Embryology

Second Year Students
UJ-GIG GI Booklet

Table of Contents

The University of Jordan
Gastroenterology Interest Group (UJ-GIG)
Booklet

Embryology

GI tract embryology 1

Written by: Yasmin Al Subaihi

Edited by: Bdour Abdallat

Development of the Oral Cavity

The mouth is unique because it originates from **two different germ layers** which meet at a specific membrane.

Feature	Source 1: Depression in Stomodeum	Source 2: Foregut (Cephalic End)
Origin	Ectoderm	Endoderm
Location	Depression (external)	Cephalic end of the gut tube
Separation	Buccopharyngeal Membrane	

- **Key Event:** During the **3rd week** of development, the buccopharyngeal membrane disappears, allowing communication between the primitive mouth and the gut.
- **"Imaginary Line":** If the membrane persisted, it would run through the sphenoid, soft palate, and the inner surface of the mandible.

Anterior to the plane (Ectodermic origin):

1. Hard palate
2. Sides of the mouth
3. Lips
4. Enamel of the teeth
5. Stomodeum
6. Maxillary and mandibular processes

Posterior to the Plane (Endodermic Origin):

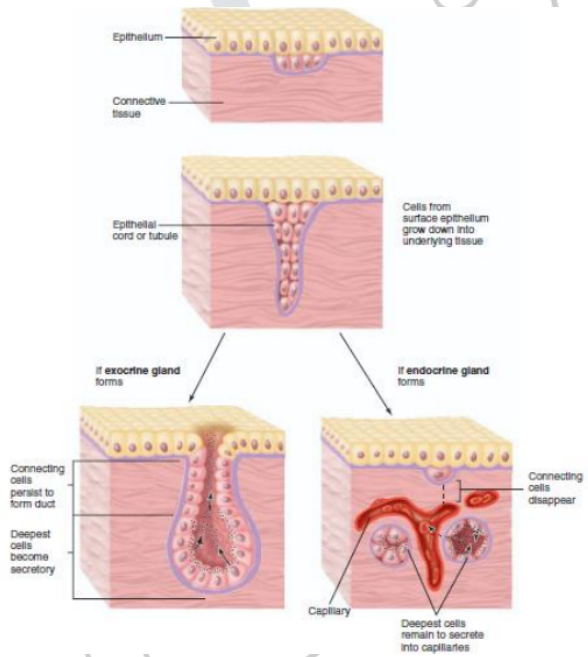
1. Tongue
2. Soft palate
3. Floor of the mouth
4. Palatoglossus and palatopharyngeal folds

Development of Salivary Glands

The salivary glands arise through a specific process of epithelial-mesenchymal interaction.

- **7th week initiation:** Glands begin as solid outgrowths of epithelial cells from the walls of the developing mouth.
- **Mechanism of growth:** These cells proliferate and project into the underlying mesenchyme (epithelial-mesenchymal interactions).
- **Branching and canalization:** The epithelial buds undergo repeated branching to form solid ducts. Eventually, the ends of these ducts form secretory acini, and both structures undergo "canalization" (hollowing out to form a tube).

Gland	Germ Layer Origin
Parotid Gland	Ectoderm (ducts and acini)
Submandibular Gland	Endoderm
Sublingual Gland	Endoderm



Notice the difference between endocrine and exocrine glands:

- **Exocrine Glands:** Retain continuity with the surface via a duct.
- **Endocrine Glands:** Lose direct continuity with the surface as their ducts degenerate; they secrete directly into capillaries (bloodstream).

Development of the Tongue

The tongue begins its development at approximately **4 weeks** where the stomodeum and pharynx meet.

The tongue is formed from several swellings across the pharyngeal arches:

1. **Anterior 2/3 (Body):** 1st pharyngeal arch. Formed by two **lateral lingual swellings** and one medial swelling (**tuberculum impar**). It is separated from the posterior third by sulcus terminalis.
2. **Posterior 1/3 (Root):** 2nd, 3rd, some of 4th pharyngeal arches. Formed by the **copula** (or hypobranchial eminence).
3. **Epiglottis:** 4th arch. Formed by a third median swelling.

Innervation:

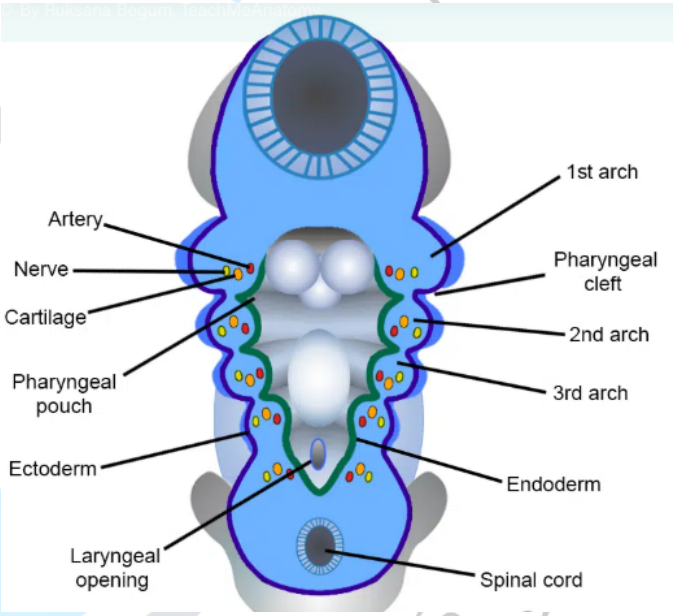
Part	Sensory Nerve	Reason (Arch Origin)
Anterior 2/3 (general)	Mandibular branch of trigeminal (V3)	Derived from 1st arch.
Anterior 2/3 (taste)	Chorda tympani (Facial - VII)	Special sensory innervation
Posterior 1/3	Glossopharyngeal (IX)	Indicates 3rd arch tissue overgrows 2nd arch.
Epiglottis/ Extreme Root	Superior laryngeal (Vagus - X)	Derived from 4th arch.
Musculature	Hypoglossal (XII)	Muscles derived from **occipital somites**.

Development of the Pharynx

Origin: The pharynx develops in the neck region from the **endoderm of the foregut**. It originates from the upper four pharyngeal pouches.

Structural formation: The endoderm is separated from the surface ectoderm by mesenchyme, which splits into **5-6 pharyngeal arches** on each side.

Clefts and pouches: These arches create external swellings called **pharyngeal clefts (ectoderm)** and internal grooves known as **pharyngeal pouches (endoderm)**.



Development of Anterior Abdominal Wall

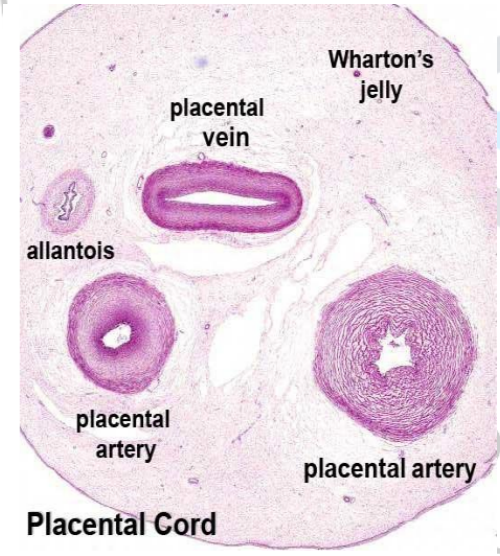
- Abdominal wall: Derived from somatopleuric mesoderm. It tangentially divides into three layers:

1. External oblique
2. Internal oblique
3. Transversus abdominis.

- Linea alba: Formed at 3 months when the right and left sides of mesenchyme fuse at the midline.

- Umbilical cord (around 45 cm): Forms when the amnion encloses the body stalk and yolk sac. It contains:

1. Wharton's jelly
2. Two umbilical arteries (deoxygenated blood)
3. One umbilical vein (oxygenated blood; right vein regresses)
4. Allantois: a duct between the umbilicus and the bladder.
5. Vitelline duct: an embryonic structure connecting the yolk sac to the midgut, providing nutrients during early development.



Vitelline Duct Remnants:

The vitelline duct normally disappears, but its persistence can lead to specific clinical conditions:

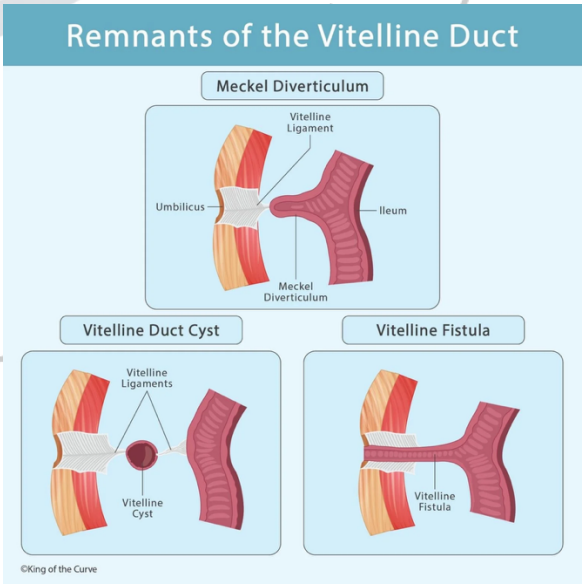
Meckel's Diverticulum (Ileal Diverticulum):

Structure: A small, persistent out pocketing of the ileum.
Location: In adults, it is typically found 40 to 60 cm from the ileocecal valve on the antimesenteric border of the ileum.
Symptoms: Usually asymptomatic. However, if it contains heterotopic (misplaced) gastric mucosa or pancreatic tissue, it can lead to ulceration, bleeding, or perforation.

Clinical correlation: If inflamed can mimic appendicitis. MCC of painless lower GI bleeding in the pediatric population. "Rule of 2s": occurs in ~2% of the population, is ~2 inches long, located ~2 feet from the ileocecal valve, contains 2 types of ectopic tissue (gastric ± pancreatic), commonly presents before age 2, and has a 2:1 male predominance.

Vitelline Cyst (Enterocystoma):

Formation: Occurs when both ends of the vitelline duct transform into fibrous cords while the middle portion remains patent and forms a large cyst.



Development of the Lungs

At **4 weeks**, a respiratory diverticulum (lung bud) appears as an outgrowth from the **ventral wall** of the foregut.

Signaling: Fibroblast Growth Factors (FGFs) from the surrounding mesenchyme instruct the endoderm to form the bud.

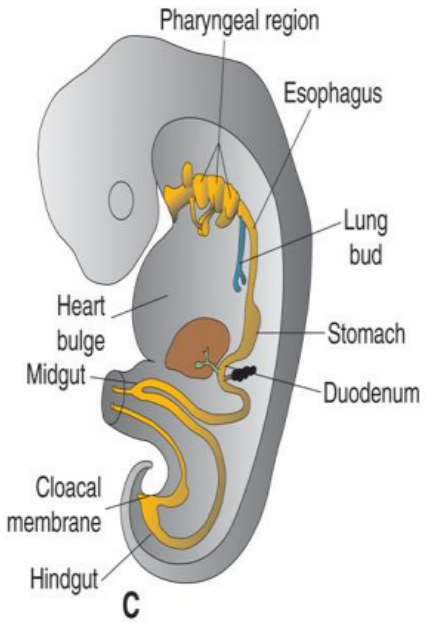
Germ Layer Contributions:

- **Endoderm** → internal epithelial lining of the larynx, trachea, bronchi, and lungs.
- **Splanchnic mesoderm** → cartilaginous, muscular, and connective tissue components.

The Tracheoesophageal Septum

Initially, the lung bud and foregut are in open communication (connected).

1. **Tracheoesophageal ridges:** Longitudinal ridges form as the bud expands caudally.
2. **Septum formation:** These ridges fuse to form the tracheoesophageal septum.
3. **Separation:** This divides the foregut into a dorsal esophagus and ventral trachea/lung buds.
4. **Laryngeal orifice:** The only remaining point of communication between the respiratory system and the pharynx.



Clinical correlation: if the whole process of separation does not occur, then an anomaly will occur referred to as tracheoesophageal fistula ± atresia. The newborn can present with excessive drooling, choking/coughing during feeds, and possible cyanosis.

The University of Jordan
Gastroenterology Interest Group (UJ-GIG)
Booklet

Histology

Upper GI Tract Embryology

Written by: Yasmin Al Subaihi

Edited by: Bdour Abdallat

[The Foregut]

The esophagus begins as a short tube that undergoes rapid lengthening as the heart and lungs descend.

Muscular Development:

Upper 2/3:

- Striated muscle
- Derived from splanchnic mesenchyme
- Innervated by the **vagus nerve**.

Lower 1/3:

- Smooth muscle
- Innervated by the **splanchnic plexus**.

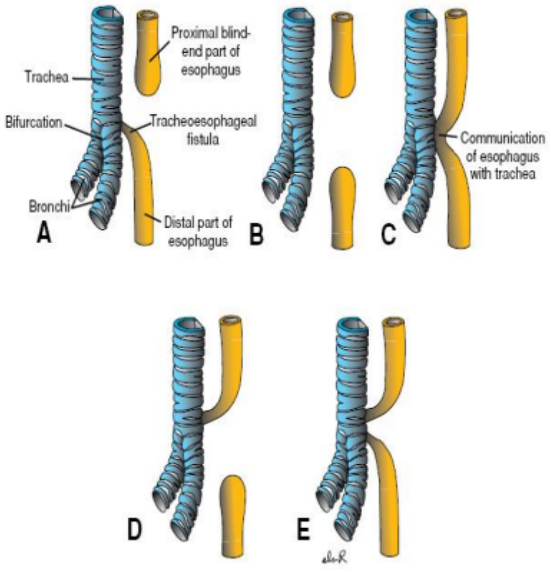
Clinical Abnormalities:

- **Esophageal Atresia & Tracheoesophageal Fistula (TEF):**

Results from the failure of separation of the trachea and esophagus.

The most common type:

Proximal esophageal atresia + distal TEF
Esophagus ends in a blind sac while the distal part connects to the trachea.



Remember A is the most common type!

- **Esophageal Stenosis:**

In addition to atresia, the lumen of the esophagus may narrow, producing **esophageal stenosis**, usually in the lower third.

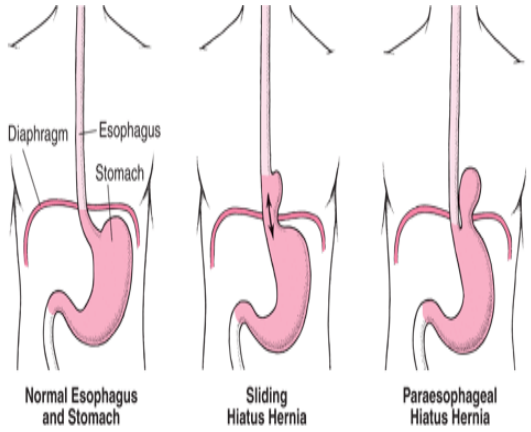
Stenosis may be caused by:

1. Incomplete recanalization
2. Vascular abnormalities or accidents that compromise blood flow (ischemic injury)

Key association: polyhydramnios
Atresia prevents the fetus from swallowing amniotic fluid, leading to excess fluid accumulation in the amniotic sac.

- **Congenital Hiatal Hernia:**

Occurs if the esophagus fails to lengthen sufficiently, pulling the stomach up into the thoracic cavity through the esophageal hiatus of the diaphragm.



Typically results in a sliding hernia.

[Stomach]

The stomach appears in the 4th week as a fusiform dilation of the foregut. Its final shape is determined by two distinct rotations:

- **Longitudinal Rotation (90° Clockwise):**
  - Left side → moves anteriorly (innervated by the left vagus).
  - Right side → moves posteriorly (innervated by the right vagus).
  - The posterior wall grows faster, forming the **greater curvature**, while the anterior wall forms the **lesser curvature**.

- **Anteroposterior Rotation:**
  - **Caudal (pyloric) part** moves right and upward.
  - **Cephalic (cardiac) part** moves left and slightly downward.

The two openings come closer to each other.

Clinical Correlation: Pyloric Stenosis

A common abnormality where the pyloric musculature hypertrophies, obstructing the gastric outlet. It typically manifests **3–6 weeks** into fetal life.

Presents with projectile vomiting.

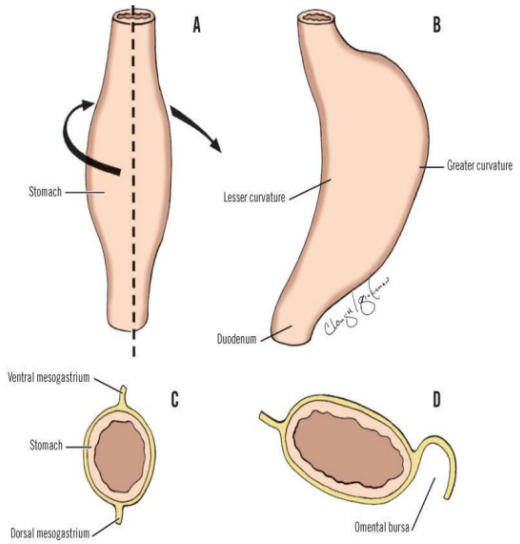
Formation of the Omental Bursa

The rotation of the stomach fundamentally changes its attached mesenteries:

Dorsal Mesogastrium: the longitudinal rotation pulls this mesentery to the **left**.

This movement creates a space behind the stomach known as the **omental bursa** (or lesser peritoneal sac).

Ventral Mesogastrium: this same rotation pulls the ventral mesentery to the **right**.



Notice how the dorsal mesogastrium forms the omental bursa (lesser sac).

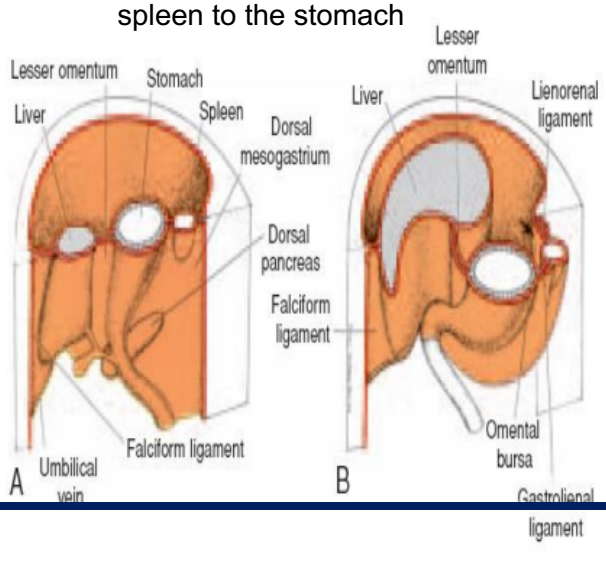
[Spleen]

During the 5th week, the spleen begins to develop within the mesentery.

- **Origin**: Mesodermal proliferation between the two leaves of the **dorsal mesogastrium**.

- **Movement**: As the stomach continues to rotate, the portion of the dorsal mesogastrium between the spleen and the dorsal midline swings left and fuses with the peritoneum of the posterior abdominal wall.

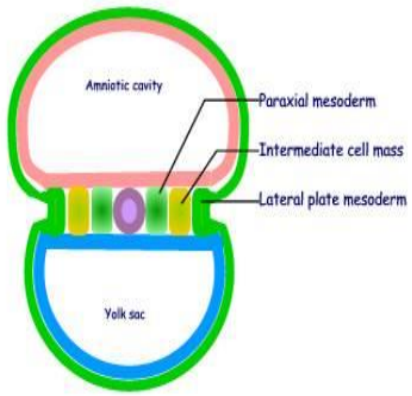
- **Ligaments**: The spleen remains **intraperitoneal** and is connected via two key ligaments:
  - **Lienorenal ligament**: Connects the spleen to the left kidney.
  - **Gastrolienal ligament**: Connects the spleen to the stomach



[Mesoderm]

By the end of the 3rd week, the intraembryonic mesoderm on each side of the midline differentiates into three distinct portions:

1. Paraxial mesoderm
2. Intermediate mesoderm
3. Lateral plate mesoderm



Intercellular clefts appear in the lateral mesoderm, dividing the plate further into two layers:

1. Somatic (parietal) layer
2. Splanchnic (visceral) layer → forms the peritoneum.

[The Body Cavities]

The space between the somatic and splanchnic layers forms the intraembryonic cavity (body cavity).

The peritoneal cavity is derived from the intraembryonic coelom caudal to the septum transversum.

Initially, these cavities are openly connected, but this connection is lost as the embryo folds cephalocaudally and laterally.

[Mesenteries]

Initially, the foregut, midgut, and hindgut are in broad contact with the posterior abdominal wall. By the 5th week, a narrowing tissue bridge creates the mesenteries.

Dorsal Mesentery

This extends from the lower esophagus to the cloaca. It takes on different names based on the organ it supports:

1. Dorsal meso**gastrium** (greater omentum)
2. Dorsal meso**duodenum**
3. Dorsal meso**colon**
4. Mesentery proper (jejunum and ileum)

Ventral Mesentery

Unlike the dorsal mesentery, the ventral mesentery exists only in the foregut region at the:

1. Terminal esophagus
2. Stomach
3. Upper duodenum.

It is derived from the septum transversum.

Growth of the liver divides the ventral mesentery into:

1. Lesser omentum

Connecting the esophagus, stomach, and upper duodenum to the liver.

Free margin of lesser omentum = hepatoduodenal ligament, and contains:

1. The bile duct,
2. portal vein,
3. and hepatic artery,

Also known as: the portal triad.

This free margin also forms the roof of the epiploic foramen of Winslow, which is the opening connecting the omental bursa (lesser sac) with the rest of the peritoneal cavity (greater sac).

2. Falciform ligament

Connects liver to the anterior (ventral) body wall. The free margin of the falciform ligament contains the umbilical vein, which is obliterated after birth to form the round ligament of the liver (ligamentum teres hepatis).

Recap:

- **Ligamentum teres hepatis (round ligament of the liver)**: Formed after birth by the obliterated umbilical vein found in the free margin of the falciform ligament.
- **Hepatoduodenal ligament**: The free margin of the lesser omentum containing the **portal triad** (bile duct, portal vein, and hepatic artery).
- **Epiploic foramen of Winslow**: The opening that connects the omental bursa (lesser sac) with the rest of the peritoneal cavity (greater sac).

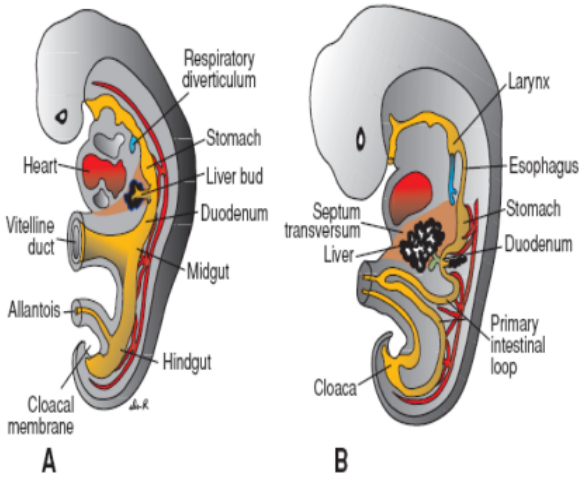
[Liver and Gallbladder]

The Liver Primordium

Appearance: The liver primordium appears in the **middle of the 3rd week**.

Hepatic Diverticulum ("Liver bud"): It begins as an outgrowth of the endodermal epithelium at the distal end of the foregut.

Growth: This bud consists of rapidly proliferating cells that penetrate the **septum transversum** (a mesodermal plate located between the pericardial cavity and the yolk sac stalk).



Notice how the liver bud is coming out of the foregut right below the stomach.

Development of the Biliary System

Bile Duct: As the liver cells continue to penetrate the septum, the connection between the hepatic diverticulum and the duodenum narrows, forming the **bile duct**.

Gallbladder and Cystic Duct: Develop from a small ventral outgrowth of the bile duct gives.

Hepatic Sinusoids: Epithelial liver cords intermingle with the vitelline and umbilical veins to form the hepatic sinusoids.

Cellular Origins

Liver Parenchyma: The liver cords (endoderm) differentiate into the parenchyma (liver cells) and form the lining of the biliary ducts.

Other Components: Hematopoietic cells, Kupffer cells, and connective tissue cells are derived from the **mesoderm of the septum transversum**.

Liver and Gallbladder Abnormalities

Minor Variations: Variations in liver lobulation, accessory hepatic ducts, and duplication of the gallbladder are common and usually asymptomatic.

Extrahepatic Biliary Atresia: Failure of recanalization of the ducts. Most patients require a **liver transplant**.

Intrahepatic Biliary Duct Atresia: A rarer condition that may be caused by fetal infections; it is often lethal but can sometimes follow an extended benign course.

[Duodenum]

Origins and Blood Supply

Dual Origin: The duodenum is formed from the terminal part of the **foregut** and the cephalic part of the **midgut**.

Anatomical Junction: The junction of these two parts is located directly distal to the origin of the liver bud.

Blood Supply: Because of its dual origin, it has a dual blood supply:

- Celiac artery (foregut).
- Superior mesenteric artery (midgut).

Rotation and Positional Changes

C-Shaped Loop: As the stomach rotates, the duodenum takes on a **C-shaped** form and rotates to the right.

Shift from Midline: This rotation, combined with the rapid growth of the pancreatic head, swings the duodenum from the midline toward the left side of the abdominal cavity.

Retroperitoneal Fixation: The duodenum and the head of the pancreas eventually press against the dorsal body wall. The right surface of the **dorsal mesoduodenum** fuses with the adjacent peritoneum, and both layers disappear.

Final Position: This process fixes the duodenum and pancreatic head in a secondarily retroperitoneal position.

Exception: A small portion of the duodenum near the pylorus, known as the **duodenal cap**, retains its mesentery and remains **intraperitoneal**.

Recanalization of the Lumen

- During the second month of development, the lumen of the duodenum is temporarily obliterated.
- Shortly, the lumen is recanalized, restoring the passageway.

[Pancreas]

Pancreatic Development

Dual Origin: The pancreas is formed from two buds—the **dorsal** and **ventral** buds—originating from the endodermal lining of the duodenum.

Migration and Fusion: As the duodenum rotates to the right and becomes C-shaped, the ventral pancreatic bud moves dorsally to lie immediately below and behind the dorsal bud. Eventually, the parenchyma and duct systems of both buds fuse.

Retroperitoneal Position: During development, the entire pancreas obtains a retroperitoneal position (minus the tail!).

Anatomy:

Ventral Bud → Uncinate process and inferior head.

Dorsal Bud → Body, tail, and upper head

Duct Systems:
Main pancreatic duct (of Wirsung) is formed by the entire ventral duct and the distal part of the dorsal duct. The proximal part of the dorsal duct may persist as the accessory pancreatic duct (duct of Santorini).

Histology

Islets of Langerhans: Develop in the third month of fetal life from parenchymatous tissue.

HOWEVER, insulin secretion begins at approximately the **fifth month**.

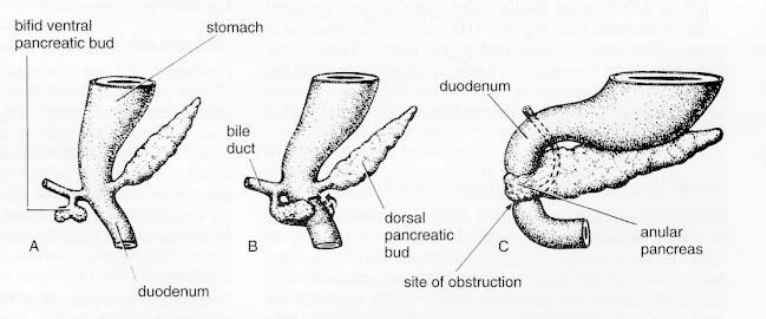
Glucagon and somatostatin secreting cells also develop from the parenchymal cells.

Connective Tissue: Formed from the splanchnic mesoderm surrounding the pancreatic buds.

Pancreatic Abnormalities

Annular Pancreas:

Occurs when the two components of the ventral pancreatic bud migrate in opposite directions rather than together. This results in the duodenum being completely surrounded by pancreatic tissue, which can cause **duodenal obstruction**.



Accessory Pancreatic Tissue:

Ectopic pancreatic tissue found anywhere from the distal esophagus to the primary intestinal loop. It is most commonly located in the **stomach mucosa** or in a **Meckel's diverticulum**.

The University of Jordan
Gastroenterology Interest Group (UJ-GIG)
Booklet

Histology

Embryology of the Midgut and Hindgut

Written by: Yasmin Al Subaihi

Edited by: Bdour Abdallat

[Midgut]

Anatomy

Boundaries:
Proximal: Distal to the bile duct opening in the duodenum.
Distal: Junction of the proximal 2/3 and distal 1/3 of the transverse colon.

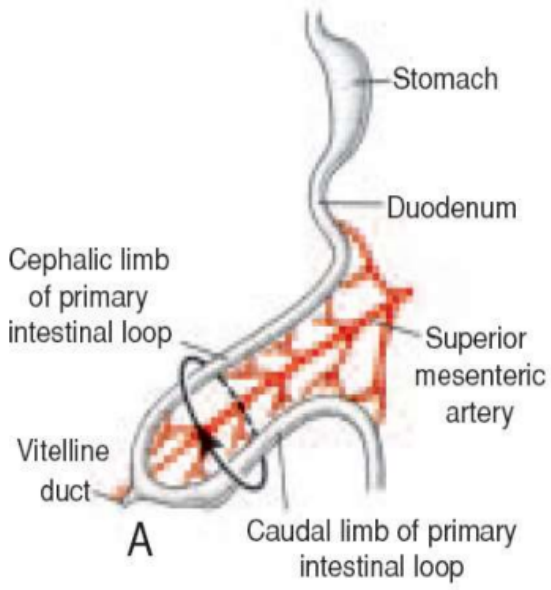
Blood Supply: Entirely by the superior mesenteric artery (SMA).

Suspension: Suspended from the posterior abdominal wall by a short mesentery.

Primary Intestinal Loop: Characterized by rapid elongation, forming a loop with a cephalic and caudal limb.
Cephalic Limb→
Distal duodenum, jejunum, and proximal ileum.

Caudal Limb→
Distal ileum, cecum, appendix, ascending colon, and proximal 2/3 of the transverse colon.

Apex: Connects to the yolk sac via the vitelline duct (yolk stalk).



Physiological Herniation and Rotation (6th week)

1. Herniation (week 6): Due to rapid liver growth, the abdominal cavity becomes too small. The intestinal loops exit (herniate) to the extraembryonic cavity within the umbilical cord.
2. Rotation: The loop rotates 270° counterclockwise around the axis of the SMA.
   - 90° during herniation.
   - 180° during return to abdominal cavity.
3. Coiling: During rotation, the small intestine (jejunum/ileum) coils significantly (vs. the large intestine which lengthens without coiling).

Retraction and Fixation (10th week)

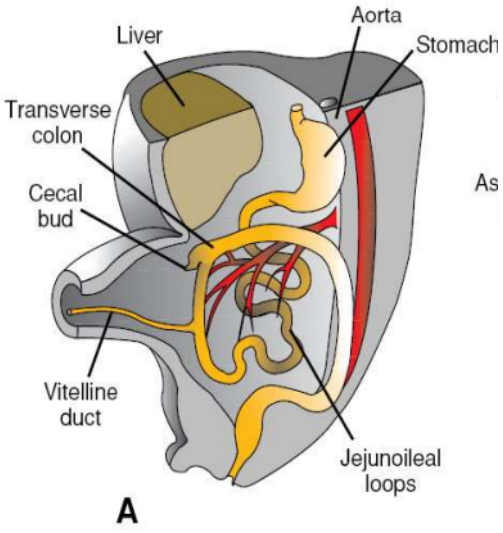
Return process: Loops return as the kidney regresses, liver growth slows down, and the abdominal cavity expands.

Sequence of return:
Jejunum: First to return, settling on the left side.

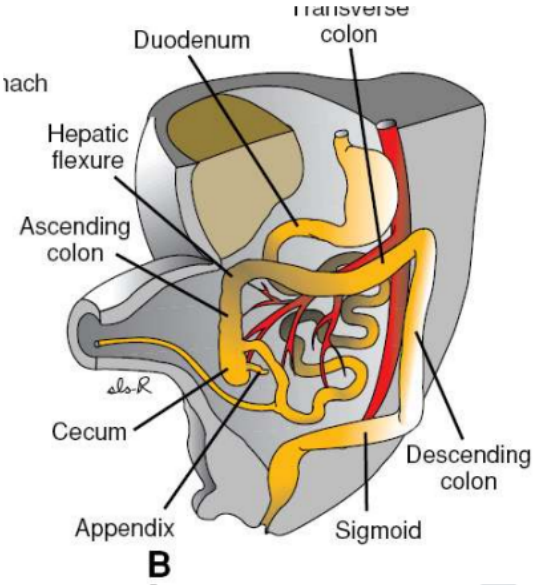
Cecal Bud: The last part to re-enter (at 6 weeks as a dilation of the caudal limb).

Descent: The cecum initially lies below the liver's right lobe before descending into the right iliac fossa, pulling the ascending colon and hepatic flexure into place.

Appendix: Forms as a narrow diverticulum at the distal end of the cecal bud. Its final position is often retrocecal or retrocolic.



A: before cecal bud descent



B: after cecal bud descent

Mesenteries

Fusion: As the ascending and descending colon reach their final positions, their mesenteries fuse with the posterior abdominal wall peritoneum, making them **retroperitoneal**.

Remember the retroperitoneal structures:

SAD PUCKER

1. **S** – **S**uprarenal (adrenal) glands
2. **A** – **A**orta & Inferior Vena Cava (IVC)
3. **D** – **D**uodenum (2nd, 3rd, and 4th parts)
4. **P** – **P**ancreas (except for the tail)
5. **U** – **U**reters
6. **C** – **C**olon (ascending and descending only)
7. **K** – **K**idneys
8. **E** – **E**sophagus (abdominal portion)
9. **R** – **R**ectum (middle third; the lower third is subperitoneal)

Mobile Segments:

- Appendix
- Lower cecum
- Sigmoid colon

Transverse mesocolon: Fuses with the greater omentum but remains mobile.

Clinical Correlations & Malformations

Rotation Defects:

1. **Volvulus**:

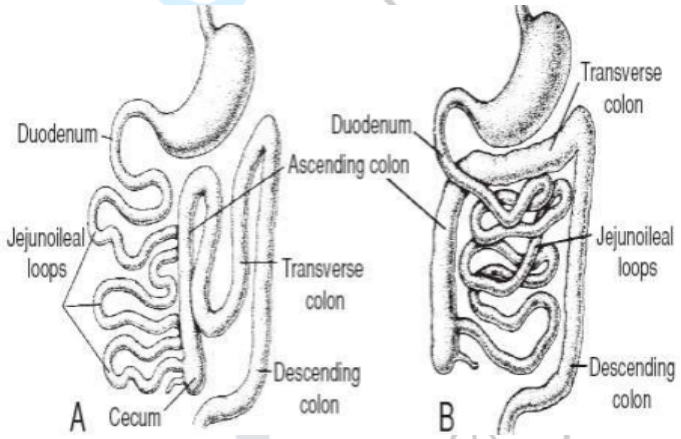
Twisting of the intestine → compromise blood supply → bowel obstruction and ischemia

2. **Left-sided Colon**:

Only 90° rotation → the colon and cecum remain on the left, small bowel on the right

3. **Reversed Rotation**:

90° clockwise rotation where the transverse colon passes behind the SMA.



A: abnormal rotation, notice how the small intestines are on the right and the large intestine is on the left side of the abdomen.

B: the primary intestinal loop is rotated 90° clockwise (reverse direction), the transverse colon passes behind the duodenum.

Gut Atresia and Stenoses

Atresia and stenoses may occur anywhere along the intestine. Most occur in the **duodenum**, few occur in the colon, and have equal frequency in the jejunum and ileum.

The most common cause of duodenal atresia is failure or recanalization.

Body Wall Defects:

Omphalocele:
- Herniation through an enlarged umbilical ring
- Covered by **amnion**
- Caused by a failure of the bowel to return from herniation.
- High association with chromosomal/cardiac anomalies.

Gastroschisis:
- Direct herniation into the amniotic cavity
- Usually to the right of the umbilicus
- Not covered by amnion (exposed)

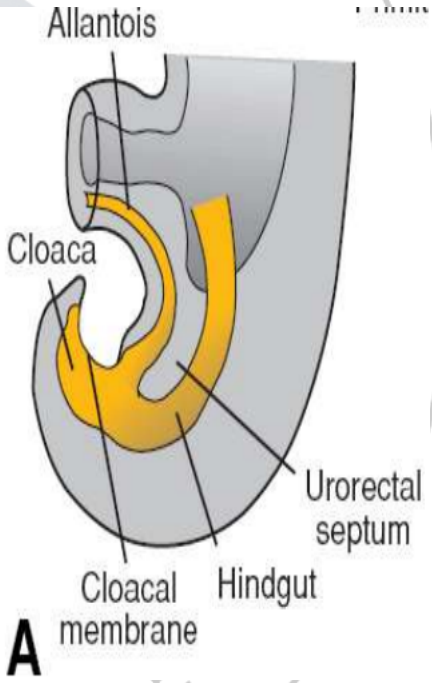
Gastroschisis	Omphalocele
Paraumbilical herniation of abdominal contents through abdominal wall defect	Herniation of abdominal contents through umbilical ring
Not covered by peritoneum or amnion A; right sided/paraumbilical	Covered by peritoneum and amnion B (light gray shiny sac); midline, membrane covered
Not commonly associated with chromosomal abnormalities; good prognosis	Associated with congenital anomalies (eg, trisomies 13 and 18, Beckwith-Wiedemann syndrome) and other structural abnormalities (eg, cardiac, GU, neural tube)

[The Hindgut and Cloaca]

Derivatives:
- Distal 1/3 of transverse colon
- Descending colon
- Sigmoid
- Rectum
- Upper anal canal.

Cloaca Development:
The cloaca is an endoderm-lined cavity where the hindgut (posteriorly) and allantois (anteriorly) enter.

Urorectal septum: A mesodermal partition that divides the allantois and hindgut, eventually forming the **perineal body**.
Anterior = Urogenital sinus
Posterior = Anorectal canal



Let's explain the process in more detail. The cloaca is the common tube at the end of the hindgut. To separate the digestive tract from the urinary tract, a layer of mesoderm called the **urorectal septum** grows downward.

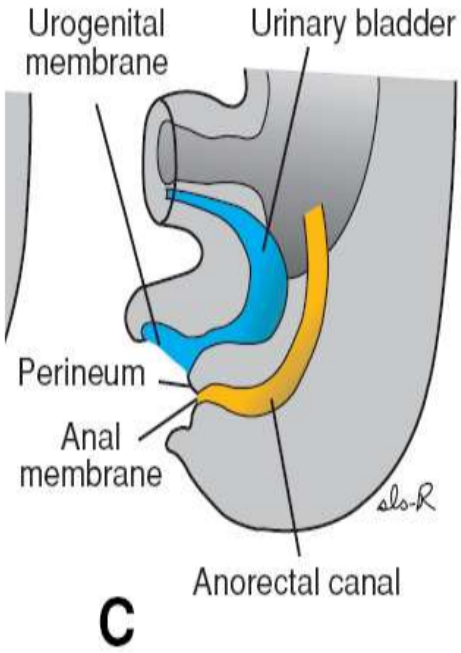
The urorectal septum grows between the allantois (future bladder/urinary path) and the hindgut (future rectum).

As this septum grows toward the cloacal membrane, it eventually fuses with it.

The point where the septum fuses with the membrane becomes the perineal body in the adult (the small area of skin between the anus and the genitals).

Once the septum reaches the bottom, it divides the cloacal membrane into two distinct parts:

1. Urogenital membrane: Located anteriorly
2. Anal membrane: Located posteriorly



Anal Canal:

1. **Upper part**: Endodermal origin.
2. **Lower part**: Ectodermal origin, supplied by inferior rectal arteries.
3. **Pectinate Line**: Junction where epithelium changes from columnar to stratified squamous.

Anorectal Malformations

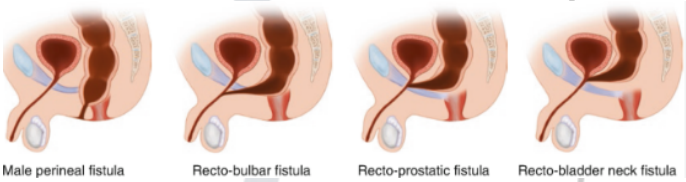
They occur when the anus and rectum do not develop properly, often due to a failure of the urorectal septum to completely divide the cloaca.

1. **Imperforate anus**: The rectum does not connect to the outside world because the anal membrane fails to break down.
2. **Fistulas (abnormal passages)**: If the urorectal septum does not fully separate the "front" (urinary/reproductive) from the "back" (digestive), the rectum will connect to other structures.

Specific Malformations by Gender:

Boys	Girls
Rectoerineal fistula: Rectum opens on the skin.	**Rectoperineal fistula**
Rectobulbarurethral fistula: Rectum connects to the urethra.	**Rectovestibular fistula**: Rectum connects to the area around the vaginal opening.
Rectoprostatic fistula: Connects to the prostate area.	**Persistent Cloaca**: A complex defect where the rectum, vagina, and urinary tract all share one common exit.

Male



Female