The Anterior Abdominal Wall, Inguinal Region and Hernias

Anatomy of the Abdomen & Pelvis 1 – Mr Barry Paraskeva (b.paraskeva@imperial.ac.uk)

1. **Demonstrate** in the living subject, and on a skeleton where appropriate, the following landmarks of the anterior abdominal wall: costal margin, xiphoid process, umbilicus, transpyloric plane, subcostal plane, anterior superior iliac spine, iliac tubercle, pubic tubercle, mid-inguinal point.

2. **Demonstrate** the use of these landmarks to divide the anterior abdominal wall into descriptive regions.

3. **Draw** sketches to outline the arrangement of the external oblique, internal oblique, transversus abdominis and rectus abdominis muscle layers, the rectus sheath, the transversalis fascia and the parietal peritoneum.

4. **Describe** the rectus sheath and its contents.

5. **Define** the linea alba and the linea semilunaris.

6. **Explain** the importance of the distinction between the fatty and membranous layers of the superficial fascia.

7. **Define** the sources and distribution of the motor and sensory nerves to the abdominal wall and diaphragm.

8. **Explain** the roles of the abdominal wall muscles in breathing and control of intra-abdominal pressure.

9. **Demonstrate** in the living subject and in dissected material the nature and course of the inguinal canal making correct use of the following terms: superficial and deep inguinal rings, mid-inguinal point, pubic tubercle, testis, testicular vessels, scrotum, spermatic cord, ductus deferens, round ligament of the uterus.

10. **Distinguish** between direct and indirect inguinal hernias.

11. **Distinguish** between acquired and congenital inguinal hernia.

12. **Summarise** the anatomical basis for femoral hernia.

13. **Outline** the lymphatic drainage of the anterior abdominal wall.

The abdominal wall

- The abdomen is a roughly cylindrical chamber extending from the inferior margin of the thorax to the superior margin of the pelvis and lower limb.

- Posteriorly, the cavity is bounded by the lumbar vertebrae and the muscles lying lateral to them:
  - **Psoas + Iliacus** – the main hip flexors of the thigh
  - **Quadratus lumborum** – rectangular muscle extending from the inferior border of the 12th rib to the posterior iliac crest on each side

- Other important posterior muscles to note are the serratus anterior and the lattisimus dorsi (although these are more relevant to thorax anatomy)
  - **Serratus anterior** – on the lateral wall of the thorax, with anterior origin and insertion along the medial border of the scapula; acts to pull the scapula forward and around the thorax
  - **Lattisimus dorsi** – large triangular muscle of the back, with origin in the thoracolumbar fascia, and insertion into the armpit

- The anterolateral abdominal wall is composed of skin, fascia (fatty superficial layer= **camper’s fascia**, deep fibrous layer= **scarpa’s fascia**) and four pairs of muscles; the external oblique, internal oblique, transversus abdominis and rectus abdominis.

- Below the skin is fat – which is normally very yellow and thick, but in especially obese patients it forms two layers; a thick yellow superficial layer and a deep oily layer.

- Deep to the muscles is a fibrous layer called the **transversalis fascia**, which is superficial to the **parietal peritoneum**. Deep to the parietal peritoneum is the **visceral peritoneum**, which lines the organs so they can slide over each other easily.
• The anterolateral abdominal muscles protect the abdominal viscera, move the vertebral column, and assist in **forced expiration** (e.g. coughing, sneezing), **defecation**, vomiting (also known as **emesis**), **urination** and childbirth (also known as **parturition**)

**Abdominopelvic Regions + Quadrants**

- The quadrants are divided by the **umbilicus line** (horizontal) and the medial line (vertical)
  - The quadrants are used to locate the site of an abdominopelvic abnormality in clinical studies
  - **Right upper** – liver, gall bladder, duodenum, head of pancreas, hepatic flexure of colon (also known as right colic flexure)
  - **Left upper** – stomach, spleen, left lobe of liver, body of pancreas, left kidney + adrenal gland, splenic flexure of colon (left colic flexure), parts of transverse + descending colon
  - **Right lower** – caecum, appendix, ascending colon, small intestine
  - **Left lower** – descending colon, sigmoid colon + small intestine
- The areas are divided horizontally by the superior TPP (**transpyloric plane** – also known as subcostal line; located halfway between the jugular notch and the upper border of the pubic symphysis, at L1/9th CC tip) and the inferior TTP (**transtubercular plane**; passes through the tubercles of the iliac crests, at L5)
  - The nine areas are used to describe the locations of organs more easily
  - **Right hypochondriac** – liver, gall bladder, small intestine, ascending colon + descending colon (right colic flexure), right kidney
  - **Epigastric** – stomach, liver, pancreas, duodenum, transverse colon, spleen
  - **Left hypochondriac** – stomach, liver (tip), pancreas (tail), small intestine, transverse + descending colon (left colic flexure), left kidney, spleen
  - **Right lumbar** – liver, small intestine, ascending colon, right kidney
  - **Umbilical** – stomach, pancreas, small intestine, transverse colon
  - **Left lumbar** – small intestine, descending colon, left kidney
  - **Right inguinal/iliac** – small intestine, caecum appendix + ascending colon (1st, 2nd + 3rd parts of colon)
  - **Hypogastric/suprapubic** – small intestine, sigmoid colon + rectum, bladder
  - **Left inguinal/iliac** – small intestine, descending + sigmoid colon
- **Caput medusa** - Other surface markings seen are the veins originating from the umbilicus to the axilla and groin – this may be observed in patients with a blocked IVC, disease, anorexia (or very skinny people) and liver disease
The sheet-like muscles

- The three sheet-like muscles, which does not include the anterior rectus abdominus; control pressure and volume in the abdomino-pelvic/peritoneal cavity.
- All three muscles originate posterolaterally, and turn into aponeuroses (sheet-like tendons) in the anterior abdominal wall (at approximately the mid-clavicular line), inserting into the fibrous band called the linea alba that extends in the mid-line from the xiphoid process of the sternum into the pubic symphysis (the cartilaginous point where the left and right pubic bones meet at the front of the pelvic girdle)
- Contraction of these muscles, with relaxation of the diaphragm, pushes the dome of the diaphragm further up into the thoracic cavity, compressing the lungs. (thus are most important expiratory muscles in deep/rapid/forced expiration)
- Contraction of these muscles, with simultaneous contraction of the diaphragm, increases the intra-abdominal pressure (providing a mechanisms for expulsion of the contents of the various abdomino-pelvic organs)

Superficial → deep, the muscles are:
- The external oblique which runs infero-medially, originating on the external posterior surface of ribs 5-12 (the lower 8 ribs, where its originating fleshy digitations interlock with the digitations of the serratus anterior and lattisimus dorsi
- The internal oblique which runs supero-medially (at right angles to the external oblique). It originates in the thoracolumbar fascia of the lower back, the anterior 2/3 of the iliac crest and the lateral 2/3 of the inguinal ligament. Its insertions are on the inferior borders of the 10th-12th ribs and the linea alba
- The transversus abdominus runs medially (horizontally) from the inner aspect of the costal margin (just medial to the line formed by ribs 7-12), the lumbar fascia, the anterior 2/3 of the iliac crest and the lateral third of the inguinal ligament. Its insertion blends into the linea alba, with the lowest fibres inserted on the pubic crest and the pectineal line (pelvic floor) along with the inferior part of the internal oblique muscle
  - This specific insertion on the pubic crest and pectineal line (formed by the blending of the transversus abdominus and internal oblique) in known as the conjoint tendon

The rectus abdominus and the rectus sheath

- The rectus abdominus is a long paired vertically running muscle that extends the entire length of the abdominal wall (narrowing as they descend), originating at the pubic crest + pubic symphysis and inserting on the cartilages of ribs 5-7 and the xiphoid process of the sternum
- The anterior surface if the muscle is interrupted by 3 transverse fibrous bands of tissue called transverse tendinous intersections (the linea alba also bisects the muscle vertically - this divides the muscle into 6 segments – think six pack)
- Has a special role as powerful flexors of the lumbar spine
- The aponeuroses of the 3 sheet-like muscles form the rectus sheaths, which enclose the rectus abdominus and meet at the middle to form the linea alba (a tough fibrous band that extends from the xiphoid process to the pubic symphysis)
  - The arrangement of the rectus sheath is different superiorly and inferiorly to the arcuate line (line ½ way between the umbilicus + pubic symphysis)
Superior to the arcuate line, the internal oblique aponeurosis splits to envelope the rectus abdominus. Inferior to the arcuate line, all 3 aponeuroses lie anterior to the rectus abdominus, therefore the muscle lies purely on the transversalis fascia.

- At the lateral margin of the rectus abdominus, the aponeuroses also fuse to form the **linea semilunaris**.
- The inferior free border of the external oblique runs in a straight line from the **anterior superior iliac spine**; ASIS (bony bit of hip that sticks out on skinny people) to the **pubic tubercle** (a forward-projecting tubercle on the upper border of the pubic bone) – this is thickened and fibrous and is termed the **inguinal ligament**.
  - The femoral nerve, artery and vein all enter the thigh by passing deep to the inguinal ligament.
  - The **inguinal canal** lies just superior to the medial end of the inguinal ligament – there is a triangular slit in the aponeurosis referred to as the **superficial inguinal ring** (the outer opening of the inguinal canal).
  - The inguinal canal contains the **spermatic cord** and **ilioinguinal nerve** in males, and the **round ligament of the uterus** and **ilioinguinal nerve** in females.

**Vessels and nerves**

- The rectus sheath contains arteries and veins lying posterior to the muscle. These are the epigastric vessels.
- There is an anastomosis between the **superior epigastric** arteries coming from the internal thoracic (branch of the subclavian) and the **inferior epigastric** arteries that ascend from the external iliac (by-pass of the abdominal aorta).
- The nerve supply to all the antero-lateral muscles comes from T6-L1.
- The intercostal nerves T6-T12 enter the abdominal wall at the anterior ends of the intercostal spaces, passing deep to the costal cartilages where these close the spaces.
- The main trunks of the nerves lie between the internal oblique and transversus layers.
The inguinal region

- The inguinal ligament is formed by the inferior folding-under of the external oblique, and runs straight from the anterior superior iliac spine to the pubic tubercle
- The deep inguinal ring (internal) is an opening in the back wall of the inguinal canal, which lies just superior and medial to the inguinal ligament. It marks the mid-point of the length of the inguinal ligament, and provides an entry through which the canal’s contents enter.
- The superficial inguinal ring is a V-shaped slit in the external oblique aponeurosis that allows the content of the canal to exit e.g. into the scrotum
- E.g. the testicles develop from the back of the abdomen at the level of the kidneys, and then descend through the deep ring into the inguinal canal and into the scrotum
- The inguinal canal contains the ilioinguinal nerve in both males + females
- In males it also contains the spermatic cord, which is covered in cremaster muscle (cremester reflex raises the testicles when cold) and 2 associated nerves
- The borders of the inguinal canal:
  - Floor – inguinal ligament
  - Anterior – external oblique aponeurosis + internal oblique
  - Roof – internal oblique arching over
  - Posterior – transversalis fascia and the conjoint tendon medially
- The inguinal region is an area of weakness in the abdominal wall, thus is often the site of an inguinal hernia.

Hernia

- **Definition:** the protrusion of a viscus (organ) through the structure that normally contains it, which creates a lump that may be seen or felt through the skin’s surface.
- There are different types of hernia: inguinal, femoral, incisional and umbilical.
- Inguinal hernia: a rupture or separation of a portion of the inguinal area of the anterior abdominal wall resulting in the protrusion of part of the small intestine.
- Inguinal hernias may be direct or indirect
- **Indirect hernias** result from the protrusion of the small intestine through the deep inguinal ring
- **Direct hernias** result from the protrusion of the small intestine through a hole that develops through the groin, in area of weakness known as **Hesselbach’s triangle**
  - Hesselbach’s triangle is formed by the lateral margin of the **rectus abdominus**, the **inferior epigastric** vessels and the **inguinal ligament**
  - This is used clinically to determine whether an inguinal hernia is direct or indirect; if the hernia is lateral to the epigastric vessels=indirect, medial to the epigastric vessels=direct
- **Components of a hernia:**
  - Hernia sac
  - Contents e.g. bowel
  - Coverings
  - Defect in containing compartment
- **Clinical features:**
  - Lump in groin, may come and go
  - Painful
  - Vomiting
  - Constipation
  - Abdominal pain
  - Abdominal distention
  - Requires emergency surgery to prevent bowel infarction
Aetiology:
- **Congenital** – the descent of the testes requires the processus vaginalis, which is a fingerlike projection of parietal peritoneum. This foetal structure normally closes, however a persistently patent processes vaginalis is a ready-made hernial sac
- **Acquired** – any cause of increased intra-abdominal pressure can exploit a weakness in the abdominal wall, which may occur with age. Fatty infiltration associated with obesity or the increase in circulating elastases that have been postulated is also a cause of weak abdominal musculature.

Treatment:
- **Conservative** – reduce risk factors e.g. improving treatment for asthma/COPD + treating constipation, but surgery is usual procedure
- **Surgery** – general principles include defining the anatomy, define inspect + excise the hernia sac, mobilisation of the spermatic cord, opening of the sac to check for contents, reconstitution of inguinal canal and suture repair (should be tension free)
  - Common method – open mesh
1. **Name** the regions of the gut from oesophagus to rectum and summarise their main functions
2. **Demonstrate** these gut regions in dissections and **point out** their identifying characteristics
3. **Define** parietal and visceral peritoneum and **explain** the functions of the peritoneum and peritoneal cavity
4. **Describe** the peritoneal reflections in relation to major parts of the gut and associated organs from the oesophagus to the rectum, with special attention to the attachments and contents of the greater and lesser omenta and the mesentery proper
5. **Draw** diagrams to explain different relationships to the peritoneum (mesenteries and retroperitoneal positions) and **list** the structures contained within a typical mesentery
6. **Describe** the boundaries of the lesser sac and of the epiploic foramen (of Winslow)
7. **Demarcate** the extent of the peritoneal cavity in a living subject and **indicate** the likely positions of the major regions of the gut
8. **Describe** the sources and distribution of arteries to important structures or organs derived from the foregut, midgut and hindgut.
9. **Describe** the bones, joints and movements of the lumbar spine, sacrum and pelvis

**The Gut + Peritoneal Cavity**

**The peritoneum**
- The peritoneum is a single continuous squamous epithelium (mesothelium) with an underlying supportive layer of areolar connective tissue which lies deep to the abdominal cavity
- The peritoneum is divided into the parietal peritoneum, which lines the wall of the abdominopelvic cavity, and the visceral peritoneum, which cover some of the organs in the cavity
- The slim space containing the serous fluid that is between the parietal + visceral portions of the peritoneum is called the peritoneal cavity. The peritoneal cavity is one of the spaced derived from the intraembryonic coelomic cavity of the embryo
  - Clinical correlation: ascites – the accumulation of several litres of fluid in the peritoneal cavity, which causes abdominal distention

**The Abdominal Gut + Mesentery**
- Early in the development of the abdominal gut tube, it becomes suspended from the dorsal (posterior) wall of the peritoneal cavity within the free edge of a peritoneal fold called the mesentery.
  - The abdominal gut is divided into 3 regions:
    - The foregut – intraabdominal oesophagus, stomach to mid duodenum, liver, pancreas + spleen
    - The midgut – mid-duodenum to left colic flexure (splenic flexure)
    - The hindgut – left colic flexure to rectum
  - The presence of a dorsal mesentery is common to all 3 regions. However the foregut also has a ventral mesentery, and so is suspended between the dorsal + ventral abdominal walls
- Abdominopelvic organs can therefore be described as intraperitoneal or retroperitoneal. Retroperitoneal organs lie on the posterior abdominal wall and are covered by peritoneum only on their anterior surfaces and do not become suspended in mesenteries and include: adrenal glands, aorta/ICV, 2nd part of duodenum, pancreas (not tail), ureters, ascending/descending colon, kidneys, oesophagus, rectum
  - The duodenum, pancreas + ascending/descending colon originally had a mesentery, then became secondarily retroperitoneal when the mesentery fused with the posterior parietal peritoneum
• The peritoneum contains large folds that weave between the organs, which bind the organs to one another + to the walls of the abdominal cavity. These also contain blood vessels, lymphatic vessels + nerves that supply the abdominal organs.
• There are 5 major peritoneal folds:
  o The greater omentum
  o Mesentery
  o The lesser omentum
  o Falciform ligament
  o Mesocolon

The falciform ligament, lesser omentum + omental bursa
• Within the ventral foregut, mesentery containing the liver splits into the falciform ligament + the lesser omentum
• The falciform ligament attaches the liver to the anterior abdominal wall + diaphragm
• The abdomen is wider than it is deep, so rapid growth of the liver results in the liver moving to the right + the spleen and dorsal mesentery moving to the left
  o The effect of this is that the bit of the peritoneal cavity (that was originally to the right of the dorsal + ventral foregut mesenteries) becomes trapped posterior to the liver and the stomach
  o This semi-isolated pocket of the peritoneal cavity is called the omental bursa (lesser sac)
  o This is clinically important as it contains important structures that cannot be seen from the main part of the peritoneal cavity (including the pancreas, much of the left kidney, left adrenal gland, posterior surface of the liver + oesophagus)
  o The omental bursa can be found by passing a finger below the free lower border of the lesser omentum through the narrow omental or epiploic foramen (entry to the lesser sac from the greater sac)
  o The portal vein, hepatic artery + bile duct run between the posterior abdominal wall and the liver within the lesser omentum near its free edge

The greater omentum
• A double sheet of peritoneum grows out from the dorsal foregut mesentery below the spleen and hangs down like an apron in front of the coils of the small intestine from the lower border of the stomach
• This fold is called the greater omentum
• The double sheet folds back on itself, forming 4 layers which fuse to form the greater sac
• The greater sac can be subdivided into colic compartments:
  o Supracolic- superior to the transverse colon
  o Infracolic – below the transverse colon

Anatomy of the GI tract

• The GI tract is a long tube, with different parts modified to form different functions
• Surrounded by mesentery with nervous + arterial supply
• The wall of the GI tract consists of 4 main layers (out-in):
  o Serosa – areolar connective tissue + epithelium
  o Muscularis – longitudinal + circular muscle required for peristalsis
  o Submucosa
  o Mucosa – epithelial, lamina propria + muscularis mucosae (inner layer lining lumen)
**Abdominal oesophagus**
- The distal oesophagus pierces the diaphragm at T10
- Goes through the right crus (muscular part of the diaphragm) which is important because it contributes to the lower oesophageal sphincter which prevents gastro-oesophageal reflux
- NB: aorta pierces diaphragm at T12

**Stomach**
- There are 4 main parts to the stomach:
  - The cardia – surrounding the opening by the cardiac notch
  - The fundus
  - Body
  - Pyloric region – consists of the pyloric antrium + pyloric canal
- A ring of smooth muscle at the distal end of the pyloric canal prevents food entering duodenum = pyloric sphincter
  - There is a greater + lesser part to the sphincter
- Clinical note: on chest x-rays, be aware that you can often see a gas bubble in the fundus of the stomach lying directly beneath the diaphragm. Do not confuse this air bubble with air in the peritoneum, say from an intestinal perforation.

**Duodenum**
- G-shaped structure
- Splits into 4 parts
  - Superior/1st – duodenal cap, not retroperitoneal, common place for peptic ulcers, passes anterior to bile duct, gastroduodenal artery, portal vein + IVC
  - Descending/2nd – contains minor + major duodenal papillae where accessory pancreatic duct + bile duct enter respectively
  - Inferior/3rd – crosses IVC, posterior to superior mesenteric artery (SMA)
  - Ascending/4th part – terminates at duodenojejunal flexure
- The relations of the duodenum are important clinically – aneurysms can compress the duodenum, ulcers can erode into the walls of surrounding vessels

**Jejunum vs. ileum**
- The jejunum + ileum make up the rest of the small intestine
- Blood supply = arterial arcades, with connecting vasa recta
- The jejunum makes up the proximal 2/5 of the SI, with the ileum forming the distal 3/5
- The jejunum diameter > ileum
- It is difficult to distinguish the jejunum from the ileum by diameter alone, but there are other features, particularly the arterial arcades + vasa recta
- The jejunum has less prominent arterial arcades with longer vasa recta
- The ileum has prominent arterial arcades with a shorter vasa recta
Large intestine
- The large intestine consists of the caecum (most proximal), vermiform appendix, ascending colon, hepatic flexure, transverse colon, splenic flexure, descending colon, sigmoid colon + rectum
- The ascending + descending colon is attached to the posterior abdominal wall – secondarily peritoneal when their mesenteries fuse with the parietal peritoneum
- The transverse colon are suspended by mesentery
  - The greater omentum fuses to the transverse colon on its posterior surface, but does not envelop it
- Distinguishing features: fatty tags (appendices epiploicae), ribbons of longitudinal muscle (taeniae coli) + segmented/pocketed haustra walls
- 2 openings:
  - Ileocaecal orifice – acts as valve preventing movement of substances back into small intestine
  - Appendix

Blood supply to the gut

Arterial supply
- The GI tract is divided into the foregut, midgut + hindgut; each with their own blood supply (unpaired arteries) arising from the aorta:
  - Coeliac trunk – supplies foregut
  - Superior mesenteric artery (SMA) – supplies midgut
  - Inferior mesenteric artery (IMA) – supplies hindgut
- The coeliac trunk branches inferior to the liver, and divides into the left gastric, splenic + common hepatic artery
- The superior mesenteric artery branches just posterior to the pancreas, and then branches into:
  - Middle colic artery
  - Right colic artery
  - Iliocolic artery
  - Jejunal arteries
  - Ileal arteries
- The junction of the midgut + hindgut is near the splenic flexure of the colon. There is a change from superior to inferior mesenteric artery supply at this level, with anastomoses between them. The inferior mesenteric artery then divides into:
  - Left colic artery
  - Sigmoid arteries
  - Superior rectal artery

Venous drainage
- The hepatic portal vein drains blood from all the abdominal viscera to the liver
- This is also joined by the superior mesenteric vein, the splenic vein (which is also joined by the inferior mesenteric just behind the spleen)
- After processing by the liver, drainage into hepatic vein and eventually into IVC
- There are 4 portosystemic anastomoses; liver or portal obstruction causes these veins to dilate widely, possibly leading to severe venous haemorrhage from the oesophagus or rectum. These include anastomoses between:
  - The esophageal + left gastric
  - Superior rectal + inferior rectal
  - Paraumbilical + epigastric
Lymphatic drainage

- As in other body parts, the lymphatic drainage of the bowel follows the arterial supply, not the venous drainage
- This is particularly important in the gut, as the two routes are very different
- The inferior mesenteric, superior mesenteric + coeliac nodes are all connected by lymphatic channels, which drain into cisterna chyli and into the thoracic duct
- Cancer may spread through these channels

Innervation of the gut

- Abdominal viscera is supplied by the autonomic nervous system
- Parasympathetic sensory innervation regulated the reflex gut function:
  o Vagus nerve
  o Pelvic splanchnic nerves S2-S4
- Sympathetic sensory innervation mediate pain:
  o Thoracic splanchnic T5-T12 (greater, lesser, least)
  o Lumbar splanchnic L1+L2

Living Anatomy – Bones + Joints of the Lumbar Vertebral Column, Sacrum + Pelvis

1. List the general + specific features that enable you to distinguish a lumbar vertebra from a thoracic or cervical vertebra
   - General vertebral features:
     o Can be divided into a body + arch
     o Have superior + inferior articular facets
   - Lumbar vertebra:
     o Large body
     o Short, bulbous spinous process – clinical use= more space between vertebrae for lumbar puncture
     o Inferior articular facets face medially, with the superior articular facets facing laterally (i.e. horizontally facing as opposed to more vertical like in thoracic)
   - Thoracic vertebra:
     o Heart shaped body
     o Rib articulation facets on body – ribs articular with transverse process + superior facet on body, and on the vertebral body above
     o Long downward facing spinous process
   - Cervical vertebra:
     o Very small
     o Spinous process divides into 2 – bifid
     o Foramen transversalium on transverse process – canal for vertebral artery branch from subclavian, i.e. important for posterior cerebral circulation

2. Look at the overall shape of the lumbar spine in the articulated skeletons + explain the functional significance of what you see
The lumbar spine is concave, with large vertebral bodies. This allows for forward bending of the entire trunk, and weight bearing function.

3. **Fit two adjoining lumbar vertebrae together and explore the range of possible movements between them**
   - Flexion/extension – allowed due to the horizontally facing articular facets
     - In the thoracic spine, this movement is limited by the spine
   - Lateral flexion – overall lateral flexion allowed, but movement considering each vertebrae restricted
   - Rotation – limited in the lumbar spine, but common in the thoracic spine
     - The cervical spine allows all movement

4. **Examine the features of the lumbar intervertebral discs.**
   a. **What is the construction of an intervertebral disc? Explain the two functioning parts**
      - Hyaline cartilage lines each vertebral column, and then fibrous cartilage forms each disc
      - Nucleus palposis has a high water content thus functions as shock-absorber
      - Anulous fibrosis forms surrounding protective layer
   b. **State the two types of intervertebral herniation**
      - Hernias result from the leakage of the nucleus palposis
      - These occur at areas where the anulous fibrosis is weakest
      - Direction of hernia may be posterior or posterolateral
   c. **Where might a patient be expected to perceive pain as a result of the different hernias?**
      - Posterolateral herniation puts pressure on the spinal nerve therefore pain is referred to corresponding dermatome
      - Posterior herniation puts pressure on the spinal nerve, therefore causing local pain

**The sacrum + pelvis**
- The *pelvic girdle* consists of the two pelvic bones, uniting anteriorly at the pubic symphysis + posteriorly with the sacrum at the sacroiliac joints
  - Functionally, the pelvic girdle provides strong + stable support for the vertebral column + lower abdominopelvic organs, as well as connecting the bones of the of the lower limbs to the axial skeleton
  - The lower limbs articulate with the pectoral girdle via acetabula sockets, which are deep and allow restricted movement
  - Each of the two hip bones consist of 3 separate bones (separated by cartilage in a new bone) which fuse together: a superior ilium, inferior+anterior pubis + posterior/inferior ischium
- The *sacrum* is directly articulated with the ilium of each pelvic bone. It is formed from 5 individual sacral vertebrae which fuse to form a single bone. The transverse processes of each vertebrae also fuse to form a large wing-like bony region on each side.
  - On the pelvic + posterior surfaces of the sacrum, there are 4 pairs of spinal foramina through which the anterior + posterior rami of the sacral nerves exit
  - The dorsal surface of the sacrum is marked by 5 predominant ridges, with the U-shaped hiatus leading to the coccyx
  - The sacroiliac joint is synovial, but there is no movement at the joint. This is because the function of the pelvic girdle is more to do with stability and strength as opposed to movement.
- The *ilium* is the largest of the 3 “hip ones”, and is composed of a superior ala + inferior border, which helps form the acetabulum.
- The superior border of the ilium = iliac crest, which ends anteriorly in a blunt ASIS
- Below the ASIS is the anterior inferior iliac spine
- Posteriorly the iliac crest ends in the PSIS, with the posterior inferior iliac spine inferior to this
- The iliac spines serve as points of attachment for the tendons of the muscles of the trunk, hip + thighs
- The medial surface of the ilium contains the iliac fossa, which the tendon of the iliacus muscle attaches
- Posterior to this fossa are the iliac tuberosity, a point of attachment for the sacroiliac ligament + the auricular surface, which articulates with the sacrum to form the sacroiliac joint
- Projecting anteriorly + inferiorly from the auricular surface is a ridge called the arcuate line

- The **ischium** forms the inferior posterior portion of the hip bone, and is comprised of a superior body and inferior ramus which fuses with the pubis

- The **pubis** is the anterior inferior part of the hip bone, comprising a superior + inferior ramus with a body between the rami
  - The anterior superior border of the pubis body is the pubic crest, which projects a pubic tubercle at its lateral end
  - The pubic symphysis is a joint between the two pubes of the hip bones, and consists of a disc of fibrocartilage
The liver + spleen

1. Know the names and contents of the mesenteries associated with the liver and spleen.
2. Define the anatomical and functional lobes of the liver.
3. Define the term “portal triad”.
4. Draw a basic diagram of the biliary tree.
5. List the three major sites of porto-systemic anastomoses and their clinical pathology in portal hypertension.
6. Know the vascular supply/drainage of the liver, spleen and gallbladder.
7. Know the anatomical relations of the liver and spleen.

Lecture structure – liver anatomy, how to draw a diagram of the biliary tree, basic spleen anatomy, porto-systemic anastomoses + their clinicopathological consequences, the mesenteries of the liver + spleen

The liver

The liver in situ
- lies deep to the ribs 5-11, with is superior border extending between the nipples in the 4th intercostal space
- the liver lies predominantly in the thorax; although it is classified as an abdominopelvic organ
  o this means the liver cannot be palpated in the abdomen; if it can this is a sign of enlargement
  o also important as injuries to the right thorax may damage the liver
- it extends from the right hypochondrium, through the epigastric region towards the left hypochondrium

Anatomical lobes of the liver
- the liver is enveloped by the ventral mesentery, which travels from the lesser curvature of the stomach to the liver as the lesser omentum
- the lesser omentum splits to envelop the liver + rejoin anteriorly to form the falciform ligament, which is used to divide the liver into its right + left anatomical lobes
- NB: the superior surface of the liver is continuous with the diaphragm
- The porta hepatitis is the name given for the entry point of the portal triad into the liver parenchyma. This is just to the right of the line of the falciform ligament

Functional liver architecture
- The liver is divided functionally into segments supplied by vascular supply by branches of the portal triad
- Each unit then drains into a tributary of the hepatic vein
- The main functional lobes are the right + left lobes, which are divided by the fossa for the gallbladder (anteriorly) + the IVC (posteriorly)
- There are then 2 further lobes which exist just to the left of the right lobe: the quadrato and caudate lobe
  - The quadrate lobe (anterior) is functionally a part of the left lobe
  - The caudate lobe is posterior and functionally independent of both the left + right lobes
- Functional anatomy is crucial as it determines the smallest independent liver unit that can be resected leaving the other segments intact (use in “bloodless” liver surgery – removal of tumours)
- The right and left functional lobes can be subdivided forming 8 segments, each with their own branch of the portal triad

The bare area + Diaphragmatic recess
- The liver is covered in peritoneum; however the peritoneal folds do not unite at the superior (diaphragmatic) surface → patch of liver uncovered by the peritoneum which is continuous with the diaphragm = BARE AREA
- Because of the folds of peritoneum do not unite, there are two blind-ended pockets of peritoneum = recesses
  - On the anterosuperior surface, 1st recess sits between the liver + diaphragm = SUBPHRENIC RECESS (poss location of pus deposition → subphrenic abscess – following bowel perforation)
  - Corresponding pocket on posteroinferior surface of liver + R kidney = HEPATORENAL RECESS

**Anatomical relations of the liver**

Indentations of the R kidney, duodenum, stomach + colon can be seen on the visceral wall of the liver (inferior surface)

**Arterial supply**

- The common hepatic artery runs in association with the bile duct + portal vein in the free edge of the lesser omentum (the hepatoduodenal ligament part)
- The common hepatic is a branch of the aorta, and then divides into the R + L hepatic (with the cystic artery supplying the gall bladder branching off the R hepatic)

**The biliary tree**

- The gallbladder functions to store and concentrate bile. Bile travels down the biliary tree and then back up to enter the gallbladder. Bile aids in the digestion of fats.
- The common bile duct (which consists of the common hepatic duct from the liver + the cystic duct from the gallbladder) reaches the duodenum by travelling in the free edge of the lesser omentum – the hepatoduodenal ligament – flows into the major duodenal papilla = ampulla of Vater (marks transition from foregut to midgut)
- The sphincter of Oddi controls the flow of digestive juices through the ampulla of Vater, as well as pushing bile up through the cystic duct into the gall bladder for storage.
- The biliary tree addresses any of the ductules within the parenchymal tissue of the liver, the R L + common hepatic duct or the cystic duct. Blockages can occur anywhere along the tree, most commonly by gall stones (visualised radiologically using contrast agents)
- **How to draw the biliary tree** (diagram opposite)

**The spleen**

- Secondary lymphoid organ ~size of fist, suspended in the dorsal mesentery
- Highly vascular organ + traumatic rupture of the spleen results in massive haemorrhage
- Sites just inferior to the left costal margin, behind ribs 9-11
- Dimensions: 1inch thick, 3 inches wide, 5 inches long, weight 200g
- **Relations of the spleen** – stomach, L kidney, tail of pancreas + colon marked indentations on the medial surface

**Arterial supply**
- Via the splenic artery, which reaches the spleen by travelling in the spleno-renal ligament
- The splenic artery is closely associated with the superior surface of the pancreas + the stomach lies anterior – therefore left gastro-omental artery also closely associated

**Portal circulation**
- Schematic of venous supply to the liver – all blood via the portal vein; formed by the anastomosis of the splenic vein + superior mesenteric vein behind the neck of the pancreas at L2
  - The inferior mesenteric vein also drains into the splenic vein
  - A branch of the portal vein (which forms part of the portal triad – travelling in the free edge of the lesser omentum) = left gastric vein
- Blood then drains from the liver directly into the IVC via 3 short hepatic veins

**Portosystemic anastomoses**
- The portal circulation effectively anastomoses in 3 regions:

<table>
<thead>
<tr>
<th>Region</th>
<th>Portal</th>
<th>Systemic</th>
<th>Pathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oesophageal</td>
<td>Left Gastric V.</td>
<td>Oesophageal tributaries to Azygos V.</td>
<td>Oesophageal varices</td>
</tr>
<tr>
<td>Paraumbilical</td>
<td>Paraumbilical Vs.</td>
<td>Ant. abdo. wall veins (superficial epigastric Vs.)</td>
<td>Caput medusae</td>
</tr>
<tr>
<td>Rectal</td>
<td>Sup. Rectal Vs.</td>
<td>Mid. And Inf. Rectal Vs.</td>
<td>Haemorrhoids</td>
</tr>
</tbody>
</table>

- If the liver is disease, venous pressure in the portal system may become raised → portal hypertension
- If the portal pressure > systemic pressure, blood may flow from the portal system to the systemic system bypassing the liver
- Haemorrhoids are usually caused by increased intraabdominal pressure from constipation or pregnancy

**Clinical correlate** – Liver disease may also causes caput medusa (dilated veins visible on the anterior abdominal wall), which may be accompanied by ascites + jaundice (other clinical signs of liver failure)

**Mesenteries of the liver + spleen**
- Mesenteries are peritoneal folds attaching viscera to the abdominal wall; contain the vessels nerves + lymphatics that supply the viscera

**The Early GI tract (<8weeks in utero)**
- The early GI tract is suspended from the abdominal wall by:
  - Dorsal mesentery (connects to posterior wall) – along whole length
  - Ventral mesentery (connects to anterior wall) – foregut region only (abdominal oesophagus → 2nd part of duodenum where bile duct enters)
- The ventral mesentery runs from the stomach to the anterior abdominal wall + envelopes the liver. However the liver grows too big for the ventral mesentery to contain it entirely – the superior part of the liver pokes out of the mesentery and is called the bare area of the liver because it has no visceral peritoneal covering
Because the ventral mesentery only runs the distance of the foregut, it has a free inferior margin = ligamentum teres + the hepatoduodenal ligament

The ventral mesentery is then divided into parts called “ligaments”
  - Gastrohepatic ligament – runs from stomach to liver; contains right + left gastric arteries
  - Hepatoduodenal ligament – runs from first part of duodenum to liver; contains portal triad
  - These 2 ligaments effectively make up the lesser omentum

The falciform ligament runs from the liver to the anterior abdominal wall. The free thickened inferior edge of the falciform ligament = ligamentum teres (contains the remnant of the umbilical vein)

The parts of the dorsal mesentery running from the stomach to spleen and spleen to posterior abdominal wall are also called “ligaments”
  - The gastrosplenic ligament – runs from stomach to spleen (contains gastro + gastro-omental vessels)
  - Splenorenal ligament – runs from spleen to posterior abdominal wall adjacent to the left kidney (contains tail of pancreas, splenic artery + vein)

Note that a mesentery contains TWO layers of peritoneum. These two layers split to surround an organ. The layer of peritoneum touching the organ is the visceral peritoneum. The peritoneal cavity is highlighted in red. Note that intraperitoneal organs (like the liver) are not actually inside the peritoneal cavity. In reality, the peritoneal cavity is potential space. It contains a small amount of fluid. The space is used up by the folded gut tube and other intraperitoneal organs.

Development of the GI tract (>8 weeks in utero)
  - During development of the foetus there is rotation of the GI tract. The mesenteries move with their associated viscera, but do not change attachments.
  - As the liver grows in the ventral mesentery, there is a clockwise rotation about the longitudinal axis of the stomach, and everything on the RIGHT side of the peritoneal cavity (i.e. the right side of the diagram above) now becomes posterior; forms a sac known as the lesser sac or omental bursa.
    - The lesser sac lies directly in front of the retroperitoneal organs including the pancreas, great vessels, duodenum + kidneys
The anterior part (which was originally left like the diagram above then forms the greater sac. There is a point at which the lesser + greater sac meet = epiploic foramen

**The lesser omentum**
- Made up of two related ligaments (forms by the ventral mesentery) which join the lesser curvature of the stomach to the inferior border of the liver + gall bladder
  - Gastrohepatic ligament + hepatoduodenal ligament
- In the free inferior edge of the lesser omentum (hepatoduodenal ligament) lies the portal triad (bile duct, hepatic portal vein + hepatic artery)
  - Clinical correlation – Pringle’s Manoeuvre: if you want to stop blood flow to the liver, you can simply compress the hepatoduodenal ligament

**Splenic ligaments**
- The gastrosplenic ligament connects the stomach to the spleen – contains the short gastric + gastro-omental vessels
- The spleno-renal ligament connects the spleen to the posterior abdominal wall, adjacent to the left kidney – contains the splenic vessels + the tail of the pancreas

<table>
<thead>
<tr>
<th>Ligament</th>
<th>From</th>
<th>To</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastro-hepatic</td>
<td>Lesser curvature of stomach</td>
<td>Liver (porta hepatis)</td>
<td>L. and R. gastric vessels</td>
</tr>
<tr>
<td>Hepato-duodenal</td>
<td>1st part of duodenum</td>
<td>Liver (porta hepatis)</td>
<td>Hepatic artery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Portal vein</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Common bile duct</td>
</tr>
<tr>
<td>Falciform</td>
<td>Liver</td>
<td>Ant. abdo. wall</td>
<td></td>
</tr>
<tr>
<td>Ligamentum Teres</td>
<td>Liver</td>
<td>Ant. abdo. wall (umbilical area)</td>
<td>Umbilical vein (remnant) Paraumbilical veins</td>
</tr>
<tr>
<td>Gastro-splenic</td>
<td>Greater curvature of stomach</td>
<td>Hilum of spleen</td>
<td>Short gastric and gastro-omental vessels</td>
</tr>
<tr>
<td>Spleno-renal</td>
<td>Hilum of spleen</td>
<td>Post. Abdo. wall over left kidney</td>
<td>Splenic vessels and tail of pancreas</td>
</tr>
</tbody>
</table>

NB: The porta hepatis is essentially the hilum of the liver. It is the point of attachment for the lesser omentum and it transmits the portal triad (hepatic A., portal V. and common bile duct).
1. Define the terms intraperitoneal, retroperitoneal and secondarily retroperitoneal.
2. List the retroperitoneal organs.
3. Demonstrate and name the major branches of the abdominal aorta.
4. Draw a basic diagram of the great vessels, kidneys, duodenum and pancreas.
5. Name the major abdominal lymph nodes and outline their pattern of drainage.

Intraperitoneal vs. Retroperitoneal

- Intraperitoneal – structures suspended from the abdominal wall by mesenteries
- Retroperitoneal – structures lying posterior to the peritoneum (only have covering of peritoneum on their anterior side). A mnemonic to remember the retroperitoneal organs is:
  - S – suprarenal glands
  - A – Aorta/IVC
  - D – duodenum (not 1st part)
  - P – pancreas (not tail)
  - U – ureters
  - C – colon (ascending + descending only)
  - K – kidneys
  - E – esophagus
  - R – rectum

  - NB: the duodenum, pancreas + colon are “secondarily retroperitoneal” – they were initially suspended in a mesentery, but this fused with the body wall during development leaving the viscus (organ) with just an anterior covering of peritoneum

Blood supply to abdominal viscera

Divisions of the GI tract

- Foregut = abdominal oesophagus → duodenum at entrance of common bile duct
- Midgut = ampulla of vater → 2/3 along transverse colon
- Hindgut = distal third of transverse colon to rectum

Initial branches of the abdominal aorta

- Each part of the GI tract has its own arterial supply = major branches of abdominal aorta
- Foregut supplied by coeliac axis (at upper L1)
- Midgut supplied by superior mesenteric artery (SMA) (at lower L1)
- Kidneys then supplied by renal arteries (between L1-L2)
- Hindgut supplies by inferior mesenteric artery (at L3)

NB: Renal vasculature

- Renal veins branch at approx. the same level as the renal arteries (L1 = transpyloric plane) from the IVC (right + anteriorly of aorta)
- The SMA also branches at approx. the same level, but branches anteriorly as opposed to laterally
- The left renal vein is longer than the right renal vein, as it runs posteriorly to the SMA
  - Clinical correlation = nutcracker syndrome; aneurysm of the SMA compresses the left renal vein causing kidney damage
- the renal arteries run posterior to the veins, with the right running posteriorly to the IVC too
The duodenum, pancreas + kidneys

**The biliary tree**
- The name given to the system of ducts which transport bile from the liver (+ gall bladder) to the second part of the duodenum = ampulla of Vater (controlled by sphincter of Oddi)
- Bile synthesis by hepatocytes + secreted into canaliculi → bile ductules → R + L hepatic duct (draining R + L anatomical lobe respectively) → Common hepatic duct, which then fuses with the cystic duct → common bile duct
- The common bile duct reaches the duodenum by travelling in the free inferior edge of the lesser omentum = hepatoduodenal ligament

**The duodenum**
- The duodenum is a G shaped organ divided into 4 parts:
  - Superior/1st part = duodenal cap, passes anteriorly to the bile duct, gastroduodenal artery, portal vein + IVC
  - Clinical correlation – common place for peptic ulcers
  - Descending/2nd part – contains minor + major duodenal papillae (major = ampulla of vater) where accessory pancreatic duct + bile duct enter respectively
  - Inferior/3rd part – crosses IVC, with SMA anterior to it
  - Ascending/4th part – terminates at duodenojejunal flexure
  - The tail of the pancreas, spleen + 1st part of the duodenum are intraperitoneal
  - The 2-4 part of the duodenum is retroperitoneal
  - The duodenum forms a G in which the head + uncinate process of the pancreas are nestled
  - The duodenum is also in close association with the right kidney
  - The relations of the duodenum are important clinically; aneurysms can compress the duodenum or ulcers can erode into the walls of vessels including the gastroduodenal artery, portal vein, IVC + SMA

**Basic pancreatic embryology**
- The pancreas develops as a ventral + dorsal bud in the ventral and dorsal foregut mesenteries respectively (i.e. starts intraperitoneal)
- The smaller ventral bud then rotates clockwise to become dorsal + associated with the dorsal pancreatic bud, trapping the superior mesenteric vein + becoming secondarily retroperitoneal
  - The tail remains intraperitoneal, lying in the splenorenal ligament
  - The superior mesenteric vessels emerge posterior to the neck of the pancreas, and then cross anterior to both the uncinate process + 3rd part of duodenum
- The originally ventral bud forms the uncinate process. The accessory pancreatic duct also originates from the ventral bud, explaining why there is a major + accessory duct
- Clinical correlate: cancer of the head of the pancreas can compress the common bile duct (close association with the biliary tree) → jaundice
Renal fascia + perinephric fat
- The kidneys are enclosed by renal fascia + perinephric fat
- Renal fascia is a specialisation of the transversalis fascia (lining of entire abdominal cavity)
- Any surgical approach to the kidney must incise the renal fascia
- The kidneys have many visceral relations; some directly, and some with an intervening layer of peritoneum. However all of the associated viscera are still separated by the perinephric fat + renal fascia

NB: diagram of the peritoneum →

Abdominal lymphatics
- Pulsatile flow in the arteries help drive the flow of lymph
- The collection of nodes draining the GI tract are collectively known as preaortic nodes; subdivided based on area + associated aortic branch (coeliac, SM + IM)
- The inferior mesenteric drains into the superior mesenteric → coeliac → cisterna chyli (dilated sac at inferior end of thoracic duct)
- Thoracic duct empties into the junction of the left subclavian + left internal jugular veins in the thorax

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Receive from</th>
<th>Drain to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coeliac</td>
<td>Foregut</td>
<td>Cisterna chyli (dilated sac at the inferior end of thoracic duct)</td>
</tr>
<tr>
<td></td>
<td>Sup. mesenteric nodes</td>
<td></td>
</tr>
<tr>
<td>Superior Mesenteric</td>
<td>Midgut</td>
<td>Coeliac Nodes (pre-aortic)</td>
</tr>
<tr>
<td></td>
<td>Inf. mesenteric nodes (pre-aortic)</td>
<td></td>
</tr>
<tr>
<td>Inferior Mesenteric</td>
<td>Hindgut</td>
<td>Sup. mesenteric nodes (pre-aortic)</td>
</tr>
</tbody>
</table>
Anatomy + Imaging: the Retroperitoneum
Anatomy of the Abdomen & Pelvis 5 – Dr Mary Crofton (m.crofton@imperial.ac.uk)

Components of the retroperitoneum/urinary tract = kidneys + adrenal glands, ureters, bladder, urethra (+ aorta, IVC and abdominal vessels)

The kidneys

- Paired retroperitoneal organ lateral to vertebral column – lie on posterior abdo wall adjacent + parallel to psoas muscle (thus at angle)
- Left superior to right (presence of liver on right side)
- Approx. 10-12cm, but variation in people’s sizes mean 3-4 lumbar vertebra = good way of accounting
- Surrounded by perinephric fat + renal fascia

Anatomical relations

<table>
<thead>
<tr>
<th>Right kidney</th>
<th>Left kidney</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior – peritoneum, R lobe of liver, duodenum, hepatic flexure of colon</td>
<td>Anterior – peritoneum, stomach, splenic flexure, tail of pancreas, small bowel, spleen</td>
</tr>
<tr>
<td>Posterior – diaphragm, quadratus lumborum</td>
<td>Posterior – diaphragm, quadratus lumborum</td>
</tr>
<tr>
<td>Lateral – abdominal wall</td>
<td>Medial – aorta, gonadal veins, psoas major, ureter</td>
</tr>
<tr>
<td>Medial – psoas major muscle, IVC, gonadal veins, ureter</td>
<td></td>
</tr>
</tbody>
</table>

Peritoneal vs. retroperitoneal

- Knowing the difference between peritoneal + retroperitoneal fluid is useful in diagnosis.
- Left = retroperitoneal fluid accumulation, right = intraperitoneal fluid. If the accumulation is within the peritoneum, you know the location of the bowel perforation is intraperitoneal.

Axial CT (left) + Coronal MRI (right) can be used to show superior position of left kidney

The Ureter
Runs from the renal pelvis to the bladder, lying on the medial edge of the psoas entering the pelvis by crossing the common iliac vessels to enter bladder posteromedially at base (at edge of trigone). However the route is different for men + women.

**Medical Imaging**

**Modalities**
- Plain radiographs of the abdomen
  - Important when looking for any calcifications, including some kidney stones
- Contrast studies
  - Intravenous urography – info on following slides
  - Urethrocystography
- Ultrasound
  - No radiation, safe, repeatable, very observant dependant (as different people may read differently)
- Computed Tomography (CT) - also uses contrast - oral and i.v.
  - Large radiation dose, therefore not as safe
- Magnetic Resonance imaging (MRI)
  - Can use a contrast, no radiation. However very expensive + time consuming.
- Nuclear Medicine studies – functional not anatomical
  - Injecting an isotope + seeing how the body handles it. Important in kidneys as can be good assessment of function, NOT ANATOMY
- Angiography/venography

**Plain abdominal X-ray**
- Useful for most renal + uretic stones, as they are visible due to calcification (not good for gall stones)
- Renal + bladder outlines are only visible because of their surrounding fat, but they are frequently obscured by bowel gas
- Ureters + abdominal vessels are not visible

**Contrast studies**

**Intravenous urogram (IVU)**
- An iodine-containing water soluble contrast is given intravenously, and then is filtered by the kidney. A standard sequence of images is taken, including an immediate nephrogram phase + delayed images
- The pelvicalyceal system can be distended by compressing the abdomen – the release of this compression can be used to show the ureters + bladder
- A post-micturation of the bladder image is also taken
- The kidneys will not be visible in the control film (due to surrounding fat). However as the contrast moves through the collecting system, ureters etc the different anatomical components become brighter. Any blockages in the ureters are seen.

**CT urogram**
- Gives high resolution of movement of contrast through the renal vascular supply + renal collecting ducts.
- Requires an early phase and late phase CT, so the radiation dose needs to be considered
- CT scans are useful for looking at vascular supply, as well as construction of 3D images – therefore very useful in investigating trauma

**Ultrasound**
- Ultrasound is operator dependant
- However no contrast or radiation is required = safe + easy
- Ultrasound is useful for assessing renal size, hydrophrosis, kidney stones + some tumours

**Cystourethrography**
Retrograde urethrography - inject contrast via the urethral meatus (used more commonly in males)
Anterograde urethrography - fill bladder with contrast (usually via a catheter as too dilute after an IVU). Fluoroscopy with spot images during voiding
Possible to measure bladder and rectal pressures during voiding to get an idea of function.

Renal Congenital variants
- Congenital variants can also be seen on an ultrasound (as well as most imaging modalities). These include:
  - Renal agenesis, pelvic kidney (kidney fails to ascend), duplex collecting systems, horseshoe kidney, malrotation, pelviuretic junction obstruction, renal ectopia (wrong place, i.e. both kidneys on 1 side)
  - **Horseshoe kidney** – seen using Tc-99m labelled nuclear scan
    - Associated with hypertension + renal stones
  - **Duplex collecting systems** – 1 kidney may have 2 pelvicalyceal systems
  - **Pelviuretic junction obstruction** is a possible complication of excessive alcohol consumption. Very painful!
  - **Renal colic (kidney stones)** – obstruction causes kidney to contract → pain. The ureter is visible the entire length when an inferior obstruction is present. A CT scan is also useful when looking into renal colic, as it can be used to rule out other possible causes of pain

The Urinary Bladder
- Midline structure covered superiorly by peritoneum but not posteriorly
- Anatomical relations:
  - Superior – small bowel + sigmoid colon
  - Anteriorly – pubic symphysis
  - Laterally – levator ani + obturator internus
- Circular muscle in wall condenses to form internal urethral sphincter at bladder neck
- Female – position of uterus variable, usually anterverted. Ureters enter bladder base around the cervix (indications involved in cervical carcinomas). Urethra very short + anterior to the vagina. Ovaries lie on the pelvic side wall on the iliac vessels but may “fall” into the pouch of Douglas or displaced anteriorly + laterally
- Male – prostate lies inferiorly at the bladder base

The Aorta
- Extends from diaphragmatic hiatus to bifurcation at level of 4th lumbar vertebra
- < 50 yrs - should be < 2 cm in diameter
- >50 yrs - considered aneurysmal if > 3 cm
- Divides into R and L common iliac arteries which divide into internal and external iliac arteries.
- Also midline median sacral branch
- Can be seen by MRI

Iliac arteries
- Divide over the sacro-iliac joint at level of sacral promontary.
- External iliac artery continues inferolaterally through the pelvis - becomes common femoral artery under the inguinal ligament
  - Supplies the lower limb
- Internal iliac artery arises medially and passes backwards and and downwards between ureter and internal iliac vein.
  - Supplies pelvic organs, perineum, buttock and sacral canal

Major branches
- Coeliac Axis - stomach, liver, spleen, pancreas and duodenum
- Superior mesenteric - small bowel and colon to splenic flexure
LSS Anatomy of the Abdomen + Pelvis

Alexandra Burke-Smith

- Inferior mesenteric to distal colon and rectum

**Major paired branches**

- Renal arteries
  - may be more than one to each kidney
  - arise anterolaterally at approximately same level as SMA - lower border of L1
  - Right renal artery passes behind IVC
  - (left renal vein passes anterior to the aorta)
- Gonadal arteries
- Adrenal arteries
- Phrenic arteries
- Lumbar arteries

**Abdominal arteriography**

- Local anaesthetic in groin over the palpable femoral artery
- Puncture femoral artery (usually Rt)
- Pass guide wire through needle up the femoral and iliac arteries into the aorta
- Remove needle leaving guide wire in place
- Pass catheter over guide wire into aorta
- Aortogram - injection of contrast into aorta
- Selective renal / coeliac / mesenteric arteriogram - manipulate catheter tip into origin of the appropriate vessel and then inject contrast
- DSA (digital subtraction angiogram) - electronically subtract the background to display only contrast in the vessels.

**The Inferior Vena Cava**

- Lies to the right of the aorta, separated by the crus
- Formed by union of the common iliac vessels at L4/5
- Receives blood from
  - paired lumbar veins
  - renal veins (left renal vein passes anterior to aorta)
  - gonadal veins (directly on right, via renal vein on left)
  - three hepatic veins
- Runs through the liver, crosses diaphragm at T8 to enter right atrium

**IVC MRI**

- Vessels best demonstrated after intravenous contrast – gadolinium based
- Direct multiplanar imaging
- Can subsequently rotate images on a workstation

To see examples of all different imaging modalities – look on powerpoint saved as imaging
Understanding visceral pain

Anatomy of the abdomen + pelvis 6 – Dr M Tharavjah (m.tharavajah@imperial.ac.uk)

Introduction to the ANS

- the autonomic nervous system has a different structure than the somatic (body) nervous system; it innervates viscera (organs) + can be divided into sympathetic/parasympathetic
- the sympathetic nervous system arise from spinal cord segments T1-L2 (thoracocolumnar)
- the parasympathetic nervous system arise from:
  - cranial nerves III, VII, IX + X (occulomotors, facial, glossopharyngeal + vagus)
  - spinal cord segments S2-S4
- both the sympathetic + parasympathetic nervous system can be divided into afferent (to the CNS) + efferent (away from the CNS)
- the efferent fibres are motor to smooth muscle or secretomotor to glands + secretory cells
- afferent fibres are also known as sensory fibres, and these run with the efferent fibres
  - sympathetic afferent fibres are associated with pain sensation
  - parasympathetic afferent fibres are associated with a particular functional sensation e.g. stretch

Distribution of autonomic nerves to the abdominal + pelvic organs

- sympathetic supply to the abdominal viscera is via splanchnic nerves
  - splanchnic nerves can be divided into greater (T5-T10), lesser (T10-T11), least (T12) [+ lumbar (L1-L2)]
  - there are also a number of splanchnic nerve associated ganglia:
    - celiac ganglion, aortic-renal ganglion, superior mesenteric ganglion + inferior mesenteric ganglion
- there is also sympathetic innervations to the skin (in addition to the somatic innervations) – this includes innervations of the sweat glands, hair follicles, smooth muscle + blood vessels
  - there is NO parasympathetic innervations to the skin surrounding the abdomen and pelvis
- parasympathetic supply to the abdominal viscera has 2 components:
  - vagus nerve (CNX)
    - branches of the vagus nerve innervates many different regions
  - pelvic splanchnic nerves (S2-S4)
    - interconnecting networks of pelvic splanchnic nerves form the superior + inferior hypogastric plexus

NB: most autonomic nerves running to the abdominal viscera run with the arteries supplying them. Therefore if you cut off the blood supply to an organ, you will most likely cut off the nerve supply.

Ganglia + Plexuses

- Autonomic nerve cell bodies form aggregations known as ganglia (these form part of the PNS, aggregations of soma in the CNS = nuclei)
- Sympathetic nerve fibres running to the abdominopelvic viscera form prevertebral ganglia known as collateral ganglia. (this is different to the sympathetic nerve fibres running to the thorax, which form the paravertebral ganglia trunk)
  - These ganglia are associated with plexuses (interconnecting network of multiple nerve branches) which surround the aorta + its branches
- Sympathetic plexuses + ganglia are named according to their associated blood vessels e.g.
  - Celiac trunk + ganglion (associated with celiac axis (UL1) + celiac artery – to organ supplied [T5-9])
  - Superior mesenteric ganglion (associated with SMA (L1) branch of aorta [T10-11])
  - Renal plexus + ganglion (associated with renal (L1) arteries [T10-12])
o Inferior mesenteric ganglion (associated with IMA (L3) [T12-L2])
o The sympathetic trunk ganglion are also associated with nerve supply following the testicular/ovarian (gonadal) artery (T10-T11)

- Parasympathetic nerve ganglia tend be within the viscera innervated, or very close to.
o However the parasympathetic nerve fibres from CNX (vagus) associated with celiac artery, SMA, renal arteries, testicular/ovarian + IMA
o Parasympathetic fibres from the sacral outflow (the pelvic splanchnic nerves) also form the superior + inferior hypogastric plexuses

<table>
<thead>
<tr>
<th>Nerves following artery</th>
<th>Viscera supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celiac trunk (immediately divides into splenic, common hepatic + left gastric)</td>
<td>Lower oesophagus</td>
</tr>
<tr>
<td></td>
<td>Stomach</td>
</tr>
<tr>
<td></td>
<td>Spleen</td>
</tr>
<tr>
<td></td>
<td>Liver + gall bladder</td>
</tr>
<tr>
<td></td>
<td>Part of pancreas</td>
</tr>
<tr>
<td></td>
<td>Part of duodenum</td>
</tr>
<tr>
<td></td>
<td>FOREGUT</td>
</tr>
<tr>
<td>SMA</td>
<td>Part of pancreas</td>
</tr>
<tr>
<td></td>
<td>Part of duodenum</td>
</tr>
<tr>
<td></td>
<td>Jejunum + ileum</td>
</tr>
<tr>
<td></td>
<td>Caecum, appendix, ascending colon + part of transverse colon</td>
</tr>
<tr>
<td></td>
<td>MIDGUT</td>
</tr>
<tr>
<td>IMA</td>
<td>Rest of transverse colon, descending colon, sigmoid colon</td>
</tr>
<tr>
<td></td>
<td>Part of rectum</td>
</tr>
<tr>
<td></td>
<td>HINDGUT</td>
</tr>
<tr>
<td>Renal arteries</td>
<td>Kidneys</td>
</tr>
<tr>
<td></td>
<td>Ureters</td>
</tr>
<tr>
<td>Testicular/ovarian arteries</td>
<td>Gonads</td>
</tr>
<tr>
<td>Superior/inferior hypogastric plexuses</td>
<td>Bladder</td>
</tr>
<tr>
<td></td>
<td>Rest of rectum</td>
</tr>
<tr>
<td></td>
<td>Uterus</td>
</tr>
<tr>
<td></td>
<td>Part of vagina</td>
</tr>
<tr>
<td></td>
<td>Ductus deferens</td>
</tr>
<tr>
<td></td>
<td>Prostate</td>
</tr>
<tr>
<td></td>
<td>Seminal vesicles</td>
</tr>
</tbody>
</table>

Referred pain

- The brain cannot localise pain sensation (involves sympathetic ANS) from organs or tissues from which there is no “map” in the cortex, i.e. cannot be localised if the location knowledge has been acquired through the sensation of touch (you can't tough organs or diaphragm)
- In these cases, pain is then referred to the region of skin supplied by nerves with the same segmental supply (this is only sympathetic). The region of skin supplied by each spinal nerve = dermatome
- By combining knowledge of nerve segments contributing to the innervations of abdominal viscera by the ANS with the pattern of dermatomes, it is possible to interpret possible sources of abdominal pain
  o NB: adjacent dermatomes overlap so that on the trunk, at least 3 spinal nerves would have to blocked to produce a region of complete anaesthesia

Dermatomes of the abdominal wall
- T7/T8 – epigastric region
- T10 – umbilical region
- T12/L1 – inguinal region
- T12/L2 – hypogastric region
Referred pain from midgut structures
- Afferent pain fibres from midgut structures (e.g. appendix) enter the spinal cord at T10
- the skin of the umbilical region is also supplied by T10 spinal nerve
- therefore appendicitis will initially present with umbilical regional pain
  - it is usually intermittent with bowel contractions
- when the inflammation of the appendix spreads to the surrounding peritoneum, the pain becomes localised and constant at the right inguinal region
  - movement of the hip joint + coughing elicits pain

Referred pain from hindgut structures
- the descending colon to anal canal is supplied by T12-L2, as well as the skin of the hypogastric region
- pain of the hindgut viscera is often referred to the hypogastric region
Non-reproductive features of the pelvis and perineum

The Pelvic Girdle

- **Bony pelvis**: consists of 2 pelvic bones + sacrum.
  - The “greater pelvis” is the shallow basin formed by the 2 iliac fossa
  - The “lesser pelvis” is the cavity formed below the pelvic brim
- **Pelvic cavity**: between the pelvic inlet and outlet; short + cylindrical in women, elongated + tapered in men
  - Pelvic organs lie within in the pelvic cavity
  - The axis of the pelvic cavity is antero-inferiorly inclined
- **Pelvic floor** (or pelvic diaphragm): sheet of muscle mainly formed by levator ani muscle; lies at pelvic outlet
  - Inferior to the pelvic floor is the perineum

Pelvic wall

Formed by the pelvic girdle, as well as the *sacrospinous* (ischial spine-sacrum)+ *sacrotuberous* (ischial tuberosity-sacrum) ligaments

Together, these form the greater + lesser sciatic foramen.

(greater = superior to sacrospinous ligament, lesser = inferior)

The pelvic cavity is lined by muscle on the medial surface of the greater trochanter of the femur:

- Piriformis (smaller)
- Obturator internus (larger)
Pelvic floor
- Separates the pelvic cavity + perineum
- Formed by collection of muscles = levator ani + coccygeus muscle
  - From midline raphe laterally =
    - Levator ani
      - Puborectalis
      - Pubococcygeus
      - Iliococcygeus
    - Coccygeus
- Muscles form a sheet/diaphragm, which has openings for the vagina (in females), urethra + anal canal
- Supports the main pelvic organs

The urinary apparatus

*Structures in the lower part of the urinary system are located in the pelvic cavity (ureters, urinary bladder + urethra)*

**Male anatomy**
- The urinary bladder + prostate (inferior) sit in the bowel formed by the levator ani
- The urethra consists of 4 parts: pre-prostatic, prostatic, membranous + spongey (~20cm long)
- The internal urethral sphincter consists of smooth muscle, and lies at the neck of the bladder – it is under involuntary control
- The external urethral sphincter consists of skeletal muscle, and lies in the perineum – it is under voluntary control

**Female anatomy**
- The female urethra is only ~4cm long
- The internal urethral sphincter is not well organised
- The external urethral sphincter is skeletal muscle surrounding the urethra in the deep perineal pouch
There are 2 extra female muscle groups to consider: the sphincter urethrovaginalis + compressor urethrae

The urinary bladder
- Tetrahedral structure when empty, with associated structure at each apex
- Ureters enter at each supero-posterior apex
- The urethra leaves through the inferolateral angle
- Superiorly covered in peritoneum (not continuous); however on expanding, the bladder extends through the peritoneum into the space between the peritoneum + transversalis fascia
- Smooth muscle sphincter (vesicae) at neck (inferior)
- Skeletal muscle sphincter (urethrae) in perineum

The rectum (see alimentary lectures for detail)
- Double-S bend acts as an anti-gravity device keeping load off sphincter
- Supplied by the ANS – well innervated therefore highly sensitive to filling
- Anal canal is supplied by somatic nerves, therefore sensitive to injury
- The skeletal muscle sphincter ani surrounding the anal canal is much less important to faecal continence than the puborectalis part of Levator ani, which puts a sharp angle into the recto-anal junction. Can be injured in a badly-performed episiotomy

NB: Arterial Supply of the pelvic organs – the internal iliac artery supplies the pelvic organs (except ovaries), pelvic walls + much of the gluteal region
The male + female pelvis

Both the male and female pelvic girdle consists of the sacrum, and pelvic bones connected by the pubic symphysis. There are distinguishing features between the male and female pelvis:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Female Pelvis (singular)</th>
<th>Male Pelvis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvic inlet</td>
<td>Oval/round</td>
<td>Narrow/heart shaped</td>
</tr>
<tr>
<td>Sub pubic angle</td>
<td>Wide &gt; 80 degrees</td>
<td>Narrow 50 -60 degrees</td>
</tr>
<tr>
<td>Ischial spines</td>
<td>Not projecting medially</td>
<td>Project medially</td>
</tr>
<tr>
<td>Greater (false) pelvis</td>
<td>Shallow</td>
<td>Deep</td>
</tr>
<tr>
<td>Lesser (true) pelvis</td>
<td>Wide, shallow &amp; cylindrical</td>
<td>Narrow, deep &amp; tapering</td>
</tr>
<tr>
<td>Y:X ratio (acetabulum)</td>
<td>Less than one</td>
<td>1 or &gt; 1</td>
</tr>
</tbody>
</table>

NB: X = distance between the pubic symphysis + the anterior margin of the acetabulum. Y = diameter of the acetabulum.

Orientation

- In the anatomical position, the ASIS + pubic tubercles are in the same plane. The greater + lesser pelvis are continuous. This can be seen in the mid-saggital section of the pelvis (diagram 1).

Peritoneum + pelvic fascia

- The parietal peritoneum continues into the pelvic cavity forming several pouches + folds.
  - However it does not reach the pelvic floor (therefore does not completely cover the pelvic viscera EXCEPT the ovaries + uterine tubes).
- The space between the pelvic wall + peritoneum is filled with connective tissue which sheaths the pelvic viscera – condensations of this fascia form “ligaments” which support the viscera e.g. the cervix, vagina + prostate.

The male pelvic cavity

- **Contents**
  - Ureter, bladder + urethra
  - Prostate, ductus deferens, seminal vesicles, bulbourethral glands
  - Rectum
  - Some of the abdominal GI tract spills into the greater pelvis
Relations of the pelvic organs

- Prostate gland surrounds the 1st/prostatic part of the urethra
- The ductus deferens from the testes passes through the inguinal canal, then over + behind the ureter to enter the urethra through the prostate
- Seminal vesicles on the back of the bladder open into the ductus deferens between the ampulla + ejaculatory duct
- The ductus deferens, seminal vesicle + prostate all empty into the prostatic urethra to form the semen

Bladder, prostate + seminal vesicle

- The male bladder “sits” on the prostate, which is transfixed by the prostatic urethra
  - A urinary catheter must negotiate a 90° bend in the urethra as it passes from the perineum to pelvis
- The prostatic urethra is defined by a smooth muscle internal sphincter, and skeletal muscle external sphincter
  - The internal sphincter is closed during ejaculation by sympathetic stimulus, and relaxed by parasympathetic stimulation
- Between the two prostatic urethral sphincters, the prostatic utricle (just an indentation on the posterior wall) + openings of the ejaculatory ducts are present
  - The tip of a urethral catheter may become lodged in the prostatic utricle
Male urethra

- The male urethra is approx. 21cm long, and its basic arrangement can be summarised as 4 parts + the external urethral orifice
- The *preprostatic part* of the urethra ~1.5cm, and is located at the neck of the bladder leading up to the internal urethral sphincter
- The *prostatic part* of the urethra ~2.5cm long, and lies between the internal + external urethral sphincter
- The *membranous part* of the urethra is ~2cm long, and lies just superior to the perineal membrane in the deep perineal pouch
  - The bulbourethral gland + duct also lies in the deep perineal pouch, and runs into the final part of the urethra at the 1st bend
- The *spongy part* of the urethra is ~15cm long, and runs from the inferior border of the perineal membrane to the external urethral orifice
  - It has 2 bends to it when flaccid, but the second is “straightened” when erect
  - Just before the external urethral orifice (which is the narrowest part), the urethra forms the navicular fossa (a bulbous widening of the urethra at the tip of the penis)

Arterial supply

- The male pelvis receives arterial supply from branches of the internal iliac artery (abdominal aorta bifurcates into the common iliacs at L4, then these divide into external + internal iliac)
  - The testis receives arterial supply from the testicular artery, which is NOT a branch of the internal iliac. The testicular artery is also known as a gonadal artery, and is one of the paired branches of the aorta.
- The vesical arteries are branches of the internal iliac artery
  - Superior vesical arteries → bladder + ductus deferens
  - Inferior vesical artery → prostate, bladder + ductus deferens
    - Prostatic branch of inferior vesical artery → prostate

The perineum

- The perineum is a diamond-shaped area between the pubic symphysis, ischial tuberosities + coccyx, that can be seen in the lithotomy position (lying down, knees up + spread)
- It can be divided into the anterior (urogenital) + posterior (anal) triangles
  - The urogenital triangle contains the roots of the external genitalia
    - in women, the openings of the urethra + vagina
    - In men, the distal part of the urethra is enclosed by erectile tissue + opens at the end of the penis
  - The anal triangle contains the anal aperture

Perineal membrane + perineal pouches

- The perineal membrane is a thick fascial, triangularly shaped structure that lines the urogenital triangle
  - It has a small gap anteriorly between the membrane + inferior pubic ligament
  - It has a free posterior margin
- The perineal membrane is related to thin potential spaces called pouches
  - The deep perineal pouch lies superior to the perineal membrane and inferior to the fascia of the pelvic diaphragm
  - The superficial perineal pouch lies inferior to the perineal membrane and fascia, deep to the skin
  - These only become “spaces” if they become fluid-filled
- Within the deep perineal pouch in both the male + female is a sheet of skeletal muscle which forms the external urethral sphincter
Bulbourethral glands and ducts also sit within the deep perineal pouch. These are the exocrine glands responsible for pre-ejaculate secretion; during sexual arousal this lubricates the urethra, neutralises acid urine traces + flushes out any residual sperm.

- The bulbourethral ducts open into the urethra just inferior to the perineal membrane

- In both men and women, a deep transverse perineal muscle on each side parallels the free margin of the perineal membrane and joins with its partner at the midline structure = **perineal body**

- The superficial pouch contains erectile tissue masses in both the male + female
  - Median erectile tissue masses = **corpus spongiosum**
    - Surrounding bulb of penis in males
    - In females, it divides round the vestibule to form the vestibular bulbs, also known as the clitoris bulbs
  - Lateral erectile tissue masses = **corpus cavernosae**
    - Attached to the ischiopubic rami
    - In males, meet to form shaft + head of penis
    - In females, meet to form clitoris
  - The pudendal nerve (S2-S4) provides all sensory + motor innervation to the perineal membrane + urogenital triangle

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**The anal triangle**
- Common structures in male and female
- Contents of the anal triangle = ischioanal fossa (fat-filled space on either side of the rectum or anal canal, located between the skin + pelvic diaphragm)
- Other contents = sacrotuberous ligament, sacrospinous ligament, pudendal nerve + internal pudendal artery
- Muscles associated with the anal triangle are:
  - Sphincter ani externus
  - Gluteus maximus
  - Obturator internus
  - Levator ani
  - Coccygeus

**The male reproductive tract**
- Testis (in scrotum) > vas deferens > spermatic cord (through superficial inguinal ring, inguinal canal + deep inguinal ring) > posterior bladder wall to ampulla of vas deferens in seminal vesicles > urethra (ejaculatory
ducts entry as well) > prostate > perineal membrane (with bulbourethral gland entry) > penis > glans (tip of penis)
- Testis: Spermatozoa produced in seminiferous tubule > rete testis > head of epididymis via efferent ductules > body of epididymis (spermatozoa stored here until ejaculation) > tail of epididymis > vas deferens

Penis
- The two corpus cavernosum run along the ischiopubic rami from the ischial tuberosity to the head of the penis, where they join and run superior + lateral (dorsal) to the corpus spongiosum + urethra
- The corpus spongiosum runs inferior to the perineal membrane overlying the bulbourethral gland in the deep perineal pouch; forms the bulb of the penis medially, then surrounds the urethra as it runs inferior (ventral) to the corpus cavernosum along the shaft of the penis
- The corpus spongiosum expands to form the head of the penis (=glans penis) over the distal ends of the corpus cavernosum

Blood supply
- Internal pudendal artery from internal iliac artery
- Deep artery – supplies corpora cavernosa
- Dorsal artery – supplies the skin and connective tissue
- Artery of bulb – bulb, corpus spongiosum, glans and urethra.
- Branches supplying the cavernous spaces are usually coiled – helicine arteries
- Parasympathetic stimulation causes helicine arteries to relax allowing blood flow

Nerves of the pelvis
- **Somatic:** Pudendal nerve (S2-S4)
  - Sensory - Dorsal nerve of penis –sensory to penile skin, glans
  - Motor – to perineal muscles bulbospongiosus and ischiocavernosus + external urethral sphincter causing ejaculation
- **Parasympathetic** – from S2-S4
  - Vasodilation of arterioles in erectile tissue (male & female)
  - Secretion in prostate, bulbourethral glands
- **Sympathetic** – from L1-L2
  - Contraction of smooth muscles of epididymis, vas deferens, seminal vesicles, prostate causing emission.
  - Contraction of internal urethral sphincter (in males) to prevent reflux of semen

Nerves of perineum
- Somatic nerves, mainly from sacral segments
- Most important nerve is Pudendal (S2-4)
- Supplies all perineal skeletal muscles
- Sensory to penis, lower urethra, lower rectum and anal canal
- The pudendal nerve leaves the pelvis from the lumbosacral plexus, passes briefly to the buttock (passing behind the sacrospinous ligament)
  - It passes posterior into the posterior perineum below the levator ani - It first enters the lateral wall of the ischioanal fossa, then branches to the anterior perineum, penis/clitoris + scrotum/vulva

Erection + ejaculation – neurovascular mechanism
1. **Erection** – central parasypathometic pathway activated by psychic stimulation
   - The pudendal artery/arterioles relax and allow blood flow into the cavernous spaces of erectile tissue
2. **Secretion** – stimulation of parasympathetic ganglia on the prostate, seminal vesicles/glands in females
3. **Emission** – central **sympathetic** pathway activated > smooth muscle contraction of vas deferens, prostate + seminal vesicles > entry of semen into urethra
   - Internal urethral sphincter in males contracts; bladder contraction is prevented by sympathetic action

4. **Ejaculation** – entry of semen into urethra triggers **somatic** reflex via pudendal nerve > contraction of bulbospongiosus muscle

5. **Detumescence** – selected **sympathetic** nerves supplying the pudendal arterioles are activated causing arteriolar constriction to restrict blood flow to cavernous spaces
Female pelvis + perineum
Anatomy of the abdomen + pelvis 9 – Dr M Tharavajah (m.tharavajah@imperial.ac.uk)

- Female pelvic organs = ovary, fallopian tubes, uterus, cervix, vagina, ureter, bladder, urethra, rectum, caecum + appendix (+ parts of sigmoid colon + ileum), as well as vessels, nerves + lymphatics
- Within the female pelvic cavity, there are organs from several systems in the boy. However there is no sharing of “passages” between these systems

Peritoneum + pelvic fascia

- The parietal peritoneum continues into the pelvic cavity, but does not reach the pelvic floor
- Uterine/fallopian tubes are completely enveloped by the peritoneum (forming the BROAD LIGAMENT – transverse mesenteries which join the uterus to the pelvic walls)
- Ovaries are suspended by mesovarium + are not fully enveloped but rather suspended by the posterior broad ligament
- Pelvic fascial condensations form further ligaments which support the pelvic viscera e.g. the cervix, vagina + prostate
  - Round ligament of uterus
  - Ligament of ovary
  - Suspensory ligament of ovary

Stability of the cervix + vagina

- There are 3 sets of fibrous bands = cervical ligaments which anchor the cervix + prevent prolapse through the vagina
  - Transverse cervical
  - Uterocervical
  - Pubocervical

The uterus + uterine tubes

- The uterus consists of a fundus, body, lower segment + cervix
- The uterine tubes consist of infundibulum, ampulla, isthmus + uterine parts
- The distal tubule opening is a potential communication point between the peritoneal cavity

Changes in uterus size in pregnancy: just after the 20th week, the uterine fundus should be at the level of the umbilicus, where it rises into the costal margin by 9 months, but then falls by the 10th. (this implies breathing difficulties late during pregnancy)
The cervix

- The cervix is a fibro-muscular “cylinder” with an internal and external sphincter
- The cervical canal is lined by mucus-secreting simple columnar epithelium. However the vaginal surface of the cervix is covered in stratified squamous epithelium (this is the epithelium used for smear test)
- The cervix projects into the anterior vaginal wall at right angles to the vaginal axis. It is held in position by strong cervical ligaments attached to the pelvis + sacrum.
  - The axis of the uterine body forms an acute angle to the angle of the vagina
- The angle between the axis of the cervix + axis of uterine body = angle of anteflexion
- The angle between the axis of the cervix + axis of the vagina = angle of antversion

The vagina

- Fibromuscular canal ~7-9cm long
- The internal end of the canal is enlarged to form a region called the vaginal vault
- The anterior wall of the vagina is related to the base of the bladder + is fused with the urethra
- Posteriorly, the vagina is related to the rectum
- Inferiorly, the vagina opens into the vestibule of the perineum immediately posterior to the external opening of the urethra.
- The vaginal fornix is the recess formed between the margin of the cervix and the vaginal wall

NB: structures palpable via the vaginal wall include the cervix, ishial spine, sacral promontory, uterine artery pulse + ovary

Arterial supply

- Main branches to the pelvic viscera are the superior vesicle, uterine + middle rectal artery (all branches of the internal iliac)
- The walls of the pelvis are supplied by sacral, gluteal + obturator branches (again branches of the internal iliac)
- The pudendal artery supplies the perineum + recto-anal region

The uterine artery
- Branch of the internal iliac artery
- Main blood supply to uterus. Enlarges during pregnancy
- Runs medially towards cervix
- Crosses ureter about 1 cm from cervix
- Uterine branch runs close to uterus in broad ligament
- Ascending branch supplies uterine tubes and ovary. (Ovary has ovarian artery from abdominal aorta)
- Descending branch supplies vagina

Female perineum

The superficial perineal structures
- Body, crus + glans of clitoris
- Ischiocavernosus muscle covering crus of clitoris
- Corpus spongiosum divides to cover 2 bulbs of vestibule

The deep perineal structures
- There are addition muscles not present in the male
- The vaginal opening with associated sphincter urethrovaginalis
- The compressor urethrae is also not present in males

Perineal spaces
- In the female, the posterior part of the corpus spongiosum forms 2 large vestibular bulbs surrounding the lower vestibule + vagina

NB: Nerve supply to pelvis same as male

Lymphatic drainage
- Pelvic organs drain mainly to external and internal iliac nodes (around the arteries)
- Ovary and testis drain to para-aortic nodes
- Perineum (including anal canal) and external genitalia drain to superficial inguinal nodes (subcutaneous below inguinal ligament).
Surface Landmarks of the Abdomen
Anatomy of the Abdomen & Pelvis – Dr M Thavarajah (m.thavarajah@imperial.ac.uk)

The 4 abdominal quadrants

The 9 abdominal regions
Vertebral Relations

Liver + Gall Bladder

Spleen

Lateral border of Erector spinae muscles
Clinical Scenarios
Anatomy of the Abdomen & Pelvis – Dr M Thavarajah (m.thavarajah@imperial.ac.uk)

CASE 1

- 22 yr old male
- Complaint: painless lump in groin
- Initial differentials for lump in groin: inguinal hernia, testicular lump, lymphadenopathy (enlarged inguinal lymph node), femoral hernia, epididymal cyst, testicular torsion
  - Significance of painless – unlikely to be femoral hernia or testicular torsion
  - Significance of age – unlikely to be femoral hernia
- O/E: lump is on one side of scrotum
  - Significance: confirms not femoral hernia as femoral hernia does not pass into scrotum, and lymphadenopathy unlikely as the superficial inguinal lymph nodes lie just inferior to the inguinal ligament
- Diagnosis: need to distinguish between inguinal hernia or testicular lump?
A herniated part of the abdominal contents would have come through the superficial inguinal ring, so you would be unable to “get above” the lump with your fingers when examining the scrotum. You can get above a lump in the testis.

- A small inguinal hernia can often be pushed back into the abdomen

**O/E:** superior surface of lump cannot be felt + easily manipulated into abdomen

**Diagnosis = Inguinal Hernia**

- **Indirect inguinal hernia** – passes through the length of the inguinal canal from the deep ring to the superficial ring. In young men it may be passing down a patent processus vaginalis. This is most likely in the patient.

- **Direct inguinal hernia** – breaks through a weak or damaged posterior wall of the inguinal canal to reach the superficial ring directly

**Differentiating between indirect + direct**

- Manipulate the hernia back into the abdomen.
- Compress the inguinal canal by light pressure medial to the mid-point of the inguinal ligament.
- Ask the patient to cough.
- This pressure will stop an indirect hernia from being pushed back through the superficial ring, but will not stop return of a direct hernia.

**O/E:** hernia is indirect – most likely (because of age) due to patent processus vaginalis

**Case 2**

- 65 yr old female
- Previous large bowel carcinoma
- Complaint: epigastric pain with posterior radiation, associated itching + weight loss (after eating)
- **O/E:** patient is jaundice (2 weeks)

**Causes of Jaundice**

- Jaundice is either classified as obstructive or non-obstructive
- Non-obstructive is rarer, and usually do to haematological disease e.g. affecting haemolysis of Hb
- Obstructive jaundice may be pre-hepatic, hepatic or post-hepatic (post-hepatic being more likely because of the association with pain after eating. The biliary tree is involved in the digestion of fats, therefore problem likely to involve biliary tree)

- Initial differentials: gall stones, cholangiocarcinoma, pancreatic tumour in head of pancreas (which is in close association with biliary tree)
- Due to the previous history of cancer, imaging is recommended. Conventional X-ray would be unlikely to give an image of adequate resolution + contrast, CT gives excellent resolution and contrast and is generally available, MRI could also have given good information, but is less widely + quickly available
- Imaging results: showed no evidence of secondary tumours in the liver or of recurrence of the colonic primary tumour. However, there was an abnormal enlargement of the head of the pancreas.

  - How could this account for Ms Buller’s jaundice?
    - The bile duct passes from the free edge of the lesser omentum posterior to the 1st part of the duodenum then posterior to the head of the pancreas to enter the 2nd part of the duodenum.
    - Enlargement of the head of the pancreas would compress the bile duct and cause post-hepatic (obstructive) jaundice.

  - How does it relate to the previous cancer of the colon?
    - There is no likely anatomical route by which a colonic carcinoma could produce a secondary tumour in the head of the pancreas.
    - This is likely to be a new pancreatic problem. It could be an inflammatory disease of the pancreas (pancreatitis) but is quite likely to be carcinoma of the head of the pancreas.
DIAGNOSIS = PANCREATIC CARCINOMA

- The pancreatic head is in close contact with the bile duct, duodenum, portal vein, superior mesenteric artery, aorta and IVC, so removal of a malignant invasive tumour at this site is difficult or impossible.

- Lymph drainage of the head of the pancreas follows the multiple arterial supplies to the pancreas so many groups of local and regional lymph nodes are likely to be involved.

- Pancreatic venous blood drains via the portal vein to the liver; early metastasis by this route is common.