4
Abdomen

Conceptual overview
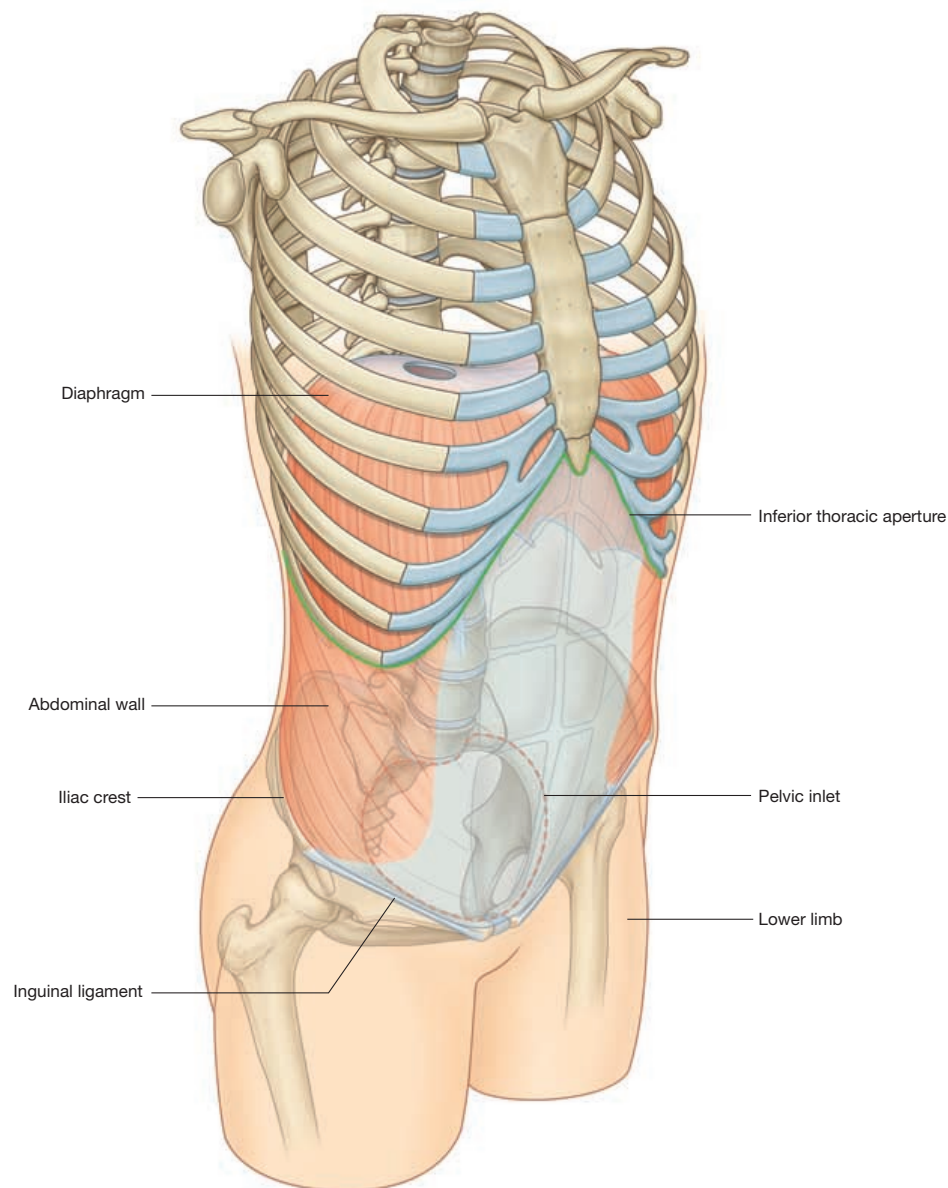
GENERAL DESCRIPTION

The abdomen is a roughly cylindrical chamber extending from the inferior margin of the thorax to the superior margin of the pelvis and the lower limb (Fig. 4.1A).
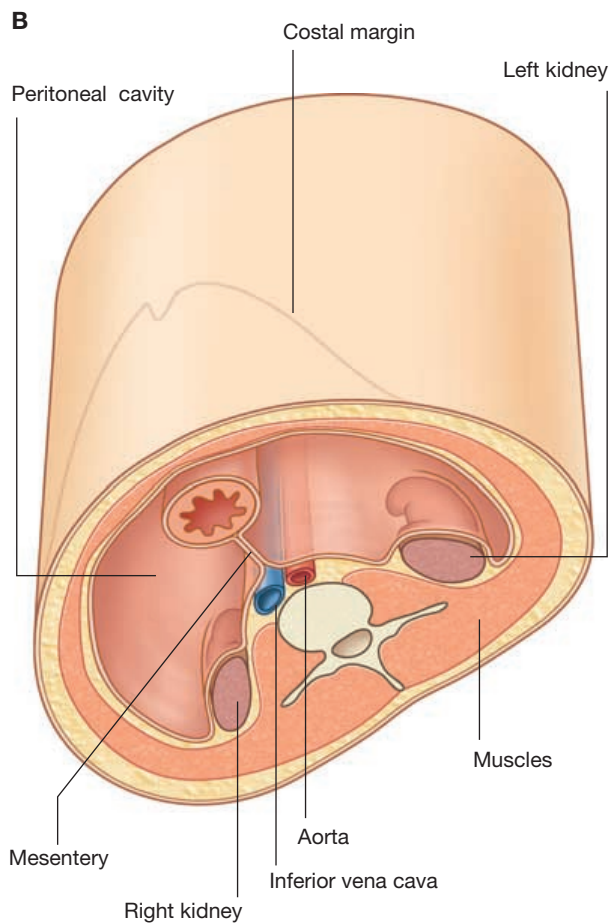
The **inferior thoracic aperture** forms the superior opening to the abdomen, and is closed by the diaphragm. Inferiorly, the deep abdominal wall is continuous with the pelvic wall at the **pelvic inlet**. Superficially, the inferior limit of the abdominal wall is the superior margin of the lower limb.

The chamber enclosed by the abdominal wall contains a single large **peritoneal cavity**, which freely communicates with the pelvic cavity.

A

Diaphragm

Inferior thoracic aperture

Abdominal wall

Iliac crest

Pelvic inlet

Lower limb

Inguinal ligament

Fig. 4.1 Abdomen. **A.** Boundaries.

B

Costal margin

Left kidney

Peritoneal cavity

Muscles

Mesentery

Aorta

Inferior vena cava

Right kidney

Fig. 4.1, cont'd. Abdomen. **B.** Arrangement of abdominal contents. Inferior view.

Abdominal viscera are either suspended in the peritoneal cavity by mesenteries or are positioned between the cavity and the musculoskeletal wall (Fig. 4.1B).

Abdominal viscera include:

- major elements of the gastrointestinal system—the caudal end of the esophagus, stomach, small and large intestines, liver, pancreas, and gallbladder;
- the spleen;
- components of the urinary system—kidneys and ureters;
- the suprarenal glands;
- major neurovascular structures.

## FUNCTIONS

Houses and protects major viscera

The abdomen houses major elements of the gastrointestinal system (Fig. 4.2), as well as the spleen and parts of the urinary system.

Much of the liver, gallbladder, stomach, and spleen, and parts of the colon are under the domes of the diaphragm, which project superiorly above the costal margin of the thoracic wall, and as a result these abdominal viscera are protected by the thoracic wall. The superior poles of the kidneys are deep to the lower ribs.

Viscera not under the domes of the diaphragm are supported and protected predominantly by the muscular walls of the abdomen.
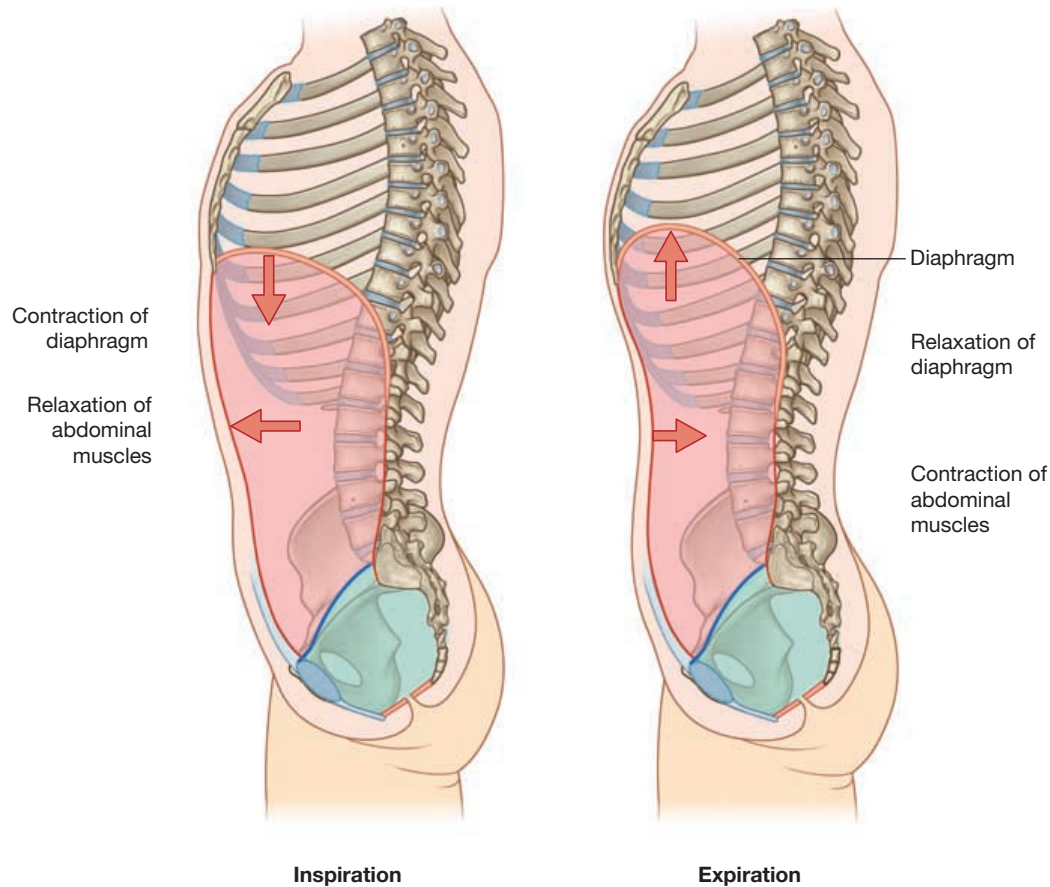
Abdomen

Rib cage

Costal margin

Spleen

Liver

Stomach

Colon

Small intestine
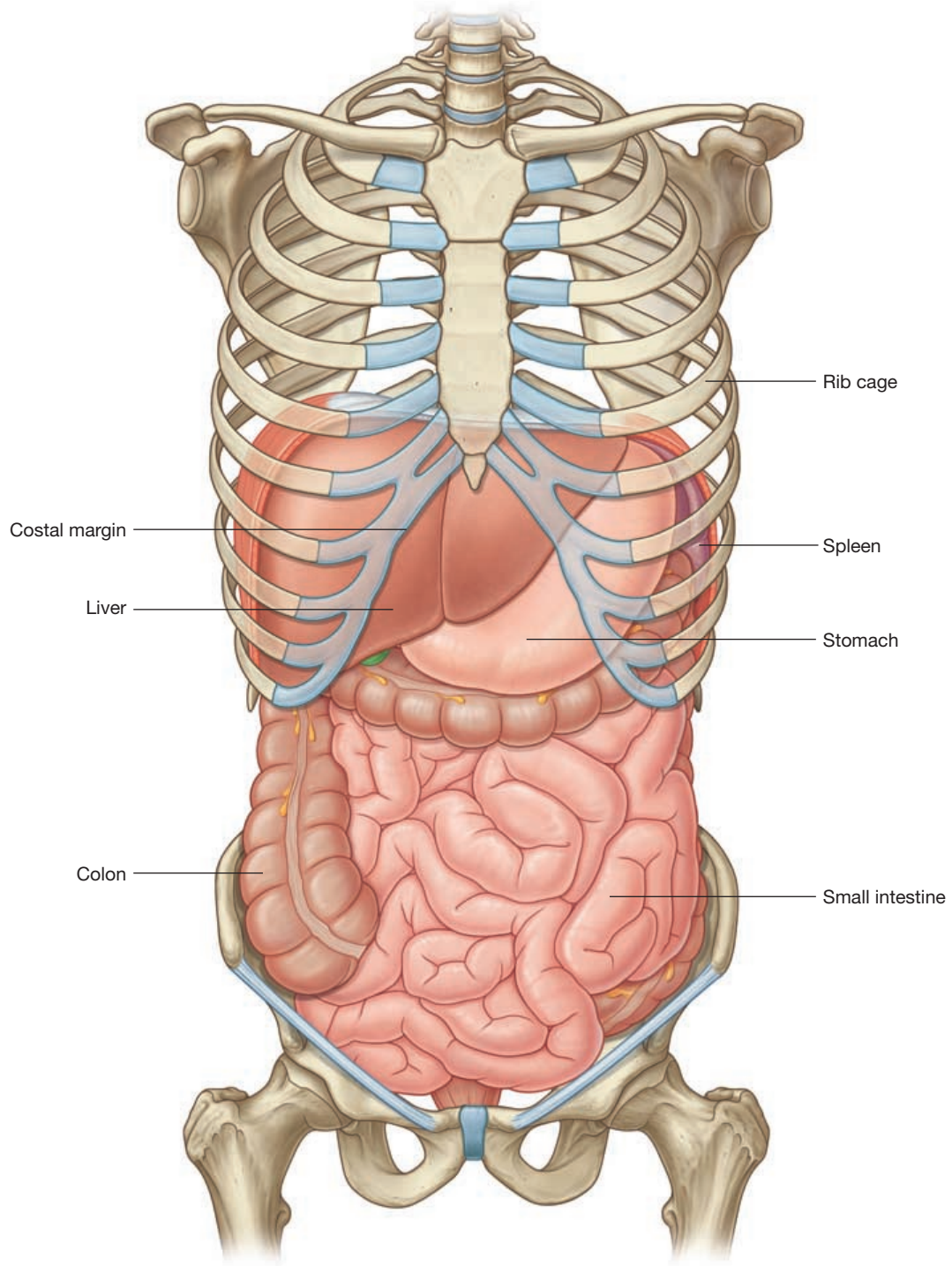
Fig. 4.2 The abdomen contains and protects the abdominal viscera.

Contraction of diaphragm

Relaxation of abdominal muscles

Diaphragm

Relaxation of diaphragm

Contraction of abdominal muscles

Inspiration

Expiration

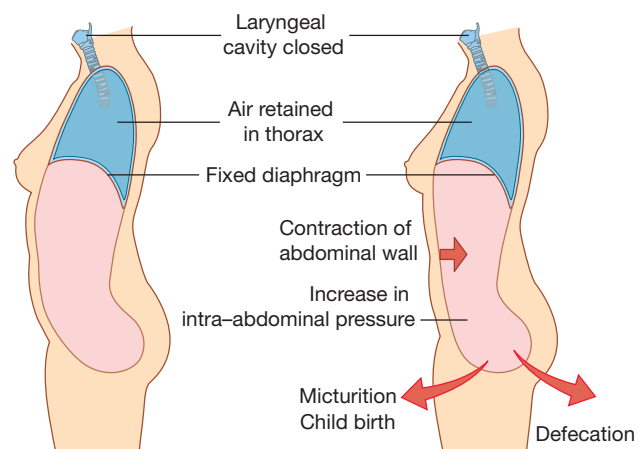**Fig. 4.3** The abdomen assists in breathing.

Breathing

One of the most important roles of the abdominal wall is to assist in breathing:

- it relaxes during inspiration to accommodate expansion of the thoracic cavity and the inferior displacement of abdominal viscera during contraction of the diaphragm (Fig. 4.3);
- during expiration, it contracts to assist in elevating the domes of the diaphragm thus reducing thoracic volume.

Material can be expelled from the airway by forced expiration using the abdominal muscles, as in coughing or sneezing.

Changes in intra-abdominal pressure

Contraction of abdominal wall muscles can dramatically increase intra-abdominal pressure when the diaphragm is

Laryngeal cavity closed

Air retained in thorax

Fixed diaphragm

Contraction of abdominal wall

Increase in intra–abdominal pressure

Micturition Child birth

Defecation

Fig. 4.4 Increasing intra-abdominal pressure to assist in micturition, defecation, and child birth.

in a fixed position (Fig. 4.4). Air is retained in the lungs by closing valves in the larynx of the neck. Increased intra-abdominal pressure assists in voiding the contents of the bladder and rectum and in giving birth.

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Abdomen

COMPONENT PARTS

Wall

The abdominal wall consists partly of bone but mainly of muscle (Fig. 4.5). The skeletal elements of the wall (Fig. 4.5A) are:

- the five lumbar vertebrae and their intervening intervertebral discs;
- the superior expanded parts of the pelvic bones;
- bony components of the inferior thoracic wall including the costal margin, rib XII, the end of rib XI and the xiphoid process

Muscles make up the rest of the abdominal wall (Fig. 4.5B):

- lateral to the vertebral column, the quadratus lumborum, psoas major, and iliacus muscles reinforce the posterior aspect of the wall—the distal ends of the psoas and iliacus muscles pass into the thigh and are major flexors of the hip joint;
- lateral parts of the abdominal wall are predominantly formed by three layers of muscles, which are similar in orientation to the intercostal muscles of the thorax—transversus abdominis, internal oblique, and external oblique;
- anteriorly, a segmented muscle (the rectus abdominis) on each side spans the distance between the inferior thoracic wall and the pelvis.

Structural continuity between posterior, lateral, and anterior parts of the abdominal wall is provided by thick


Fig. 4.5 Abdominal wall. **A.** Skeletal elements. **B.** Muscles.
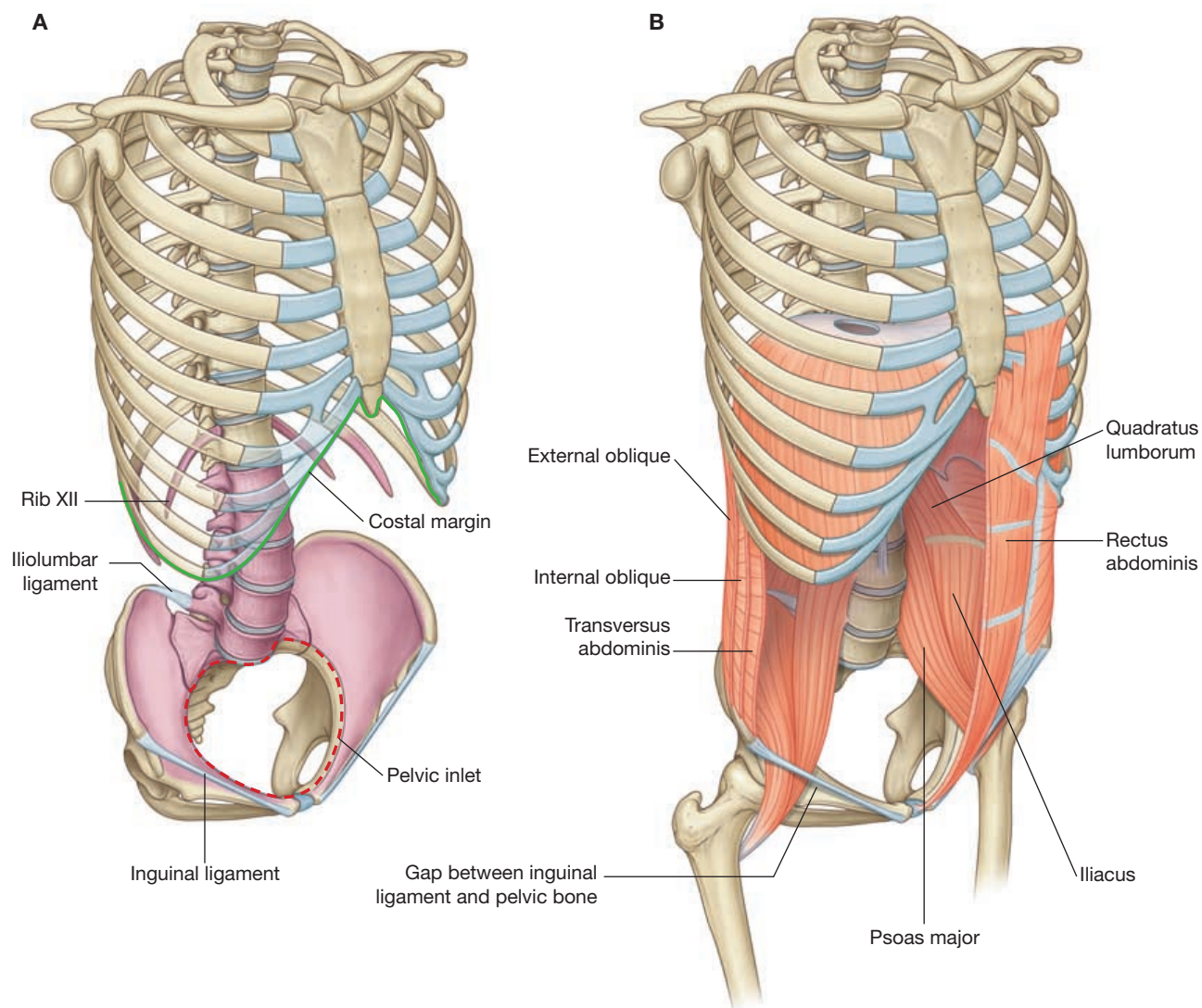
fascia posteriorly and by flat tendinous sheets (aponeu-roses) derived from muscles of the lateral wall. A fascial layer of varying thickness separates the abdominal wall from the peritoneum, which lines the abdominal cavity.

Abdominal cavity

The general organization of the abdominal cavity is one in which a central gut tube (gastrointestinal system) is sus-pended from the posterior abdominal wall and partly from the anterior abdominal wall by thin sheets of tissue (**mesenteries**; Fig. 4.6):

- a ventral (anterior) mesentery for proximal regions of the gut tube;
- a dorsal (posterior) mesentery along the entire length of the system.

Different parts of these two mesenteries are named according to the organs they suspend or with which they are associated.
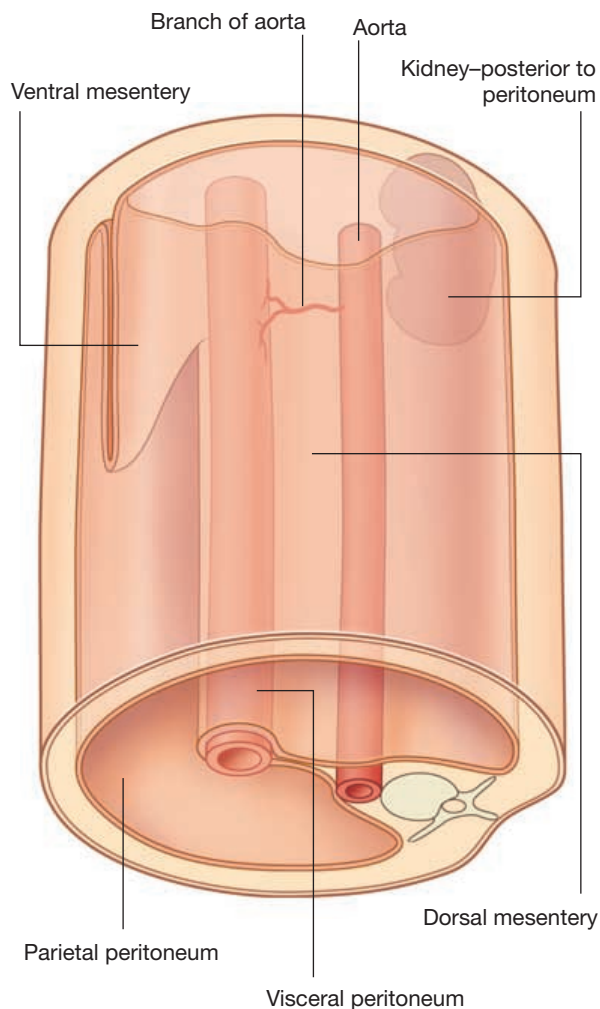
Fig. 4.6 The gut tube is suspended by mesenteries.

Major viscera, such as the kidneys, that are not sus-pended in the abdominal cavity by mesenteries are associ-ated with the abdominal wall.

The abdominal cavity is lined by **peritoneum**, which consists of an epithelial-like single layer of cells, (the **mesothelium**) together with a supportive layer of con-nective tissue. Peritoneum is similar to the pleura and serous pericardium in the thorax.

The peritoneum reflects off the abdominal wall to become a component of the mesenteries that suspend the viscera:

- **parietal peritoneum** lines the abdominal wall;
- **visceral peritoneum** covers suspended organs.

Normally, elements of the gastrointestinal tract and its derivatives completely fill the abdominal cavity, making the peritoneal cavity a potential space, and visceral peri-toneum on organs and parietal peritoneum on the adja-cent abdominal wall slide freely against one another.

Abdominal viscera are either intraperitoneal or retroperitoneal:

- **intraperitoneal** structures, such as elements of the gastrointestinal system, are suspended from the abdominal wall by mesenteries;
- structures that are not suspended in the abdominal cavity by a mesentery and that lie between the parietal peritoneum and abdominal wall are **retroperitoneal** in position.

Retroperitoneal structures include the kidneys and ureters, which develop in the region between the peri-toneum and the abdominal wall and remain in this posi-tion in the adult.
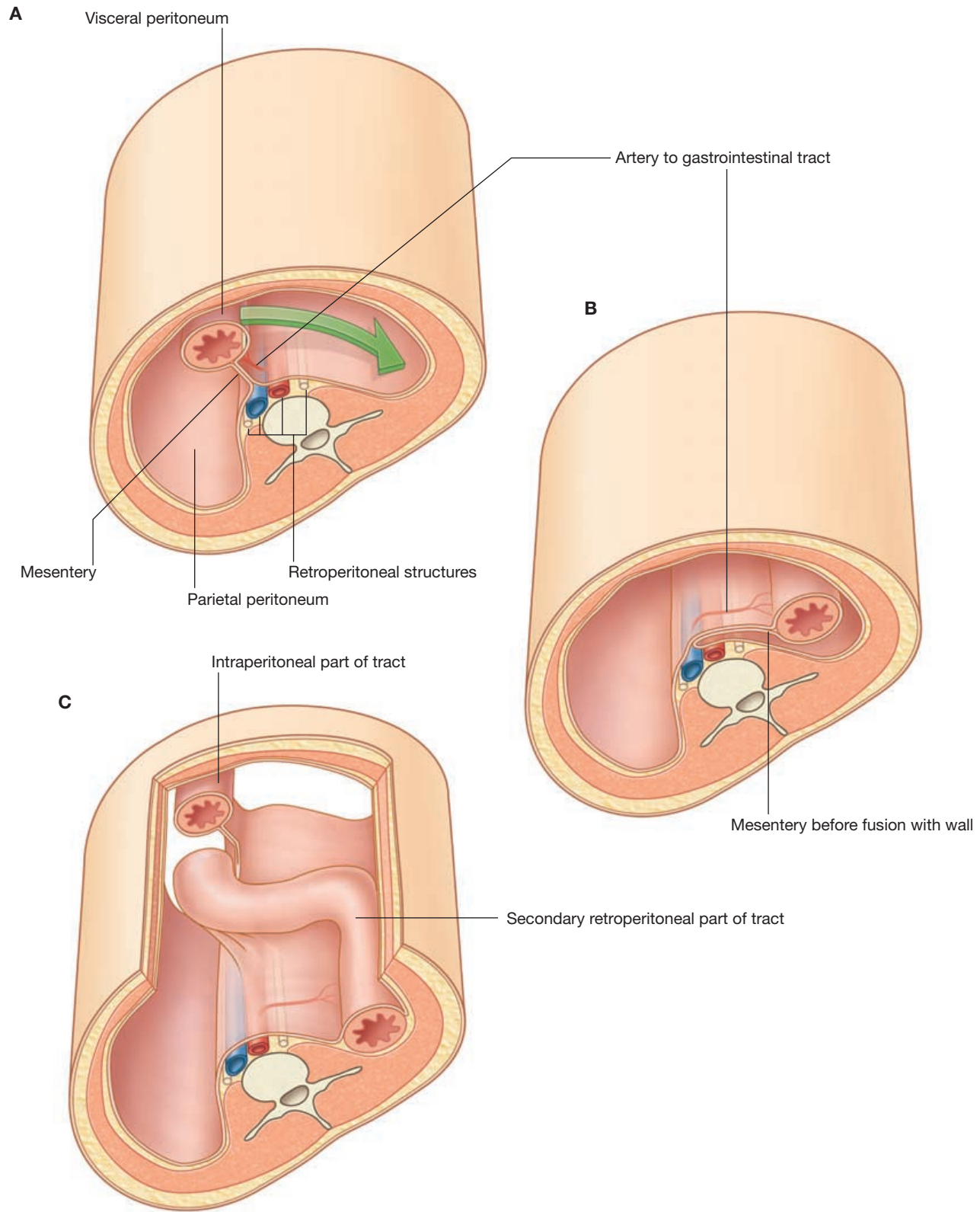
During development, some organs, such as parts of the small and large intestines, are suspended initially in the abdominal cavity by a mesentery, and later become retroperitoneal secondarily by fusing with the abdominal wall (Fig. 4.7).

Large vessels, nerves, and lymphatics are associated with the posterior abdominal wall along the median axis of the body in the region where, during development, the peritoneum reflects off the wall as the dorsal mesentery, which supports the developing gut tube. As a consequence, branches of the neurovascular structures that pass to parts of the gastrointestinal system are unpaired, originate from the anterior aspects of their parent structures, and travel in mesenteries or pass retroperitoneally in areas where the mesenteries secondarily fuse to the wall.

Generally, vessels, nerves, and lymphatics to the abdom-inal wall and to organs that originate as retroperitoneal structures branch laterally from the central neurovascular structures and are usually paired, one on each side.

Abdomen

A

Visceral peritoneum

Artery to gastrointestinal tract

B

Mesentery

Parietal peritoneum

Retroperitoneal structures

Intraperitoneal part of tract

C

Mesentery before fusion with wall

Secondary retroperitoneal part of tract

Fig. 4.7 A series showing the progression (**A** to **C**) from an intraperitoneal organ to a secondarily retroperitoneal organ.

Inferior thoracic aperture

The superior aperture of the abdomen is the inferior thoracic aperture, which is closed by the diaphragm (see p. 000). The margin of the inferior thoracic aperture consists of vertebra TXII, rib XII, the distal end of rib XI, the costal margin, and the xiphoid process of the sternum.
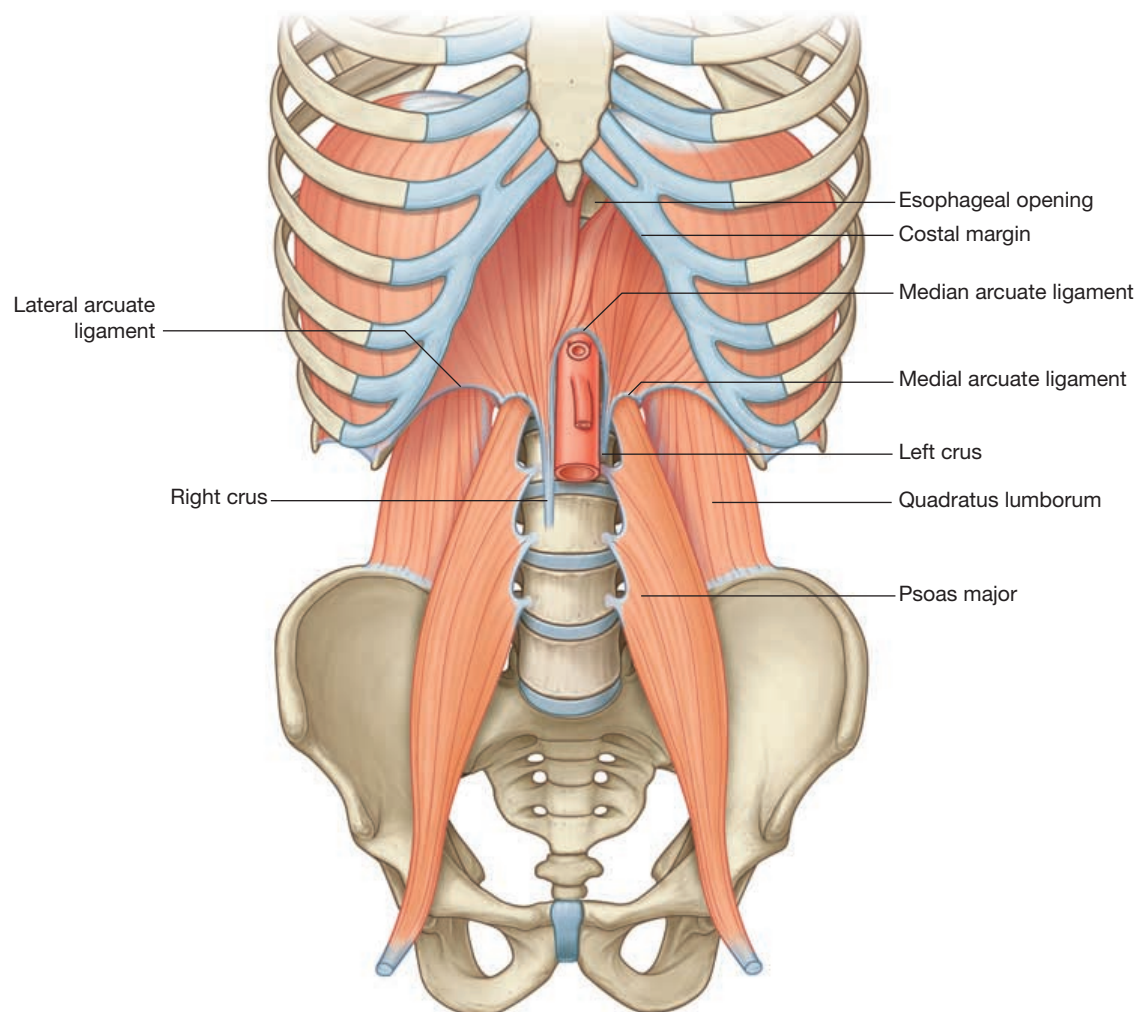
Diaphragm

The musculotendinous diaphragm separates the abdomen from the thorax.

The diaphragm attaches to the margin of the inferior thoracic aperture, but the attachment is complex posteriorly and extends into the lumbar area of the vertebral column (Fig. 4.8). On each side, a muscular extension (crus) firmly anchors the diaphragm to the anterolateral surface of the vertebral column as far down as vertebra LIII on the right and vertebra LII on the left.

Because the costal margin is not complete posteriorly, the diaphragm is anchored to arch-shaped (arcuate) ligaments, which span the distance between available bony points and the intervening soft tissues;

- **medial** and **lateral arcuate ligaments** cross muscles of the posterior abdominal wall and attach to vertebrae, the transverse processes of vertebra LI and rib XII, respectively;
- a **median arcuate ligament** crosses the aorta and is continuous with the crus on each side.

The posterior attachment of the diaphragm extends much further inferiorly than the anterior attachment. Consequently, the diaphragm is an important component of the posterior abdominal wall, to which a number of viscera are related.

Esophageal opening
Costal margin
Median arcuate ligament
Medial arcuate ligament
Left crus
Quadratus lumborum
Psoas major
Lateral arcuate ligament
Right crus

Fig. 4.8 Inferior thoracic aperture and the diaphragm.

Abdomen

Pelvic inlet

The abdominal wall is continuous with the pelvic wall at the pelvic inlet, and the abdominal cavity is continuous with the pelvic cavity.

The circular margin of the pelvic inlet is formed entirely by bone:

- posteriorly by the sacrum;
- anteriorly by the pubic symphysis;
- laterally, on each side, by a distinct bony rim on the pelvic bone (Fig. 4.9).

Because of the way in which the sacrum and attached pelvic bones are angled posteriorly on the vertebral column, the pelvic cavity is not oriented in the same vertical plane as the abdominal cavity. Instead, the pelvic cavity projects posteriorly, and the inlet opens anteriorly and somewhat superiorly (Fig. 4.10).

RELATIONSHIP TO OTHER REGIONS

Thorax

The abdomen is separated from the thorax by the diaphragm. Structures pass between the two regions through or posterior to the diaphragm (see Fig. 4.8).
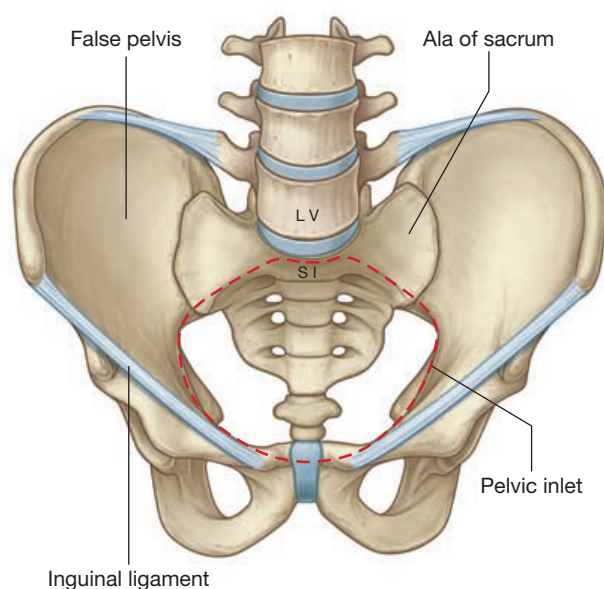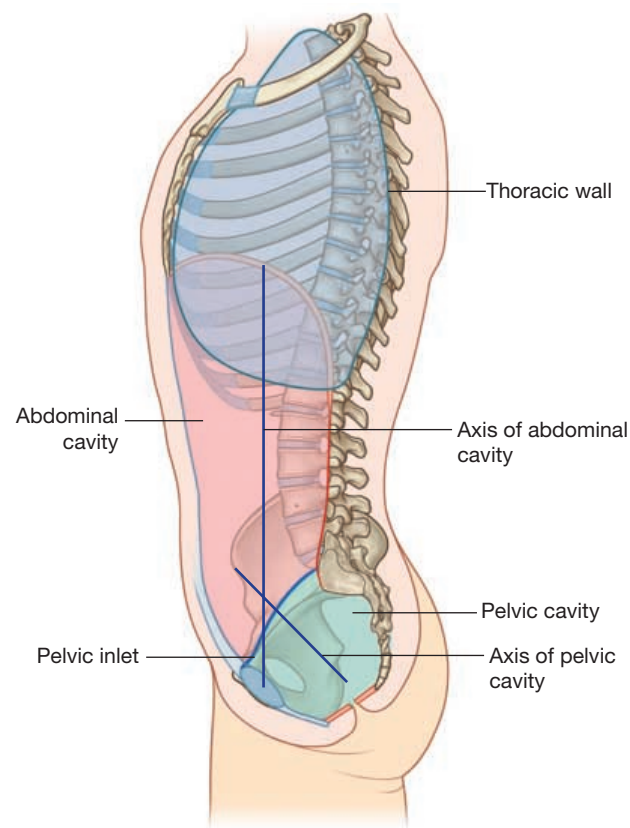
Pelvis

The pelvic inlet opens directly into the abdomen and structures pass between the abdomen and pelvis through it.

The peritoneum lining the abdominal cavity is continuous with the peritoneum in the pelvis. Consequently, the abdominal cavity is entirely continuous with the pelvic cavity (Fig. 4.11). *Infections in one region can therefore freely spread into the other.*

The bladder expands superiorly from the pelvic cavity into the abdominal cavity and, during pregnancy, the uterus expands freely superiorly out of the pelvic cavity into the abdominal cavity.

Fig. 4.9 Pelvic inlet.

**Fig. 4.10** Orientation of abdominal and pelvic cavities.

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Lower limb

The abdomen communicates directly with the thigh through an aperture formed anteriorly between the inferior margin of the abdominal wall (marked by the inguinal ligament) and the pelvic bone (Fig. 4.12). Structures that pass through this aperture are:

- the major artery and vein of the lower limb;

- the femoral nerve, which innervates the quadriceps femoris muscle, which extends the knee;
- lymphatics;
- the distal ends of psoas major and iliacus muscles, which flex the thigh at the hip joint.

As vessels pass inferior to the inguinal ligament, their names change—the external iliac artery and vein of the abdomen become the femoral artery and vein of the thigh.
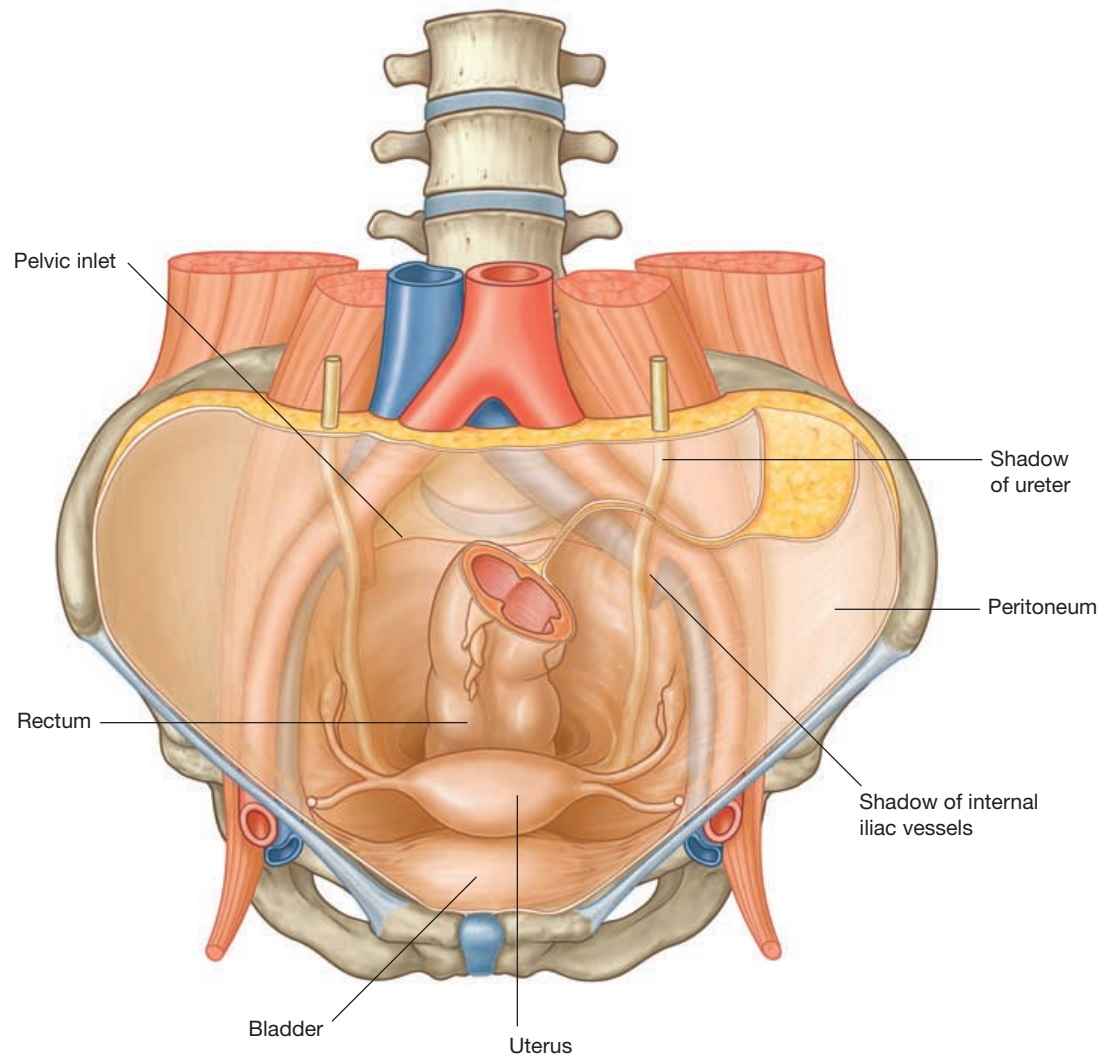
Fig. 4.11 The abdominal cavity is continuous with the pelvic cavity.

Abdomen

KEY FEATURES

Arrangement of abdominal viscera in the adult

A basic knowledge of the development of the gastrointestinal tract is needed to understand the arrangement of viscera and mesenteries in the abdomen (Fig. 4.13).

The early gastrointestinal tract is oriented longitudinally in the body cavity and is suspended from surrounding walls by a large dorsal mesentery and a much smaller ventral mesentery.

Superiorly, the dorsal and ventral mesenteries are anchored to the diaphragm.

The primitive gut tube consists of the foregut, the midgut, and the hindgut. Massive longitudinal growth of the gut tube, rotation of selected parts of the tube, and secondary fusion of some viscera and their associated mesenteries to the body wall participate in generating the adult arrangement of abdominal organs.

Development of the foregut

In abdominal regions, the **foregut** gives rise to the distal end of the esophagus, the stomach, and the proximal part of the duodenum. The foregut is the only part of the gut tube suspended from the wall both by the ventral and dorsal mesenteries.

A diverticulum from the anterior aspect of the foregut grows into the ventral mesentery, giving rise to the liver and gallbladder, and ultimately, to the ventral part of the pancreas.

The dorsal part of the pancreas develops from an outgrowth of the foregut into the dorsal mesentery. The spleen develops in the dorsal mesentery in the region between the body wall and presumptive stomach.

In the foregut, the developing stomach rotates clockwise and the associated dorsal mesentery, containing the spleen, moves to the left and greatly expands. During this process, part of the mesentery becomes associated with, and secondarily fuses with, the left side of the body wall.

At the same time, the duodenum, together with its dorsal mesentery and an appreciable part of the pancreas, swings to the right and fuses to the body wall.

Secondary fusion of the duodenum to the body wall, massive growth of the liver in the ventral mesentery, and fusion of the superior surface of the liver to the diaphragm restricts
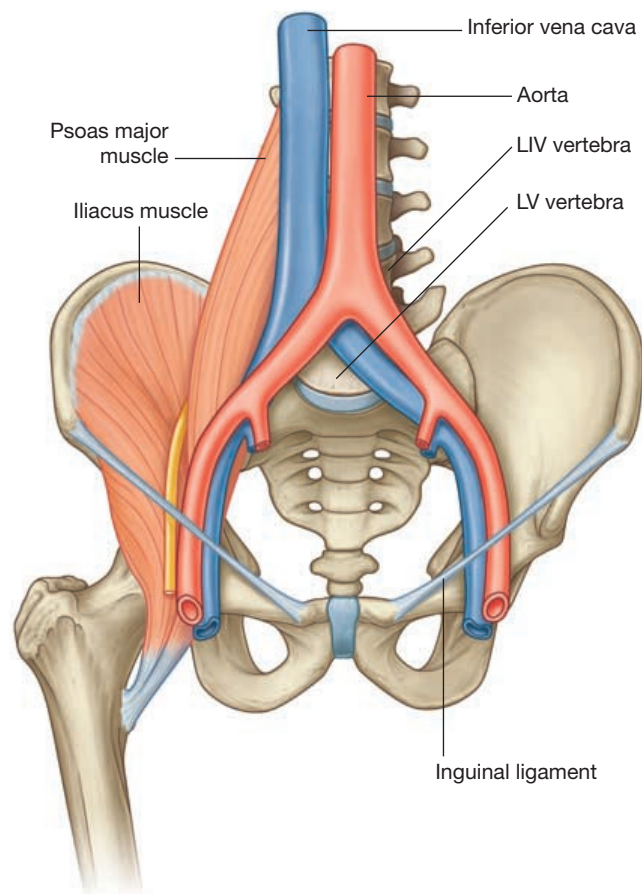

Fig. 4.12 Structures passing between the abdomen and thigh.

the opening to the space enclosed by the ballooned dorsal mesentery associated with the stomach. This restricted opening is the **omental foramen** (**epiploic foramen**).

The part of the abdominal cavity enclosed by the expanded dorsal mesentery, and posterior to the stomach, is the **omental bursa** (**lesser sac**). Access, through the omental foramen to this space from the rest of the peritoneal cavity (**greater sac**) is inferior to the free edge of the ventral mesentery.

Part of the dorsal mesentery that initially forms part of the lesser sac greatly enlarges in an inferior direction, and the two opposing surfaces of the mesentery fuse to form an apron-like structure (the **greater omentum**). The greater omentum is suspended from the greater curvature of the stomach, lies over other viscera in the abdominal cavity, and is the first structure observed when the abdominal cavity is opened anteriorly.
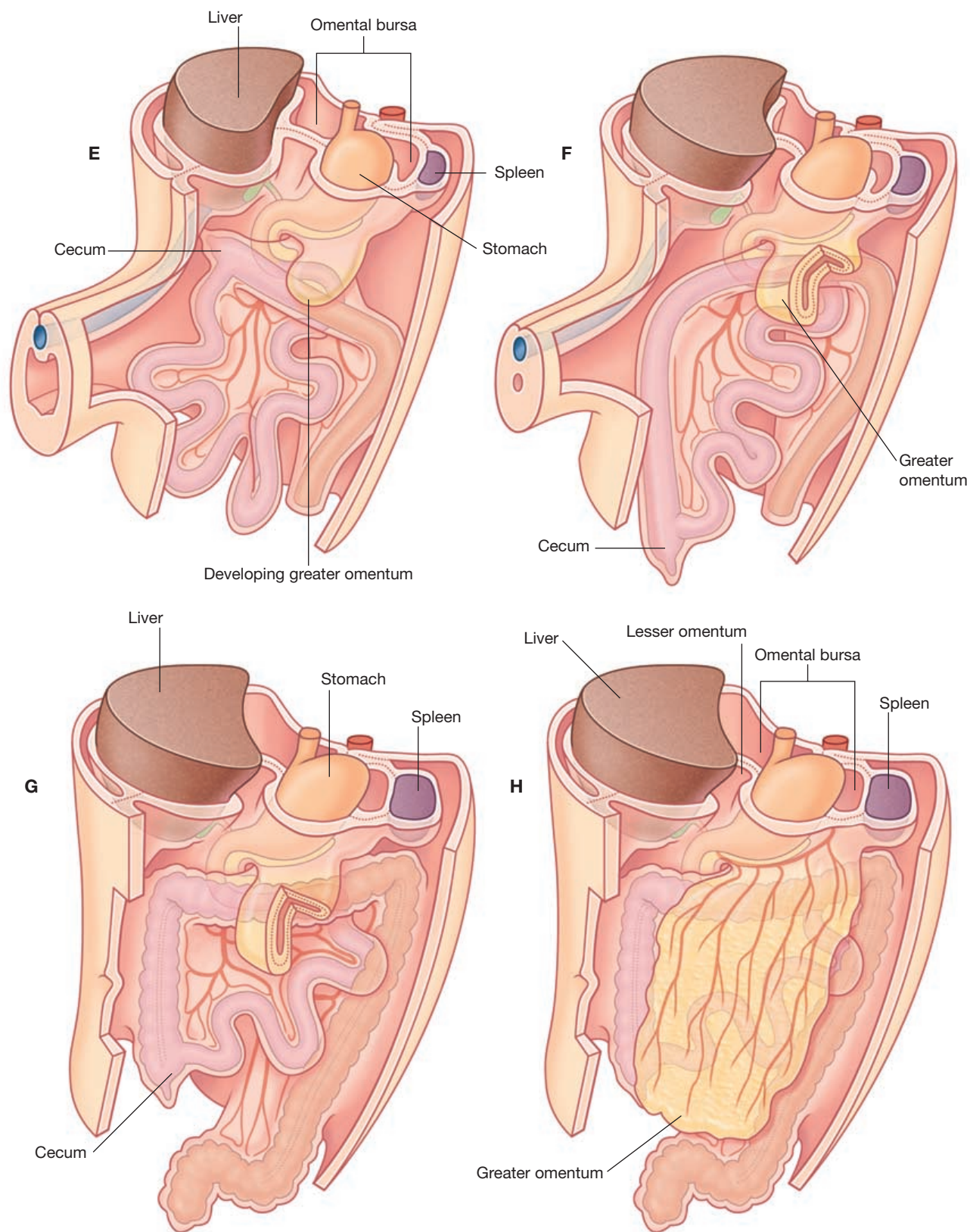
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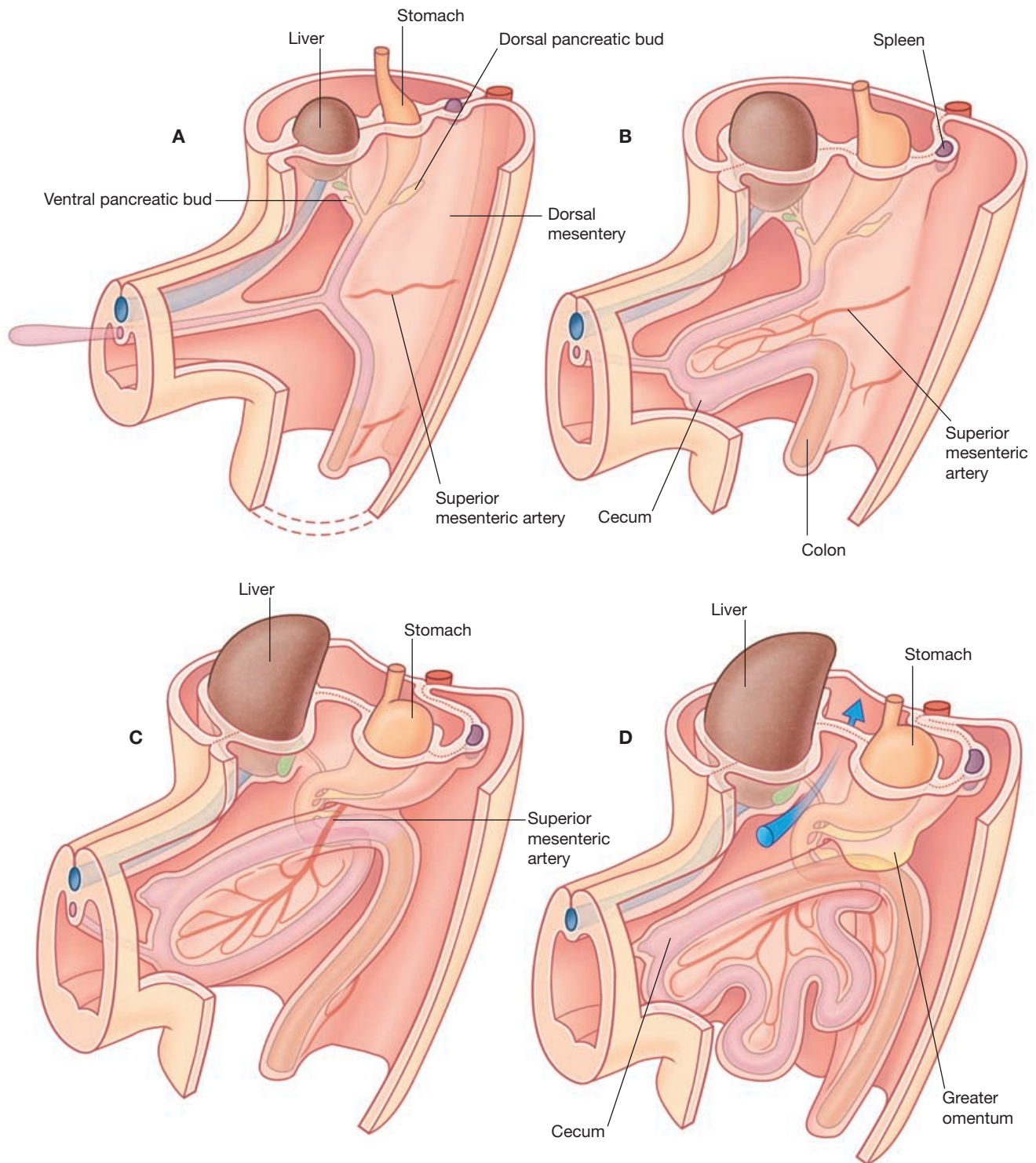
Fig. 4.13 A series (**A** to **H**) showing the development of the gut and mesenteries.

Continued

Abdomen

Fig. 4.13, cont'd A series (**A** to **H**) showing the development of the gut and mesenteries.

Development of the midgut

The midgut develops into the distal part of the duodenum, the jejunum, ileum, ascending colon, and proximal two-thirds of the transverse colon. A small yolk sac projects anteriorly from the developing midgut into the umbilicus.

Rapid growth of the gastrointestinal system results in a loop of the midgut herniating out of the abdominal cavity and into the umbilical cord. As the body grows in size and the connection with the yolk sac is lost, the midgut returns to the abdominal cavity. While this process is occurring, the two limbs of the midgut loop rotate counterclockwise around their combined central axis, and the part of the loop that becomes the cecum descends into the inferior right aspect of the cavity.

The cecum remains intraperitoneal, the ascending colon fuses with the body wall becoming secondarily retroperitoneal, and the transverse colon remains suspended by its dorsal mesentery (transverse mesocolon). The greater omentum hangs over the transverse colon and the mesocolon and usually fuses with these structures.

Hindgut

The distal one-third of the transverse colon, descending colon, sigmoid colon, and the superior part of rectum develop from the hindgut.

Proximal parts of the hindgut swing to the right and become the descending colon and sigmoid colon. The descending colon and its dorsal mesentery fuse to the body wall, while the sigmoid colon remains intraperitoneal. The sigmoid colon passes through the pelvic inlet and is continuous with the rectum at the level of vertebra SIII.

Skin and muscles of the anterior and lateral abdominal wall and thoracic intercostal nerves

The anterior rami of thoracic spinal nerves T7 to T12 follow the inferior slope of the lateral parts of the ribs and cross the costal margin to enter the abdominal wall (Fig. 4.14). Intercostal nerves T7 to T11 supply skin and muscle of the abdominal wall, as does the subcostal nerve T12. In addi-
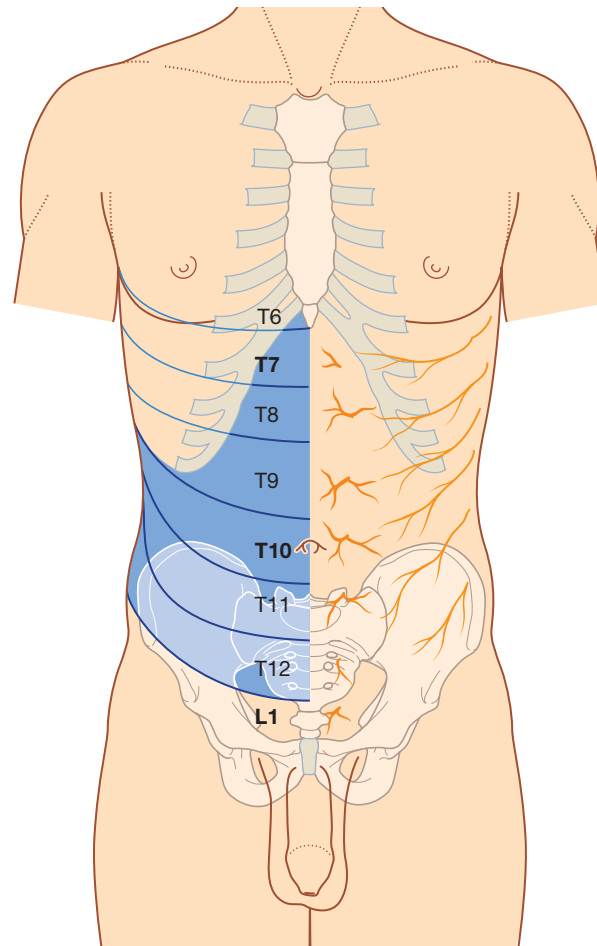
Fig. 4.14 Innervation of the anterior abdominal wall.

tion, T5 and T6 supply upper parts of the external oblique muscle of the abdominal wall; T6 also supplies cutaneous innervation to skin over the xiphoid.

Skin and muscle in the inguinal and suprapubic regions of the abdominal wall are innervated by L1 and not by thoracic nerves.

Dermatomes of the anterior abdominal wall are indicated in Figure 4.14. In the midline, skin over the infrasternal angle is T6 and that around the umbilicus is T10. L1 innervates skin in the inguinal and suprapubic regions.

Muscles of the abdominal wall are innervated segmentally in patterns that generally reflect the patterns of the overlying dermatomes.

Abdomen

The groin is a weak area in the anterior abdominal wall

During development, the gonads in both sexes descend from their sites of origin on the posterior abdominal wall into the pelvic cavity in women and the developing scrotum in men (Fig. 4.15).

Before descent, a cord of tissue (the **gubernaculum**) passes through the anterior abdominal wall and connects the inferior pole of each gonad with primordia of the scrotum in men and the labia majora in women (labioscrotal swellings).

A tubular extension (the **processus vaginalis**) of the peritoneal cavity and the accompanying muscular layers of the anterior abdominal wall project along the gubernaculum on each side into the labioscrotal swellings.

In men, the testis, together with its neurovascular structures and its efferent duct (the ductus deferens) descends into the scrotum alo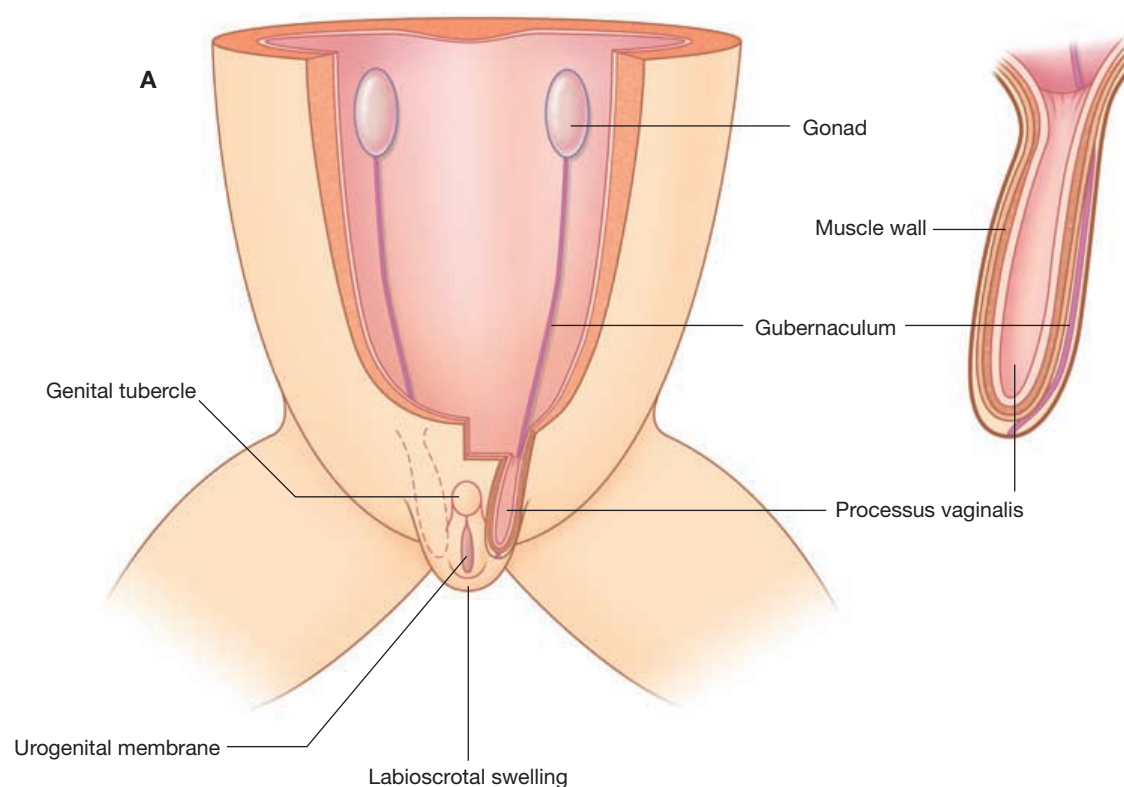ng a path, initially defined by the gubernaculum, between the processus vaginalis and the accompanying coverings derived from the abdominal wall.

The **inguinal canal** is the passage through the anterior abdominal wall created by the processus vaginalis. The **spermatic cord** is the tubular extension of the layers of the abdominal wall into the scrotum that contains all structures passing between the testis and the abdomen.

The distal sac-like terminal end of the spermatic cord on each side contains the testis, associated structures, and the now isolated part of the peritoneal cavity (the cavity of the tunica vaginalis).

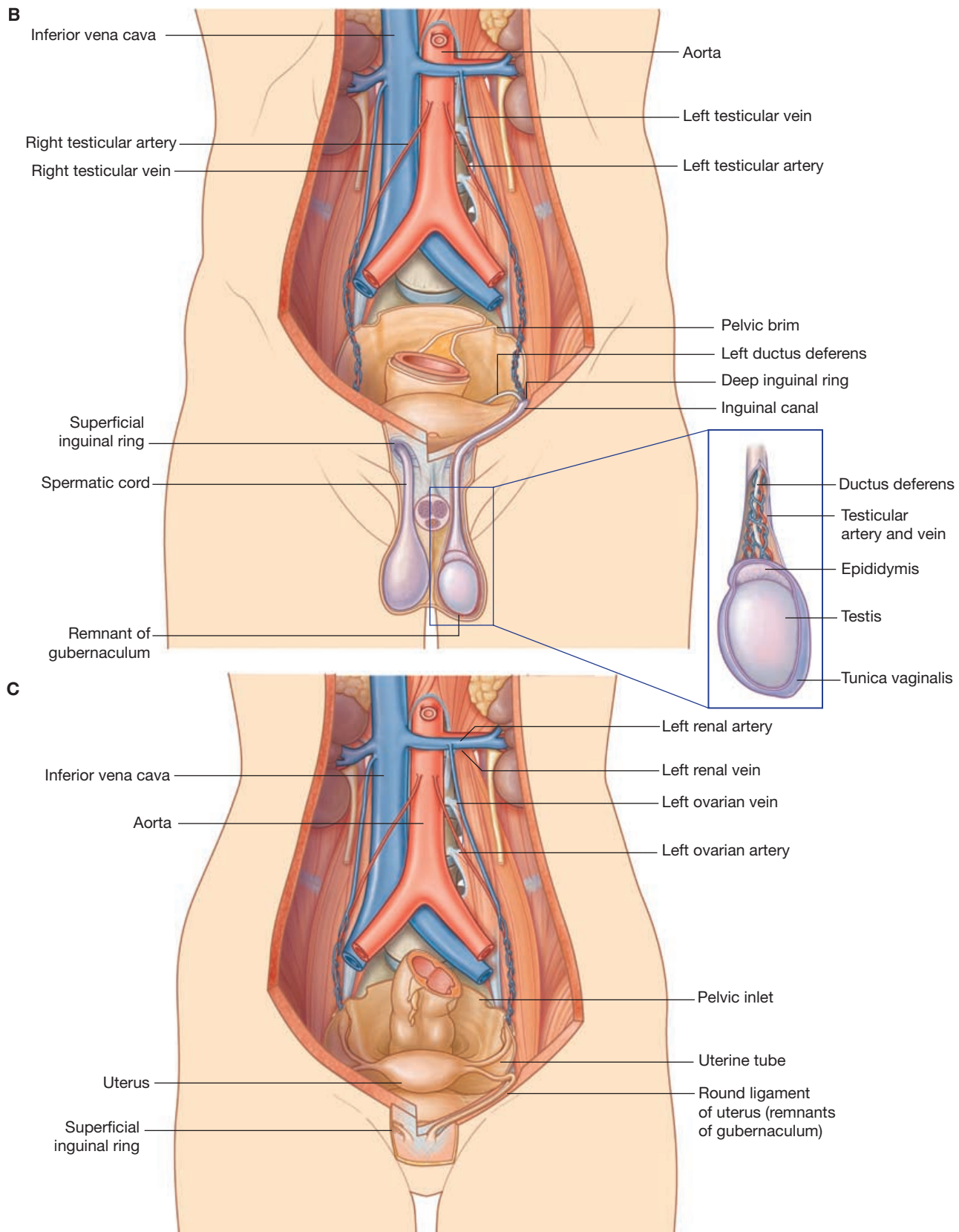In women, the gonads descend to a position just inside the pelvic cavity and never pass through the anterior abdominal wall. As a result, the only major structure passing through the inguinal canal is a derivative of the gubernaculum (the round ligament of uterus).

In both men and women, the groin (inguinal region) is a weak area in the abdominal wall (Fig. 4.15).

Fig. 4.15 Inguinal region. **A.** Development.

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B

Inferior vena cava

Aorta

Left testicular vein

Right testicular artery

Left testicular artery

Right testicular vein

Pelvic brim

Left ductus deferens

Deep inguinal ring

Inguinal canal

Superficial inguinal ring

Spermatic cord

Ductus deferens

Testicular artery and vein

Epididymis

Testis

Remnant of gubernaculum

Tunica vaginalis

C

Left renal artery

Left renal vein

Inferior vena cava

Left ovarian vein

Aorta

Left ovarian artery

Pelvic inlet

Uterine tube

Uterus

Round ligament of uterus (remnants of gubernaculum)

Superficial inguinal ring

Fig. 4.15, cont'd Inguinal region. **B.** In men. **C.** In women.
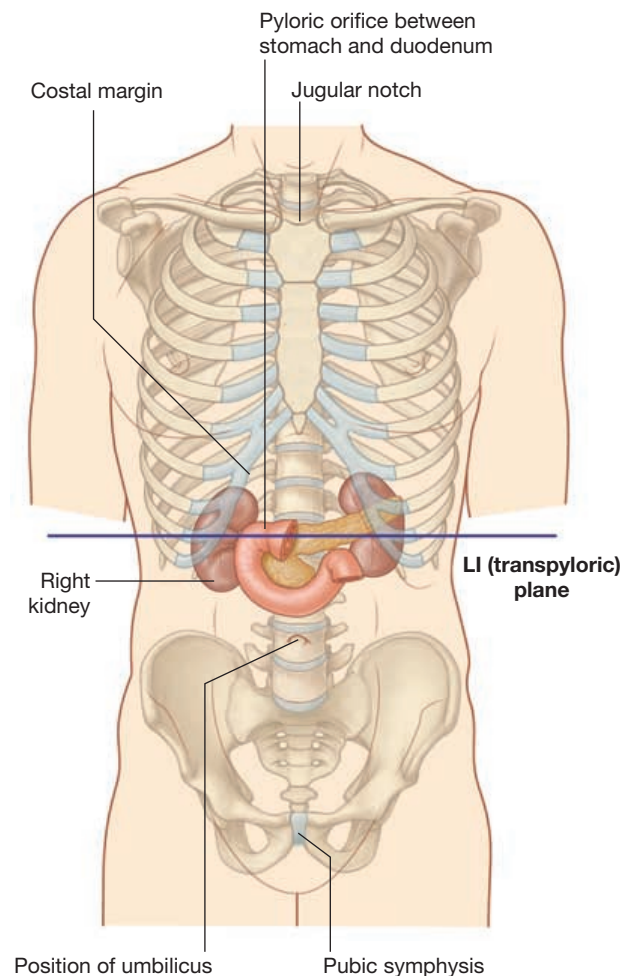
Abdomen

Vertebral level LI

The transpyloric plane is a horizontal plane that transects the body through the lower aspect of vertebra LI (Fig. 4.16). It:

- is about midway between the jugular notch and the pubic symphysis, and crosses the costal margin on each side at roughly the ninth costal cartilage;
- crosses through the opening of the stomach into the duodenum (the pyloric orifice), which is just to the right of the body of LI—the duodenum then makes a characteristic C-shaped loop on the posterior abdominal wall and crosses the midline to open into the jejunum just to the left of the body of vertebra LII, while the head of the pancreas is enclosed by the loop of the duodenum, and the body of the pancreas extends across the midline to the left;
- crosses through the body of the pancreas;
- approximates the position of the hila of the kidneys, though because the left kidney is slightly higher than the right, the transpyloric plane crosses through the inferior aspect of the left hilum and the superior part of the right hilum.
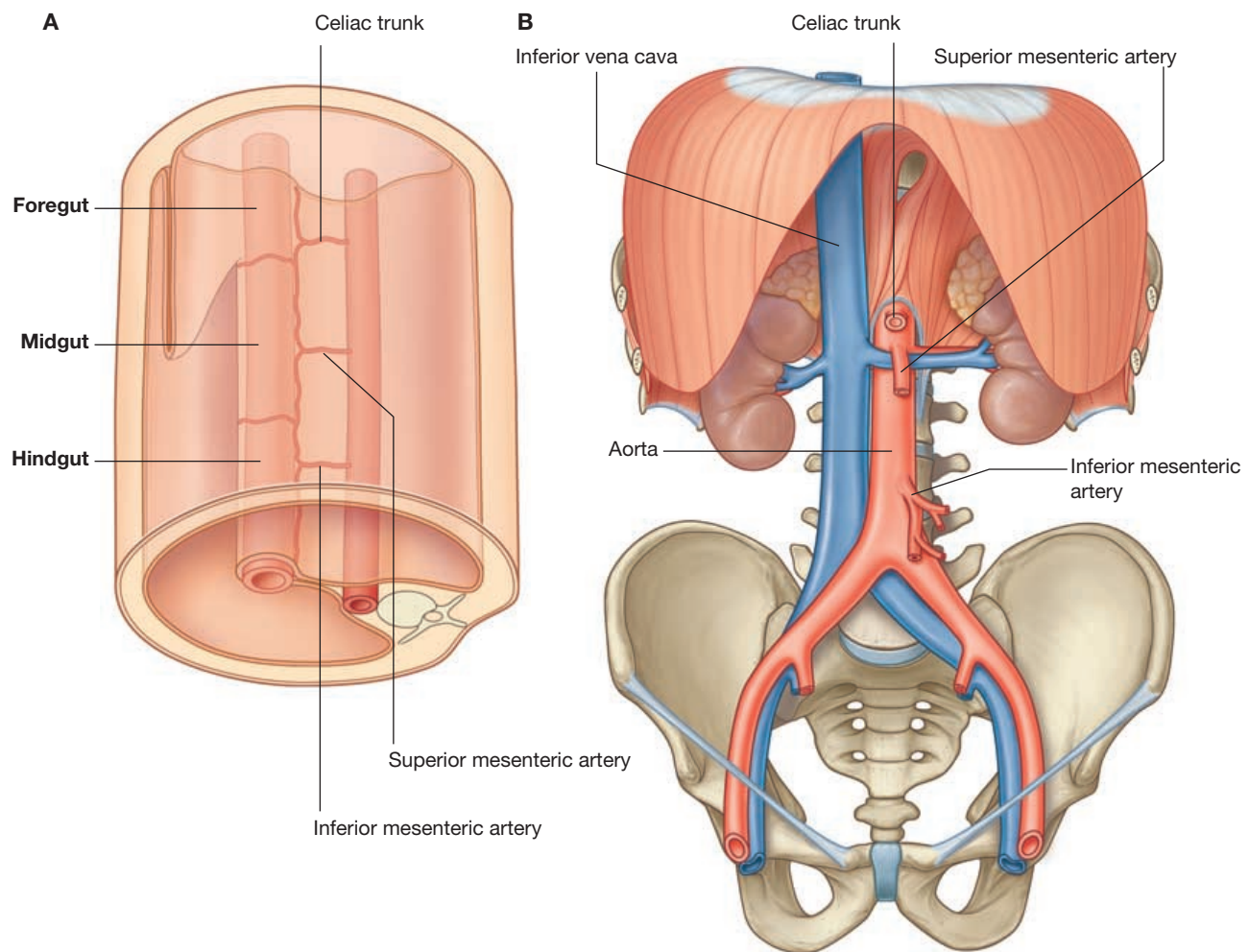
The gastrointestinal system and its derivatives are supplied by three major arteries

Three large unpaired arteries branch from the anterior surface of the abdominal aorta to supply the abdominal part of the gastrointestinal tract and all of the structures (liver, pancreas, and gallbladder) to which this part of the gut gives rise to during development (Fig. 4.17). These arteries pass through derivatives of the dorsal and ventral mesenteries to reach the target viscera. These vessels therefore also supply structures such as the spleen and lymph nodes that develop in the mesenteries. These three arteries are:

- the celiac artery, which branches from the abdominal aorta at the upper border of vertebra LI and supplies the foregut;
- the superior mesenteric artery, which arises from the abdominal aorta at the lower border of vertebra LI and supplies the midgut;
- the inferior mesenteric artery, which branches from the abdominal aorta at approximately vertebral level LIII and supplies the hindgut.

Pyloric orifice between stomach and duodenum

Costal margin

Jugular notch

Right kidney

LI (transpyloric) plane

Position of umbilicus

Pubic symphysis

Fig. 4.16 Vertebral level LI.

Fig. 4.17 Blood supply of the gut. **A.** Relationship of vessels to the gut and mesenteries. **B.** Anterior view.

Abdomen

Venous shunts from left to right

All blood returning to the heart from regions of the body other than the lungs flows into the right atrium of the heart. The inferior vena cava is the major systemic vein in the abdomen and drains this region together with the pelvis, perineum, and both lower limbs (Fig. 4.18).

The inferior vena cava lies to the right of the vertebral column and penetrates the central tendon of the diaphragm at approximately vertebral level TVIII. A number of large vessels cross the midline to deliver blood from the left side of the body to the inferior vena cava:

- one of the most significant is the left renal vein, which drains the kidney, suprarenal gland, and gonad on the same side;
- another is the left common iliac vein, which crosses the midline at approximately vertebral level LV to join with its partner on the right to form the inferior vena cava—these veins drain the lower limbs, the pelvis, the perineum, and parts of the abdominal wall.

Fig. 4.18 Left to right venous shunts.
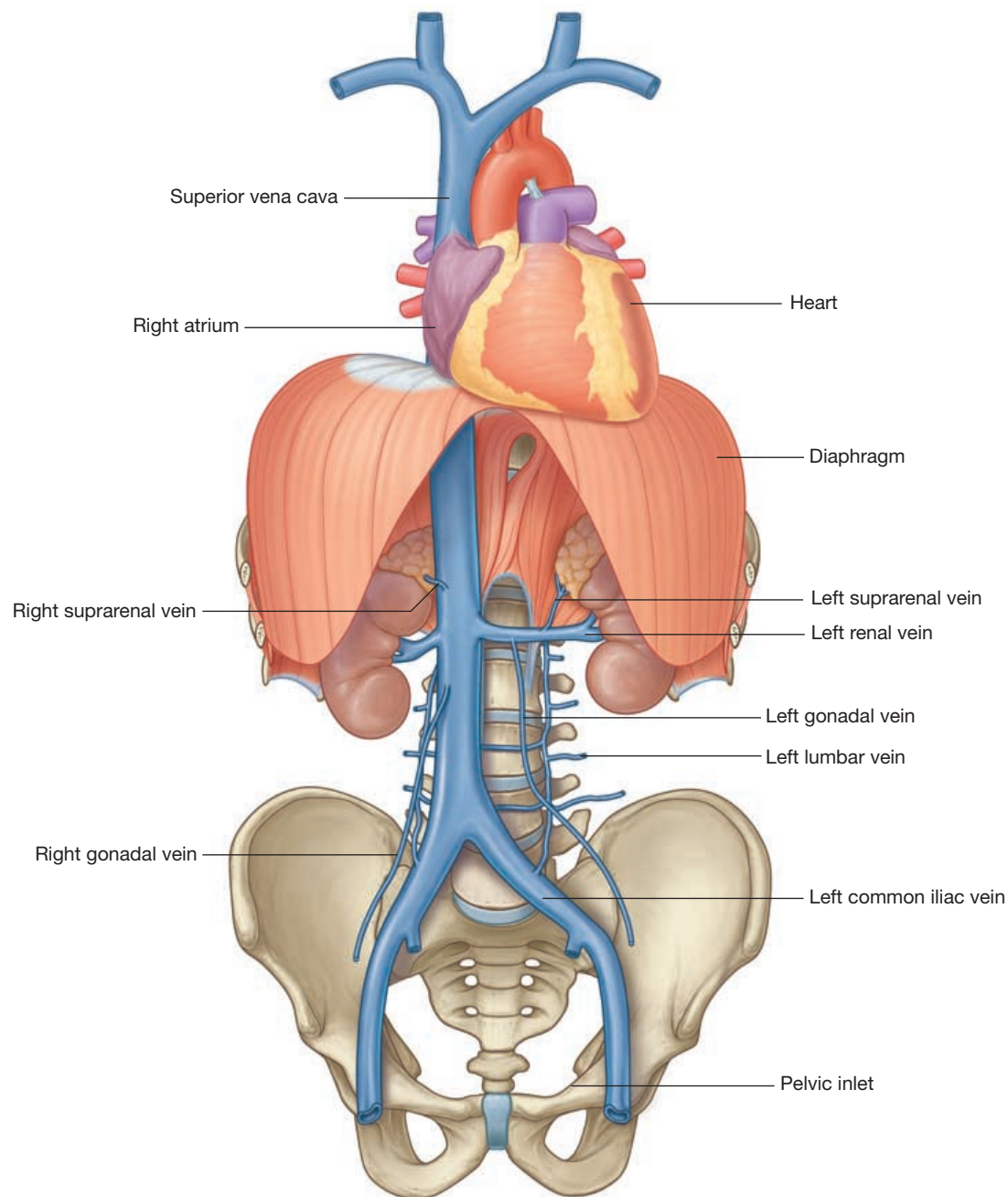
■ other vessels crossing the midline include the left lumbar veins, which drain the back and posterior abdominal wall on the left side.

## All venous drainage from the gastrointestinal system passes through the liver

Blood from abdominal parts of the gastrointestinal system and the spleen passes through a second vascular bed, in the liver, before ultimately returning to the heart (Fig. 4.19).

Venous blood from the digestive tract, pancreas, gallbladder, and spleen enters the inferior surface of the liver through the large **hepatic portal vein**. This vein then ramifies like an artery to distribute blood to small endothelial-lined hepatic sinusoids, which form the vascular exchange network of the liver.

After passing through the sinusoids, the blood collects in a number of short **hepatic veins**, which drain into the inferior vena cava just before the inferior vena cava penetrates the diaphragm and enters the right atrium of the heart.

Normally, vascular beds drained by the hepatic portal system interconnect, through small veins, with beds drained by systemic vessels, which ultimately connect directly with either the superior or inferior vena cava.

Hepatic veins

Esophagus

Hepatic portal vein

Umbilicus

Rectum
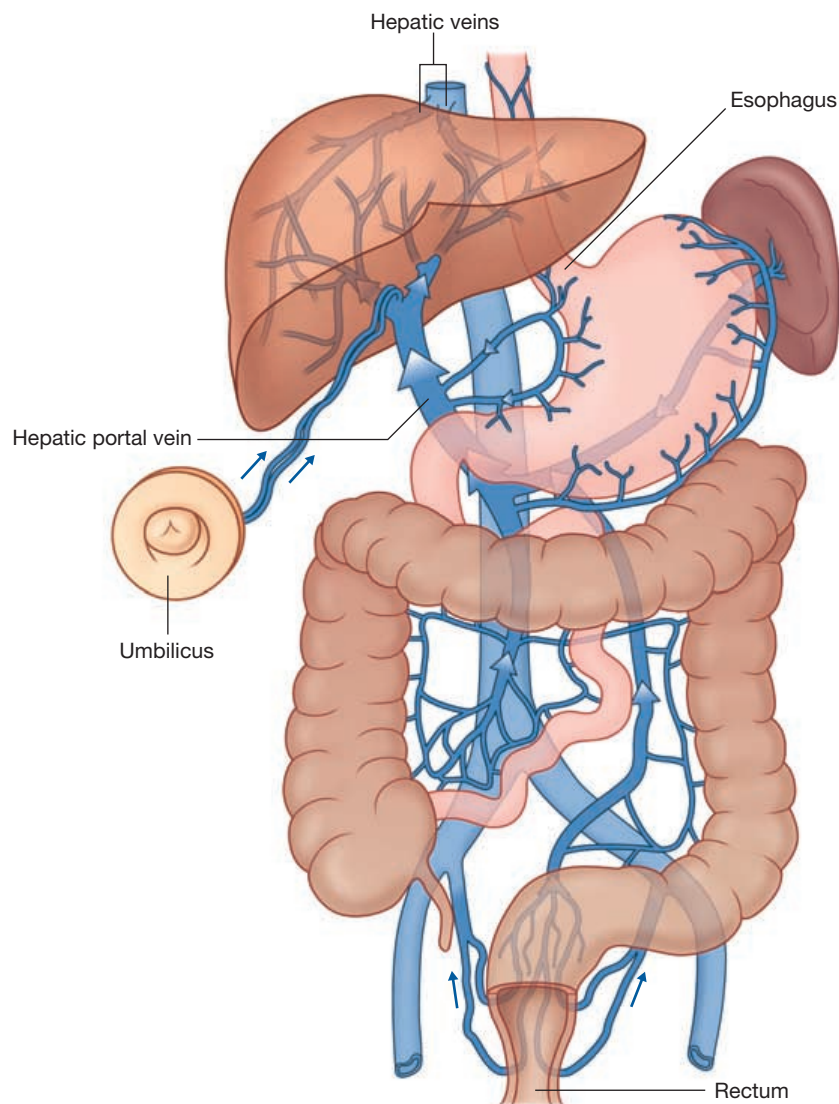
Fig. 4.19 Hepatic portal system.

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Portacaval anastomoses

Among the clinically most important regions of overlap between the portal and caval systems are those at each end of the abdominal part of the gastrointestinal system:

- around the inferior end of the esophagus;
- around the inferior part of the rectum.

Small veins that accompany the degenerate umbilical vein (**round ligament of the liver**) establish another important portal–caval anastomosis.

The round ligament of the liver connects the umbilicus of the anterior abdominal wall with the left branch of the portal vein as it enters the liver. The small veins that accompany this ligament form a connection between the portal system and para-umbilical regions of the abdominal wall, which drain into systemic veins.

Other regions where portal and caval systems interconnect include:

- where the liver is in direct contact with the diaphragm (the bare area of the liver);
- where the wall of the gastrointestinal tract is in direct contact with the posterior abdominal wall (retroperitoneal areas of the large and small intestine);
- the posterior surface of the pancreas (much of the pancreas is secondarily retroperitoneal).

Blockage of the hepatic portal vein or vascular channels in the liver

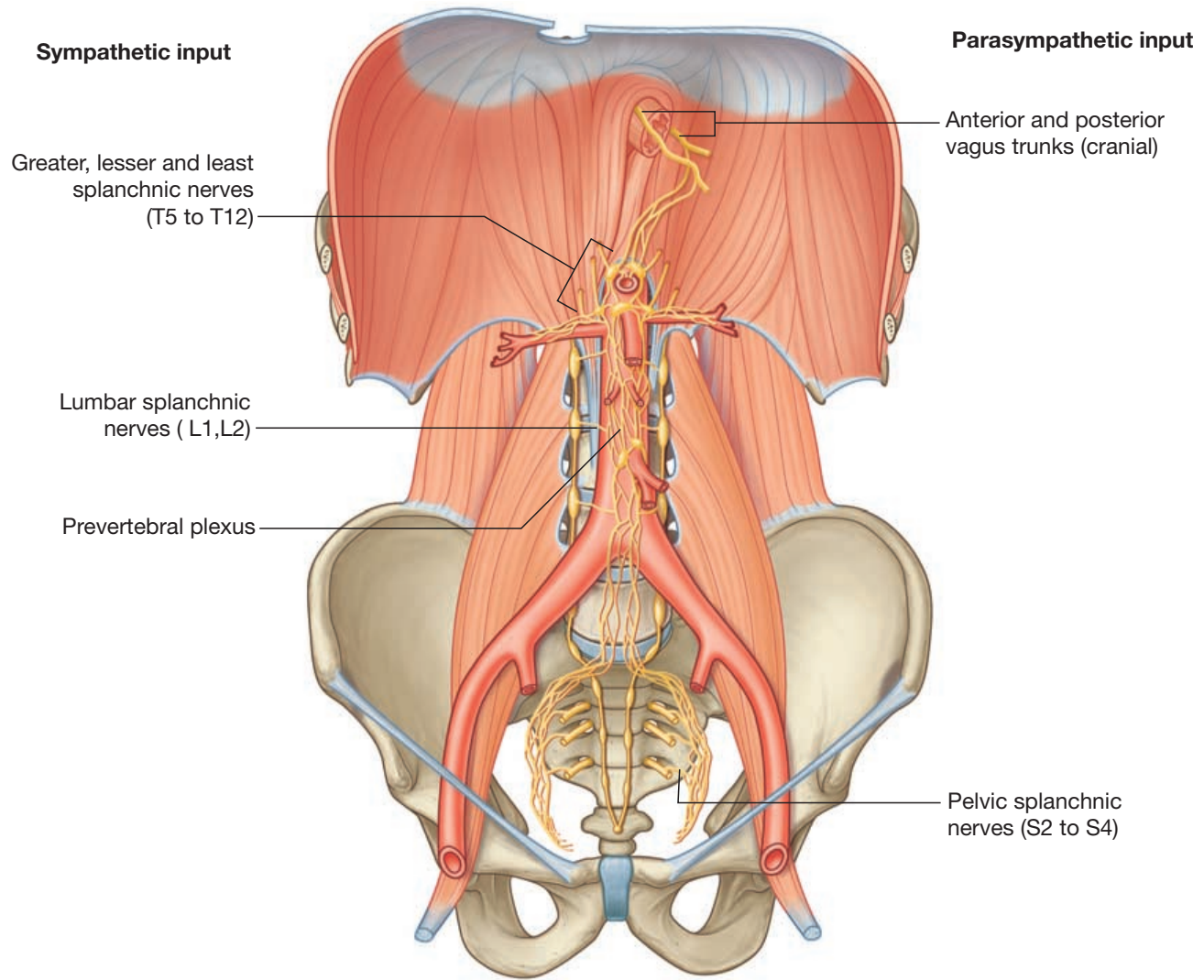Blockage of the hepatic portal vein or of vascular channels in the liver can affect the pattern of venous return from abdominal parts of the gastrointestinal system. Vessels that interconnect the portal and caval systems can become greatly enlarged and tortuous, allowing blood in tributaries of the portal system to bypass the liver, enter the caval system, and thereby return to the heart. *Portal hypertension can result in esophageal varices and hemorrhoids at the esophageal and rectal ends of the gastrointestinal system, respectively, and in 'caput Medusae' in which systemic vessels that radiate from para-umbilical veins enlarge and become visible on the abdominal wall.*

Abdominal viscera are supplied by a large prevertebral plexus

Innervation of the abdominal viscera is derived from a large prevertebral plexus associated mainly with the anterior and lateral surfaces of the aorta (Fig 4.20). Branches are distributed to target tissues along vessels that originate from the abdominal aorta.

The prevertebral plexus contains sympathetic, parasympathetic, and visceral sensory components:

- sympathetic components originate from spinal cord levels T5 to L2;
- parasympathetic components are from the vagus nerve [X] and spinal cord levels S2 to S4;
- visceral sensory fibers generally parallel the motor pathways.

Sympathetic input

Parasympathetic input

Anterior and posterior
vagus trunks (cranial)

Greater, lesser and least
splanchnic nerves
(T5 to T12)

Lumbar splanchnic
nerves (L1,L2)

Prevertebral plexus

Pelvic splanchnic
nerves (S2 to S4)

Fig. 4.20 Prevertebral plexus.

Regional anatomy

The abdomen is the part of the trunk inferior to the thorax (Fig. 4.21). Its musculomembranous walls surround a large cavity (the **abdominal cavity**), which is bounded superiorly by the diaphragm and inferiorly by the pelvic inlet.

The abdominal cavity may extend superiorly as high as the fourth intercostal space, and is continuous inferiorly with the pelvic cavity. It contains the **peritoneal cavity** and the abdominal viscera.
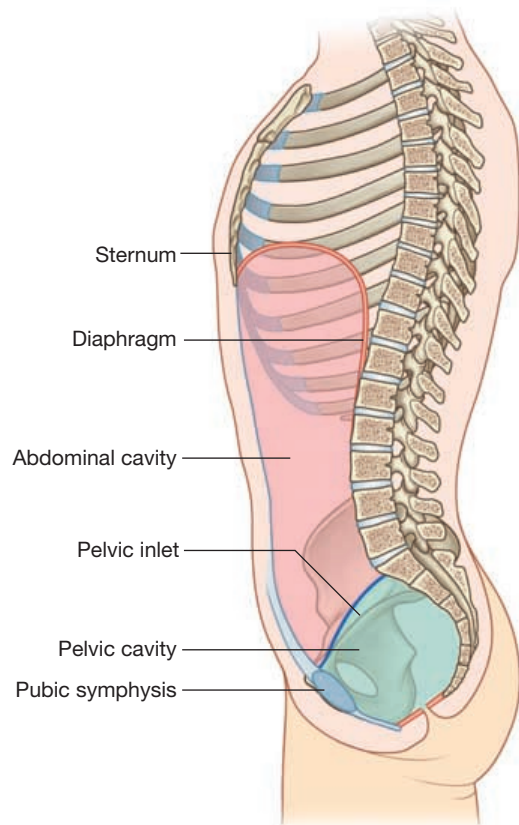
SURFACE TOPOGRAPHY

Topographical divisions of the abdomen are used to describe the location of abdominal organs and the pain associated with abdominal problems. The two schemes most often used are:
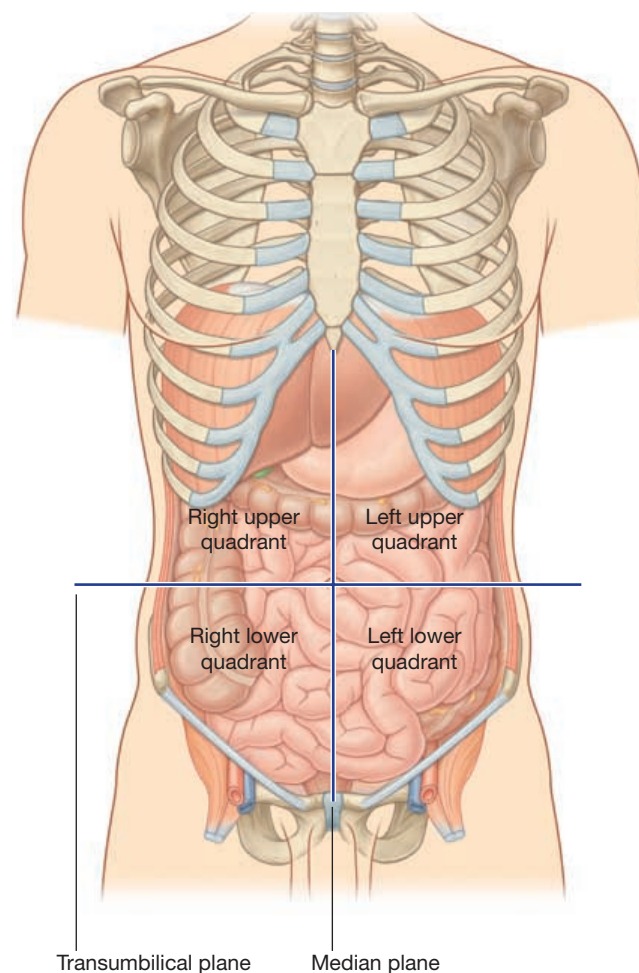
- a four-quadrant pattern;
- a nine-region organizational description.

Four-quadrant pattern

For the simple four-quadrant topographical pattern a horizontal transumbilical plane passes through the umbilicus and the intervertebral disc between vertebrae LIII and LIV and intersects with the vertical median plane to form four quadrants—the right upper, left upper, right lower, and left lower quadrants (Fig. 4.22).

Sternum

Diaphragm

Abdominal cavity

Pelvic inlet

Pelvic cavity

Pubic symphysis

Fig. 4.21 Boundaries of the abdominal cavity.

Right upper quadrant

Left upper quadrant

Right lower quadrant

Left lower quadrant

Transumbilical plane

Median plane

Fig. 4.22 Four-quadrant topographical pattern.
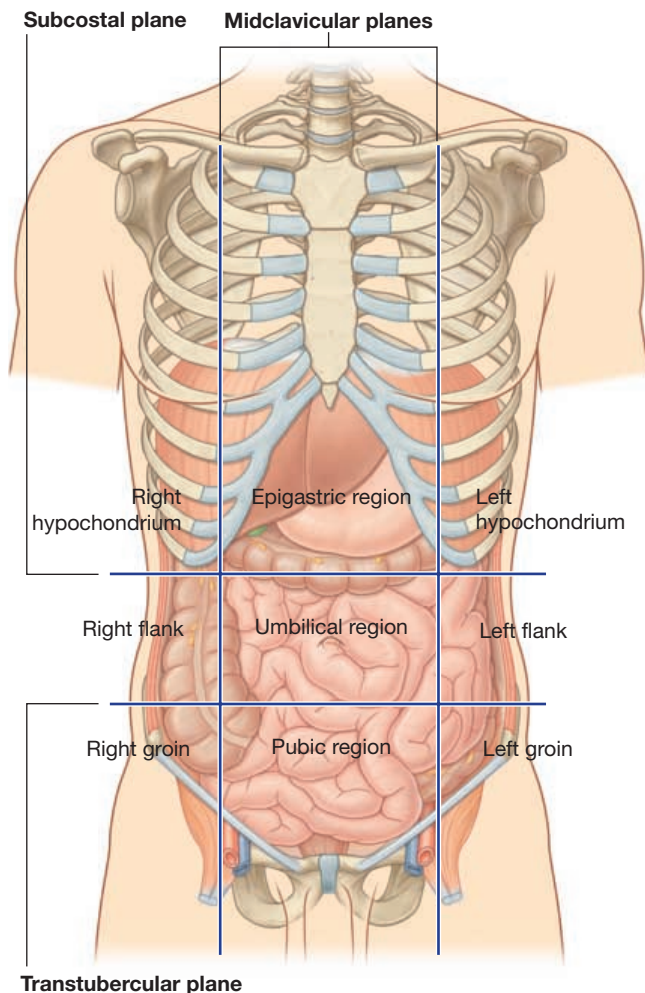
Nine-region organizational pattern

The nine-region organizational description is based on two horizontal and two vertical planes (Fig. 4.23):

■ the superior horizontal plane (the **subcostal plane**) is immediately inferior to the costal margins, which places it at the lower border of the costal cartilage of rib X and passes posteriorly through the body of vertebra LIII (note, however, that sometimes the **transpyloric plane** halfway between the suprasternal (jugular) notch and the symphysis pubis or halfway between the umbilicus and the inferior end of the body of the sternum, passing posteriorly through the lower border of vertebrae LI and intersecting with the costal margin at the ends of the ninth costal cartilages is used instead);

■ the inferior horizontal plane (the **intertubercular plane**) connects the tubercles of the iliac crests, which are palpable structures 5 cm posterior to the anterior superior iliac spines, and passes through the upper part of the body of vertebra LV;

■ the vertical planes pass from the midpoint of the clavicles inferiorly to a point midway between the anterior superior iliac spine and pubic symphysis.

These four planes establish the topographical divisions in the nine-region organization. The following designations are used for each region: superiorly the right hypochondrium, the epigastric region, and the left hypochondrium; inferiorly the right groin (inguinal region), pubic region, and left groin (inguinal region); and in the middle the right flank (lateral region), the umbilical region, and the left flank (lateral region) (Fig. 4.23).

Subcostal plane   Midclavicular planes

Right hypochondrium   Epigastric region   Left hypochondrium

Right flank   Umbilical region   Left flank

Right groin   Pubic region   Left groin

Transtubercular plane

Fig. 4.23 Nine-region organizational pattern.

In the clinic

Surgical incisions

Access to the abdomen and its contents is usually obtained through incisions in the anterior abdominal wall. Traditionally, incisions have been placed at and around the region of surgical interest. The size of these incisions was usually large to allow good access and optimal visualization of the abdominal cavity. As anesthesia has developed and muscle-relaxing drugs have become widely used, the abdominal incisions have become smaller.

Currently, the most commonly used large abdominal incision is a central craniocaudad incision from the xiphoid process to the symphysis pubis, which provides wide access to the whole of the abdominal contents and allows an exploratory procedure to be performed (laparotomy).

Other approaches use much smaller incisions. With the advent of small cameras and the development of minimal access surgery, tiny incisions can be made in the anterior abdominal wall and cameras inserted. The peritoneal cavity is 'inflated' with carbon dioxide to increase the space in which the procedure is performed. Further instruments may be inserted through small portholes and procedures such as cholecystectomy (removal of the gallbladder) and appendectomy (removal of the appendix) can be carried out, allowing the patient to return home sooner than a large abdominal incision would allow.

Abdomen

ABDOMINAL WALL

The abdominal wall covers a large area. It is bounded superiorly by the xiphoid process and costal margins, posteriorly by the vertebral column, and inferiorly by the upper parts of the pelvic bones. Its layers consist of skin, superficial fascia (subcutaneous tissue), muscles and their associated deep fascias, extraperitoneal fascia, and parietal peritoneum (Fig. 4.24).
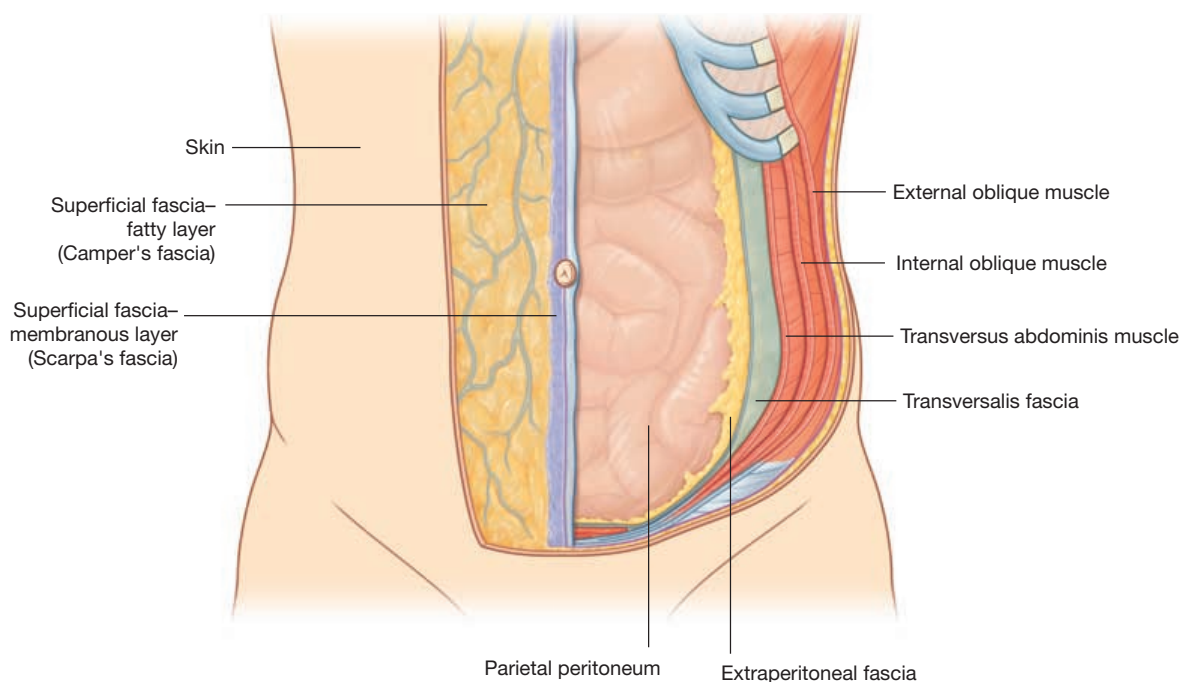
Superficial fascia

The superficial fascia of the abdominal wall (subcutaneous tissue of abdomen) is a layer of fatty connective tissue. It is usually a single layer similar to, and continuous with, the superficial fascia throughout other regions of the body.

However, in the lower region of the anterior part of the abdominal wall, below the umbilicus, it forms two layers: a superficial fatty layer and a deeper membranous layer.

Superficial layer

The superficial fatty layer of superficial fascia (**Camper's fascia**) contains fat and varies in thickness (Figs. 4.25 and 4.26). It is continuous over the inguinal ligament with the superficial fascia of the thigh and with a similar layer in the perineum.

In men, this superficial layer continues over the penis and, after losing its fat and fusing with the deeper layer of superficial fascia, continues into the scrotum where it forms a specialized fascial layer containing smooth muscle fibers (the **dartos fascia**). In women, this superficial layer retains some fat and is a component of the labia majora.

Skin

Superficial fascia– fatty layer (Camper's fascia)

Superficial fascia– membranous layer (Scarpa's fascia)

External oblique muscle

Internal oblique muscle

Transversus abdominis muscle

Transversalis fascia

Parietal peritoneum

Extraperitoneal fascia

Fig. 4.24 Layers of the abdominal wall.

Deeper layer

The deeper membranous layer of superficial fascia (**Scarpa's fascia**) is thin and membranous, and contains little or no fat (Fig. 4.25). Inferiorly, it continues into the thigh, but just below the inguinal ligament, it fuses with the deep fascia of the thigh (the **fascia lata**; Fig. 4.26). In the midline, it is firmly attached to the linea alba and the symphysis pubis. It continues into the anterior part of the perineum where it is firmly attached to the ischiopubic rami and to the posterior margin of the perineal membrane. Here, it is referred to as the **superficial perineal fascia** (**Colles' fascia**).
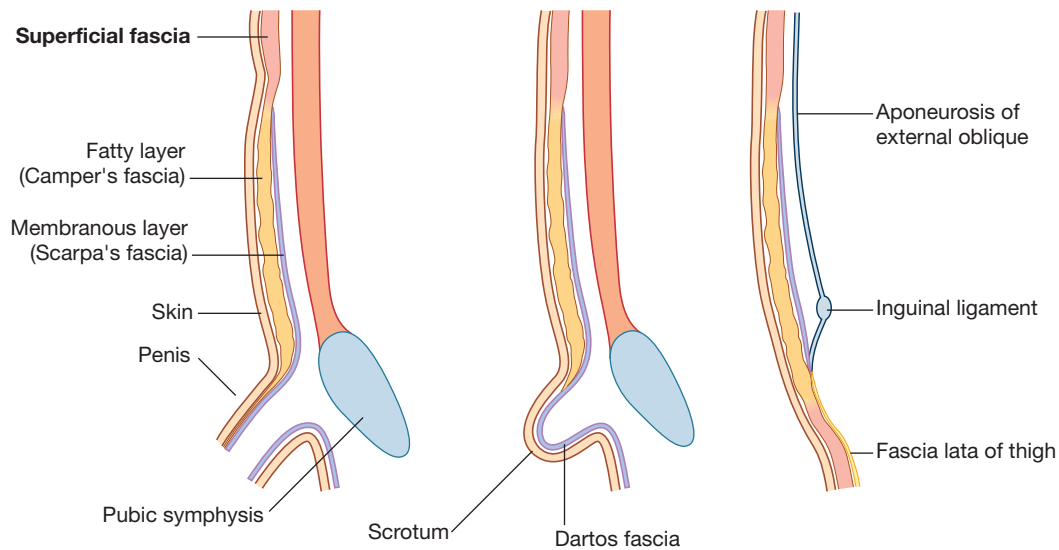
Fig. 4.25 Superficial fascia.
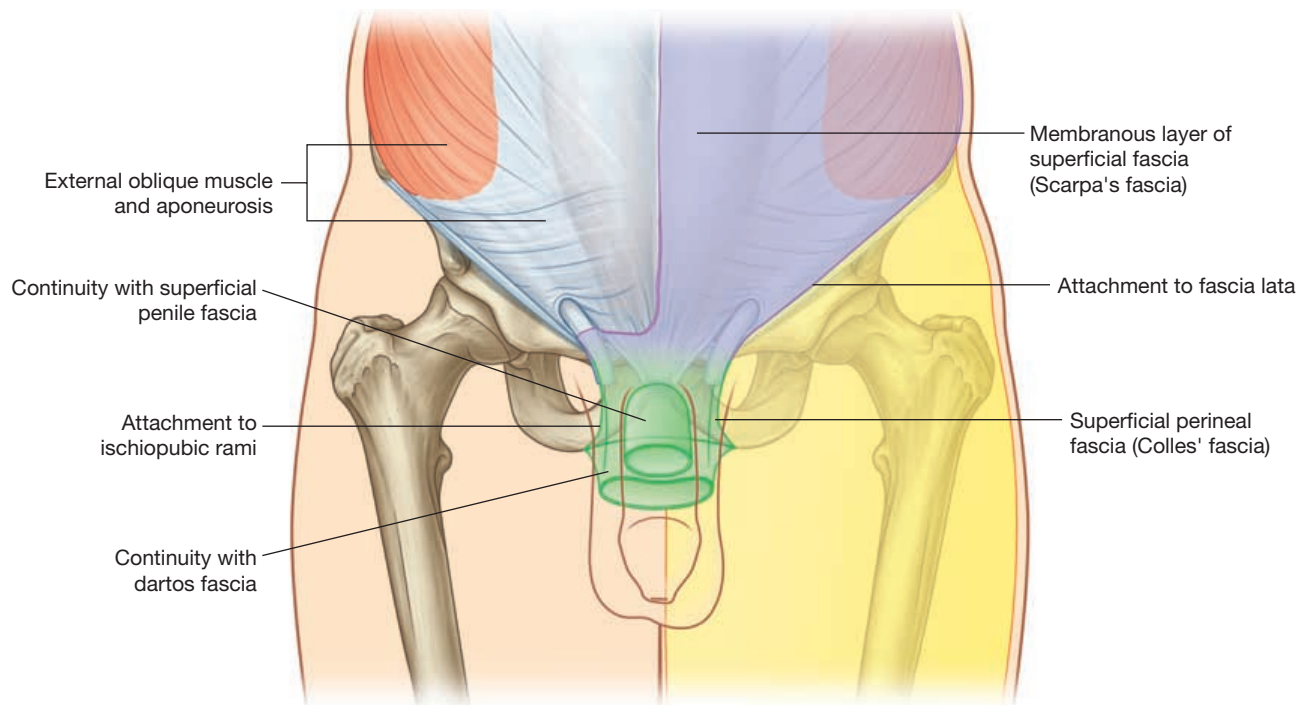
Fig. 4.26 Continuity of membranous layer of superficial fascia into other areas.

Abdomen

In men, the deeper membranous layer of superficial fascia blends with the superficial layer as they both pass over the penis, forming the superficial fascia of the penis, before they continue into the scrotum where they form the dartos fascia (Fig. 4.25). Also in men, extensions of the deeper membranous layer of superficial fascia attached to the pubic symphysis pass inferiorly onto the dorsum and sides of the penis to form the **fundiform ligament of penis**. In women, the membranous layer of the superficial fascia continues into the labia majora and the anterior part of the perineum.

Anterolateral muscles

There are five muscles in the anterolateral group of abdominal wall muscles:

- three flat muscles whose fibers begin posterolaterally, pass anteriorly, and are replaced by an aponeurosis as the muscle continues towards the midline—the external oblique, internal oblique, and transversus abdominis muscles;
- two vertical muscles, near the midline, which are enclosed within a tendinous sheath formed by the aponeuroses of the flat muscles.

Each of these five muscles has specific actions, but together the muscles are critical for the maintenance of many normal physiologic functions. By their positioning, they form a firm, but flexible, wall that keeps the abdominal viscera within the abdominal cavity, protects the viscera from injury, and helps maintain the position of the viscera in the erect posture against the action of gravity.

In addition, contraction of these muscles assists in both quiet and forced expiration by pushing the viscera upward (which helps push the relaxed diaphragm further into the thoracic cavity) and in coughing and vomiting.

All these muscles are also involved in any action that increases intra-abdominal pressure, including parturition (childbirth), micturition (urination), and defecation (expulsion of feces from the rectum).

Flat muscles

External oblique

The most superficial of the three flat muscles in the anterolateral group of abdominal wall muscles is the **external oblique**, which is immediately deep to the superficial fascia (Fig. 4.27). Its laterally placed muscle fibers pass in an inferomedial direction, while its large aponeurotic component covers the anterior part of the abdominal wall to the midline. Approaching the midline, the aponeuroses are entwined, forming the linea alba, which extends from the xiphoid process to the pubic symphysis.
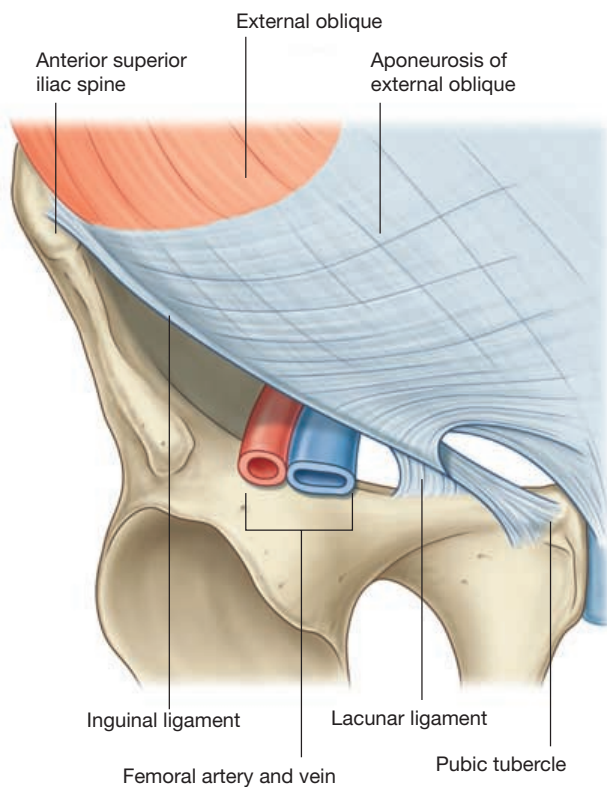

Fig. 4.27 External oblique muscle and its aponeurosis.
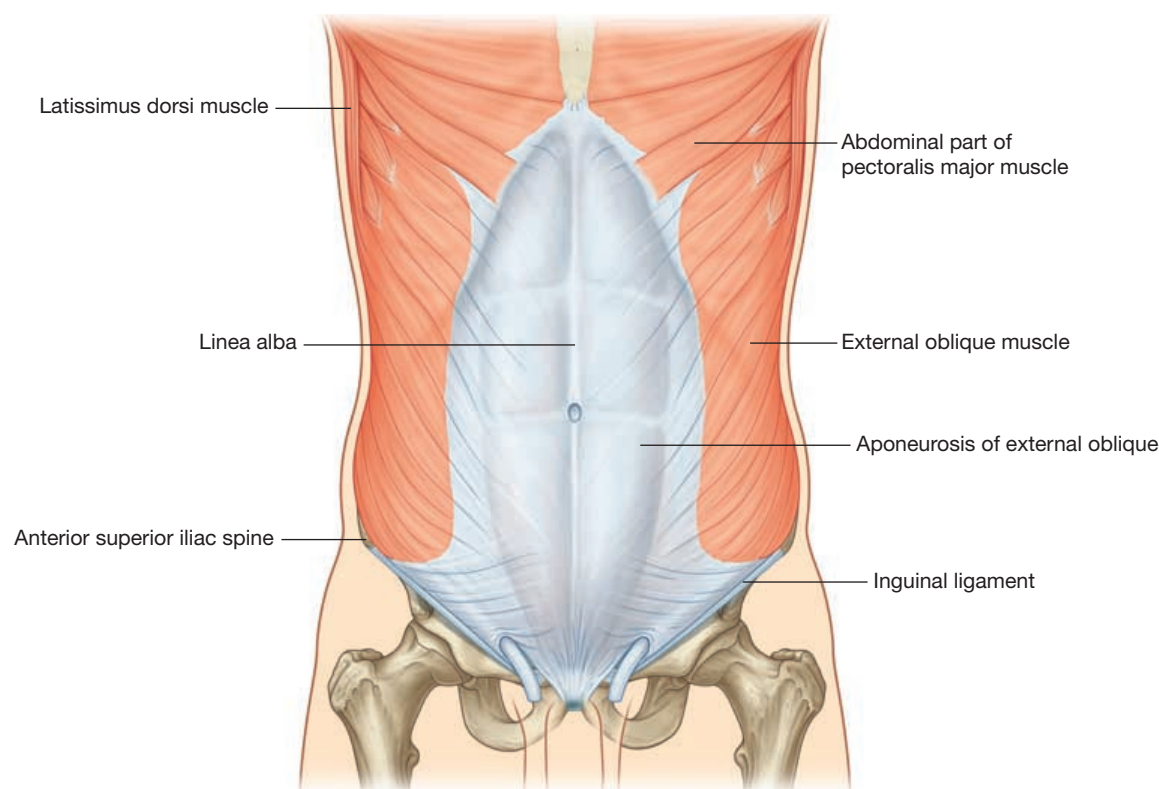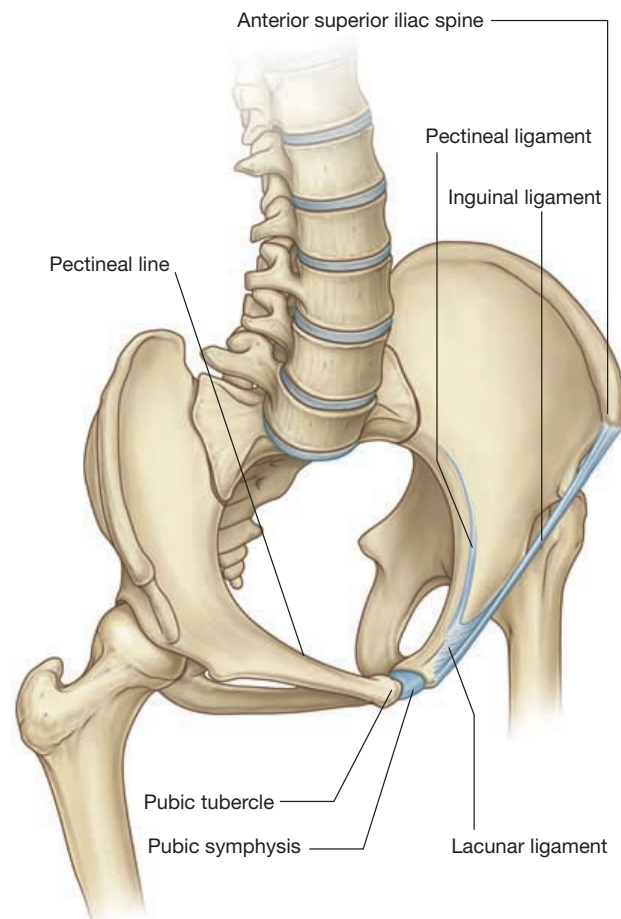
Associated ligaments

The lower border of the external oblique aponeurosis forms the **inguinal ligament** on each side (Fig. 4.27). This thickened reinforced free edge of the external oblique aponeurosis passes between the anterior superior iliac spine laterally and the pubic tubercle medially (Fig. 4.28). It folds under itself forming a trough, which plays an important role in the formation of the inguinal canal.

Several other ligaments are also formed from extensions of the fibers at the medial end of the inguinal ligament:

- the **lacunar ligament** is a crescent-shaped extension of fibers at the medial end of the inguinal ligament that pass backward to attach to the **pecten pubis** on the superior ramus of the pubic bone (Figs. 4.28 and 4.29);
- additional fibers extend from the lacunar ligament along the pecten pubis of the pelvic brim to form the **pectineal** (**Cooper's**) **ligament**.

Fig. 4.29 Ligaments of the inguinal region.

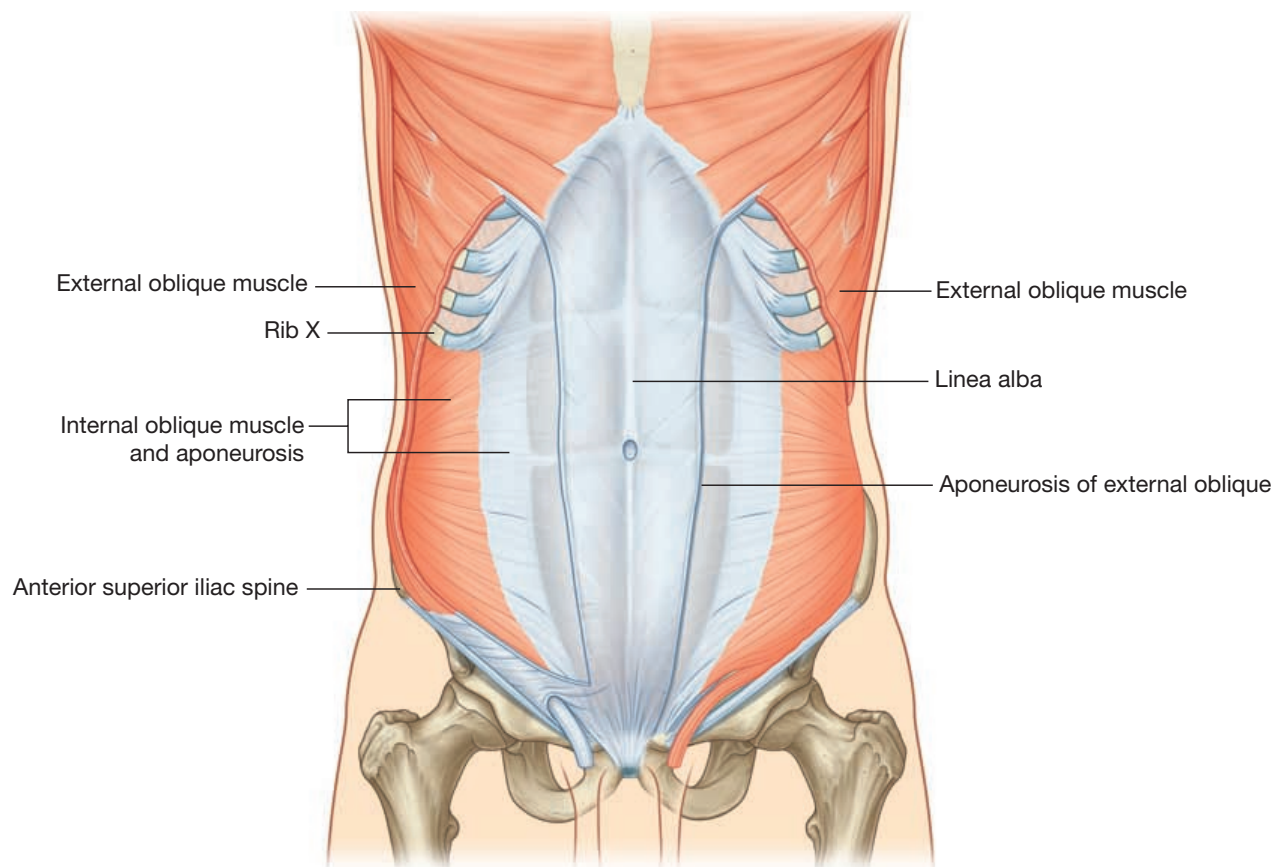**Fig. 4.28** Ligaments formed from the external oblique aponeurosis.

Abdomen

Internal oblique

Deep to the external oblique muscle is the **internal oblique** muscle, which is the second of the three flat muscles (Fig. 4.30). This muscle is smaller and thinner than the external oblique, with most of its muscle fibers passing in a superomedial direction. Its lateral muscular components end anteriorly as an aponeurosis that blends into the linea alba at the midline.

Transversus abdominis

Deep to the internal oblique muscle is the **transversus abdominis** muscle (Fig. 4.31), so-named because of the direction of most of its muscle fibers. It ends in an anterior aponeurosis, which blends with the linea alba at the midline.

External oblique muscle

Rib X

Internal oblique muscle and aponeurosis

Anterior superior iliac spine

External oblique muscle

Linea alba

Aponeurosis of external oblique

Fig. 4.30 Internal oblique muscle and its aponeurosis.

Transversalis fascia

Each of the three flat muscles is covered on its anterior and posterior surfaces by a layer of investing abdominal fascia. In general, these layers are unremarkable except for the layer deep to the transversus abdominis muscle (the **transversalis fascia**), which is better developed.

The transversalis fascia is a continuous layer of fascia that lines the abdominal cavity and continues into the pelvic cavity. It crosses the midline anteriorly, associating with the transversalis fascia of the opposite side, and is continuous with the fascia on the inferior surface of the diaphragm. It is continuous posteriorly with the deep fascia

covering the muscles of the posterior abdominal wall and attaches to the thoracolumbar fascia.

After attaching to the crest of the ilium, the transversalis fascia blends with the fascia covering the muscles associated with the upper regions of the pelvic bones and with similar fascia covering the muscles of the pelvic cavity. At this point, it is referred to as the **parietal pelvic** (or **endopelvic**) **fascia**.

There is therefore a continuous layer of fascia surrounding the abdominal cavity that is thick in some areas, thin in others, attached or free, and participates in the formation of specialized structures.
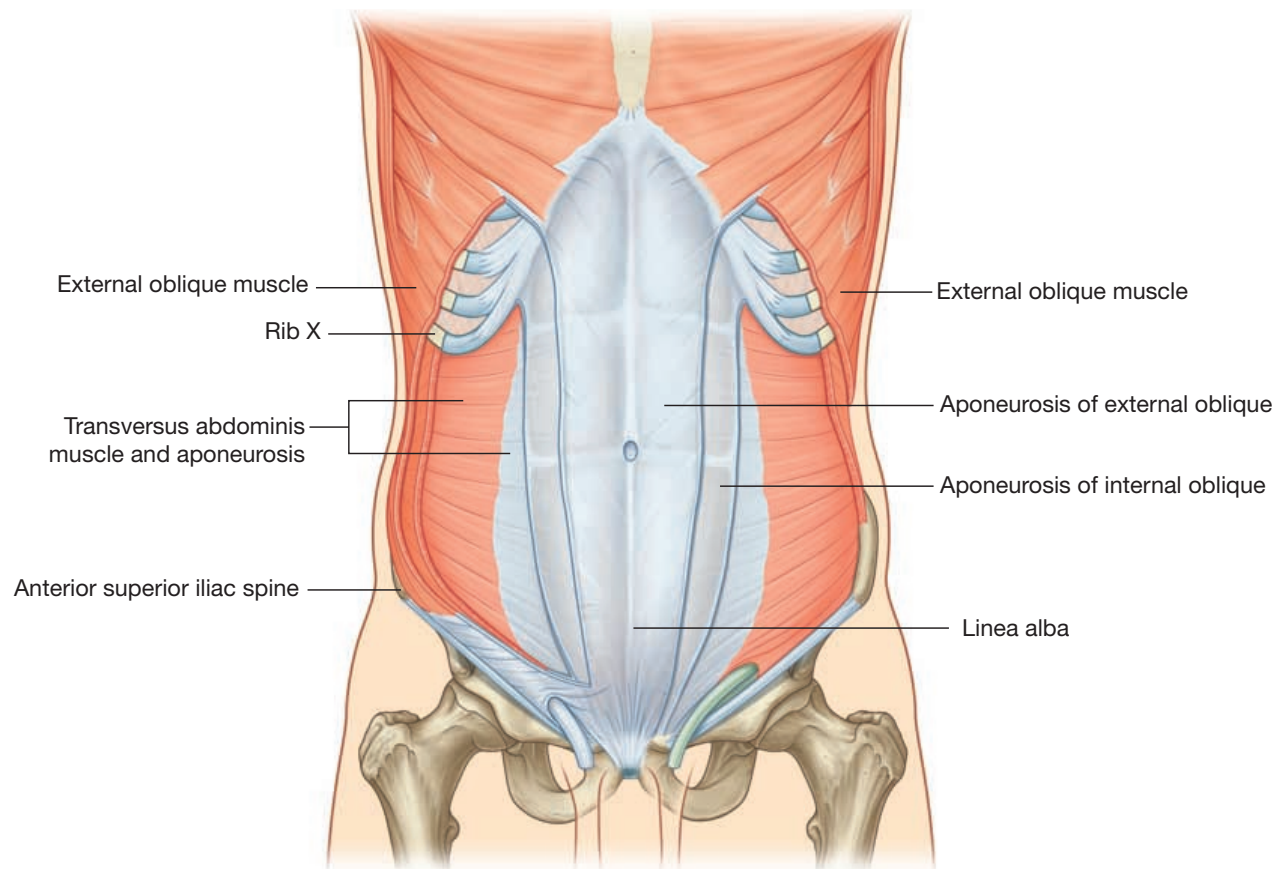
Fig. 4.31 Transversus abdominis muscle and its aponeurosis.

Abdomen

Vertical muscles

The two vertical muscles in the anterolateral group of abdominal wall muscles (Table 4.1) are the large rectus abdominis and the small pyramidalis (Fig. 4.32).

Rectus abdominis

The **rectus abdominis** is a long, flat muscle and extends the length of the anterior abdominal wall. It is a paired muscle, separated in the midline by the linea alba, and it

Table 4.1 Abdominal wall muscles

Muscle	Origin	Insertion	Innervation	Function
External oblique	Muscular slips from the outer surfaces of the lower eight ribs (ribs V to XII)	Lateral lip of iliac crest; aponeurosis ending in midline raphe (linea alba)	Anterior rami of lower six thoracic spinal nerves (T7 to T12)	Compress abdominal contents; both muscles flex trunk; each muscle bends trunk to same side, turning anterior part of abdomen to opposite side
Internal oblique	Thoracolumbar fascia; iliac crest between origins of external and transversus; lateral two-thirds of inguinal ligament	Inferior border of the lower three or four ribs; aponeurosis ending in linea alba; pubic crest and pectineal line	Anterior rami of lower six thoracic spinal nerves (T7 to T12) and L1	Compress abdominal contents; both muscles flex trunk; each muscle bends trunk and turns anterior part of abdomen to same side
Transversus abdominis	Thoracolumbar fascia; medial lip of iliac crest; lateral one-third of inguinal ligament; costal cartilages lower six ribs (ribs VII to XII)	Aponeurosis ending in linea alba; pubic crest and pectineal line	Anterior rami of lower six thoracic spinal nerves (T7 to T12) and L1	Compress abdominal contents
Rectus abdominis	Pubic crest, pubic tubercle, and pubic symphysis	Costal cartilages of ribs V to VII; xiphoid process	Anterior rami of lower seven thoracic spinal nerves (T7 to T12)	Compress abdominal contents; flex vertebral column; tense abdominal wall
Pyramidalis	Front of pubis and pubic symphysis	Into linea alba	Anterior ramus of T12	Tenses the linea alba

Fig. 4.32 Rectus abdominis and pyramidalis muscles.
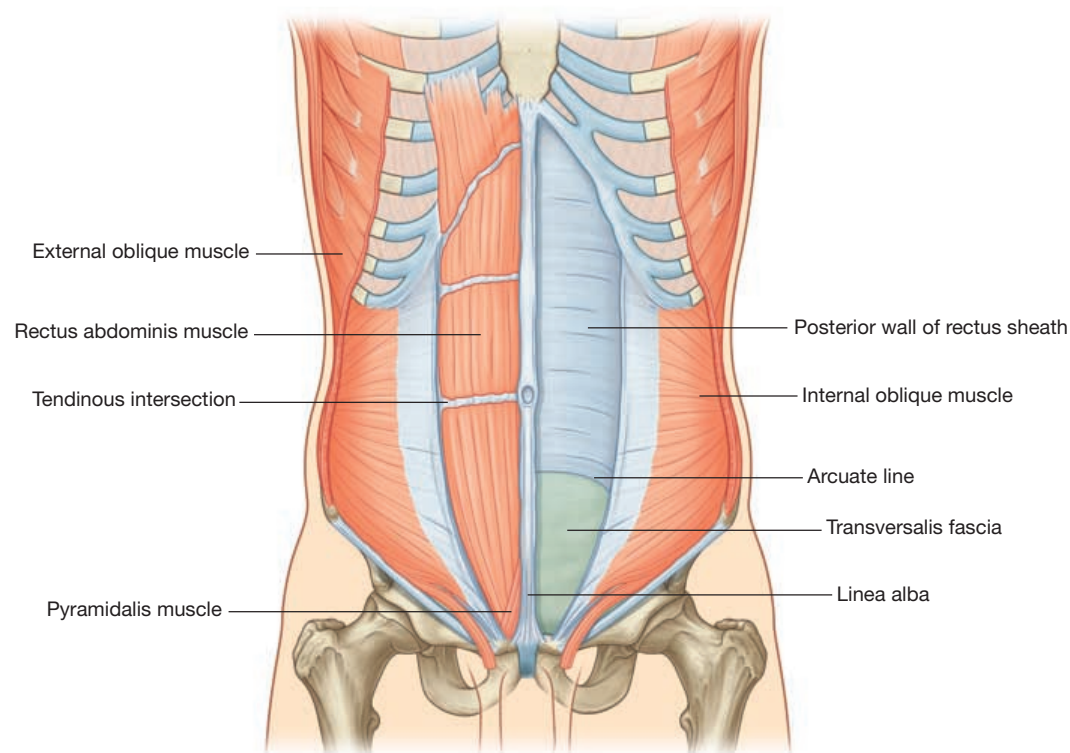
widens and thins as it ascends from the pubic symphysis to the costal margin. Along its course, it is intersected by three or four transverse fibrous bands or **tendinous intersections** (Fig. 4.32). These are easily visible on individuals with a well-developed rectus abdominis.

Pyramidalis

The second vertical muscle is the **pyramidalis**. This small, triangular-shaped muscle, which may be absent, is anterior to the rectus abdominis, has its base on the pubis, and its apex is attached superiorly and medially to the linea alba (Fig. 4.32).
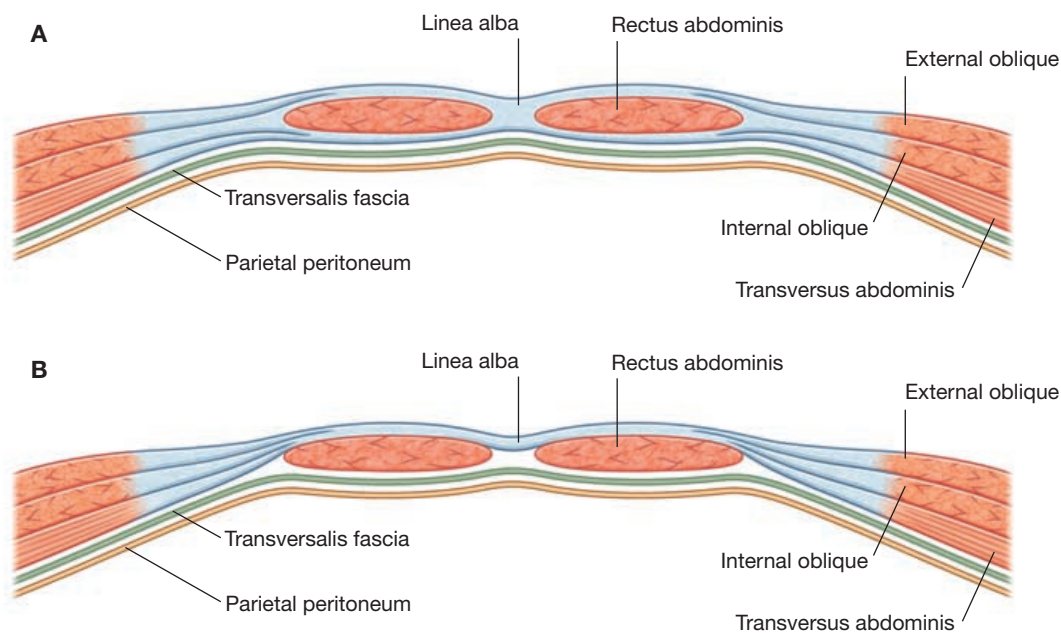
Rectus sheath

The rectus abdominis and pyramidalis muscles are enclosed in an aponeurotic tendinous sheath (the **rectus sheath**) formed by a unique layering of the aponeuroses of the external and internal oblique, and transversus abdominis muscles (Fig. 4.33).

The rectus sheath completely encloses the upper three-quarters of the rectus abdominis and covers the anterior surface of the lower one-quarter of the muscle. As no sheath covers the posterior surface of the lower quarter of the rectus abdominis muscle, the muscle at this point is in direct contact with the transversalis fascia.

The formation of the rectus sheath surrounding the upper three-quarters of the rectus abdominis muscle has the following pattern:

- the anterior wall consists of the aponeurosis of the external oblique and half of the aponeurosis of the internal oblique, which splits at the lateral margin of the rectus abdominis;
- the posterior wall of the rectus sheath consists of the other half of the aponeurosis of the internal oblique and the aponeurosis of the transversus abdominis.

At a point midway between the umbilicus and the pubic symphysis, corresponding to the beginning of the lower one-quarter of the rectus abdominis muscle, all of the aponeuroses move anterior to the rectus muscle. There is no posterior wall of the rectus sheath and the anterior wall of the sheath consists of the aponeuroses of the external oblique, the internal oblique, and the transversus abdominis muscles. From this point inferiorly, the rectus abdominis muscle is in direct contact with the transversalis fascia. Marking this point of transition is an arch of fibers (the **arcuate line**; see Fig. 4.32).

Fig. 4.33 Organization of the rectus sheath. **A.** Transverse section through the upper three-quarters of the rectus sheath. **B.** Transverse section through the lower one-quarter of the rectus sheath.

Abdomen

Extraperitoneal fascia

Deep to the transversalis fascia is a layer of connective tissue, the **extraperitoneal fascia**, which separates the transversalis fascia from the peritoneum (Fig. 4.34). Containing varying amounts of fat, this layer not only lines the abdominal cavity, but is also continuous with a similar layer lining the pelvic cavity. It is abundant on the posterior abdominal wall, especially around the kidneys, continues over organs covered by peritoneal reflections, and, as the vasculature is located in this layer, extends into mesenteries with the blood vessels. Viscera in the extraperitoneal fascia are referred to as **retroperitoneal**.

In the description of specific surgical procedures, the terminology used to describe the extraperitoneal fascia is further modified. The fascia towards the anterior side of the body is described as preperitoneal (or, less commonly, properitoneal) and the fascia towards the posterior side of the body has been described as retroperitoneal (Fig. 4.35). Examples of the use of these terms would be the continuity of fat in the inguinal canal with the preperitoneal fat and a transabdominal preperitoneal laparoscopic repair of an inguinal hernia.

Peritoneum

Deep to the extraperitoneal fascia is the peritoneum (see Figs 4.6 and 4.7 on pp. 4-7–4-8). This thin serous membrane lines the walls of the abdominal cavity and, at various points, reflects onto the abdominal viscera, providing either a complete or a partial covering. The peritoneum lining the walls is the parietal peritoneum; the peritoneum covering the viscera is the visceral peritoneum.

The continuous lining of the abdominal walls by the parietal peritoneum forms a sac. This sac is closed in men, but has two openings in women where the uterine tubes provide a passage to the outside. The closed sac in men and the semi-closed sac in women is called the peritoneal cavity.
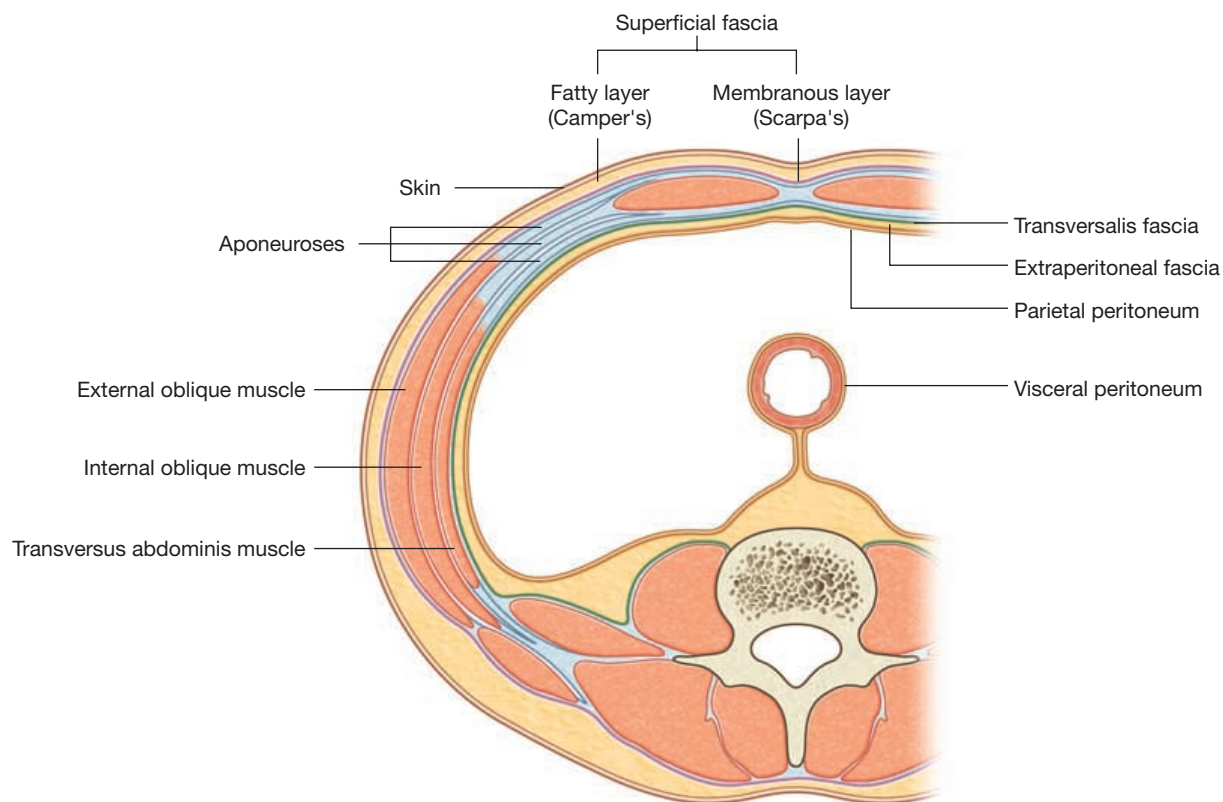
Fig. 4.34 Transverse section showing the layers of the abdominal wall.