Anatomy – Test 2 (Part 1)
This one isn’t as good as others

• Anterior Abdominal Wall and Inguinal Canal
  ○ Objectives
    ▪ Define the boundaries of the abdominal cavity and the skeletal components related to the abdominal wall
    ▪ Describe the major surface landmarks of the anterior abdominal wall
    ▪ Describe the lines and planes that are used to divide the abdomen into quadrants and regions
    ▪ Describe the attachments, orientations, relative positions, actions and fascia of the 4 major abdominal muscles
    ▪ Define the blood supply, nerve supply, fascial layers, muscle layers, extraperitoneal fat and parietal peritoneum of the anterior abdominal wall. How do these relate to the various surgical approaches to the abdominal cavity?
    ▪ Describe the configuration of the anterior and posterior walls of the rectus sheath superior and inferior to the arcuate line
    ▪ Define the inguinal canal, including the location of the deep and superficial inguinal rings
    ○ Know the structures forming the walls of the inguinal canal
    ○ Define the function and mechanics of the inguinal canal
    ○ Describe the contents of the inguinal canal. How do these differ between the sexes?
    ○ Describe the borders of the inguinal triangle
    ▪ Define the anatomy and relationships of the processus vaginalis, spermatic cord, epididymus, cremaster muscle, testes and scrotum
    ▪ Describe the coverings of the spermatic cord and their role in the descent of the testes during development. How do these layers relate to the coverings of the scrotum?
    ▪ Chart the blood supply and lymphatic drainage of the testis. How do they differ from that of the scrotum?
    ▪ What is an inguinal hernia? What features distinguish a direct from an indirect inguinal hernia?
  ○ Anterior Abdominal Wall
    ▪ Definitions
      ○ Abdomen – area between thorax and pelvis
      ○ Abdominal Cavity – the space enclosed by the abdominal wall
        ▪ Continuous with pelvic cavity but together are called the abdominopelvic cavity
        ▪ Contains abdominal viscera and peritoneal cavity
        ▪ Borders – lumbar vertebrae, thoracic diaphragm, border of pelvic cavity (imaginary line going through vertebra? And pubic symphysis), and anterior abdominal wall
      ○ Anterior abdominal wall – musculocutaneous sheet anchored to the ribs, lumbar vert and pelvis
        ▪ Bends and rotates trunk
        ▪ Supports trunk by creating a hydrostatic tube between the thorax and pelvis
        ▪ Raises abdominal pressure (for loud speech, vomiting, defecation, child birth)
      ○ Linea alba – white line on median plane of abdomen, turns brown in pregnant women
    ▪ Clinical Relevancy
      ○ Diagnostic
        ▪ Can palpate abdominal organs
        ▪ Rigidity and/or rebound tenderness (when abdomen rebounds it is tender) indicate irritation of the deep surface (will occur with appendicitis)
        ▪ Can be enlarged - 5 F’s and 1 T (fetus, fluid, fat, flatus, feces and tumor)
    ▪ Surgical – repair inguinal hernia
  ○ Subdivisions
    ▪ 4 Quadrants
      ▪ Boundaries - Median Plane & Transumbilical Plane (through IV disc of L3/L4 and umbilicus)
      ▪ Quadrants – Right and left, upper and lower quadrants (RUQ, RLQ, LUQ, LLQ)
    ▪ 9 Regions
      ▪ Boundaries – the two midclavicular lines (runs through middle of inguinal ligament), subcostal plane (end of ribs and at L2), transtubercular plane (through top of pelvis at L5)
      ▪ Regions
        ▪ Right and Left – hypochondriac (‘underneath cartilage’), lumbar and inguinal
        ▪ In the middle – epigastric, umbilical and hypogastric
    ▪ Transpyloric plane – at L1
    ▪ ASIS (anterior superior iliac spine) - can be seen as indentation on skin because there isn’t much fat above it
    ▪ Interspinous plane – connects the two ASIS
Layers
- Skin
- Superficial fascia
  - Camper’s fascia – fatty superficial layer of superficial fascia
  - Scarpa’s fascia – membranous deep layer of superficial fascia
- Deep fascia – just below Scarpa’s fascia and inbetween each layer of abdominal muscle
  - Continuous with the aponeurosis of each muscle
- Muscles – three layers sandwiched by deep fascia
- Neurovascular bundles – in between the last two layers of muscle
- Transversalis fascia – instead of deep fascia after last layer of muscle, you have this
- Extraperitoneal fat
- Parietal peritoneum

Muscles
- Innervation – anterior rami of T7-T12 spinal nerves ± L1
- Combined Action – compress abdominal contents
- External oblique
  - Attachments – inferior ribs, anterior ½ of iliac crest, ASIS, (skips inguinal ligament), pubic tubercle
  - Unilateral Action – rotates to opposite side; Bends to same side
  - Orientation – fingers in pockets
  - Note - superficial inguinal ring is a gap in the aponeurosis
- Internal Oblique
  - Attachments – anterior 2/3 of iliac crest
    - Lateral ½ of inguinal ligament
    - Thoracolumbar fascia?
    - Inferior ribs
    - Conjoint tendon (falx inguinalis) – attached to pectineal line of superior pubic ramus
      - Thin and weak, prone to hernia
    - Unilateral Action – rotates to same side
      - Bends to same side
  - Orientation – not fingers in pockets
  - Cremaster Muscle – portion of internal oblique muscle only in males that wraps around the testes
    - Innervated by the genital branch of the genitofemoral nerve?
      - Cremaster reflex – stimulate inner thigh and see if testicles retract
    - Originates at L1 & L2?
- Transverse Abdominal
  - Attachments – thoracolumbar fascia
    - Iliac crest
    - lateral 1/3 of inguinal ligament, thus does not contribute a layer to the spermatic cord
      - note - transversalis fascia does contribute to spermatic cord
    - Conjoint tendon
  - Action – ↑ abdominal pressure
- Rectus Abdominis
  - Attachments – costal cartilages of ribs 5-7 plus xyphoid process
    - Pubic crest; Pubic symphysis
  - Action – flex trunk anteriorly
  - Tendinous intersections – CT that connects to rectus sheath and causes 6-pack
- Pyramidalis – down at bottom like a pyramid, present in only 80% of the people
  - Attachments – pubic crest & linea alba

Other landmarks
- Inguinal ligament
- Lacunar ligament - part of the aponeurosis of the external oblique muscle which is reflected backward and lateralward, and is attached to the pectineal line
- Superficial inguinal ring
- Pectineal line
- Pubic tubercle
- Pubic symphysis
- Pubic crest
- Pectineal ligament (continuous with lacunar ligament)

### Rectus Sheath
- **Linea alba** – band of dense CT separating the rectus abdominis muscle
  - Place where aponeuroses of the abdominal muscles intermix
- **Linea semilunaris** – along outside of rectus abdominis
- **Arcuate Line** – the crescent shaped inferior border of the posterior layer of the rectus sheath located approximately 1/3 of the distance from the umbilicus to the pubic crest
  - Allows for the inferior epigastric artery to have better access to rectus abdominis
  - Above arcuate line – aponeurosis of transverse abdominal and half of the internal oblique pass behind the rectus abdominis
  - Below arcuate line – aponeuroses of all the muscles travel in front of the rectus abdominis

### Innervation
- **Anterior rami** of spinal nerves supply:
  - Motor – abdominal muscles
  - Sympathetics – sweat glands, blood vessels
  - Sensory – skin, muscles and *parietal* peritoneum
- Pathway – they travel between the internal oblique and transverse abdominis muscle and pierce the rectus sheath to supply the rectus abdominis and supply the anterior cutaneous branches
  - **lateral cutaneous branch** – branches at lateral side and goes *superficially* to about the linea semilunaris
  - **anterior cutaneous branch** – the rest of the nerve stays deep then comes through near the linea alba to supply medial portion
- Specific names for different dermatome nerves
  - T7-T11 – thoracoabdominal nerves
  - T12 – subcostal nerve
  - L1 – *iliohypogastric nerve*
  - L1 – *ilioinguinal nerve* (a little lower than iliohypogastric nerve)
    - Both L1 nerves supply mons pubis region

### Blood Supply
- Branches of **anterior internal thoracic – musculophrenic, superior epigastric**
- Costal origins – blah
- Branches of **external iliac – inferior epigastric, deep circumflex iliac artery**
- Branches of **femoral – superficial epigastric artery, superior circumflex iliac artery**
- **External iliac** becomes femoral artery as it passes the inguinal ligament
- Note – venous drainage matches arterial supply

### Clinical Correlation
- If you cut at median line down abdomen then there is no nerve damage, but this will affect the linea alba, so a **paramedian cut** is made
- **McBurney’s Point** – directly above where the appendix connects
  - 1/3 the length of the line from the ASIS to the umbilicus
  - must be careful of L1 nerves
- **Subcostal cut** – not done much anymore
- **Suprapubic cut** – only affects cutaneous innervation (used for C section)
  - Inguinal Canal
- Allows the testes to get through
  - An oblique intermuscular passage through the inferior portion of the anterior abdominal wall
    - Oblique because it makes it harder for the intestines to get through
  - During development, it serves as a route of passage for the testes from the posterior abdominal wall to the scrotum
  - Just lateral to inferior epigastric vessels?
  - It contains the spermatic cord in males and the round ligament in females
  - It runs parallel and superior to the inguinal ligament along the medial ½ of the ligament
  - Extends from the deep inguinal ring (lateral) to the superficial inguinal ring (medial)
  - Gubernaculum - ct that gets shorter and pulls testes out
  - Process vaginalis - outpouching of the peritoneum
  - Intercrural fibers. Lateral crus, Medial crus – part of fascia of external oblique?
  - Internal spermatic fascia
  - Borders
    - Anterior – aponerosis of external abdominal oblique
    - Posterior – transversalis fascia, medially reinforced by the conjoint tendon
    - Floor – inguinal ligament, lacunar ligament
    - Roof – arching fibers of the internal oblique and transverses abdominal muscles
  - Sagittal Section of medial region of inguinal canal –
  - Female Inguinal Canal
    - Canal of Nuck – invagination of peritoneum with the round ligament
    - Round ligament – equivalent to gubernaculum
      - During pregnancy it gets stretched and can cause groin pain
  - Spermatic Cord
    - Contents - Vas deferens, testicular artery, artery of Vas, pampiniform plexus of veins, lymph vessels and nerves
    - Layers
      - External spermatic fascia – from external oblique aponeurosis
      - Cremasteric fascia – from internal oblique
      - Internal spermatic fascia – continuous with transversalis fascia
  - Scrotum
    - Thin skin
    - Dartos Tunic – helps regulate temperature of testes
      - Colles’ fascia – outer, continuous with Scarpa's fascia
      - Dartos muscle – inner; continuous with Camper's fascia
  - Clinical Correlation
    - Hydrocele – excess fluid in the tunica vaginalis
      - Can be in either the spermatic cord or the testis
    - Hematocele – blood accumulating in the tunica vaginalis
  - Testes & Epididymus
    - Get PICTURE
      - Cavity of tunica vaginalis
      - Lobules of epididymis – storage
      - Efferent ductules
      - Rete testes - an anastomosing network of delicate tubules located in the hilum of the testicle that carries sperm from the seminiferous tubules to the vasa efferentia
      - Septa – made by tunica albuginea
      - Visceral layer of tunica vaginalis
      - Cavity of tunica vaginalis
      - Parietal layer of tunica vaginalis
      - Blood Supply - testicular arteries (right and left)
Nerve Supply – follows testicular arteries?
Lymphatic Drainage
  • For Testes – follows testicular arteries to lumbar lymph nodes
  • For Scrotum – goes to inguinal lymph nodes

Inguinal Hernias
  • Hernia – the abnormal protrusion of a structure from the cavity in which it belongs
  • Inguinal hernia – abdominal hernia through the anterior abdominal wall in the inguinal region
    • Direct – leaves the abdominal cavity medial to the inferior epigastric artery (within inguinal triangle)
      ▪ Travels anteriorly through the posterior wall of the inguinal canal that is formed by transversalis fascia and exits via the superficial inguinal ring, hence only the medial portion of the inguinal canal is traveled
      ▪ Covered by one or two layers of the spermatic cord
      ▪ Transversalis fascia forms the hernial sac
      ▪ Less common than indirect hernias, usually occurs in men older than 40
    • Indirect – leaves abdominal cavity lateral to the inferior epigastric artery
      ▪ Travels through the deep inguinal ring, the entire inguinal canal and the superficial inguinal ring
      ▪ Covered by all three layers of the spermatic cord
      ▪ The remains of the process vaginalis forms the hernial sac
      ▪ 20 times more common in males than females
      ▪ Can differentiate from a hydrocele because it is reductable and casts a shadow

• Boundaries of Inguinal Triangle
  • Medial – lateral border of the rectus abdominis muscle
  • Lateral – inferior epigastric vessels
  • Inferior – inguinal ligament
  • Site of indirect hernias

• Peritoneum and Major Vessels
  • Objectives
    ▪ Define the peritoneum and peritoneal cavity
    ▪ Understand what distinguishes parietal from visceral peritoneum
    ▪ Describe the shape and extent of the peritoneal cavity
    ▪ Know what the borders of the greater and lesser sac are
    ▪ Describe the components of the greater and lesser omentums
    ▪ Know what forms the borders of the epiploic foramen. What spaces does it connect
    ▪ Know what organs and structures within the abdomen are intraperitoneal (peritoneal) and which are primarily and secondarily retroperitoneal
    ▪ Be able to describe and give examples of peritoneal pouches, folds, recesses and gutters
    ▪ Distinguish between mesentery, mesocolon, greater omentum, lesser omentum and the various peritoneal ligaments
    ▪ Describe the causes and relations of the peritoneal reflections located on the anterior abdominal wall
    ▪ List the three unpaired branches of the abdominal aorta. Know the terminal branches of these main arteries
    ▪ Describe the venous drainage from the abdominal viscera. What is the hepatic portal system?
    ▪ What is a portal-systemic anastomoses? Where do four major portal-systemic anastomoses occur in the body and what is the clinical significance of varicosities at these sites?
  • Peritoneum – a large thin, transparent sheet of serous membrane which lines the walls of the abdominopelvic cavity and is reflected onto the viscera
    • Parietal peritoneum – lines the abdominal and pelvic walls
    • Visceral peritoneum – covers abdominal and pelvic organs
    • Peritoneal cavity – potential space between adjacent layers of peritoneum usually containing a small amount of fluid
      ▪ Subdivided by the greater and lesser omentum into two sacs, the Greater sac and the Lesser Sac (omental bursa)
      ▪ Omental foramen – connects the 2 sacs; is right behind hepatic portal vein
      ▪ In males the peritoneal cavity is a closed space, in females it communicates with the exterior (due to reproductive tract)
  • Mesentery – double layer of peritoneum that connects an intraperitoneal organ to the posterior abdominal wall
    • Has a fatty CT core in which blood vessels, nerves and lymphatics travel to and from the intraperitoneal organ
    • Organs with a mesentery are freely movable
Intraperitoneal Organs – covered with visceral peritoneum except at sites where the mesentery attaches

- Do not have a mesentery
- Secondarily Retroperitoneal – started with mesentery but it fused with posterior abdominal wall

Note – there aren’t any organs in the peritoneal cavity

<table>
<thead>
<tr>
<th>Intraperitoneal</th>
<th>Retroperitoneal</th>
<th>Secondarily Retroperitoneal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach - greater and lesser omentum</td>
<td>Esophagus</td>
<td>Pancreas – except for tail that may extend into the lienorenal ligament</td>
</tr>
<tr>
<td>Liver – falciform ligament, coronary ligaments, triangular ligaments, lesser omentum</td>
<td>Rectum</td>
<td>Duodenum – except for a portion of the first segment that is attached to the hepatoduodenal ligament</td>
</tr>
<tr>
<td>Jejunum &amp; Ileum – the mesentery</td>
<td>Kidneys</td>
<td>Ascending Colon</td>
</tr>
<tr>
<td>Cecum – mesocecum</td>
<td>Suprarenal</td>
<td>Descending Colon</td>
</tr>
<tr>
<td>Appendix – mesoappendix</td>
<td>Glands</td>
<td></td>
</tr>
<tr>
<td>Transverse Colon – transverse mesocolon</td>
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<td></td>
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<tr>
<td>Sigmoid Colon – sigmoid mesocolon</td>
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<tr>
<td>Spleen</td>
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Omentum – double layer of peritoneum beginning at the stomach and proximal part of duodenum

- Lesser Omentum – attaches the stomach along lesser curvature to the liver
  - Subdivided into hepatogastric and hepatoduodenal ligaments
  - Note – hepatoduodenal ligament contains hepatic artery, portal vein and bile duct
- Greater Omentum – attaches the stomach along greater curvature to the posterior abdominal wall
  - Subdivided into gastrophrenic, gastroplenic and gastrocolic ligaments

Peritoneal Ligaments – double layer of peritoneum which connect organs to organs or organs to the body wall

- Basically just named parts of the mesentery (ex. hepatoduodenal ligament)

Lateral view –
- Superior recess – top part of lesser sac, above liver
- Inferior recess – lower part of lesser sac, in between stomach and transverse colon, leading towards greater omentum
  - Note that the greater sac is just about everything you see anteriorly after taking off the anterior abdominal wall

Peritoneal Folds – a ridge on the surface of the body wall covered with parietal peritoneum produced by an underlying vessel, duct or obliterated fetal vessel

- Lateral Umbilical Folds – contains inferior epigastric vessels
- Medial Umbilical Folds – contains obliterated umbilical artery
- Median Umbilical Fold – contains the urachus

Peritoneal Recesses (Fossa) – a pouch of peritoneum formed by peritoneal folds or ligaments

- Inferior recess of the lesser sac
- Hepatorenal pouch – up by liver and kidneys
- Rectovesical pouch – down in pelvis

Peritoneal Gutters – attachments of the mesentery to the posterior abdominal wall as well as the positions of the ascending and descending colon form 4 gutters that can conduct fluids to other regions of the peritoneal cavity

- Supracolic Compartment – above top of transverse colon, contains hepatorenal pouch
  - Liquids must travel to the right to get to rectouterine pouch because of the phrenicocolic ligament on the left
- Infracolic Compartment – contains:
  - Right Paracolic Gutter – lateral to ascending colon
  - Left Paracolic Gutter – lateral to descending colon
  - Right infracolic space – medial to ascending colon, kinda boxed in by SI
  - Left infracolic space – medial to descending colon, has free access to rectouterine pouch

Blood Supply
- Three unpaired arteries off of the descending aorta
  - Celiac Artery, superior mesenteric artery and the inferior mesenteric artery
Branches of the celiac artery

- Left gastric
- Splenic – goes behind stomach
  - Branches - Short gastric, left gastro-omental, pancreatic, posterior gastric artery
- Common hepatic
  - Proper hepatic – branches into right gastric, left hepatic, right hepatic and cystic
  - Gastroduodenal – branches into supraduodenal, superior pancreaticoduodenal and right gastro-omental

Branches of superior mesenteric artery

- Define them by their targets
- Inferior pancreaticoduodenal artery
- Middle colic artery – supplies middle region of the transverse colon
- Right colic artery – supplies middle ascending colon
- Ileocolic artery – supplies cecum and part of ileum, gives off appendicular artery
- Intestinal branches – for jejunum and ileum

Branches of the inferior mesenteric artery

- Left colic artery
- Sigmoidal arteries
- Superior rectal artery

Marginal Artery of Drummond – all the anastomosing channels connecting the branches of the superior and inferior mesenteric arteries

Hepatic Portal Venous System - Begins at venous capillaries in GI, ends at venous sinusoids in liver

- Inferior mesenteric vein → splenic vein → superior mesenteric vein → portal vein → liver

Portal Hypertension

- Occurs when portal circulation through the liver is obstructed (can be caused by liver disease or tumor)
- Pressure rises in the portal vein causing blood to back up and possibly reverse flow into systemic system
- Causes varicosities (enlarged veins)

Sites of Portal-Systemic Anastomoses

<table>
<thead>
<tr>
<th>Portal Vein</th>
<th>Systemic Vein</th>
</tr>
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<tbody>
<tr>
<td>Esophageal varices</td>
<td>Esophageal branch of left gastric</td>
</tr>
<tr>
<td>Anorectal varices (basically same as internal hemmroids)</td>
<td>Superior rectal branch of inferior mesenteric</td>
</tr>
<tr>
<td>Caput Medusae</td>
<td>Paraumbilical (in falciform ligament) branch of portal</td>
</tr>
<tr>
<td>Retroperitoneal varices (veins of Retzius)</td>
<td>Colic, duodenal and pancreatic</td>
</tr>
<tr>
<td></td>
<td>Lumbar and renal to inferior vena cava</td>
</tr>
</tbody>
</table>

GI Tract and Associated Organs

- Objectives
  - Abdominal parts of the esophagus
  - Stomach
- Identify – cardiac and pylorus orifices, relation with greater and lesser omentum, anterior and posterior surfaces, fundus and cardinal notch, body and angular incisure, pyloric antrum, pylorus, pyloric sphincter, pyloric canal, mucous membrane appearance, gastric folds (rugae), muscles of stomach wall
- Describe relations of stomach with adjacent structures
- Describe the blood supply of the stomach

### Small Intestine
- Identify and distinguish the 3 major divisions of the small intestine: duodenum, jejunum and ileum. Note the major and minor duodenal papillae
- Describe their locations and relationships to other abdominal structures including mesenteries and peritoneum
- Describe the blood supply of the small intestine, note the distinct features of the jejunal and ileal vessel arcades and vasa recta

### Large Intestine
- Identify the various parts including the appendix, their location and relationships to other abdominal structures including mesenteries and peritoneum
- Describe the blood supply of the large intestine
- Identify the appendix and its relationships
- Describe the teniae coli, omental appendices, haustra, semilunar folds
- Understand the location and relations of the colic flexures

### Liver
- Define its major function
- Describe the anatomical and functional lobes of the liver
- Define the relations of the liver to other abdominal structures
- Describe the porta hepatic and its contents
- Describe the peritoneal ligaments and the bile ducts associated with the liver
- Describe the blood supply of the liver

### Gall Bladder
- Describe its location, parts, relationships, functions, and the bile duct system

### Pancreas
- Describe its location, relationships, functions and the pancreatic duct system
- Define its parts
- Describe its blood supply

### Spleen
- Describe its location, relationships, functions and blood supply

### Esophagus
- 3 Constrictions
  - Superior – **superior esophageal sphincter** (made by muscles of inferior pharyngeal sphincter)
  - Middle – arch of aorta and primary bronchi
  - Inferior – **inferior esophageal sphincter** formed by right crus of the diaphragm
    - If this doesn’t work then acid can get up
- Vagal trunk autonomies travel with esophagus

### Esophagogastric Junction (Z-line)
- Transition of tissue from esophagus to stomach

### Clinical Correlations
- **Hiatal hernia** – protrusion of a portion of the stomach through the esophageal hiatus
  - Phrenicoesophageal ligaments get loose and let the stomach come up
- **Pyrosis** – regurgitation of food and acid above the Z-line of the esophagus eroding the esophageal mucosa
  - Gastroesophageal Reflux Disorder (GERD) – often associated with hiatal hernia

### Stomach
- Has 3 muscle layers instead of the normal 2 in the GI tract
- 4 Segments
  - **Cardia** – where esophagus enters the stomach
  - **Fundus** – where gas accumulates
  - **Body** – separated by **angular incisure** from pyloric antrum
- **Pyloric Part**
  - **Pyloric antrum** (just next to body) and **pyloric canal** can be seen best when stomach is empty
    - When empty, the antrum looks like a deflated sac and the canal still looks like a canal
  - **Pyloris** – has lots of **circular** smooth muscle and is thus very distinct
    - **Pyloric sphincter** – regulates rate of food getting into duodenum
    - **Pyloric orifice** – just the opening
- **Cardiac notch** – angle between esophagus and fundus
- **Gastric folds (rugae)** – all squiggly and in the *lateral* portion of the stomach
- **Gastric canal** – folds that are **longitudinal** and in the *medial* portion of stomach
Note – ampulla (duodenal cap) follows right after the pyloric sphincter and is part of duodenum
- It is much wider in diameter than the end of the stomach because there aren’t any muscles there

- Blood Supply
  - Hepatic artery → right gastric artery
  - Hepatic artery → gastroduodenal artery → Right gastro-omental artery
  - Celiac trunk → splenic artery
    - Posterior gastric artery
    - Left gastro-omental artery

- Small Intestine
  - Duodenum
    - 4 Parts
      - Superior – intraperitoneal
      - Descending – secondarily retroperitoneal
        - Minor duodenal papilla – connection of accessory pancreatic duct; secretes pancreatic enzymes and bicarbonate (to reduce stomach acid)
        - Major duodenal papilla – where bile and pancreatic enzymes enter
          - Horizontal (inferior) – secondarily retroperitoneal, runs behind superior mesenteric artery
          - Ascending – secondarily retroperitoneal
    - Duodenojejunal Flexure – is an acute angle and the bend is supported by the suspensory ligament of the duodenum (Treitz)
      - Marks transition to intraperitoneal jejunum
      - The suspensory ligament connects to the vertebra and diaphragm. It is contractile and can change angle

- Blood Supply
  - Common hepatic → gastroduodenal artery → superior pancreaticoduodenal artery → posterior superior pancreaticoduodenal artery and anterior superior pancreaticoduodenal artery
  - Superior mesenteric artery → inferior pancreaticoduodenal artery → posterior inferior pancreaticoduodenal artery and anterior inferior pancreaticoduodenal artery
  - Both of those endings anastomose and supply duodenum and head of pancreas
  - Note – splenic artery supplies tail of pancreas

- Clinical Correlation
  - Arteriomesenteric Occlusion of the Duodenum – compression of the horizontal part of duodenum by the superior mesenteric artery because it holds the weight of much of the small intestine
    - More often in tall, frail, weak, slender people with poor abdominal muscles
    - Presents with nausea and vomiting 1-2 hours after meals
    - Just have them lay down to take the tension off

- Jejunum – most of the nutrient absorption here, 8 ft, often in left superior part
- Ileum – 12 ft, often in right inferior part
- No sharp delineation between jejunum and ileum

<table>
<thead>
<tr>
<th>Jejunum</th>
<th>Ileum</th>
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<tbody>
<tr>
<td>Diameter</td>
<td>2-4 cm</td>
</tr>
<tr>
<td>Wall</td>
<td>Thicker</td>
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<tr>
<td>Vessels</td>
<td>Fewer arcades (1-2)</td>
</tr>
<tr>
<td></td>
<td>Longer vasa recta (&quot;longer name&quot;)</td>
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<td></td>
<td>Poorer anastomoses</td>
</tr>
<tr>
<td>Amount of fat</td>
<td>Less, does not go over intestine, thus more rosey</td>
</tr>
<tr>
<td>Plicae circularis</td>
<td>Numerous, can be seen on X-Ray</td>
</tr>
<tr>
<td>Peyser’s patches</td>
<td>Few</td>
</tr>
<tr>
<td></td>
<td>More arcades</td>
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<tr>
<td></td>
<td>Shorter vasa recta</td>
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<td>Better anastomoses</td>
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<td>More, encroaches intestine (goes over to the halfway point)</td>
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</tbody>
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- Plicae circularis – circular folds in SI that ↑ surface area of intestine
- Arcades – interconnect adjacent arteries

- Clinical Correlation
  - Intussusception – telescoping into adjacent section (SI folds inside itself)
    - Most common in children
- **Volvulus** – twisting of a loop to such an extent that blood flow through mesentery is obstructed
  - Large Intestine – absorbs water, ions; bacteria break down large polysaccharides
    - Parts – cecum, appendix, ascending colon, right colic flexure, transverse colon, left colic flexure (higher than right and connected to phrenicocolic ligament), descending colon, sigmoid colon, rectum and anal canal
    - **Ileocecal fold flaps** – entrance of SI into LI which may *act as a valve*, note that part of cecum is below this
- **Orifice of appendix**
- **Four Features of the Large Intestine**
  - **Tenia Coli** – three longitudinal bands of smooth muscle on outside of LI
  - **Haustra** – bumps which compartmentalize fecal material
    - semilunar folds – on inside, separate the haustra
  - **Omental appendicies** – lobules of fat
  - Larger diameter
- **Clinical Correlations**
  - **Diverticula** – outpocketings of large intestine, possibly due to fecal matter being too dense and causing it to pop out. Incidence is 50% in the West, but .01% in Africa due to ↓ fiber in western diet
    - Most often in *sigmoid colon*
    - **Diverticulosis** – presence of diverticula in the wall of the large intestine
    - **Diverticulitis** – inflammation of the diverticula
  - **Endoscope**
    - If by mouth, can go to duodenum
    - If by butt, can go to end of large intestine
    - If by pill, can go all the way through
  - **Position of Appendix**
    - **Retrocecal** – 2/3rds of the time
    - **Pelvic** – 1/3rd of the time
    - Note – 3 tenia coli converge at the base of the appendix
  - Liver – largest gland, stores glycogen and secretes bile
    - 4 anatomical lobes – left, right, **caudate, quadrate**
    - 3 functional lobes – left, right and caudate
    - each has their own branch of hepatic artery and portal vein
    - 8 surgical segments – segmental blood supply allows for surgical removal of diseased segments
    - Blood Supply – 75% from portal vein, 25% from hepatic artery
    - Venous drainage – **hepatic veins** drain directly into inferior vena cava
  - **Surface anatomy**
    - **Anterior**
      - Faliform ligament – divides right and left anatomical lobes
        - **Ligamentum teres** - remnant of the *fetal umbilical vein*; connected to faliform ligament
        - **Left Triangular ligament** – extensions of the *coronary ligaments* (anterior and posterior)
        - **Cantlie Line** – vertical line on right lobe just medial to gallbladder
          - Division of right and left functional lobe
    - **Posterior**
      - Left triangular ligament → anterior and posterior coronary ligaments
        - Note – coronary ligaments have gaps between the two sheaths
      - **Caudate lobe** – bounded by the **ligamentum venosum** (remnant of the ductus venosus) medially and the inferior vena cava laterally
      - **Quadrate lobe** – bounded by remnant of umbilical vein (ligamentum teres) medially, the porta hepatis superiorly, the gallbladder laterally
      - **Porta hepatis** – a fissure that transmits the hepatic portal vein, the hepatic artery proper, the common hepatic duct, nerves and lymphatics
Right triangular ligament → anterior and posterior coronary ligaments
- These open up and create a bare area on the top of the right lobe of the liver (up against the diaphragm)

Biliary Ducts and Gallbladder
- Gallbladder – collects and stores bile, concentrates it (if too concentrated then gallstones)
  - Fundus (top part), Body, Neck forming cystic duct (and spiral valve)
  - Joins common hepatic duct to create bile duct
- Bile Duct System
  - Right and left hepatic ducts → common hepatic duct then cystic duct joins → bile duct which joins the main pancreatic duct → to form the hepatopancreatic ampulla (a cavity where they join, opens into the major duodenal papilla)
  - Accessory pancreatic duct – drains into minor duodenal papilla
  - Sphincters
    - Sphincter of bile duct, sphincter of pancreatic duct, sphincter of oddi (for the hepatopancreatic ampulla)
    - Each is innervated by autonimcs which control release of contents

Cholecystitis – associated with blockage of the gallbladder or any of the ducts due to gallstones
- Stones usually get stuck in neck or hepatopancreatic ampulla

Pancreas – exocrine function is to release pancreatic enzymes, endocrine function is insulin and glucagon
- 4 Parts – Head (associated with duodenum, contains uncinate process which is the part of the pancreas behind the superior mesenteric vessels), Neck (anterior to superior mesenteric vessels, Body and Tail

Spleen – delicate structure with thin capsule, most frequently injured organ in the abdomen
- Hilum – site of gastrosplenic and splenorenal ligament attachments and where splenic vessels enter and leave
- If bleeding and sac ruptures then blood will go into greater sac, specifically hepatorenal sac but then will go to the right pericolic gutter then into pelvic cavity
- If stab wound then diffuse pain caused by sympathetics, sharp pain caused by somatically innervated parietal peritoneum
- A horizontal stab wound at rib 9-11 would have to go through costodiaphragmatic recess to get to spleen and would thus would collapse lung

Development of the GI System
- Objectives
  - List the three major regions of the embryonic gut and define the boundaries (limits) of each in terms of embryonic structures and definitive structures
  - List the structures derived from the foregut. What is the blood supply of the structures derived from the caudal portion of the foregut?
  - What are the germ layers of origin for the epithelial structures derived from the foregut; the smooth muscle and CT; vascular supply; nerve supply?
  - Describe the development of the dorsal and ventral mesenteries and the formation of the lesser sac
  - Describe the development of the esophagus, stomach and duodenum. What results from the rotation of the stomach? What developmental anomalies are associated with each?
  - List the derivatives of the hepatic diverticulum
  - Describe the formation of the liver within the substance of the septum transversum
  - Describe the pancreatic buds and their positional changes involved in the formation of the adult pancreas, especially the formation of the definitive biliary and pancreatic duct system as well as related developmental anomalies
  - Define the terms stenosis, atresia, hernias, polyhydramnios
  - Describe the development of the spleen in the dorsal mesogastrium

Formation of Primordial Gut
- Endoderm from yolk sac forms lumen of GI
- Mesoderm forms CT and BV of GI
- Allantoic diverticulum eventually forms urachus (median ligament)
- Primordial gut consists of a tube that is closed at the cranial and caudal ends
  - Forms at week 4 due to folding of head, tail and lateral walls and incorporating the yolk sac into the embryo.
Lined primarily by *endoderm* which forms the epithelium and glands of the digestive tract
- The cranial end, the **stomodeum** is lined by *ectoderm* and closed off by the **oropharyngeal membrane**
- The caudal end, the **proctodeum** is lined by *ectoderm* and closed off by the **cloacal plate/membrane**
- **Splanchnic mesoderm** surrounding the primordial gut forms the muscle and CT layers of the digestive tract

- **Note** - *yolk stalk*
- **Dorsal aorta** forms from opening in *mesoderm*

- **Foregut** – gives rise to the esophagus, stomach, liver and pancreas, *proximal* half of duodenum
  - Also the celiac trunk,
  - Ventral mesentery - lesser omentum, falciform ligament, coronary/triangular ligaments
  - Dorsal mesentery – gastrosplenic, splenorenal, ga?stro?olic, greater omentum
  - **Motor nerve** - vagus

- **Midgut** – gives rise to the *distal* half of the duodenum, jejunum, ileum, cecum, appendix, ascending colon and the right 2/3rds of the transverse colon
  - Also the superior mesenteric artery, dorsal mesentery (mesointestine, mesoappendix, transverse mesocolon)
  - **Motor nerve** - vagus

- **Hindgut** – develops into the left 1/3rd of the transverse colon, the descending colon, sigmoid colon and the rectum down to the ano-rectal line (the **pectinate line**), which is the endoderm-ectoderm junction
  - Also the inferior mesenteric artery, dorsal mesentery (sigmoid colon)
  - **Motor nerve** – pelvic splanchnic nerves

- **Hox genes** expressed by the *endoderm* and *splanchnic mesoderm*; regulate (in part) the regional differentiation of the primordial gut

- **Timeline**
  - By End of 1ˢᵗ Month – primordial gut has formed
  - By End of 3ʳᵈ Month – the adult organization is present
  - By the Late Fetal Period – parietal cells have differentiated and the digestive system is functional

- **Mesentery**
  - **Primitive peritoneal cavity** is the **coelomic cavity**
  - Primitive gut is enveloped by mesentery on both the dorsal and ventral sides
  - Formed by a double layer of mesothelium eventually called the parietal and visceral peritoneum
  - The ventral mesentery degenerates during development, *except* for the foregut ventral mesentery which develops into specialized structures
  - **Gut starts out almost entirely intraperitoneal**
  - The mesentery houses all the blood vessels, nerves and lymphatics for the gut

- **Development of Autonomic Nervous System**
  - Sympathetic innervation reaches gut via a splanchnic nerve then prevertebral ganglion
  - The sympathetic postganglionic cells of the pre- and para-vertebral ganglia are formed from migrating *neural crest cells*
  - Parasympathetic and sympathetic innervation travels via the vagus and innervates the neurons of the **Auerbach’s Plexus** and **Meissner’s Plexus** of the gut wall
  - **Enteric Nervous System** also forms from migrating *neural crest cells*
  - **Hirschsprung’s Disease** – absence of enteric ganglia (Auerbach’s and Meissner’s) in the wall of the **colon**
    - Caused if neural crest cells don’t migrate properly

- **Foregut** – oral cavity to the duodenum
  - Includes, salivary glands, tonsils, lower respiratory tract, liver, gallbladder, pancreas
  - **Development of the Esophagus**
Mesenchyme of the caudal pharyngeal arches provides the striated muscle of the upper 1/3rd.

Splanchn mesenchyme provides the smooth muscle of the lower 1/3rd.

Elongates and endoderm proliferates to obliterate the lumen, but it then recannulates.
  - The recannulation can lead to developmental anomalies
    - Esophageal atresia – blind end
      - Can cause polyhydramnios if amniotic fluid doesn’t have access to GI tract
    - Esophageal stenosis – narrowing of lumen

- Congenital short esophagus – if esophagus doesn’t elongate properly then diaphragm formation will be moved way up and you will get a congenital hiatal hernia

Development of the Stomach

- Starts as a dorsal enlargement during the 4th week
- Differential growth causes greater and lesser curvatures
- As it enlarges the tube rotates 90° clockwise
  - The ventral mesentery then produces the lesser sac (and lesser omentum), which expands superiorly (superior recess behind liver) and inferiorly (interior gastrocolic ligament)
  - The dorsal mesentery elongates inferiorly to form the greater omentum

Development of the Duodenum

- Begins to form during week 4 at transition point between foregut and midgut
- Differential growth causes a C shape, just like the stomach, but with the opposite orientation
- It also rotates 90° clockwise with the stomach
- Endoderm of duodenum proliferates lumen becomes obliterated, but it recannulates by week 8
  - Can cause abnormalities like duodenal stenosis, duodenal atresia (and resulting polyhydramnios)

Development of Liver, Gallbladder and Biliary Apparatus

- Hepatic Diverticulum – evagination from the ventral surface of the caudal foregut that gives rise to the liver, gallbladder and biliary apparatus
  - Grows into the ventral mesentery and on into the septum transversum (which is the primordial diaphragm, composed of splanchnic mesoderm)
  - Reflections of the ventral mesentery on the diaphragm become the coronary and triangular ligaments
  - Liver
    - Proliferating endodermal cells form cords of hepatic cells and the epithelia cells of the biliary system in the liver
      - These coar anastomose around the endothelium lined spaces that form the hepatic sinusoids
    - The CT, endothelial cells, hemopoietic tissue and kupffer cells arise from the splenic mesenchyme of the ventral mesentery
      - The gallbladder and cystic duct form from the small caudal part of the hepatic diverticulum
      - The extrahepatic biliary apparatus is initially solid, but becomes cannulized
        - Can result in biliary atresia or biliary agenesis
          - Initially the bile duct is attached to the ventral surface of the duodenum, but after its rotation it is on posterior surface

- Progeny of Ventral Mesentery
  - Lesser omentum (hepatoduodenal ligament, hepatogastric ligament), visceral peritoneum of the liver, and the falciform ligament

- Development of the Pancreas
  - Arises from two evaginations of the caudal foregut called the pancreatic buds
  - Dorsal pancreatic bud – larger and develops into the neck, body and tail of pancreas
**Ventral pancreatic bud** – smaller and develops into the uncinate process and the head

**Main pancreatic duct** – derived from duct of ventral bud AND distal part of dorsal bud duct

**Accessory pancreatic duct** – made from the proximal end of the dorsal bud duct

- Endocrine and exocrine pancreatic tissues formed from endodermal cells
  - Makes sense since it is an outpocketing of foregut

**CT of pancreas formed from splanchic mesoderm**

**Pancreatic Abnormalities**

- **Accessory (ectopic) Pancreatic Tissue** – pancreatic tissue forming in the wrong place
  - Can form in the wall of the stomach, duodenum, ileal diverticulum
- **Anular Pancreas** – ventral pancreatic bud splits and goes anterior and posterior around duodenum
  - Leads to obstruction or constriction

**Development of the Spleen**

- Arises from the mesenchyme of the **dorsal mesogastrium**
- **No endodermal components in the spleen**
  - Kinda makes sense because it doesn’t secrete anything into the GI tract
  - The spleen begins to develop during week 5 and *initially is lobulated*, but by birth it is its mature shape

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**Development of the GI System 2**

- **Objectives**
  - List the adult structures derived from the midgut
  - What is the blood supply and autonomic innervation pattern of the structures formed from the embryonic midgut?
  - Describe the positional changes that take place during the process of midgut rotation and fixation. What developmental abnormalities are associated with these processes?
  - Correlate the organ positional relationships within the abdominal cavity with the developmental history of the region
  - What is a Meckel’s form of ileal diverticulum? Umbilico-ileal fistula? What is the congenital basis of these conditions?
  - Briefly describe the positional changes that occur in the arteries and veins associated with the caudal foregut and midgut
  - Briefly describe the formation of enteric autonomic ganglia of the digestive system from neural crest cells
  - Describe the developmental errors leading to: biliary atresia, anular pancreas, omphalocoe, hiatal and umbilical hernias, segmental duplication of the intestinal tract, malrotations of the midgut resulting in subhepatic cecum, mobile cecum, and volvus
  - Define/describe the allantois, cloaca, cloacal membrane, anal pit, proctodeum, urorectal septum. How do these structures relate to those of the adult colon, rectum, anal canal and urogenital organs?
  - Describe the process by which the proctodeum (anal pit) is formed
  - Define/describe the location of the tissue that will form the urorectal septum
  - List the major structures (organs) that are definitively situated anterior to the tissue plane created by the urorectal septum; those situated posterior to the plane
  - Describe the vascular supply (blood and lymphatic) and innervation of the portion of the anal canal derived from the hindgut the portion of the anal canal derived from the proctodeum
  - Explain: congenital megacolon, imperforate anus, fistulae between the rectum and urethra in the male, anoperineal fistulae, anal stenosis, imperforate anus, anorectal agenesis
  - Summarize the vascular supply of each portion of the gut (stomodeum, supradiaphragmatic foregut, infradiaphragmatic foregut, midgut, hindgut, proctodeum)
  - Summarize the autonomic innervation of the portions of the gut mentioned above

- **Development of the Midgut**
The midgut forms the distal part of the duodenum, jejunum, ileum, appendix and the large intestine up to and including the proximal 2/3rds of the transverse colon

All derivatives of the midgut are supplied by the superior mesenteric artery

During week 6, the midgut elongation exceeds the capacity of the peritoneal cavity (intraembryonic coelom). This produces a physiological umbilical herniation of the midgut into the extraembryonic coelom in the proximal part of the umbilical cord

- The cranial limb of the midgut loop forms the small intestine
- The caudal limb of the midgut loop forms the terminal part of the ileum and the large intestine
- Ileal diverticulum – abnormality caused by the remnant of the proximal part of the yolk salk
  - 2-4% of the population has it

Rotation of the Midgut Loop

- While in the yolk sac, the midgut rotates 90° counterclockwise
- The midgut loop then returns to the abdomen
  - The small intestine returns first and occupies the central part of the abdomen
  - As the large intestine returns it rotates another 180° counterclockwise
  - This puts everything in the right place, except the cecum is up against the liver
    - The ascending colon then grows down to put the cecum in the right spot
    - The cecum arises from the cecal diverticulum (a small bump in the tube)
    - The appendix arises from a diverticulum at the base of the cecum
- Rotation and stuff ends by week 12

Fixation of the Intestine

- Almost everything is intraperitoneal at first, it only becomes secondarily retroperitoneal after everything is in the right place
- To do so it just fuses to the posterior abdominal wall

Development of the Cecum and Appendix

- Note that the haustra develop in adult

Abnormalities of the Midgut

- Malrotation of the midgut – Any anomaly associated with improper or incomplete rotation and fixation of the primary intestinal loop
  - Nonrotation – The 180° rotation does not occur resulting in the large intestines on the left and the small intestines on the right side of the abdominal cavity
  - Mixed Rotation and volvulus (twisting of the intestine which cuts off the blood supply) – incomplete rotation results in the cecum being located just inferior to the pylorus of the stomach. Connective tissue bands passing over the duodenum anchor the cecum. Often occurs with volvulus
  - Reversed Rotation – The primary intestinal loop rotates clockwise resulting in the transverse colon being located posterior to the duodenum and superior mesenteric vessels
    - Causes superior mesenteric artery to compress and constrict the transverse colon
  - Subhepatic cecum and appendix – The cecum becomes fixed to the liver
    - Can be perfectly normal, but if appendix becomes inflammed then doc may think it is a gallbladder stone because of the location of the pain
  - Internal Hernia – A loop of small intestine pushes into the mesentery
  - Mobile Midgut with possible volvulus – Most common midgut anomoly, 10% of the population have it. Results from incomplete fixation of the ascending colon
    - No real problem, but causes increased risk of volvulus.
- **Hernias**
  - **Omphalocele** – Failure of a portion of the intestines to return to the abdominal cavity during week 10
    - The herniated mass is surrounded by *epithelium of the umbilical cord*
  - **Gastroschisis** – a hernia of the abdominal viscera through the lateral wall of the abdomen.
    - Due to a defect in closure of the lateral folds during week 4 when the lateral walls are formed
    - *Nothing covers the herniated viscera*
  - **Umbilical Hernia** – Develops after the successful return of the intestine to the abdominal cavity
    - Due to defect in closure of the umbilicus
    - *The herniated mass is surrounded by skin*
  - **Internal Hernia** – a loop of SI pushes into the mesentery of the midgut loop

- **Ileal (Meckel) Diverticulum** – typically a 3-6 cm long outpocketing of the ileum
  - Due to a. May be attached to the umbilicus
  - May contain ectopic gastric or pancreatic tissue (that is bad because of enzymes)

- **Duplication of the Small Intestine** – can happen two different ways, due to problems with lumen recannulating
  - **Cystic Type** – cyst forms and looks just like small intestine, but doesn’t communicate with it
  - **Tubular Type** – septum forms during recannulation and results in two intestines
    - One often blindly ends
Development of the Hindgut

- Hindgut gives rise to the left 1/3rd of the transverse colon, the descending colon, sigmoid colon, rectum and superior portion of the anal canal. Also the epithelium of the bladder and most of the urethra
- All derivatives of the hindgut are supplied by the inferior mesenteric artery
- Cloaca – the expanded terminal part of the hindgut lined by endoderm
  - The cloacal membrane is in contact with the surface ectoderm
  - Proctodeum (anal pit) – the region of the surface ectoderm overlying the cloacal membrane
- Allantois – an extension of the yolk sac that is continuous with the urogenital region and will become the urinary bladder
  - ‘empties into’ the cloaca
  - Becomes the urachus (median umbilical fold) in the adult
- During development, the cloaca is subdivided by the urorectal septum into a ventral urogenital region/sinus and a dorsal anal-rectal region/sinus
  - At week 7 the urorectal septum fuses with the cloacal membrane at the future perineal body and subdivides the cloacal membrane into the urogenital membrane and the dorsal anal membrane
    - The dorsal anal membrane usually ruptures at week 8
- HUH??
  - The ventral part of the cloacal sphincter becomes all the muscles of the urogenital triangle
  - The dorsal part of the cloacal sphincter becomes the external anal sphincter
- Things here done by the 3rd month of development

Development of the Anal Canal

- The upper 2/3rds is derived from the hindgut
  - Supplied by sympathetic nerves and superior rectal artery
- The lower 1/3rd is derived from the proctodeum
  - Supplied by somatic nerves and the inferior rectal artery
- Pectinate Line – border between the two embryologically distinct regions
  - Site of former anal membrane
- White line – where the mucosa change, is a little more caudal than the pectineal line

Anorectal Anomalies

- Persistent cloaca –
- Anal stenosis –
- Persistent anal membrane – also called, membranous anal atresia or imperforate anus
- Anal agenesis with anoperineal fistula – anal canal doesn’t form at the anal pit, the urorectal septum missed and came in too far anteriorly
- Rectovaginal fistula with anal agenesis – rectum goes into vagina
- Rectourethral fistula with anorectal agenesis – rectum goes into urethra
- Rectal Atresia – rectum stops

GI and Associated Glands

- Objectives
  - List the functions of the liver
  - Identify the components of the portal triad. Identify what the function is of each component
  - Describe the models of liver organization including the classic liver lobule, portal lobule and liver acinus
  - Describe the path of blood flow and bile flow in the liver
  - Describe the histological and functional organization of liver sinusoids including the contribution of Kupffer cells and endothelial cells
  - Describe the bile canaliculi and their function
  - Describe the general ultrastructure of the hepatocyte
  - Identify the endocrine and exocrine portions of the pancreas
- Describe the histological organization of the islets of Langerhans. List the function of various cell types
- Describe the histological organization of the gall bladder and correlate the function to the morphology of the organ
- **Liver**
  - Has both endocrine (directly into the bloodstream) and exocrine (into ducts) function
  - Where nutrients from the digestive tract are processed and then stored or sent out to bloodstream
  - Where toxins from the digestive tract are removed
- **Three Physiological Functions**
  - Vascular Functions – the storage and filtration of blood
  - Secretory/Excretory Functions – vitamin storage & excretion, synthesis of bile
  - Metabolic Functions – protein synthesis, lipoprotein and cholesterol synthesis, carbohydrate metabolism, metabolism of lipid-soluble drugs and steroids, urea formation
- **Glisson’s capsule** - dense irregular CT capsule enveloping the liver
- **Blood Supply**
  - 2000 ml, ie 1/3 of total cardiac output goes through it each minute
  - **Dual blood supply**, receives blood from arterial and venous sources
    - **Hepatic portal vein** – from digestive tract, spleen and pancreas. Provides 75% of liver blood
      - Gives rise to distributing veins → inlet venules → sinusoids
    - **Left and Right Hepatic Arteries** – branches of celiac trunk. Provides 25% of liver blood
      - Gives rise to distributing arterioles → inlet arterioles → sinusoids
    - Inlet venules & inlet arterioles → sinusoids → central vein → larger veins → right and left hepatic veins
    - The central vein is at the center of each liver lobule which is hexagonally shaped and surrounded by CT comprising portal tracts
      - The portal tract contains 6 sets of (one at each corner) hepatic arteries, hepatic portal veins, bile ducts (receives stuff from hepatocytes) and lymph vessels
      - Portal tract is separated from the parenchyma of the lobules by
        - **Space of Moll** – a narrow potential space which is origin of hepatic lymph
        - **Limiting Plate** – a sleeve of modified hepatocytes used for liver regeneration
- **Three Concepts in Liver Organization**
  - **Classic Lobule** – hexagonal-shaped parenchymal region bounded by portal tracts at each corner
  - **Portal Lobule** – described in terms of bile flow, a triangular region of hepatocytes with three central veins and all the bile within the triangle flowing in to a central bile duct
  - **Hepatic Acinus** – bounded by two central veins at the long axis, two portal tracts on the short axis and a distributing arteriole on the short axis
    - Hepatic cords in this model are divided into three zones
    - **Zone 1** – cells closest to arteriole receive well oxygenated blood with lots of nutrients, minimally exposed to metabolic waste
    - **Zone 2** – receive moderately oxygenated blood, intermediate exposure to metabolic waste
    - **Zone 3** – cells closest to central vein, poorly oxygenated blood, high metabolic waste
      - Primary site of alcohol and drug detoxification
      - Much more vulnerable to toxic damage and thus will be first to degenerate in liver disease
- **Hepatic Plates & Sinusoids**
  - **Hepatic plates/cords** – hepatocytes arranged in cords 1-2 cells thick
    - Hepatocytes have numerous microvilli
    - Cords bounded by sinusoids and the **Space of Disse**
      - **Space of Disse** – between cords and sinusoids and contains blood plasma, but not blood cells or platelets
        - Serves as a molecular holding tank for substances entering and leaving the hepatocyte
  - **Perisinusoidal Cells of Ito** – irregular cells with long cytoplasmic processes, concentrate Vit. A
  - **Hepatic Sinusoids** – formed from simple squamous endothelial cells that are discontinuous and without a basal lamina
    - Endothelial membrane contains holes called **Sieve Plates** which allow sub .5 micron substances through the endothelial wall
    - Supported by reticular fibers
Lumen contains Kupffer Cells which are large, branched phagocytic cells that phagocytose damaged RBCs and plasma debris.

Liver Hepatocytes
- Metabolize things from gut, store them as cellular inclusions and release them into sinusoids in response to hormonal or neural signals
- Varied structure depending on position in liver lobule
- Organelles
  - Nucleus is variable in size, numerous mitochondria, abundant RER and free ribosomes, prominent Golgi, numerous peroxisomes, lysosomes, endosomes, contains lipid droplets
- Drug and Toxin Metabolism
  - Abundant SER for drug metabolism and detox. Contains ‘microsomal mixed-function oxidase system’ responsible for metabolism of antibiotics and toxins
    - Deactivates toxins by methylation, conjugation, oxidation, etc.
  - Cytochrome P-450 involved in drug metabolism
  - Many liver enzymes are inducible (upregulated by continuous exposure)
  - First Pass Effect – drugs or toxins from GI are changed or deactivated in liver

Hepatocyte Domains
- **Lateral Domain** – part of hepatocyte that borders other hepatocytes
  - Membranes of adjacent hepatocytes form Bile Canaliculus, which is the beginning of the bile duct
    - Membranes adjacent to bile canaliculi are surrounded by tight junctions to isolate duct
    - Short microvilli protrude into the bile canaliculus
    - Bile canaliculi → Bile Ductules (in the portal region) → portal bile ducts → left and right hepatic ducts
    - This stuff is lined by cuboidal epithelium
- **Sinusoidal Domain** – border of hepatocyte that borders sinusoid
  - Hepatocyte and sinusoid are separated by Space of Disse
  - Hepatocytes provide numerous microvilli into space of Disse to ↑ SA and absorption
  - Lots of membrane transport here and thus lots of Na/K ATPase and adenylate cyclase activity

Bile
- Bile does not contain digestive enzymes
  - Dilutes and neutralizes acidic chyme
  - Adjusts intestinal pH so that pancreatic enzymes can function
  - Emulsifies fat
  - Allows for excretion of degradation products of old RBCs
  - Allows for excretion of excess cholesterol synthesized in the liver
- Transported from hepatocytes to bile canaliculi via ATP dependent transporters
- Contents
  - **Bile Salts** – 80% of which are resorbed by SI, 10% synthesized by hepatocytes fresh (taurocholate, glycocholate)
  - **Bilirubin** – yellowish-green toxic product of hemoglobin degredation
    - Elevated levels cause jaundice
  - Electrolytes, cholesterol, phospholipids, lecithin, IgA

The Gallbladder
- Stores, concentrates and releases bile
- Not considered a gland
- 5 Layers
  - **Simple Columnar Epithelium** – composed of clear cells and brush cells
  - **Lamina Propria** – vascularized loose CT
  - **Muscularis Externa** – smooth muscle of mixed orientation
  - **Perimuscular CT**
  - **Simple squamous epithelium** – a thin serous outer layer
- **Cholecystokinin-pancreozymin (CCK)** – hormone produced by the enteroendocrine cells of the intestinal epithelium that signals the gallbladder to contract
- **Sphincter choledochus** – at end of bile duct and is relaxed by CCK
- **Gallstones** – cholesterol precipitates and forms stones in gallbladder
  - Can lodge in the cystic or common hepatic ducts

- **The Pancreas**
  - Accessory digestive organ that releases digestive enzymes
  - Enveloped by a *thin capsule of CT* which forms delicate *septa* that divide it into lobules
  - **Tubuloacinar gland** – functional unit of pancreas; surrounded by loose CT; are round to oval-shaped secretory units
    - **Pancreatic Acinar Cells** – about 40-50 in a tubuloacinar gland; pyramidal-shaped; form the *secretory component*
      - **Basal Region of Acinar Cell** – rests on basement membrane, contains *round nucleus*, well developed RER containing numerous polysomes (basophilic), numerous mitochondria
      - **Apical Region of Acinar Cell** – contains *zymogen granules* (acidophilic), well developed golgi apparatus, lots of microvilli on *luminal side*
        - Tight junctions and other junctions isolate the lumen from intercellular space
      - Function – secretes a bunch of enzymes which aid in digestion
        - Enzymes secreted as *proenzymes* which have to be activated by *trypsin* in the duodenum
        - **Trypsin inhibitor** secreted by acinar cells to prevent autodigestion of pancreas
        - **Pancreatitis** can lead to lysis of acinar cells and the release of active digestive enzymes into abdominal cavity
      - There is a list of enzymes it secretes, but I’m not going to memorize it
      - Regulation – basal surface of acinar cells have *receptors for CCK* and this regulates them
    - **Centroacinar Cells** – form beginning of pancreatic intercalated duct system
      - each tubuloacinar gland contains 3-4 cuboidal centroacinar cells (centrally located)
      - Small, stellate, clear cytoplasm. Nuclei in the center; light staining
      - Function – secrete *bicarbonate ions* which maintain duodenal pH
      - Regulation – regulated by the hormone *secretin*, which is produced by the duodenum

- **Pancreatic Ducts**
  - Intercalated ducts from neighboring acini join to form larger *intralobular ducts* composed of *simple cuboidal-columnar cells*
  - Intralobular ducts from several lobules converge to form larger *interlobar ducts* composed of *low columnar epithelium*
  - The interlobular ducts empty into the main pancreatic duct, which merges with the duodenum
- **Pancreatic Islets of Langerhans**
  - Multihormonal, microorgans composed of ovoid bunches of clear endocrine (secrete right into blood) cells
  - Most numerous in *tail* region of pancreas

- **Liver Disease**
  - **Hepatitis C**
    - Most common blood-borne infection; leading cause of liver transplant
    - Results in infection and inflammation of liver causing destruction of hepatocytes
    - Symptoms – fatigue, ↓ appetite, weakness, nausea, joint & muscle pain, fibrosis of liver
    - Treatment – antiviral drugs (interferon & ribaviron)
  - **Cirrhosis**
    - Fibrosis of the liver following hepatocyte damage
    - Associated with alcoholism, chronic hepatitis, bile obstruction
    - Symptoms – jaundice, portal hypertension, esophageal varices & GI bleeding, anemia, hepatic coma due to too much ammonia in blood
  - **Inherited Diseases of the Liver**
    - **Wilson’s Disease** – autosomal recessive; causes copper accumulation in the liver, brain, cornea and kidney
      - Treatment – low copper diet
    - **Hemochromatosis** – inherited disease of *iron overload*
      - Symptoms – joint pain, fatigue, abdominal pain
      - Treatment – phlebotomy (remove 1 pint of blood every 2-4 months)
Common Lab Tests for Liver Damage
- Liver enzymes in blood ↑ with hepatocyte damage (ex. AST (aspartate aminotransferase), ALT (alanine aminotransferase))
- ↑ bilirubin, ↓ plasma albumin, ↑ blood clotting times (PT/PTT) (makes sense)

Liver Failure Pathophysiology
- ↓ Protein Synthesis
  - ↓ albumin synthesis leads to ↓ osmotic pressure in the blood resulting in edema
  - ↓ synthesis of clotting factors → spontaneous internal bleeding
- ↓ Metabolic Detoxification → ↑ plasma levels of toxins → hepatic coma
- ↓ Bile secretion → bile accumulation in liver and plasma → jaundice

Esophagus, Stomach and Intestines
- Objectives
  - Describe the overall plan of the alimentary canal
  - Describe the features of each layer of the alimentary canal
  - Describe the innervation of the alimentary canal
  - Describe the specialization of each region of the alimentary canal
  - Describe/list the functions of the alimentary canal by region and cell type
  - Describe the function of the specialized cells of the gut (eg digestive glands, gastric pits, enterochromaffin cells, paneth cells, mucus neck cells etc.
  - Describe the structural and functional regions of the esophagus
- GI Tract Functions
  - Stomach – mechanical disruption; absorption of water and alcohol
  - Small Intestine – chemical & mechanical digestion, absorption
  - Large Intestine – absorbs electrolytes & vitamins
- General Layers of GI Tract
  - Mucosa – innermost layer
    - Epithelium
      - In esophagus and anus (beginning and end) it is protective stratified squamous
      - In the rest of the GI it is simple columnar
        - Secretes enzymes and absorbs nutrients
        - Goblet cells – secrete mucous
        - Enteroendocrine cells – secrete hormones
    - Lamina Propria – basically same throughout; thin layer of CT containing vasculature, lymph, thin nerves, sometimes glands
  - Muscularis Mucosae – usually 2 thin layers of smooth muscle (except in esophagus)
  - Submucosa – thick CT, loose fibroelastic; contains BV, glands, lymphatics, and:
    - Submucosal (Meissner’s) Plexus – neurons which sets up the peristaltic wave
      - Mainly secretory-motor
      - Releases hormones and peptides
  - Muscularis Externa – outer layer of muscle
    - Circular muscle – inner
    - Myenteric (Auerbach’s) Plexus – neurons between these two layers
      - Mainly motor
      - Drives and regulates peristalsis
    - Longitudinal muscle – outer
      - Is skeletal muscle in mouth, pharynx, upper esophagus and anus (controls swallowing and defecation)
      - Is smooth muscle in all other places; peristalsis
  - Serosa – contains CT on the inside and epithelium on the outside
- Innervation of the Gut
  - All neurons and support cells derived from neural crest
  - In response to stretch or pressure, serotonin (5-HT) is released and received by submucosal (Meissner’s) neurons. The myenteric ganglia are then responsible for the peristaltic wave
  - Autonomic Inputs – don’t live in GI wall; aren’t part of enteric system; only modify gut action
    - Parasympathetic (ACh) ↑ motility
• Sympathetic (NE) relaxes the gut

○ Esophagus
  - Has folds that allow it to expand
  - *Stratified squamous* epithelium
  - Muscularis mucosae – *unique; single layer of discontinuous* smooth muscle
  - **Esophageal-cardiac glands** – in mucosa; near pharynx and end of esophagus
    - Different from esophageal glands in submucosa
  - Submucosa contains **esophageal glands**
    - **Esophageal glands** – unique to esophagus and duodenum
      - *serous* glands that secrete pepsinogen and lysosyme
  - Muscularis externa has three different portions – upper portion is all skeletal, middle is a mix, lower is all smooth

○ Stomach
  - Chemical digestion using HCl, pepsin, renin, gastric lipase
  - Has *three* layers of muscularis externa
    - **Oblique layer** – *innermost* extra layer that aides in mechanical digestion
    - Note – the *middle* circular layer forms the **pyloric sphincter**
  - **Rugae** – folds of mucosa and submucosa
  - Epithelium is *simple columnar*
  - **General Gastric Glands and Pits**
    - **Gastric Pits** – invaginations of the mucosa that ↑ SA and allow for expansion
    - **Gastric Gland** – bottom of gastric pit; in lamina propria; contains a bunch of different cells
      - Separated in to *isthmus, neck and base*
      - **Surface lining cell** – protective, secretes *watery* mucous
      - **Regenerative cell** – responsible for replacing cells in pit and gland
      - **Mucous neck cell** – makes mucous
      - **Parietal cell** – makes HCl (converts enzymes into active form) and **gastric intrinsic factor** (aides in absorption of B12)
      - **Chief cell** – (in base) makes pepsinogen, gastric lipase, renin (unknown function)
      - **Enteroendocrine cell** – (in base) releases glucagon???, and makes:
        - **Gastric inhibitory peptide** – when in pylorus this causes ↓ in gastric churning by inhibiting function of gastrin
        - **Gastrin hormone** – made by **G Cells** (a type of enteroendocrine cell)
          - Causes the release of gastric juice, ↑ gastric motility, relaxes pyloric sphincter, constricts esophageal sphincter
    - Note – composition of cell types, and depth of pits and glands varies depending on the part of the GI
      - Cardiac mucosa contains mainly surface lining cells and *no chief cells*
      - Glands are highly coiled and gastric pits are shallow
      - Fundic mucosa contains lots of surface lining cells and regenerative cells
      - Glands are long and straight, gastric pits are short
      - Pyloric mucosa contains mainly mucous neck cells and *few* chief cells
      - Glands are branched and deep, gastric pits are deep
  - **Parietal Cells** – release HCl and change shape when active
    - Things that stimulate parietal cells
      - Gastrin and histamine - released when EC cells are *stretched*
      - Acetylcholine – released by vagus nerve

○ Small Intestine
  - Duodenum (10 inches), jejunum (8 feet), ileum (12 feet)
  - **General Villi Structure**
    - **Crypt of Leiberkuhn** – simple or branched tubular glands that look like narrower portion at base of villi; contains:
- **Surface absorptive cell** – near top; absorb water, reesterify fatty acids, form chylomicrons, transport absorbed nutrients
- **Goblet Cell**
- **Enteroendocrine cells** and **Regenerative cells**
- **Paneth Cell** – diagnostic for small intestine; synthesizes and secretes *lysosome*

- **Regional Differences in Villi**
  - **Duodenum** – villi are broad, numerous, tall
    - Contain **Brunner’s glands** (diagnostic) and few goblet cells
      - **Brunner’s Glands** – in submucosa, branched tubulo-alveolar glands that secrete mucous-alkaline fluid that neutralizes chyme
  - **Jejunum** – villi are narrow, less dense, shorter
    - Contain many goblet cells
  - **Ileum** – villi are narrowest, least dense, shortest
    - Contain many goblet cells, and **Peyer’s Patches** (which contain M Cells and are diagnostic)
    - Note – Peyer’s Patches are only on the side of the gut opposite the mesentery

- **Things that ↑ SA - plicae circularis**, villi (equiavelent to gastric pit), microvilli
  - Note – the villi have smooth muscle and can contract, this helps the chylomicrons within the lymphatics of the villi move

- **Large Intestine**
  - 5 feet long, rectum last 8 inches, anal canal is last inch
  - Has Crypt of Leiberkuhn without villi
  - No paneth cells
  - Lots of surface absorptive cells and goblet cells
  - Muscular Externa – normal circular layer; longitudinal layer is divided into three fascicles called *taenia coli*
    - These muscles have constant tone and result in *haustra* and *sacculations*
  - Rectum – crypts are fewer and deeper; ↑ goblet cells
    - **Recto-anal Junction** – epithelium becomes stratified squamous and contains *circumanal glands*
  - Anus – outer layer of muscularis externa disappears, inner layer becomes *internal anal sphincter*
    - **Puborectalis** – ?? skeletal muscle
    - **External anal sphincter** – skeletal muscle that gives voluntary control over defecation

### Posterior Abdominal Wall

- **Objectives**
  - Describe the skeletal, muscular, and fascial components of the posterior abdominal wall
  - Describe the attachments and actions of the psoas major, iliacus and quadratus lumborum muscles
  - Understand the attachments, arches, apertures, components, innervations, and blood supply of the diaphragm
  - Be able to describe the relationships of the diaphragm to structures which pass through it
  - Describe the course and “paired” branches of the abdominal aorta and inferior vena cava as they travel through the posterior abdomen
  - Understand the system of lymphatic vessels and nodes located along the posterior abdominal wall. What is the pattern of lymphatic drainage within the abdomen?
  - Describe the branches of the lumbar plexus, including their courses and innervations
  - Describe the anatomy, relations, fascial coverings, internal structure and vascular supply of the kidneys
  - Know the course of the ureter as it passes along the posterior abdominal wall on its way to the urinary bladder
  - Describe the anatomy, relations, internal structure, and vascular supply of the suprarenal glands

- **Skeleton**
  - 12th rib, 5 lumbar vertebrae, sacrum, wings (ala) of ilium
  - **Iliolumbar ligament** – PSIS to TP of L5

- **Muscles**
  - **Quadratus Lumborum**
    - Attachments – 12th rib, L1-L4 TP, iliolumbar ligament, posterior iliac crest
    - Innervation – ventral rami of T12-L4
    - Unilateral Action – same side bending
    - Bilateral Action – extension
  - **Psoas Minor** – absent in most people; is mainly a tendon
    - Attachments – T12-L1 vertebral body to pectineal line (of pelvis)
• Innervation – L1
• Action – weak flexor of trunk
  ▪ Psoas Major – in cow this is the tenderloin, if it is cross section then it is filet minon
    • Attachments – TP of L1, bodies and IV discs of lumbar vertebrae → lesser trocanter of femur
    • Innervation – L2-L4
    • Action – flexes lower extremity at hip joint
  ▪ Iliacus – together with the psoas major is called the Iliopsoas
    • Attachments – ala of ilium, sacroiliac ligament, ala of sacrum → lesser trocanter
    • Innervation – femoral nerve (L2-L4)
    • Action – flexes lower extremity at hip joint
  ▪ Iliopsoas Test – if psoas is irritated then it wants to be in relaxed state. Inflammation of appendix can irritate
    • Test its irritation by extending hip joint and determining if there is pain

○ Fascia
  ▪ Psoas major fascia superiorly → makes medial arcuate ligament
  ▪ Quadratus lumborum fascia superiorly → makes lateral arcuate ligament
    • Laterally → contributes to thoracolumbar fascia
  ▪ Thoracolumbar fascia has contributions from three things
    • Posterior Layer – from posterior erector spinae fascia
    • Middle Layer – from anterior erector spinae fascia
    • Anterior Layer – from quadratus lumborum fascia

○ Thoracoabdominal Diaphragm
  ▪ GET PICTURE
  ▪ Has central tendon and muscular part
  ▪ Right Crus – connects to L3 and creates esophageal hiatus
  ▪ Left Crus – connects to L2 and is attachment point for Ligament of Treitz
  ▪ Median Arcuate Ligament – formed from fibers of left and right crus
    • Bridges over aorta
  ▪ Medial Arcuate Ligament – formed from deep fascia of psoas major
    • Connects either crus to the TP of L1
    • Psoas major goes through it
  ▪ Lateral Arcuate Ligament – formed from deep fascia of quadratus lumborum
    • Connects TP of L1 to 12th rib
    • Quadratus lumborum goes through it
  ▪ Sternotcostal Hiatus – lets superior epigastric artery through
  ▪ Lumbocostal Triangle – on left side and doesn’t contain muscle fibers, just fascia
    • Is a weak point and is vulnerable to diaphragmatic hernia
  ▪ I Ate 10 Eggs At Noon
    • Inferior Vena Cava goes through central tendon at T8 and dilates during inspiration
    • Esophagus and vagal trunks go through at T10
    • Aorta, thoracic duct, azygos, and hemiazygos go through at T12
  ▪ Innervation
    • Intercostal Nerves (T5-T11) and Subcostal Nerves (T12) – provides sensory innervation to lateral part of diaphragm
    • Phrenic Nerves (C3-C5) – motor and sensory; referred pain to shoulder region
      ○ Hiccups – irritation to phrenic nerve
      ○ Lesion to One Phrenic Nerve – deinnervated part is pushed upwards by abdominal pressure at rest and is pushed farther up during inspiration for same reason
  ▪ Blood Supply
    • Supply to anterior portion provided by branches off internal thoracic
      ○ Pericardiacophrenic Vessels – supply surface of pericardial sac and anterior midline of diaphragm
      ○ Musculophrenic Vessels – supplies anterior diaphragm along costal margin
    • Supply to posterior portion provided by branches off aorta
Superior Phrenic Vessels – branches off of aorta right before it goes through diaphragm
Inferior Phrenic Vessels – branches off aorta right after it goes through diaphragm

Abdominal Aorta
- Vessel Categories: unpaired (supply viscera), paired (supply kidney and suprarenal etc.), paired parietal (supply wall)
- Inferior Phrenic –
- Right and Left Renal – originate at L1
- Right and Left Gonadal – originate at L2
- Common Iliac – two branches of abdominal aorta starting at L4
  - Becomes External Iliac after giving off Internal Iliac
  - External iliac also gives off deep circumflex iliac and inferior epigastric
- Becomes Femoral after going under inguinal ligament
- Median Sacral – comes off at branch of common iliacs
- Aortic Aneurysm – especially in lower part of abdominal aorta; can pulse with heartbeat

Inferior Vena Cava – no valves, almost everything is paired
- Right and left hepatic vein –
- Right phrenic veins –
- Right suprarenal vein –
- Right renal vein – no branches (except to azygos vein?)
- Left renal vein – has branches to left suprarenal vein, hemiazygos vein and left gonadal vein
- Right gonadal vein –
  - Bifurcates at L5 into common iliac veins which then bifurcate into internal and external iliacs
- Median sacral vein – is a branch off of left common iliac

Abdominal Lymphatics
- Visceral Nodes – found on organs or mesentery
- Parietal Nodes – associated with abdominal wall and large arteries
  - Lymph Flow = visceral nodes → parietal nodes → cysterne chyli → thoracic duct
- Cysterne Chyli – at L1-L2 and is behind the internal vena cava and is a confluence of lymph vessels
  - Goes through aortic hiatus; origin of thoracic duct
  - There is a big list of visceral nodes, but I’m not going to memorize those

Nerves of Posterior Abdominal Wall
- Subcostal Nerve (T12) – just below 12th rib, sensory and motor to skin and parietal peritoneum
- Lumbar Plexus – L1-L5; located in the psoas major muscle
  - Iliohypogastric (L1) - sensory and motor to skin and parietal peritoneum
  - Ilioinguinal (L1) - sensory and motor to skin and parietal peritoneum
  - Genitofemoral (L1 & L2)
    - Genital Part – enters inguinal canal and supplies cremaster muscle in male
      - In females it is a sensory nerve to the anterior aspect of the labia
    - Femoral Part – goes inferior to inguinal ligament to supply skin on anterior aspect of thigh
  - Lateral Femoral Cutaneous (L2 & L3) – under inguinal ligament near ASIS to supply lateral thigh skin
  - Femoral (L2-L4) – travels lateral to psoas major; provides motor innervation of quadriceps
  - Obturator (L2-L4) – travels medial to psoas major; provides motor innervation to thigh adductors
    - Goes through obturator foramen
• Lumbrosacral Trunk (L4-L5) – travels medial and posterior to psoas major; connects to sacral plexus
  ○ Contributes to ciatic nerve

• Sympathetic Trunk – supplies viscera
  ○ Kidneys
    • Function – remove excess water, salts and nitrogenous wastes
    • Location – retroperitoneal from T12 to L3; the right one is lower because of liver

• Anatomy
  • Capsule – thin fibrous layer almost inseperable from kidney
  • Cortex and Medulla –
  • Renal Columns (glomeruli?) – extensions of cortex
  • Renal Pyramid – part of medulla; apex is capped by minor calyx
  • Minor calyx → major calyx → renal pelvis
  • Renal Sinus – cavity in kidney containing fat, outside of calices, renal pelvis, arteries and veins, ANS
  • Renal Calculi – kidney stones; as it moves down ureter it will cause loin then groin pain due to stimulation of T11 – L2

• Renal Coverings
  • Perirenal Fat – around kidney, underneath the renal fascia
  • Renal Fascia – continuous laterally with transversalis fascia and medially with psoas major fascia
  • Pararenal Fat – fat outside renal fascia around kidney
  • Note – surgical approach to kidney is posterior lateral to minimize infection of abdominal cavity (renal fascia would contain infection)

• Suprarenal Glands
  • Functions
    • Cortex – produces and secretes corticosteroids and androgens
    • Medulla - Chromaffin Cells (modified sympathetic neurons) produce and secrete catecholamines (epinephrine and norepinephrine)
      ○ Chromaffin cells are innervated by preganglionic sympathetic fibers of the greater splanchnic nerve
  • Above kidney and surrounded by fibrous capsule, perirenal fat, renal fascia, and pararenal fat
  • Arterial Supply
    • Superior suprarenal artery – a branch off of inferior phrenic artery
    • Middle suprarenal artery – branch off of abdominal aorta
    • Inferior suprarenal artery – branch off of renal artery
  • Venous Drainage
    • Left suprarenal vein – drains into left renal vein
    • Right suprarenal vein – drains into inferior vena cava
  • Note – right is pyramidal shaped, left is semilunar shaped

• Urinary System
  • Objectives
    • List the organs of the urinary system and give their functions
    • List and describe the gross external structure of the kidney
    • List and describe the gross internal structure and organization of the kidney
    • Define, list and contrast the subdivisions of the kidney
    • Define, list and contrast the parts of the uriniferous tubule, nephron and collecting duct
    • Describe and contrast the two major types of nephrons based upon their location in the kidney
    • Describe and relate the morphology of the various parts of the nephron and collecting ducts to their functions
    • Describe the structure of the filtration barrier and relate it to its function
    • Describe and integrate the blood supply to the kidney with its function
    • Describe and examine how the circulation to the cortex is different from that of the medulla of the kidney. Relate this to the function of the kidney
Describe the morphology of the ureter and relate the structure to its function
Describe the morphology of the urinary bladder and relate the structure to its micturition function
Describe and contrast the structure of the male and female urethra and relate its structure to function

- **Kidney**
  - Nephrotosis – “floating kidney”, kidney drops into pelvis due to deficient renal fascia or adipose tissue
    - Can kink the ureter
  - Helps form Vit D
  - Secretes
  - **Erythropoietin** – stimulates RBC production
  - **Rennin** – stimulates ↑ in BP
  - **Medullipin I** – stimulates ↓ in BP

- **Internal Morphology**
  - **Cortex** – darker staining, contains **renal corpuscles** (which are diagnostic)
  - **Medulla** – lighter staining
    - **Renal Pyramid** – has apex; **renal papillae** (apical tip of pyramid),
    - **Renal Columns** – cortical material extending down into medulla between pyramids
  - **Lobes** – pyramid plus overlying cortical material
  - **Lobules** – subdivision of cortex containing
    - **Medullary Rays** – located at center of lobule, contains straight portions of proximal and distal tubules and collecting ducts
    - **Cortical Labyrinth** – tubule material around ray, contains renal corpuscle and proximal and distal convoluted tubules
  - Minor and Major Calycies

- **Uriniferous Tubule**
  - **Nephron** – starts in cortex, then runs in medullary rays, dips into medulla, returns to cortex to apex?
    - Four Parts – each with distinct epithelium
      - **Bowman’s Capsule** – dilation at beginning of nephron
        - **Parietal Layer** - simple squamous epithelium; outer
        - **Bowman’s Space** – contains **glomerular filtrate**
          - **Glomerular Filtrate** – fluid forced out of capillaries by hydrostatic pressure across filtration barrier
        - **Visceral Layer** – modified simple squamous epithelium called **podocytes**
          - **Podocytes** – cover outside of the capillaries forming the glomerulus
        - Part of **Renal Corpuscle** which is the Bowman’s capsule plus the **glomerulus**
          - **Glomerulus** – not part of nephron; tuft of capillaries
            - Capillaries are fenestrated without diaphragms
            - Supplied by afferent arteriole and drained by efferent arteriole
          - **Juxtaglomerular apparatus** – where it is associated with distal tubule
          - **Mesangial Cells** – phagocytic cells; **intraglomerular** vs **extraglomerular**
        - **Vascular Pole** – where blood vessels enter
        - **Urinary Pole** – where proximal tubule drains Bowman’s Space
  - **Proximal Tubule**
    - **Convoluted Portion** – highly coiled in cortex around corpuscle; in cortical labyrinth
    - **Straight Portion** – dives straight down towards medulla in medullary rays
      - simple cuboidal epithelium that is acidophilic – diagnostic
      - lumen is small and almost obliterated by brush border – diagnostic
      - Function – water absorption. brush border of microvilli ↑ SA for this
        - More than 80% of all water is reabsorbed here
        - All glucose, amino acids, proteins and bicarbonate ions absorbed here
        - Active transport of Na & Cl from filtrate to outside tubule causes water to follow
          - Tight junctions line cells of lumen; numerous mitochondria
      - **Loop of Henle** - Goes into medulla and then back up to cortex
○ **Descending Limb** – consists of **thick segment** with *simple cuboidal epithelium* and **thin segment** with *simple squamous epithelium*
  - Highly permeable to water and *lets it in?*
  - Is thick segment same as straight portion of proximal tubule?
○ **Ascending Limb** – with thick and thin segment (same types of epithelium)
  - **thick segment** also known as straight portion of distal tubule
○ Note – thin segments look like wide capillary without RBCs
○ Note – urea and penicillin enter into lumen here

### Distal Tubule

- **Straight Portion** – AKA thick segment of ascending limb of loop of Henle
  - *low simple cuboidal epithelium* – diagnostic
  - Well defined large lumen – diagnostic
  - Cells contain lots of mitochondria and connected by zonula occludens (tight junctions)
- **Macula Densa** – specialized portion of nephron where distal tubule touches the renal corpuscle of the *same nephron*
  - Darker than rest of tubule and with tall cells with tightly packed nuclei - diagnostic
  - Marks dividing point between straight and convoluted portions
- **Convoluted Portion** – shorter than proximal convoluted tubule (fewer cross sections) - diagnostic
  - *low simple cuboidal epithelium with distinct edge on apical surface* – diagnostic
  - Larger, more prominent lumen than PCT but slightly smaller in diameter
  - Paler staining than PCT (not as acidophilic)
- **Function**
  - Highly *impermeable to water*
  - Na pumps remove Na from filtrate
- **Hormones Affecting this Region**
  - **Aldosterone** – ↑ water resorption, ↑ BP, concentrates urine
    - stimulates Na pumps to take Na out of filtrate
    - released by adrenal glands
  - **Atrial Natriuretic Factor (ANF)** – vasodilator that ↓ BP and causes ↑ urine flow (diuresis)
    - ↑ glomerular filtration rate by opening afferent arteriole and constricting efferent arteriole
    - Inhibits secretion of aldosterone, ADH and rennin → ↓ Na resorbed → polyuria
    - Released by atrial myocytes
  - **Parathyroid Hormone** – causes resorption of Ca
    - Secreted by parathyroid gland when there is too little Ca in blood
      - Ends by dumping into collecting tubule
- **Types of Nephrons**
  - **Cortical Nephrons** – ‘short’ nephrons; most common type
    - Renal corpuscle in outer cortex; most of loop in cortex and outer medulla
  - **Juxtamedullary Nephrons** – ‘long’ nephrons
    - Renal corpuscle next to corticomedullary junction; loop dives deep into pyramid
- **Inner Medulla** – contains mostly collecting ducts and *thin segments*
- **Outer Medulla** – contains collecting ducts, thick *and* thin segments
- **Filtration Barrier**
- **Between blood and glomerular filtrate**
- **3 Structures**
  - **Fenestrated Capillary without Diaphragms** – prevents cells from passing
  - **Basal Lamina** – prevents large molecules and ions from passing
    - fusion of the basal lamina of capillary and podocytes
    - *is negatively charged*, thus prevents passage of negatively charged ions
  - **Podocytes** – visceral layer of Bowman’s capsule; highly modified *simple squamous*
    - Numerous processes cover outside of capillary
  - **Pedicels** – smaller processes off of the main processes that *interdigitate* with each other
    - **Filtration Slits** – narrow space between pedicels
- **Slit Diaphragm** – covers filtration slit and filters out negatively charged ions and medium sized molecules/proteins
  - **Function**
    - High resistance in *efferent arteriole* causes fluid to pass through fenestra
    - Fluid passes through basal lamina, things filtered out
    - Fluid passes through diaphragms, things filtered out
    - Glomerular filtrate drained into proximal convoluted tubule
  - **Intraglomerular mesangial cells** – keep barrier clean by phagocytosis
  - Things that cause damage to filtration barrier
    - **Albuminuria** – albumin in urine due to hypertension, vascular injury, mercury poisoning, bacterial toxins
    - **Proteinuria** – protein in urine due to diabetes or glomerulonephritis
    - **Glomerulonephritis (Bright’s Disease)** – inflammation of glomerulus often caused by bacterial toxins; allows proteins and cells through
- **Juxtaglomerular Apparatus** – where distal tubule makes contact with afferent arteriole
  - **Macula Densa** – monitors volume of filtrate and Na concentration, if too low then instructs juxtaglomerular cells to secrete renin
    - Part of distal tubule
  - **Juxtaglomerular Cells** – secrete renin
    - Part of afferent arteriole; modified smooth muscle cells
    - Renin – converts angiotensinogen to angiotensin I which is converted to angiotensin II which is a vasoconstrictor and ↑ BP
      - Also ↑ aldosterone
  - **Extraglomerular mesangial cells** – support cells of the juxtaglomerular apparatus
- **Collecting Ducts**
  - Filtrate Flow = nephron → cortical collecting tubule → medullary collecting ducts → papillary ducts
    - **Cortical Collecting Ducts** – lined by *simple cuboidal epithelium*
      - **Principle Cells** – unknown function, difficult structure
      - **Intercalated Cells** – actively transport H+ against gradient
        - clearly defined lateral membranes – *diagnostic*
    - **Medullary Collecting Ducts** – *cuboidal*; larger in diameter; in outer zone of medulla
      - Also contain principle cells and intercalated cells
    - **Papillary Collecting Ducts** - at apex of pyramid and empty into minor calyx through the *area cribrosa* (a sieve-like region at apex of pyramid)
    - **Interstitial Cells** – found between collecting ducts; arranged like rungs on a ladder
      - **Medullipin I** – secreted by these cells and eventually is a vasodilator that ↓ BP
  - Function
    - Concentrates urine
    - Normally are *impermeable* to water
      - With *antidiuretic hormone* the ducts reabsorb (are permeable to) water
        - This means that it concentrates urine and ↓ urine volume
      - No antidiuretic hormone then ducts don’t reabsorb (because they are impermeable to) water
        - Urine becomes hypotonic and ↑ volume (*diuresis*)
- **Vascular Supply to Kidney**
  - Renal artery → interlobar arteries → arcuate arteries (between medulla and cortex junction) → interlobular arteries (radially off of arcuate arteries) → afferent arterioles → glomerulus → efferent arteriole →
    - Cortex and medulla have different blood supplies from the efferent arteriole
      - **Peritubular Capillary Network** – formed from efferent arterioles coming from *cortical* nephrons
        - Drain into interlobular veins
      - **Vasa Recta** – formed from efferent arterioles coming from *juxtamedullary* nephrons
        - Run down into *medulla* alongside collecting ducts
○ Function – pick up reabsorbed water and ions outside nephron and return it to body
○ Drain into **arcuate veins**
  - → **interlobular veins** (only from peritubular capillary network) → **arcuate veins** → **interlobar veins** → **renal veins**

○ Calyces
  - **Minor Calyx** - *transitional epithelium* to form barrier
  - **Major Calyx** - *transitional epithelium*
  - Smooth muscle layer to move urine
  - **Renal Pelvis** – extension of calyces
    - Place where kidney stones form
      ○ Formed from precipitation of calcium phosphate, carbonate, & uric acid
      ○ Caused by dehydration, pH imbalance, excess calcium, frequent urinary tract infections, urine retention
      ○ When passing through ureters it is very painful
      ○ **Lithotrispy** – ultrasound to break up kidney stones

○ Ureter – completely impenetrable to liquid
  - Three Layers
    - **Mucosa** - *transitional epithelium* with lamina propria on outside
      ○ Star shaped lumen – diagnostic
    - **Muscularis** – 2 layers of smooth muscle but their order is reversed – diagnostic
      ○ Longitudinal layer is on inside, circular layer is on outside
      ○ Lower 1/3rd has 3rd layer of longitudinal muscle
      ○ Provides peristaltic wave
    - **Adventitia** – CT layer

○ Urinary Bladder
  - **Trigone** – flattened triangle of epithelium on posterior wall; has different embryological origin
  - Three Layers
    - **Mucosa** - *transitional epithelium* with lamina propria on outside
      ○ Transitional Epithelium – dome shaped cells on surface
      ○ When epithelium is non-distended – 12-15 cell layers
        - Looks like accordion-like plaques of membrane
      ○ When epithelium is distended – 4-6 cell layers
    - **Muscularis** – contains **Detrusor Muscle** which has three layers of smooth muscle: inner longitudinal, circular and outer longitudinal
    - **Adventitia** – outer serous CT
  - **Urethral Opening**
    - **Internal Sphincter** – extension of circular smooth muscle layer
    - **External Sphincter** – skeletal muscle; part of UG diaphragm
  - **Micturition**
    - Stretch receptors send info to spinal cord
    - **Parasympathetic** impulses cause contraction of detrusor and relaxation of internal sphincter
    - Conscious stimulation causes external sphincter to relax

○ Urethra
  - Crescent-shaped lumen – diagnostic
  - Epithelium gradually changes from *transitional* → *tall columnar* → *stratified squamous non-keratinized epithelium*
  - Has smooth muscle layer surrounding it

○ Clinical
  - **Incontinence** – normal for infants, but in adults can be due to nerve injury, bladder infection/irritation, or trauma to sphincter
  - **Retention** – can happen
  - **Urethritis** – infection of urethra
  - **Cystitis** – infection of bladder (more common in females)
  - **Pyelonephritis** – inflammation of renal pelvis
**Perineum**

- **Objectives**
  - Define the boundaries of the perineum
  - Define the boundaries of the ischioanal fossa
  - Describe the course of the pudendal nerve and internal pudendal vessels through the gluteal region and anal triangle
  - Define the location and contents of the pudendal canal
  - Describe the course and distribution of the inferior rectal nerve and vessels
  - Describe the location and divisions of the external anal sphincter muscle
  - Define the location and importance of the perineal body
  - Define the types of hemorrhoids and the vessels involved in each type
  - Describe the lymphatic drainage of the anal triangle
  - Understand the importance of the fat in the ischiorectal fossa

- **Skeletal Structure**
  - **Pelvis**
    - Hip bones belong to *appendicular skeleton*, sacrum belongs to *axial skeleton*
  - **Obturator Foramen** –
  - **Ischial Spine** – can be palpated during pelvic examination
  - **Ischial Tuberosity** – what you sit on
  - Note – ASIS and pubic symphysis are in same plane when pelvis is in anatomic position
  - **Sex Differences**
    - Male – pelvic bones are usually *heavier* because of muscle mass
      - Iliac wings are *less flared*
    - Female – pelvis is *wider; pubic angle is greater*
      - *Sacral promontory* – ridge of S1 vertebra can be palpated on pelvic exam
  - **Pelvic brim/inlet** – ridge of bone circumferentially at level of S1 and pubic symphysis
    - **False Pelvis** – superior to pelvic brim
    - **True Pelvis** – inferior to pelvic brim
    - Note – urinary bladder & uterus can span between both cavities only if full

- **Hip (Coxal) Bone**
  - Made of *ilium* superiorly, *ischium* dorsally, *pubis* ventrally; all fused together
  - **Acetabulum** – where femur articulates, where all three bones fuse
  - **Greater Sciatic Notch** – made into *greater sciatic foramen* by the *sacrotauberous ligament*
    - Greater sciatic foramen contains inferior gluteal vessels, internal pudendal vessels, inferior gluteal nerve, pudendal nerve, sciatic nerve, posterior femoral cutaneous nerve, Nerve to obturator internus, Nerve to quadratus femoris, superior gluteal vessels, superior gluteal nerve
  - **Lesser Sciatic Notch** – made into *lesser sciatic foramen* by the *sacrospinous ligament* and *sacrotauberous ligament*
    - Lesser sciatic foramen contains the tendon of the Obturator internus, internal pudendal artery, internal pudendal veins, pudendal nerve, nerve to the obturator internus

- **Female Pelvis Measurements**
  - **Conjugate diameter** – about 11 cm; distance from top of pubic symphysis to the sacral promontory
    - This is also the *plane of the pelvic inlet* and is completely open to the pelvis
    - Only dimension that doesn’t change during child birth
    - Approximated by *diagonal conjugate* which goes from *bottom* of pubic symphysis to sacral prom.
      - Measured by sticking fingers in vagina
  - **Plane of Pelvic Outlet** – about 11.5 cm; bottom of pubic symphysis to end of coccyx
    - Pelvic diaphragm closes it
  - **Relaxin** – allows pelvis to move and pubic symphysis expand?
  - **Muscles of Pelvis**
    - **Levator Ani (Pelvic Diaphragm)** – is very concave; bounded by *tendinous arch* laterally
      - Contains *anorectal hiatus*
      - Some fibers take origin on fascia of tendinous arch and the obturat?or int?ernus
      - **UG Diaphragm** – *not part of levator ani*
        - At ventral part of levator ani; is flat and tendinous
        - Connects one ischiopubic ramus to the other
        - Contains *uretal hiatus* and probably the opening for the vagina
-made of 1. perineal membrane, 2. deep pouch (a potential space), 3. superior fascia of UG diaphragm

- **Piriformis** – connects sacrum to femur; goes through *greater sciatic foramen*
- ** Obturator internus** – connects pelvis to femur; goes through *lesser sciatic foramen*

- **Perineum** – inferior to pelvic diaphragm
  - **Lithotomy Position** – looking at perineum with legs spread eagle and bent
  - Note – penis and scrotum are extensions of the perineum
  - Note – gluteus maximus is *not* part of the perineum

- **Triangles**
  - **Urogenital Triangle** – from each *ischial tuberosity* to the pubic symphysis
  - **Anal Triangle** – from each *ischial tuberosity* to the tip of coccyx
    - Is the same in males and females
    - Note – anus is the opening, the *anal canal* is different

- **Ischioanal Fossa** – packed full of fat that helps keep anus closed; lateral to anus

- **Ischiatric Body** – lots of CT, lots of stuff connects here

- **Nerves and Blood Vessels of Perineum**
  - **Pudendal Nerve** and **Internal Pudendal Artery** both pass through the greater *and* lesser sciatic foramen
    - Both give off an *inferior rectal* branch
    - The *inferior rectal nerve* is motor to the anal sphincter and sensory over anal triangle
  - **Pudendal Canal** – made of fascia of *obturator internus* and contains the pudendal artery (lateral pudendal), nerve and vein
    - Situated right up against the obturator internus muscle

- **Anal Canal**
  - Between rectum and anus, starts with the *anal columns*, which are ridges in the canal caused by *internal venous plexi*
  - **Anal valves** – pockets at the end of the anal columns that collect mucous until defecation when it is released
  - **Pectinate Line** – where endoderm and ectoderm contributions meet; is just below the end of the anal columns
    - Above pectinate line → no pain (autonomics); Below pectinate line → pain (due to somatic innervation)
  - **White Line of Hilton** – transition to *keratinized epithelium*

- **Arteries**
  - Inferior rectal artery
  - Middle rectal artery – is variable and does not branch from the pudendal
  - Superior rectal artery – comes from the inferior mesenteric artery

- **Veins**
  - The two plexi communicate freely due to *portal-caval anastomoses*
    - **GET PICTURE?**
  - **Internal venous plexus** – drains into *portal system*
    - Where *internal hemroids* occur
  - **External venous plexus** – drains into *inferior rectal vein → vena cava*
    - Where *external hemroids* occur, are very painful
    - Tears here can be very painful and are called *fissures*
      - If fissure becomes infected then you can get an *anal abscess*, which can be large and go into ischioanal fossa. If the abscess goes away, but scar tissue doesn’t then you can get a fistula into the ischioanal fossa
  - Hemroids – caused by ↓ venous return
    - There aren’t any valves in these veins and thus if the portal system is backed up then it can go to the inferior vena cava due to the portal-caval anastomoses and visa-versa
    - Increased risk during late pregnancy (↓ venous return due to pressure from uterus), liver disease (liver drainage backed up), chronic constipation (↑ pressure)
  - **Internal Hemroids** – due to superior rectal vein & internal venous plexus
    - Are *submucosal*
Can occur with liver disease since those veins drain into portal system
Can protrude into anal canal, if they do, doc puts a rubber band around them till they fall off
Don’t cause pain
- **External Hemroids** – due to inferior rectal vein and external venous plexus
  - Are *subcutaneous* (just deep to perianal skin)
  - Drain into inferior vena cava

- Dermatome to Perianal skin
  - S2-S4, but mainly S3-S4
  - Find picture somewhere

**Perineum – UG Triangle**

- **Objectives**
  - Describe the fascial reflections in the urogenital triangle and the relationships each layer has to the major subdivisions of the UG triangle (superficial and deep pouches)
  - Define the relationships of the fascia of the UG triangle to that on the anterior abdominal wall
  - Be able to trace the possible routes of spread for fluids escaping into the potential space between the superficial and deep fascia of the UG triangle
  - Describe the contents of the superficial and deep pouches of the UG triangle
  - Describe the course of the pudendal nerve and internal pudendal vessels (and branches) through the superficial and deep pouches
  - Describe the role of the autonomic nervous system in the male and female sexual response
  - Describe the arrangement of the erectile bodies for the penis/clitoris
  - Define the blood and nerve supply to the penis/clitoris
  - Define the position and importance of muscles in the superficial and deep pouches
  - Define the perineal body and list the muscles that attach to it
  - Be able to define the following: vulva, vestibule, prepuce, hymen, episiotomy, circumcision

- **Male**
  - Fascia
    - Camper’s and Scarpa’s fascia extend into urogenital triangle, but with modification → called **Dartos Tunic**
      - If liquid gets underneath the dartos tunic then it can go along the entire tract of it
        - If bulb of penis ruptures then urine can get out and inflate the dartos tunic (doesn’t happen in women)
    - **Scarpa’s fascia** becomes the **Colles’ Fascia**, which fuses with the perineal body and surrounds the penis & scrotum
    - **Camper’s fascia** loses its fat and becomes the **Dartos Muscle**
      - Smooth muscle fibers insert into dermis of skin of the scrotum and are *temperature sensitive*
        - if warm then relax, if cold then contract
        - Make the texture of the scrotum
      - No muscle in female, fat instead
  - **Layers**
    - **Superior fascial layer of urogenital diaphragm** (deepest) → **deep peritoneal pouch** (potential space)
      → **perineal membrane** → **superficial perineal pouch/space** (potential space) → Colle’s fascia (superficial)
  - **Muscles of Superficial Perineal Pouch**
    - **Ischiocavernosus muscle** – skeletal muscle, connects to ischial tuberosity and ends before shaft of penis
      - Envelops the **crus of the penis**
      - Action – establish and maintain erection
    - **Bulbospongiosus muscle** – skeletal muscle
      - Envelopes either side of **bulb of penis**
      - Action – compress bulb of penis to get the last bit of urine out; helps establish and maintain erection
  - **Superficial transverse perineal muscle** – goes from ischial tuberosity to perineal body
  - **Erectile Tissue**
    - **Corpus spongiosum** – extension of bulb of penis in shaft
      - Becomes **glans penis**
      - Is softer to make sure that the urethra doesn’t get compacted
    - **Corpus cavernosum** – extension of **crura of penis** in shaft
  - **Urethra** – has three parts,
    - **Prostatic** – goes through prostate
Membranous - where the sphincter urethrae is
  ○ goes through pelvic floor, deep pouch and perineal membrane

Penile – enters bulb of penis and runs length of shaft in center of corpus spongiosum

Bullonitis – inflammation of glans penis
Postitis – inflammation of foreskin

Note – after circumcision 40% of the nerve endings are removed

Clinical Problems in Uncircumcised

Thymosis – foreskin that is too short and full erection can’t happen
Parathymosis – foreskin doesn’t retract over glans leaving it exposed. Produces a collar of extra skin that causes constriction

Priopism – erection that will not dissipate after 4 hours; not related to sexual stimulation
  ○ Causes blood to be stagnant and thus oxygen is used up, can cause tissue to die

Cross Section of Penis

Superficial dorsal vein of penis – can be seen through skin; has irregular course; above Deep Fascia

Deep (Buck’s) Fascia – very thick

Deep dorsal vein of penis – right in dorsal middle
  ○ Gets compressed by erectile tissue preventing blood from leaving and causing erection
  ○ Empties into venous plexus around prostate

Dorsal artery of penis – paired, is just lateral to deep dorsal vein

Dorsal nerve of penis – paired, is lateral to dorsal artery
  ○ Note – goes into deep pouch then goes into superficial pouch before going into penis

Deep artery of penis – in center of corpus cavernosum

Nerves of Perineum

Pudendal has three main branches – inferior rectal, perineal and dorsal nerve of penis
  ○ Perineal nerve – innervates superficial pouch
  ○ Dorsal nerve of penis – goes into deep pouch; just sensory

Arteries of Perineum

Branching differs slightly

Internal Pudendal Artery – inferior rectal, perineal, dorsal artery of penis, deep artery of penis
  ○ After perineal artery is given off, the pudendal artery continues and eventually gives off its terminal branches, the dorsal artery of penis and the deep artery of penis

Deep Pouch of Male (below perineal membrane)

Things that go through perineal membrane – dorsal artery of penis, dorsal nerve of penis, deep artery of penis, duct of bulbourethral gland, urethra, artery of bulb of penis
  ○ Note - deep dorsal vein of penis goes through level of perineal membrane, but not actually through it

Bulbourethral Gland (Cowper’s Gland) – an accessory reproductive gland that produces pre-ejaculate only during sexual arousal
  ○ Duct pierces perineal membrane and empties into urethra at bulb of penis
  ○ Pre-ejaculate – an alkaline secretion to neutralize acidity in urethra and vagina

Deep transverse perineal muscle – similar to superficial transverse perineal muscle, just deeper

Sphincter urethrae muscle – stops urination voluntarily

Note – all skeletal muscle of the UG triangle is innervated by the perineal nerve

Cross Sections

Note the perineal membrane separating the deep and superficial pouches
Note that the penis is in anatomical position when it is erect
Be able to identify all the muscles

Female

External Genitalia of Female

Mons Pubis – thicker subcutaneous fat deposition in postpubesent to premenopausal women
Labium Majorum – filled with fat and meets anteriorly and posteriorly
Posterior junction goes away after first vaginal delivery

- **Vulva** – everything between the labium majus (including mons pubis)
- **Labium Minorum** – contains erectile tissue; meets over the clitoris anteriorly, meets posteriorly
  - Within bounds - Clitoris, external urethral orifice, vaginal orifice, opening of greater vestibular gland
  - Does not contain fat
- **Clitoris** – only function is for sexual arousal
  - Cross Section
    - Only 2 erectile bodies, the corpus cavernosa
    - Still has Buck’s fascia and same vessels and nerves
  - **Crus of Clitoris**, also **Body of Clitoris**
  - **Glands of Clitoris** – tip of clitoris; not connected to a corpus spongiosum as in males because females don’t have one
- **Female circumcision** – removes prepus of clitoris; illegal
- **Episiotomy** – procedure to cut posterior wall of vagina before giving birth to prevent tearing
  - Medial Cut – ↓ bleeding, but ↑ healing time (through linea alba)
  - Medial-Lateral Cut - ↑ bleeding, but ↓ healing time (not through linea alba)
  - Tearing during vaginal delivery could cause anal-vaginal fistula
- **Hymen** – membrane at vaginal orifice
  - **Annular Hymen** – is the prepubescent form, can be imperforate if abnormal
  - **Parous Introitus** – has had baby, nothing left of hymen

### Muscles

- **Superficial**
  - **Ischiocavernosus** – same as male; still coats erectile crus which becomes corpus cavernosa in clitoris shaft
    - Action – establish and maintain clitoral erection
  - **Superficial transverse perineal** – same
  - **Bulbospongiosus** – truly paired in female, runs on either side of vaginal orifice
    - Action - Helps ↓ size of vaginal orifice during sexual arousal
    - Action - Helps force secretion of gland out
    - Covers paired erectile bodies, the **bulbs of the vestibule**
  - **Bulbs of the Vestibule** – meet anteriorly and stop, they don’t extend out to clitoris

- **Deep**
  - **Sphincter Urethrae** – some fibers surround the urethra; some fibers surround the vagina
    - **Compressor Vaginae** – fibers of sphincter urethrae that surround vagina and can be voluntarily contracted
  - **Deep transverse perineal** – same as in male

### Greater Vestibular Gland

- **Equivalent to Bulbourethral/Cowper’s gland** in male
- Opens into vestibule
- **Paraurethral (Skene’s) Duct** – housed between the urethra and vagina
- Homologous to prostate gland; associated with female ejaculation; secretions similar to prostatic ones
- **G-Spot** – anterior vaginal wall has dense network of nerve endings and can cause vaginal orgasm
- **Nerves, Arteries and Veins** – identical to male
- **Cross Sections**
  - Identify – perineal membrane, bulb of vestibule, bulbospongiosus, round ligament of uterus, crus of clitoris, perineal body

### Pelvis (walls and floor)

- **Objectives**
  - Define the relationship of the tendinous arch to the obturator internus and levator ani muscles
  - Explain the difference in orientation of the pelvic and UG diaphragms
  - Define the parts of the pelvic diaphragm/UG diaphragm
  - Describe the relationship of the parts of levator ani to pelvic organs
  - Describe the nerve supply to levator ani
  - Describe the branching pattern of the internal iliac artery
Describe the distribution of the branches of the sacral plexus
Define the subplexi that are derived from the inferior hypogastric plexus

True Pelvis – Female

- True pelvis – from top of hip bone to pelvic brim
- Identify – ovary, uterus, uterine tube, median umbilical fold containing urachus
- Body of uterus rests on the urinary bladder when it is empty

Peritoneum

- **Rectouterine Pouch** – lowest point of the peritoneal cavity, thus *fluid can accumulate* here
  - Note – there is a very small part of the vaginal wall superior to the uterus (right around the retrouterine pouch) that separates the vaginal cavity (outside) from the peritoneal cavity
  - Fluid can also be drained through this small separation
- **Vesicouterine Pouch** – in between urinary bladder and uterus; nothing should be in it
  - Parietal peritoneum is more loosely connected around the urinary bladder and disconnects from wall when it is full

Rectum

- Upper 1/3rd – peritoneum on anterior & lateral surfaces
- Middle 1/3rd – peritoneum on anterior
- Lower 1/3rd – no peritoneum

Urinary Bladder

- **Detrussor Muscle** – muscle of the urinary bladder; *parasympathetics* cause it to contract
  - Epithelium has ruggae
- **Ureteric orifice** – two of them; where ureters enter urinary bladder
  - Come in *obliquely* to prevent backflow
- **Trigone** – mucosa is very adherent to muscle here, thus no ruggae
  - From the two ureteric orifices to urethral orifice
- Parasympathetics contract detrusor and relax internal urinary sphincter (in males)
  - **Internal urethral sphincter** - Females do not have one, in males it closes off bladder, especially during sexual stimulation to prevent semen and urine from mixing

Uterus and other parts

- **Fundus** – everything above the uterine tubes
- **Body** – basically everything else (except cervix)
- **Cervix** – divided into *supravaginal* and *vaginal* portions
  - Is mainly fibrous tissue and is *not* sloughed off during menses
- **Broad Ligament** – double layer of peritoneum containing BVs and stuff; separated into:
  - **Mesometrium** – from uterus out to tubes, kinda like a butterfly; also covers supravaginal cervix
    - Divided into *anterior* and *posterior* portion (just the two sides of the peritoneum)
  - **Mesovarium** – from round ligament to around ovary
    - The portion around the ovary has a different epithelium, it is *more cuboidal*
  - **Mesosalpinx** – from round ligament to around uterine tube
    - Note – mesovarium is continuous with the mesosalpinx
  - Note – each portion of the broad ligament is at a right angle to adjacent part
- Opening of Peritoneum
  - In females there is an opening into the peritoneal cavity between the fimbriae and ovary
  - When egg is released, it enters the peritoneal sac
- **Endometriosis** – when lining of uterus establishes itself outside the uterine cavity
  - Can go into uterine tube and out into greater sac
  - Difficult to treat because during each cycle it gets bigger

Uterine Tubes

- **Uterine Part** – right at uterus
- **Isthmus** – a narrower section just medial
- **Ampulla** – wider portion around the bend; this is where *fertilization* should occur
- **Infundibulum** – last bit
  - **Fimbriae** – contain *smooth muscle* and drape over ovary at ovulation
  - Usually one stays attached to the ovary at all times
• **Vesicular Appendage** – homologue of epididymus in male; connected to the **Epoophoron**
• **Internal Os** – opening marks narrowing of lumen at junction of the body and cervix
• **External Os** – opening at end of cervix into vagina that marks *transition of epithelium*
  - This area is vulnerable to cancer, thus pelvic exam checks it
  - Will be *circular* and open if the woman has *not* had a vaginal delivery
  - Will be *oval* and closed if the woman has had a vaginal delivery
• Note – ovary gets dimpled/pitted with each ovulation
• **Connections of Uterus**
  - At the supravaginal part of the cervix the **endopelvic fascia** connects the uterus to the pelvis
    - **Transverse cervical ligament (Cardinal Ligament)** – thickening of endopelvic fascia
      - contains uterine artery
    - Uterus also supported by levator ani
• **Uterus-Vagina Angle**
  - Cervix pierces the *anterior* wall of the vagina
  - **Anteversion** – angle of vagina to cervix at the external os
    - Supposed to be around 90º, **retroversion** – if angle is *increased*
      - If angle is 180º then uterus will encroach into vagina
  - **Anteflexion** – angle within uterus between body and cervix, at internal os
    - Supposed to be around 170º, **retroflexion** if increased
    - Angle doesn’t really affect fertilization, does affect implantation
  - **Uterine Prolapse** – acquired condition usually due to multiple pregnancies
    - 1st Degree – uterus slightly descended into vagina
    - 2nd Degree – cervix at introitus (right at vaginal opening)
    - Complete prolapse – uterus flying out of the vagina
    - **Kegel exercises** – strengthen pelvic floor can help prevent this
• **Ectopic Pregnancy** – most common place is in ampulla (due to scarring??)
  - If in peritoneal cavity then it could be due to a failure of the infundibulum or *backwards movement* of the fertilized egg
• **Functions of the Vagina**
  - Lower birth canal
  - Female organ of copulation
  - Acts as a duct for flow of sloughed endometrium

### Development of the Urinary System

- **Objectives**
  - List the germ layers from which the urinary system develops
  - List/describe the structures that are contributed by the pronephros, mesonephros and metanephros and their respective duct systems
  - Describe the region of the embryonic body in which the mesonephros and metanephros develop
  - Define/describe/explain the tissues or structures that combine to form the metanephric kidney
  - Be able to list the parts of the uriniferous tubule that are derived from each tissue or structure
  - Be able to relate the role of the following substances (blah) in the development of the kidney or in congenital defects
  - Describe the development of the vascular supply to the definitive kidney. Explain the occurrence of ‘accessory renal arteries’
  - Define/describe/explain fetal lobulation of kidney, renal agenesis, renal duplication, Potter’s syndrome
  - Explain the formation of a ‘horseshoe’ kidney and its positional relationships with surrounding organs and vessels
  - Define/describe/explain polycystic kidney and its morphology and pathogenesis
  - Explain the formation of the ureters, renal pelvises, and calices. Explain the bifid ureter and common clinical findings associated with it
  - List and describe the developmental history of the 3 portions of the UG sinus. What definitive structures are derived from each?
  - Explain how extrophy of the bladder occurs
  - Explain the development of the urethra
  - Be able to relate the timing and chronology of the development of the urinary system
- **Early Development of Urogenital System Overview**
  - UG system develops from *intermediate mesoderm*
  - **Nephrogenic Cord** – *intermediate mesoderm* that breaks away from somites and forms the *urinary system*
  - **Urogenital Ridge** - *intermediate mesoderm* around nephrogenic cord; *medial* portion forms *genital system*
- **Pronephros (Cervical Nephrotomes) Development**
  - Present in the *neck*
- Appear early in 4th week but rapidly degenerate
- Rudimentary and nonfunctional, equivalent to kidneys in fish

- **Mesonephros (Thoracolumbar Mesonephric System) Development**
  - In same ‘plane?’ as pronephros and are made of about 40 units and a mesonephric duct (on each side)
  - Appear in late 4th week
  - Act as interim kidneys
  - Form from intermediate mesoderm

- **Mesonephric tubules** enlarge to connect to the mesonephric duct
  - LIM-2 – induces aggregation of intermediate mesenchyme cells into mesonephric duct
  - Pax-2 – induces conversion of intermediate mesoderm into mesonephric tubules
  - WT-1 – also necessary for mesonephric tubule formation
  - Mesonephric tubules differentiate into rudimentary nephrons, the tubule even makes a Bowman’s capsule
  - **Mesonephric Excretory Unit** – made of renal corpuscle and mesonephric tubule
    - There are about 40 of them and at the end of the 5th week the cranial ones degenerate
    - All gone by week 10

- **Mesonephric Duct** – first appears in mid 4th week
  - Drain the mesonephric excretory units into cloaca
  - Where they join with the cloaca eventually will become the urinary bladder
  - Start out as rods of cells but after meeting the cloaca the start to cannulate caudally to cranially
  - They then fuse to the mesonephric tubules
  - Functional by 6 weeks, degenerate by 10 weeks
    - Except in males, it forms part of the tubules of the testes

- **Metanephros Development**
  - Permanent kidneys start development during 5th week and start functioning during 9th week

- **Sources**
  - From **Metanephric Diverticulum/ureteric bud** the ureter, renal pelvis, calyces and collecting ducts are formed
    - Forms as an outgrowth of mesonephric duct
  - From **Metanephric mass of intermediate mesoderm/metanephric blastema** the nephrons are formed
  - **Reciprocal Induction** causes both of these sources to induce each other to form kidney
    - Ureretic bud induces formation of the metanephric blastema from intermediate mesoderm
    - WT-1 from metanephric blastema → ↑ GDNF which induces growth and branching of ureteric bud
      - C-Ret – on ureteric bud and is receptor of GDNF; necessary for bifurcation (beginning at day 32)
      - Blastema mesenchyme aggregates
      - Transcription factors induce ureteric bud formation and transform cells into epithelial cells
  - Each ureteric bud becomes capped with metanephric blastema

- **Branching**
  - **Get Figure 12.6**
    - First bifurcation forms the renal pelvis
    - 6th week – 4 bifurcations form 16 branches that fuse together to form major calyces
    - 7th week – 4 more bifurcations and things fuse together to form minor calyces causing lobulated look
    - Through 32nd week – more bifurcations form the collecting ducts

- **Nephron Formation**
  - At the end of each collecting duct there is a cellular mass of metanephric blastema (mesoderm) which differentiates into metanephric vesicles which elongate into metanephric tubules to form the nephron
  - Lateral end of tubule thins and forms Bowman’s Capsule
  - Glomerulus forms from outgrowth of aorta
  - Tubule differentiates into each part of the nephron and then called definitive nephron
  - **Metanephric Excretory Unit** – nephron and renal corpuscle

- Excretions go into amniotic fluid

- **Positional Changes**
  - Initially located close together in pelvis and hilum is ventral
  - Kidneys ascend relative to other organs and rotate medially so that hilum is medial
• In the right position by 9th week

# Factors and Stuff

## Transcription Factors

- **WT-1** – expressed by blastema, regulates GDNF synthesis to induce ureteric bud formation
- **Pax-2, BF-2 & Wnt-2** – all needed to induce ureteric bud formation and transform mesenchymal cells into epithelial cells
- **Mox-1, N-myc & Hoxc-9** – required for nephron differentiation & glomerulus formation
- **c-ret** – a receptor for GDNF; responsible for branching and growth of ureteric bud
  - lack of receptor causes bifid ureters and renal agenesis
- **PDK-1** – bad expression causes epithelial hyperplasia and **polycystic kidney disease** (autosomal dominant)

## Growth Factors

- **NGF** – expression in the blastema is necessary for formation of nephrogenic tubules
- **GDNF** – needed for branching of ureteric bud
- **IGF** – over-expression causes Wilm’s Tumors (lots of weird tissue in tumors)

## Other

- **Cadherins** – make tight junctions in epithelial tubes
- **Laminin & Integrin** – necessary for diapedesis to occur as cells migrate

## Development of Vascular Supply

- Blood supply of kidney changes as it ascends, but in general it always gets its blood from nearest vessels
  - 1st – from common iliac arteries
  - 2nd – from segmental branches off aorta, until it finally makes renal artery
- The caudal arteries normally degenerate

## Abnormalities

- **Accessory Renal Arteries**
  - Can have multiple renal arteries (30%)
  - **Polar Renal Artery** – a second artery that causes obstruction of ureter
    - Can cause **hydronephrosis** (dilation of pelvis and calyces due to backup of urine; can kill tissue)

## Congenital Abnormalities of the Kidney

- **GET FIGURE 12-13**

## Renal Agenesis

- **Unilateral** – probably due to lack of uretic bud; usually no symptoms
- **Bilateral** – multifactorial factors; failure of uretic bud or metanephric blastema to form
  - No excretion of urine into amniotic sac causes ↓ amniotic fluid
  - Associated with **Potter’s Syndrome** (not enough amniotic fluid causes face to be smushed)

## Pelvic Kidney

- Failure of kidney to ascend

## Divided Kidney with Bifid Ureter

- Due to incomplete division of ureteric bud
  - Will have two renal pelvices going to one kidney

## Discoid Kidney (Pancake)

- Both kidneys fail to ascend and fuse together in the pelvis

## Horseshoe Kidney

- **inferior** poles fuse together to form one U shaped kidney
  - Kidney ascension stopped by inferior mesenteric artery

## Supranumerary Kidney

- Caused by two ureteric buds on one side

## Supranumerary Kidney with Bifid Ureters

- Complete division of ureteric bud

## Malrotation

- Can happen different ways: no rotation or lateral rotation
  - Usually associated with ectopic kidneys

## Unilateral Fused Kidney

- One ureter crosses midline; kidneys fuse together in pelvis prior to ascending

## Multicycstic Dysplastic Kidney

- Numerous clear fluid cysts throughout the kidney, with epithelial hyperplasia
  - Cilium are non-functional and so epithelial cells divide profusely and form cysts
  - One of the most common genetic diseases
  - Presents as recurrent urinary infections
  - Caused by **PDK** mutation (16th chromosome)
    - Autosomal Dominant form - **PDK-1** affected, presents around 40-50 years
Autosomal Recessive form - PDK-2 affected, presents in childhood

Development of Urinary Bladder
- Starts around 5th week with the formation of the urogenital sinus from the cloaca (by the urorectal septum dividing the cloaca)
- Epithelium is derived from endoderm
- Smooth muscle and CT derived from mesenchyme
- Urogenital membrane – covers inferior opening
- Urogenital sinus is divided into 3 parts: vesical part (continuous with allantois superiorly), pelvic part (middle portion), phallic part (caudal part)
  - All from endoderm

Males
- Vesical part forms most of bladder; Pelvic portion becomes membranous and prostatic urethra; Phalic part forms proximal penile urethra
- Distal penile urethral formed by glandular uretral plate which is from ectoderm

Females
- Vesical part forms most of bladder; Pelvic portion becomes complete urethra; Phalic part forms vestibule of vagina
- Allantois degenerates into urachus which becomes median umbilical ligament
  - Congenital Urachal Defects – due to urachal lumen still present
    - Urachal Cysts –
    - Urachal Sinus – clear fluid from lumen wall drains out of umbilicus
    - Urachal Fistula – urachus open and urine drains out of umbilicus

Formation of Trigone and connection of Ureters
- Exstrophy – opening of any hollow organ
  - Ureters connect to urinary bladder and mesonephric ducts attach to urinary bladder wall
    - GET PICTURE FROM HANDOUT
  - Mesonephric ducts continue on inferiorly to the urethra and do not connect with urinary bladder
  - Forms trigone
  - Defects can misdirect ureters directly into urethra in males or into vestibule in females
- Abnormal Exstrophy – if anterior wall of bladder fails to close then eversion of urinary bladder onto outside surface of anterior abdominal wall