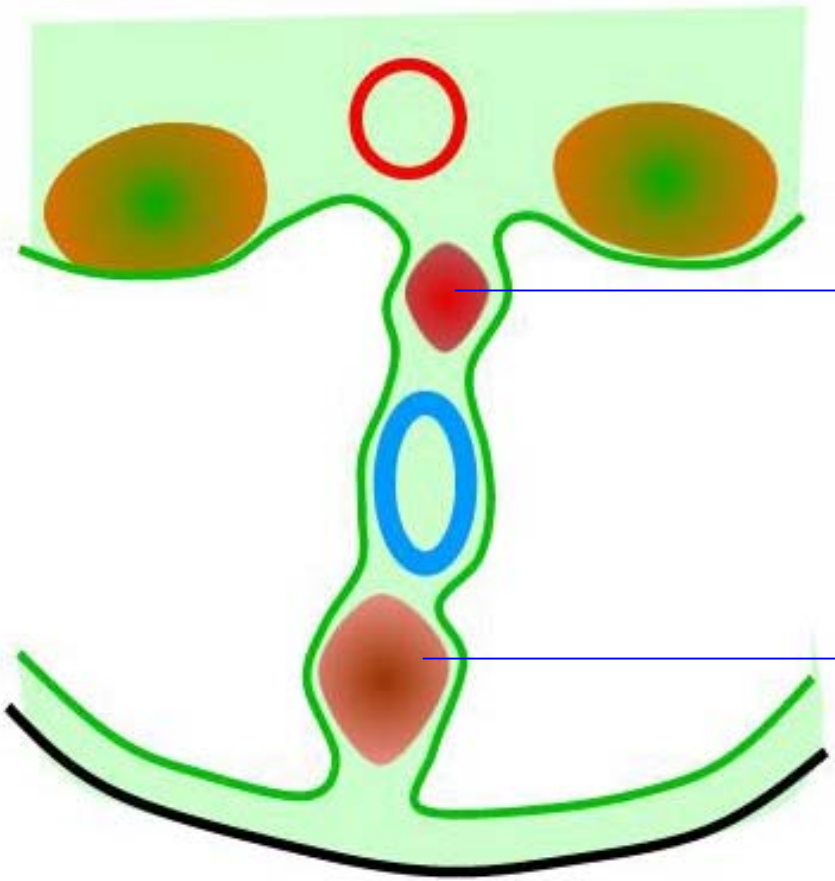
d. Shift to the left - of both the dorsal mesentery and the stomach

The stomach develops in the septum transversum and has dorsal and ventral mesenteries

28 day embryo: TS at the level of septum transversum



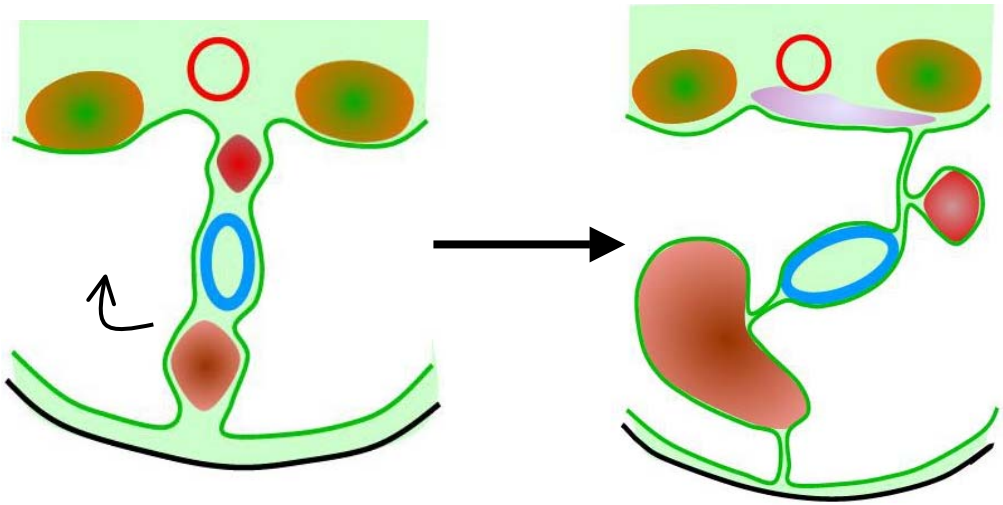
The liver and spleen develop within the mesenteries of the stomach



The spleen develops in the dorsal mesentery.

The liver develops in the ventral mesentery.

The stomach undergoes 90° rotation around cranio-caudal axis during the 5th week



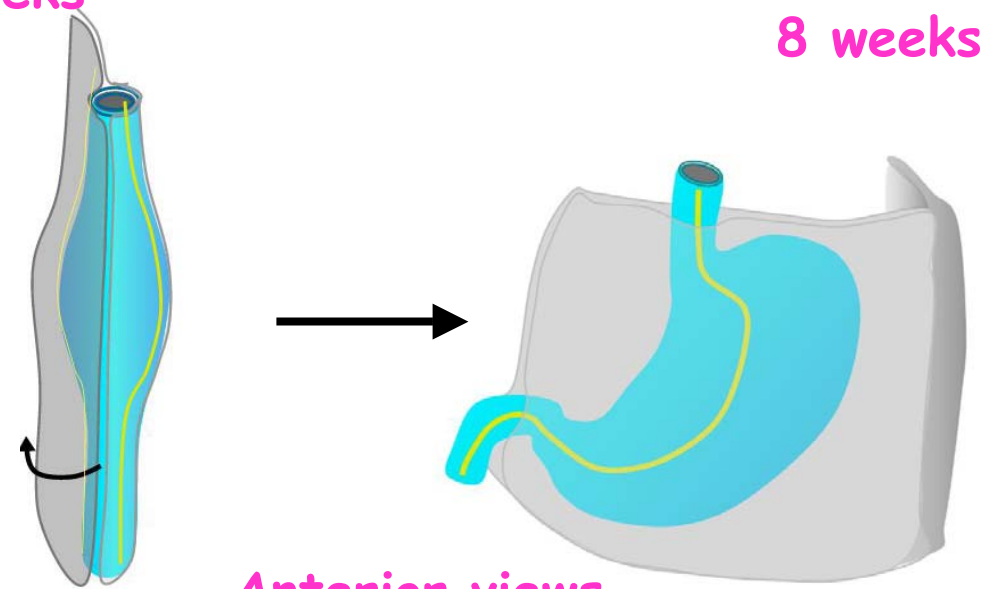
Transverse sections

It hinges on the dorsal mesentery and folds 90° to the right.

The dorsal mesentery shifts to the left.

4 weeks

8 weeks



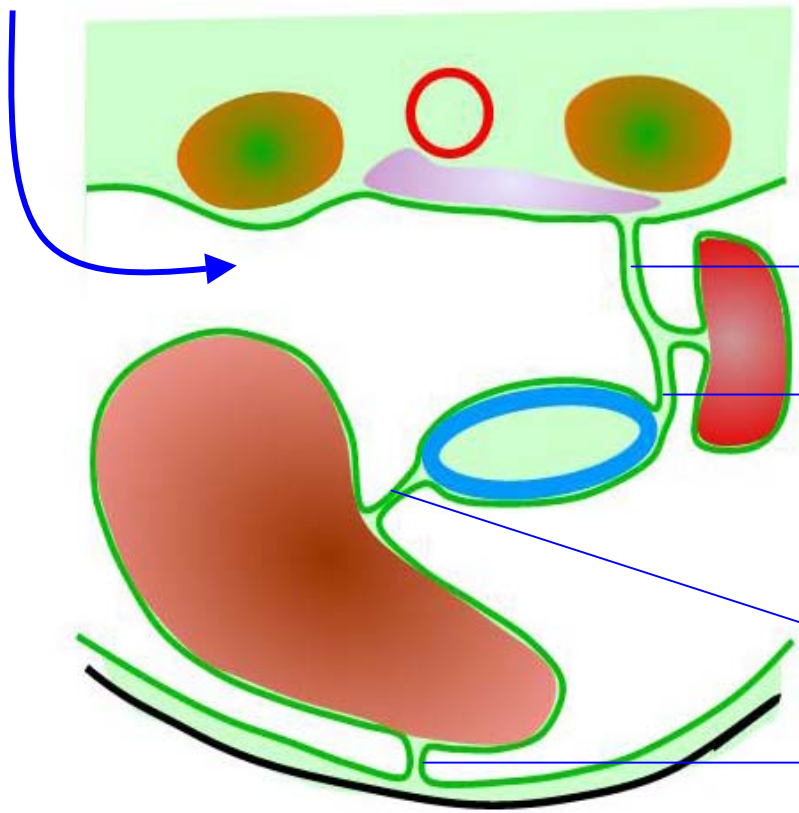
Anterior views

The vagus nerves serve as markers:

Left → ventral
Right → dorsal.

The omental bursa forms as a result of rotation of the stomach.

It communicates with the peritoneal cavity on the right.



Note peritoneal ligaments related to the stomach:

Lieno-renal lig.

Lieno-gastric lig.

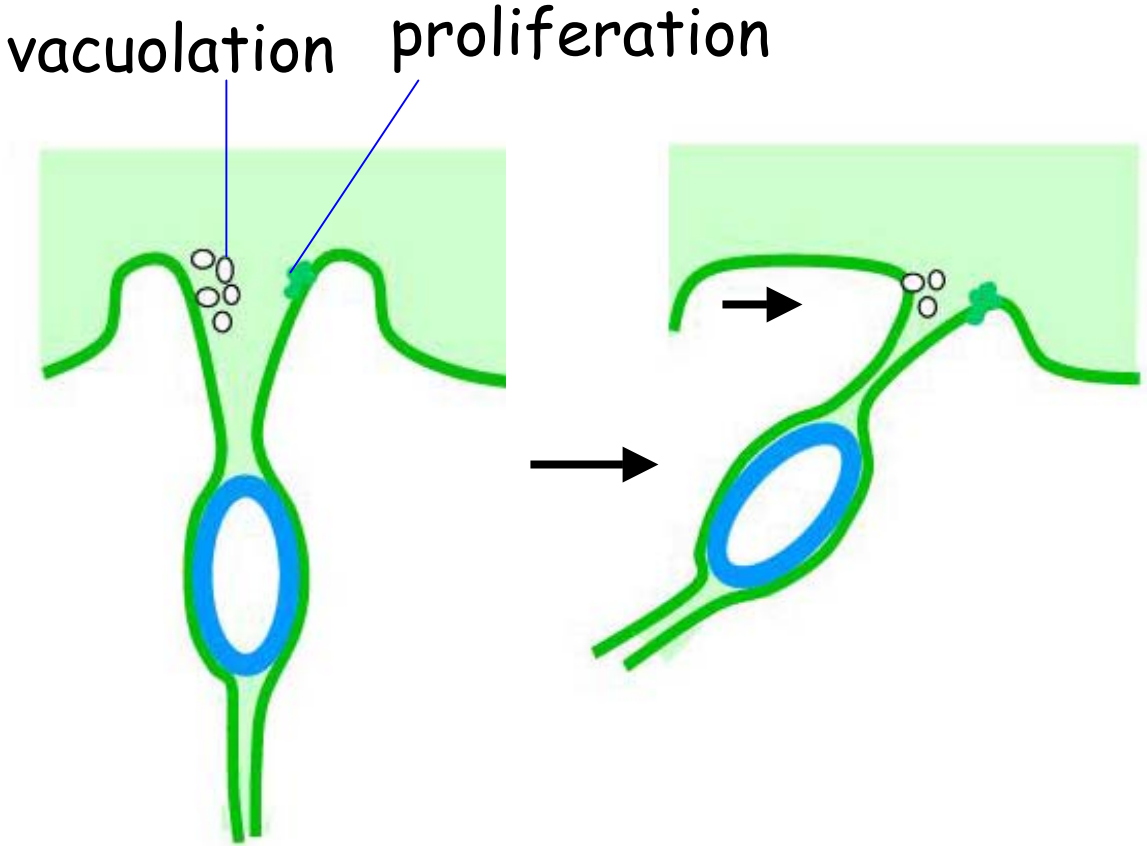
} Dorsal mesentery

Lesser omentum

Falciform lig.

} Ventral mesentery

As rotation occurs, the dorsal mesentery of the stomach shifts to the left.



This occurs by differential proliferation and vacuolation at the broad base of the dorsal mesentery

The stomach is also shifted bodily to the left due to growth of the liver on the right side

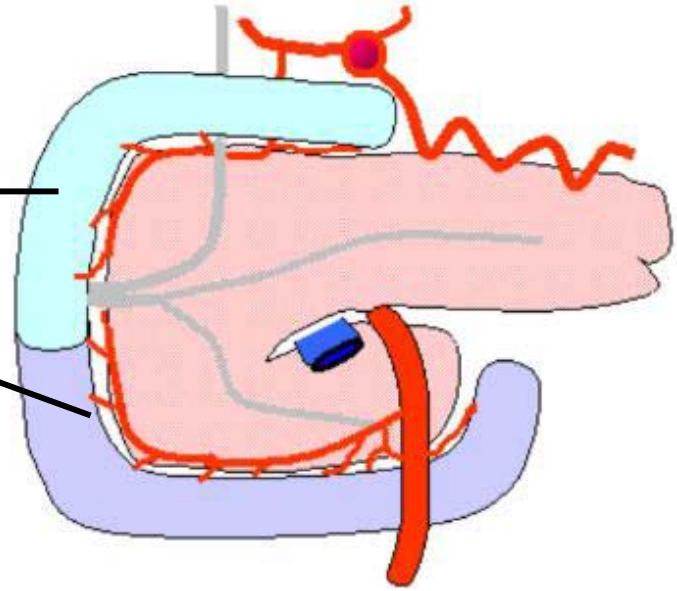
The Duodenum

- is derived from the terminal end of the foregut and the proximal end of the midgut;
- receives a dual blood supply from foregut and midgut arteries (coeliac and superior mesenteric)
- the origins of the liver and pancreatic buds are just proximal to the junction of the two parts
- becomes C-shaped through differential growth
- rotates 90° to the right, the same rotation as occurs in the stomach
- becomes secondarily retroperitoneal, and loses its mesentery. Consequently the pancreas, developing in its mesentery also becomes retroperitoneal.
- its lumen is obliterated by rapid cell proliferation during the 2nd month (5-8 weeks) and is re-canalized by apoptosis soon after.

The Duodenum

Derived from the:

- distal end of foregut
- proximal end of midgut



becomes C-shaped by differential growth

Receives a dual blood supply from foregut and midgut arteries (coeliac and superior mesenteric arteries)

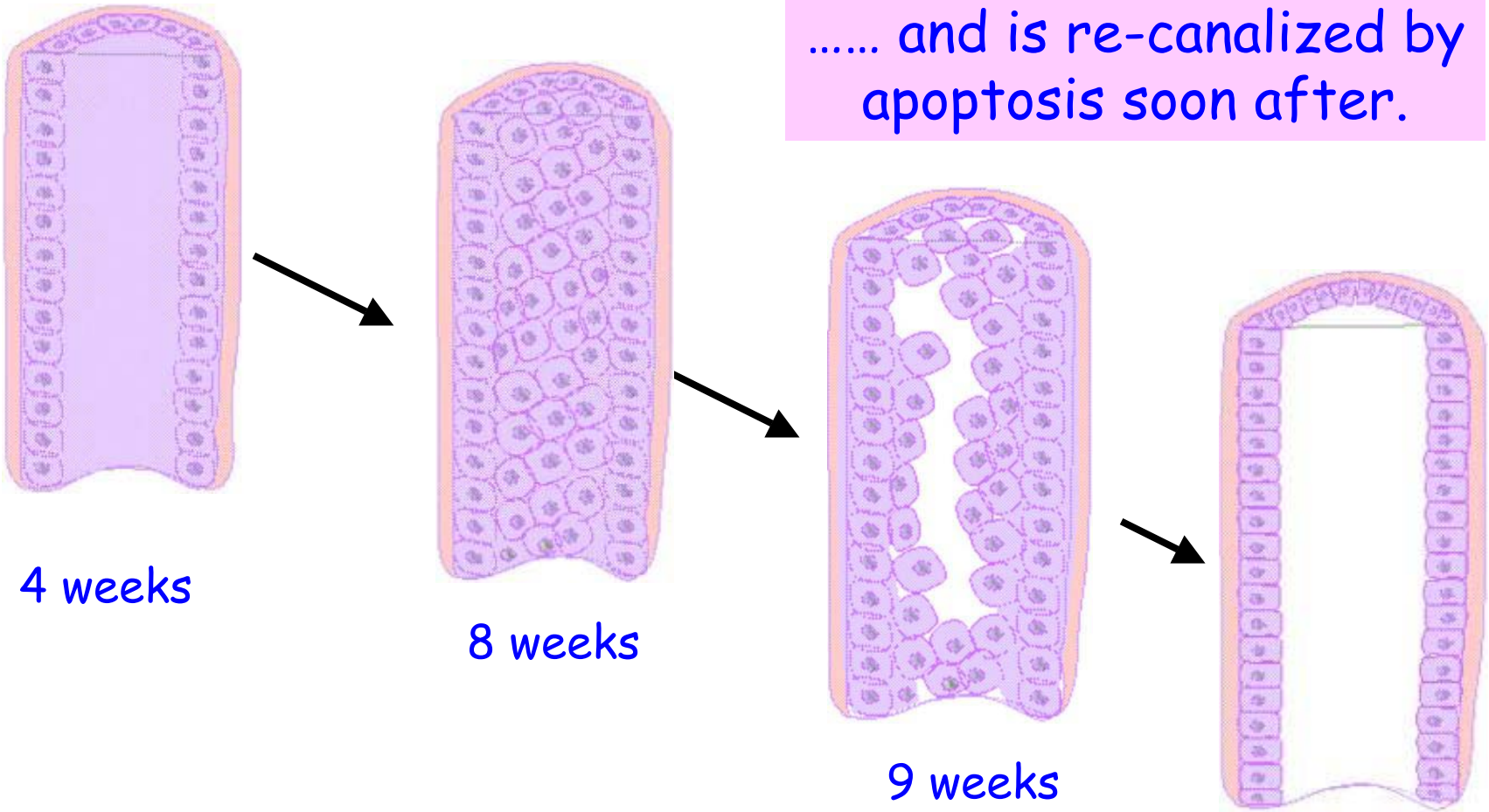
Originally in the midline, it rotates 90° to the right (the same rotation as occurs in the stomach)

Gives rise to the liver and pancreatic buds from the distal foregut.

It loses its mesentery and becomes secondarily retroperitoneal

The lumen of the duodenum is obliterated by rapid cell proliferation during the 2nd month …….

…… and is re-canalized by apoptosis soon after.



4 weeks

8 weeks

9 weeks

10 weeks

Duodenal Atresia and Stenosis

Most cases of duodenal atresia result from incomplete recanalization of the lumen distal to the duodenal papilla.

Clinical Features:

- repeated bile-stained vomiting on first day postnatal
- double bubble - bubble in stomach and bubble in dilated part of the duodenum separated by the air-free pyloric canal.
- no intestinal gas shadows
- relieved by resection of obstructed segment

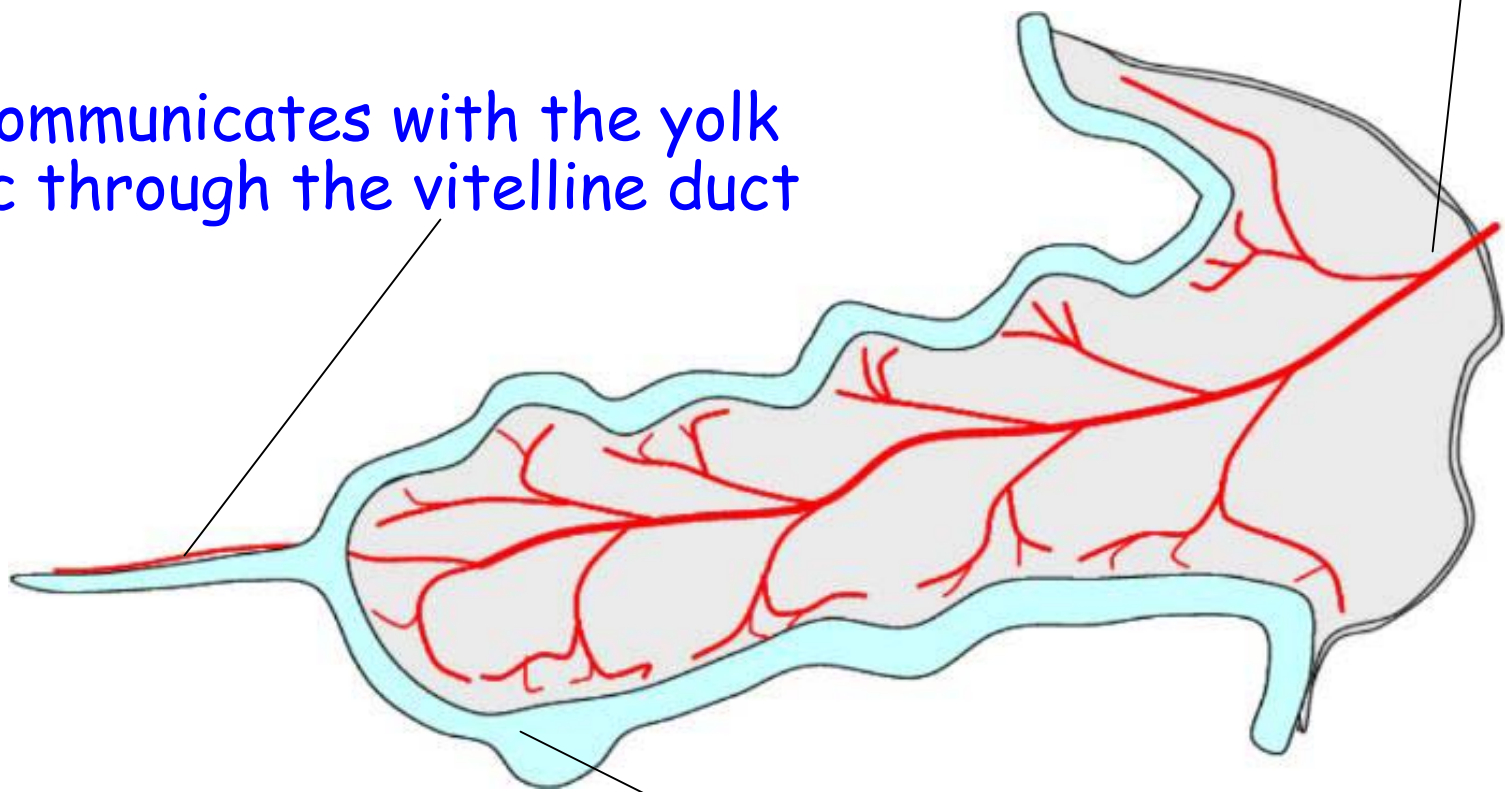
About 25% of cases are associated with Down syndrome

The Midgut

at 5 weeks consists of a simple loop suspended by a dorsal mesentery

supplied by the superior mesenteric artery

communicates with the yolk sac through the vitelline duct

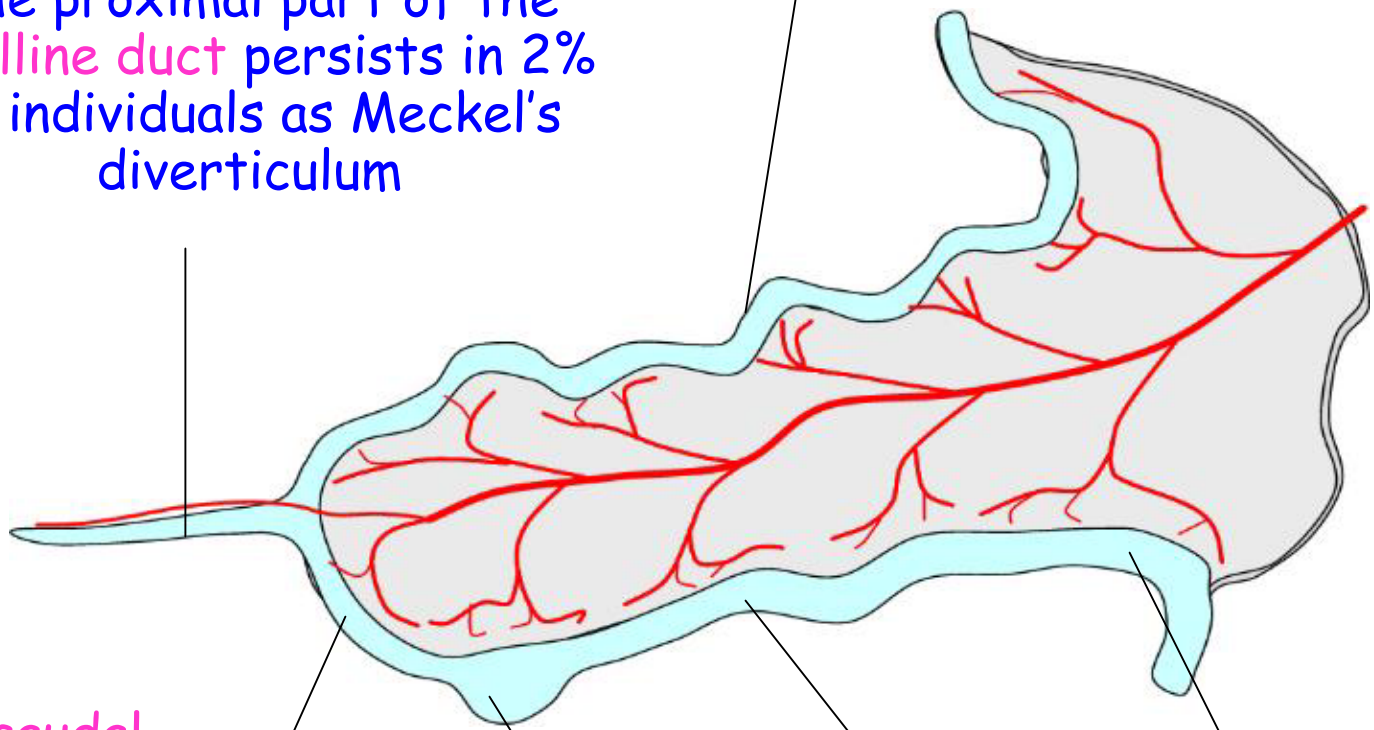


swelling in the caudal limb marks the future caecum

Midgut Derivatives

The cranial limb elongates greatly to form the jejunum and two-thirds of the ileum

The proximal part of the vitelline duct persists in 2% of individuals as Meckel's diverticulum



The caudal limb forms:

Distal end of ileum

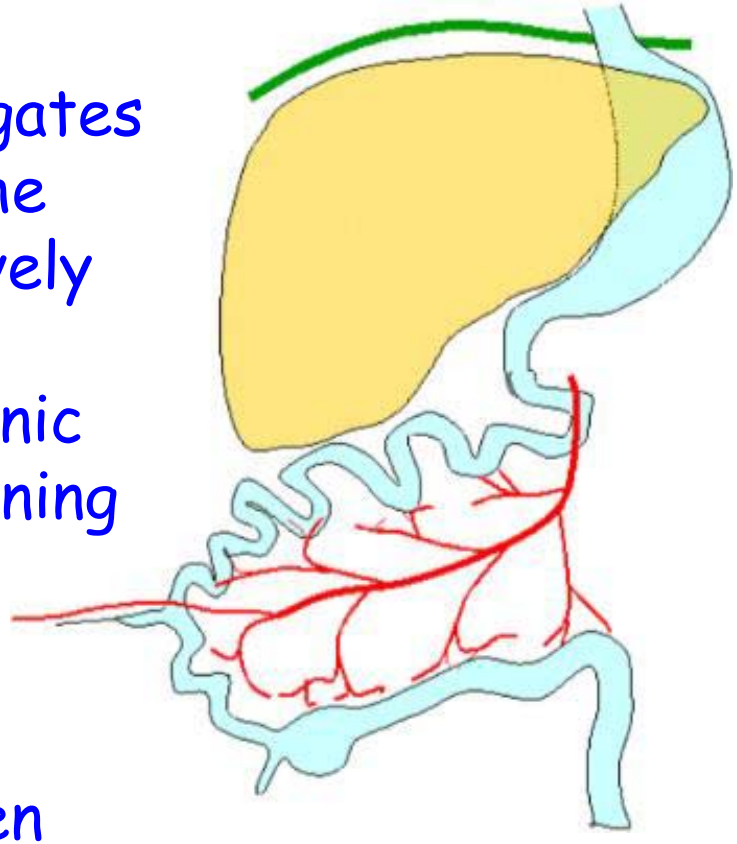
Caecum & appendix

Ascending colon

Transverse colon

Midgut Herniation

At 6 weeks the midgut loop elongates rapidly and the liver enlarges. The abdominal cavity becomes relatively small and part of the intestine herniates into the extra-embryonic coelom,through the coelomic opening next to the umbilical cord.

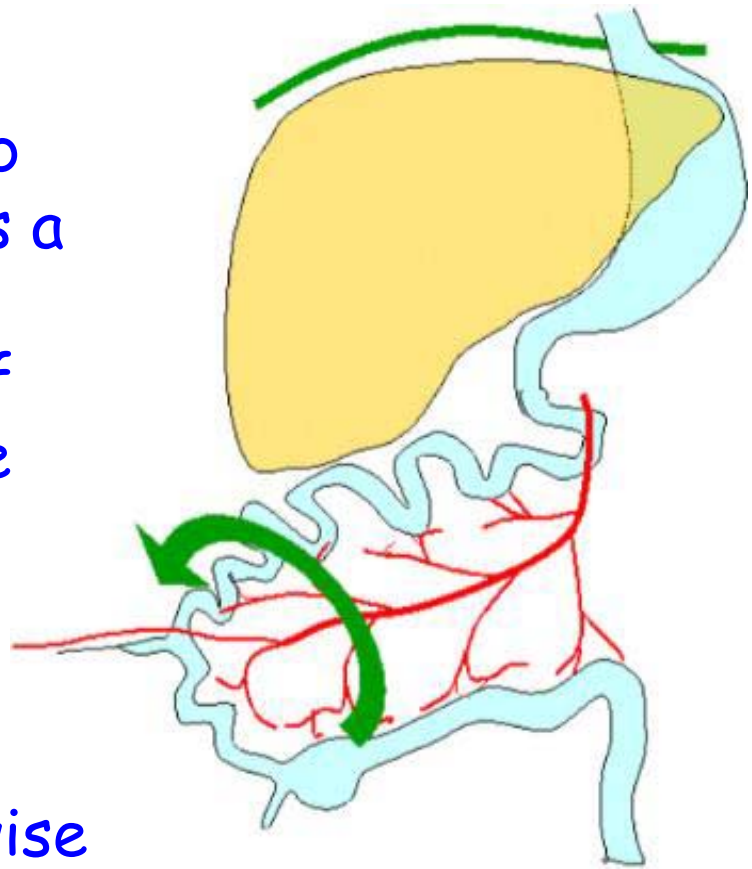


Midgut Retraction

During the 10th week the abdomen enlarges and the intestine returns into the abdominal cavity. As this occurs, the midgut loop rotates so that the different parts of the intestine acquire their definitve positions in the abdominal cavity.

Midgut Rotation

- The caecum in the caudal limb of the midgut loop is taken as a landmark for rotation.
- It 'rotates' through a total of 270° anticlockwise to acquire its definitive position.

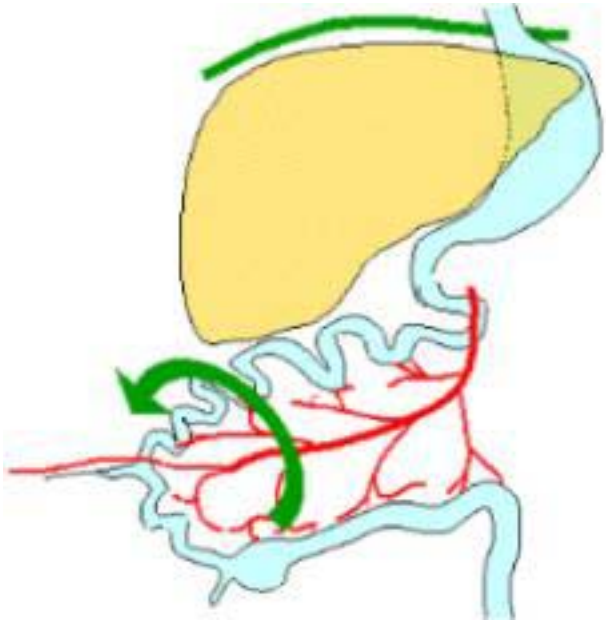


Rotation occurs in two stages:

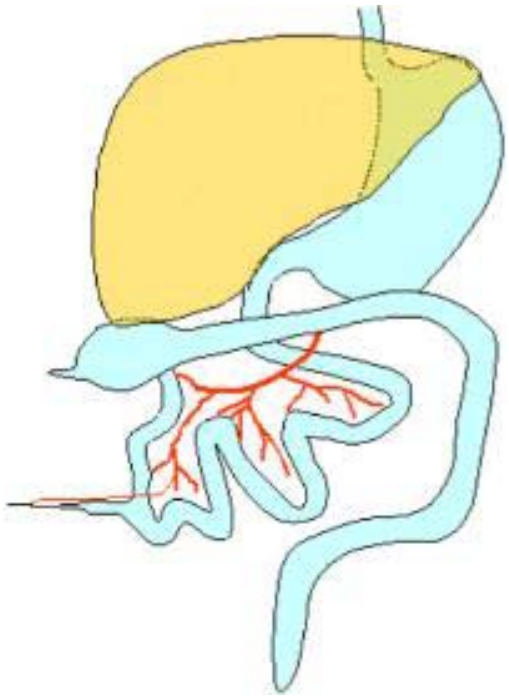
a. At 6 weeks: 90° anti-clockwise
 – the caecum is shifted to the left

b. At 10 weeks: 180° anticlockwise
 – the caecum acquires its definitive position

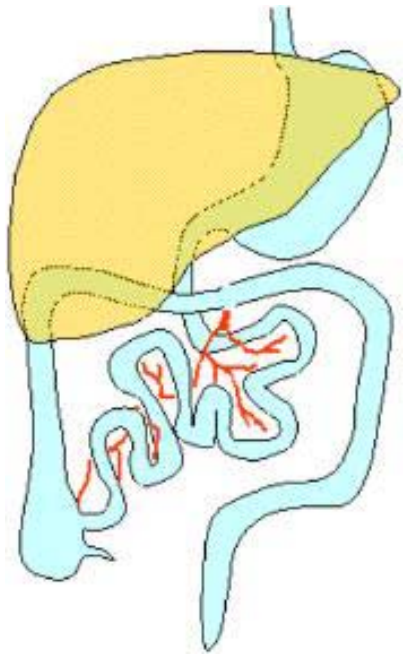
Three positions of the caecum during midgut development



Caecum situated caudally
6 weeks

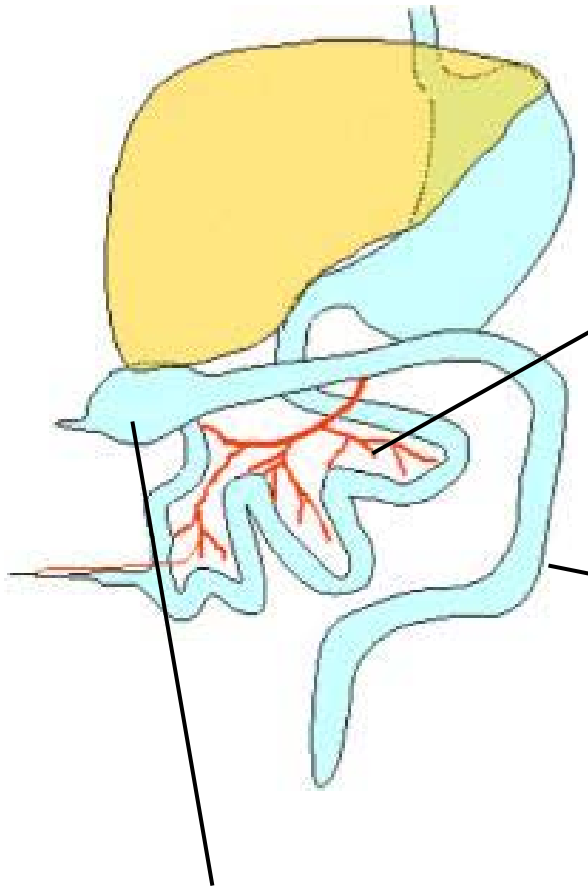


Caecum below right lobe of liver
10 weeks



Caecum in right iliac fossa
11 weeks

Retraction and Rotation of the Midgut Derivatives



During the return of the gut, the loops of small intestine (cranial limb) return first, and are situated to the right of the dorsal mesentery.

The descending colon (hindgut) is shifted to the left.

The caecum is the last to return, and has to be located to the right.

Atresia of the Jejunum, Ileum and Colon

- Atresias of the small intestine and colon are rare
- most cases are segmental rather than localized.
  ie. they involve a long segment of the jejunum or ileum
- some cases involve a large segment of the midgut loop derivatives – termed "apple peel" atresia because a short segment of intestine distal to the atresia is coiled around the superior mesenteric artery remnant.

Atresias of the jejunum, ileum or colon, unlike duodenal atresia, result from arterial occlusion rather than failure of recanalization

Most cases present as intestinal obstruction a few days after birth

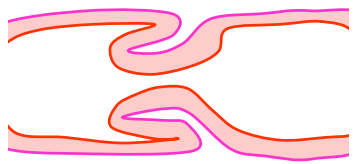
Malrotation of the gut

- Clockwise rotation results in intestinal situs inversus
- Failure of rotation may result in left-sided caecum, appendix and ascending colon
- Incomplete rotation - subhepatic caecum and appendix

Some cases of malrotation are asymptomatic but may cause diagnostic problems in cases of appendicitis in later life

Volvulus is a rotation of an intestinal loop around a branch of the superior mesenteric artery
- it may cause intestinal obstruction or even gangrene
-some cases correct spontaneously but surgical intervention is usually performed

Intussusception is the invagination of a segment of intestine in itself, causing obstruction



Persistent Vitello-intestinal Duct and Meckel's Diverticulum

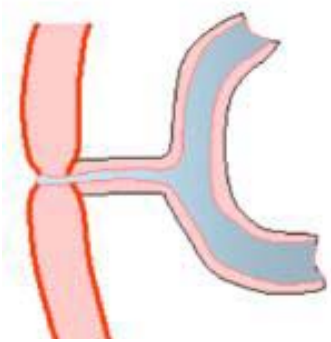
There are various degrees of persistence of vitelline duct:

- Vitelline fistula – meconium oozes out of umbilicus
- Vitelline cyst – part od duct is not obliterated
- Vitelline cord – attaches ileum to umbilicus
- Meckel's diverticulum – persistent proximal part of vitelline duct occurs in 2% of normal individuals

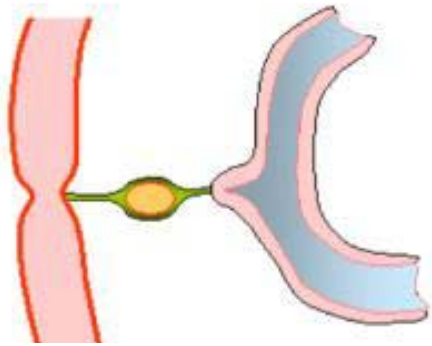
Combinations of the above may also occur

Persistent vitelline duct of any degree may contain ectopic gastric mucosa ad pancreatic acini causing intestinal ulceration and bleeding

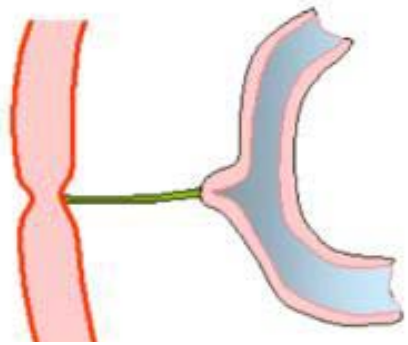
Anomalies of the Vitelline Duct



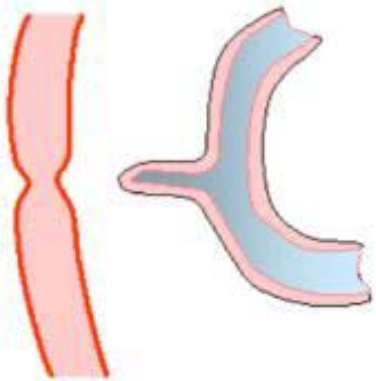
Vitelline fistula



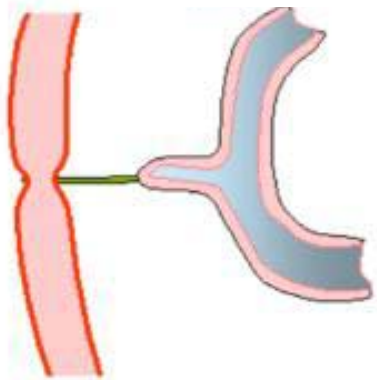
Vitelline cyst



Vitelline cord



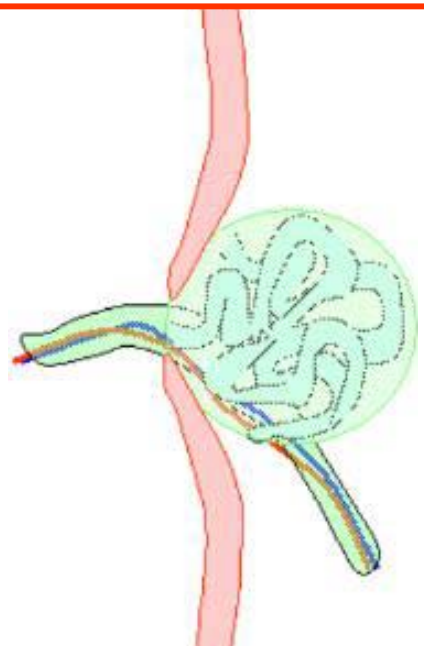
Meckel's diverticulum



Meckel's diverticulum and vitelline cord

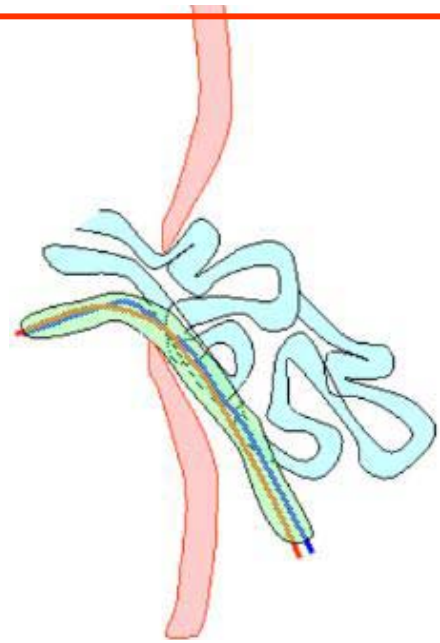
Any type of persistent vitelline duct may contain ectopic gastric mucosa and pancreatic acini causing intestinal ulceration and bleeding

Omphalocoele



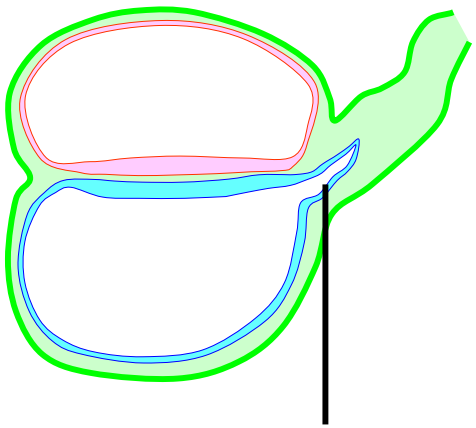
- Herniation of abdominal viscera through a large umbilical ring
- defect of lateral plate mesoderm
- Viscera covered by peritoneal and amniotic membrane
- 50% have other serious congenital or chromosome abnormalities

Gastroschisis



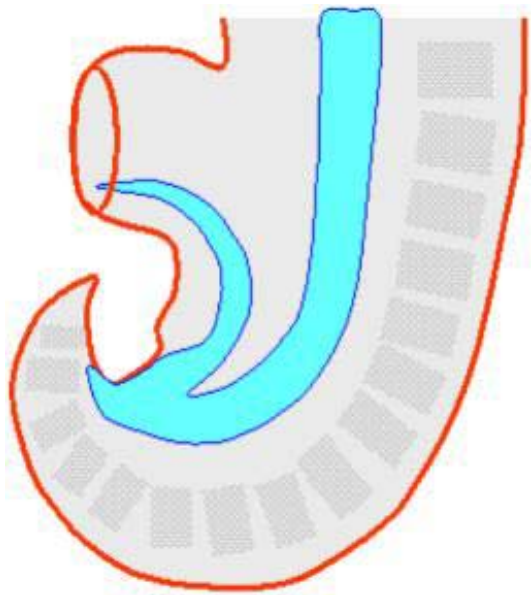
- Herniation of viscera through ruptured abdominal wall defect into the amniotic cavity
- to the right of the umbilicus
- no covering membranes; viscera bathed directly in amniotic fluid.
- less commonly associated with other anomalies

The Hindgut



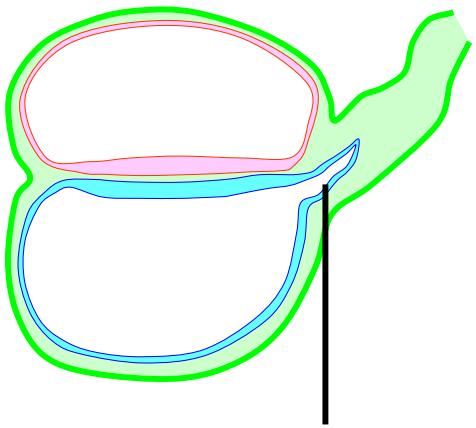
The allantois appears at about 16 days as a small diverticulum projecting from the caudal end of the yolk sac into the connecting stalk

26 days: After formation of the tail fold, the allantois and hind gut open into a common chamber the cloca. The cloacal membrane separates cloaca from the proctodaeum.



The urorectal septum separates the hindgut from the allantois. It grows towards the cloacal membrane. It is derived from mesoderm at the junction between the connecting stalk and yolk sac.

The Hindgut



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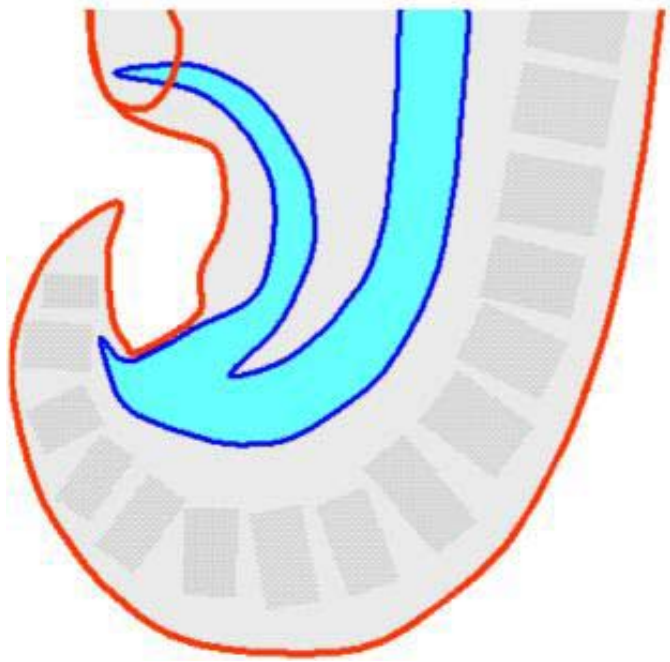

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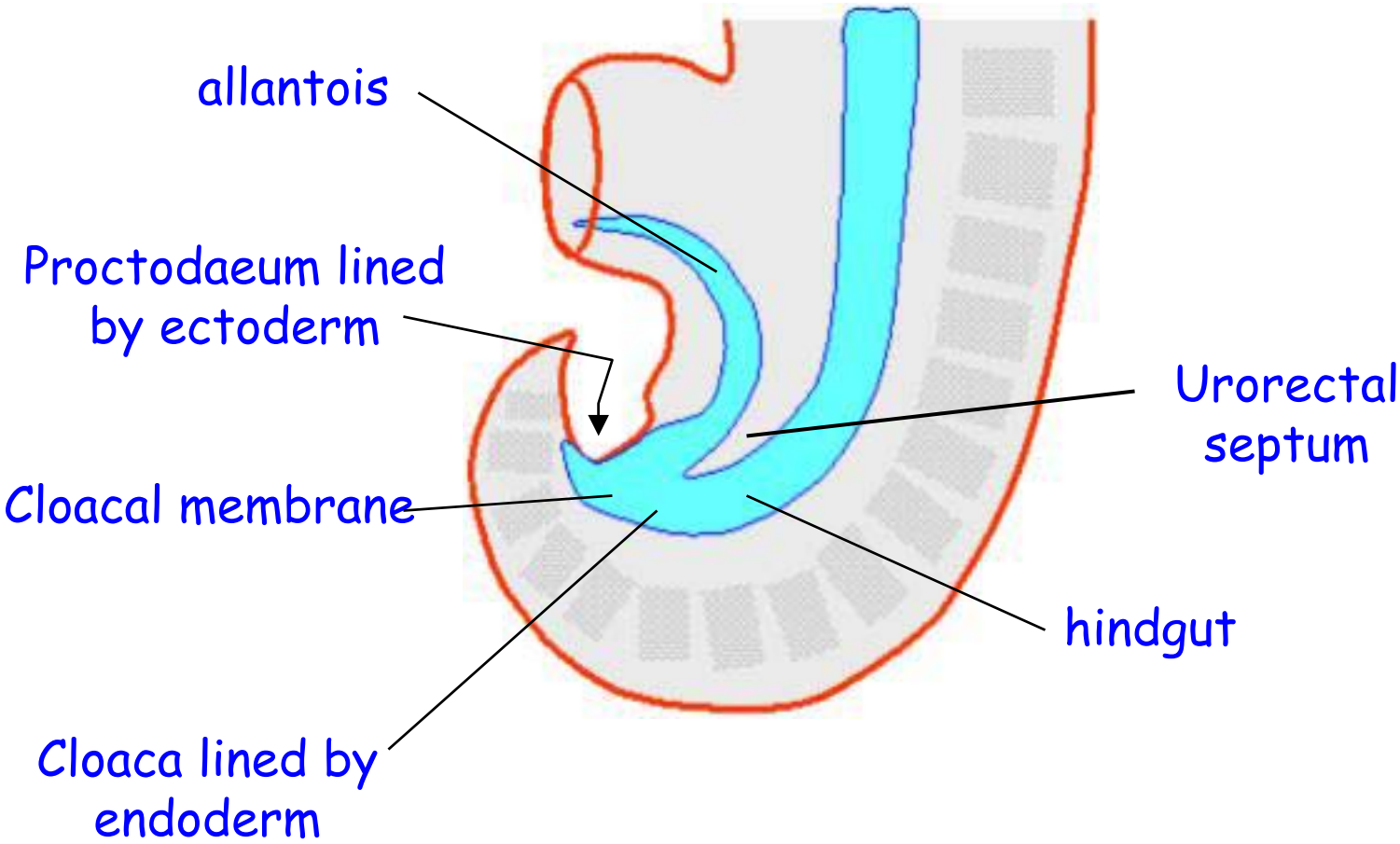
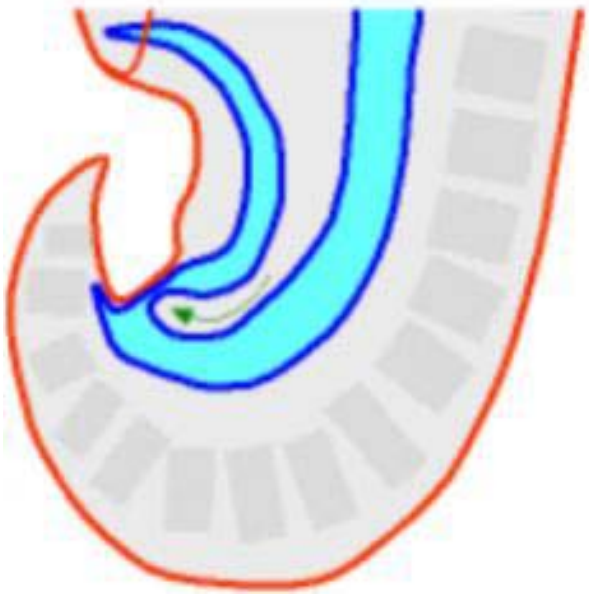
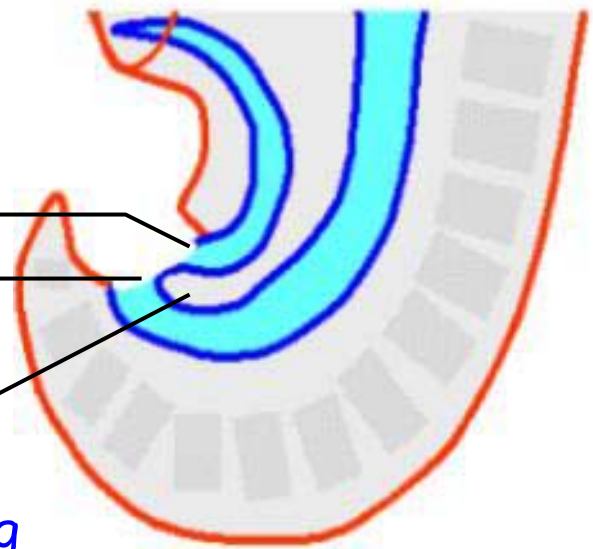
The Hindgut


allantois
Proctodaeum lined by ectoderm
Urorectal septum
Cloacal membrane
hindgut
Cloaca lined by endoderm



The urorectal septum grows towards the cloacal membrane but does not fuse with it. It is derived from mesoderm at the junction between the connecting stalk and yolk sac.

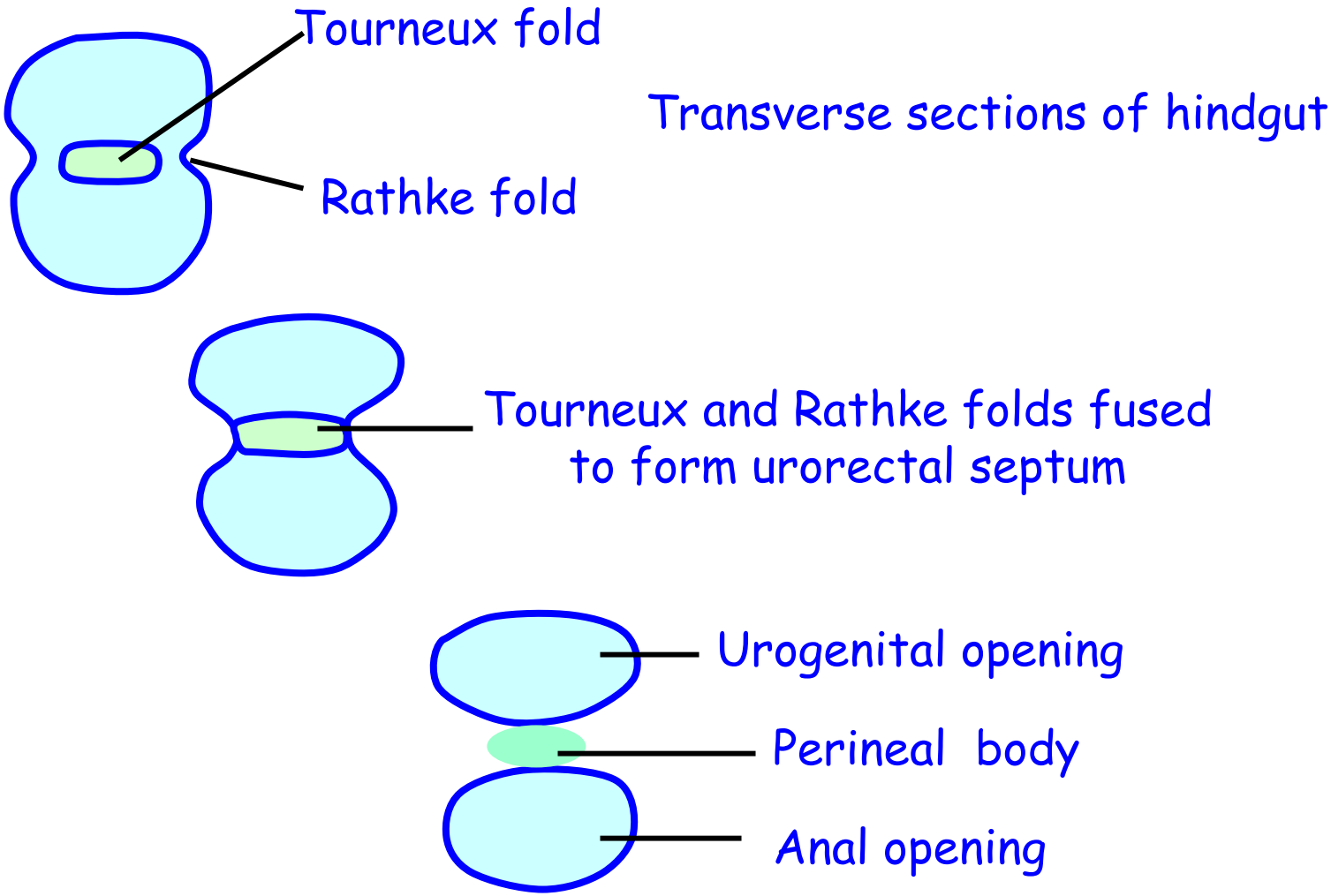
During the 7th week the cloacal membrane disappears, exposing a ventral urogenital sinus opening and a dorsal anal opening.



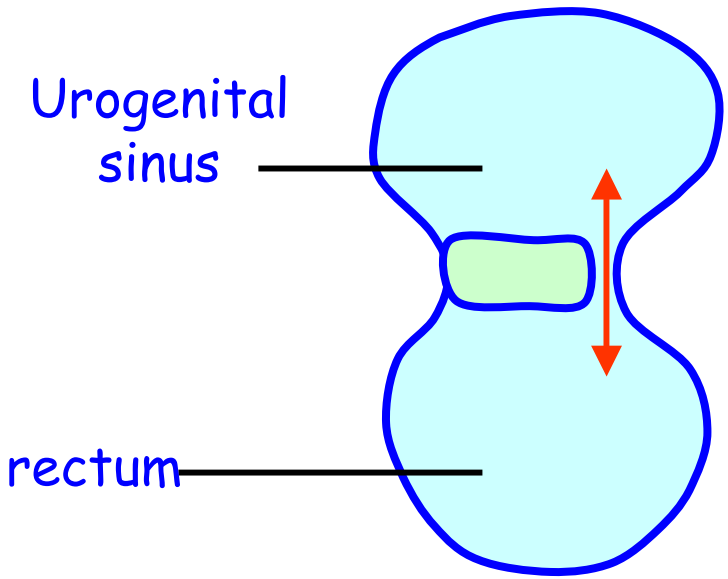
The tip of the urorectal septum, separating the two openings forms the perineal body.

The urorectal septum is composed of two folds:

1. A superior, midline fold of Tourneux
2. Paired (right and left) lateral Rathke folds



Defects in the Fusion of the Tourneux Fold and the Rathke fold Result in Various Forms of Uro-rectal Fistula

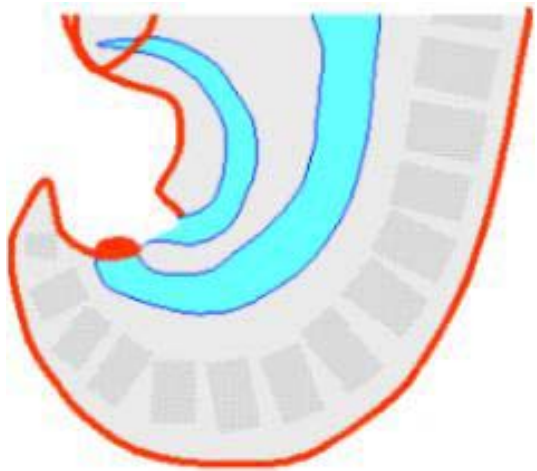


Depending on the level of the defect and the sex of the embryo the fistulas may be:

Recto - vesical
Recto - urethral
Recto - vaginal
Recto – vestibular
Ano - perineal

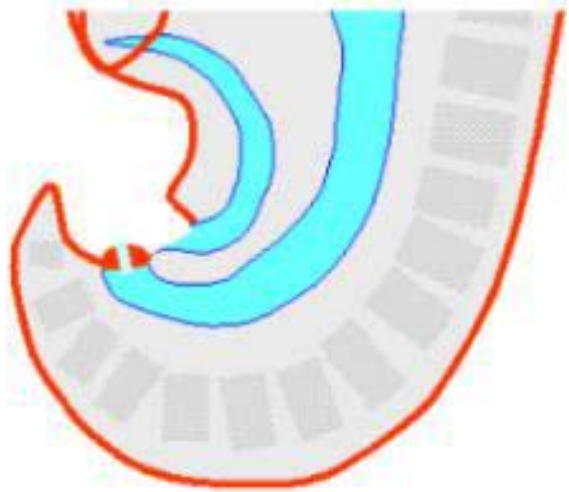
The Anal Canal

- At the end of the 8th week, after rupture of the cloacal membrane, proliferation of ectoderm occludes the anal opening.



- During the 9th week the opening is recanalized.

- Thus the terminal part of the anal canal is ectodermal in origin and supplied by the inferior rectal artery.



- The junction between ectoderm and endoderm is the pectinate line.

Pattern of Histodifferentiation in the Gastrointestinal Tract

4 weeks: formation of primordia
– stomach dilatation;
-duodenal loop;
- midgut loop;
- caecal dilatation

5 – 6 weeks – development of circular muscle - splanchnopleure

6-7 weeks – proliferation with occlusion of lumen in oesophagus and SI

8-9 weeks – recanalization – oesophagus and duodenum
Differentiation of epithelial derivatives
- pits and gland rudiments in stomach
- Villi and crypts in intestines + glands in duodenum
Differentiation of longitudinal muscle

9 – 10 weeks – differentiation of cell types – oxyntic cells, chief cells, mucus neck cells, surface epithelial cells

Aganglionic Megacolon – Hirschsprung Disease

Due to congenital absence of parasympathetic ganglia in the colon. This is a neural crest migration defect. It may be due to a genetic mutation of the *RET* gene, a tyrosine kinase receptor involved in neral crest cell migration.

It varies in extent –

80% involve sigmoid colon and rectum;

3% involve the whole colon.

The End

Go to Liver and Pancreas.ppt