TRAUMATIC INJURIES OF THE ORGANS OF THE PELVIS: ADULT AND PEDIATRIC

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I. Introduction

In this chapter we will review the traumatic injuries of the organs of the pelvis, which will include the urinary bladder, the rectum, the anal canal, and the internal genital organs. Although the rectum and anal canal represent the terminal portions of the gastrointestinal tract, only the rectum lies within the pelvis. However, for the sake of continuity we will consider the two parts together.

As in previous chapters, the first part of this chapter will be devoted to the relevant anatomy of the pelvis and its contained organs. As discussed previously, the purpose of a discussion of the relevant anatomy is two fold. First, it will constitute a review of the anatomy for the medical students, pathology residents, forensic pathology fellows, forensic nurses, emergency room residents, and trauma surgeon residents, aiding them in understanding the pathophysiologic dynamics of traumatic injuries to the pelvis and its contained organs. Second, since this educational blog may also be used by medicolegal investigators, paramedics, law enforcement personnel, and attorneys who have little knowledge of anatomy, such a review will help them to develop a better understanding of the affects of trauma on the victims.

There will also be a discussion of the mechanisms of injury to the pelvic cavity and its contained organs.

II. Relevant Anatomy of the Pelvis

A. Overview: The pelvis is the lower part of the trunk, which serves as an anatomic transition from the abdomen to the lower extremities. The human pelvis evolved over thousands of years so that it could accommodate prolonged upright posture. To that end the human pelvis has a backward bend called the **sciatic notch**, which is not see in other primates (Figs. 1 & 2). The backward bend in the pelvis makes it easier for humans to stand perfectly upright with minimal effort. Another interesting feature of the human pelvis is that it has more tail segments and hence a longer tail (**coccyx**) than apes and some other primates.

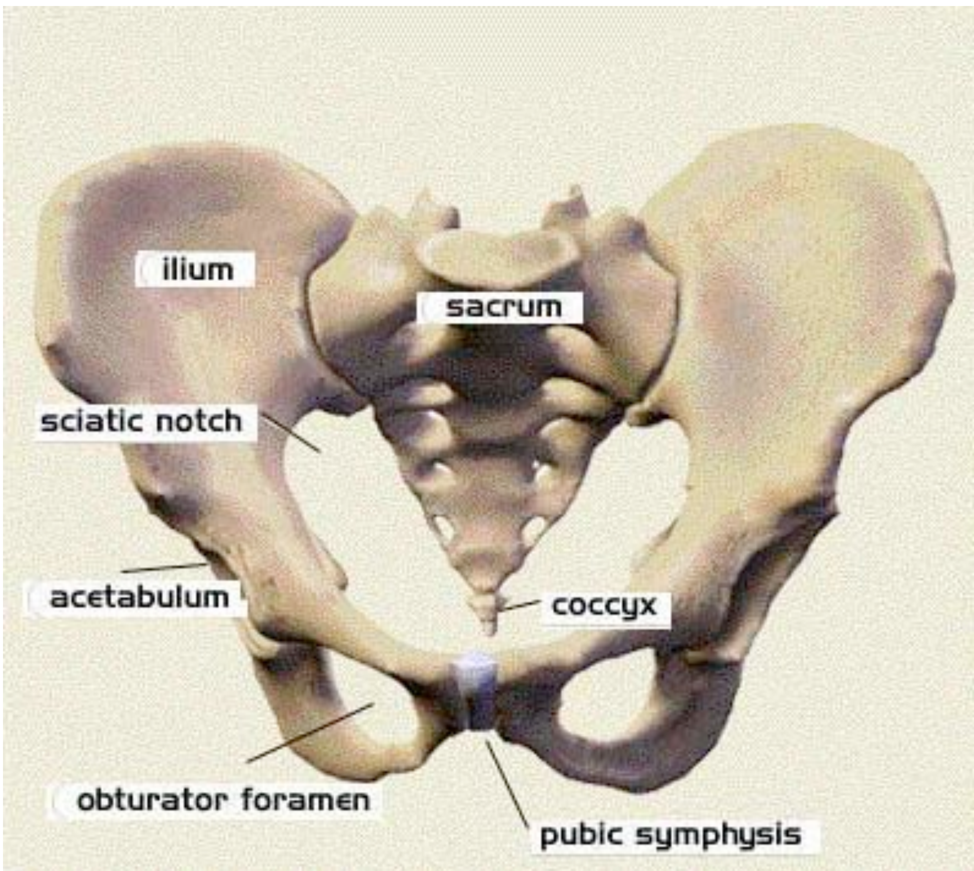


Fig. 1. In the above image the sacrum appears as a triangular bone at the base of the spine. It is also at the upper and back part of the pelvic cavity. Its upper part or base articulates with the last lumbar vertebra, its apex with the coccyx or tailbone. It is curved upon itself, with the concave facing forward. The central part of the sacrum is directed backward, to give the pelvic cavity not only greater capacity, but to support the visceral load of the pelvic organs. (family.blogspot.com)

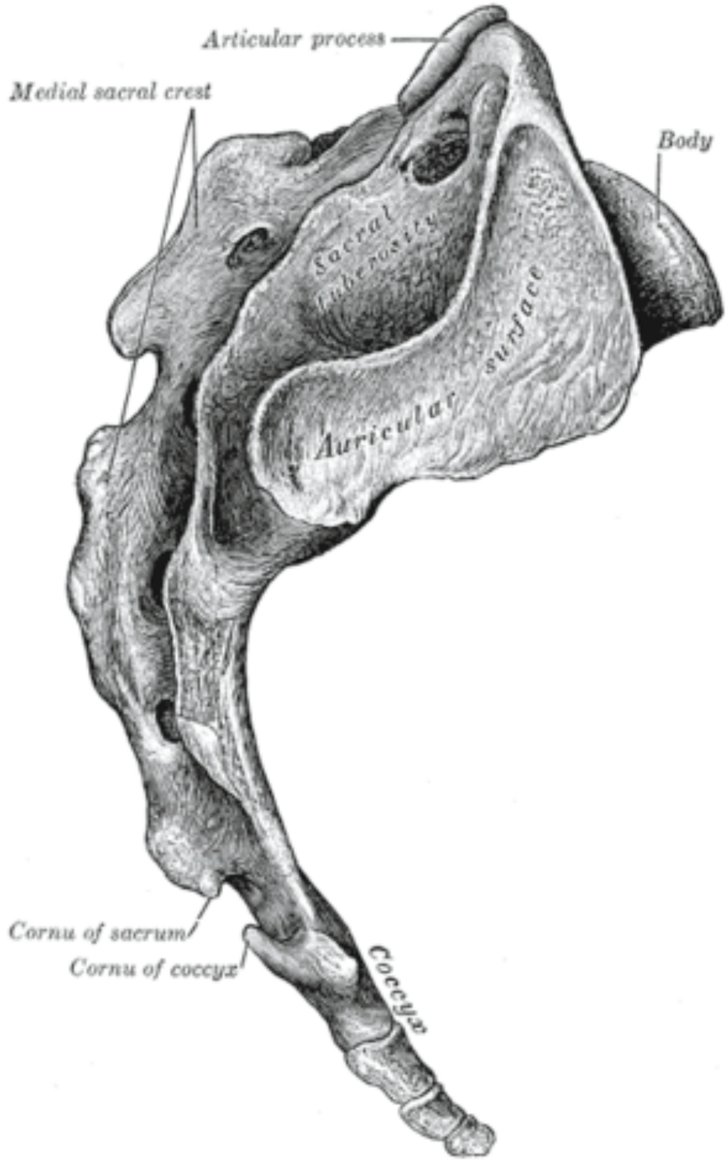


Fig. 2. This is a lateral view of the sacrum and coccyx. Note the prominent backward curve of the sacrum and the coccyx. (Wiki)

There is a line of thought that as the apes and some of the other primates evolved they did not need their tails, in part because it got in the way of sitting. It is believed as humans evolved they needed their longer tails, most especially with a backward bend, to not only aid them in standing upright, but also to help support the pelvic contents, keeping them from falling out during standing upright. This is why in humans the tail curls under and not out (Fig. 2). The coccyx also participates in the formation of the pelvic floor through muscle and ligament attachments, along with the backward bend of the coccyx, which bears the load of the visceral organs (Figs. 1 & 2). The other function of the pelvic floor is to control the openings of the rectum and urogenital organs that pass through the pelvic floor, making it weaker.

Besides standing and walking, the human pelvis, as is also true in some mammals, must accommodate sitting. To facilitate sitting many primates and humans have sitting bones, which provide some rocker action on their bottoms often with abundant padding. Despite the padding, even those with extra padding, prolonged sitting is not recommended due to the potential compression of the vascular blood supply to the lower extremities.

The pelvis has one other function and that is to serve as an attachment site for the external genitalia.

To summarize, the human pelvis has five functions: to aid in the attachment of the lower extremities to the axial skeleton, to facilitate standing upright and walking, protection of the pelvic viscera, to accommodate sitting, and to serve as an attachment for the external genitalia.

The human pelvis consists of four anatomic structures: **the pelvic skeleton**, **the pelvic cavity**, **the pelvic floor (diaphragm)**, and **the perineum**, which is below the **pelvic diaphragm**. Since the perineum rest below the pelvic diaphragm, which forms the floor of the pelvic cavity, some anatomist do not include the perineum as part of the pelvis. The perineum will be discussed in the next chapter, "**Traumatic Injuries of the Perineum: Adult and Pediatric**."

B. The Pelvic Skeleton: In humans, the pelvic skeleton is formed by four bones: Two **innominate** (**os coxae** or **hip bones**), one **sacrum**, and one **coccyx**. The posterior component of the pelvic skeleton is formed by the sacrum and coccyx, whereas the lateral and anterior component is formed by the two innominate bones.

1. **Innominate bones:** These bones form most of the bony pelvis. They are joined to one another in front by the **pubic symphysis** and, behind (posteriorly), are joined to the sacrum, thus forming a ring of bone, which encloses the pelvis and unites the trunk to the lower extremities (Fig. 3).

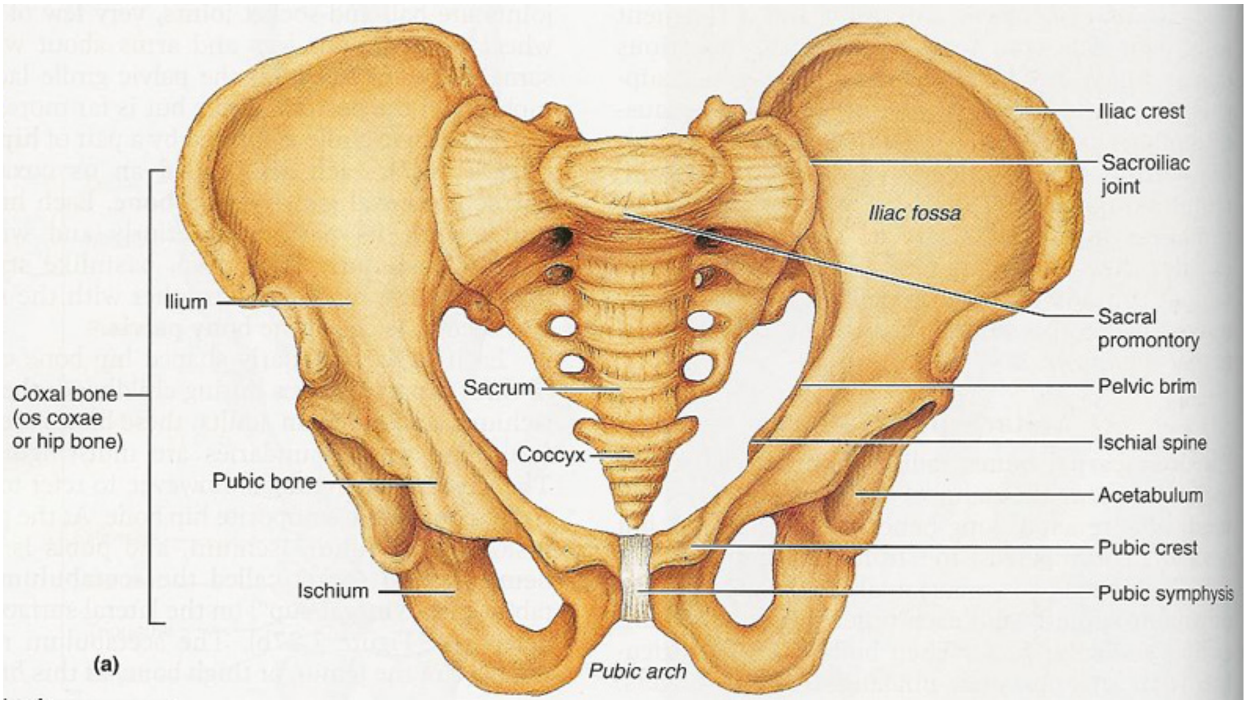


Fig. 3. The above image depicts the hip bone, its component parts, the ilium, ischium, and the pubic bone. Also shown are the pubic symphysis, sacrum, coccyx, and the acetabulum, which allows the pelvis to unite the trunk with the lower extremities. (Wiki)

The two hip bones are each formed by three separate bones, the **ilium**, the **ischium**, and the **pubis** (Fig. 3). These three separate bones fuse typically at age 16 to 17, in the **acetabulum**, which is a U shaped socket, that articulates with the head of the **femur**. Although the points of fusion can be readily discerned during the teenage years, they are indistinguishable in the adult. When examining the hip bone, the acetabulum is directed outward and downward as depicted in Fig. 3, with the **acetabular notch** pointing directly forward (Fig. 4).

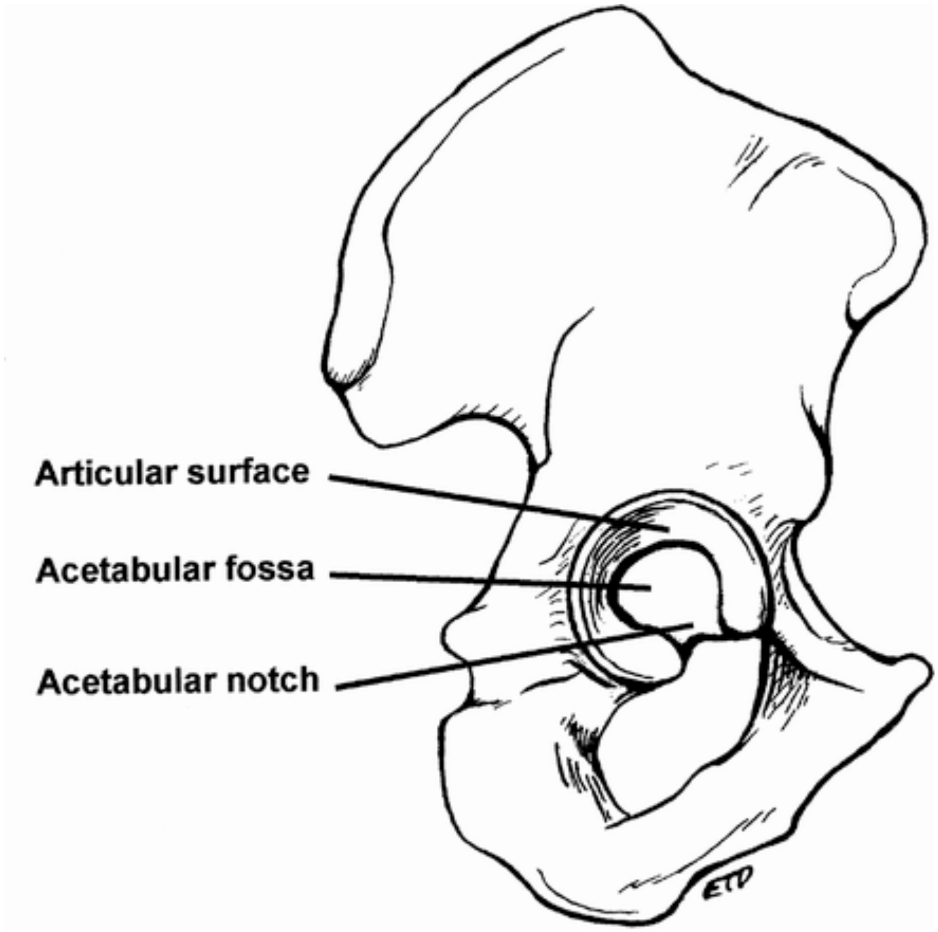


Fig. 4. This image shows the acetabulum, the spherical socket of the ball-and-socket hip joint. You will note the socket is deficient anteroinferiorly, as is the lunate-shaped articular surface. This opening is known as the acetabular notch. The central cartilage-devoid depression is known as the acetabular fossa. (radiographics.rsna.org)

(a). Ilium: This is the largest bone of the pelvis and consist of two parts, and upper and lower. The lower part is the smallest and is referred to as the **body**, and forms approximately two-fifths of the upper acetabulum. The upper part is the larger portion, being expanded into a fan, which is referred to as the **ala** (wing of the ilium). The ala and body are separated by a curved line, the **arcuate line**.

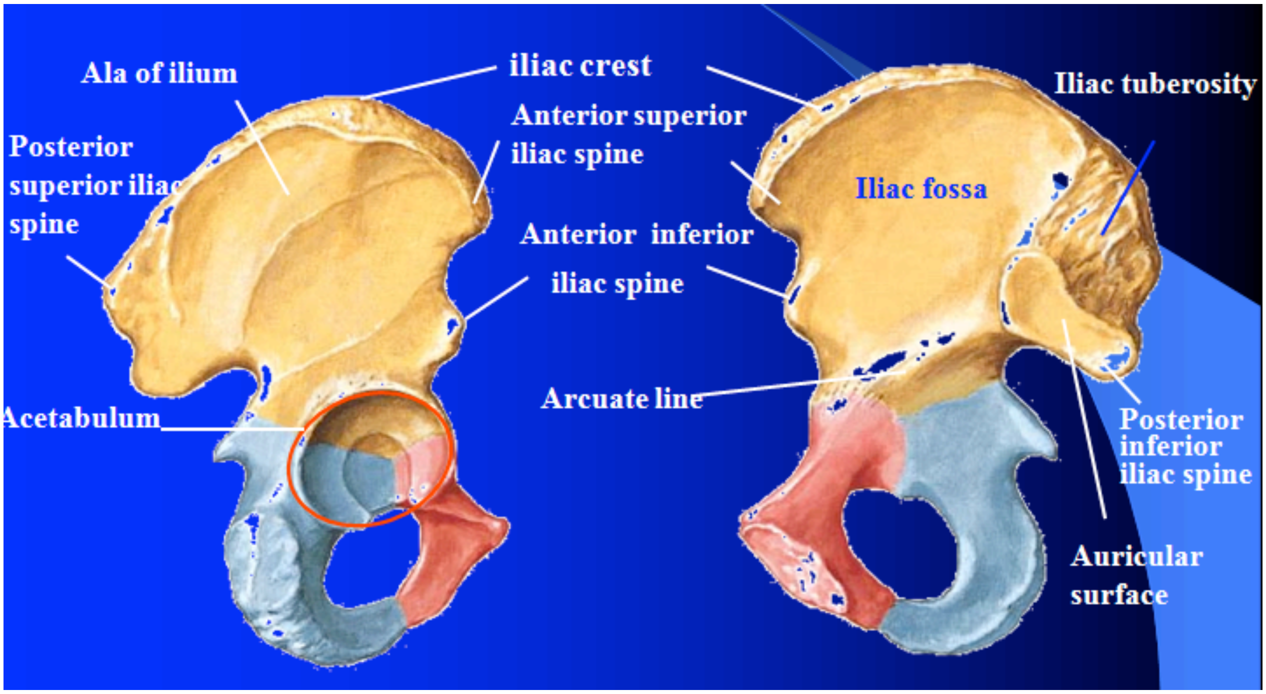


Fig. 5. The above image shows the lateral surface (left) and the medial surface (right) of the ilium. In the left image note the ala and the acetabulum. Looking at the acetabulum you can see three colors. The yellow color, which forms a little less than two-fifths of the acetabulum, represents the body of the ilium. The blue color represents the ischium, which provides the lower and side boundaries of the acetabulum. The ischium provides a little more than two-fifths of the acetabulum. The pink color represents the pubic bone, which forms approximately one-fifth of the acetabulum. The right image shows the location of the arcuate line, which divides the ala of the ilium, from the body of the ilium, which is below the arcuate line. (Wiki)

The **arcuate line** forms part of the border of the pelvic inlet. From a functional standpoint, the arcuate line indicates where weight is transferred from the sacroiliac joint to the hip bone (Figs. 3, 5 & 12). Also, in combination with the **pectineal line**, it forms the **iliopectineal line** (Fig. 21). The iliopectineal line is the border of the iliopubic eminence. When the iliopectineal line is combined with the sacral promontory, it makes up the **linea terminalis** (Figs. 6 & 7).

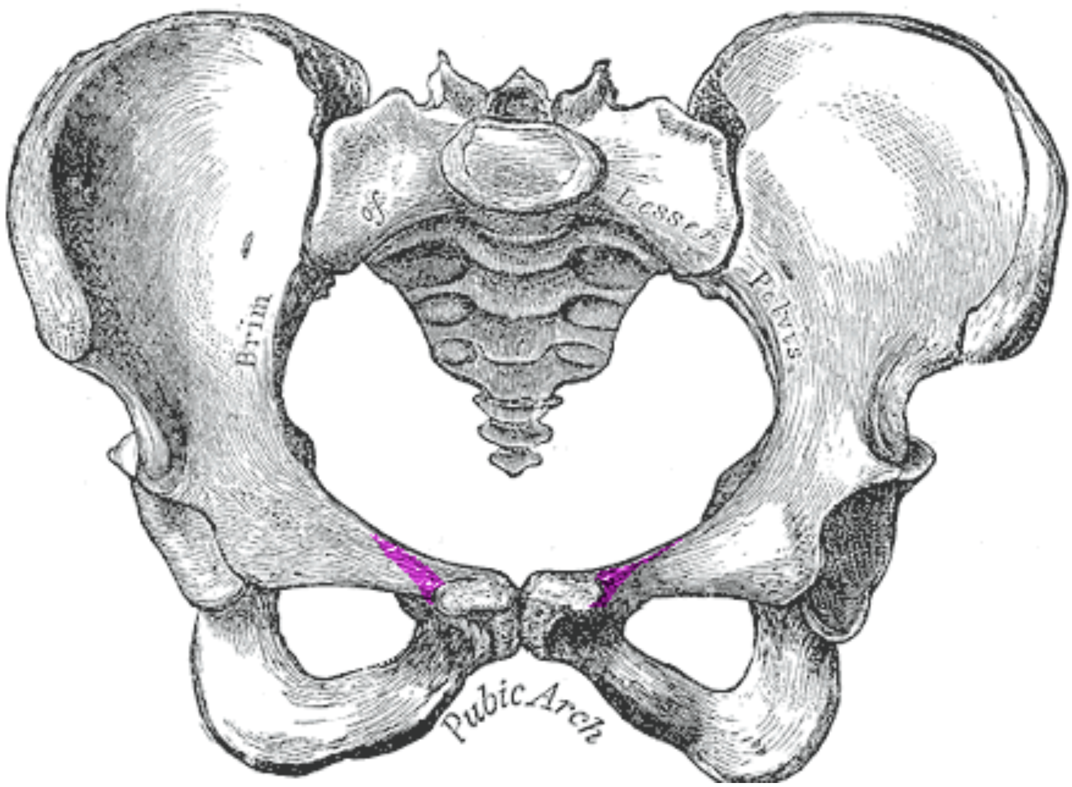


Fig. 6. The rose color on the pubic bone represents the pectineal line. (Wiki)

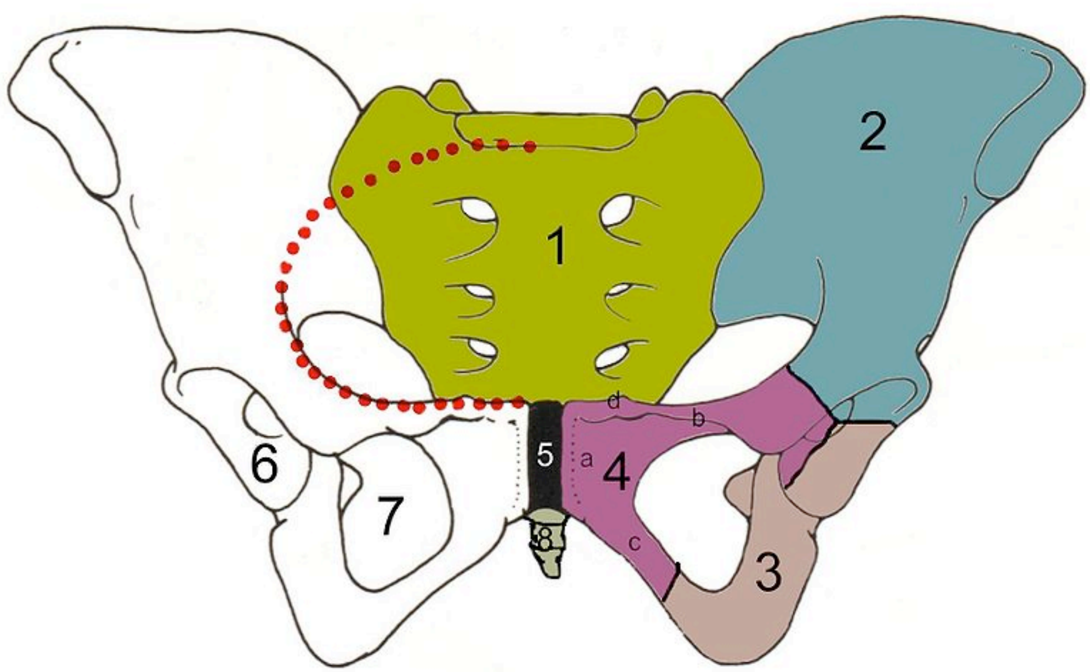


FIg. 7. The above image depicts the linea terminalis (innominate) line represented by the red dotted line. (1) sacrum, (2) ilium, (3) ischium, (4) pubis, (5) pubic symphisis, (6) acetabulum, (7) obturator foramen, (8) coccyx (Wiki)

The **linea terminalis** is part of the **pelvic brim**, which is the edge of the **pelvic inlet** (Fig. 8). The pelvic inlet divides the **abdominopelvic cavity** into the **abdominal cavity** (above the inlet) from the **pelvic cavity**, which is below the inlet (Figs. 9 & 10).

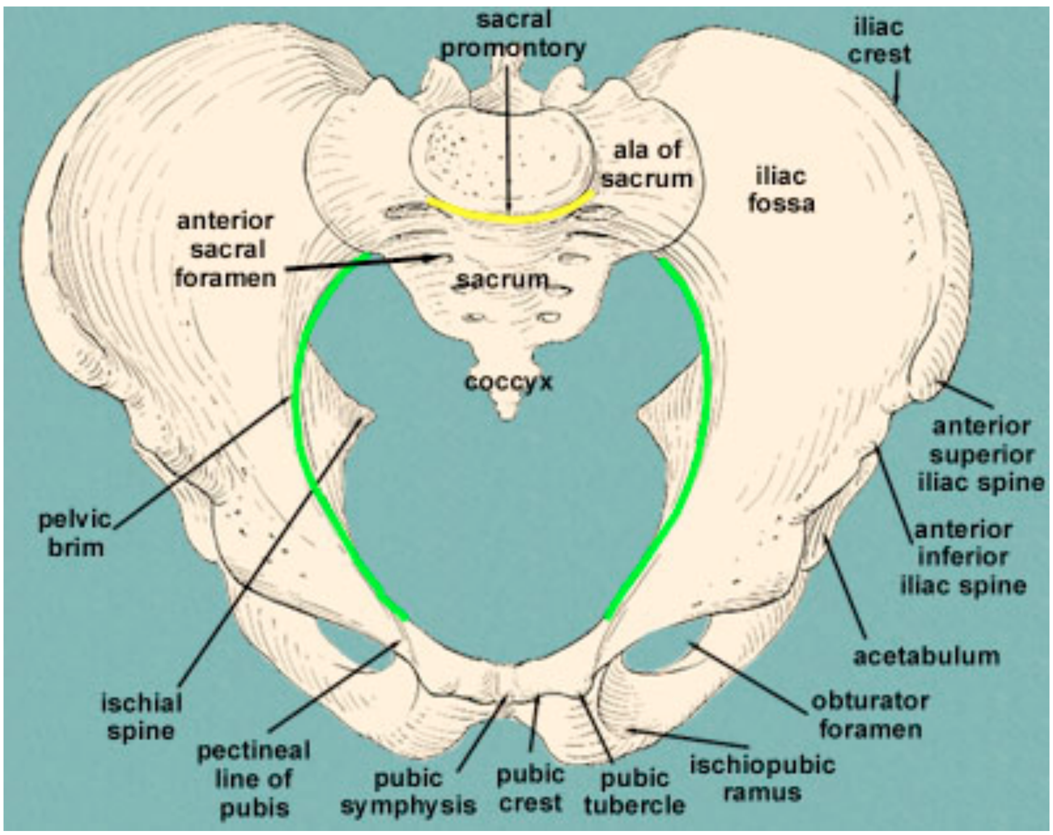


Fig. 8. The lime-green line represents the pelvic inlet. It is typically 11-12 cm from back to front, and 13-13.5 cm from side to side. (home.comcast.net)

However, some anatomists will extend the pelvic cavity above the pelvic inlet. When this is done, the pelvic cavity is divided into the **false pelvis** (above the inlet), and the **true pelvis**, which is below the inlet. You will also see the terms **greater** and **lesser pelvis**. The greater pelvis is that part of the pelvis above the pelvic inlet, hence it is the same as the false pelvis. The lesser pelvis is below the pelvic inlet, thus it is the same as the true pelvis.

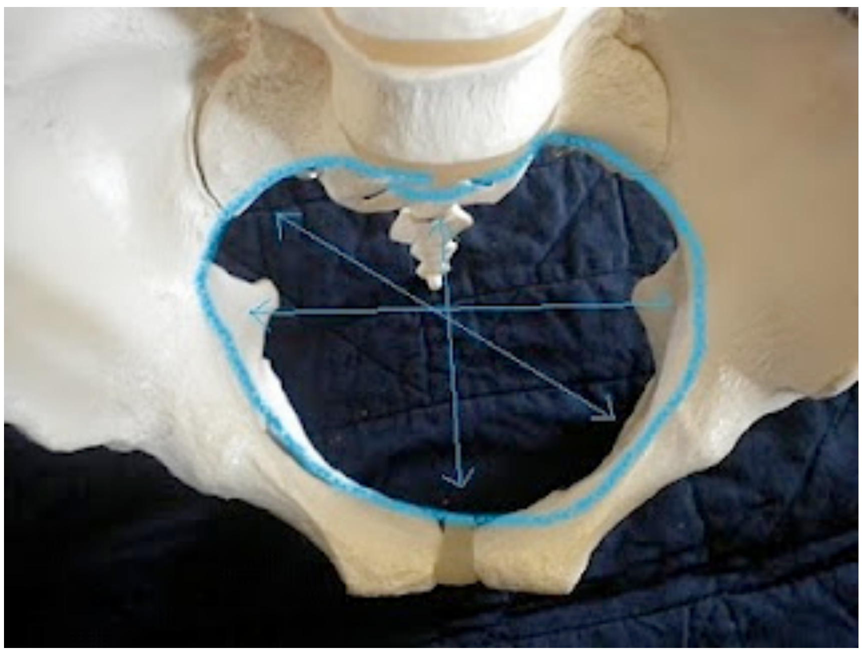


Fig. 9. The pelvic cavity is the narrower part of the pelvis. It has a more equally rounded diameter, each direction being about 12 cm wide. The **ischial spines**, the bony prominences that make up the narrowest part of the pelvis, are typically 11 cm apart. (naturalbirthinkitsap.blogspot.com)

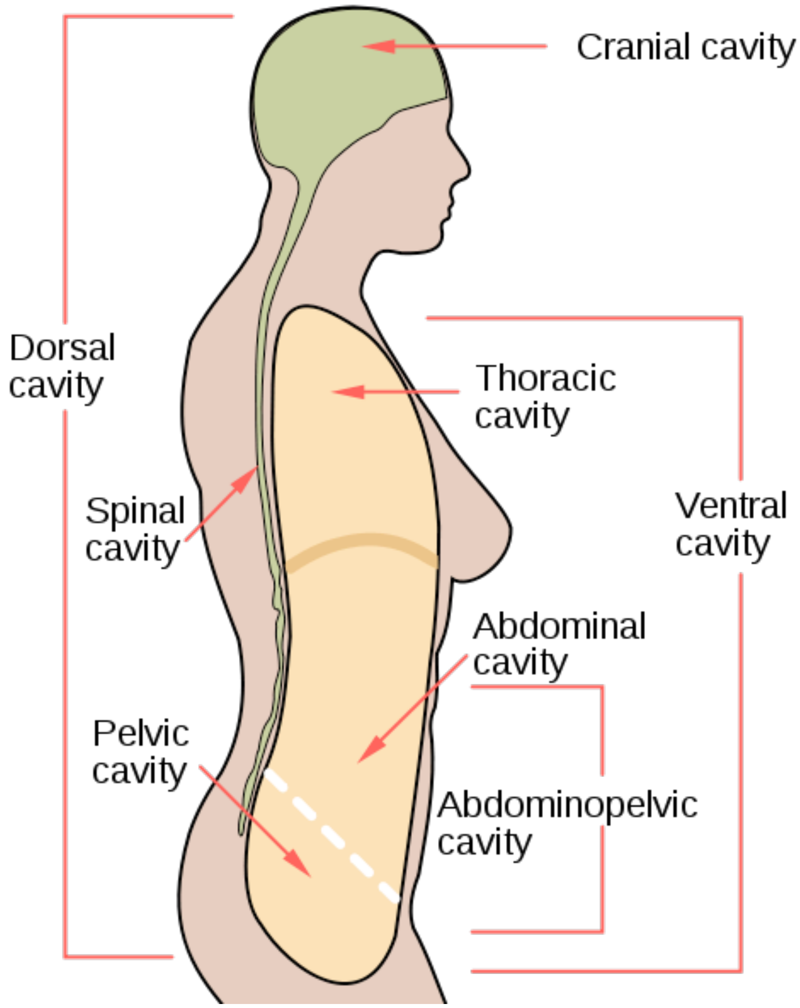


Fig. 10. The above is a drawing depicting the cavities of the body. The white dotted line represents the pelvic inlet separating the abdominal cavity from the pelvic cavity. (Wiki)

The **body** forms the thickened base of the ilium. It is its external surface that contributes to a little less than the upper two-fifths of the acetabulum (Fig. 5). The upper part of this surface is smooth contributing to the lunar articular surace with the femur. The lower portion of this surface is rough, contributing to the acetabular fossa in the central portion of the cup (Figs. 4 & 5). The internal surface of the body contributes to the lateral wall of the **true pelvis** and provides attachment for the **obturator internus muscle**.

The **ala** is the large fan-shaped, wing-like portion of the ilium, which has two surfaces and three margins (Fig. 5). The surfaces are the **external** or **gluteal** (the **gluteal muscles** arise from the **gluteal surface**) (Fig. 11) and the **internal** or **sacropelvic surface** (Figs. 5 & 12). The **sacropelvic surface** of the ileum is behind and below the **iliac fossa**; it includes the **iliac tuberosity**, the **auricular surface** and the **smooth pelvic surface** below and in front of the **auricular surface** (Figs. 5 & 12). The **margins** are the superiorly arched **iliac crest**, the **anterior margin**, and the **posterior margin**. The **margins** serve as attachment points for many muscles.

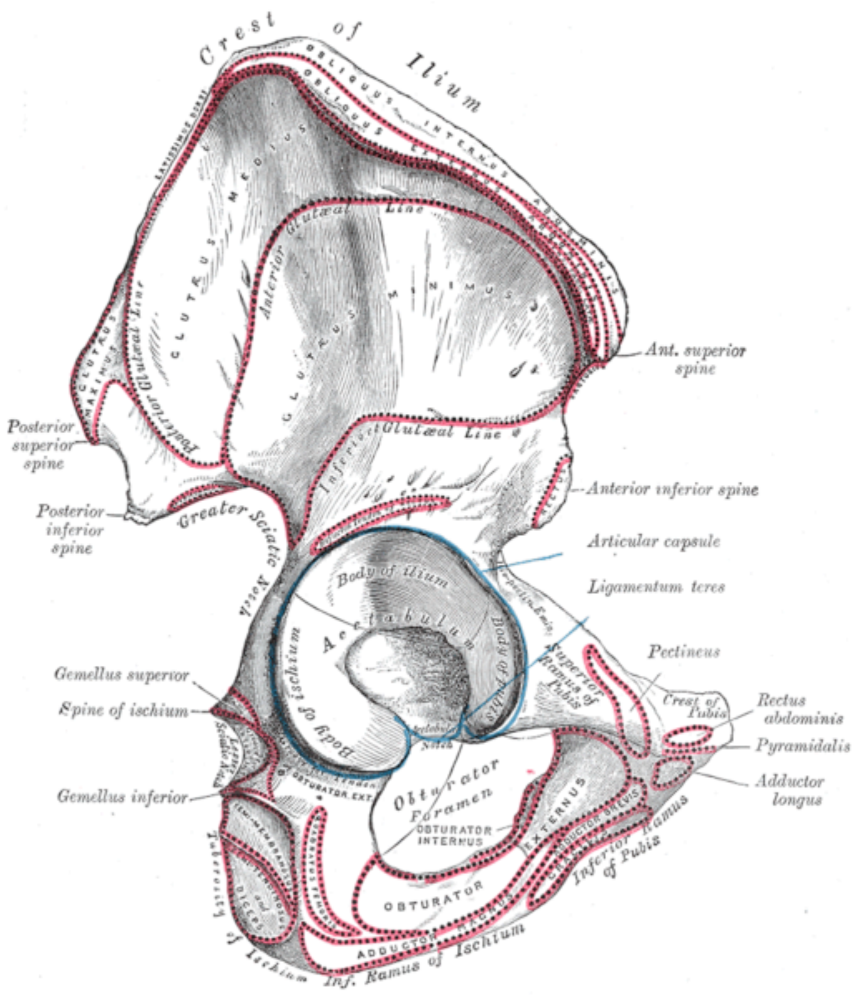


Fig. 11. The above drawing shows the lateral (external surface) of the hip. The ala is the large fan-shaped bone capped by the crest of the ilium. Below the crest is the **gluteal surface.** The attachment of the **gluteus medius muscle** is between the

posterior gluteal line and the **anterior gluteal line**. The **gluteus minimus muscle** attaches between the **anterior gluteal line** and the **inferior gluteal line**. Between the **inferior gluteal line** and the upper part of the acetabulum is a rough, shallow groove, from which the reflected tendon of the **rectus femoris** arises. (Wiki).

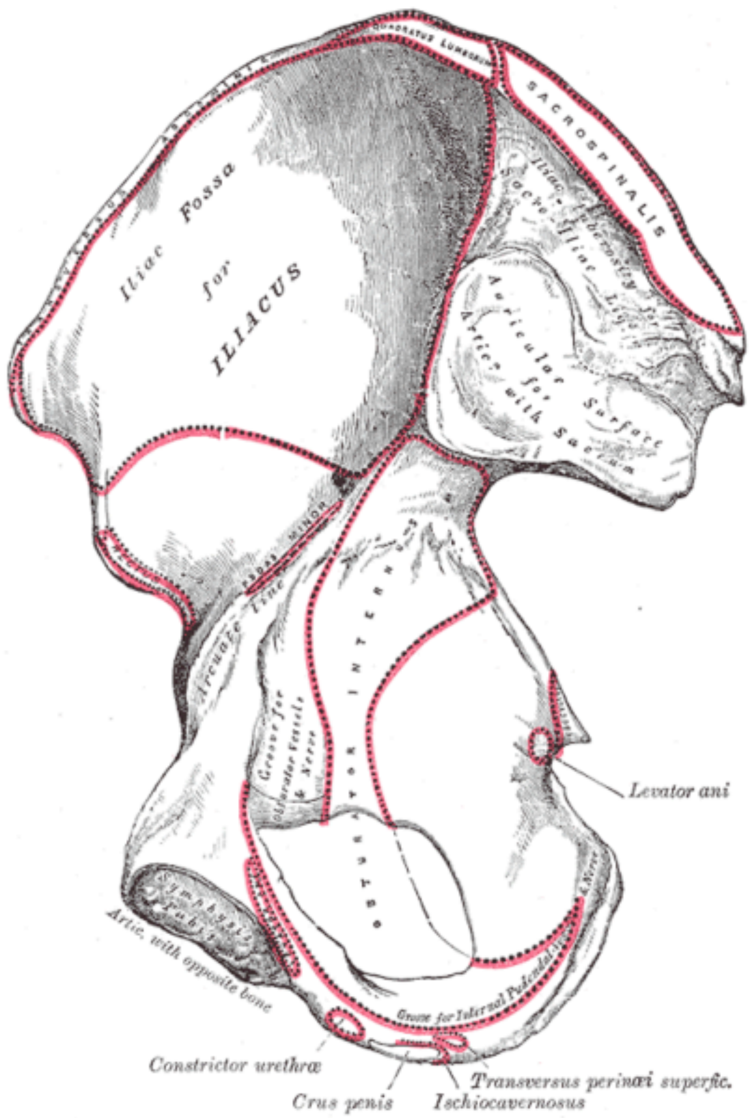


Fig. 12. This is a drawing of the internal surface of the **ala**. It has a large, smooth, concave surface, called the **iliac fossa,** which gives origin to the **iliacus muscle**. Immediately below this is a smooth, rounded border, the **arcuate line**. (Wiki)

The **iliac crest** is the rim of the fan-shaped **ala** (Figs. 3, 5 & 11). The crest has slightly overhanging **external lip**, which extends its whole length. It serves as an attachment surface for the **fascia lata**. The lip also serves for the attachment of the **external oblique muscle** in its anterior half, for the **latissimus dorsi** in its posterior one-third, and the **tensor fasciae latae muscle** anteriorly. Approximately 6 cm behind the anterior limit of the crest is the thickened **tubercle**. The **internal lip** is located at the upper limit of the **iliac fossa**; it provides attachment for the **iliac fascia.** In its anterior two-thirds it serves as an attachment site for the **transversus abdominis muscle** and, posterior to this, to the **quadratus lumborum muscle**. There is a third line on the crest, the **intermediate line**, which provides attachment for the **internal adominal oblique muscle** in its anterior two-thirds.

At the anterior end of the **iliac crest** is the **anterior superior spine** to which is attached the **inguinal ligament** and the **sartorius muscle** (Figs. 5 & 11). At the posterior end of the iliac crest is the **posterior superior spine**, which serves as an attachment site for the **sacrotuberous ligament**, the **posterior sacroiliac ligament**, and the **multifidus muscle** (Figs. 5,11 & 23). There are two other iliac spines, the **posterior inferior iliac spine** and the **anterior inferior iliac spine** (Figs. 5 & 11).

On the posterior border of the ala are two projections (spines), separated by a notch, the **posterior superior iliac spine**, discussed above, and the **posterior inferior iliac spine**, which corresponds with the posterior extremity of the **sacropelvic surface** of the bone. Directly below the posterior inferior iliac spine is the **greater sciatic notch** (Fig. 11).

The **anterior inferior iliac spine** is a bony eminence on the anterior border of ala. It is separated from the **anterior superior iliac spine** by a shallow notch. The upper part of the anterior inferior iliac spine serves as an attachment for the **rectus femoris muscle**, whereas its lower part is the point of attachment of the **iliofemoral ligament**. It also borders the rim of the **acetabulum** (Figs. 11 & 18).

(b). Ischium: This is the posterior-inferior V-shaped portion of the hip bone. It forms the lower and back part of the hip bone. It is located below the **ilium** and behind the **pubis**. The superior portion of this bone forms approximately one-third of the acetabulum. The blunt apex of the V is heavy and rounded as the **ischial tuberosity** (Figs 13 & 14). When we are in a sitting position the weight of the body rests on the two ischial tuberosities, hence they are especially robust in response to their weight-bearing function. The ischium is composed of a **body** and a **ramus**. Some anatomist further subdivide the ramus into two parts, the **superior ramus** and **inferior ramus**, thus in this anatomical classification the ischium has three parts (Figs. 13 & 14).

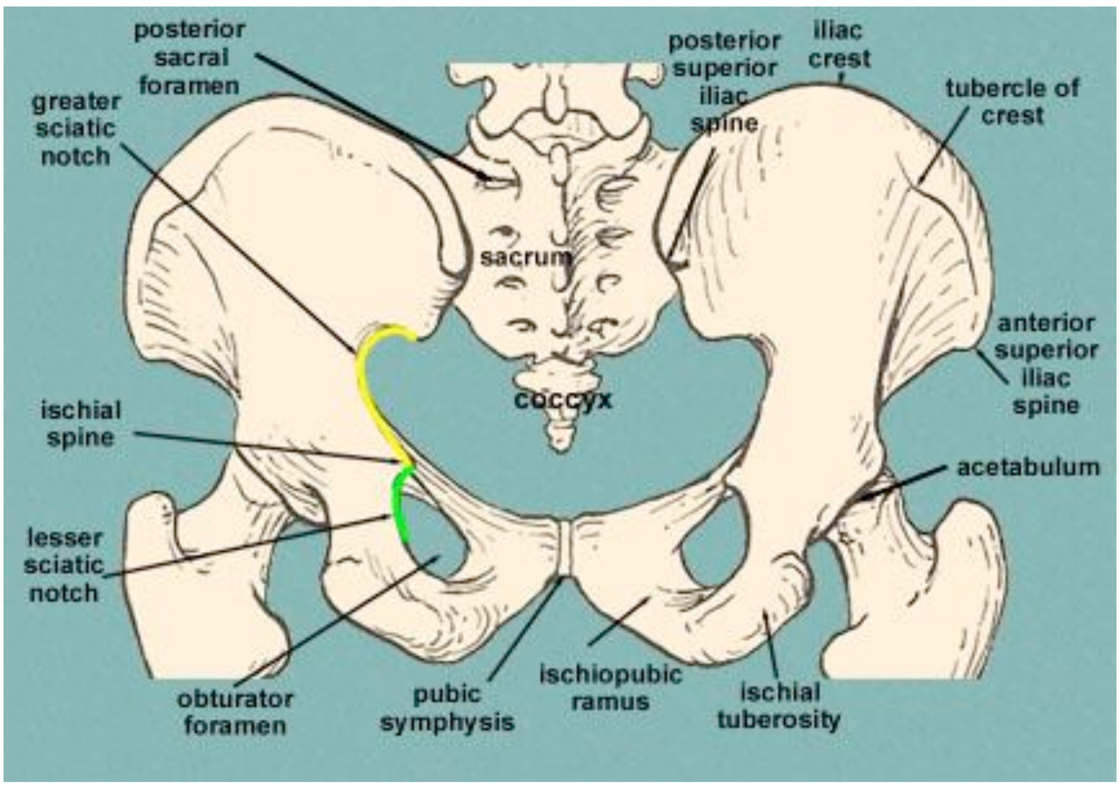


Fig. 13. This is a posterior (rear) view of the pelvis. The **ischial tuberosity** can be seen at the base to the left and right of center. (lollylegs.com)

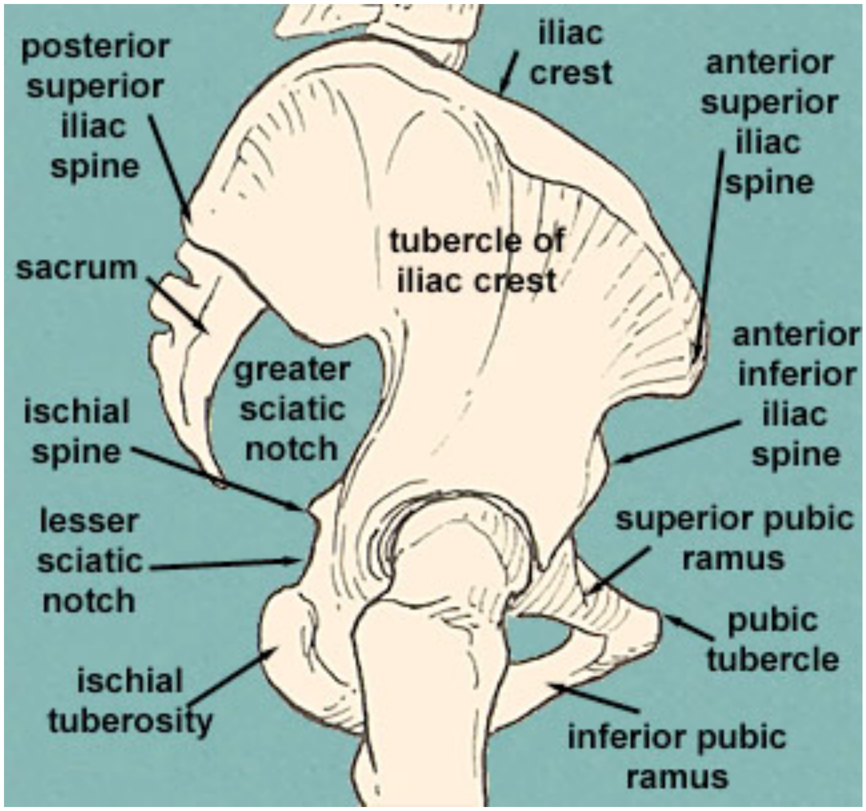


Fig. 14. This is a side view of the pelvis. The **ischial tuberosity** can be seen at the base to the posterior (rear) of the pelvis (left side). (lollylegs.com)

The **body** is heavy in response to its weight-bearing function. It is the superior portion of the body that forms approximately two-fifths of the **acetabulum**. It contains a prominent blunt projection called the **spine of the ischium**, which is directly above the **lesser sciatic notch** (Figs. 13 & 14). It serves as an attachment point for the **sacrospinous ligament**. On the **pelvic surface** is attached the **levator ani** and **coccygeus muscles**, and the **parietal pelvic fascia** (Figs.12 & 19). The **superior gemelius muscle** attaches along its **external surface**. Immediately above the spine of the ischium is the **greater sciatic notch** (Figs. 11, 13 & 14). The sacrospinous ligament extends across the greater sciatic notch converting it into the **greater sciatic foramen** (Fig. 15). It is through this foramen the **piriformis muscle** passes, as well as all vessels and nerves, which leave the pelvis for the gluteal region and back of the thigh. Below the **ischial spine** is a small notch, the **lesser sciatic notch**;

it is smooth due to a cartilaginous coating, except for two or three shallow hollows through which the subdivisions of the **tendon of the obturator internus muscle** pass. The notch is converted into a foramen, the **lesser sciatic foramen**, by the **sacrotuberous and sacrospinous ligaments** (Figs. 13, 14, 15, 27 & 28). Through this foramen pass the tendon and nerve of the **obturator internus**, the **pudendal nerve**, and the **internal pudendal vessels**. The **ischial tuberosity** is located posteriorly on the **superior ramus** (Figs. 11, 13 & 14). It is also referred to as the **sitz bone** or **sitting bone**. It marks the lateral boundary of the **pelvic outlet** (Fig. 17). The tuberosity is divided into

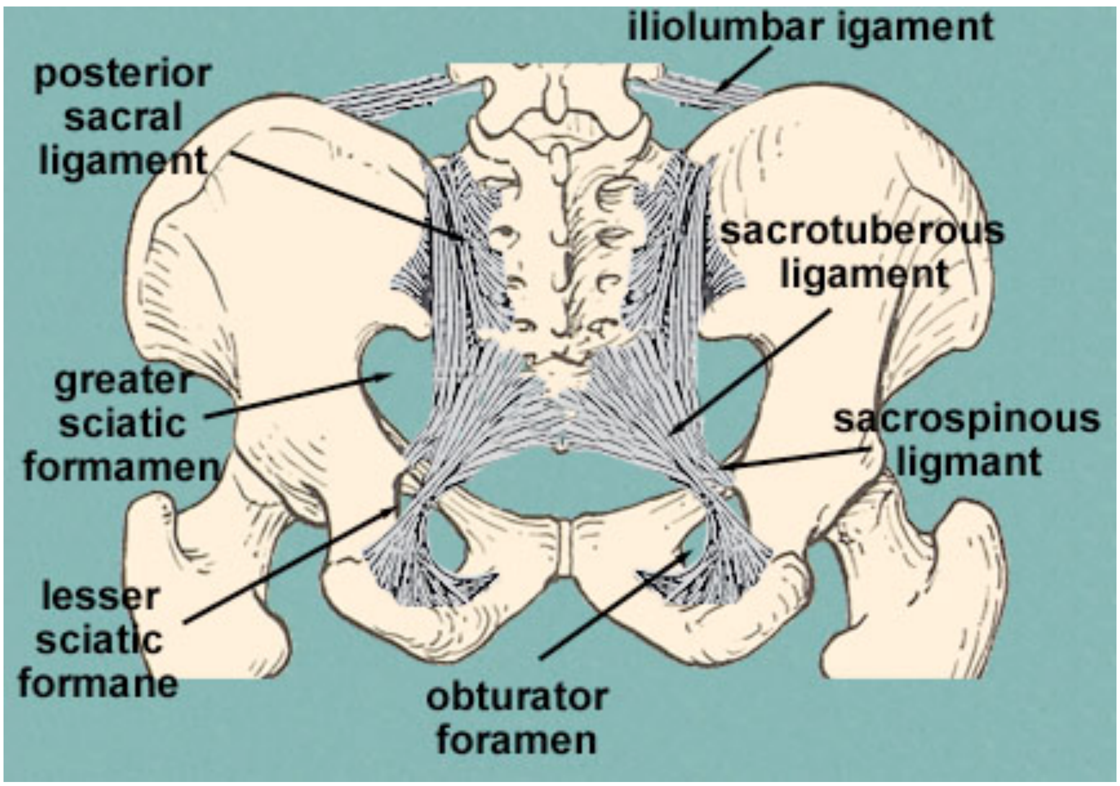


Fig. 15. Strong ligaments are necessary to hold the hip bone to the sacrum. These are found both posteriorly (the above image) and anteriorly (Fig. 16). The ligaments posteriorly are stronger than those anteriorly. The posterior ligaments as shown above are the **sacrotuberous, sacrospinous,** and **posterior sacral ligaments**. The fifth lumbar vertebra also has a strong tie-in with the ilium through the **iliolumbar ligament**. (home.comcast.net)

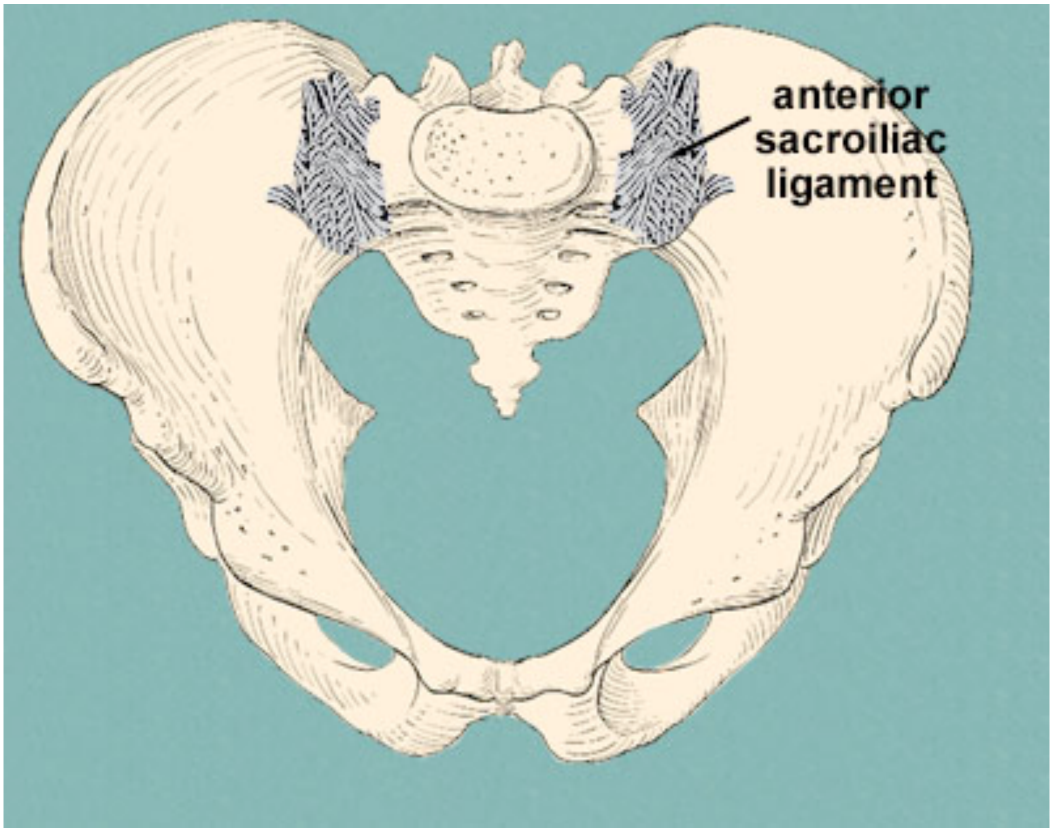


Fig. 16. This image depicts the anterior ligaments, **anterior sacroiliac**, which hold the hip bone to the sacrum. (home.comcast.net)

Fig. 17. The above image depicts the pelvic outlet. It is narrower side to side than it is front to back. The transverse diameter is about 11 cm. The anteroposterior diameter is about 11.5 cm. The **ischial tuberosities** are the most lateral bone eminences. (naturalbirthinkitsap.blogspot.com)

two portions, the upper smooth **quadrilateral portion**, and the lower rough **triangular portion**. An oblique ridge divides the upper quadrilateral portion, into an upper **external portion**, which gives origin to the **semimenbraneous muscle**, and a lower **internal portion**, which serves as a point for attachment of the long head of the **biceps femoris** and the **semitendinous muscles** (Fig. 18).

The lower rough triangular portion is divided into two parts, an **outer** and **inner**, by a prominent longitudinal ridge. The outer gives attachment to the **adductor magnus** and the inner to the **sacrotuberous ligament** (Figs. 18 & 19).

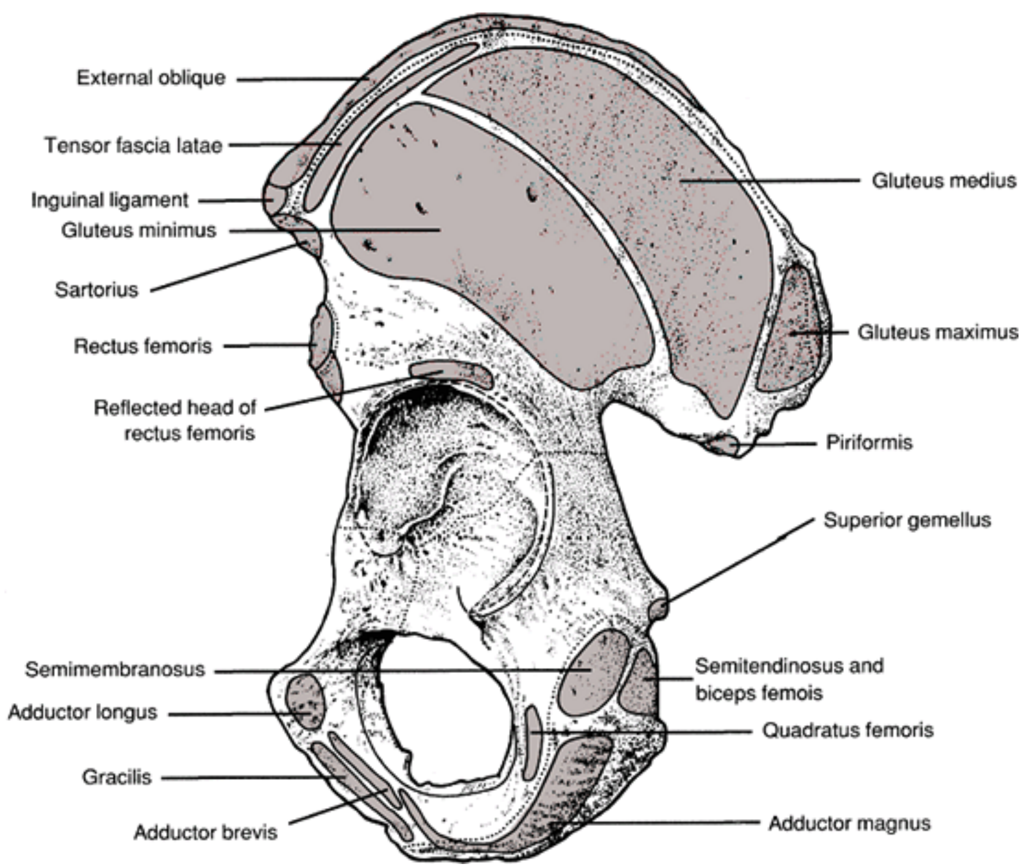


Fig. 18. The above image depicts a lateral projection of the left innominate bone. Note the muscular attachments to the ilium, ischium, and pubis. (health-7.com)

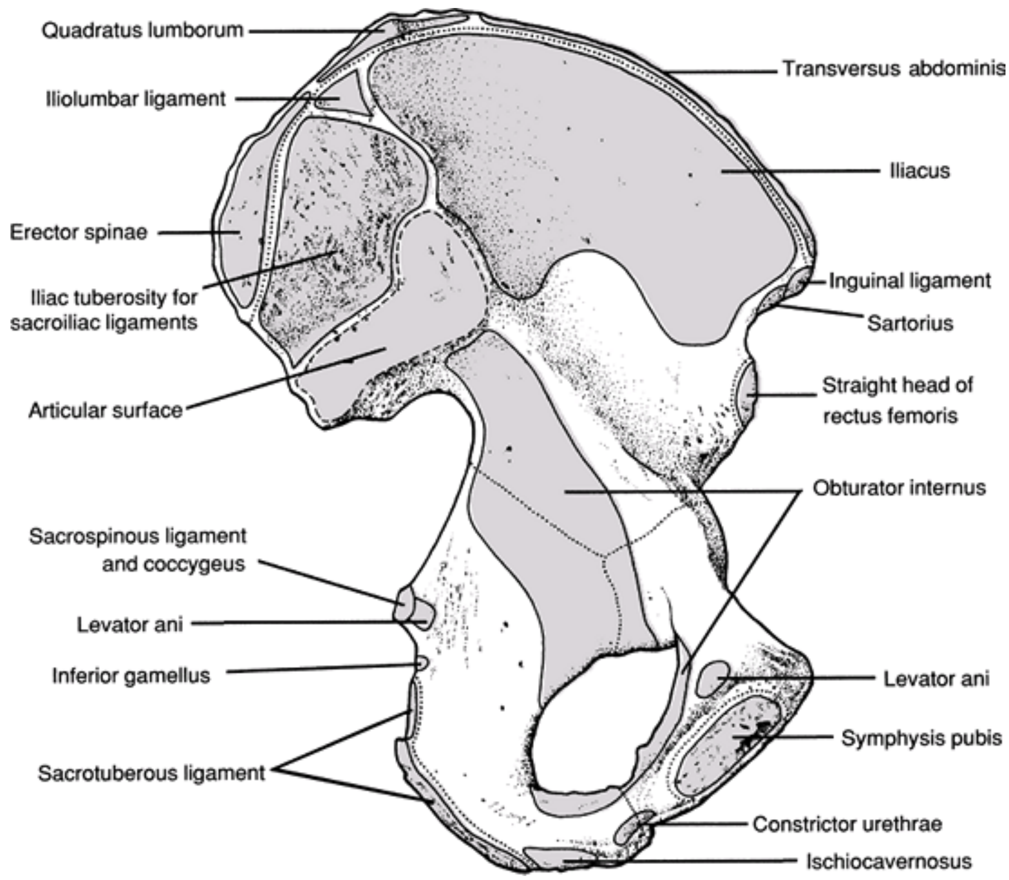


Fig. 19. The above image depicts a medial projection of the left innominate bone with muscle attachments and an outline of the sacroiliac joint surface. (health-7.com)

The **ramus** of the **ischum** can be divided into two parts, the **superior ramus** and **inferior ramus**. The superior ramus (descending ramus) projects downward and backward from the body. It has three surfaces: **external**, **internal**, and **posterior**.

The **external surface** is quadrilateral in shape. This surface is continuous with the **inferior ramus**. It gives origin to the **quadratus femoris** and some fibers of the **obturator externus** and **adductor magnus** (Fig. 18).

The **internal surface** forms part of the wall of the **lesser pelvis** (Fig. 8). It serves as an attachment for the falciform prolongation of the **sacrotuberous ligament**, the **transversus perinaei**, and the **ischiocavernous muscles**

(Figs. 12 & 19).

The **posterior surface** forms the **tuberosity of the ischium** (Figs. 11 & 19).

The **inferior ramus of the ischium (ascending ramus)** is thin, flattened part of the ischium, which ascends from the superior ramus, and joins the **inferior ramus of the pubis** (Fig. 11). Its **outer surface** serves for the attachment of the **obturator externus** and some fibers of the **adductor magnus** (Fig. 11 & 18); its inner surface forms part of the anterior wall of the pelvis.

Its **medial border** forms part of the **outlet of the pelvis** (Fig. 17 top of image), as well as having two ridges, which are continuous with similar ridges of the **inferior ramus of the pubis**. To the **outer ridge** is attached the deep layer of the **superficial perineal fascia (fascia of Colles,** which is also referred to as the **membranous layer of the subcutaneous connective tissue of the perineum)**, and to the **inner ridge** of the **inferior fascia of the urogenital diaphragm** (Fig. 20). Between the ridges attaches the **superficial transverse**

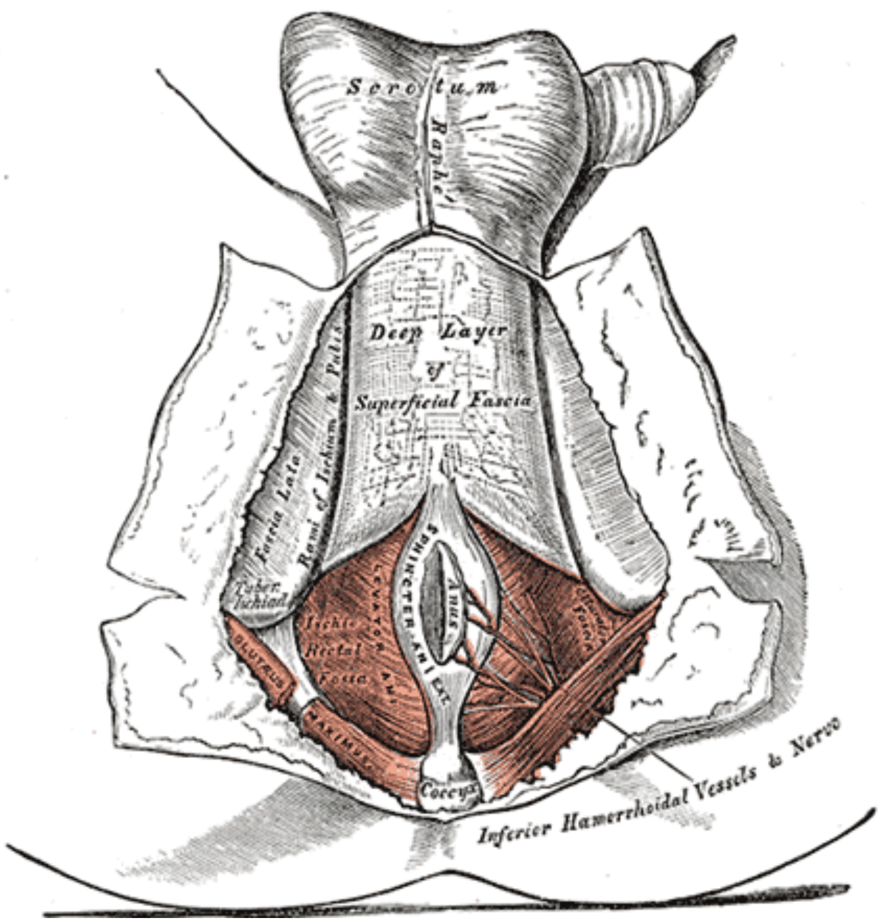


Fig. 20. The above drawing shows the **deep layer of the superficial fascia** or **Colles' fascia.** In front it is continuous with the **superficial fascia of the penis** and **Scarpa's fascia.** On either side it is firmly attached to the margins of the **rami of the pubis** and **ischium**, **lateral to the crus penis** and as far back as the **tuberosity of the ischium.** Posteriorly, it curves around the **transversi perinaei superficiales** to join the lower margin of the **inferior fascia of the urogenital diaphragm**. In the middle line, it is connected with the **superficial fascia** and with the **median septum of the bulbospongiosus**. (Wiki)

perineus muscle posteriorly, the **crus of the penis (** or **clitoris)** anteriorly, and the **ischiocavernous muscle**. The ischiocavernous covers the crus of the penis. It is also attached to the medial aspect of the ischial tuberosity.

The lateral border of the **inferior ramus** forms part of the medial margin of the **obturator foramen** (Figs. 13, 15 & 19).

(c). Pubis: The **pubis** is composed of three parts, **body**, and the **superior** and **inferior rami** (Fig. 5).

The **body** is the flat wide portion of the pubic bone, which unites in the center with the body of the opposite side to form the **pubic symphysis** (Figs. 3, 8, 13 & 19). The body forms one-fifth of the acetabulum completing the fossa of the acetabulum with the body portions of both the ilium and ischium, for the **head** of the **femur** (Figs. 13 & 14). The superior edge of the body is referred to as the **pubic crest,** which begins laterally at the **pubic tubercle** and extends to the **pubic symphysis**, measuring approximately 3 cm (Fig. 8). Laterally, it is confluent with the **arcuate line** of the ilium (Figs. 7 & 8 and p 7). As previously noted, the arcuate line in combination with the pectineal line (Figs. 6, 7, 8 & 21) form the iliopectineal line, which provides attachment for the **falx inguinalis**, the **lacunar ligament**, the reflected **inguinal ligament**, and the **pectineal fascia** (Fig. 21).

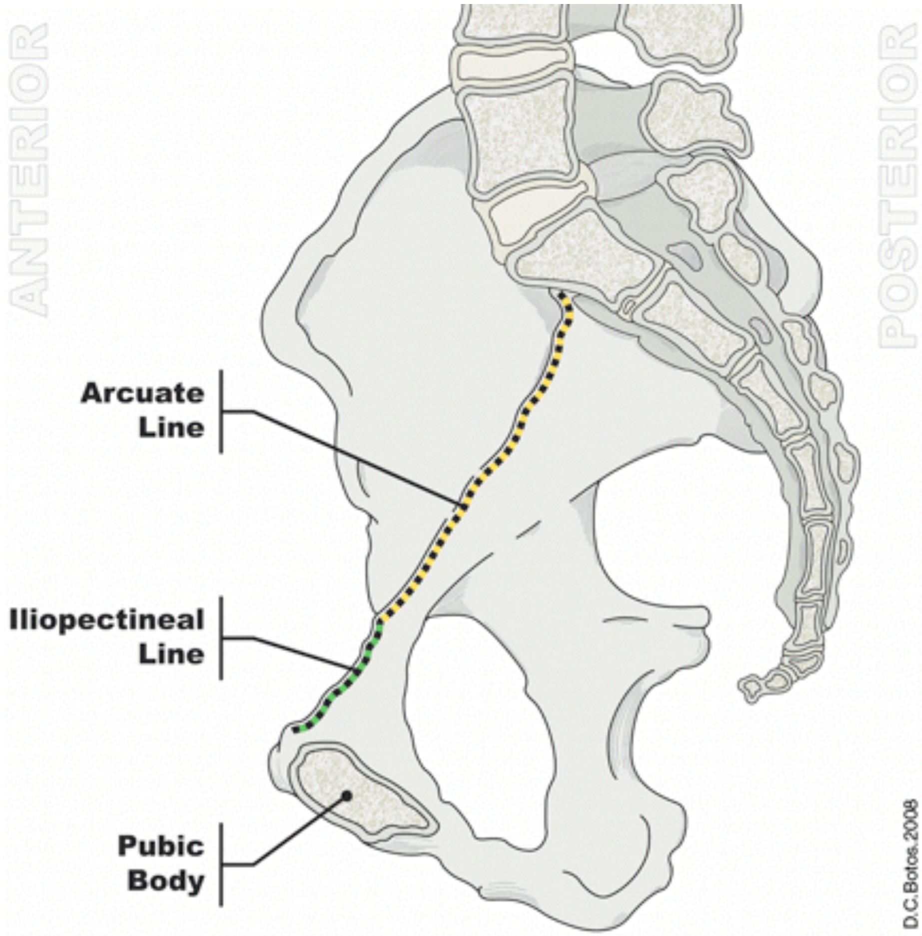


Fig. 21. This image is a schematic showing the orientation of the arcuate line along the medial surface of the hemipelvis. (radiographics.rsna.org)

The **internal surface** of the body of the pubis forms part of the wall of the **lesser pelvis** and gives origin to part of the **obturator internus** (Fig. 19). The **superior ramus** is in front of the **pubic crest** (Figs. 8 & 14). The anterior border of the **superior pubic ramus** has a sharp margin, the **obturator crest**, which forms part of the circumference of the **obturator foramen** and provides attachment for the **obturator membrane** (Figs. 22 & 23). The obturator crest extends from the **pubic tubercle** to the **acetabular notch** and gives origin to the **pubofemoral ligament**, which is also attached to the **iliopubic eminence**, **superior pubic ramus** and the **obturator membrane**. The lateral portion of the underside of the superior pubic ramus forms the upper border of the obturator foramen and presents, laterally a broad, deep, groove, the **obturator groove** for the passage of the **obturator nerve** and vessel.

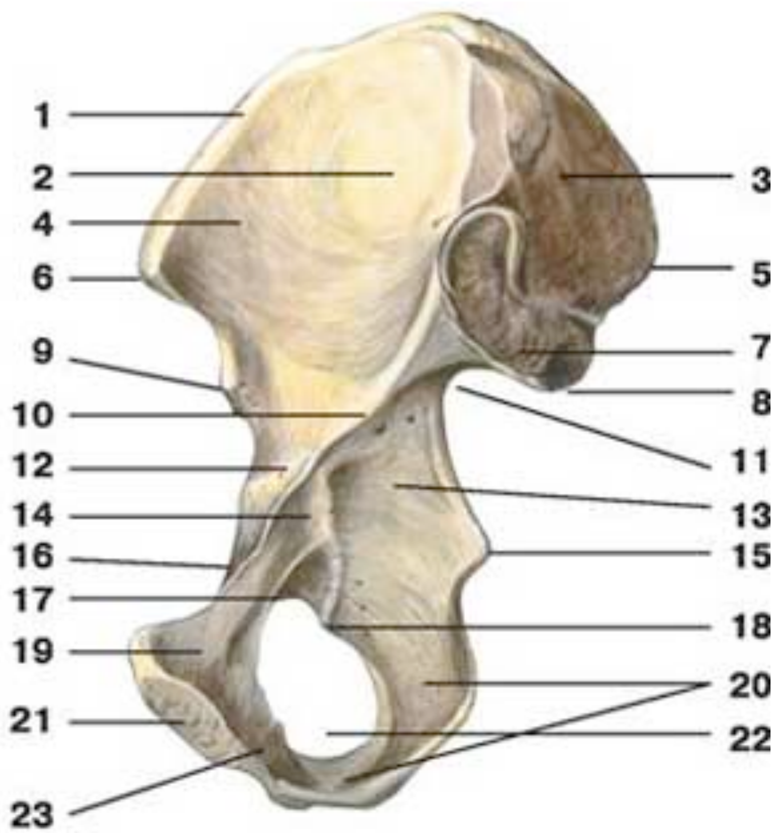


Fig. 22. The above drawing depicts the inside view of the pelvic bone. (1) iliac crest, (2) iliac fossa, (3) iliac tuberosity, (4) iliac wing, (5) upper iliac spine posterior, (6) upper anterior superior iliac spine, (7) ear-shaped surface, (8) lower rear hip spine, (9) lower anterior superior iliac spine, (10) arcuate line, (11) greater sciatic notch, (12) body of ilium, (13) body of ischium, (14) body of pubic bone, (15) ischial spine, (16) pubic crest, (17) obturator crest, (18) anterior obturator tubercle, (19) the superior ramus of the pubic bone, (20) superior ramus of the ischium and inferior ramus of the ischium (21) articular surface of the pubic bone, (22) obturator foramen, (23) inferior ramus of the pubic bone. (anthropotomy.com)

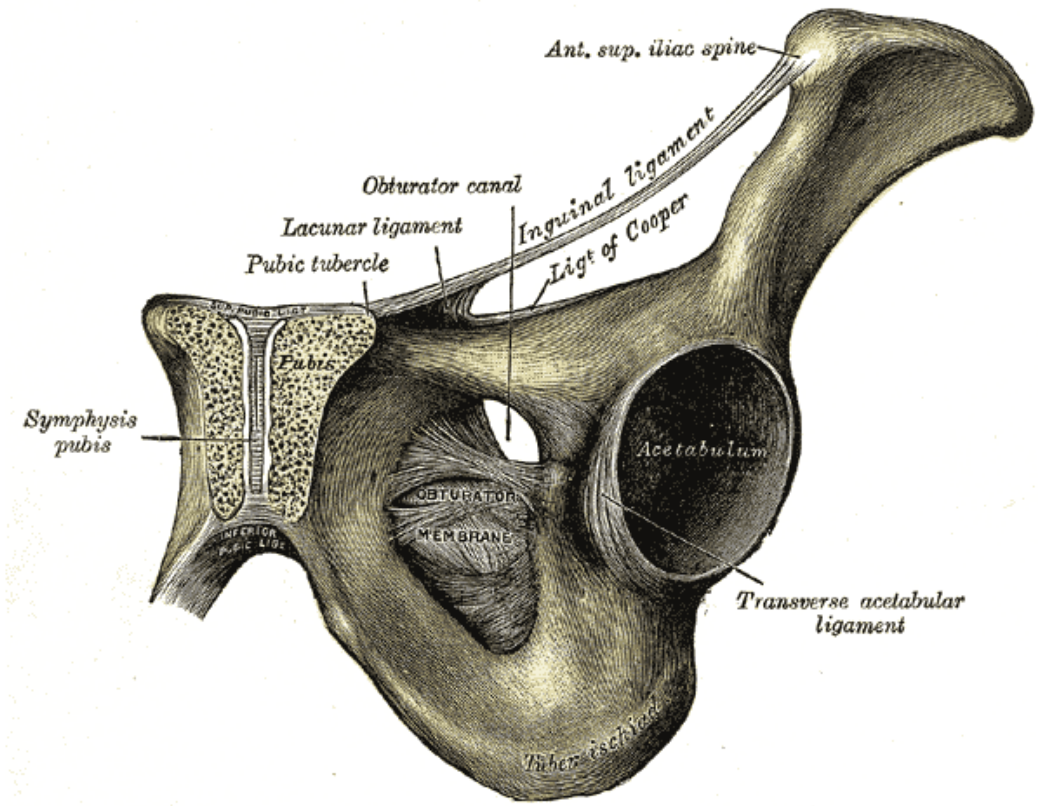


Fig. 23. The above figure depicts the obturator membrane crossing the obturator foramen thus, producing the obturator canal. (Wiki)

Remember, along the medial aspect of the underside (inferior surface) is the obturator crest, which forms part of the circumference of the obturator foramen, and serves for the attachment of the obturator membrane. The obturator membrane closes (obturates) most of the obturator foramen, with the exception of its superior lateral portion, where it leaves an opening, the obturator canal, through which the obturator nerve and vessels, passing through the obturator groove, leave the pelvis and enter the thigh (Fig. 23).

The **posterior surface of the lateral portion of the superior pubic ramus** forms part of the anterior boundary of the **lesser pelvis**. It also provides attachment for some fibers of the obutrator internus.

The **medial portion of the superior ramus**, which was formerly called the body, has a superior margin, referred to as the pubic crest (page 22). The lateral-most point of the pubic crest is the pubic tubercle.

The medial end of the **inguinal ligament** attaches to the tubercle, whereas the **rectus abdominis** and **pyramidalis muscles** take origin from the crest (Figs. 11, 18 & 19). Passing upward and laterally from the pubic tubercle is a ridge, the **pecten pubis** (**pectineal line**), which joins with the **arcutate line**, and the sacral promontory to form the **linea terminalis**, which marks the brim of the **lesser pelvis**, also discussed on pages 8 & 9, Figs. 7 & 8). To the pecten pubis is attached the **inguinal falx**, the **lacunar ligament** (**Gimbernat's ligament**), the **reflected inguinal ligament** (**triangular fascia**), and the **pectineal fascia**, also discussed on page 22 (Fig. 23).

The **posterior surface** of the medial part of the superior ramus underlies the urinary bladder and serves for the attachment for the **levator ani** and **obturator internus muscles,** as well as the **medial puboprostatic ligaments** (Figs. 12 & 19). The **anterior surface** gives origin to the **adductor longus, gracilis, adductor brevis,** and **obturator externus muscles** (Figs. 11 & 18). The **medial border of the superior pubic ramus** is referred to as the **symphyseal surface**. It is crossed by eight or nine transverse ridges to which the symphysis pubis is attached (Figs. 12, 22 & 23). The two hip bones are joined anteriorly at the pubic symphysis by fibrocartilage, which is covered by hyaline cartilage, referred to as the **interpubic disc** (**interarticular disc**). Two ligaments, the **superior** and **inferior pubic ligaments**, reinforce the symphysis (Fig. 24).

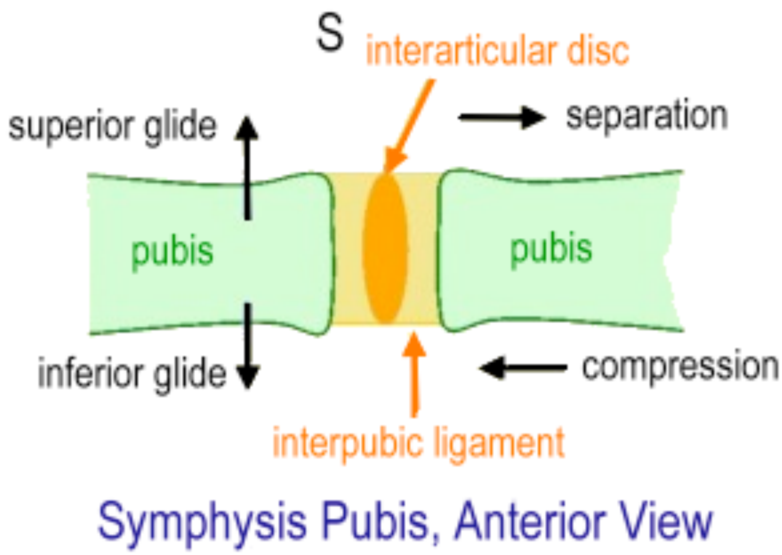


Fig. 24. The above illustration depicts the architecture of the symphysis. (kimir.co.kr)

The **inferior ramus of the pubic bone** extends inferiorly and posterolaterally in continuity with the **inferior ramus of the ischium** (Figs. 11, 18 & 22). Its **anterior surface** serves for the attachment of the adductor brevis, adductor magnus, and the external obturator muscles. The gracilis muscle arises next to its medial border. Its **posterior surface** gives origin to the internal obturator and sphincter urethrae muscles (Fig. 19).

The **medial border** has two ridges, which are separated by an intervening space. These ridges are continuous with similar ridges of the **inferior ramus of the ischium**, discussed on page 21, and Fig. 20. As previously discussed, the **internal ridge** serves for the attachment of the **inferior fascia of the urogenital diaphragm.** The **external ridge** gives attachment to the **subcutaneous connective tissue of the perineum** (**Fascia of Colles**).

The **lateral border** forms part of the circumference of the **obturator foramen**, and gives attachment to the **obturator membrane** (Fig. 23).

(d). Acetabulum: This is a deep concave cavity, which receives the head of the femur (Figs. 4, 5, 11 & 23). It is located within the center of the lateral aspect of the hip bone, facing anteroinferiorly. The surface of the wall of the concavity consist of two parts, the **semilunar articular** portion and a deep, **central**

nonarticular (**acetabular fossa**) portion (Fig. 4). As previously stated, approximately two-fifths of the articular part is provided by the body of the ischium, which is the lower and side boundaries of the acetabulum; the body of the ilium provides about two-fifths of the articular surface, which is the upper boundary; and one-fifth of the articular surface is provided by the body of the pubis, which is near the midline. The non-articular portion is referred to as the acetabular fossa, which is continuous with the **acetablular notch** inferiorly (Fig. 4). The notch is bridged by the **transverse ligament** with the margins of the notch serving for the attachment of the **ligamentum capitis femoris**. The rim of the acetabulum serves for the attachment of the **glenoid labrum of the hip joint.**

(e). Obturator Foramen: This is a large opening surrounded by the bodies and rami of the ischium and pubis. It lies below and slightly anterior to the acetabulum (Figs. 11, 13, 15 & 22). It has an oval form in the male pelvis and a more triangular form in the female (Fig. 25). The margins of the obturator foramen serves for the attachment of the **obturator membrane**, except superolaterally, where it provides for a communication between the pelvis and thigh through the **obturator groove**, which allows for the passage of the obturator vessels and nerve (Fig. 23).

2. Sacrum: The **sacrum** is a large triangular bone at the base of the spine forming the posterosuperior wall, the upper and back part of the pelvic cavity, where it is wedged between the two hip bones (Figs. 1, 3, 8 &13). Its upper or superior surface has a wide base, which projects forward forming the **sacral promontory** and articulates with the **fifth lumbar** vertebra forming the **lumbosacral angle** (Fig. 3 & 8). Its bottom part or apex articulates with the **coccyx** (**tailbone**) (Figs. 1, 3, 8 & 13). It is typically formed from the fusion of five vertebrae, however, in some cases the sacrum consist of the fusion of six vertebrae. In childhood these sacral vertebrae are unfused. They begin to fuse between the ages of 16 and 18, and are usually completely fused by age 34.

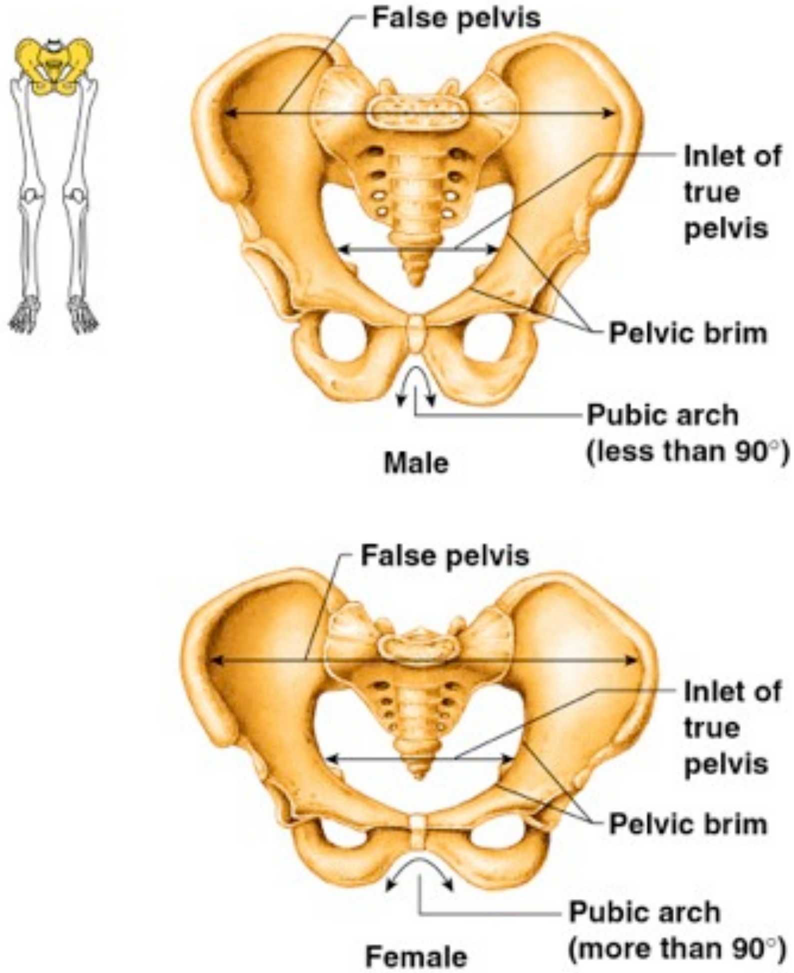


Fig. 23. The above image shows the rounded nature of the obturator foramen in the male, whereas the female obturator foramen has a more triangular configuration. (Wiki)

The sacrum in males and females differs in shape; this difference is referred to as **sexual dimorphism**. In the female the sacrum is shorter and wider than in the male (Fig. 24); the lower half forms a greater angle with the upper; the upper half is nearly straight, the lower half presenting the greatest amount of curvature. The bone is also directed more obliquely backward; this increases the size of the pelvic cavity and makes the sacrovertebral angle more prominent. In the male the curvature is more evenly distributed over the whole length of the bone, and is altogether larger than in the female.

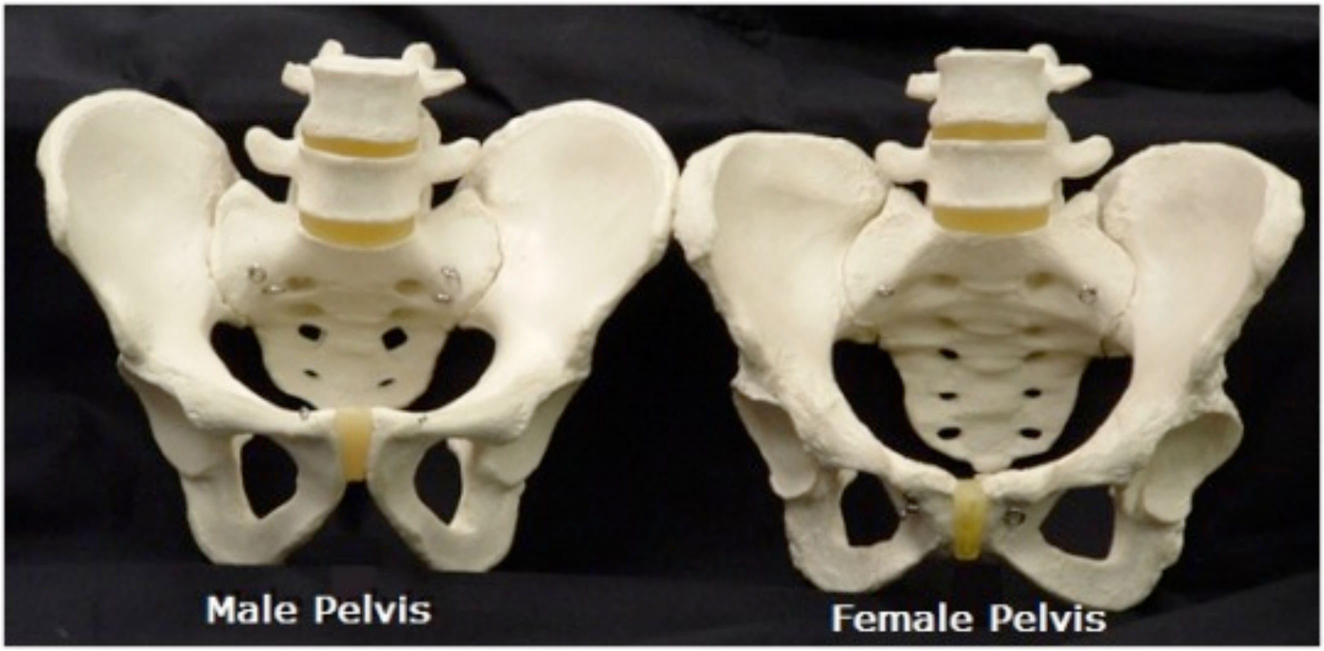


Fig. 24. Note the differences in the sacrum of the male and female. (Wiki)

The pelvic surface of the sacrum is concaved and smooth (Fig. 25). It is convex and very irregular on its posterior or dorsal surface (Fig. 26). The purpose of the concavity on its pelvis surface is to allow more room for the contents of the pelvic cavity. The concave surface contains four **transverse ridges**, which separate the vertebral bodies of the original five sacral vertebrae. At the lateral ends of these ridges are the pelvic **sacral foramina**, which allow passage of the **vertebral rami of the sacral nerves** and branches of the **lateral sacral arteries**. Immediately lateral to the foramina are grooves for the sacral nerves, as well as ridges for attachment of fibers of the **piriformis muscle** (Fig. 25).

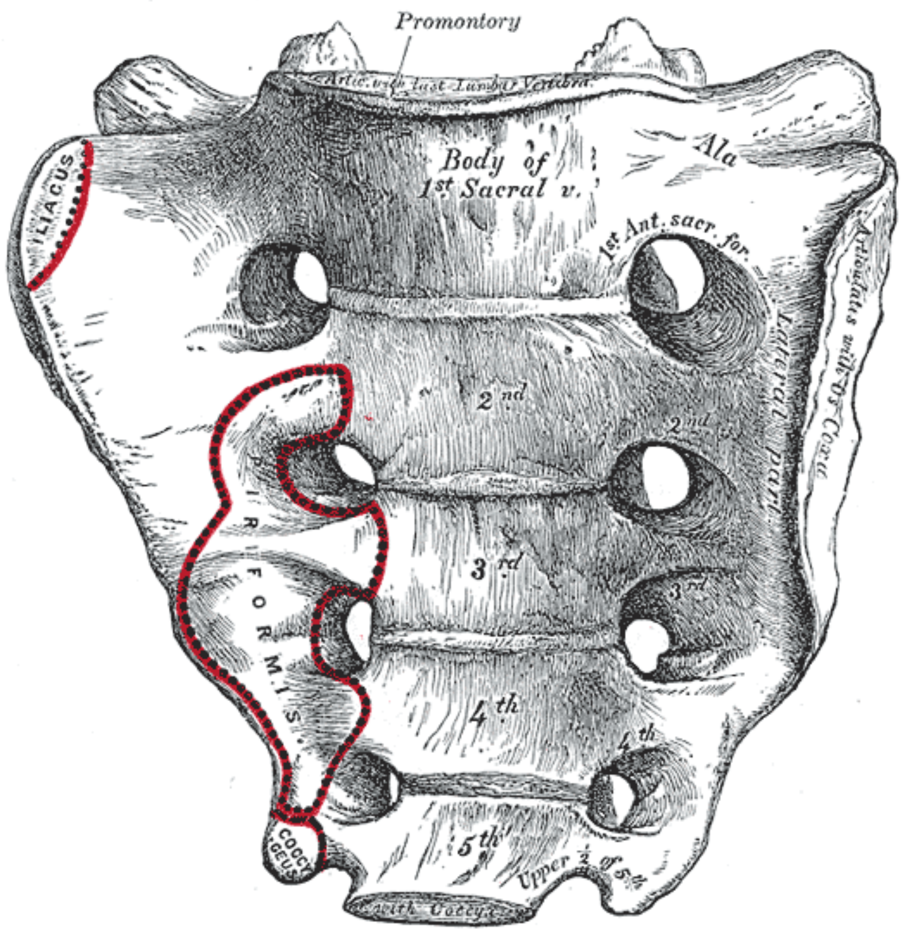


Fig. 25. The above shows the pelvic surface of the sacrum. Note the four transverse ridges, the sacral foramina at their lateral ends, and the ridges for the attachment of the fibers of the **piriformis muscle** outlined in red. (Wiki)

The markedly irregular dorsal surface has four **dorsal sacral foramina**. In the midline of the dorsal surface are the fused, reduced spinous processes of the sacral vertebrae forming the **median sacral crest** (Fig. 30). Immediately lateral to the median sacral crest is a shallow groove overlying the fused laminae. This groove serves as an attachment point for the **multifidus muscle**. Typically, the laminae of the fifth segment, and sometimes the fourth, fail to meet producing the **sacral hiatus**, which is the inferior entrance to the vertebral canal. Just medial to the dorsal sacral foramina is the **intermediate sacral crests**, which are formed from the fused articular processes of the sacral vertebrae, except for the upper articular process of the first sacral vertebra, which has a large oval facet for articulation with the inferior articular surface of the fifth lumbar vertebra and the inferior articular processes of the fifth sacral vertebra, which form the **sacral horns**, which are connected to the **horns of the coccyx** (Fig. 26).

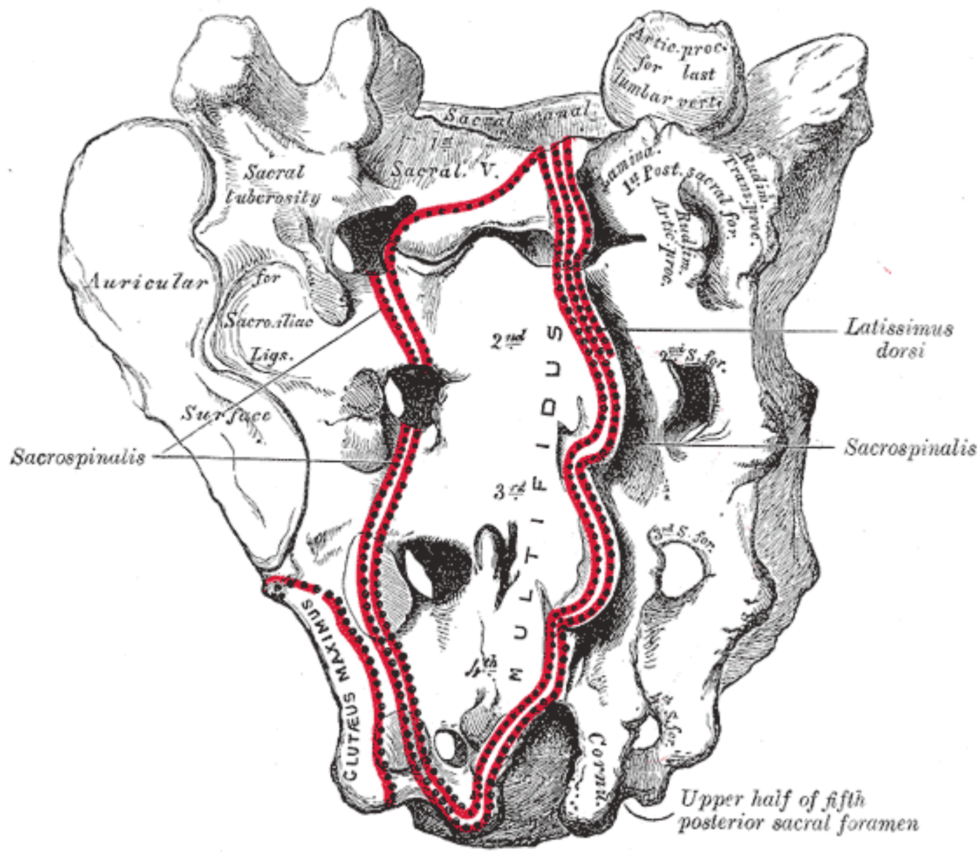


Fig. 26. This image is of the dorsal surface of the sacrum. Note its marked irregularity, The articular surface for the fifth lumbar vertebra, and the attachment sites for the various muscles including the multifidus are outlined in red. (Wiki)

Lateral to the **dorsal sacral foramina** are the **lateral sacral crests**, which represent the fused **transverse processes**. Superiorly they provide attachment for the **dorsal sacroiliac ligaments**, of which there is an upper and lower part. The upper part, the **short dorsal sacroiliac ligament,** extends from the first and second transverse tubercles on the back of the sacrum to the tuberosity of the ilium. The lower part, the **long dorsal sacroiliac ligament,** which extends between the third transverse tubercle of the back of the sacrum and the posterior spine of the ilium (Fig. 15, p 17 & Fig. 27).

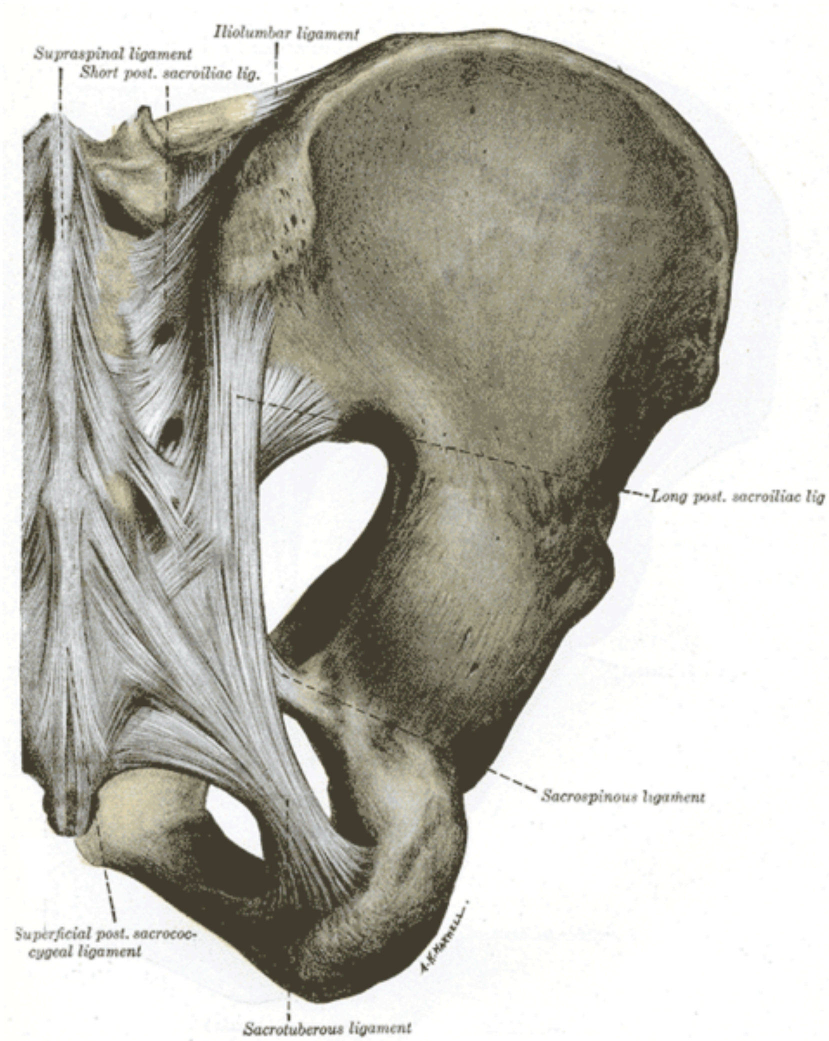


Fig. 27. This image is of the posterior (dorsal) surface of the bony pelvis. Note the short and long posterior (dorsal) sacroiliac ligaments. (Wiki)

There is also **anterior sacroiliac ligaments**, which connect the anterior surface of the lateral part of the sacrum to the margin of the auricular surface of the ilium and to the preauricular sulcus (Fig. 16, p 18 & Fig. 28).

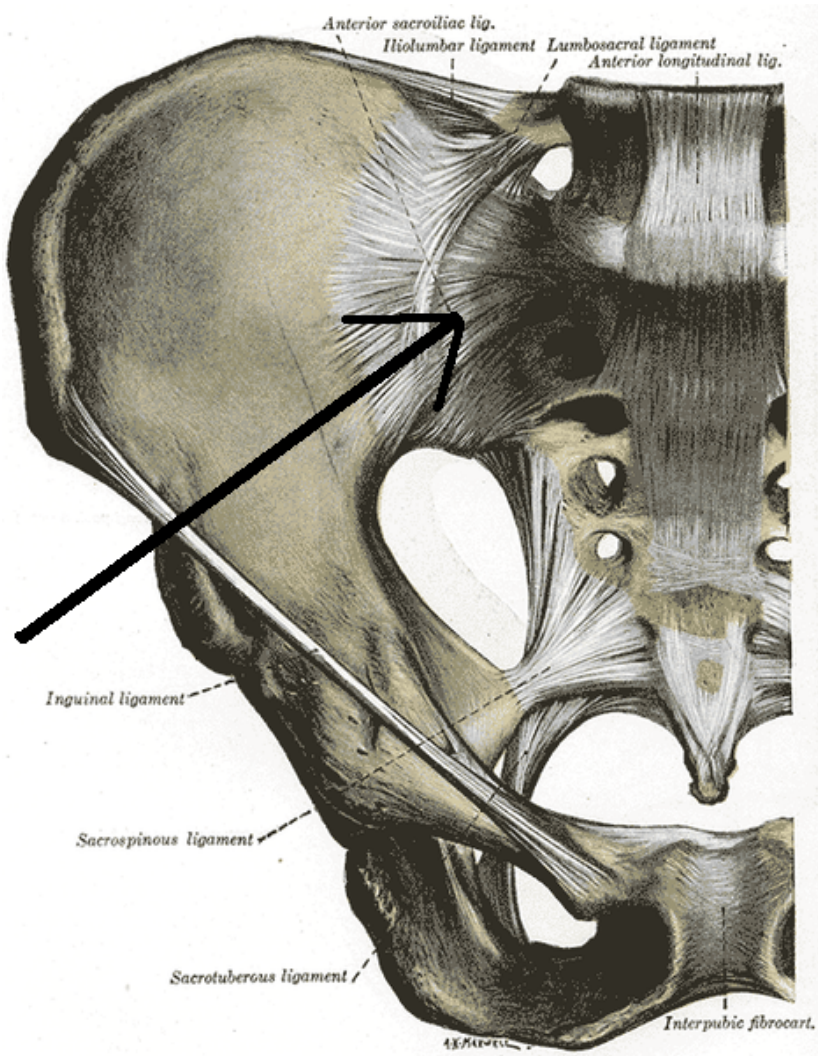


Fig. 28. This image is of the anterior (pelvic) surface of the pelvis showing the location of the anterior sacroiliac ligament, which is denoted at the tip of the black arrow. (Wiki)

Along with the sacroiliac ligaments there are also **sacrospinous ligaments**, which are triangular ligaments attached by its apex to the ischial spine, and medially by it broad base, to the lateral margins of the sacrum and coccyx. The posterior and anterior sacroiliac ligaments prevent the sacrum from rotating on the sacroiliac joints. The sacrospinous ligaments prevent posterior rotation of the ilium with respect to the sacrum (Figs. 27 & 28). Together with the **sacrotuberous ligaments**, it converts the **greater sciatic notch** into the **greater sciatic foramen** and the **lesser sciatic notch** into the **lesser sciatic foramen** Fig. 15). The two ligaments, the sacroiliac and sacrospinous, stabilize the hip bone of the sacrum and prevent the promontory from tilting forward. In addition, the sacroiliac joints are enclosed by a very taut joint capsules, which are further strengthened by anterior, interosseous, and dorsal sacral ligaments.

The **lateral surface** of the sacrum is broad superiorly and narrowed into a thin edge inferiorly. Superiorly it has two lateral projections referred to as **ala** (**wings**), which articulate with the ilium through the sacroiliac joints (Fig. 29).

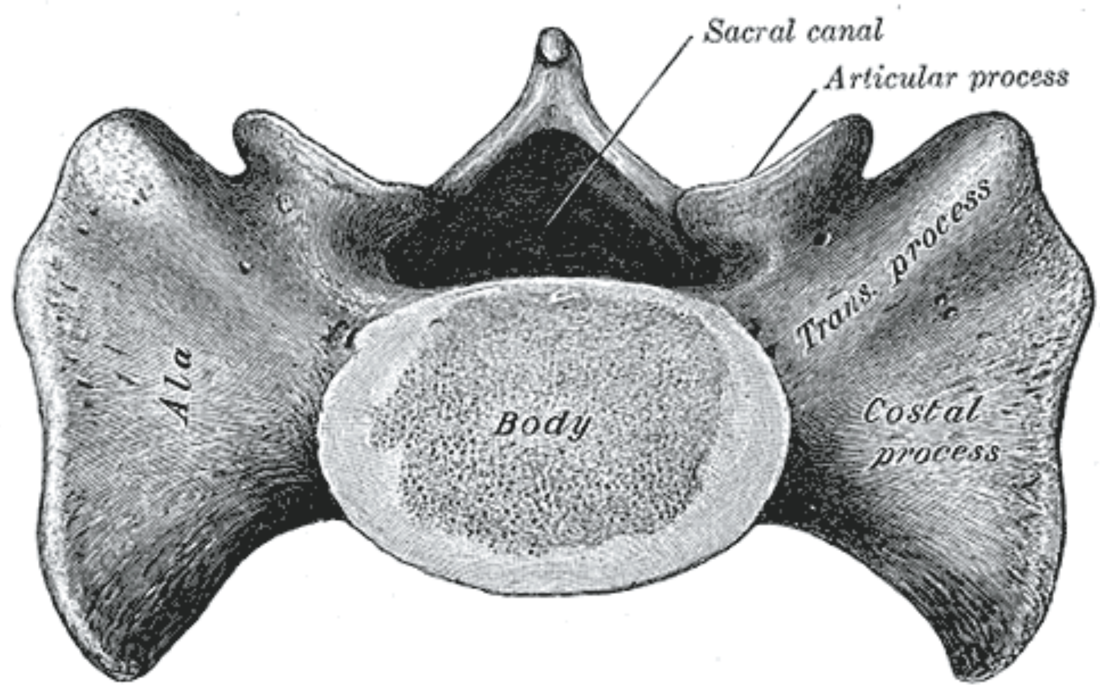


Fig. 29. The above image is the base of the sacrum, superior view. This is the part that articulates with the fifth lumbar vertebra. It is formed by the costal and transverse processes of the first sacral vertebra. The ala supports the psoas major and lumbosacral trunk, and in the articulated pelvis is continuous with the iliac fossa. (Wiki)

Directly behind the sacral articular surface of the joint are three deep impressions for the attachment of the dorsal (posterior) sacroiliac ligament discussed on page 32, (Figs. 15 & 16, p 17-18 & Figs. 27 & 28).

The **superior surface** of the sacrum has a prominent anterior projecting border called the **sacral promontory** (Figs. 3, p 5 & 8, p 9 & Fig. 25). It marks part of the pelvic inlet and serves as the anatomic site at which the rectosigmoid junction occurs. With the iliopectineal line it forms the linea terminalis (Fig. 7, p 7).

The **sacral canal** runs through the greater part of the sacrum (Fig. 29). Superiorly, it is triangular in form; inferiorly, its posterior wall (dorsal wall) is incomplete due to the fact the laminae of the fifth sacral segment, and sometimes the fourth, fail to meet, which creates the **sacral hiatus** (Figs. 30 & 31). The sacral hiatus allows for access to the vertebral canal. In addition, the lateral wall of the sacral canal has four intervertebral foramina, through which the canal is continuous with the pelvic (anterior) and dorsal foramina (Fig. 32). The canal contains the **cauda equina**, **filum termainale**, and the **spinal meninges**.

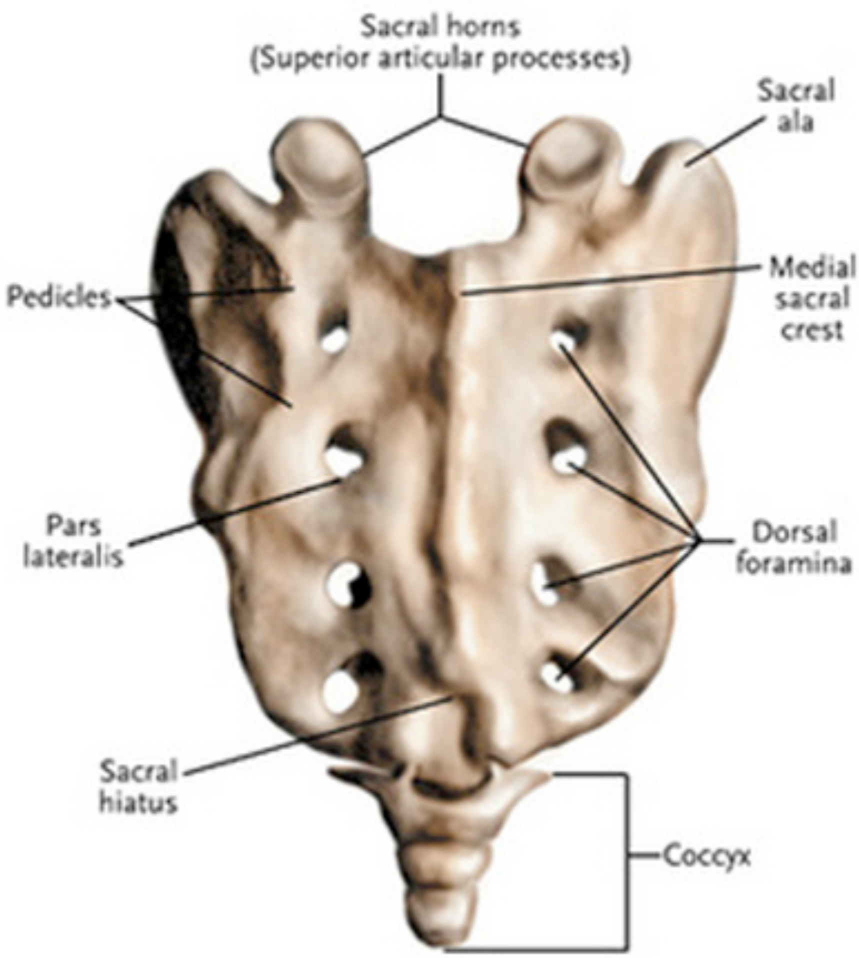


Fig. 30. The above image shows the dorsal surface of the sacrum and various anatomic landmarks including the sacral hiatus. (Wiki)

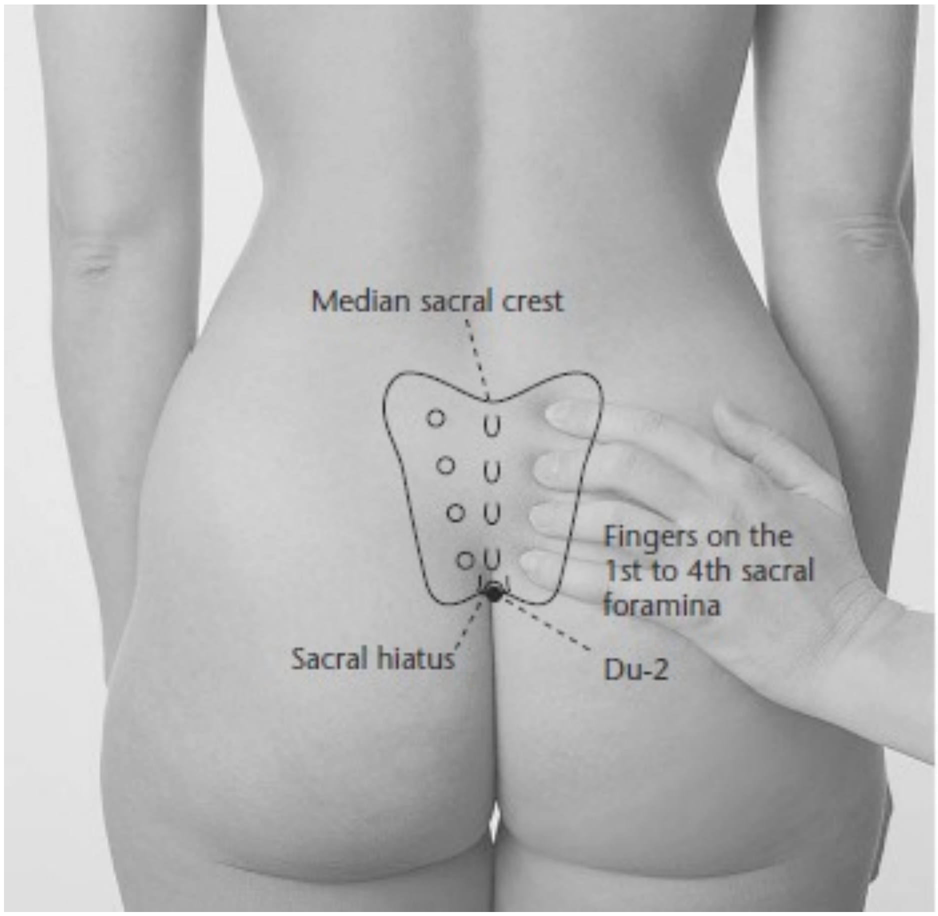


Fig. 31. This image is the posterior view of a woman with the dorsal surface of the sacrum superimposed, showing the location of the sacral hiatus. (Wiki)

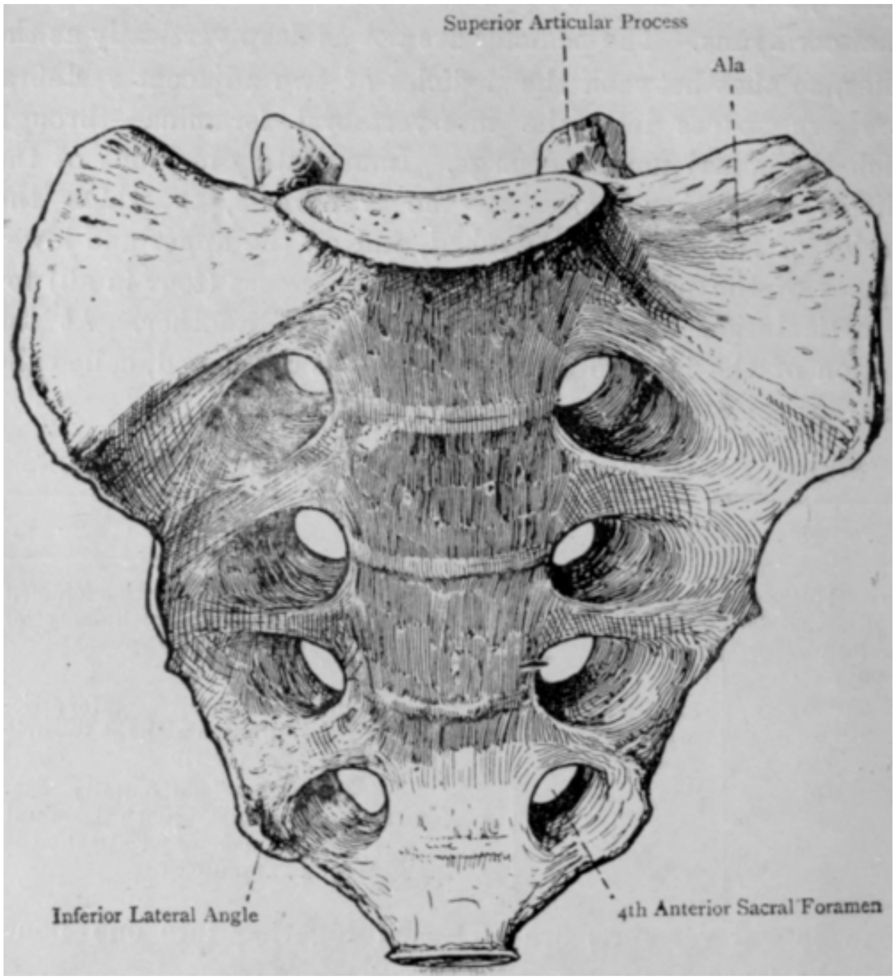


Fig. 32. This image is of the pelvic surface of the sacrum denoting the location of the fourth anterior sacral foramina. (Wiki)

*Remember, the **spinal cord** ends at the **conus medullaris**. In the adult this is located between L1 and L2 vertebrae thus, the spinal cord occupies the upper two-thirds of the vertebral canal. At birth the conus medullaris is at the level of L3 vertebra. Up to the third month of fetal life the spinal cord occupies the entire length of the vertebral canal, but after that time the differential rate of growth of the vertebral column exceeds that of the spinal cord.*

At the level of the middle of the sacrum, the **subarachnoid and subdural spaces** fuse; the lower **sacral spinal roots** and the **filum terminale** pass through the **arachnoid** and **dura mater** at that level. The filum terminale with its meningeal and dural coverings emerge below the sacral hiatus, passing downward across the surface of the fifth sacral vertebra and **sacrococcygeal joint** to attach to the dorsal surface of the **first segment of the coccyx** as the **coccygeal ligament** (Figs. 27 & 34). The coccygeal ligament together with the **lateral, anterior, posterior**, and **intercornual sacrococcygeal ligaments** stabilize the **sacrococcygeal symphysis** (Figs. 33 & 34).

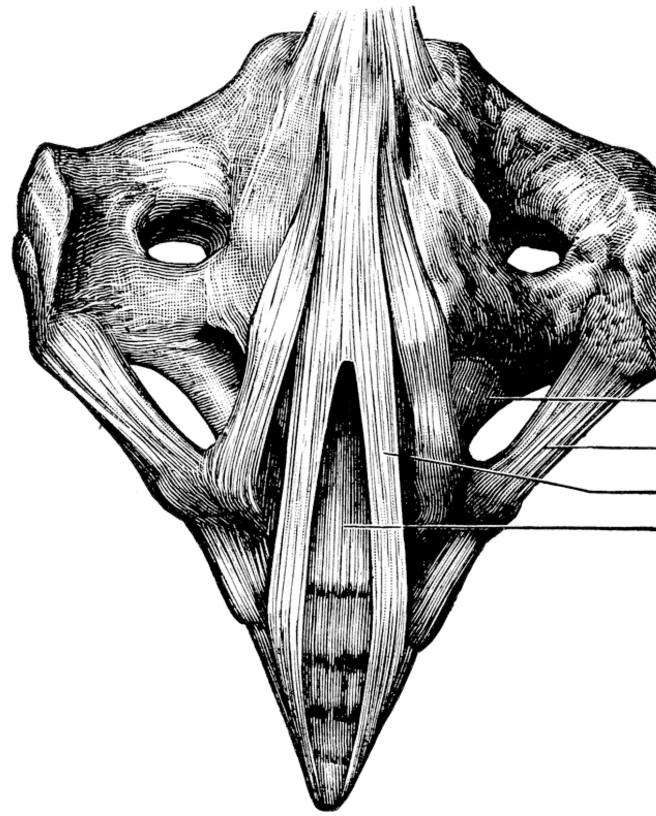


Fig. 33. This image depicts the location of the **lateral sacrococcygeal ligament** and the **superficial** and **deep portions of the posterior sacrococcygeal ligaments**. (Wiki)

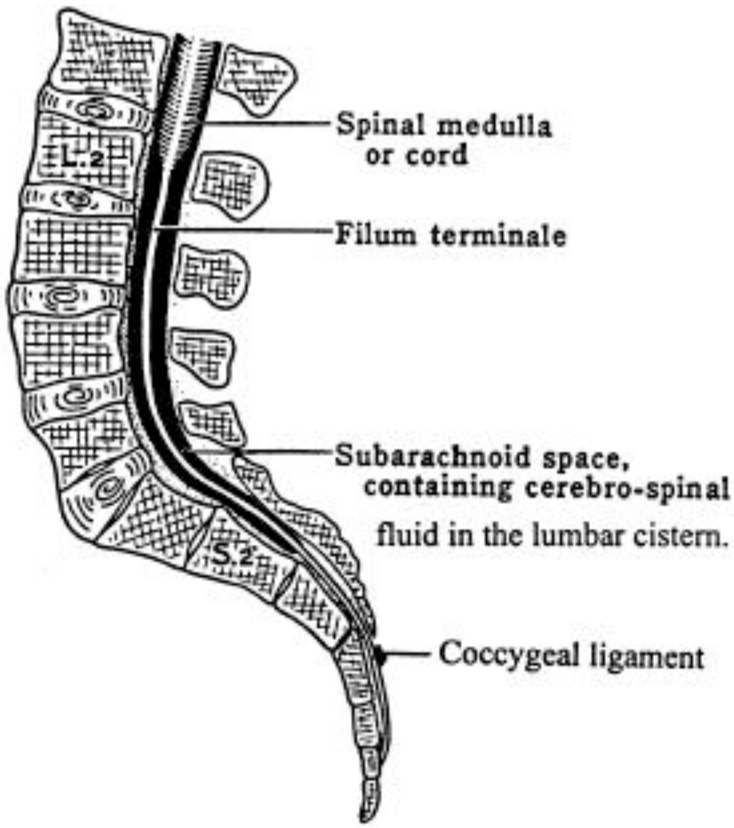
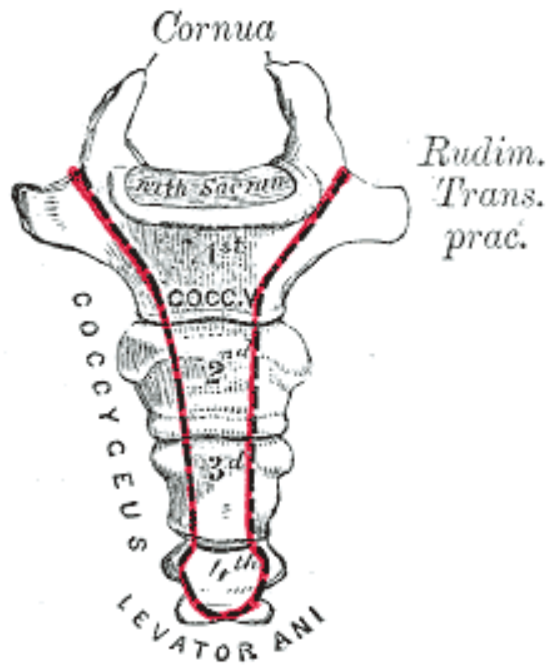


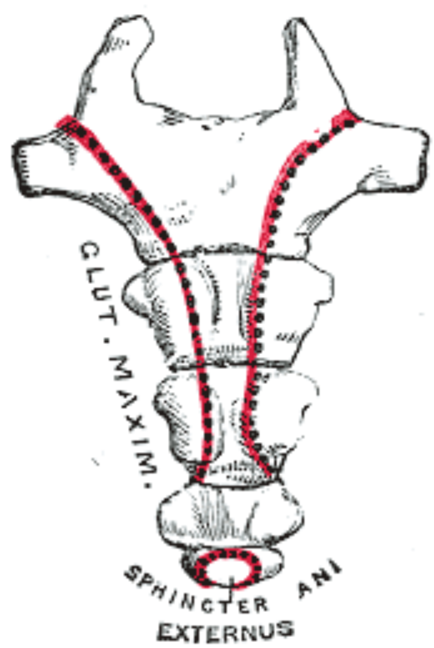
Fig. 34. This image shows the location of the **filum terminale** and its transition into the **coccygeal ligament**. (Wiki)

3. **Coccyx:** The **coccyx** is a small triangular bone, formed typically through the fusion of four rudimentary vertebrae. However, the number of fused coccygeal segments can vary between three to five and the first segment may be separate from the rest. These vertebrae are rudimentary (reduced in size), having no pedicles, laminae or spinous processes (Fig. 35). From the apex of the sacrum it projects downward and ventrally. It is attached superiorly to the apex of the sacrum by a fibrocartilaginous joint, the **sacrococcygeal symphysis**, which permits limited movement between the sacrum and the coccyx. Its **pelvic surface** is concave, projecting upwards and forwards (Fig. 35). The pelvic surface is smooth, providing attachment for part of the **coccygeus** and **levator ani muscles**. The **dorsal surface** has rudimentary articular processes, which present as a row of **tubercles**. The most superior tubercle, the **coccygeal horns**, project upward to articulate with the most inferior sacral tubercles (**the horns of the sacrum**), and

by doing so enclose the **fifth sacral foramina**, through which the **fifth spinal nerve** passes. The dorsal surface provides attachment for the **gluteus maximus** (Fig. 35). The **sphincter ani** is attached to the tip of the coccyx (Fig. 35).



Anterior Surface



Posterior surface

Fig. 35. The above drawing shows the anterior and posterior surfaces of the coccyx, the sites of attachment of the various muscles, and the coccygeal horns (cornua), which articulate with the horns of the sacrum. (Wiki)

The base of the first coccygeal vertebral body has an oval, articular facet for the sacral apex, forming the **sacrococcygeal symphysis**. The sacrococcygeal symphysis is re-enforced by the lateral, anterior, posterior, intercornual and coccygeal ligaments previously discussed on page 39, Fig. 33.

From a functional standpoint the coccyx partially closes the **pelvic outlet** and functions as an attachment for muscles, which close the **pelvic diaphragm** (Fig. 35). As indicated above, the components of the bony pelvis are held together by dense strong ligaments, the **iliolumbar, sacrotuberous, sacrospinous,** and the **sacroiliac** (Figs. 15 &16, p 17-18 & Figs. 27 & 28).

C. The Pelvic Cavity: The **pelvic cavity** is the body cavity that is bounded by the bones of the pelvis and which primarily contains the reproductive organs and the rectum (Fig. 10). Its oblique roof is the **pelvic outlet** (the superior opening of the pelvis). Its lower boundary is the **pelvic floor**. The edge of the **pelvic inlet** is referred to as the **pelvic brim**, which is a line that passes through the prominence of the sacrum, the **arcuate** and **pectineal lines**, and the upper margins of the **pubic symphysis** (Figs. 6, 7, 8, p 8-10 & Fig. 21). In many respects, the pelvic cavity is simply an inferior continuation of the abdominal cavity, which is reflected by the fact that certain of the organ systems of the abdominal cavity are continued into the pelvic cavity: the pelvic cavity contains the terminal portions of the gastrointestinal tract (sigmoid colon and rectum), and the urinary system (ureters, bladder, and the beginning of the urethra). The rectum is in the back of the pelvis, in the curve of the sacrum and coccyx; the bladder is in front, behind the pubic symphysis. In the female, the uterus and vagina occupy the interval between these viscera (Figs. 36 & 37).

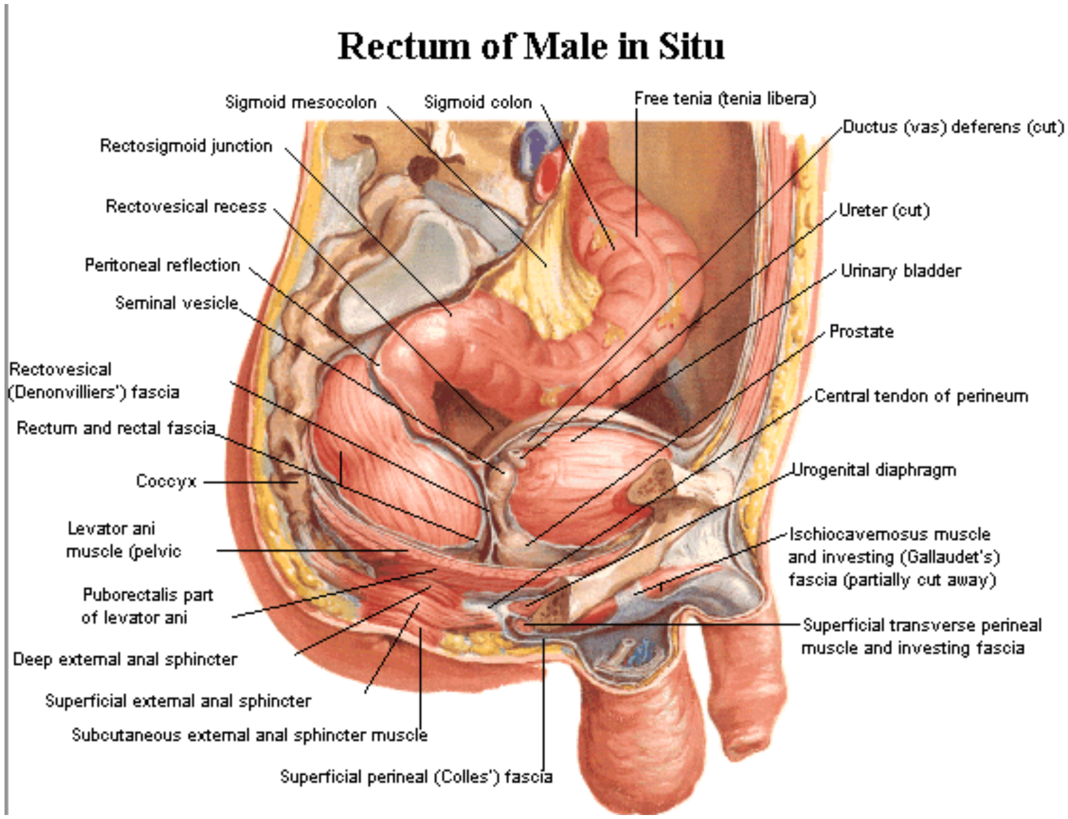


Fig. 36. This illustration shows the location of the various anatomic structures in the pelvic cavity of the male. (Wiki)

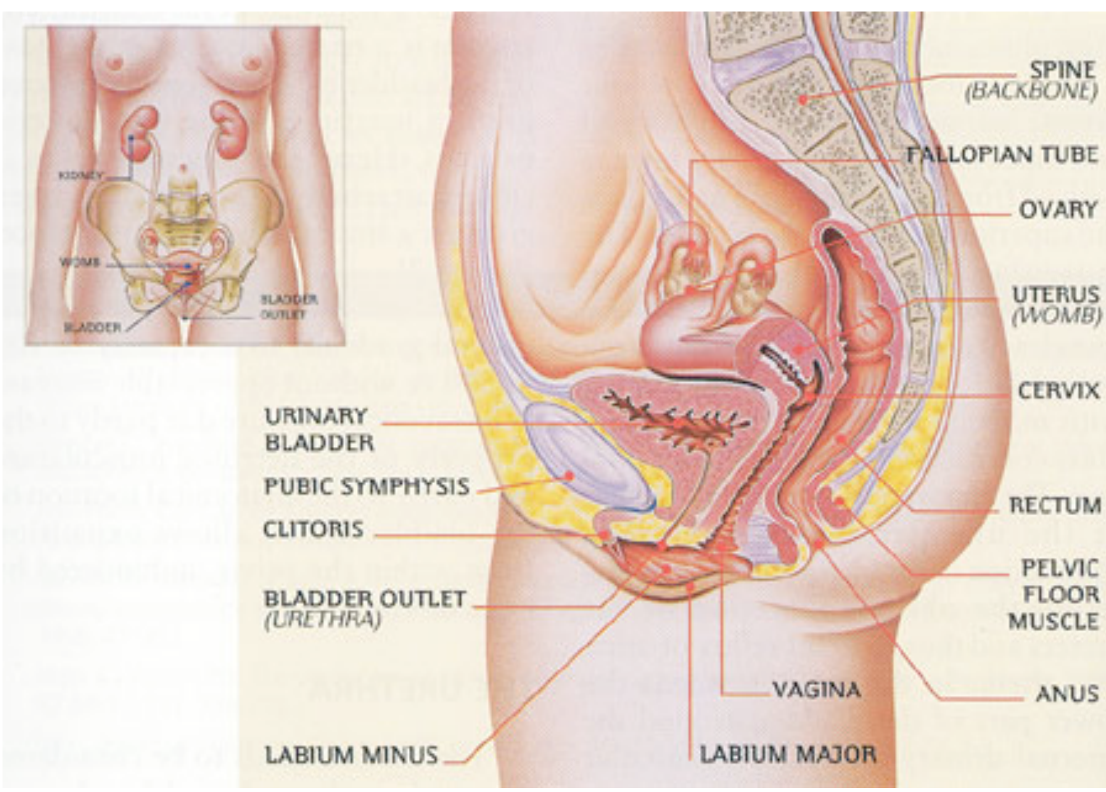


Fig. 37. The above image shows the location of the various anatomic structures in the pelvic cavity of the female. (www.sfcs.org.sq)

The peritoneum continues into the pelvis, partially covering the pelvic organs, and forming various ligaments and mesenteries draping over the vasculature and other structures, passing from the pelvic walls to the viscera (Fig. 38).

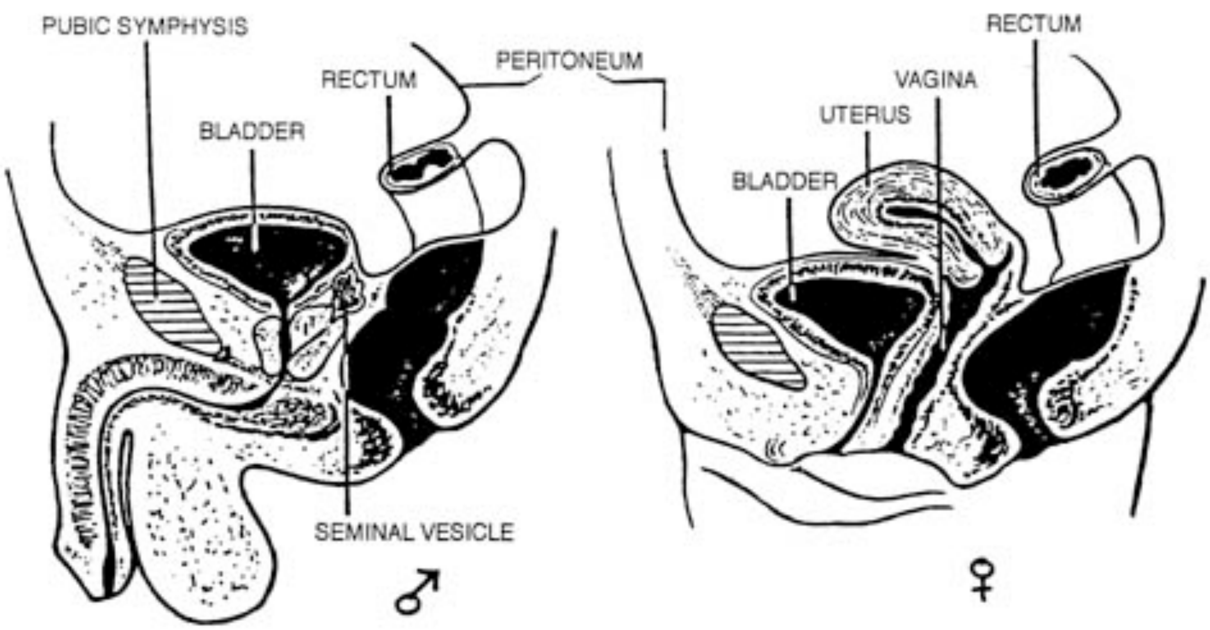


Fig. 38. This is a drawing illustrating a midsagittal section of the male and female pelvis, showing the relative positions of the pelvic organs and the extent of the peritoneal covering (shaded). (www.emory.edu/Anatomy/AnatomyManual/pelvis) (From: O'Rahilly, Basic Human Anatomy, Fig. 3 1-9, p. 28 1)

It is important to understand, the peritoneum does not extend to the lowest points of the pelvic diaphragm, thus there is a significant **subperitoneal space** between the peritoneum and the pelvic diaphragm, organs or portions thereof, vasculature, and fascial ligaments, which play an important role in supporting the organs of the pelvic cavity.

The pelvis is divided into the **greater** (**pelvis major** or **false pelvis**) and the **lesser** (**pelvis minor** or **true pelvis**) **pelves** by an oblique plane, which passes through the sacral promontory, the arcuate line of the ilium, the pectineal line of the pubis, and the upper margin of the pubic symphysis (Figs. 6, 7, 8, p 8-9 & Fig. 21, p 23). The whole line is referred to as the terminal line (innominate line), which is for practical purposes the pelvic brim.

The **greater pelvis** is above the oblique plane and is sometimes considered part of the lower abdominal cavity (Fig. 10); it is largely the **iliac fossa**, at vertebral levels L5 and S1 and contains the ileum and sigmoid colon. The **femoral nerve** from L2-L4 is in the greater pelvis, but not in the lesser pelvis. The **lesser pelvis** is below the oblique plane and pragmatically forms the pelvic cavity in considering it contains the pelvic viscera (**urinary bladder and pelvic ureters, and the urethra, rectum, prostate, seminal vesicles, vas deferens and ampulla in males, and the vagina, cervix and uterus and possibly the ovaries in females),** hence the occasional reference to the true pelvis as the "**obstetric pelvis**." The **pelvic splanchnic nerves** arising at S2-S4 are in the lesser pelvis. The boundaries of the true pelvis are the pubic symphysis anteriorly, sacrum and coccyx posteriorly, and the bodies of the ischia laterally (Fig. 3, p 5 & Fig. 39).

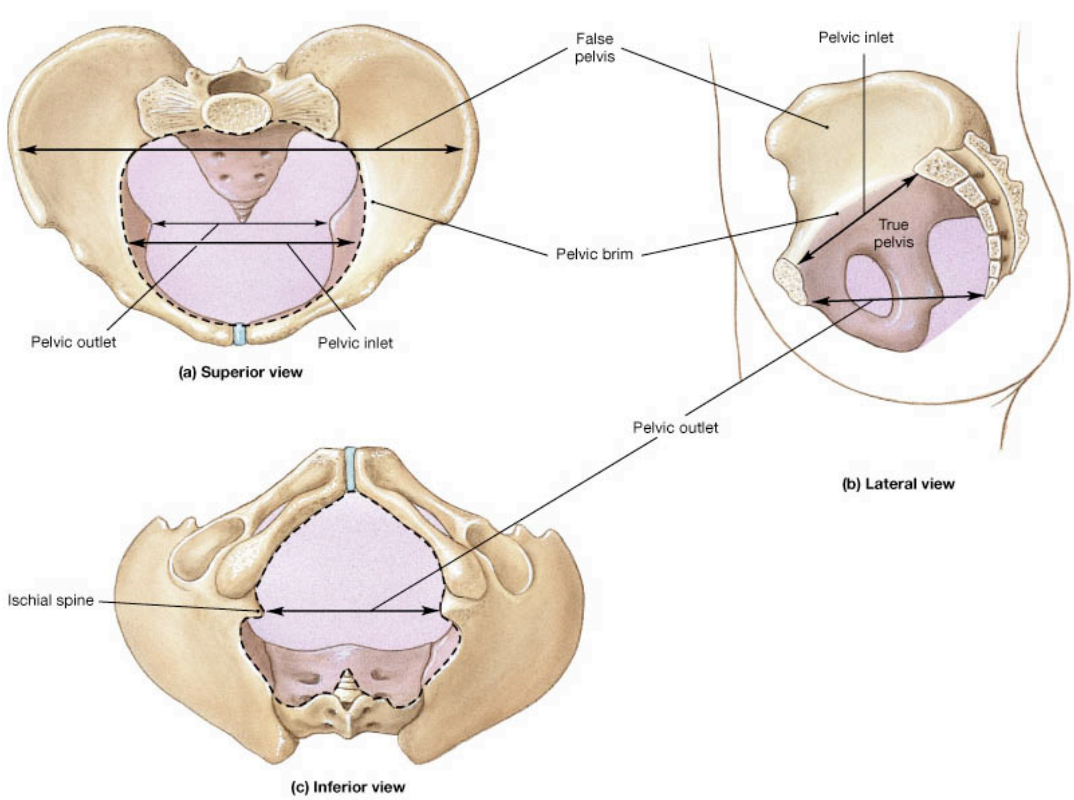


Fig. 39. The above illustration shows the ring of bones that constitute the pelvis: the two ossa coxae (the hip bones, which are comprised by the ilium, ischium, and pubic bones), the sacrum and the coccyx. The pelvis is divided into:

False (greater) pelvis: the superior part bounded by the expanded, blade-like portions of each ilium superior to the arcuate line, and encloses the organs of the inferior abdominal cavity.

True (lesser) pelvis: inferior to the iliopectineal line and bonded by both pubic bones, both ischium, the sacrum and coccyx. The boundaries of the true pelvis are:

Pelvic inlet: superior boundary of the true pelvis bounded by the pelvic brim, which includes the base of the sacrum, ileopectineal line, and the superior margin of the pubic symphysis.

Pelvic outlet: inferior opening bounded by the coccyx, ischial tuberosities and the the inferior border of the pubic symphysis. (virtual.yosemite.cc.ca.us) (Wiki)

The **true pelvis** can be divided into three regions: the **superior pelvic aperture (pelvic inlet), pelvic cavity,** and the **inferior pelvic aperture (pelvic outlet).** The **superior aperture (pelvic inlet)** is the oval shaped opening in the female and the heart shaped in the male (Figs. 39 & 40).

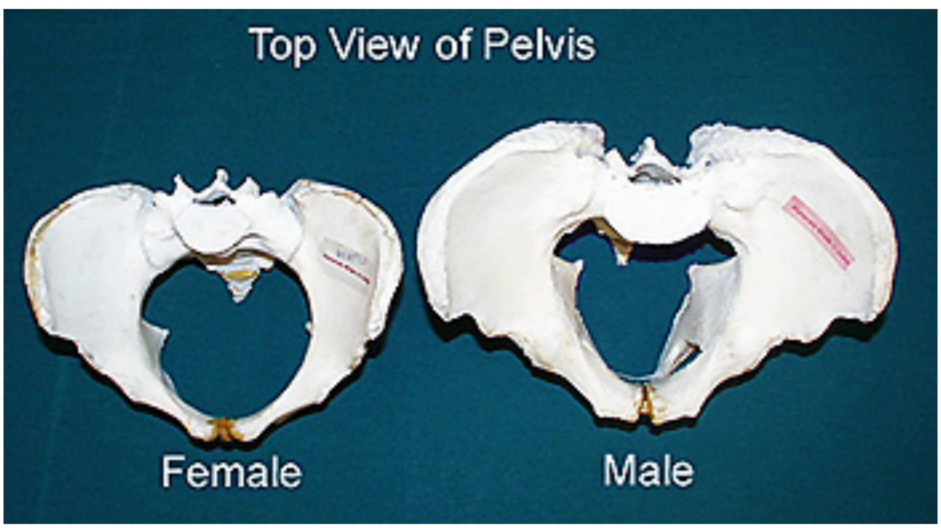


Fig. 40. Note the oval shaped pelvic inlet in the female pelvis vs the heart shaped pelvic inlet in the male. The pelvic inlet in females is larger to facilitate birthing. (forensicanth-nu.wikispaces.com)

As previously indicated, its periphery is demarcated by the lineal terminalis, which has a pubic portion (pectineal line), and an illial portion, (arcuate line) (Figs. 6 & 21). Thus, the boundaries of the inlet are: (1) anteriorly the pubic symphysis, (2) laterally, the linea terminalis, (3) posteriorly, the sacral promontory, and 4) inferiorly, the line extending from the tip of the coccyx to the inferior border of the pubic symphysis.

The organs contained within the **pelvic cavity** have been listed above under pelvic viscera. In essence, the pelvic cavity contains the rectum, bladder, and reproductive organs. The walls of the pelvic cavity are formed by the pubic symphysis anteriorly, the obturator internus muscles laterally, and the piriformis muscles posteriorly (Fig. 41).

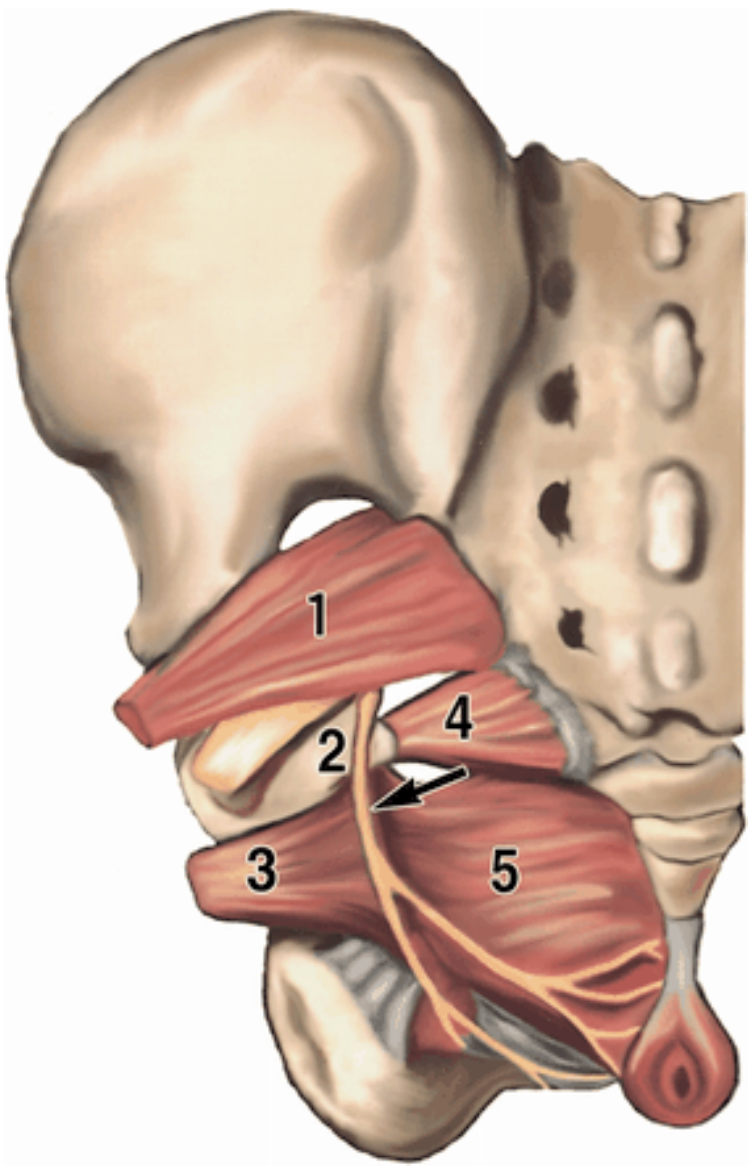


Fig. 41. The above image shows the muscles forming the lateral wall of the pelvis, specifically, the obturator internus and piriformis msucles, the latter is exiting the greater sciatic foramen. 1, piriformis muscle; 2, ischial spine; 3, obturator internus muscle; 4, coccygeus muscle; 5, levator ani muscle; and arrow the pudendal nerve. (radiographics.rsna,org)

The **inferior pelvic aperture** (**pelvic outlet**) is bounded anteriorly by the pubic symphysis, posteriorly by the sacrum and coccyx, and laterally by the ischial tuberosities (Figs. 13 & 14, p 15-16). In essence, the pelvic outlet is the region between the subpubic angle or pubic arch, the ischial tuberosities and the coccyx. Inferiorly, it is closed by the pelvic diaphragm that is composed mainly by the two levator ani and coccygeus muscles (Figs. 41, 42 & 43).

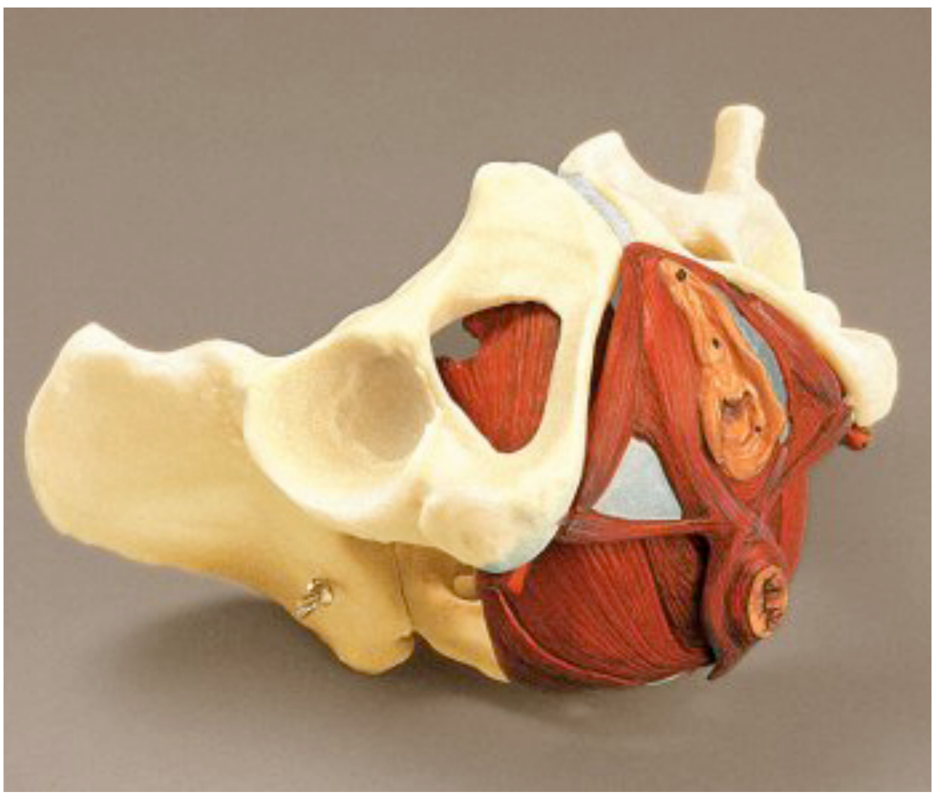


Fig. 42. This is a anteriolateral view of the pelvic floor showing the location of the various muscles, which form it. (artofthaimassage.com)

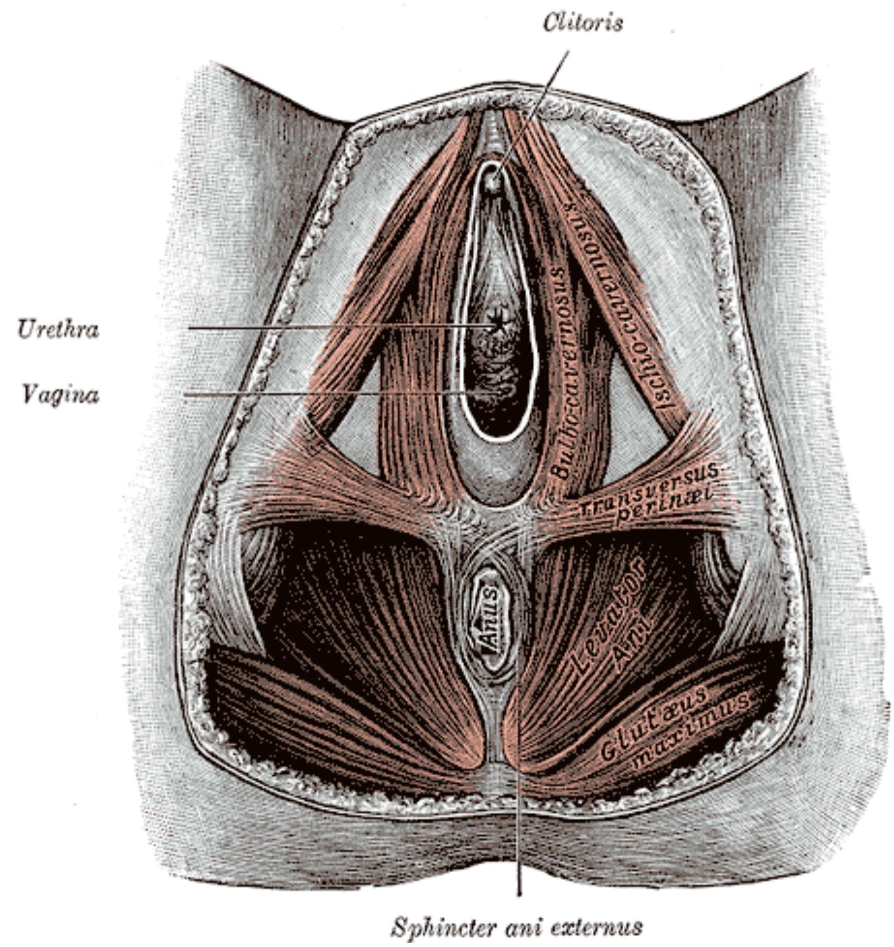


Fig. 43. This is a view of the pelvic floor from directly below. The levator ani together with the coccygeus muscles (Figs 41 & 42) form the pelvic diaphragm. (Wiki)

As noted in Figs. 23, 24 & 40, the male and female pelvis are different anatomically. This difference is referred to as **sexual dimorphism**, which are represented as follows:

1. The female pelvis is larger and broader than the male pelvis, which is taller, and more compact. The bones are more delicate and the muscular impressions are less marked (Figs. 23 & 24, p 29-30).

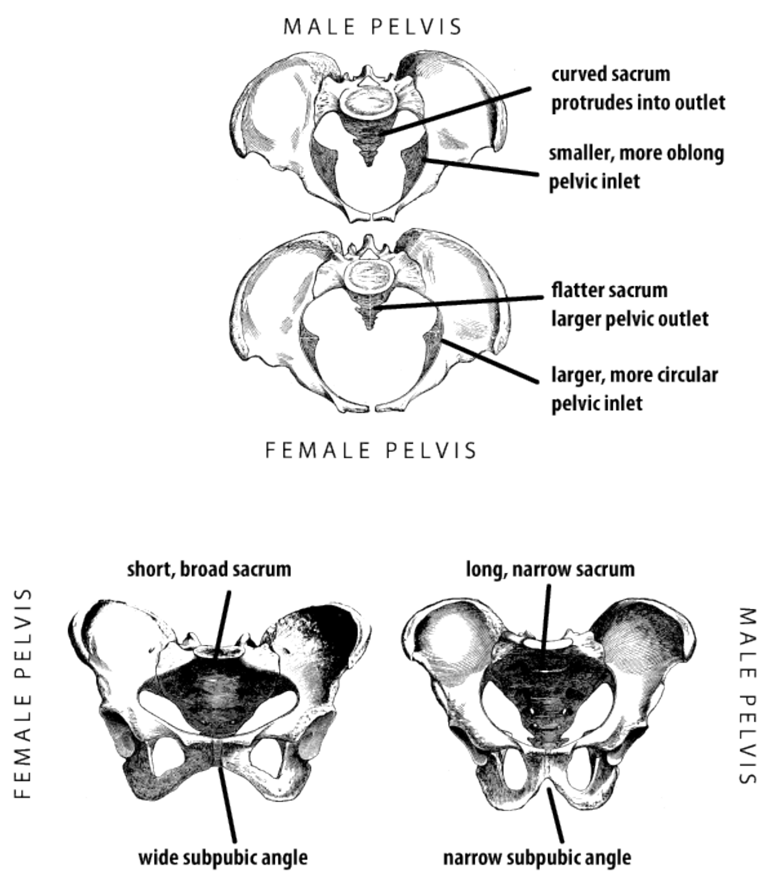
2. The female inlet is larger and oval in shape, while the male sacral promontory projects further giving the inlet a heart shape (Figs. 23 & 24, p 29-30 & Fig. 40).

3. The sides of the male pelvis converge from inlet to outlet, whereas the sides of of the female pelvis are wider apart. This is because the ilia flare more laterally and the anterior iliac spines are more widely separated causing a widening of the hips with respect to the male (Figs. 23 & 24, p 29-30 & Figs. 39 & 40).

4. The superior aperture of the lesser pelvis is wider in the female (Figs. 39 & 40).

5. The angle between the inferior pubic rami is acute (70°) in men, but obtuse (90-100°) in females (Fig. 23). Hence, this angle is referred to as the **subpubic angle** in men and the **pubic arch** in females. Also, the bones forming the angle or arch are more concave in females but straight in males Figs 45 & 46).

6. The distance between the ischial bones is narrow in males, thus the pelvic outlet is narrower, but in females the ischial bones distance is wider, thus their outlet is much larger (Figs. 8, 9, p 9-10 & Figs. 39 & 44).



SEXUAL DIMORPHISM OF THE PELVIS

Fig. 44. The above drawings show the fundamental differences in the pelves of male and females. Note the prominence of the ischial spines in the males vs. females as well as the dimensions of the greater sciatic notch are far larger in the female vs. the male. (johnhawks.net)

The ischial spines and tuberosities are heavier and project farther into the pelvic cavity in males. The greater sciatic notch is wider in females.

7. The iliac crests are higher and more pronounced in males, making their false pelvis deeper and narrow than females (Figs. 23 & 24p 29-30 & Fig. 44).

8. The male sacrum is long, narrow, and more straight, and has a pronounced sacral promontory. The female sacrum is shorter, wider, and more curved posteriorly, and has a less pronounced promontory (Figs. 45 & 46).

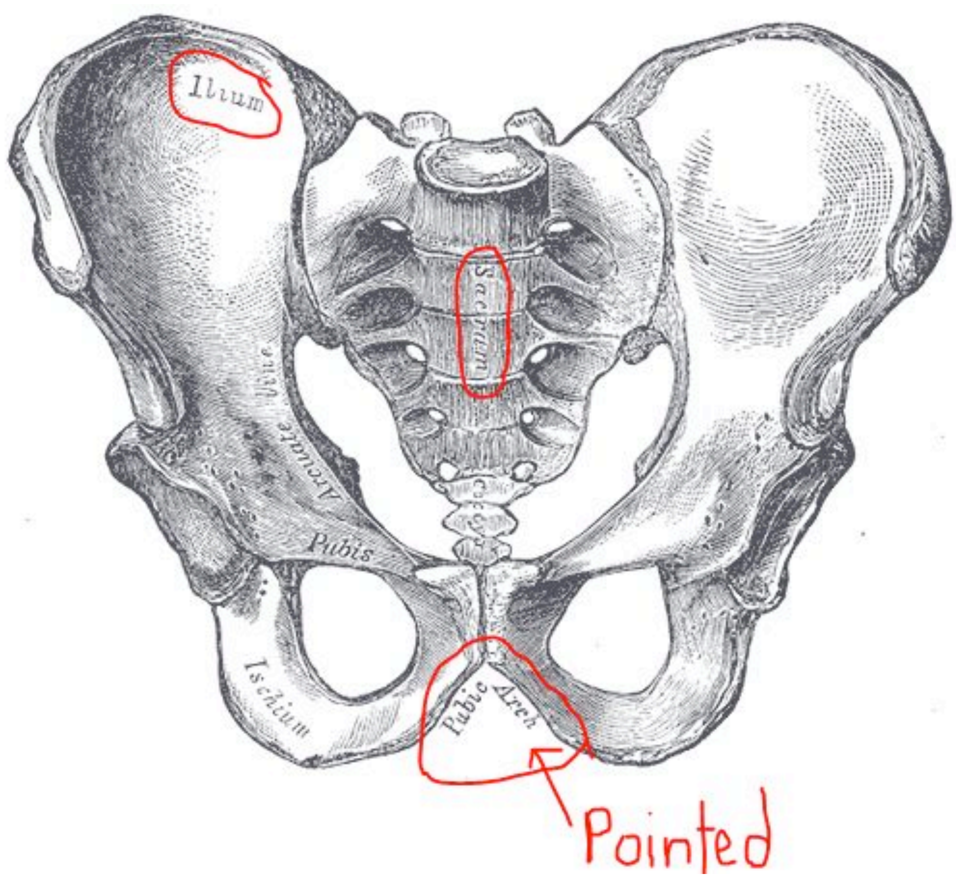


Fig. 45. This image is of a male pelvis. Note the narrow subpubic angle, the long, narrow and relatively straight sacrum, the converging nature of the ala of the ilium and the pronounced sacral promontory. (clarissadraper.blogspot.com)

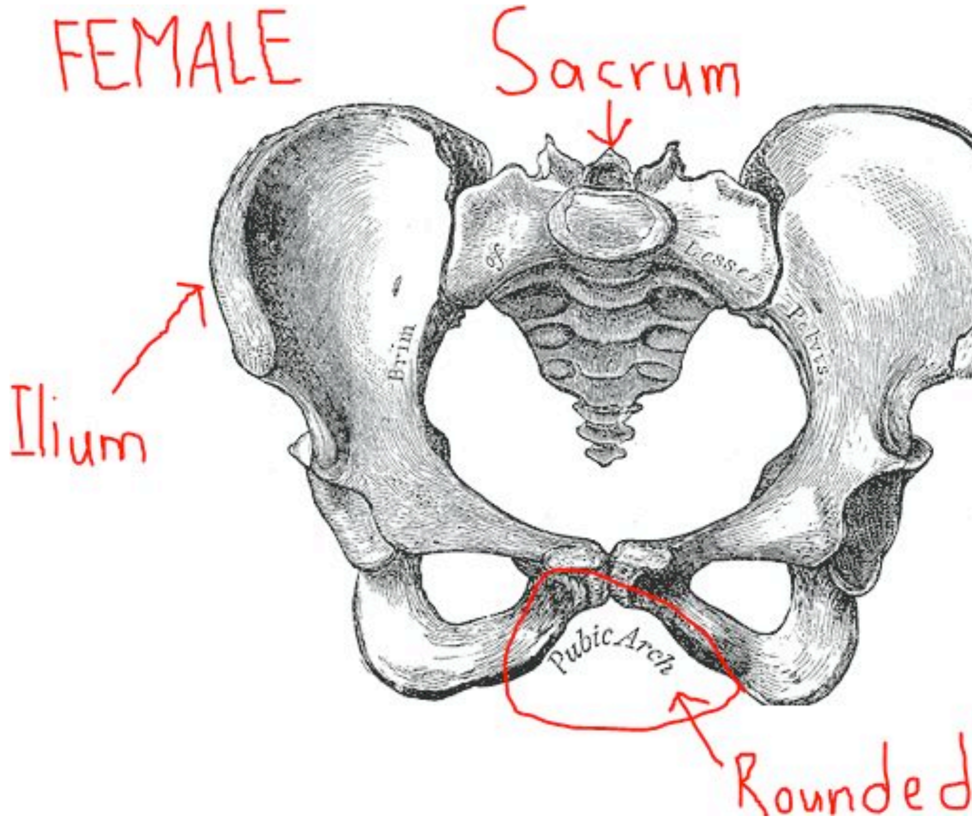


Fig. 46. This image is of a female pelvis. Note the ilium is more expanded, the sacrum is flatter and broader, the sacral promontory is less pronounced and the pubic arch is rounder. (clarissadraper.blogspot.com)

9. The acetabula are smaller and wider apart in females than in males. In males, the acetabulum faces more laterally, while in females it faces more anteriorly. Consequently, when men walk the leg can move forwards and backwards in a single plane. In women, the leg must swing forward and inward, from where the pivoting head of the femur moves the leg in another plane. This change in the angle of the femoral head gives the female gait its characteristic swinging of their hips (Fig. 24, p 30).

The **arterial blood supply** to the pelvic cavity is primarily from branches of the **internal iliac artery**. The exceptions are the **testicular** and **ovarian arteries**, which arise from the anterior aspect of the **abdominal aorta** just below the **renal arteries**; the **superior rectal artery**, which is a continuation of the **inferior mesenteric artery**, crosses the **pelvic brim**, and supplies the upper part of the **rectum**; and the

median sacral artery, which supplies the posterior surface of the **rectum.** *An important point to remember is the ovaries and testes have an embryonic origin near the kidneys. The ovaries and testes take their blood supply with them as they migrate. Since the testes migrate through the inguinal canal to the scrotum, the testicular artery is not seen in the pelvis. However, as the ovaries descend into the pelvis, they pull the ovarian artery with them as they cross the pelvic inlet, and into pelvis.*

The **venous** drainage of the pelvis parallels the arterial blood supply. Thus, most of pelvic cavity proper and perineum are drained by tributaries of the **internal iliac veins**, which drain into the **inferior vena cava**. There are exceptions however to this rule. *Remember, the structures supplied by branches of the* ***celiac trunk, superior*** *and* ***inferior mesenteric artery*** *drain into the* ***portal vein****. The upper part of the* ***rectum****, which as has been pointed out above, is supplied by the* ***superior rectal branch*** *of the* ***inferior mesenteric artery****, which will therefore drain into the* ***portal vein*** *by way of the* ***superior rectal*** *and* ***inferior mesenteric veins.***

The ovaries drain by way of the ovarian veins into the ***inferior vena cava*** *or* ***renal vein.***

The **lymphatic** drainage of the pelvis follows the venous drainage. For most of the pelvic cavity proper, the lymphatics drain into nodes located around the **internal iliac vessels**. These in turn drain into the **common iliac nodes**, which drain into the **para-aortic nodes**. There are exceptions, however. The lymphatic drainage of the ovaries is to the **para-aortic nodes** in the abdomen, paralleling the blood supply.

When it comes to **innervation** of the pelvic cavity you need to keep in mind that most of the nerves of the abdominal cavity do not continue into the pelvis. There are however exceptions: a) the **obturator nerve** derived from **L2-L4 spinal segments** crosses the pelvic brim and travels in the pelvic cavity for a short distance before exiting through the **obturator foramen** to supply the **adductor muscles** of the thigh and the **gracilis muscle**. b) the **lumbosacral trunk** consist of nerve fibers which connect the **lumbar plexus** and **sacral plexus**. It is composed of the entire **anterior division** of the **fifth** and part of the **fourth lumbar nerves**; it appears at the medial margin of the **psoas major** and runs downward over the pelvic brim to join with contributions arising from **S1-S3 spinal segments** to form the **sciatic nerve**, which is the largest nerve in the body. This nerve leaves the pelvis through the **greater sciatic foramen** and extends from the inferior border of the **piriformis muscle** to the lower one-third of the thigh, where it divides into two nerves, the **pre-axial tibial nerve** and the **post-axial common peroneal nerve**. It supplies the major innervation to the back of the thigh and muscles of the leg and feet. c) the **sympathetic trunk** continues to the sacral levels of the pelvis, with **postganglionic sympathetic fibers** joining the **sacral** and **coccygeal nerves**. **Postganglionic sympathetic fibers** also leave the **hypogastric plexus**, which is located over the **sacral promontory**, to innervate the smooth muscle in the pelvic viscera and vasculature.

The **preganglionic parasympathetic nerve** supply to the pelvis is derived entirely from **S2-S4**, which are also called the **pelvic splanchnic nerves.** *Remember, **parasympathetic postganglionic neurons** tend to be located in the walls of the pelvic viscera and the **vagus nerve** supplies the gastrointestinal tract only as far as the left colic flexure.*

D. Pelvic Diaphragm (Floor of the Pelvis): The pelvic floor has two functions, which in actuality are conflicting. The one function is to close the **pelvic outlet** posteriorly thus, bearing the load of the visceral organs. The other function is to control the openings anteriorly of the **urethra, vagina,** and **anal canal**; such openings impart a weakness to the pelvic floor. To accomplish both of these seemingly conflicting functions it utilizes a system of overlapping sheets of muscles and connective tissue to close the pelvic floor (Figs. 41, 42 & 43). The **pelvic diaphragm** is stretched like a hammock between the **pubis** in front and the **coccyx** behind, being attached along the **lateral pelvic wall** to a thickened condensed connective tissue, the **tendinous arch of the pelvic fascia (tendinous arch of the levator ani)** (Fig. 47).

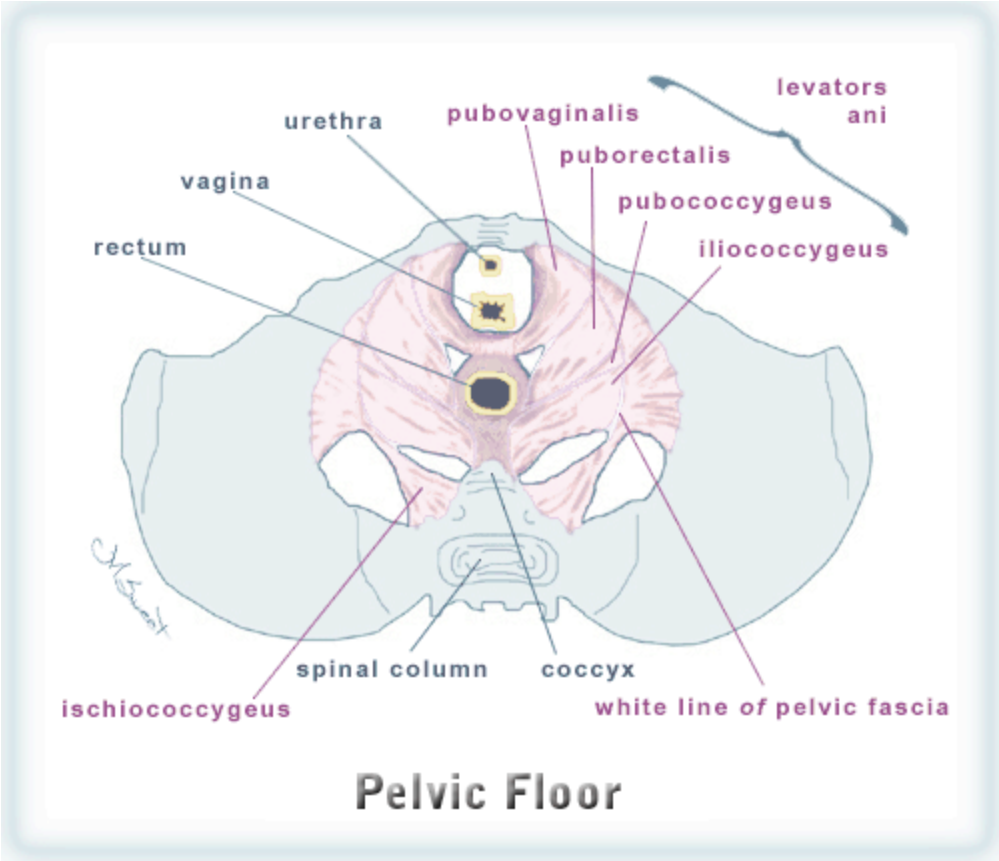


Fig. 47. This is a drawing of the floor of the pelvis in a female depicting the anatomic locations of the components of the levator ani muscles and the tendinous arch of the levator ani (white line of the parietal pelvic fascia. (Wiki)

This band is a remnant of the degeneration of the tendon of the **iliococcygeus** in humans, and is more properly referred to as the **white line of the parietal pelvic fascia.** This band provides attachment for the condensations of the visceral pelvic fascia, which provides to the urethra, bladder and vagina. It is located on the superior medial aspect of the upper fascia over the levator ani muscle (Fig. 48). *Remember, the **iliococcygeus** is part of the levator ani group of muscles. It arises from the inner side of the ischium and from the posterior part of the **tendinous arch of the obturator fascia**, and is attached to the coccyx and anococcygeal raphé; it is usually very thin or partially or completely replaced by fibrous tissue. At the level of anal canal its fibers blend with the longitudinal coat of the anal canal.*

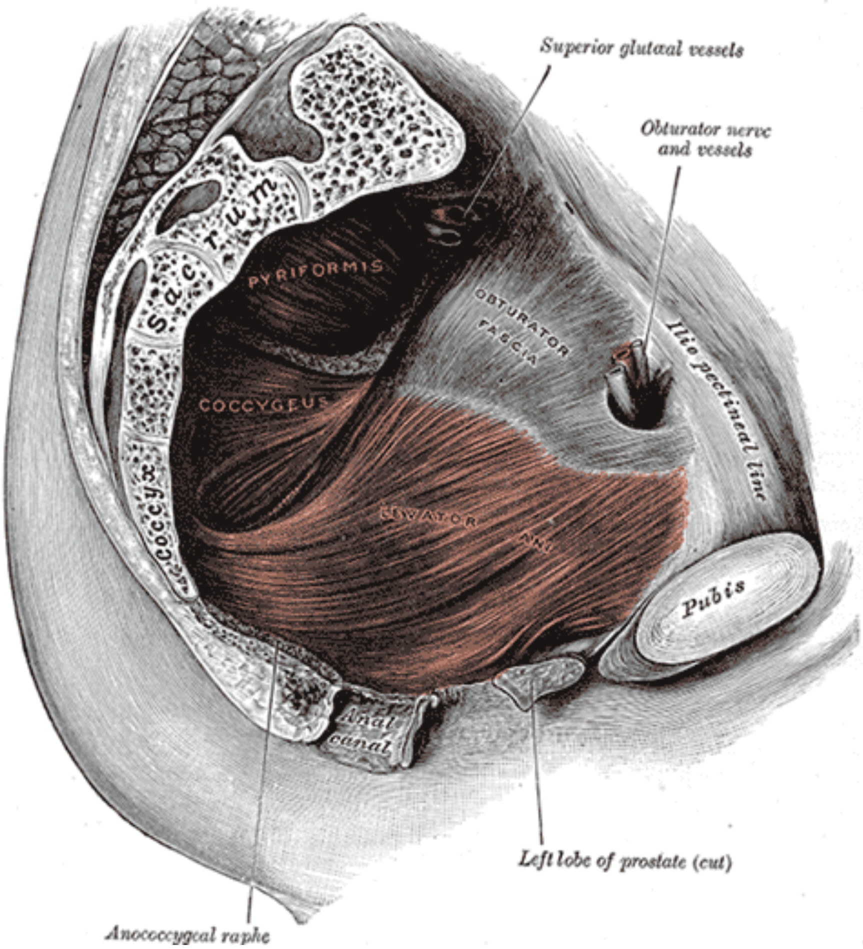


Fig. 48. This image shows the location of the iliococcygeus muscle, which is a part of the levator ani muscle group shown above. It takes its origin from the **ischial spine** and from the posterior part of the **tendinous arch of the obturator fascia**. (Wiki)

To allow for the passage of the urethra and anus in the male, and the urethra, vagina and anal canal in the female, there is separation of the two halves of the pelvic diaphragm in front of the **rectum**.

As indicated above, the pelvic diaphragm consists of the **levator ani** and **coccygeus muscles** and the **superior** and **inferior fasciae** (Figs. 41, 42, 43 & 48).

Levator ani: This is a broad muscle, which is the principal component of the hammock-like floor of the pelvis (Figs. 41, 42, 43 & 48). It is a thin sheet of muscle, which consists of three principal parts: **pubococcygeus, puborectalis,** and **iliococcygeus muscles**. The levator ani arises, in part, from the dorsal surface of the pubis along an oblique line, which extends from the lower part of the **symphysis** to the **obturator canal** (Fig. 48). The more **medial portion** arising from the pubis constitutes the **puborectalis**, the more **lateral portion** applies to the **pubococcygeus**. The **puborectalis** passes backward from the dorsum of the pubis, along the edge of the **genital hiatus** in contact with the side of the prostate or vagina and, turning behind the rectum, it joins the puborectalis from the opposite side at the midline, thus forming a U-shaped rectal sling, which holds forward the **recto-anal junction.** The puborectalis draws the recto-anal junction anteriorly, towards the pubis. By doing this it takes pressure from the **external anal sphincter** and supports the vagina and bladder in the female, and the bladder, seminal vesicles, and prostate in the male.

The **pubococcygeus** arises from the back of the pubis and from the anterior part of obturator fascia (Fig. 48), and is directed backward almost horizontally along the side of the anal canal toward the coccyx and sacrum, to which it attaches. Between the termination of the vertebral column and the anus, the two pubococcygei muscles come together and form a thick, fibromuscular layer lying on the **anococcygeal raphé** (Fig. 48) formed by the **iliococcygeal muscles**. The pubococcygeus muscle controls urine flow and contracts during orgasm. It also aids in childbirth as well as core stability. A strong pubococcygeus muscle has also been linked to a reduction in urinary incontinence and proper positioning of the baby's head during childbirth.

The origin and insertion of the **iliococcygeus muscles** have been discussed on page 53, Fig. 48. From a functional standpoint, the insertion of its muscle fibers into the wall of the anal canal holds the anorectal junction anteriorly, thereby increasing the angle between the rectum and anal canal. This prevents the passage of feces between the rectum and anal canal when defecation is not desired. However, when these parts contract, they raise the canal over the descending mass of feces, thereby aiding defecation.

Along with the various portions of the levator ani muscular sheet inserting on the coccyx and sacrum, the fibrous band running from the rectum and coccyx called the **anococcygeal raphé** (Fig. 48), they also insert onto a fibrous body lying between the prostate or vagina and rectum, known as the **perineal body.** The following muscles converge onto and attach to the perineal body: **external anal sphincter muscle, bulbospongiosus muscle, anterior fibers of the levator ani muscles, fibers from the external urinary sphincter and the deep transverse perineal muscle.** The perineal body is essential for the integrity of the pelvic floor, especially in females. Its rupture during delivery leads to widening of the gap between the anterior free borders of the levator ani muscles of both sides, thus predisposing women to prolapse of the uterus, rectum, or even the urinary bladder.

Although I have covered the functions of the individual muscles which comprise the levator ani muscles I would like to briefly review its overall function. This muscle group supports and raises the pelvic floor and resist increased internal pressure as in forced expiration and defecation. By resisting the inferior thrust of increases in abdominal pressure as occurs in coughing, sneezing and defecation, it maintains urinary continence. During delivery, it also supports the fetal head during uterine contractions.

The **innervation** of the levator ani muscles is by **S2-S4 spinal segments**. Specifically, the **puborectalis** and **iliococccygeus** are supplied by branches of the **sacral plexus** from the **third** and **fourth sacral segments**. The **pubococcygeus** is supplied by the **second** and **third sacral segments**.

The **arterial supply** to the levator ani muscles is through branches of the **inferior gluteal, inferior vesicle** and **pudendal arteries.**

Coccygeus (ischiococcygeus): This muscle lies next to the posterior border of **Iliococcygeus**, i.e. it is dorsal to the levator ani. It arises from the **spine of the ischium**, as well a the **saccrospinous ligament**. It inserts into the borders of the coccyx and the fifth sacral segment.

The coccygeus muscle draws the coccyx forward, thus elevating the pelvic floor. It assist the levator ani in supporting the pelvic viscera.

It is **innervated** by branches of **S3-S4 spinal segments**.

It receives its vascular supply through the **lateral sacral artery**, which is a branch of the **internal iliac artery**.

Superior fascia: The **superior fascia** of the pelvic diaphragm represents a continuation of the **transversalis fascia**, which forms an internal parietal lining of the entire abdominopelvic cavity, hence it is also called the **parietal abdominopelvic fascia**. It also attaches to the **inner lip of the iliac crest** and then descends over the **obturator fascia,** than onto the superior surface of the **pelvic diaphragm** covering also the **piriformis muscles** (Fig. 49 & 50).

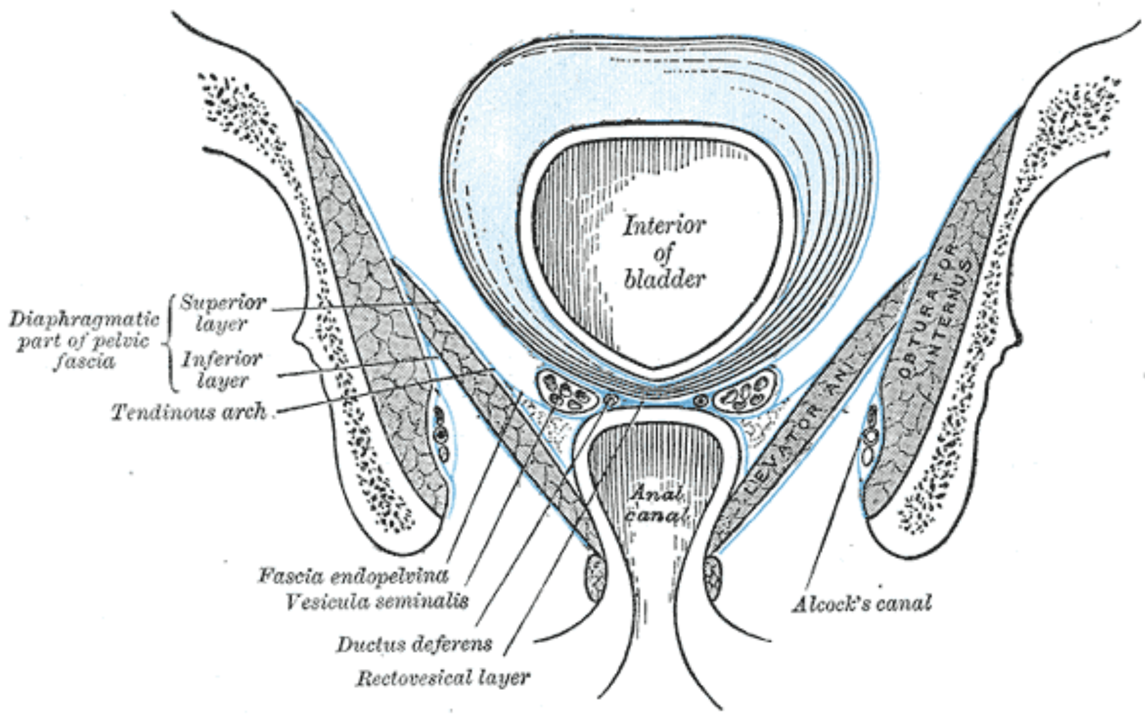


Fig. 49. This drawing is of a coronal section of the pelvis, showing the arrangement of the diaphragmatic part of the pelvic fascia. The diaphragmatic part of the pelvic fascia covers both surfaces of the levator ani. The **superior fascia** in front is attached to the back of the pubic symphysis about 2 cm above its lower border. Laterally, it extends across the back of the superior ramus of the pubis for a distance of about 1,25 cm, when it reaches the **obturator fascia.** It is attached to this fascia along a line which extends to the spine of the ischium. (Wiki).

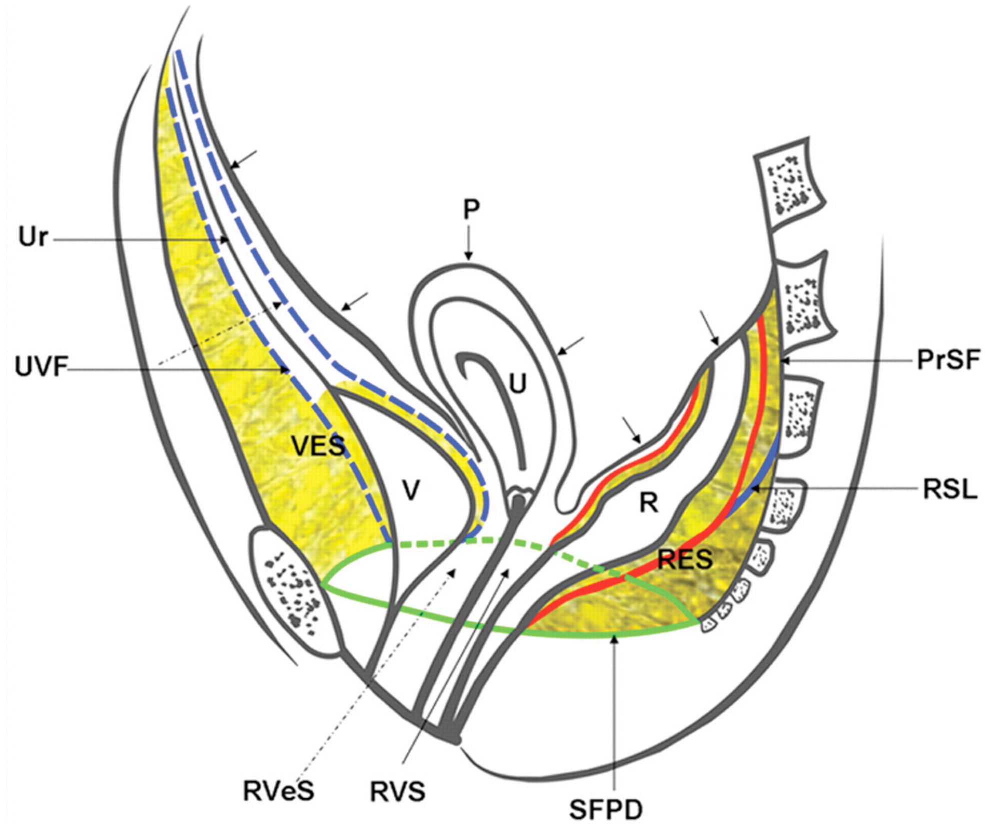


Fig. 50. This is a sagittal diagram showing the pelvic structures. P = peritoneum, PrSF = presacral parietal fascia, R = rectum, RSL = rectal-sacral ligament, RVeS = rectovesical septum, RVS - rectovaginal septum, SFPD = superior fascia of the pelvic diaphragm, U = uterus, UVF = umbilicovesical fascia, V = vesica, Ur = urachus. The yellow area that surrounds the vesica shows the vesical extraperitoneal space (VES), which is located anterior to the peritoneum and posterior to the transversalis fascia. The yellow area that surrounds the rectum shows the rectal extraperitoneal space (RES), which is located between the wall of the rectum below the rectal peritoneal reflection and the parietal pelvic fascia. (www.ajronline.org)

Inferior fascia: The **inferior fascia** of the pelvic diaphragm is an extension of the fascia of the **obturator internus muscle** (Fig. 49). Anteriorly, it is attached to the superior pubic ramus and, at the **genital hiatus**, it blends with the superior fascia of of the **urogenital diaphragm** (Figs. 51 & 52). The genital hiatus is the oval opening between the **levator crura**, through which pass the vagina and urethra. The shape of the genital hiatus depends on the degree of contracture of the levator ani muscles.

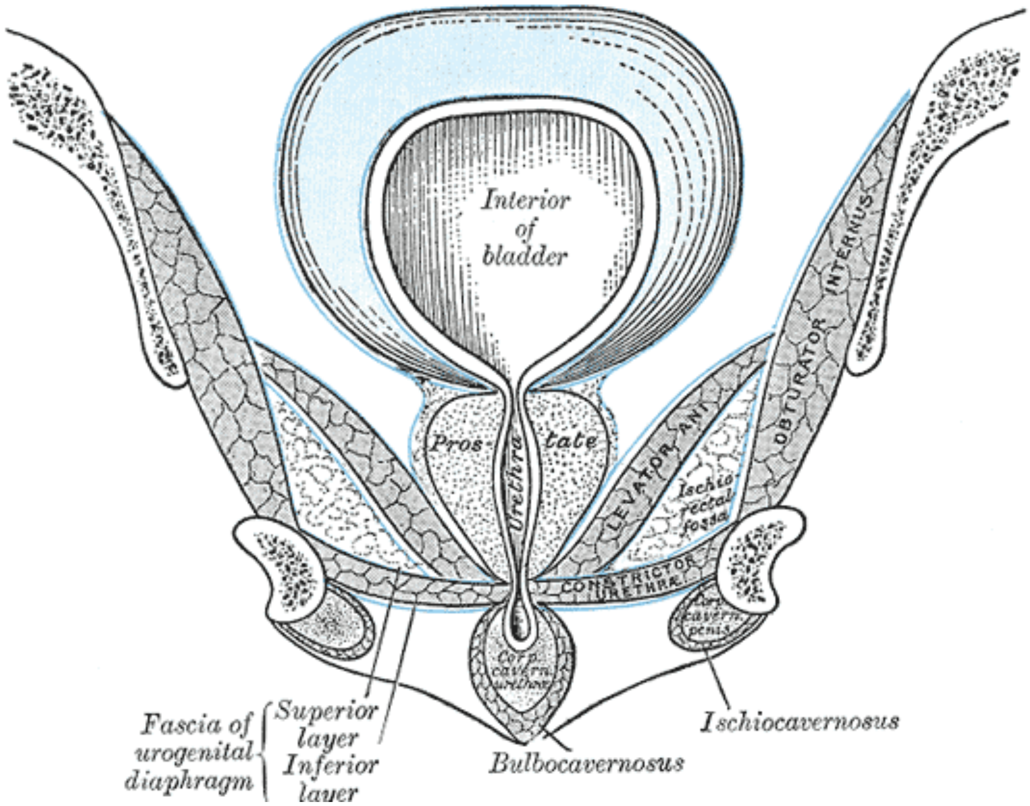


Fig. 51. This image is a coronal section of the anterior part of the pelvis, through the pubic arch seen from the front. The superior layer of the fascia of the urogenital diaphragm is labeled at the lower left. The superior layer of the fascia of the urogenital diaphragm is continuous with the obturator fascia and stretches across the pubic arch. Behind, this layer of the fascia it becomes continuous with the inferior fascia and with the fascia Colles (Fig. 52); in front it is continuous with the fascial sheath of the prostate, and is fused with the inferior fascia to form the transverse ligament of the pelvis. (Wiki)

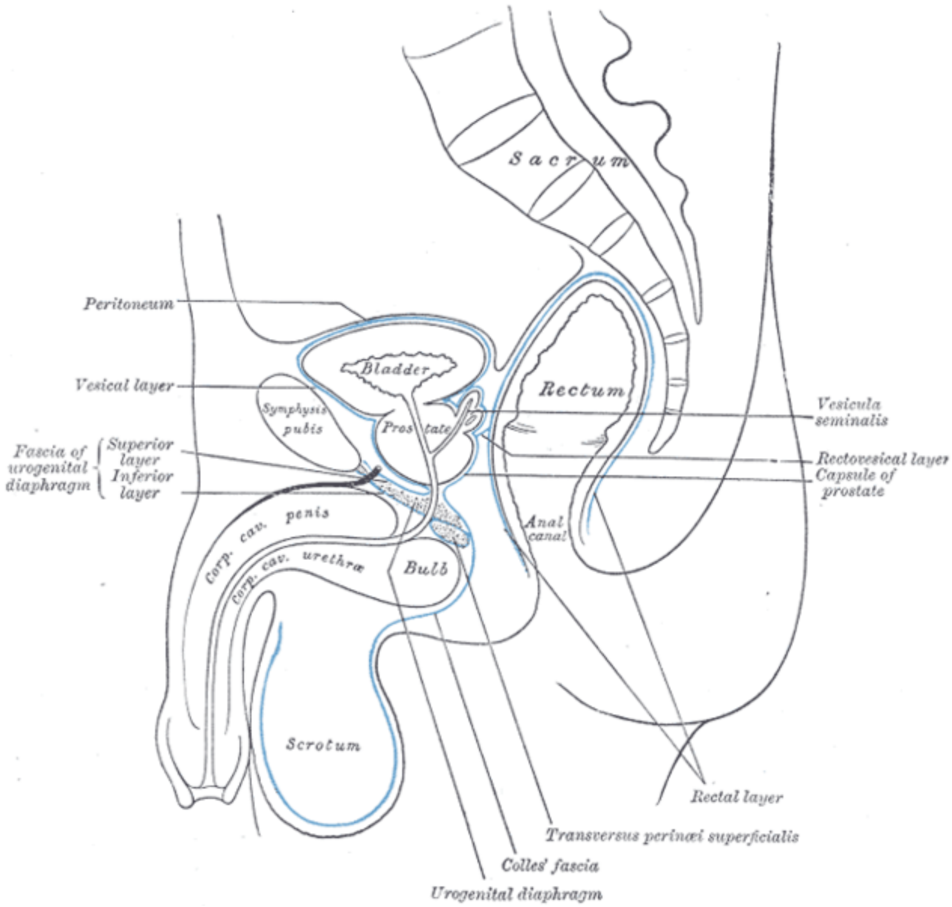


Fig. 52. This image is a median section of the pelvis, showing the arrangement of the fasciae. The superior layer of the urogenital diaphragm is labeled at the center left. Its fusion with the fascia of Colles is labelled in the lower aspect of the image. (Wiki)

The **urogenital diaphragm** is also referred to as the **perineal membrane**. This is a fibromuscular plate lying between the pubic rami, extends posteriorly to the anterior rectal wall. It lies anterior to the levator ani muscles and closes the genital hiatus. Except for the **deep transverse perineal muscles**, the urogenital diaphragm contains few muscle fibers. The urogenital diaphragm is most susceptible to injury at the point it is traversed by the vaginal canal. Because it is composed mostly of fibrous connective tissue, it does not handle well the distention and dilation that occurs during delivery. The levator ani muscles that surround the genital hiatus, however, when exposed to the same forces, can assume normal position and dimensions, if intact, within a short time. Thus, as a result of childbirth there is a transient widening of the genital hiatus for a short period, as long as the perineal membrane is not significantly damaged. If significantly damaged, the genital hiatus will assume a greater width after delivery as compared to before.

The last anatomic feature of the pelvis itself that we will cover is the **fascia of the pelvis**, which consist of the **visceral fascia (endopelvic fascia)** and the **parietal fascia**. The **visceral fascia** covers the **pelvic organs**, forming a subserous covering for them and enclosing their vascular pedicles. It binds the pelvic viscera to each other and to the **parietal fascia**. It is also continuous with the **extraperitoneal connective tissue**.

The **parietal fascia of the pelvis** are the **fascia of the obturator internus muscle,** the **superior fascia of the pelvic diaphragm** and the **fascia of the piriformis muscle**. It covers the **internal surface (facing the pelvic cavity)** of the floor and walls of the pelvic cavity.

Where the visceral and parietal fascia are continuous, as occurs where the organs penetrate the pelvic floor, the fascia thickens to form the **tendinous arch of the pelvic fascia (arcus tendinous fasciae pelvis)**. These arches are tendinous bilateral bands that run from the pubis to the sacrum, next to the viscera.

There are two ligaments which are considered parts of the visceral fascia, the **puboprostatic ligament** in the male and the **pubovesical ligament** in the female and male. The puboprostatic ligament is a thickening of the **superior fascia of the pelvic diaphragm** in the male, which extends laterally from the prostate to the **tendinous arch of the pelvic fascia** and continues anteriorly and medially from the **tendinous arch to the pubis** (Figs. 53 & 54).

The **pubovesical ligament** is a ligament that extends from the neck of the bladder to the inferior aspect of the pubic bones. In the female it is divided into the **lateral pubovesicle ligament** and the **medial pubovesicle ligament**. In the male the **pubovesicle ligament** is parallel and medial to the **puboprostatic ligament** (Fig. 55).

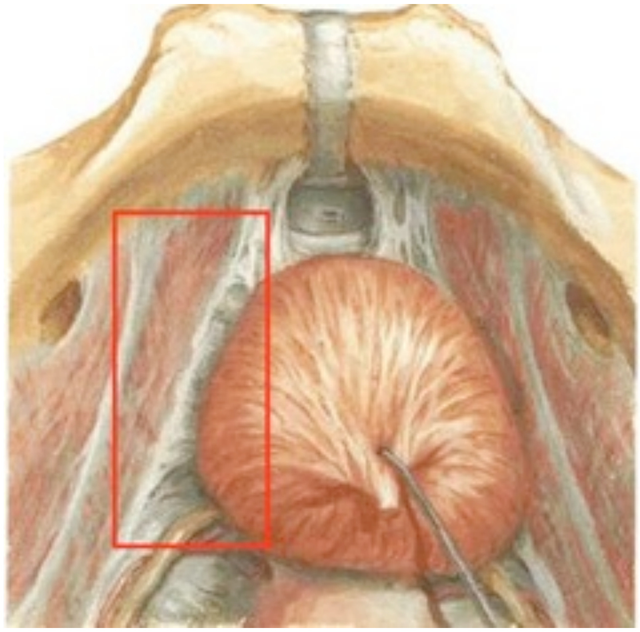


Fig. 53. This image shows the location of the lateral puboprostatic ligament. (quizlet.com)

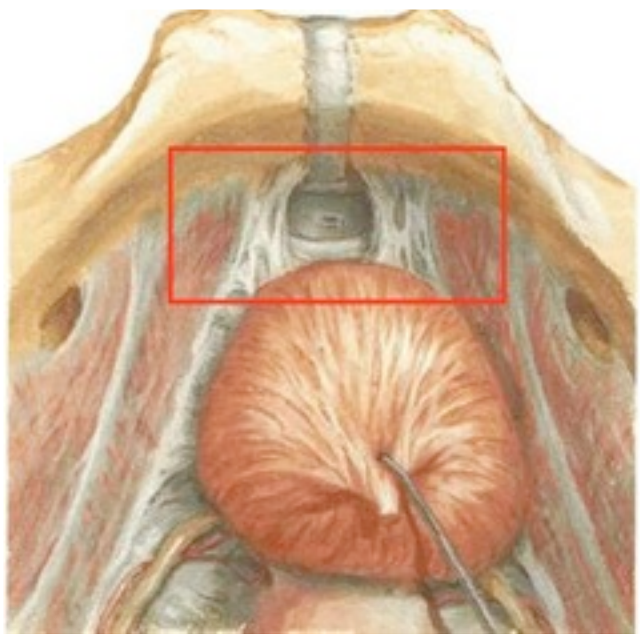


Fig. 54. This image shows the location of the medial puboprostatic ligament. (quizlet.com)

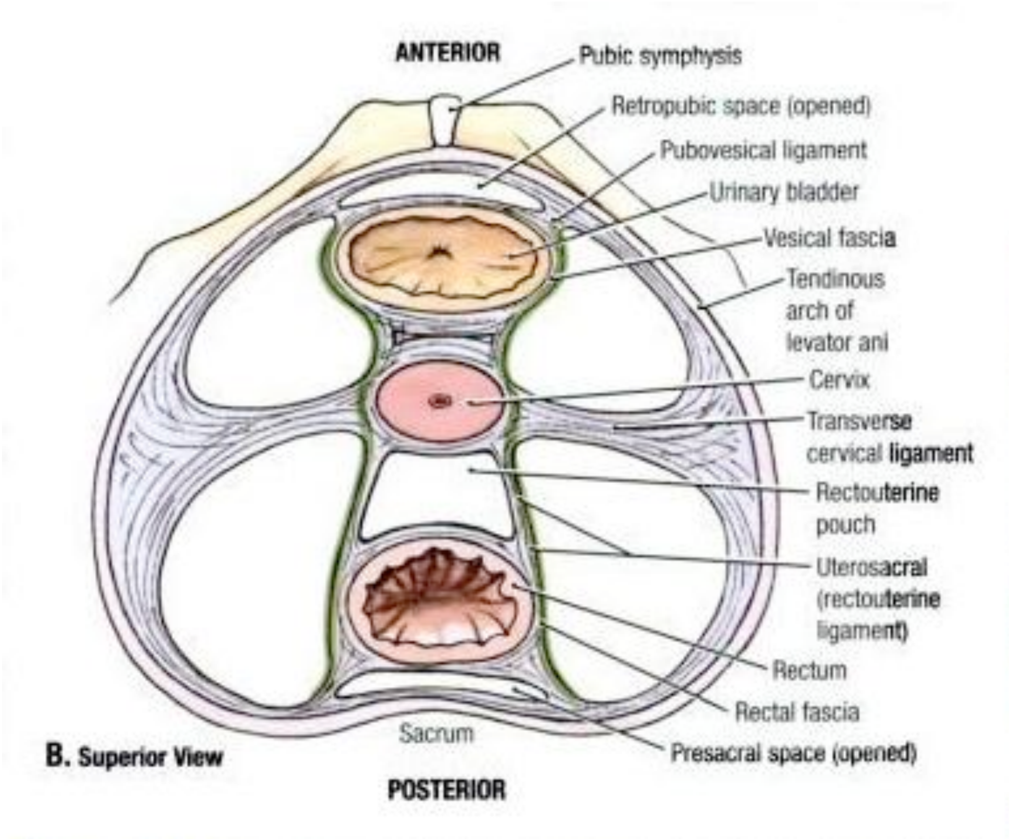


Fig. 55. This is an illustration of the female pelvis showing the location of the various ligaments including the pubovesical ligament. (anatomytopics.wordpress.com)

III. Relevant Anatomy of the Contents of the Pelvic Cavity Proper

In our discussion of the contents of the pelvic cavity, we are concerned with the components of three major organ systems: **urinary**, **gastrointestinal**, and **reproductive**.

A. The urinary system: The pelvic cavity proper contains the terminal portion of the **ureters**, the **bladder**, and the beginning of the **urethra**. The retroperitoneal portion of the ureter has been discussed in the previous chapter, “Traumatic Injuries of the Organs of the Retroperitoneal space: Adult and Pediatric,” pages 39-46.

1. **Pelvic portion of the Ureter:** This is about 12.5 cm long and begins at the point where the ureter crosses the bifurcation of the **common iliac artery** or the beginning of the **external iliac artery** (Fig. 56). The pelvic ureter descends retroperitoneally on the side of the pelvic wall. In the male it reaches the posterolateral aspect of the **bladder** in front of the upper end of the **seminal**

vesicle. At the level of the **ductus deferens** it turns over the posteriorsuperior aspect of the bladder and passes down over the fundus, crossing the termination of the vas deferens. The ureters pass obliquely through the wall of the bladder for about 2 cm, so that the internal openings are much closer together than their external penetrations of the bladder wall (Fig. 57). This oblique passage has a functional purpose, for as the bladder is being emptied, the contraction of the bladder musculature acts as a sphincter of the ureter, preventing reflux of urine into the ureters. There is evidence of a **ureteral sphincter mechanism** in man. The longitudinally oriented muscle bundles of the terminal ureter continue into the bladder wall and at the ureteric orifices become continuous with the **superficial trigone muscles**.

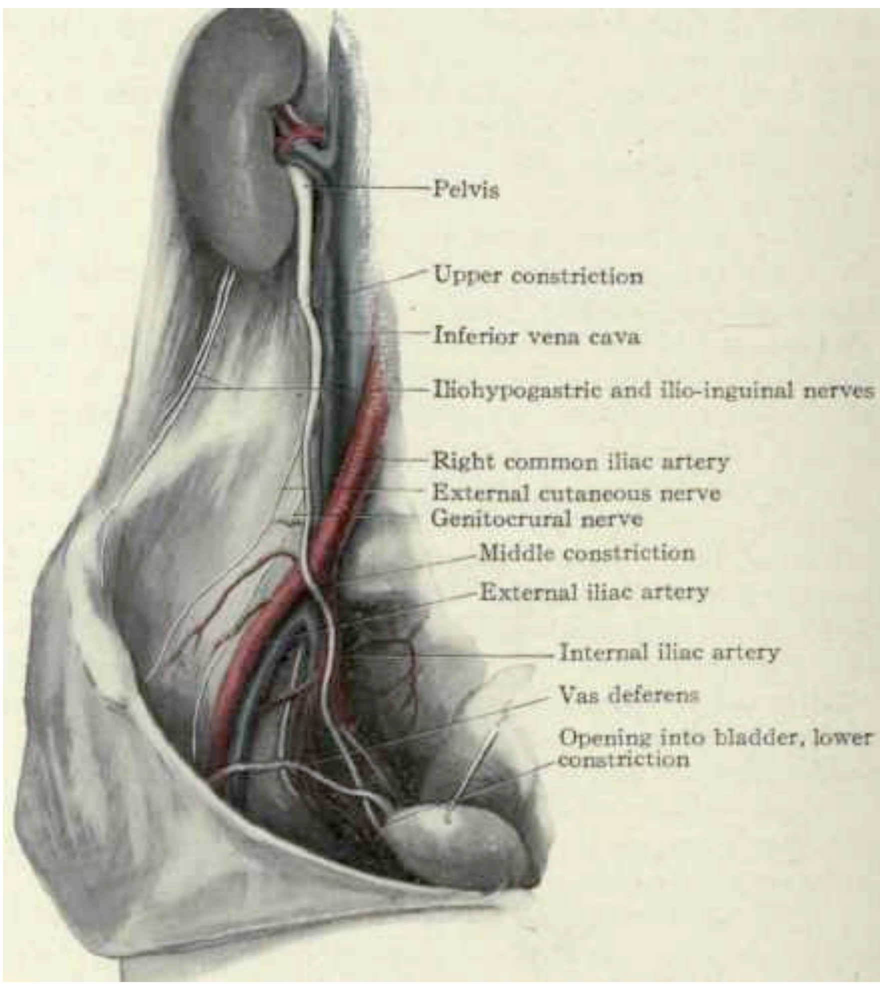


Fig. 56. The above image shows the ureter, its course and anatomic relations. (chestofbooks.com)

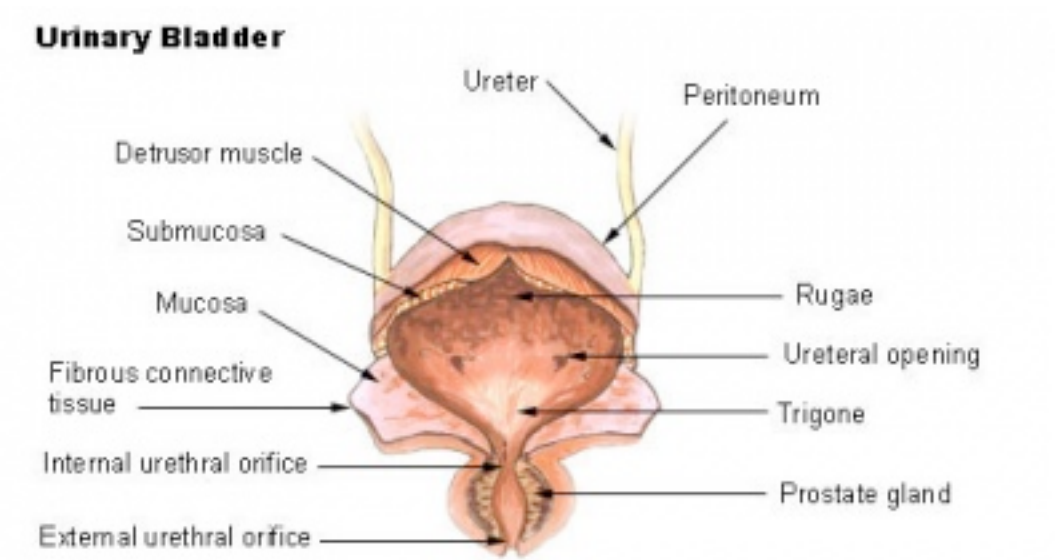


Fig. 57. This image shows the histology of the bladder and the location of the entrance of the ureter into the bladder wall and their opening into the lumen of the bladder. (php.med.unsw.edu.au)

In the female, as the ureter descends along the lateral wall of the pelvis, it underlies the **parietal peritoneum** behind and below the ovary and forms the posterior and inferior limits of the **ovarian fossa**. It continues forward and medialward to the bladder passing the **cervix** of the **uterus** and the **lateral fornix** of the **vagina** at a distance of 1 to 2 cm.

As previously discussed in the last chapter the ureter has three muscular layers: inner longitudinal, middle circular, and the outer longitudinal. In the mid-third and distal-thirds, the middle circular fibers form a thicker stratum than in the upper-third (Fig. 58).

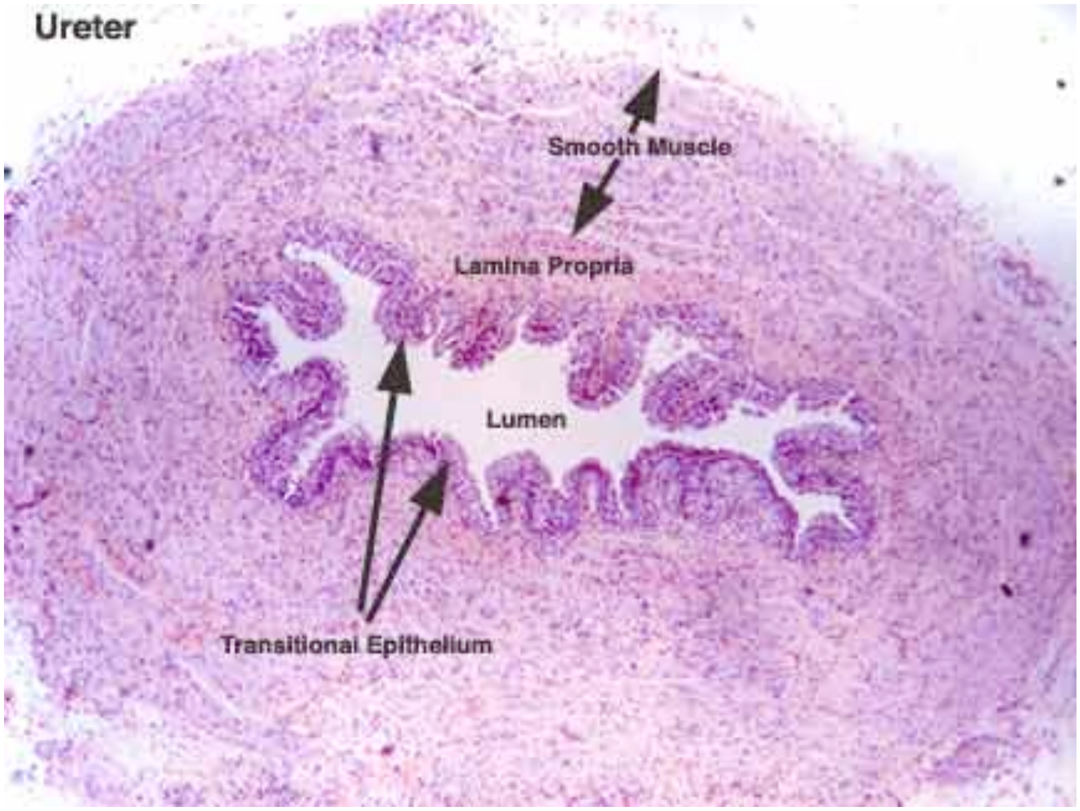


Fig. 58. This is a photomicrograph depicting the three layers of the ureter: mucosal layer with its lining transitional epithelium and lamina propria, the muscularis with its smooth muscle and the light aerolar tissue peripheral to the muscularis, the adventia, which is not labeled. (anatomytopics.wordpress.com)

The **arterial supply** to the pelvic portion of the ureter is from branches of the **inferior vesical**, which also supplies a large part of the **trigone of the bladder**, and the **middle rectal arteries of the internal iliac system**. The pelvic ureter may also be supplied by branches of the internal iliac artery directly. In the female, the **uterine artery** sends a small branch to the ureter as it crosses it.

The **veins** of the ureter typically follow the arterial supply. **Inferiorly**, they drain into the **inferior vena cava** via the **internal iliac vein** and, **superiorly**, they drain into the **inferior vena cava** through the **testicular (**or **ovarian)** veins or through the **renal veins**.

Lymphatic drainage of the pelvic ureter begins in the submucosal, intramuscular and adventitial plexuses, which communicate with each other and ultimately drain into **collecting vessels**. The collecting vessels in turn drain into the **common,**

external or **internal iliac nodes.**

The **innervation** of the pelvic portion of the ureter is derived from the **inferior hypogastric plexus** (Fig. 59).

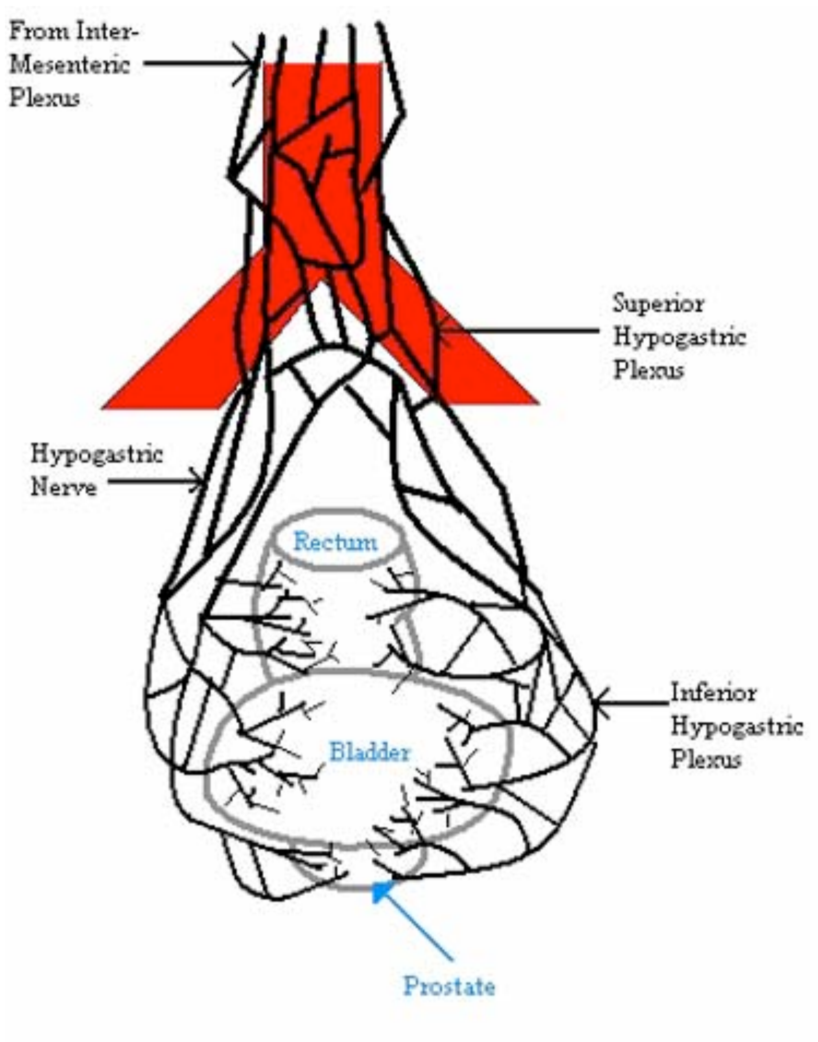


Fig. 59. This is a diagram of the inter-mesenteric plexus, superior hypogastric plexus, hypogastric nerve, and inferior hypogastric plexus. The inferior hypogastric plexus represents the focus of all autonomic control within the pelvis. It is a paired meshwork of nerves located on either side of the rectum lying medial to the internal iliac vessels. The sympathetic contributions into the inferior hypogastric plexuses stem from two sources. The largest sympathetic contribution is from the superior hypogastric plexus. The superior hypogastric plexus contains no parasympathetic fibers, so it is purely a sympathetic plexus. The superior hypogastric plexus itself receives upper lumbar contributions from the inter-mesenteric plexus, as well as contributions from L3 and L4 splanchnic nerves. Located within the abdomen at the bifurcation of the aorta, the superior hypogastric plexus descends into the pelvis and bifurcates as the right and left

hypogastric nerves. Please not these “nerves” aren’t really what is traditionally thought of as a nerve, they are more like mesh works than solid nerve trunks. These nerve mesh works diverge lateral to the rectum on either side and curve outward and backward as they make their way down about 7.5-10 cm into the pelvis. They interconnect the superior and inferior hypogastric plexuses and contain no ganglia. The hypogastric nerves convey the majority of the sympathetic contribution from the superior hypogastric plexus into the inferior hypogastric plexuses. (med.umich.edu)

The exact role of **autonomic innervation** of the ureter is not completely understood. Ureteral peristalsis appears to originate from intrinsic smooth muscle pacemaker sites located in the **minor calcyes of the renal collecting system**. The autonomic nervous system may exert some modulating effect on this process, but the exact role is unclear. The ureter receives **preganglionic sympathetic input** from **T10-L2 spinal segments**. **Sympathetic postganglionic fibers** arise from several ganglia in the **aortorenal, superior,** and **inferior hypogastric autonomic plexuses**. **Parasympathetic input** is supplied by **S2-S4 spinal segments**.

Pain perception and **somatic referred renal pain fibers** are stimulated by **distention** in the **renal capsule, renal collecting system,** or **ureter**. Direct mucosal irritation to the upper urinary tract may also stimulate **nociceptors** (receptors for pain, which are activated through injury to body tissues from either physical stimuli such as mechanical, thermal, or electrical stimuli, or from chemical stimuli such as the presence of a toxin or an excess of a nontoxic substance. Most nociceptors are either in the skin or the walls of viscera). Signals travel with the **sympathetic nerves** and result in a visceral-type pain referred to the sympathetic distributions of the kidney and ureter (T8-L2 spinal segments). Pain and reflex muscle spasm are typically produced over the distributions of the **subcortical, iliohypogastric, ilioinguinal,** and/or **genitofemoral nerves**, resulting in **flank**, **groin,** or **scrotal (or labial) pain** and **hyperalgesia** (increased nociception or pain sense).

2. **Urinary Bladder:** The **urinary bladder** is a hollow muscular organ which collects urine excreted by the kidneys so that it may be disposed of through urination (Fig. 57). Urine enters the bladder through the ureters and exits through the urethra. In

infants the bladder is located in the abdomen; it reaches the **false pelvis (pelvis major)** by the age of six. It does not reach its adult position within the **true pelvis** until after puberty. The structures of the pelvic walls, which form the space for the bladder are the **obturator internus muscle** above and the **pelvic diaphragm (levator ani muscle)** below. In the male, the posterior surface of the bladder is closely related to the **ductus deferens, seminal vesicles,** and **rectum**, being separated from the rectum by the **rectovesical septum** (Fig. 52). Inferiorly, the bladder rests on and is firmly attached to the base of the prostate gland. The **urethra** is located at the inferior aspect of the bladder, passing through the prostate.

In females, the bladder sits inferior to the **uterus** and anterior to the **vagina**; thus its maximum capacity is lower than in males. The urinary bladder typically holds approximately 400 cc in the adult male, less in the female, however, the desire for micturition commonly occurs at lower volumes.

Voluntary control is imposed primarily by the **inferior frontal gyrus of the cerebral cortex**. One can tolerate holding up to 500 cc of urine, however, once you exceed this capacity pain begins to develop due to tension in the bladder wall. This pain is referred to the cutaneous areas supplied by T10-L2 and S2-S4, including the lower anterior abdominal wall, perineum and penis. Inferiorly, the female bladder lies on the **pelvic diaphragm** and, in the **genital hiatus**, on the **urogenital diaphragm** (Figs. 43 & 51). The female bladder is separated from the uterus by the **vesicouterine excavation (uterovesical pouch of Meiring or Dunn's pouch)** (Fig. 60). The pouch is an important anatomical landmark for chronic endometriosis, which causes cyclical pain in women of child bearing age. Dunn's pouch is also an important factor in retroversion of the uterus (the tipping of an entire organ or part thereof in a posterior direction, such as the tipping back of the entire uterus about the pelvic axis), which can often complicate pregnancies.

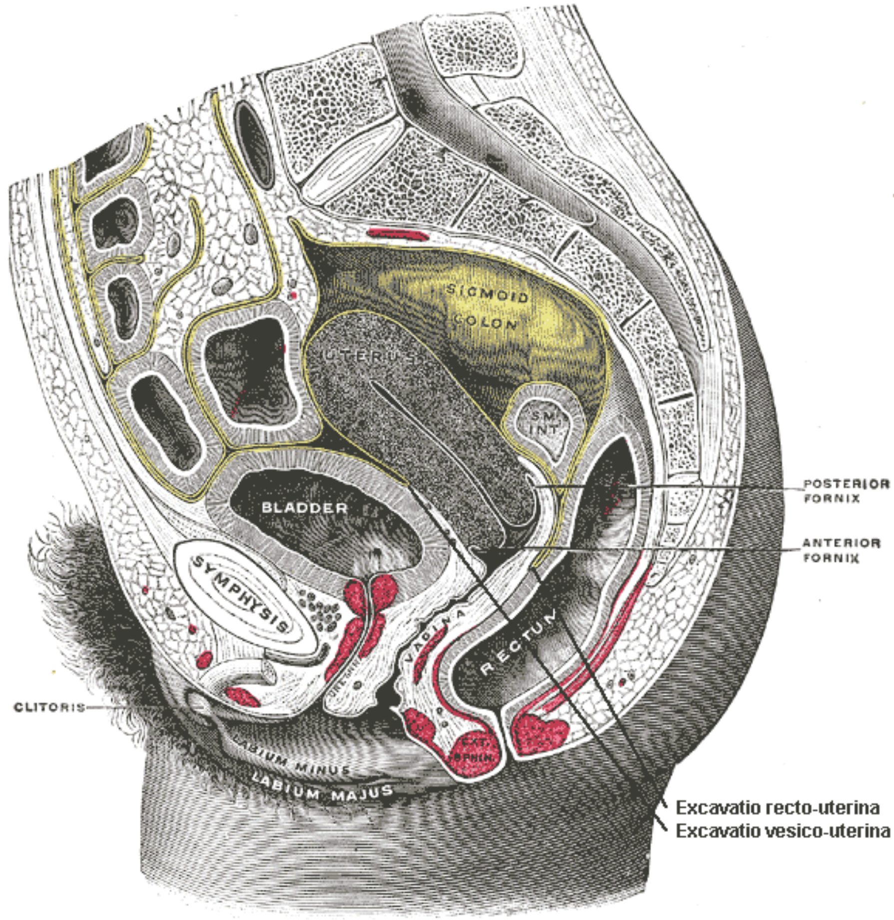


Fig. 60. This image is of a sagittal section of the lower part of a female trunk, right side. The vesicouterine excavation (uterovesical pouch of Meiring or Dunn's pouch) is labeled at the bottom right. This pouch is shallow, being formed from the peritoneum over the uterus and bladder, continued over the intestinal surface and fundus of the uterus onto its vesical surface, which covers as far as the junction of the body of the uterus and cervix, and then to the bladder. The vesicouterine excavation is also close to the anterior fornix of the vagina. Dunn's pouch is an important anatomical landmark for chronic endometriosis. (Wiki)

The fundus of the bladder is also the base of the bladder, formed by the posterior wall (Fig. 60). In the above image the fundus of the bladder is immediately next to the excavatio vesico-uterina.

The bladder is fixed inferiorly by the condensations of the **pelvic fascia**, which attaches it to the **pubis, lateral pelvic side walls,** and **rectum**. In both sexes, fibromuscular bands of tissue, the **pubovesical ligaments**, extend from the bladder neck to the inferior aspect of the **pubic bones**. These bands originate from the **detrusor muscle of the bladder** (Fig. 55). In the female, they constitute the superior extensions of the **pubourethral ligaments** (Figs. 61 & 62).

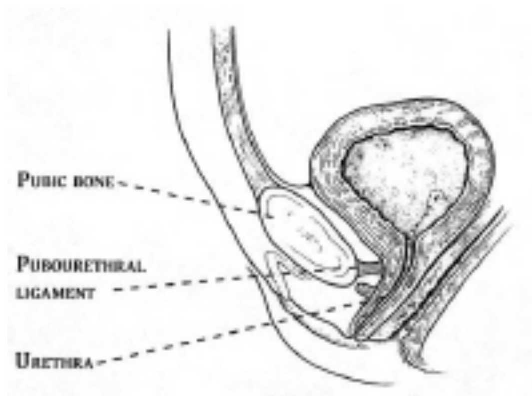


Fig. 61. This image shows the pubourethral ligaments suspending the female urethra under the pubic arch. (emedicine.medscape.com)

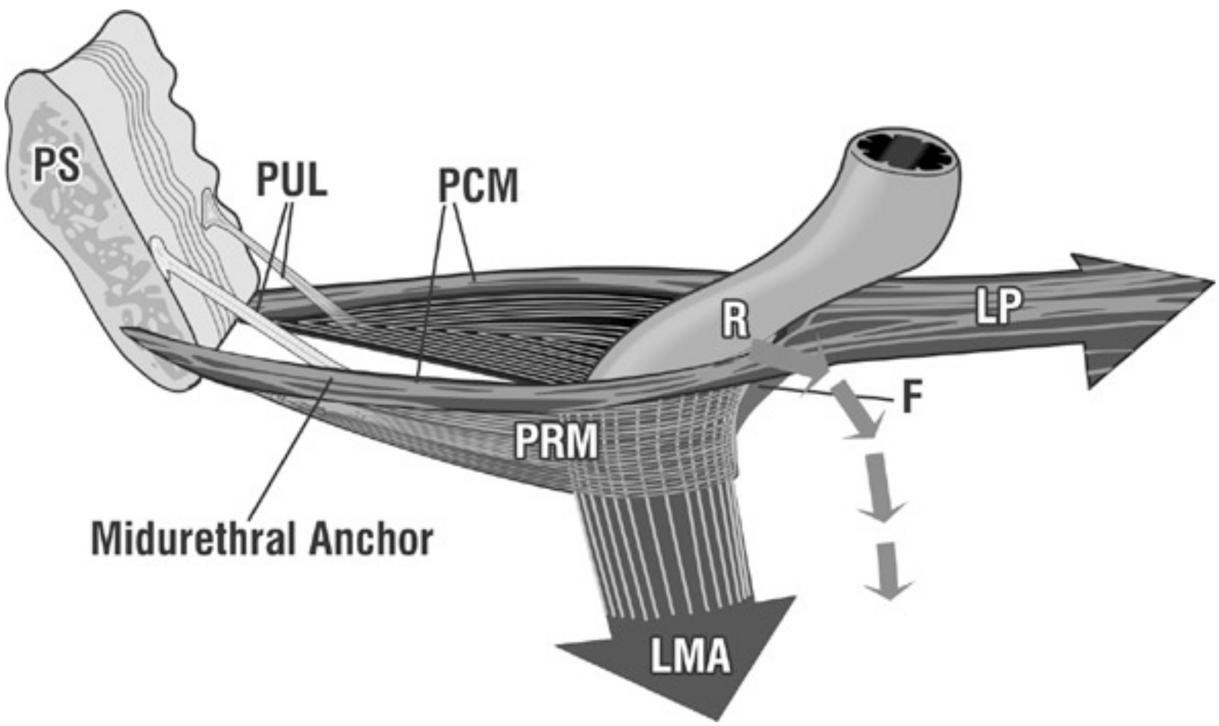


Fig. 62. This drawing depicts the function of the pubourethral ligaments (PUL), the puborectalis muscle (PRM), the pubococcygeus muscles (PCM), the levator plate (LP), the rectum (R), fascial attachment (F) and the longitudinal muscle of the anus (LMA). The PUL anchor the PCM, which fuse posteriorly to form the LP. PUL laxity will weaken the ability of LP to contract and be tensioned. LP tensioning is a prerequisite for backward stretching of the R, and downward rotation around PRM by the LMA. The

small arrows represent the LP/LMA rotational vectors. It is this rotation, which assists anorectal closure and forms the anorectal angle. F, identifies the fascial attachment of LP to the rectal wall. PS, represents the pubic symphysis. (pelviperineology.org)

In the male, the **detrusor muscle** extends over the anterior surface of the prostate condensing distally and anteriorly to form the **puboprostatic ligaments** (Figs. 53 & 54).

The apex of the bladder is connected to the **umbilicus** by remnants of the **urachus**, which forms the **median umbilical ligament** (Fig. 63).

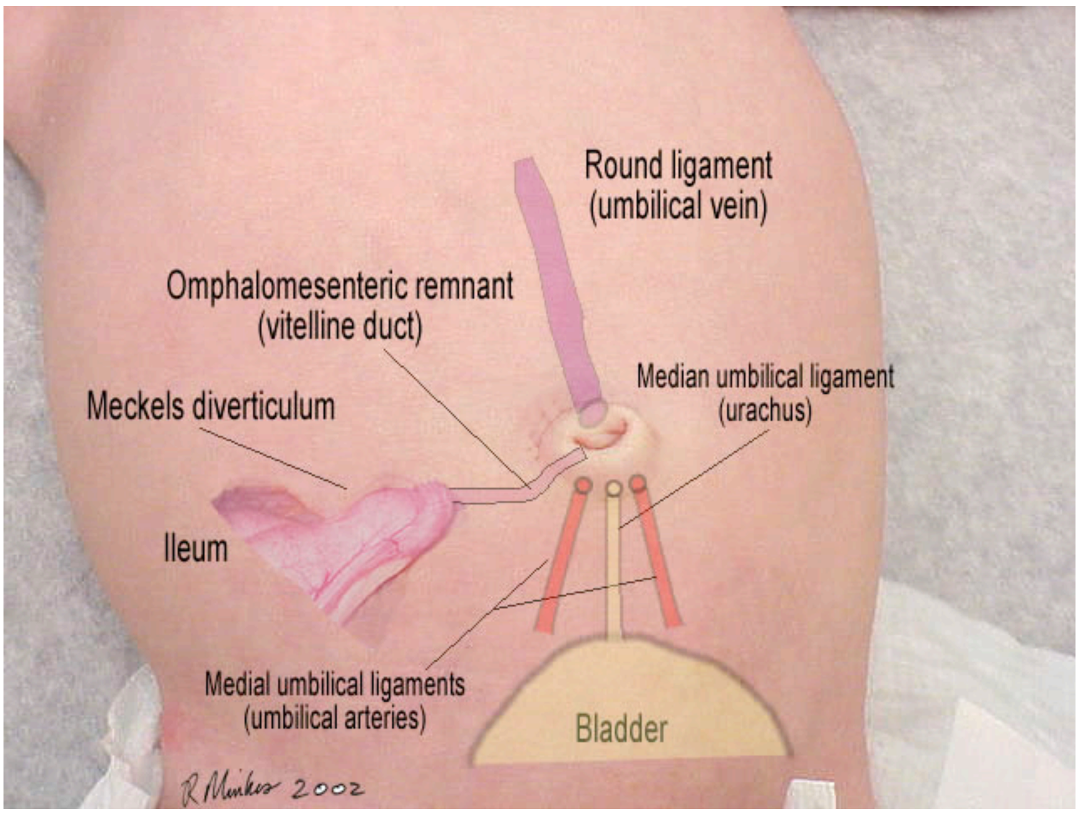
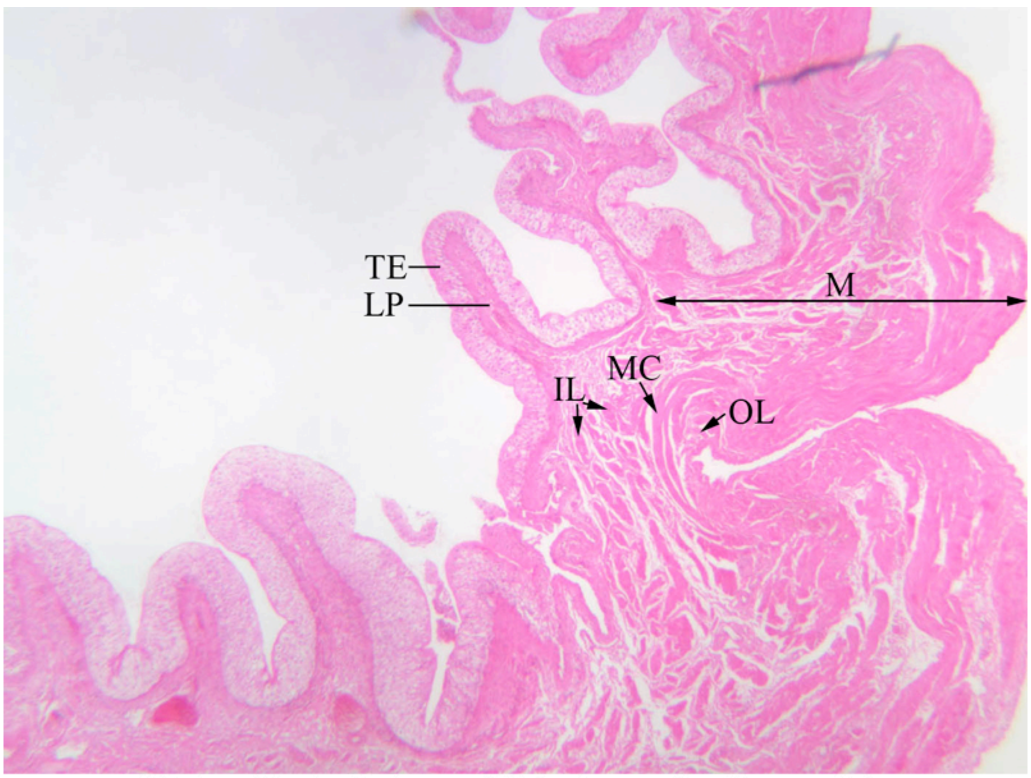


Fig. 63. The above image depicts the anatomic relationship between the umbilicus and its embryologic attachments. (radiographics.net)

The urachus is the fibrous remnant of the **atlantois**, which is a canal that drains the urinary bladder of the fetus that joins and runs within the **umbilical cord**. Typically, the lumen of the urachus is filled in, being represented only by longitudinal muscle fibers derived from the detrusor muscle. The urachus usually contains portions of the original lumen that is covered by epithelium, which persists into adult life. Rarely, the lumen remnants can lead to the development of a **urachal fistula, cyst, sinus or adenocarcinoma**. Should the lumen of the urachus remain open, it is possible for urine to leak from the umbilicus, as occurs in a **urachal fistula**. A partially preserved segment of the urachus, but with no communication between the bladder and the umbilicus, can lead to the development of a **urachal cyst**.

The **anatomic structure of the bladder** consist of four layers: **serosal, muscular, submucosal** and **mucosal** (Fig. 64).



TE - transitional epithelium LP - lamina propria M - muscularis
IL - inner longitudinal MC - middle circular OL - outer longitudinal layer of muscularis

Fig. 64. These photomicrographs of the urinary bladder depict its histology. The serosal layer is not labeled. It represents the outer surface of the muscularis or the outer longitudinal layer of the muscularis. (anatomytopics.wordpress.com)

(a). Serosal layer (tunica serosa): The serosal layer is a partial layer derived from the peritoneum. It covers only the superior surface and the upper parts of the lateral surfaces. The peritoneum extends from these surfaces on to the abdominal and pelvic walls (Fig. 64).

(b). Muscular layer (tunica muscularis): The muscular layer consists of three layers of smooth muscle fibers (**detrusor muscle)**. An external layer in which the fibers are for the most part arranged longitudinally (Fig. 64).

Some of the fibers of the external layer, in both sexes, give rise to fibers which extend to the pubis thus, forming the **pubovesical muscle** (Fig. 65).

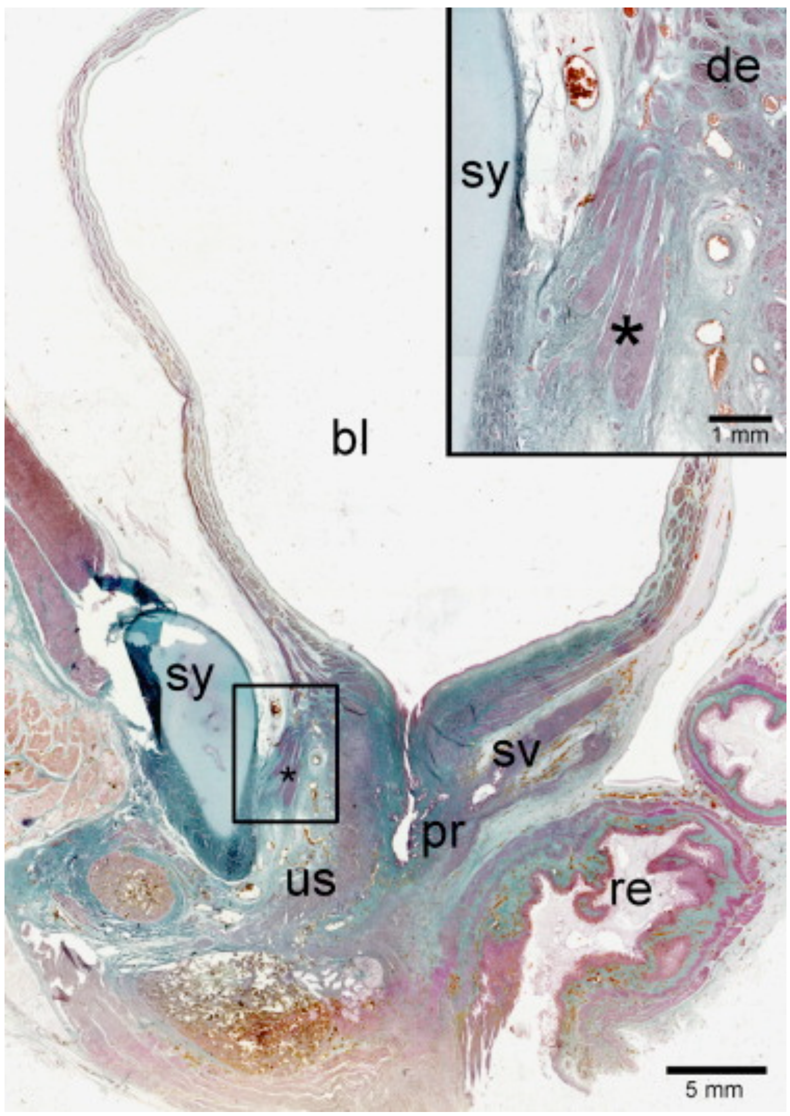


Fig. 65. The above images are photomicrographs of a sagittal section of a newborn infant male using the Crossmon staining technique. The insert shows the pubovesicle muscle at higher magnification; bladder (bl); detrusor (de); prostate (pr); rectum (re); seminal vesicle (sv); urethral sphincter (us). (sciencedirect.com)

In the male other fibers arise from the base of the prostate gland and its capsule. In the female the fibers arise immediately in front of the vagina. This layer of muscle is also referred to as the **Detrusor urinae muscle** by some anatomist. The fibers of the **middle circular layer** for the most part are thinly and irregularly scattered on the body of the bladder (Fig. 64). Although the fibers are roughly arranged transverse to the long axis of the bladder, in actuality they pursue an oblique course. Around the internal urethral orifice, they form a circular layer, referred to as the **sphincter vesicae**, which is continuous with the muscular fibers of the prostate in the male (Figs. 66 & 67).

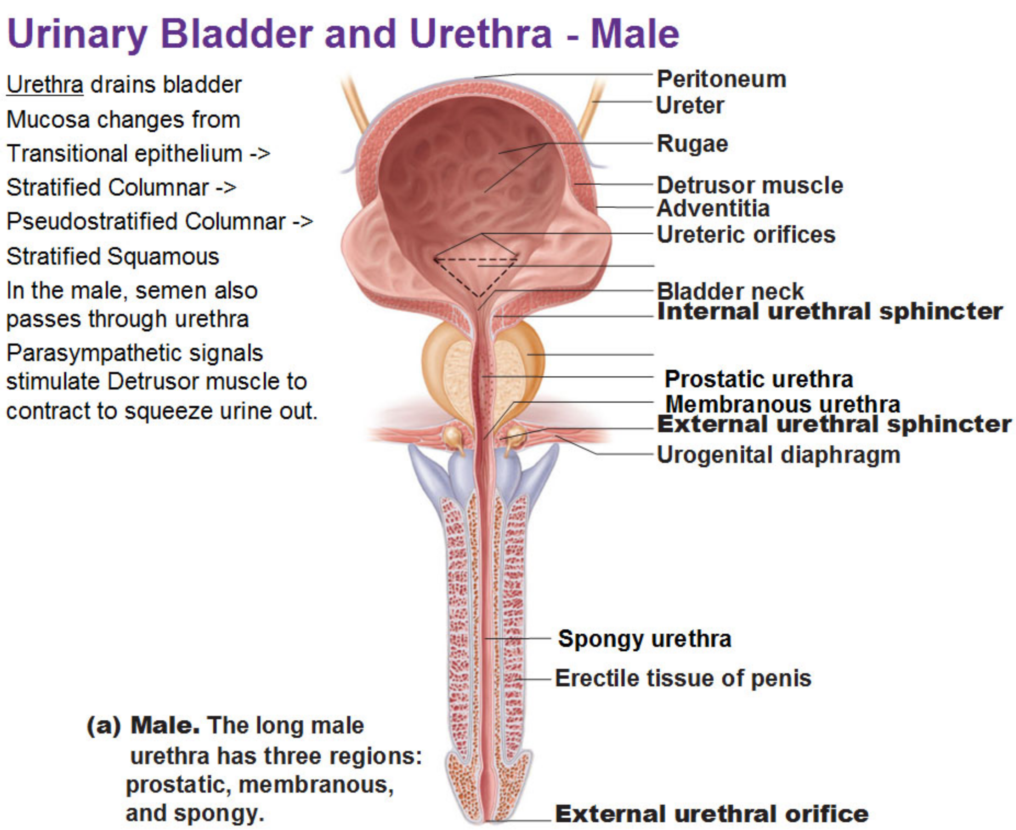


Fig. 66. The above image depicts the general anatomy of the male bladder and urethra. (antranik.org)

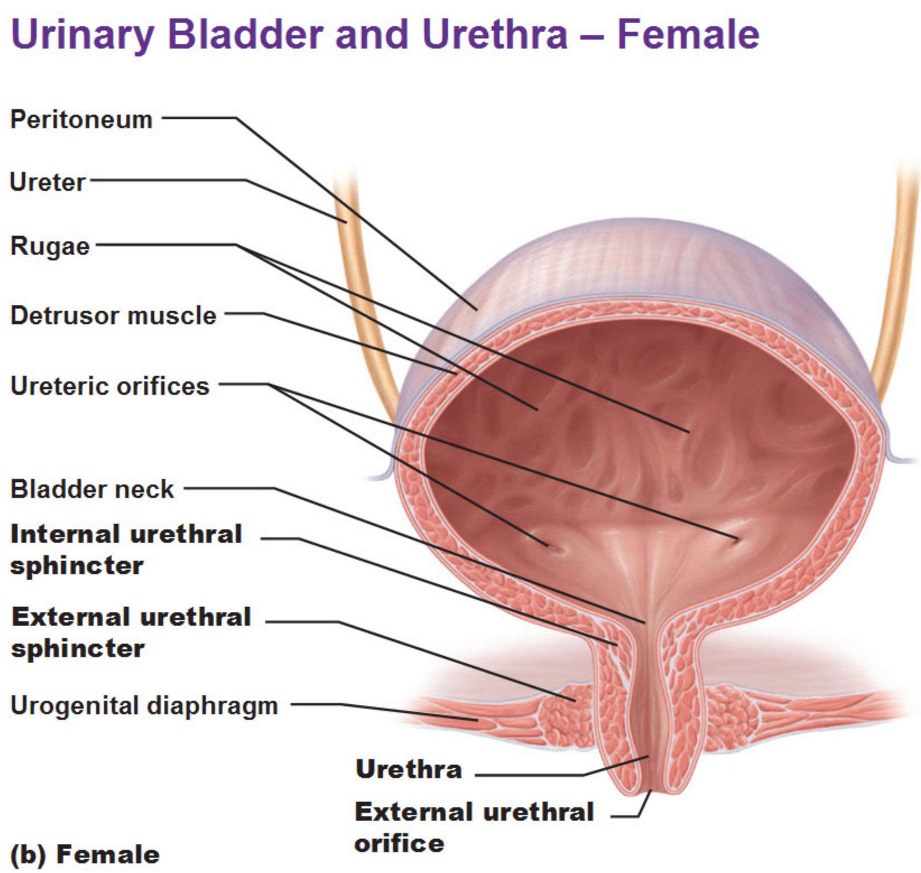


Fig. 67. This image depicts the general anatomy of the female bladder and urethra. (antranik.org)

The fibers of the **internal layer** are arranged roughly in a longitudinal direction. Within this internal layer are two band of fibers, which originate behind the orifices of the ureters (Figs. 66 & 67), converge to the back of the prostate, and are inserted by means of a fibrous process into the middle lobe of the prostate. These are the **muscles of the ureters**, described by Sir C. Bell, who suggested that during the contraction of the bladder they serve to retain the oblique direction of the ureter, thus preventing reflux of urine into them.

(c). Submucosal layer (tela submucosa): consists of a layer of areolar tissue, which connects the muscular and mucosal layers (Fig. 64,).

(d). Mucosal layer (tunica mucosa): This layer is continuous through the ureters with the lining membrane of the renal tubules, and below with that of the urethra (Fig. 64,). The loose texture of the areolar tissue composing the submucosa layer allows the mucous coat to be thrown into folds or rugae when the bladder is empty except for the region of the trigone (Fig. 57). As the bladder fills the rugae are stretched and become flat when it is distended (Figs. 66 & 67).

On the posterior wall of the bladder, lying immediately above the bladder neck, is a small triangular area called the **trigone** (Fig. 57, p 67 & Fig. 68).

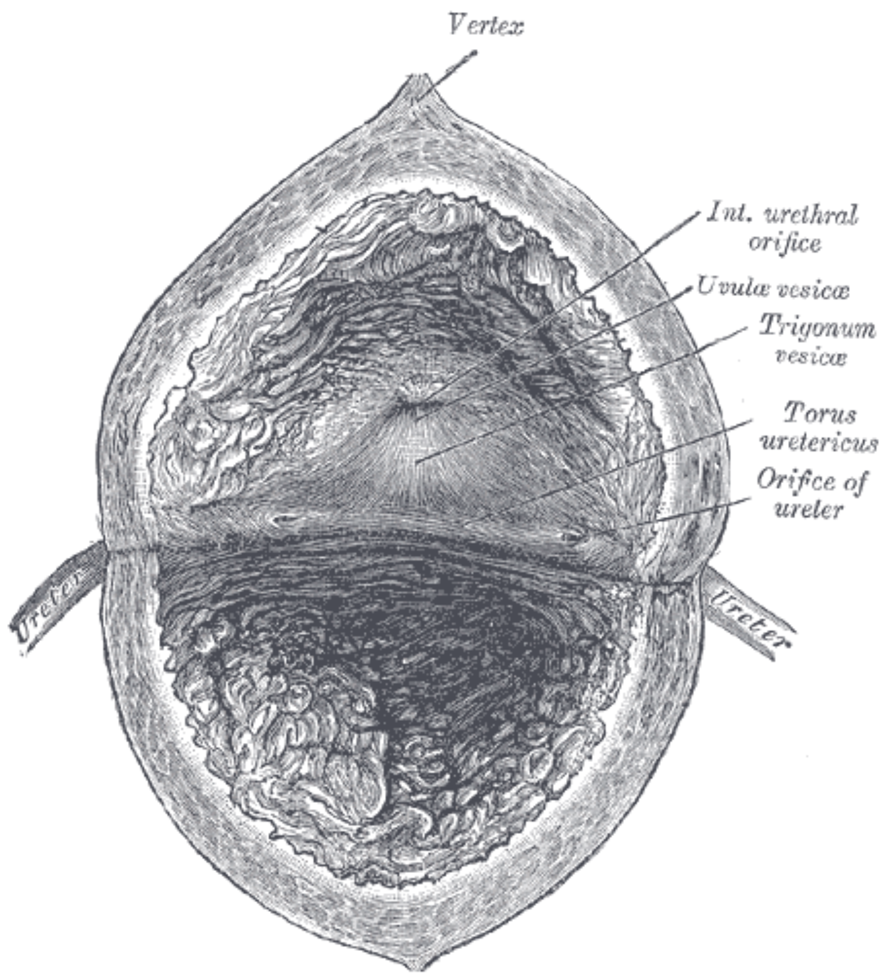


Fig. 68. The above image is of the interior of the bladder with the bladder being cut from above downward showing the triangular trigone, which at its lowermost apex opens into the urethra. At the uppermost angles are the openings of the ureters into the bladder. The trigone can be identified by the fact that its mucosa, the inner lining of the bladder, is smooth, in contrast to the remaining bladder mucosa, which is folded to form rugae. You will also note thickening of the muscle between the openings of the ureters, which are referred to as **torus uretericus (interureteric crest)**. There is also thickening between the ureteral orifices and the internal urethral meatus (orifice). This thickening is referred to as **Bell's muscle**, which demarcates the trigone from the remainder of the bladder. (Wiki)

The trigone is very sensitive to expansion and once stretched to a certain degree, the urinary bladder signals the brain of its need to empty.

3. **Bladder neck:** The **bladder neck** is considered separately from the anatomic discussion of the urinary bladder because its smooth muscle is histologically, histochemically and pharmacologically distinct from the **detrusor muscle** of the bladder (Figs. 66 & 67). The smooth muscle of the bladder neck surrounds the trigone. The smooth muscle orientation of the bladder neck differs between the sexes.

   (a). Female: The smooth muscle of the bladder neck is smaller in diameter as compared to the smooth muscle of the detrusor muscle. The badder neck sits above the **pelvic floor** supported by the **pubovesical ligaments,** the **endopelvic fascia of the pelvic floor** and the **levator ani** (Fig. 55, p 65). These structures also support the urethra at rest; when the intra-abdominal pressure increases the levator ani muscles contract thus, maintaining urethral closure and preventing the leakage of the urine. However, pregnancies and increasing age modify this anatomic relationship, such that the bladder neck comes to lie beneath the pelvic floor. Thus, with increase intra-abdominal pressure the bladder neck and the urethra are not subjected to the same force of levator ani contraction, hence women may experience urinary incontinence (Fig. 69).

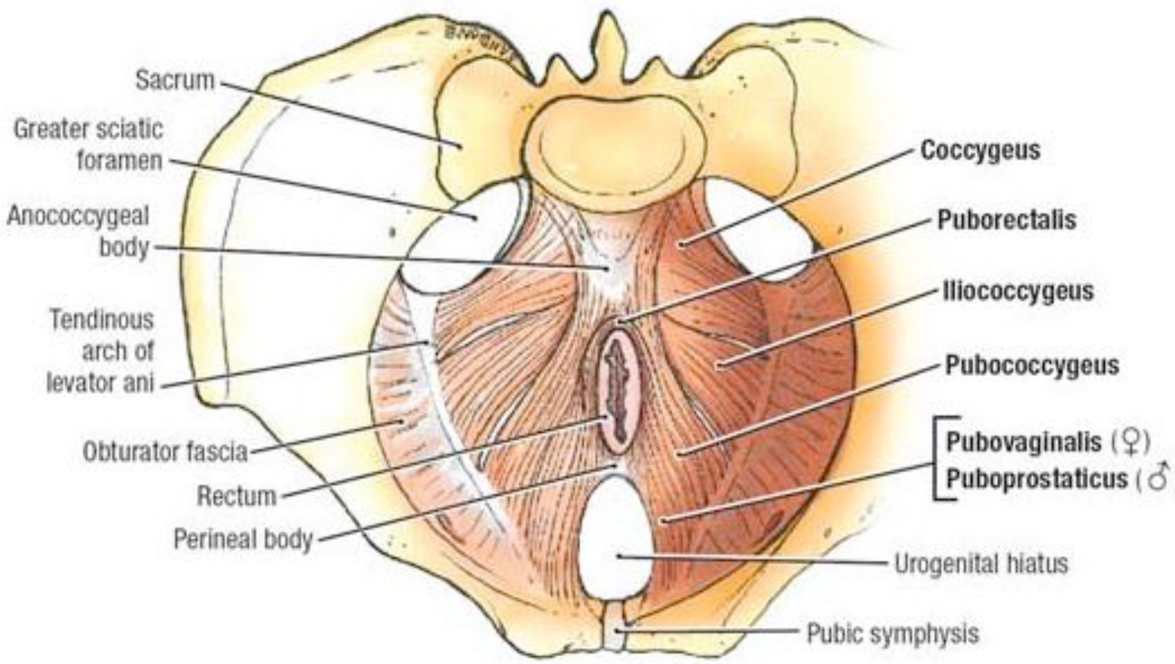


Fig. 69. Remember, the pelvic floor has three layers of support: the **endopelvic fascia**, the **levator ani muscles** and the **perineal membrane**.
The **endopelvic fascia** (outer stratum of the pelvic fascia) is a viscero-fascial layer that lies immediately beneath the peritoneum and connects the viscera to the pelvic sidewalls. It presents an extension of the **transveralis fascia** which drapes on the pelvic floor. It is the first layer of the pelvic floor.
The endopelvic fascia becomes condensed to form the **urethropelvic** and **puboprostatic ligaments**. The urethropelvic ligaments are an anterior medial condensation of the endopelvic fascia, which combines with fibers from the **pubococcygeus muscle** to span the area from the anterior aspect of the **tendinous arc** to the bladder neck and proximal urethra. The puboprostatic ligament attaches the inferior surface of the pubic symphysis to the junction of the prostate and the external sphincter. The puboprostatic ligaments, in conjunction with the **pubourethralis muscle** prevent the rotational decent of the proximal urethra.
The **levator ani muscle** is the second layer of pelvic floor and considered the true muscular floor of the pelvis that provides the main support for the pelvic organs. The layer formed by the levator ani muscle and its fascial layers (superior and inferior) is referred to as the **pelvic diaphragm**. The levator ani is composed of three parts: the **pubococcygeus, iliococcygeus** and **ischiococcygeus muscles**.
The **perineal membrane (urogenital diaphragm)** is the third layer of the pelvic floor and it provides weak support for the urethra (Fig. 76). (uronotes2012.blogspot.com)

(b). Male: The bladder neck is encircled by a smooth muscle collar, which has its own **adrenergic innervation**. This smooth muscle color extends to encircle the periprostatic portion of the urethra. The smooth muscle cells, which form this ‘preprostatic sphincter‘ are small compared to the smooth muscle of the detrusor, being separated from it by connective tissue. It is important to understand the ‘preprostatic sphincter‘ is not responsible for urinary continence. It is a **genital sphincter** that allows for antegrade ejaculation of semen. Unlike the detrusor and the rest of the urethral smooth muscle of both sexes, the ‘preprostatic sphincter‘ is innervated with **sympathetic noradrenergic nerves** and is almost totally devoid of **parasympathetic cholinergic nerves**. Contraction of the ‘preprostatic sphincter‘ serves to prevent the retrograde flow of the ejaculate through the proximal urethra into the bladder. From a pragmatic standpoint, when a male has a transurethral resection of the prostate, the ‘preprostatic sphincter‘ is disrupted which results in retrograde ejaculation (Figs. 70 & 71).

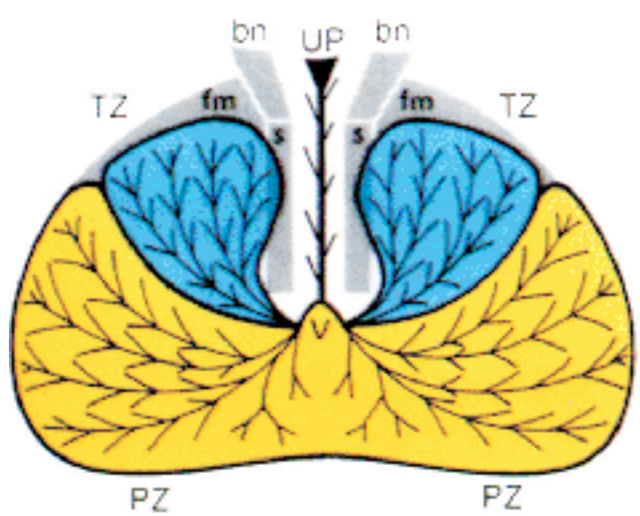


Fig. 70. This is an oblique coronal section digram of the prostate showing the location of the peripheral zone (PZ) and transition zone (TZ) in relation to the proximal urethral segment (UP), verumontum (V) (also referred to as the seminal colliculus of the prostatic urethra), preprostatic sphincter (s), bladder neck (bn), anterior fibromuscular stroma (fm), and periurethral region with periurethral glands. The branching pattern of the prostatic ducts is indicated; the medial transition zone ducts penetrate into the sphincter. (flylib.com)

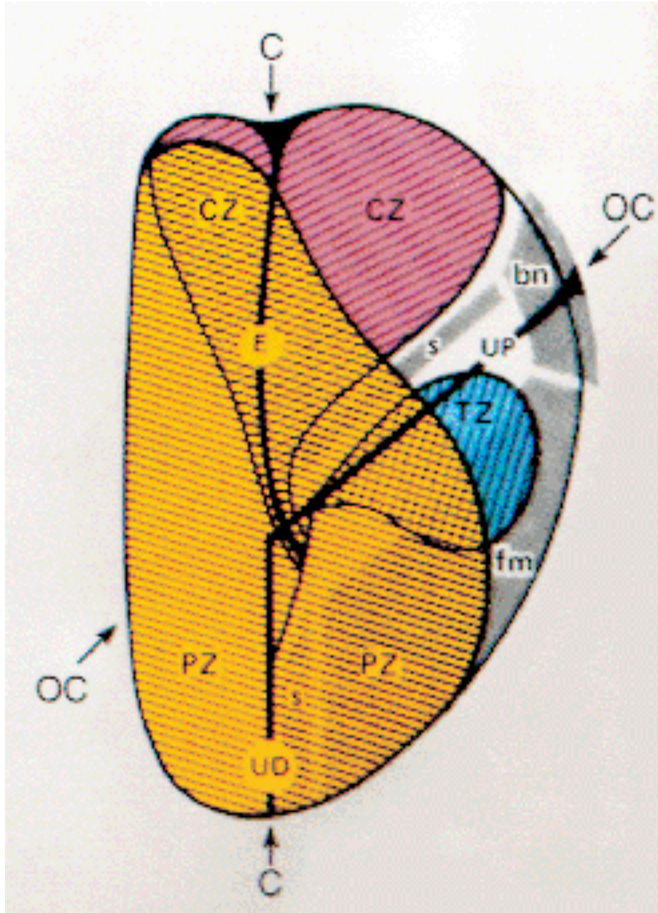


Fig. 71. This is a sagittal diagram of the distal prostatic urethral segment (UD), proximal urethral segment (UP), and ejaculatory ducts (E) showing their relationships to a sagittal section of the anteromedial nonglandular tissues [bladder neck (bn), anterior fibromuscular stroma (fm), preprostatic sphincter (s), distal striated sphincter (s) (this is labeled immediately above UD to the right)]. These structures are shown in relation to a three-dimensional representation of the glandular prostate [central zone (CZ), peripheral zone (PZ), transition zone (TZ)]. The coronal plane (C) and oblique coronal plane (OC) are indicated by arrows. (flylib.com)

The **vascular supply** of the bladder is the **superior** and **inferior vesicle arteries** from the **anterior trunk** of the **internal iliac arteries**. This is supplemented by the **obturator** and **inferior gluteal arteries**. In the female additional supplemental supply is provided by the **uterine** and **vaginal arteries.**

The **veins** which drain the bladder form a dense vesicle plexus around the neck of the bladder and its inferolateral surface. This plexus ultimately drains into the **internal iliac vein**. In males, the vesicle plexus also communicated with the

prostatic plexus, which is a part of **Batson venous plexus**. (Fig. 72).

The **lymphatics** which drain the bladder originate from three plexuses: **mucosal, intermuscular,** and **serosal**. Most of the three sets of **collecting ducts** drain to the **external iliac nodes**, although some may drain to the **internal iliac nodes**, the **common iliac nodes** and the lymph nodes of the **obturator fossa**.

The **innervation** of the bladder originates from the **pelvic plexuses**, which are comprised of **autonomic nerves** and **ganglia** on the lateral aspect of the **rectum, internal genitalia** and the **bladder base**. They consist of both **sympathetic** and **parasympathetic components,** each of which contains both **efferent** and **afferent fibers**.

The **preganglionic parasympathetic fibers** originate from the **parasympathetic nucleus** in the **intermediolateral column of gray matter in sacral spinal segments S2-S4**. These preganglionic fibers form the **pelvic splanchnic nerves**, which enter the pelvic plexuses on the posterolateral aspect of the rectum (Fig. 72).

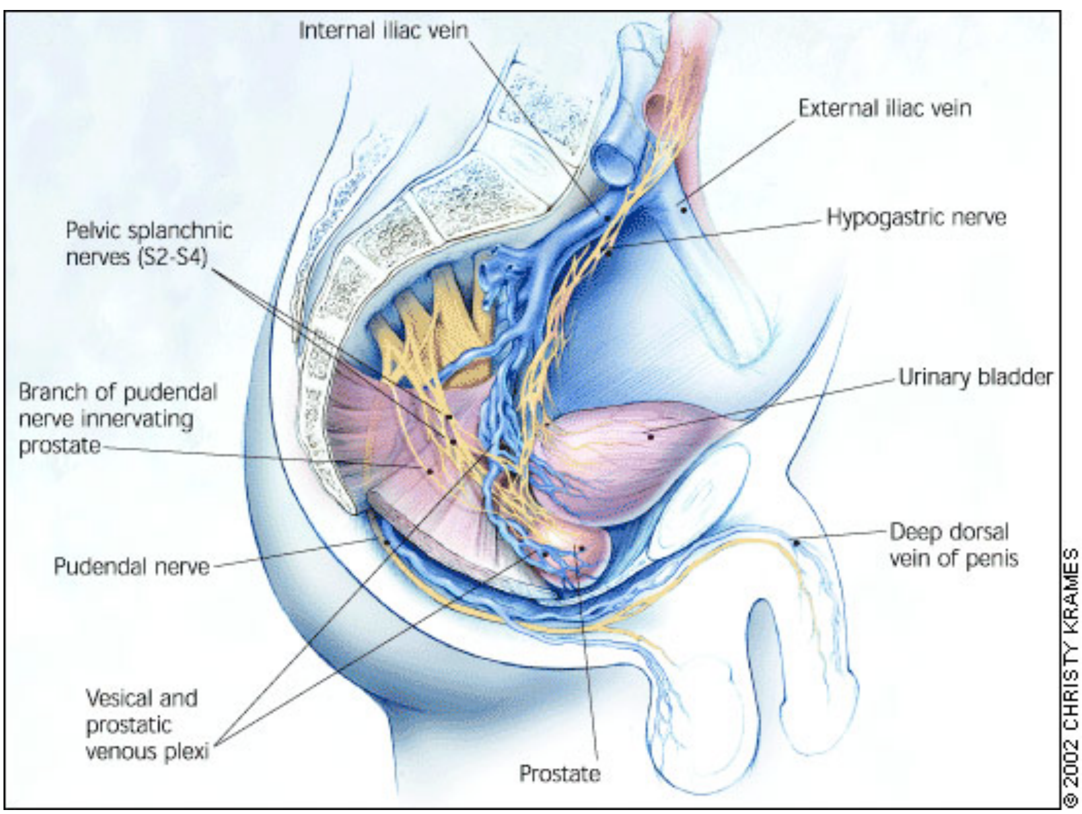


Fig. 72. The above image shows the location of a portion of **Batson venous plexus** and the **pelvic splanchnic nerves**. Batson venous plexus is a network of valveless veins that connect the deep pelvic and thoracic veins, which drain the inferior end of the bladder, breast, and prostate to the **internal vertebral venous plexuses**. They are thought to provide a hematogenous route for metastatic spread of rectal and prostate cancer to the vertebral column or brain. The plexus is named after anatomist **Oscar Vivan Batson**, who first described it in 1940. (morningreportmsh.blogspot.com)

On reaching the pelvic plexus they form synapses with **postganglionic neurons**. The postganglionic neurons are primarily **cholinergic**, but they may also contain **purinergic, peptidergic** and **nitrergic**. The fibers of these postgnglionic neurons innervate the **detrusor smooth muscle**. Activation of this **parasympathetic system** causes sustained contraction of the bladder and relaxation of the urethral sphincter with bladder emptying. *Remember, when it comes to visceral smooth muscles, induction of contraction occurs through the parasympathetic system, whereas inhibition of contraction occurs through sympathetic stimulation.*

The **sympathetic fibers** originate from the **sympathetic nucleus** in the **intermediolateral column of gray matter in T10-L2 spinal segments**. These fibers form the **celiac** and **mesenteric plexus** around the great vessels in the abdomen (Fig. 73). They synapse with the **postganglionic neurons**, the fibers of which travel in the **hypogastric nerve** to reach the body of the bladder and urethra. The **postganglionic sympathetic fibers** provide inhibitory input to the bladder and urethra. Thus, activation of the hypogastric nerve induces relaxation of the body of the bladder and contraction of the bladder outlet and urethra, which in turn contributes to urine storage in the bladder. The **postganglionic fibers** are primarily **noradrenergic**, but may also be **purinergic** and **peptidergic**. These fibers primarily innervate the **longitudinal** and **circular muscle fibers** of the bladder neck and proximal urethra with a minor component innervating the detrusor muscle.

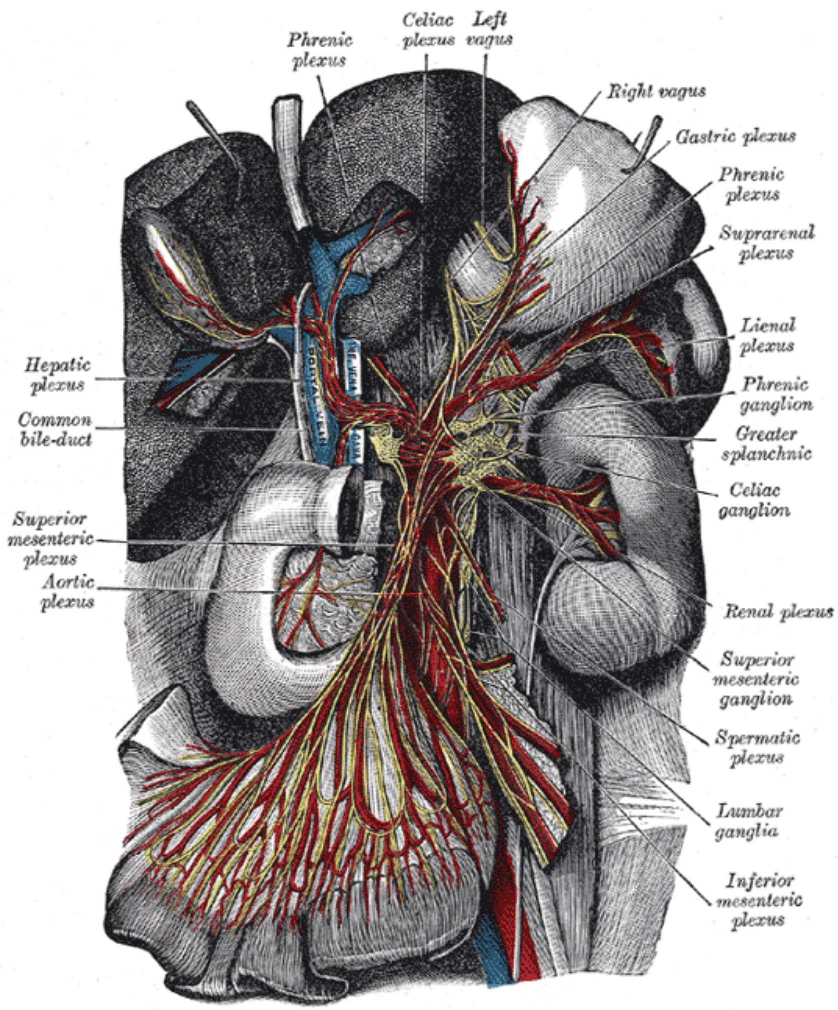


Fig. 73. This image shows the Celiac plexus and ganglion and the Superior and Inferior mesenteric plexuses. (www.ask.com)

Sensory information is transmitted through **afferent nerves** from numerous receptors in the lower urinary tract via the **pelvic, hypogastric** and **pudendal nerves** to **spinal cord**.

The **afferent sensory fibers** are in the **pelvic nerve**, with the cell bodies of these neurons being located in the **dorsal root ganglia of S2-S4**. The pelvic nerve afferents has two types of fibers, **myelinated A-delta fibers** and **unmyelinated C-fibers**. The myelinated A-fibers control normal micturition and are sensitive to gradual distention of the bladder. The unmyelinated C-fibers do not respond to

bladder distention, however, they respond to various pathological conditions.
It appears one type of sensory information conveyed by the **afferent fibers** in the **hypogastric nerve** is an excitatory input induced by chemical irritation of the bladder mucosa as demonstrated in the experiments of Mitsui *et al.* This sensory information is mediated by a **spinobulbospinal pathway** through a relay center in the **rostral brainstem**, which cause an increase in micturition frequency. The cell bodies of these neurons are located in the **dorsal rami of T10-L2**.

The sensory information conveyed by the **afferent fibers** in the **pudendal nerve** originate in the urethra, as well as the **rectum, clitoris or penis,** and **perineal skin**. The cell bodies of these neurons are located in the **dorsal rami of S2-S4**. *Remember, the pudendal nerve also supplies motor innervation to the muscles of urogenital diaphragm and muscles of the penis and clitoris*.

In summary, the smooth muscle of the bladder, the **detrusor muscle**, is innervated by **sympathetic fibers** from the **lumbar spinal cord** and **parasympathetic fibers** from the **sacral spinal cord**. Fibers in the **pelvic nerves** constitute the main **afferent limb** of the voiding reflex; the **parasympathetic fibers** to the bladder constitute the excitatory **efferent limb** also travel in these nerves. Part of the urethra is surrounded by the **external urethral sphincter**, which is innervated by the **somatic portion of the pudendal nerve** originating in the spinal cord, in an area called **Onuf's nucleus.**

Onuf's nucleus consist of a small group of neurons located in the **sacral anterior horns** between **S1-S2** or **S2**-**S3**. Typically, Onuf's nucleus is located primarily in **S2**, however, it can extend to the caudal end of the **first sacral segment** or to the **middle part of the third sacral segment**. The neurons in Onuf's nucleus are motor neurons, which innervate the striated muscles of the **external sphincter muscles,** the **muscles of the pelvic floor**, including the **anal sphincter,** the **bulbocavernosus** and **ischiocavernosus msucles**, the **penis** and **clitoris,** the **scrotum** and **perineum** and thus is also involved in defecation, ejaculation and other sexual functions.

Smooth muscle bundles extend downward on either side of the proximal urethra serving as the **internal urethral sphincter**. The distal urethra is encircled by skeletal muscle, the **external urethral sphincter.**

Micturition is fundamentally a **spinobulbospinal reflex** facilitated by higher brain centers, such as the **pontine micturition center** and, like defecation, is controlled by voluntary facilitation and inhibition.

There are two distinct phases involved in micturition: the **storage phase**, when urine is stored in the bladder; and the **voiding phase**, when urine is released through the urethra. As discussed above, the muscles controlling micturition are controlled by the **autonomic** and **somatic nervous systems**. During the storage phase the **internal urethral sphincter** remains tense and the **detrusor muscle** is relaxed by **sympathetic** stimulation (Fig. 74, a). During voiding phase **parasympathetic** stimulation causes the detrusor muscle to contract. Simultaneously, nerve impulses passing down the sympathetic fibers and the pudendal motor fibers cease momentarily, allowing relaxation of the normally tonically contracted bladder neck and prostatic urethra induced by the sympathetic nerves, along with conscious relaxation of the external urethral sphincter via the pudendal nerve, thus allowing urine to flow (Fig. 74, b)

The function of these two distinct phases is dependent on both conscious signals from the brain and the firing rate of sensory fibers from the bladder and urethra. During the **storage phase,** the bladder wall stretch is low, thus the action potentials carried by the sensory neurons from the stretch receptors fire at a low frequency. Low-frequency afferent signals cause relaxation of the bladder by inhibiting **sacral preganglionic parasympathetic neurons** and exciting **lumbar sympathetic neurons.** Simultaneously, these afferent impulses will cause contraction of the bladder neck and urethra through excitation of the **preganglionic sympathetic neurons,** as well as contraction of the external urethral sphincter through excitation of **Onuf's nucleus.**

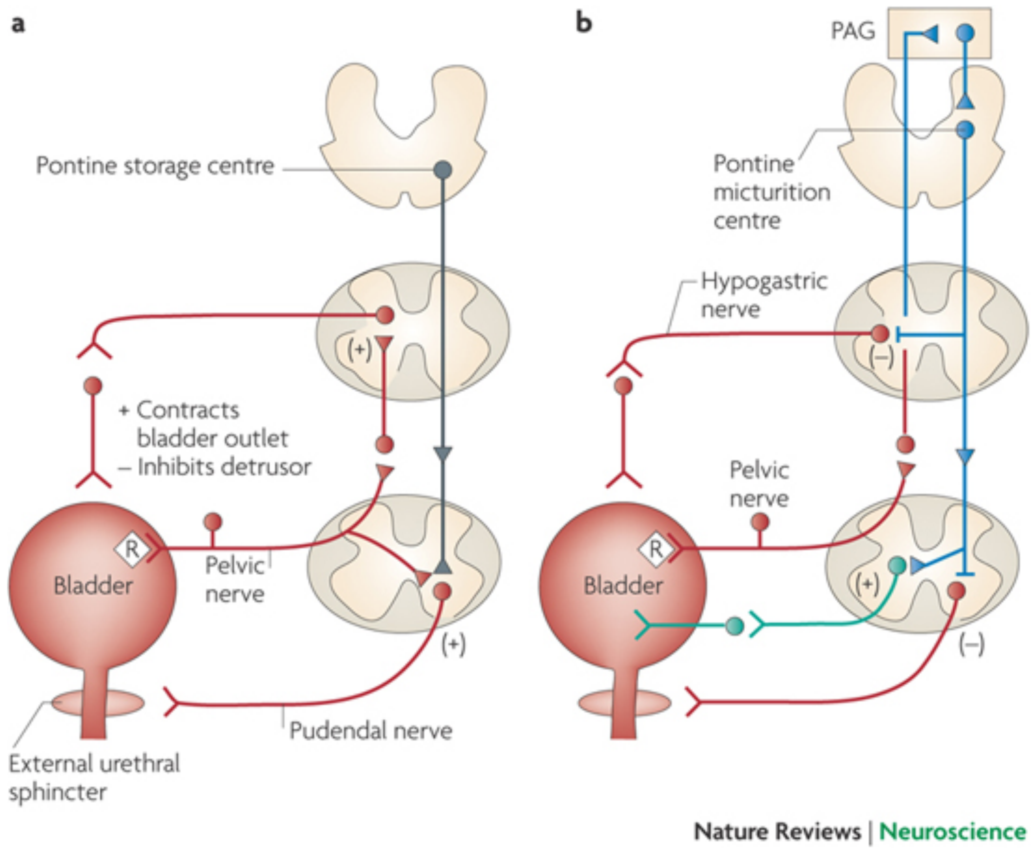


Fig. 74. The above illustration has two parts: **a.** represents the **urine storage reflexes** and **b.** the **voiding reflexes.**
During the storage of urine, distention of the bladder produces low-level vesical afferent firing. This in turn stimulates the sympathetic outflow in the hypogastric nerve to the bladder outlet (the bladder base and the urethra) and the pudendal outflow to the external urethral sphincter. These responses occur by spinal reflex pathways and represent guarding reflexes, which promote continence. Sympathetic firing also inhibits contraction of the detrusor muscle and modulates neurotransmission in the bladder ganglia. A region in the rostral pons (the pontine storage center) probably increases striated urethral sphincter activity.
During the voiding phase, there is intense bladder-afferent firing in the pelvic nerve, which activates the spinobulbospinal reflex pathways (shown in blue) that passes through the pontine micturition center. This stimulates the parasympathetic outflow to the bladder and to the urethral smooth muscle (shown in green) and inhibits the sympathetic and pudendal outflow to the urethral outlet (shown in red). Ascending afferent input from the spinal cord might pass through relay neurons in the periaqueductal grey (PAG) before reaching the pontine micturition center. *These diagrams do not address the generation of conscious bladder sensations, (Fig. 75) nor mechanisms that underlie the switch from storage to voiding, both of which presumably*

involve cerebral circuits above PAG. R in the above diagrams represents receptors on afferent nerve terminals. (nature.com) (Wiki)

As the volume in the bladder increases the rate of afferent firing of action potentials also increases, causing a conscious sensation of the need to urinate. These afferent signals ascend in the spinal cord to the **periaqueductal gray matter**, where they project both to the **pontine micturition center** and to the **cerebrum**. The periaqueductal gray matter and the pontine micturition center upon receiving this afferent information, integrate it with the descending input from higher brain centers, such as the **prefrontal cortex**, the **insular cortex** and the **anterior cingulate gyrus** to determine storage and voiding activity. At a certain level of afferent activity, the conscious urge to void becomes difficult to ignore. . Once the voluntary signal to begin voiding has been issued by the higher brain centers, neurons in the pontine micturition center fire maximally, causing excitation of the sacral preganglionic neurons. The firing of these neurons causes the wall of the bladder to contract; as a result, a sudden, sharp rise in intravesical pressure occurs. Simultaneously, the pontine micturition center causes inhibition of Onuf's nucleus, resulting in relaxation of the external urinary sphincter. When the external urinary sphincter is relaxed urine is released from the urinary bladder when the pressure there is great enough to force urine to flow out of the urethra. The flow of urine through the urethra has an overall excitatory role in micturition, which helps sustain voiding until the bladder is empty (Fig. 75).

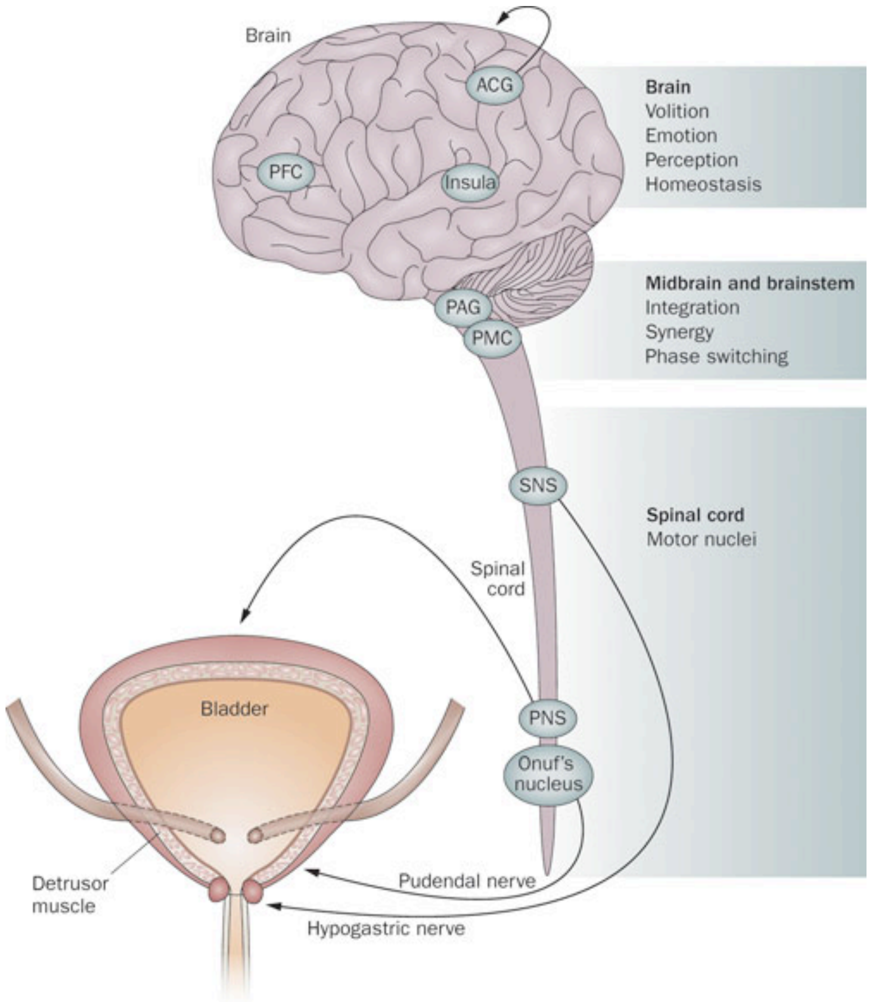


Fig. 75. This diagram depicts the autonomic control of the bladder and its outlet mediated by nerve centers at several points in the central nervous system (CNS). The spinal cord contains the autonomic motor nuclei for the peripheral nervous system (PNS) supplying the detrusor, for the sympathetic nervous system (SNS) supplying the bladder neck, genital sphincter, and for Onuf's nucleus supplying the EUSphincter and urethra. The brainstem and midbrain contain the pontine micturition center (PMC) and periaqueductal (PAG), respectively; these receive afferent information and integrate it with descending input to determine storage and voiding activity, synergic behavior of the lower urinary tract, and integration with other vegetative systems. Higher brain centers are crucial regarding volitional control, conscious perception, emotional responses and vegetative integration. The key higher centers include the prefrontal cortex (PFC), the insular cortex (insula) and the anterior cingulate gyrus (ACG). (nature.com)

It is believed in infants, voiding is an involuntary reflex with voluntary control being attained by 2 to 3 years-of-age. Thus, bed wetting is considered normal up to 3-years-of-age. Bed wetting occurs because of incomplete myelination of motor fibers of the bladder resulting in loss of voluntary control of micturition.

4. **Urethra:** The **urethra** is located at the inferior aspect of the bladder (Figs. 57, 66, 67 and 68). It passes through the prostate in the male, while in the female the shorter urethra leaves the pelvic cavity immediately through a hiatus in the pelvic diaphragm.

   At the junction of the urethra and bladder is a smooth muscle sphincter, **the internal sphincter muscle of the urethra**. Since it is composed of smooth muscle it is under **involuntary control**. It is tonically contracted by the **sacral plexus** through the **hypogastric plexus of the sympathetic nervous system**. During micturition it is relaxed through branches from the **pelvic plexus (S2-S4) parasympathetic system**. This is the primary muscle for maintenance of continence of urine.

   (a). Male urethra: This is approximately 18-20 cm in length, with a diameter between 5-6 mm, extending from the internal orifice in the urinary bladder to the external opening (meatus), at the end of the penis. It is composed of two parts, the **anterior** and **posterior urethra**. The **anterior urethra** is approximately 16 cm long, with its proximal portion lying within the **perineum** and the distal portion located within the **penis**, surrounded by the **corpus spongiosum**. The **posterior urethra** is 4 cm long and lies in the pelvis. Both the posterior and anterior urethra are further subdivided.

   The posterior urethra is divided into the **periprostatic, prostatic** and **membranous portions**.

   The **periprostatic urethra** is approximately 1 cm long and extends from the bladder base to the prostate (Fig. 76).

   The **prostatic urethra** is from 3-4 cm in length, passing through the prostate gland, closer to the anterior than the posterior surface. Throughout its length it has a narrow longitudinal midline ridge on its posterior wall, the **urethral crest**. To each side of the crest is a groove, the **prostatic sinuses**, into which open 15-20 **prostatic ducts** (Fig. 76). At approximately the midpoint of the crest is a rounded eminence, the **seminal colliculus (verumontanum)**. It is at this point the urethrae turns 35 ^{0} anteriorly. Also, within the median plane of the colliculus is a small slit that leads into a ‘blind’ pouch, the **prostatic utricle**. This structure is formed from the fused ends of the **paramesonephric ducts** and is the male homologue of the **uterus**, from which it gets its name ‘**utricle**‘ and the **vagina**. On each side of the slit-like opening are two openings for the **ejaculatory ducts** (Fig. 76).

The **membranous portion** of the urethra traverses the **urogenital diaphragm** and is the shortest part of the male urethra, measuring 2-2.5 cm. It is also the narrowest section of the urethra with exception of the slit-like **external urethral orifice.** It pierces the urogenital diaphragm about 2.5 cm behind the **pubic symphysis**. Within the diaphragm it is surrounded by fibers of the external urethral sphincter muscle. The **bulbo-urethral glands** lie behind and to either side of this portion of the urethra (Fig. 76).

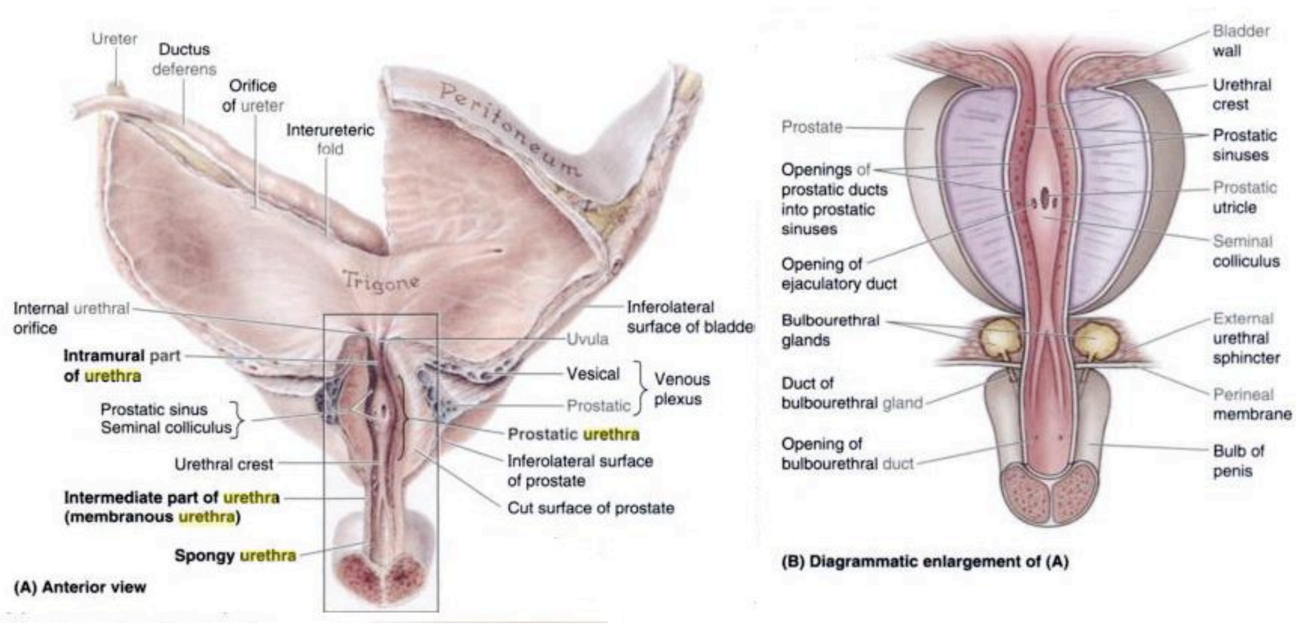


Fig. 76. These images depict the various anatomic components and their relationships of the male urethra. (anatomytopics.wordpress.com)

The structure of the of the **external urethral sphincter muscle** is still controversal. There are two main ideas regarding its structure: it is a part of the **urogenital diaphragm**, or it extends from the base of the bladder up to the urogenital diaphragm and is an integral part of the urethra. Some anatomist question whether it possesses somatic innervation (*remember, the somatic nervous system consists of efferent nerves responsible for stimulating muscular contraction and thus is concerned with voluntary control*) or mixed innervation (i.e. autonomic and somatic).

At the level of the bladder neck, smooth muscle fibers are of oblique and longitudinal orientation, with longitudinal fibers running parallel to the longitudinal smooth fibers of the prostatic urethra. There are also some striated muscle fibers, which run obliquely up to the detrusor muscles.

At the level of the **prostatic** and **membranous urethra**, the **prostatic capsule** is noted to surround the prostate and is inseparable from the fibromuscular stroma of the prostate. It contains both smooth and striated muscular fibers, as well as vascular elements and nerve fibers. The striated muscle fibers are present in the anterior and the lateral faces of the prostatic capsule. The majority of these fibers are concentrated at the level of the apex of the prostate.

At the level of the external urethral sphincter, the striated muscle cannot be separated from the internal smooth muscle layer of the prostatic and membranous urethra. Beneath the striated muscles of the external sphincter, smooth muscle arranged in a circular formation is evident. The striated muscle fibers are also arranged in a circular pattern in the membranous urethra, and were intermingled with smooth muscle fibers in the posterior and lateral aspects of the sphincter.

The **anterior urethra** is divided into the **bulbar urethra (spongy portion)**, which is surrounded by the **bulbospongiosus** and is entirely within the **perineum**, measuring about 1 cm in length, and the **penile** component, which continues to the tip of the penis, and measures about 15 cm. The luminal diameter of the penial component of the urethra is approximately 5 mm. The **bulbourethral glands** open into the **bulbar urethra**.

The **external urethral opening (meatus)**, which is the vertical slit at the end of the **glans penis**, is both the narrowest part of the urethra and its least distensible portion. An instrument passing through this opening should pass through any of the other parts of the urethra. The external opening is bounded by a small labium. The membranous portion of the urethra is the next narrowest portion. However, this narrowing is due to the contraction of the external urethral sphincter muscle thus the membranous urethra is distensible.
The **arterial supply** of the male urethra is from the **urethral artery,** which takes origin from the **internal pudendal artery** or the **common penile artery**. Along with the urethral artery, the urethra is supplied by the **dorsal penile artery**, which is also a branch of the **internal pudendal artery**.
The **venous drainage** of the **anterior urethra** is to the **dorsal veins of the penis** and the **internal pudendal vein**, which drain to the **prostatic plexus**. The **posterior urethra** drains to the **prostatic** and **vesicle venous plexus**, which drain to the **internal iliac veins**.
The **lymphatic drainage** of the **posterior urethra** is primarily to the **internal iliac nodes**, with a few draining to the **external iliac nodes**. Lymphatic vessels from the **membranous urethra** drain to the **internal iliac nodes**, although a few may drain to the **external iliac nodes**. Vessels from the **anterior urethra** drain to the **deep inguinal nodes**. Some of the lymphatic vessels drain to the **presymphyseal lymph nodes**, whereas others drain to the **external iliac nodes**.
Innervation of the smooth muscle of the **urethra** is through the **prostatic plexus**, which lies within the **pelvic fascia**. *Remember, the prostatic plexus is a continuation of the lower part of the pelvic plexus (inferior hypogastric plexus).* The pelvic plexus lies on each side of the **rectum** in the male, and on the sides of the **rectum** and **vagina** in the female. The nerve contributions to the pelvic plexus are the **hypogastric nerve;** the **lumbar splanchnic nerves**, which emerge from the **sympathetic trunk;** and the **pelvic splanchnic nerves**, which arise from the **second, third** and **fourth sacral spinal segments** and contribute **parasympathetic efferent fibers** to the plexus.

The **sympathetic preganglionic neurons**, which are located in the **sympthetic nucleus in the intermediolateral column of gray matter**, which are located in the **T10-L2 spinal segments**, although some experts list these neurons in **T11-L2**, access the bladder through the **parasympathetic juxtamural ganglia**. Most **parasympathetic ganglia**, at least outside the head, are categorized as **juxtamural (near to the wall of a cavity)** or **intramural (within the wall of a cavity)**. The sympathetic fibers have an inhibitory effect on the smooth muscle at the base of the bladder and the urethra thus, they allow filling of the bladder during the storage phase. *Remember, the sympathetic fibers also cause contraction of the **preprostatic sphincter** during ejaculation, thus preventing reflux into the bladder.*

The parasympathetic preganglionic neurons, which supply the bladder and urethra are located in the **parasympathetic nucleus in the intermediolateral column of gray matter of S2-S4.** Stimulation of the parasympathetic fibers cause the detrusor muscle to contract and the urethra to relax.

The striated muscle of the **external urethral sphincter** is innervated by **somatic nerves**, the neuronal cell bodies of which are located in Onuf's nucleus, which was previously discussed under the innervation of the bladder, pages 87-91. The nerve fibers of this nucleus innervate the skeletal muscle of the external urethral and anal sphincters, the muscles of the pelvic floor including the bulbocavernous and ischiocavernous muscles and the penis through branches of the **pudendal nerve**. Thus, the nerve fibers of Onuf's nucleus are involved in micturition, defecation, ejaculation and other sexual functions.

Urinary continence, which occurs at the level of the membranous urethra is mediated by the radial folds of the urethral mucosa, the submucosal connective tissue, the intrinsic urethral smooth muscle, the striated external urethral and the pubourethral component of the levator ani. The external urethral sphincter represents the point of highest intraurethral pressure in the normal contracted state.

For **micturition** to occur not only is activation of the of the **parasympathetic**

system necessary, but there must be simultaneous activation of the **symphthetic system**. The parasympathetic system causes the urethra and bladder neck to relax due to the release of **nitric oxide** from the parasympathetic nerves in the bladder neck and urethra. In addition, sympathetic innervation of the internal sphincter and the smooth muscle of the external urethral sphincter must be inhibited, as well as the motor neurons of Onuf's nucleus. The motor neurons of Onuf's nucleus are inhibited through stimulation of the **inhibitory interneurons** located in the **commissural nucleus** that terminate on Onuf's neurons. These inhibitory interneurons are activated by **efferent fibers** from the **hypothalmus, lateral pontine reticular formation** and the **neucleus retroambiguous**. The activation of these brainstem nuclei is through an ascending pathway that is activated by the **sensory nerves (stretch receptors)** in the detrusor muscle, as well as sensory nerves in the wall of the urethra. These sensory nerves send impulses through the **pelvic** and **pudendal nerves** to neurons in the **sacral periacqueductal gray matter**. These neurons in turn send impulses through an ascending pathway to the **pontine micturition center**. This results in not only activation of the neurons in the pontine micturition center, but also neurons in the **preoptic area** and the **inferior frontal cortex**. In humans, activation of the pontine micturition center appears to be lateralized to the right side.

(b). Female urethra: The **female urethra** is approximately 4 cm long, and corresponds to the prostatic and membranous portions of the male urethra (Fig.77). Its lumen is between 5-6 mm in diameter. It begins at the **internal urethral meatus** (Fig. 68, p 79), approximately opposite the middle of the **symphysis pubis** and runs anteroinferiorly behind the symphysis pubis, embedded in the **vaginal wall of the vagina**. Its upper part is separated from the vagina by loose areolar tissue, but its lower portion is embedded in it. It crosses the **perineal membrane** and is surrounded by the voluntary external urethral sphincter. Some of these muscle fibers enclose the urethra and vagina together. The **external urethral meatus** is located 2.4 cm behind the

glands clitoris. Except during micturition, the anterior and posterior walls of the urethra are in apposition. In addition, the urethral epithelial surface is thrown into longitudinal folds, as in the male, one of which, on the posterior wall is especially prominent and is referred to as the **urethral crest** (Fig. 76, A). As in the male urethra, the female urethra contains many **urethral glands** and minute pit-like recesses called **urethral lacunae**, which open up into the urethra (Fig. 76, B & Fig. 78). In addition, the female urethra contains a special group of glands, **Skene' glands**, which are located near the lower end of the urethra. These glands open into the **para-urethral duct**, which drain into a small aperture located in a vestibule at the sides of the **external urethral orifice** (Fig. 79). These glands are the female counterpart to the male's prostate and are referred to as the 'female prostate.' Like the male prostate it secretes PSA, with levels of this antigen increasing in the presence of carcinoma of these glands. During orgasm, these glands expel fluid like the prostate.

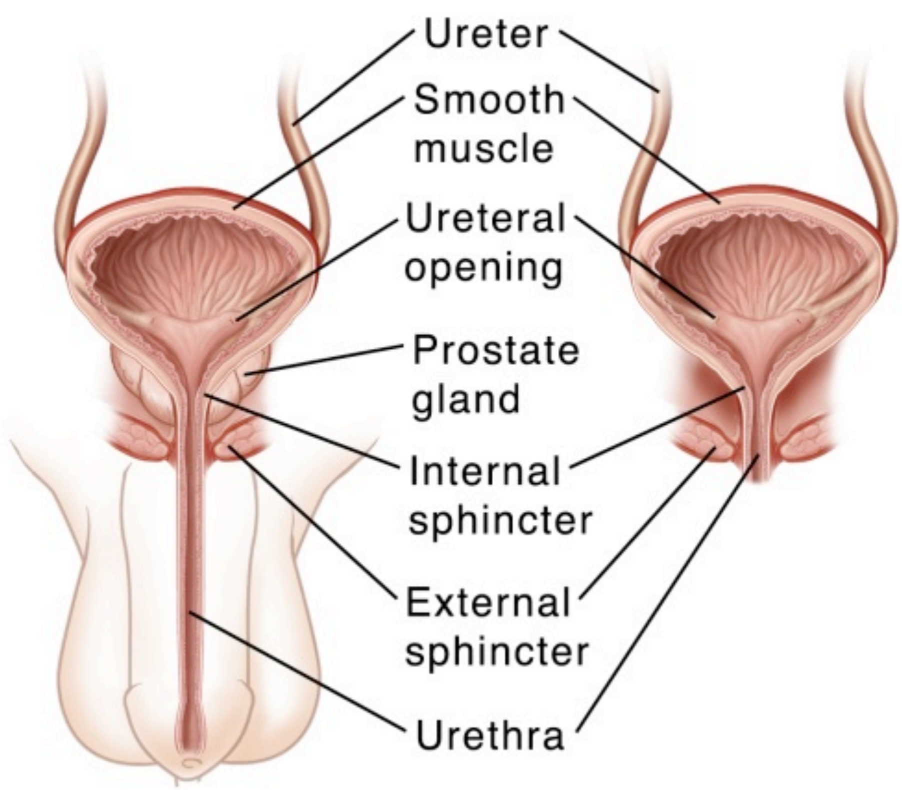


Fig. 77. The above image shows the bladder and urethra of the male (left) and female (right). (www.yalemedicalgroup.org)

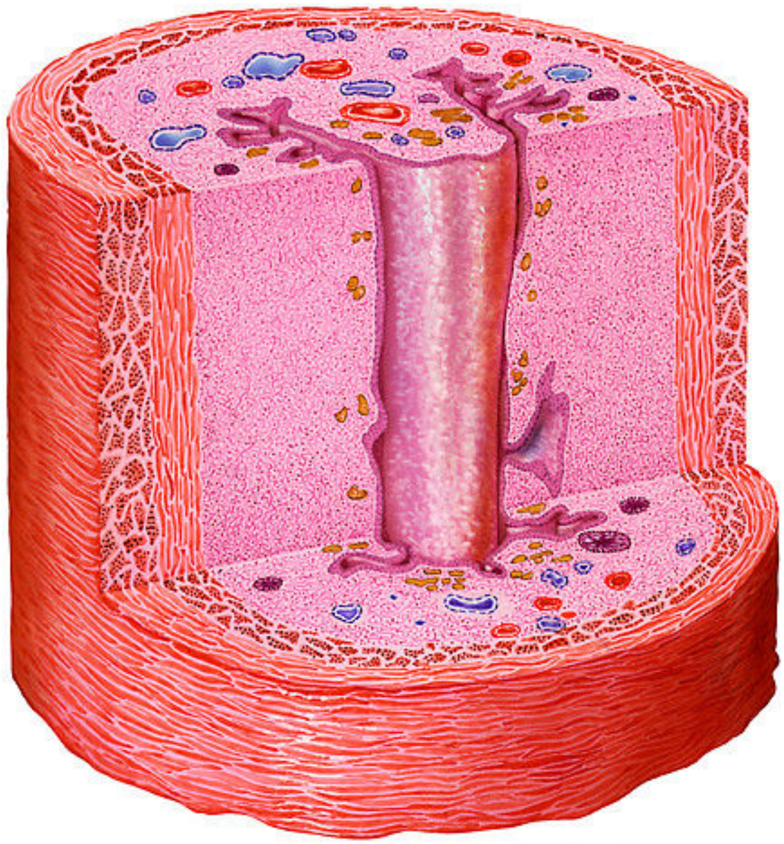


Fig. 78. This drawing depicts a section through the female urethra. At the center is the lumen, through which the urine travels. It is surrounded by a thin layer of epithelial tissue. The next layer, the largest layer seen, is a spongy erectile tissue (pink) consisting of connective tissue, muscles, blood vessels (red-arteries and blue-veins) and mucus-secreting glands (yellow), which open into the pit-like recesses, the urethral lacunae. Mucus protects the epithelium from the corrosive urine. Urine pH can vary between 4.6 and 8, with neutral (7) being the norm. Lastly, there are 2 layers of muscles, longitudinal (inner) and circular (outer) which contract to aid in the expelling of urine. (www.sciencephoto.com)

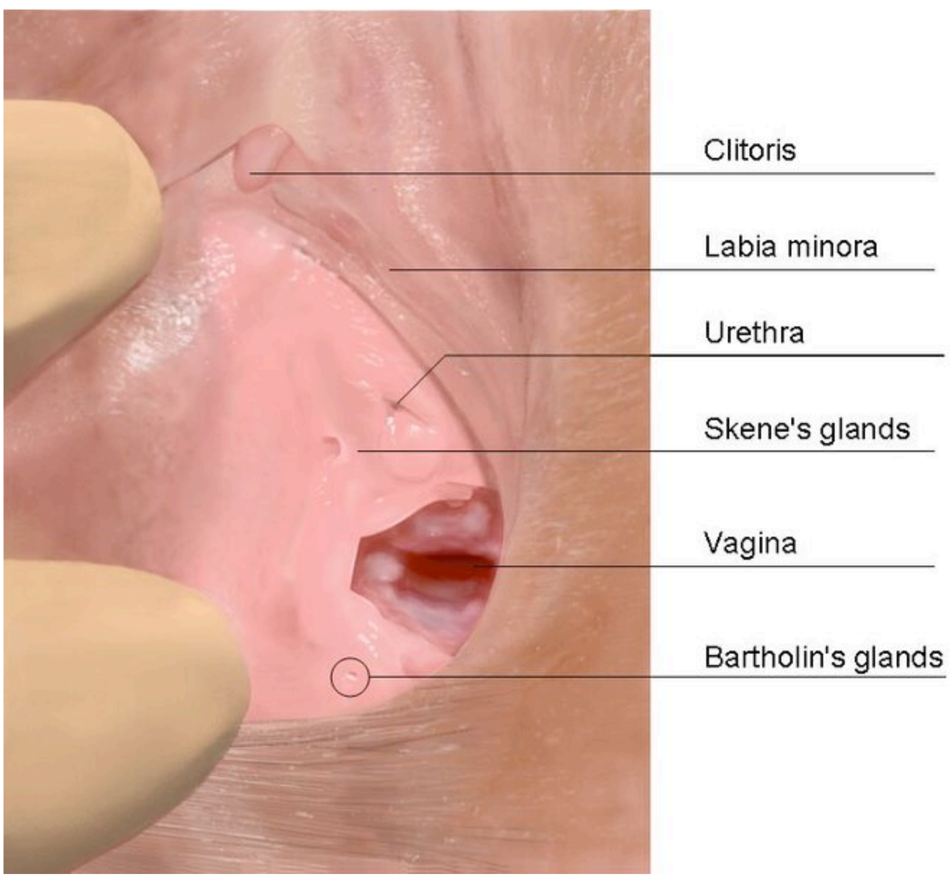


Fig. 79. This image depicts the location of Skene's glands. (Wiki)

The **arterial supply** is primarily by the **vaginal artery**. In addition it also receives blood from the **inferior vesicle artery**.

The **veins** of the urethra drain into the **vesicle venous plexus** around the bladder neck, and into **internal pudendal veins**.

The urethral **lymphatics** drain to the **internal** and **external iliac nodes**.

Innervation of the female urethra parallels that of the male urethra. The **parasympathetic preganglionic fibers** arise from the neurons in the **S2-S4 spinal segments**. These fibers pass by way of the **pelvic splanchnic nerves** to the **vesicle plexus** where they form synapses with **postganglionic neurons**, the fibers of which end in the smooth muscle of the urethra as in the case of the male (Fig. 80).

As in the male, the **preganglionic sympathetic fibers** arise from the neurons in the **sympathetic nucleus of the intermediolateral gray column in T(10) 11-L2 spinal segments**. However, the preganglionic fibers extend to a plexus which is located around the vaginal arteries where they form synapses with the neurons of the **postganglionic sympathetic fibers** (Fig. 80).

Somatic fibers which innervate striated muscle originate from **S2-S4 spinal segments**. These somatic fibers travel with the **pelvic splanchnic nerves**, but do not synapse in the **vesicle plexus** (Fig. 80)

Sensory fibers from receptors in the urethra reach the **spinal segments of S2-S4** through the pelvic splanchnic nerves.

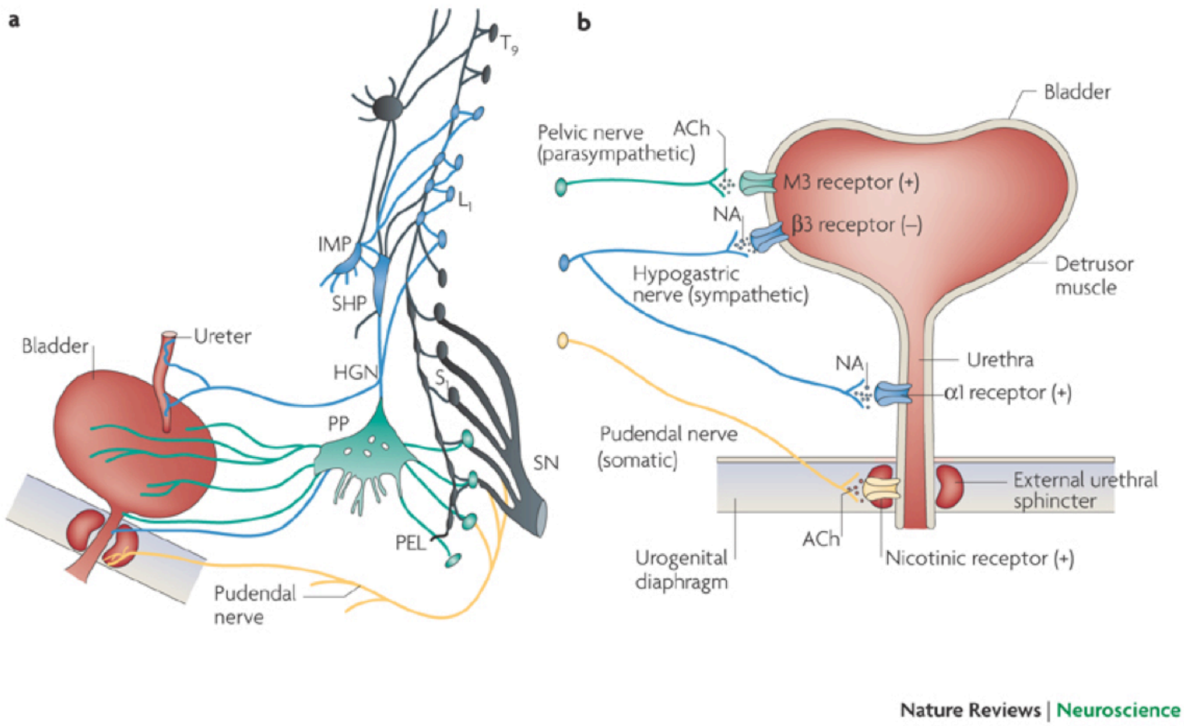


Fig. 80. This is a depiction of the innervation of the female lower urinary tract. In **a**, sympathetic fibers (shown in blue) originate in T (10) 11-L2 spinal segments and run through the inferior mesenteric ganglia (inferior mesenteric plexus, IMP) and the hypogastric nerve (HGN) or through the paravertebral chain to enter the pelvic nerves at the base of the bladder and the urethra. Parasympathetic preganglionic fibers (shown in green) arise from S2-S4 spinal segments and travel in sacral roots and pelvic nerves (PEL) to ganglia in the pelvic plexus (PP) and in the bladder wall. This is where the postganglionic nerves that supply parasympathetic innervation to the bladder arise. Somatic motor nerves (shown in yellow) that supply striated muscles of the external urethral sphincter arise from S2-S4 motor neurons and pass through the pudendal nerves.

b, depicts the efferent pathways and neurotransmitter mechanisms that regulate the lower urinary tract. Parasympathetic postganglionic axons in the pelvic nerve release acetylcholine (ACh), which produces a bladder contraction by stimulating M3 muscarinic receptors in the bladder smooth muscle. Sympathetic postganglionic neurons release noradrenaline (NA), which activates β3 adrenergic receptors to relax bladder smooth muscle and activates α1 adrenergic receptors to contract urethral smooth muscle. Somatic axons in the pudendal nerve also release ACH, which produces a contraction of the external sphincter striated muscle by activating nicotinic cholinergic receptors. Parasympathetic postganglionic nerves also release ATP, which excites bladder smooth muscle, and nitric oxide, which relaxes urethral smooth muscle (not shown). L1, first lumbar root; S1, first sacral root; SHP, superior hypogastric plexus; SN, sciatic nerve; T9, ninth thoracic root. (neurores.wikidot.com)

Urinary continence in the female is through the urethral sphincter mechanism which consist of the intrinsic striated and smooth muscle of the urethra, the mucosa and submucosal connective tissue, and the puborectalis component of the levator ani, which surrounds the urethra at the point of maximum concentration of these muscles. In the female, the striated muscle component of the external sphincter mechanism surrounds the middle and lower thirds of the urethra in the female. It blends above with the smooth muscle of the bladder neck and below with the smooth muscle of the lower urethra and vagina. Contraction of this part of the sphincter compresses the urethra against the relatively fixed anterior vaginal wall. Remember the urethral mucosa and submucosa are estrogen dependent, hence, their atrophy in the postmenopausal woman may contribute to urinary incontinence (Fig. 78).

B. **Internal Reproductive Organs:** Both the male and female genital organs consist of an **external** and **internal set**. In the male, the external set includes the **penis testes, epididymis,** and the **scrotum**. In the female, the external genital structures are the **labia majora, mons pubis, labia minora, clitoris** and the **vestibule of the vagina**. The external genital organs of both the male and female will be discussed under the **perineum**.

The male **internal genital organs** consist of the **vas deferens** and the **ejaculatory ducts**. The **prostate gland, seminal vesicles** and **bulbourethral glands** are considered **accessory glands** (Fig. 81)

The female **internal genital organs** consist of the **vagina, uterus, fallopian tubes** and **ovaries** (Fig. 82).

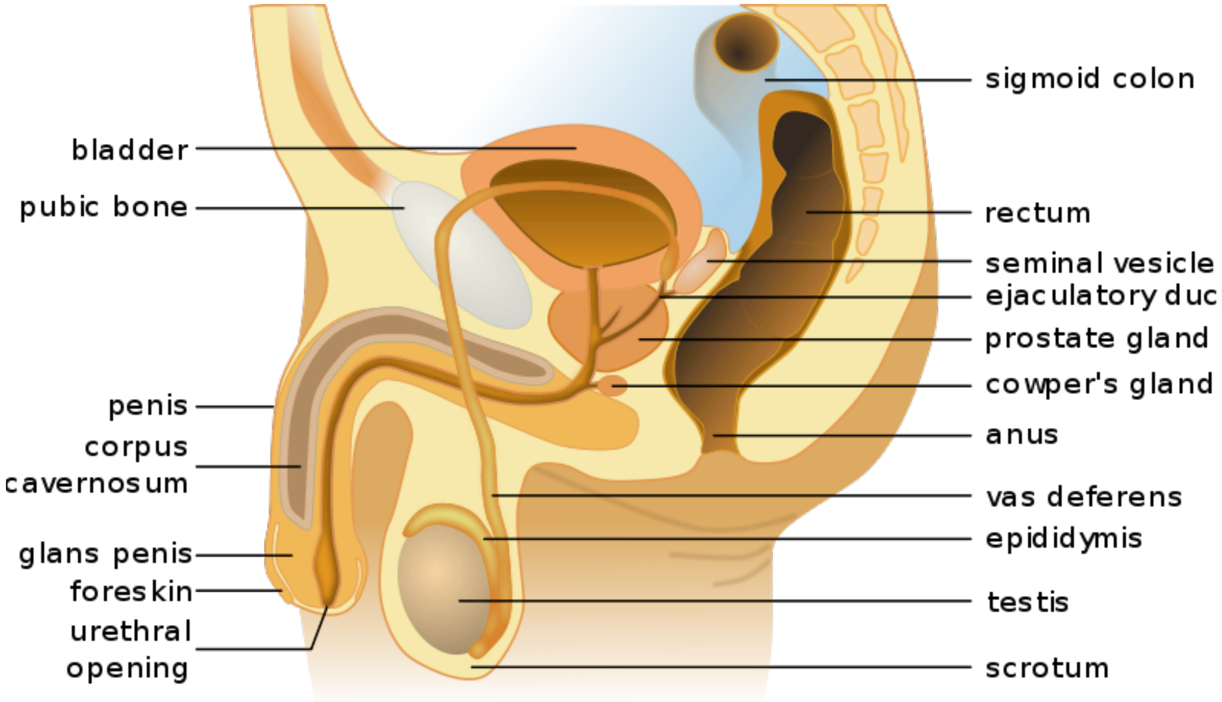


Fig. 81. Drawing of male external and internal sexual anatomy. (uk.ask.com)

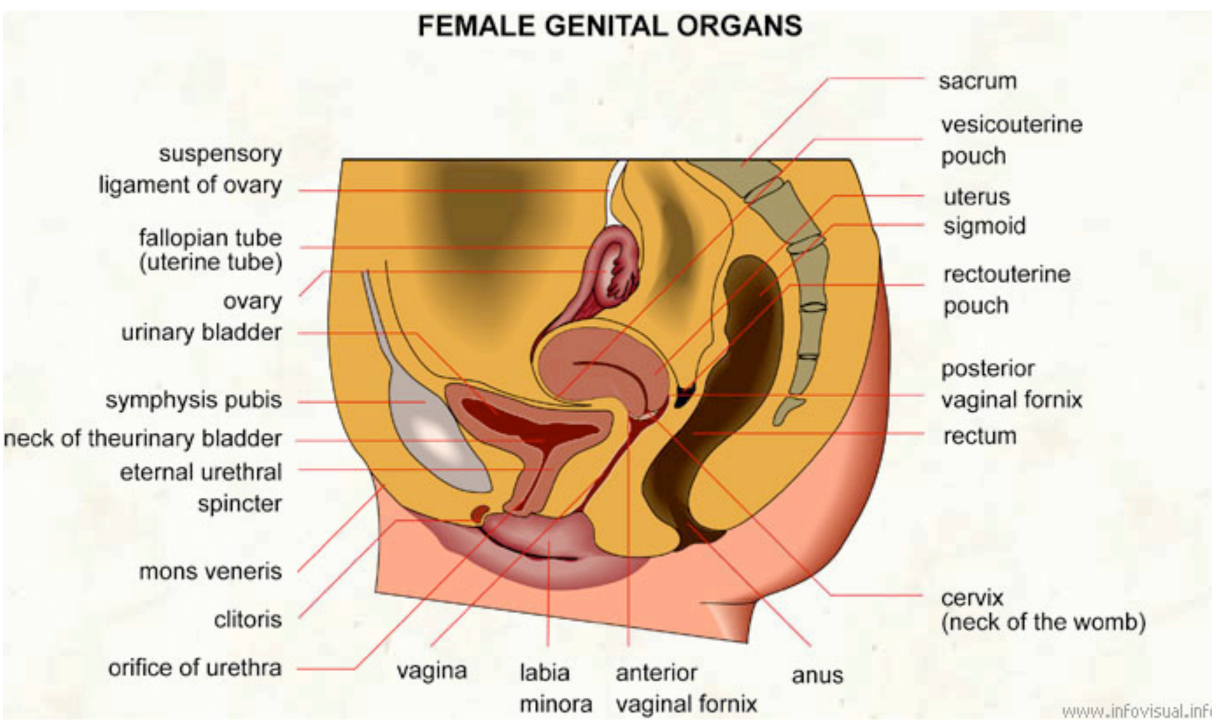


Fig. 82. Drawing of female external and internal sexual anatomy. (www.infovisual.info)

1. Male Internal Reproductive Organs

(a.) Ductus Deferens (vas deferens): This is a fibromuscular tube, which is the distal continuation of the **epididymis** beginning at the tail of the epididymis. It serves as the excretory duct of the **testes** to transport sperm cells from the ep-epididymis to the ipsilateral **ejaculatory duct**, which is formed by the joining of **ductus deferens** and the duct of the **seminal vesicle**. The ductus deferens measures about 45 cm in length (Figs. 81 & 83).

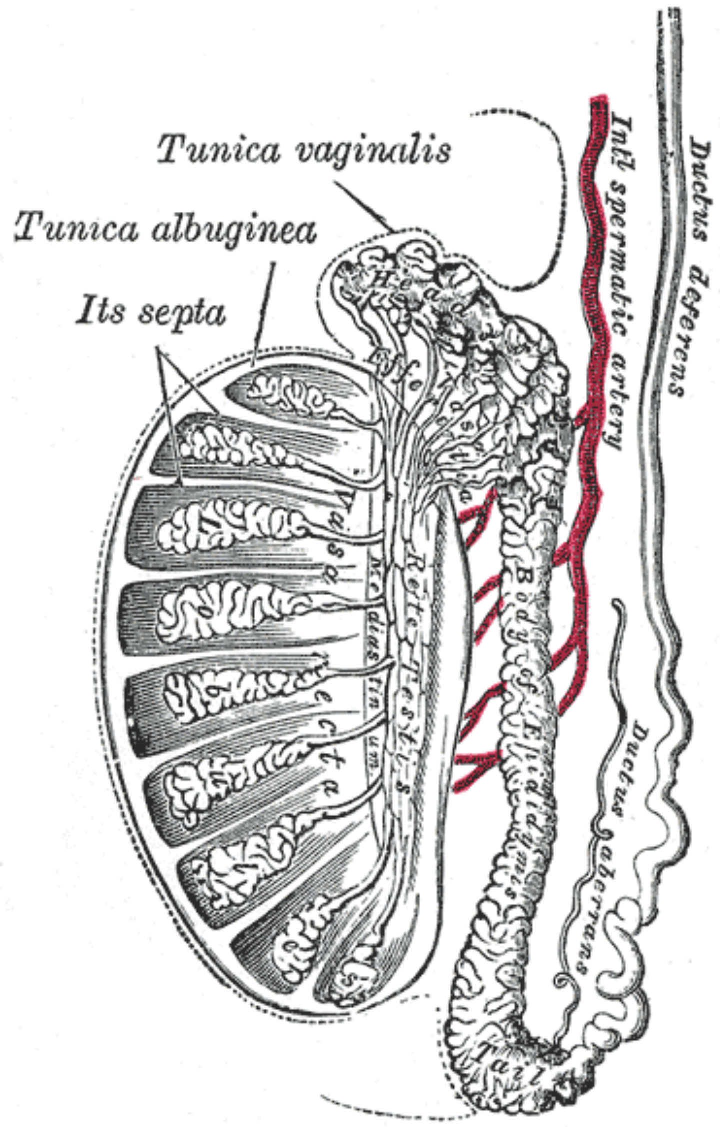


Fig. 83. This drawing is of a vertical section of the testis, to show the arrangement of the ducts. (Wiki)

The ductus deferens runs upward from the epididymis in the **spermatic cord**. passing through the **inguinal canal.** At the deep **inguinal ring** it leaves the spermatic cord, curves around the lateral side of the **inferior epigastric artery** and ascends for approximately 2.5 cm, then crosses over the **external iliac vessels** to enter the **true pelvis (pelvis minor)**. In the pelvis it lies external to the **pelvic cavity**, but adheres to the **parietal peritoneum**. It passes along the lateral wall of the true pelvis, crosses the **ureter** near the posterolateral angle of the **bladder**, continues medial to the distal ureter. After crossing the ureter, it bends at an acute angle so that it passes anteriomedially between the posterior surface of the bladder and the upper pole of the **seminal vesicle**. It then descends medial to the seminal vesicle and ureter. As it descends it enlarges to form the ampulla of the ductus deferens as it passes posterior to the bladder (Fig. 84).

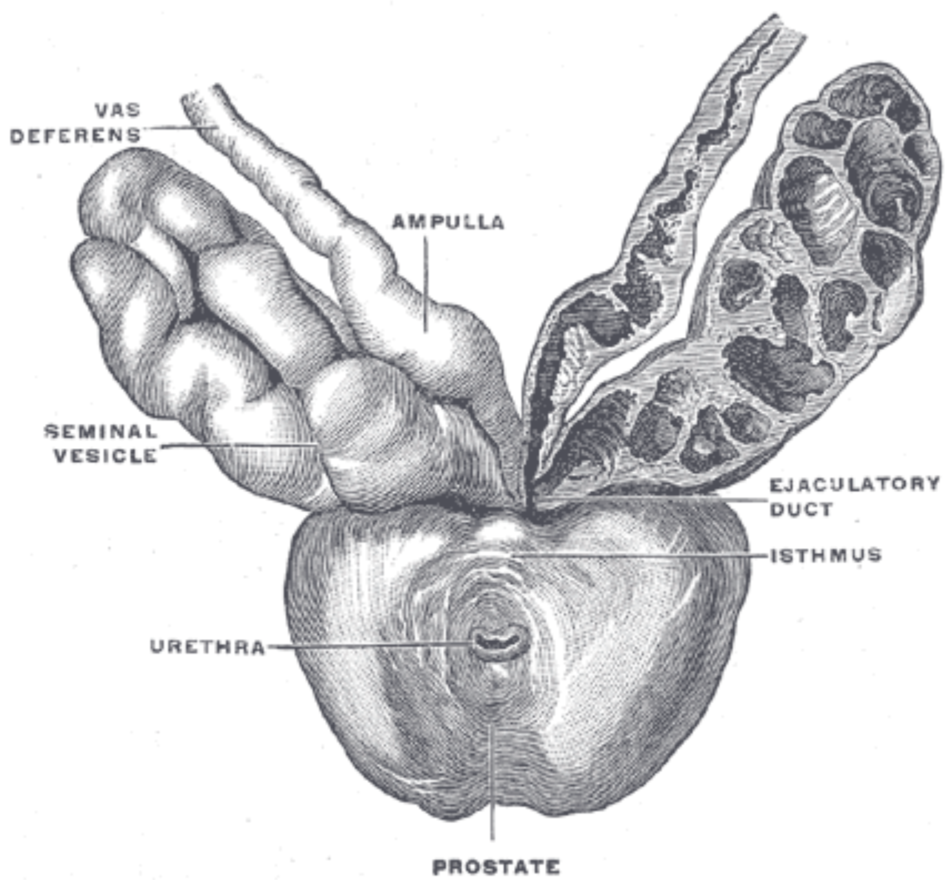


Fig. 84. The above is a drawing depicting the prostate with seminal vesicles and the duct of the vas deferens with its terminal enlargement into the ampulla, viewed from in front and above. (Wiki)

Immediately before joining the duct of the seminal vesicle to form the ejaculatory duct, the diameter of the ductus deferens greatly decreases in size.

The **arterial supply** of the ductus is typically from the **superior vesicle artery,** although on occasion it can be supplied by the **inferior vesicle artery**. The superior vesicle artery ends by forming an anastomoses with the **testicular artery** to supply the epididymis and testis.

The **veins** drain from the vas deferens and seminal vesicles to the **pelvic venous plexus**.

The **lymphatic vessels** drain to the **external** and **internal iliac nodes**.

The **innervation** of the vas deferens is derived from the **inferior hypogastric (pelvic) plexus**. It is richly innervated by the **autonomic nervous system**, which is composed mainly of **sympathetic fibers**, which facilitate rapid contraction for the expulsion of sperm during ejaculation.

(b). Ejaculatory Ducts: The **ejaculatory ducts** are formed just below the base of **prostate** by the union of the ducts of the **seminal vesicles** and the **ampulla of the vas deferens**. Each duct is approximately 2 cm long, with each lying almost completely within the prostate, running along the middle and lateral lobes, each duct opens by slit-like apertures into the **prostatic urethra** on the **colliculus seminalis (verumontanum)** at either side of the opening of the **prostatic utricle** (Figs. 76, 85 & 87). The ejaculatory ducts are divided into three distinct sections: **proximal, middle** and **distal**.

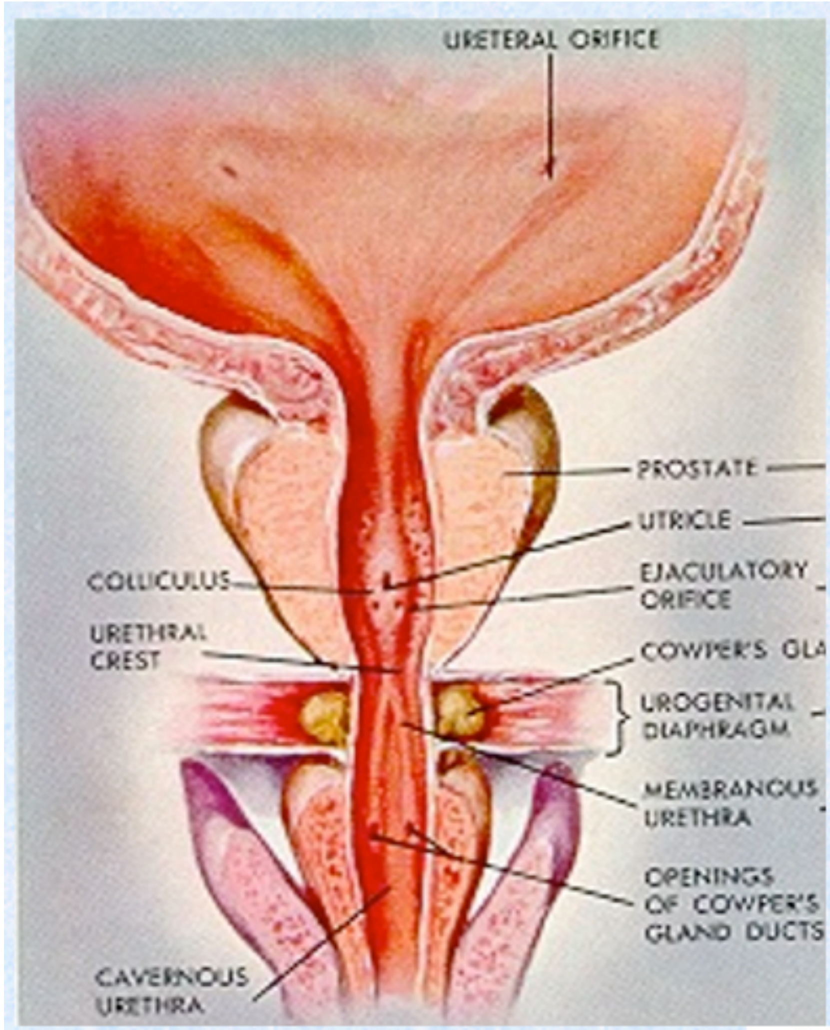


Fig. 85. This is a drawing of the male lower urinary tract, which shows the openings of the ejaculatory ducts into the colliculus seminalis (verumontanum). (marcinfertility.org)

The **proximal ejaculatory duct**, though a distinct anatomical structure, formed in the posterior-superior surface of the prostate by union of the seminal vesicles and the ampulla of the ductus deferens; is in reality an extension of the seminal vesicle (Figs 84 & 86). This is exemplified microscopically by the fact the ejaculatory duct consist of three layers, an outer smooth muscle layer, which is continuous with the muscle fibers of the **seminal vesicles**, a middle layer composed of collagenous tissue (connective tissue) and an inner mucosal layer consisting of pseudostratified columnar epithelium.

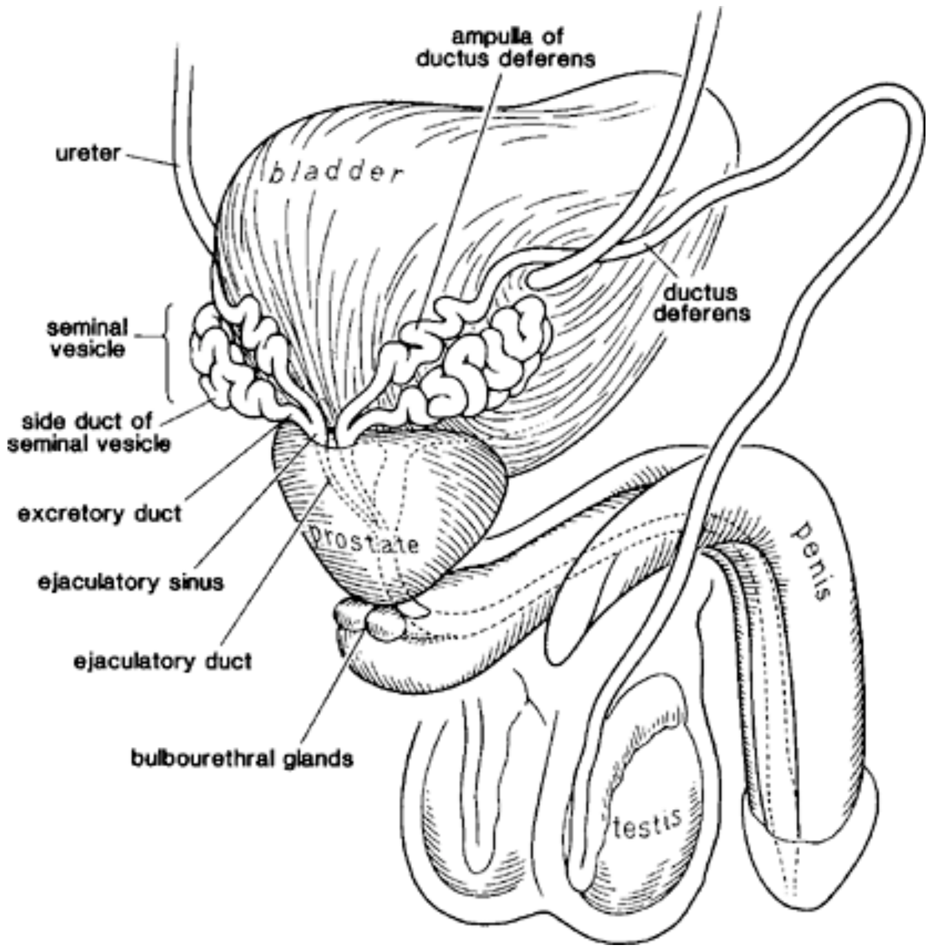


Fig. 86. This is a diagram of the excretory duct system from the vas to the ejaculatory ducts. (flylib.com)

The **middle ejaculatory duct** is the intraprostatic portion, initially running for 10-15 mm on the posterior surface, enters the prostate, running for another 5-8 mm. Microscopically this portion of the duct is surrounded by connective tissue. The outer muscular layer of the proximal portion is now atrophied, leaving a thinner collagenous layer.

The **distal ejaculatory duct** begins when the middle portion enters the central zone of the prostate. The distal portion course on either side of the p**rostatic utricle**, ending at the **seminal colliculus (verumontanum)** (Fig. 85). Microscopically, the distal duct does not have a clear outer muscular layer. Instead, it has intermittent bundles of longitudinal muscle fibers that encase the duct. Also, the middle collagenous layer is much thinner in the distal segment. Within the seminal colliculus is a longitudinal band of smooth muscle fibers between the two ducts. These smooth muscle fibers are believed to represent the terminal segment of the **trigone muscle** of the bladder.

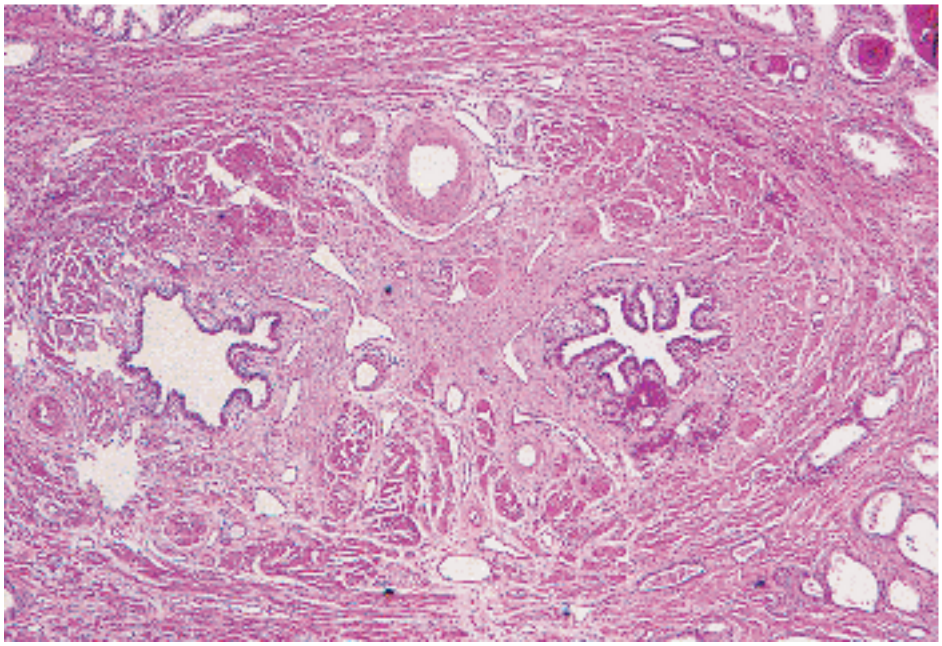


Fig. 87. This is a photomicrograph of the two ejaculatory ducts (right & left of the midline) within the prostatic parenchyma. This section is next to the verumontanum of the prostatic urethra. (flylib.com)

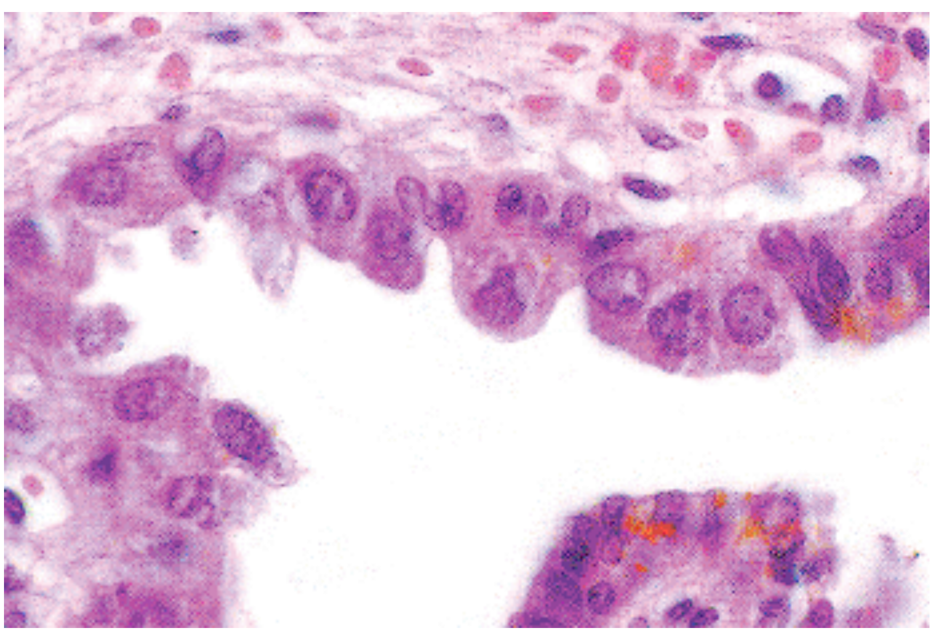


Fig. 88. The above is a photomicrograph of the prostatic portion of the ejaculatory duct as depicted in Fig. 87. (flylib.om)

(c). Accessory Glands: As stated above the **accessory glands** of the male reproductive organs are the **prostate, seminal vesicles** and **bulbourethral glands**. Since we have just discussed the ejaculatory ducts, we will discuss seminal vesicles first.

Seminal vesicles: These are a pair of tubular, saccular, contorted tubular glands that lie against the posterior inferior surface of the bladder, one on each side, diverging like the limbs of a V (Figs. 84 & 86). Each seminal gland is approximatley 5 cm long in its contorted, coiled state, though when the coils are unfolded it measures approximately 10-15 cm in length, with a diameter of 3-4 mm. The upper pole is a 'blind' pouch, whereas the lower end is a straight tube, which joins the **vas deferens** at the base of the prostate to form the **ejaculatory duct**. Immediately posterior to the seminal vesicles, ampulla of the ductus deferens, and the ejaculatory ducts is the **rectum**, being separated from it by the **Denonvillier's fascia** (Fig. 36, p 43).

The paired seminal vesicles, ampulla of the vas deferens, and the ejaculatory ducts form a functional unit.

The wall of the seminal vesicle consist of an external connective tissue layer, the **adventitia**, containing numerous elastic fibers; middle layer composed of smooth muscle, thinner than that of the vas deferens and consisting of an inner circular and outer longitudinal layers, and an internal layer, the mucosa of which is markedly folded (Figs. 89 & 90). Due to the extensive folding of the mucosa numerous compartments are formed, all of which communicate with lumen. The mucosal surface is covered by epithelium, which is usually pseudostratified, however, it can also be simple columnar to cuboidal (Fig. 91).

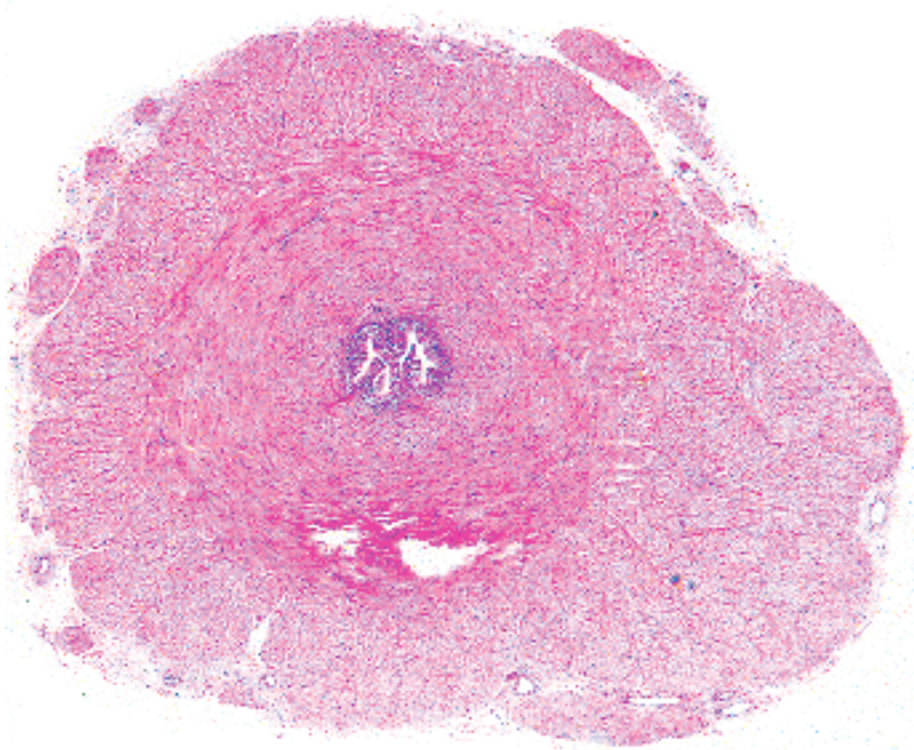


Fig. 89. This is a photomicrograph of the vas deferens showing its thick muscle coat, tiny lumen, and slightly folded mucosa. (flylib.com)

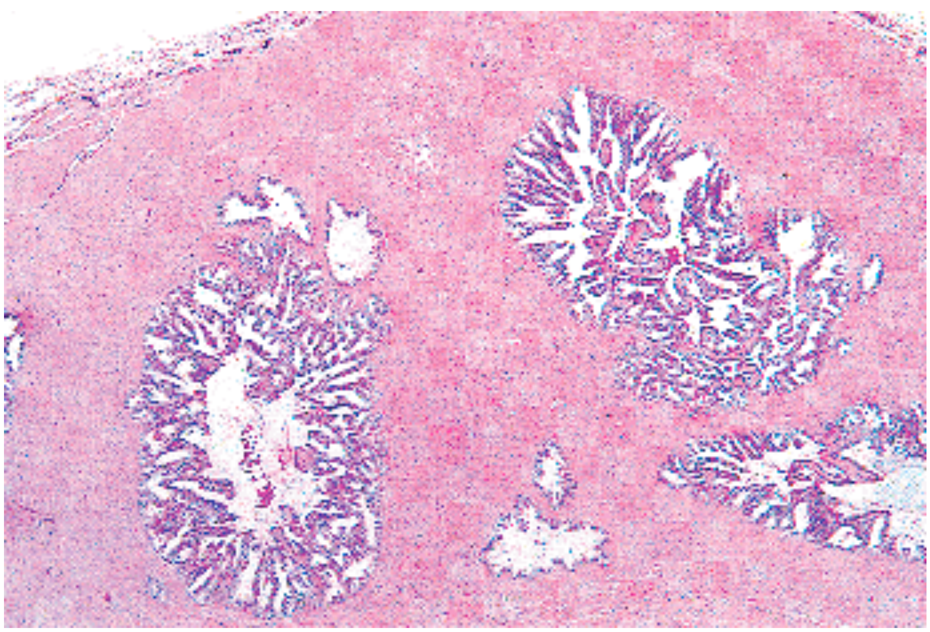


Fig. 90. This is a photomicrograph of the seminal vesicle showing the alveolus-like arrangement of the mucosal folds and cross sections of side ducts. (flylib.com)

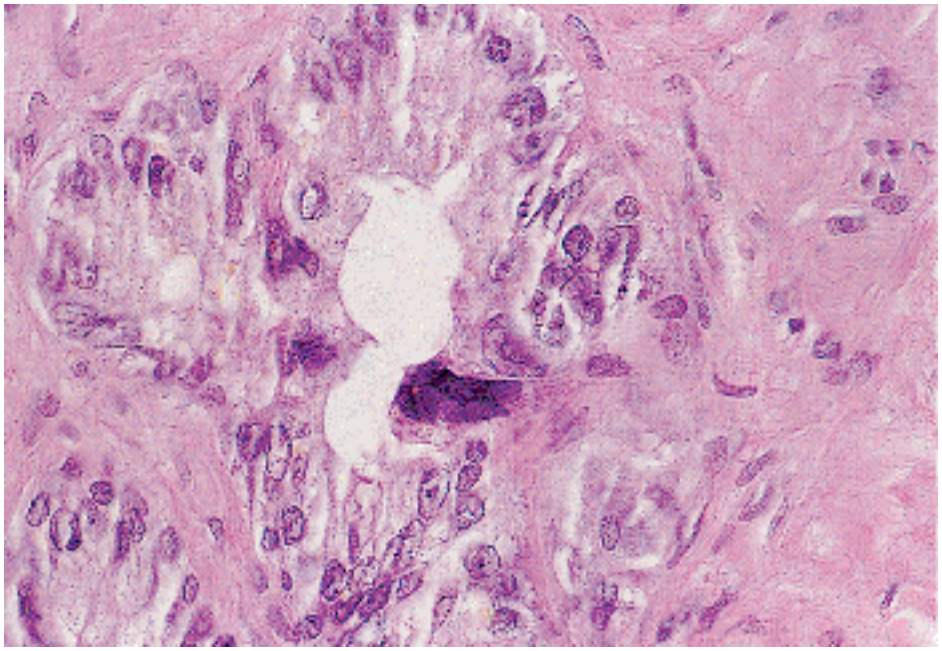


Fig. 91. This photomicrograph is of the epithelial surface of the seminal vesicle glands. (flylib.com)

It is important to remember, the seminal vesicles do not serve as a reservoir for spermatozoa as their name might suggest. Storage of spermatozoa is accomplished by the **epididymis**. However, it is possible to see spermatozoa in the lumen of the seminal vesicle after death, which is presumably the result of back flow.

The **arterial supply** of the seminal vesicles is similar to that of the prostate. The primary arterial supply is derived from the **inferior vesicle, internal pudendal,** and **middle rectal arteries**.

The **veins** and **lymphatics** follow the arteries. The lymphatics drain to the **internal iliac nodes**.

The **innervation** to the seminal vesicles is from the **sympathetic nervous system**, with the **preganglionic fibers** arising from the **superior lumbar nerves** passing to the **inferior hypogastric (pelvic) plexus**, where they either form synapses with ganglion cells or they pass directly through to form synapses with ganglion cells in the wall of the seminal vesicles. The **postganglionic sympathetic fibers** innervate the smooth muscle, causing

them to contract during ejaculation.
The seminal vesicles also receive **parasympathetic innervation**, which originates from the **pelvic splanchnic nerves**. Acetylcholinesterase containing nerves occur in the muscular coat, however, the majority are found under the epithelium within the connective tissue of the lamina propria.
Functionally, the seminal vesicles produce 50-60% of the total volume of seminal fluid, which is a yellowish, alkaline fluid that contains fructose, vitamin C, citric acid, lipofuscin, the latter of which accounts for the yellowish color, as well as large quantities of **prostaglandins** and **fibrinogen**. The remainder is produced by the prostate gland (about 30%), the vas deferens (about 10%), with a small contribution from the bulbourethral glands.
During the process of emission and ejaculation, each seminal vesicle empties its contents into the ejaculatory duct shortly after the vas deferens empties the sperm. This adds greatly to the bulk of the ejaculated semen, and the fructose and other substances in the seminal fluid are of considerable nutrient value for the ejaculated sperm until the sperm fertilizes the ovum.
Prostaglandins are believed to aid fertilization in two ways: (1) by reacting with the female cervical mucus to make it more receptive to sperm movement and (2) by possibly causing backward, reverse peristalic contractions in the uterus and fallopian tubes to move the ejaculated sperm toward the ovaries (a few sperm reach the upper ends of the fallopian tubes within 5 minutes).
The epithelial cells lining the mucosa are highly influenced by testosterone levels, which dictate the size and activity levels of these cells.
Prostate Gland: This is a pyramidal fibromuscular gland, which surrounds the prostatic urethra from the base of the bladder to the **membranous urethra**. It is composed of secretory elements and tubuloalveolar glands surrounded by smooth muscle. The glandular elements are concerned with the secretion of a portion of the seminal fluids, and the muscular elements contribute to continence and ejaculation.
The prostate gland underlies the male bladder, resting by its apex on the pelvis and urogenital diaphragm (Figs. 52, p 62, 66, p 77 & Figs 81, 86 & 92).

Its base is structurally continuous with the bladder wall. The ampulla of the rectum is immediately behind it, being separated from the prostate by **Denonviller's fascia** (Fig. 51, p 61). The lateral surfaces are related to the superior fascia of the pelvic diaphragm. The prostate has no true fibrous capsule. It is however, covered with a sheath provided by condensation of the endopelvic fascia (Figs. 51 & 52, p 61 & 62), which is continuous with the **medial** and **lateral puboprostatic ligaments** (Figs. 53 & 54, p 64 & Fig. 93). The posterior surface of the apex of the prostate and the external urethral sphincter is fixed to the **perineal body** and the lateral rectal wall by the **rectourethralis muscle** (Fig. 93).

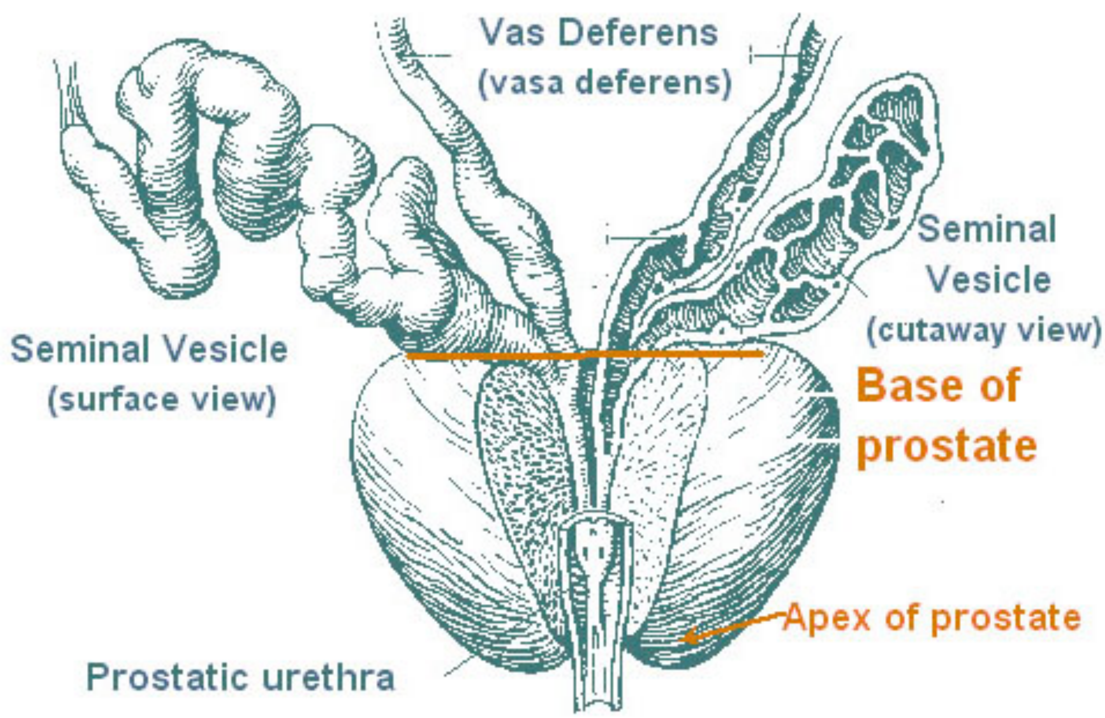


Fig. 92. This is a drawing depicting the base and apex of the prostate. The base is directed upward near the inferior surface of the bladder. The greater part of this surface is directly continuous with the bladder wall (Fig. 36, p 43).
The apex is directed downward and is in contact with the superior fascial of the urogenital diaphragm (Fig. 93). (Wiki)

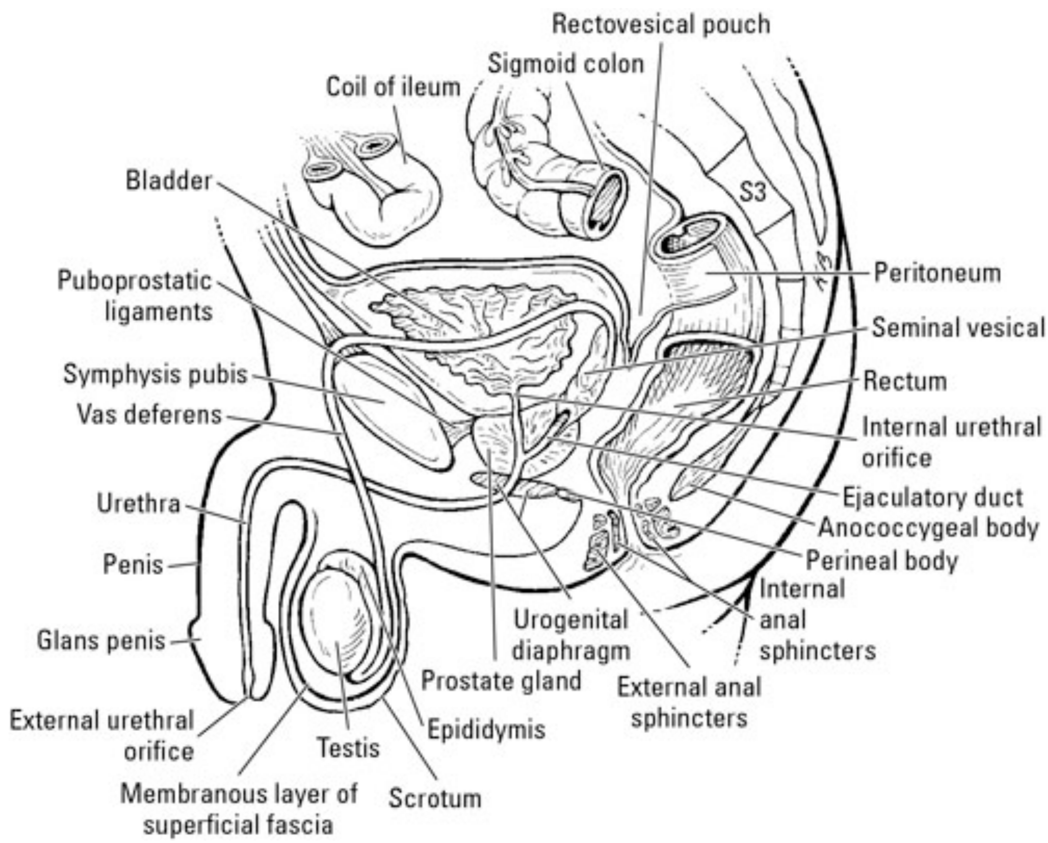


Fig. 93. This is a drawing showing the male perineum and associated anatomical structures. (www.dummies.com)

The anterior surface of the prostate lies in the arch of the pubis, separated from it by **Santorini's plexus**, which is a venous plexus on the ventral and lateral prostatic surfaces.

The prostate measures 4 cm across its base; it is about 3 cm in its vertical diameter and about 2 cm in its anteroposterior diameter. In the child to early teenage years it weighs about 8 grams, whereas in the adult it weighs approximately 40 grams, but with benign prostatic hypertrophy it may weigh as much as 180 grams or more, which typically develops after age 40.

Embryologically, the prostate, except for the central zone, is derived from the **urogenital sinus**. The central zone, as is true of the **epididymis, vas deferens, seminal vesicles, ejaculatory ducts,** and the **efferent ducts of the testis** are derived from the **Wolffian duct system**.

The prostate itself begins its morphogenesis during the 12 week of intrauterine growth. Multiple endodermal outgrowths appear from the epithelial lining of the prostatic portion of the urogenital sinus and rapidly insinuate themselves into the surrounding mesenchyme. These prostatic ducts soon lengthen and branch, and eventually canalize to form distinct glandular structures. The stimulus for this development appears to be testosterone secreted from the developing testes.

Structurally, the prostate consists of fibromuscular stroma enclosing branching tubuloalveolar glands arranged in lobules surrounded by stroma (Fig. 94). The aveolar glands consist of acinal units composed of an epithelial compartment made up of epithelial, basal, and neuroendocrine cells and a stromal component that includes fibroblast and smooth muscle cells (Fig. 95). These components are separated by a basement membrane.

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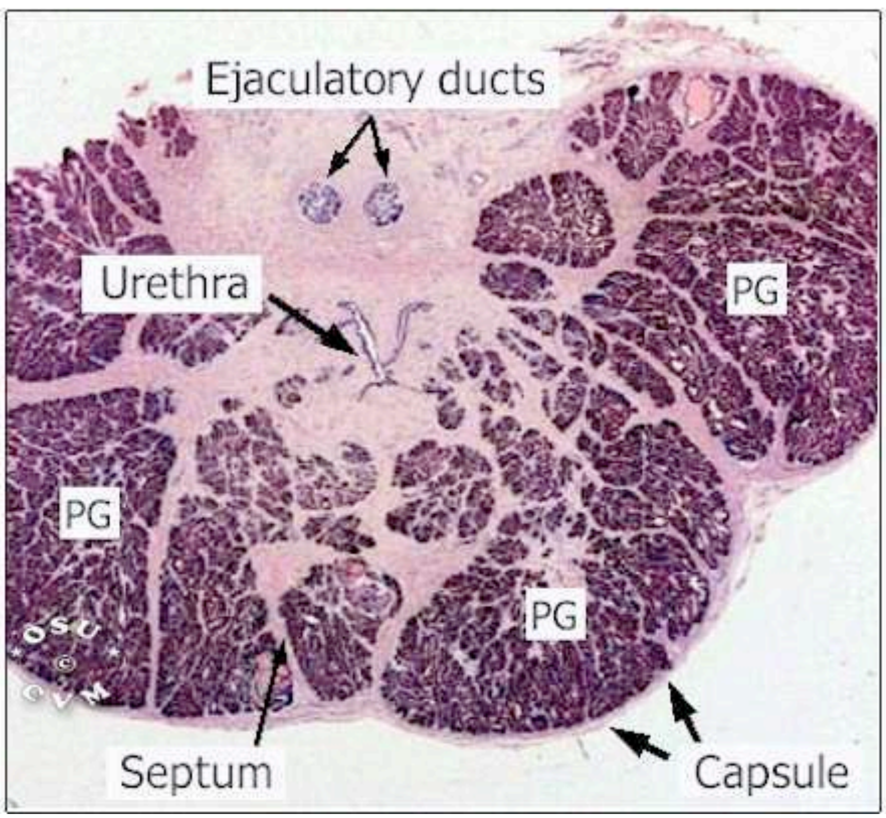


Fig. 94. This is a photomicrograph taken at low power to show the anatomic arrangement of the fibromuscular stroma (septum) and the branching tubuloalveolar glands which are arranged in lobules surrounded by the stroma. (instruction.cvhs.okstate.edu)

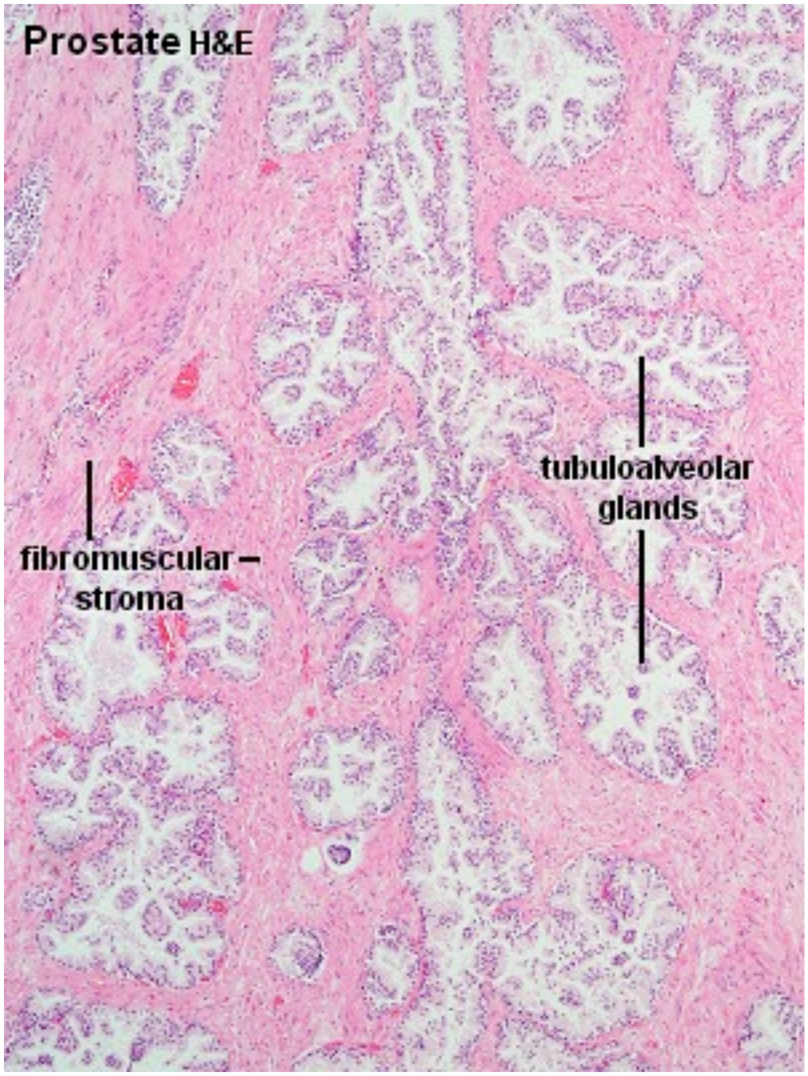


Fig. 95. This is a photomicrograph taken at a higher power than that of Fig. 94. It shows the branching tubuloalveolar glands separated by fibromuscular stroma. (Wiki)

The prostate can be divided in two ways: by **zone** or by **lobes**.

The prostate has four distinct zones: **peripheral zone, central zone, transition zone,** and **anterior fibromuscular zone (or stroma)** (Figs. 96 & 97).

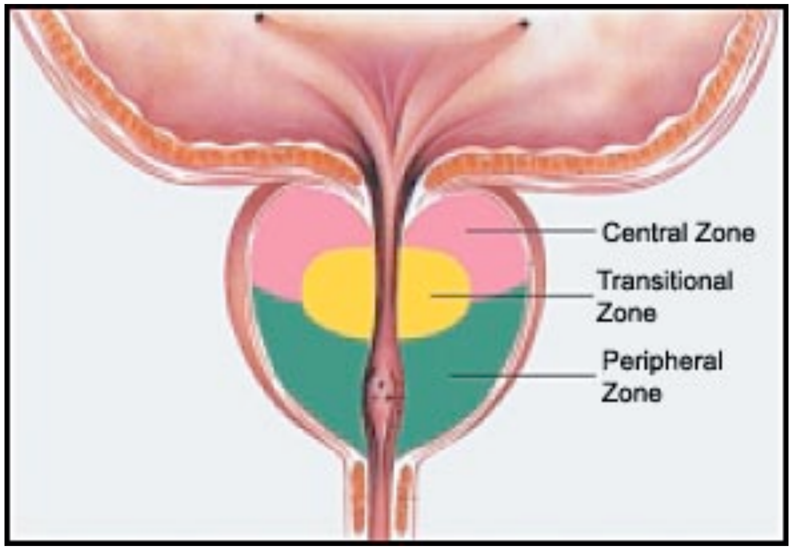


Fig. 96. This is a frontal representation of the zones of the prostate. (prostate-cancer.org)

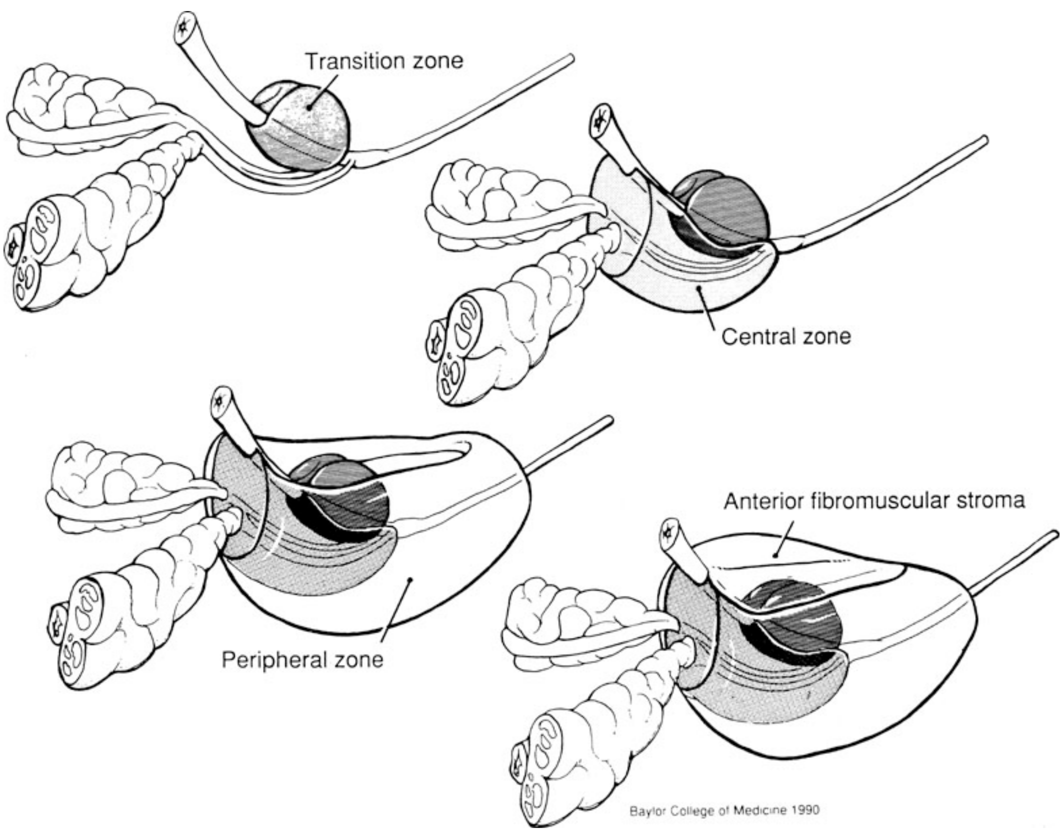


Fig. 97. These drawings are a more lateral representation of the zones of the prostate. (scgap.systemsbiology.net)

(1). Peripheral zone: This represents 70% of the gland in young men. It is located in the subcapsular portion of the posterior aspect of the prostate gland that surrounds the distal urethra. Approximately 70-80% of prostate cancers arise from this zone.

(2). Central zone: This represents approximately 25% of the gland. This zone surrounds the ejaculatory ducts. Approximately 25% of prostatic cancers arise here, which typically are aggressive.

(3). Transition zone: This accounts for approximately 5% of the gland at puberty. This zone surrounds the distal part of the preprostatic urethra. It continues to grow throughout life and is responsible for the disease, **benign prostatic hypertrophy**, which can grow to form the bulk of the prostate. Approximately 20% of prostate cancers originate in this zone.

(4). Anterior Fibromuscular zone: This zone represents approximately 5% of the prostate. This zone is devoid of glandular components, and is composed of muscle and fibrous tissue.

The **lobe** classification system is more commonly used in anatomy. In this system the prostate is divided into four lobes, although five lobes can be recognized in the fetus up to 20 weeks gestation. The four lobes are **anterior, posterior, lateral** and the **middle (median)**. The **anterior** corresponds to the **transitional zone**; the **posterior** to the **peripheral zone**; the **lateral**, which spans all zones; and the **middle** corresponds to the **central zone** (Fig. 98). As previously discussed, the prostate consist of fibromuscular stroma enclosing glandular elements. The fascia which covers the prostate is firmly adherent to it. Extending from this fascia into the parenchyma are numerous fibromuscular septa, which divide the prostate into approximately 50 lobules (Fig. 95). Within each lobule are glandular elements arranged around minute, slightly branched tubules, which lead into twenty to thirty prostatic ducts. Most of these ducts empty into the prostatic sinuses at either side of the urethral crest of the posterior urethral wall (Figs. 76, p 93 & 85, p 107).

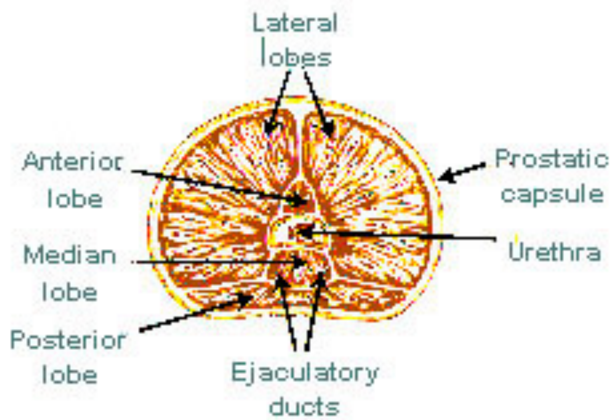


Fig. 98. This drawing depicts the lobes of the prostate. (myprostate.com.au)

The **arterial supply** to the prostate is through branches from the **inferior vesicle, middle rectal arteries** and the **internal pudendal artery** of the **internal iliac system**.

The **veins** of the prostate drain into a **prostatic plexus** located in the prostatic sheath in front and at the sides of the gland (**Santorini's plexus**). The plexus also receives the **deep dorsal vein** of the penis, as well as communicating with the **vesicle plexus**. Ultimately, the veins of the prostate drain into the **vesicle plexus** and the **internal iliac veins**.

The **lymphatic drainage** of the prostate is associated with that of the **seminal vesicles** and the **neck** of the **bladder**. The prostatic lymph vessels drain primarily to the **internal iliac, sacral** and **obturator nodes**. However, due to the association with those of the seminal vesicles and the neck of the bladder, they also can drain to the **external iliac nodes**.

The **innervation** of the prostate is through an abundant supply of nerves from the **inferior hypogastric (pelvic) plexus**. The prostatic capsule is covered by numerous nerve fibers and ganglia posterolaterally (Fig. 99).

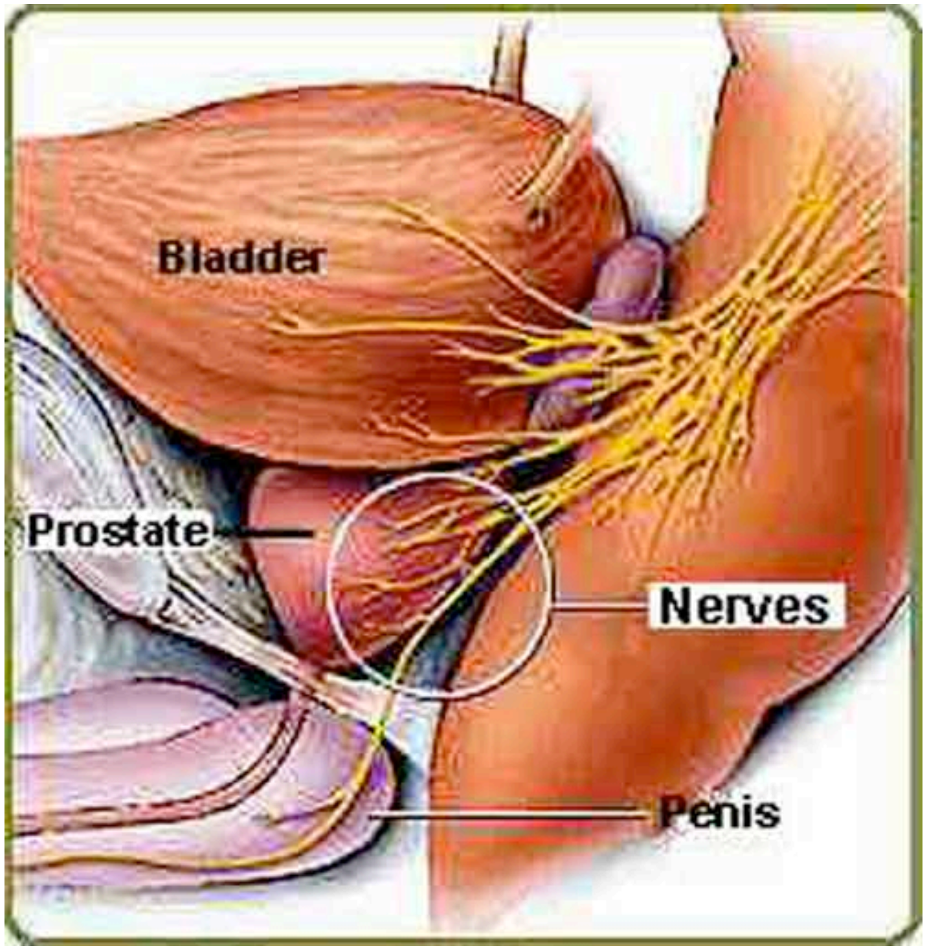


Fig. 99. This image depicts the extensive nerve plexus on the prostatic capsule. (quadernisocialisti.wordpress.com)

The greatest density of nerves is found in the **preprostatic sphincter**; fewer fibers are found in the **anterior fibromuscular stroma**, and the **peripheral zone** is the least densely innervated.

Sympathetic fibers originate in the **intermediolateral column of gray matter** in **T10-L2 spinal segments**, traverse the **lumbar sympathetic paravertebral chain**, and reach the **pelvic plexus** through the **superior hypogastric plexus** and the **pelvic continuation of the sympathetic trunks**. The superior hypogastric plexus is formed from the **celiac plexus** and the **first four lumbar splanchnic nerves** that divides into two **hypogastric nerves**.

The **parasympathetic fibers** arise from the **intermediolateral cell column** of

S2-S4 spinal segments. They emerge as **pelvic splanchnic nerves** to join the **hypogastric nerve** and branches from the **sacral sympathetic ganglia** to form the **inferior hypogastric (pelvic) plexus** (Fig. 59, p 69).

In respect to **sensory innervation** of the prostate, little is known although some have suggested the majority of the **afferent innervation** of the ventral prostate is localized to sensory nerves from **L5-S1 spinal segments** with minimal innervation from **T12-L2**.

Somatic innervation to the skeletal muscle of the **external urethral sphincter** is supplied by the **pudendal nerve**, which arises from the **ventral division of the second, third, and fourth sacral ventral rami**.

Functionally, the primary function of the prostate gland is to support and promote male fertility and insemination. The prostate gland secretes a thin, milky fluid, which contains calcium, zinc, citrate ion, phosphate ion, a clotting enzyme, profibrinolysin, prostate-specific antigen (PSA), and acid phosphatase. Both the prostate epithelial cells and stromal cells express androgen receptors and depend on androgens for growth.

During ejaculation the capsule of the prostate gland contracts simultaneously with the contractions of the vas deferens so that the thin, milky fluid of the prostate gland adds to the quantity of semen, which varies between 0.1-10 ml per ejaculation. The secretory function of the prostate is mediated by cholinergic innervation (parasympathetic) from the pelvic and hypogastric nerves, while the contractile function is mediated by the alpha-adrenegric receptors (sympathetic) that predominate in the stroma.

Bulbourethral Glands: These glands are also referred to as **Cowper's glands** (Figs. 76 & 81, p 93 &103, Figs. 85 & 86, p 107 & 108). They are analogous to the **Bartholin's glands** in the female.

They are two small, round, yellow, lobulated masses measuring approximately 10 cm in diameter. They are located posterior and lateral to the **membranous portion of the urethra** at the base of the penis, between two layers of the **fascia of the urogenital diaphragm**, above the **perineal membrane** in the **deep perineal pouch**. They are enclosed by muscle fibers of the **external**

urethral sphincter. These glands are tubuloalveolar, composed of several lobules held together by fibrous tissue (Fig. 100). Each lobule consist of acini, lined by columnar epithelial cells, which open into a duct that joins ducts of the other lobules to form a single excretory duct.

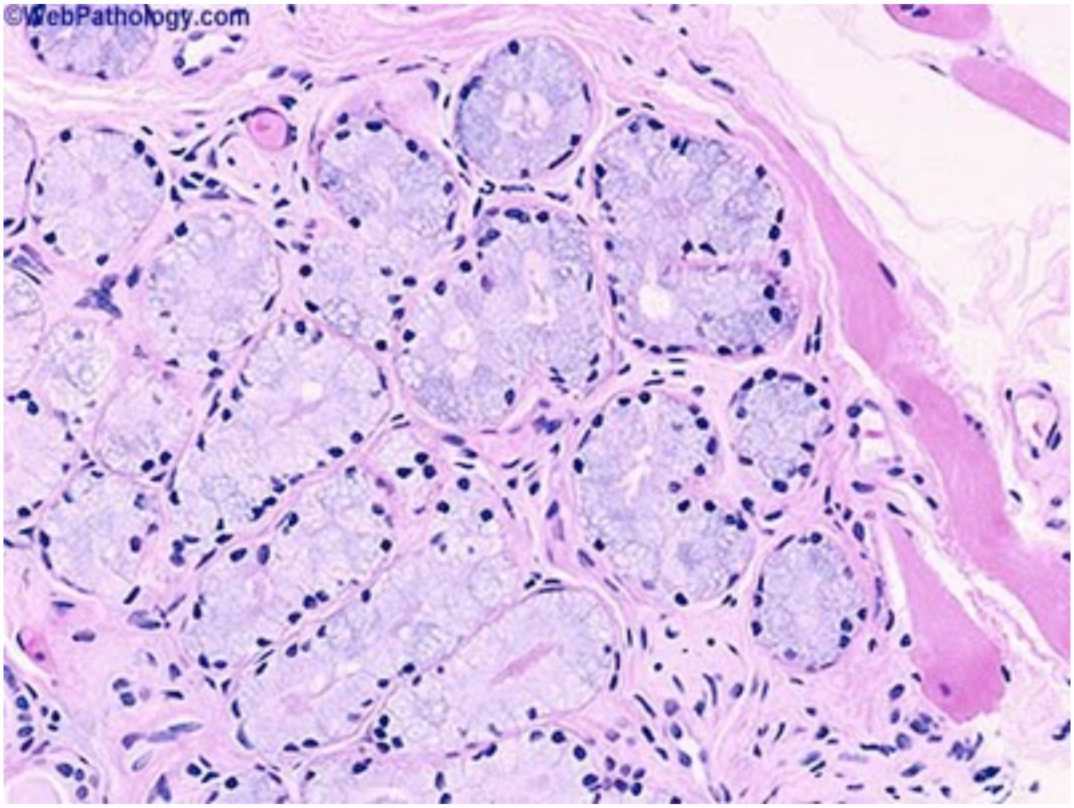


Fig. 100. This is a photomicrograph of a portion of the Bulbourethral (Cowper's) gland. As seen above these glands have a lobular configuration and are often associated with skeletal muscle fibers. The glands are lined by goblet cells distended with mucin. The small hyperchormatic nuclei are pushed to the periphery. Sometimes ducts lined by cuboidal cells are present in the center of the lobules. (www.oncopathology.info)

The excretory duct of each gland varies in length between 2.5 and 3 cm. They continue forward, external to the mucosa of the **membranous urethra**, penetrating the **perineal membrane** (Fig. 76, B, p 93). It opens in the floor of the **bulbar urethra** at the base of the penis, 2.5 cm below the perineal membrane. With age the glands diminish in size.

Functionally, they produce a clear, salty, viscous secretion referred to as the **pre-ejaculate** during sexual arousal. This fluid helps lubricate the urethra for spermatozoa to pass through, as well as neutralizing any trace of acidic urine in the urethra, flushing it out along with any foreign matter. *What is important to remember, Cowper's gland also produces* ***prostatic specific antigen (PSA)***. Tumors of Cowper's gland may increase PSA to suggest the presents of cancer of the prostate.

2. Female Internal Reproductive Organs

(a). Vagina: The is formed from the urogenital sinus. It is the female organ of copulation consisting of a fibromuscular tube lined by non-keratinized stratified squamous epithelium (Fig. 101). If forms the inferior portion of the female

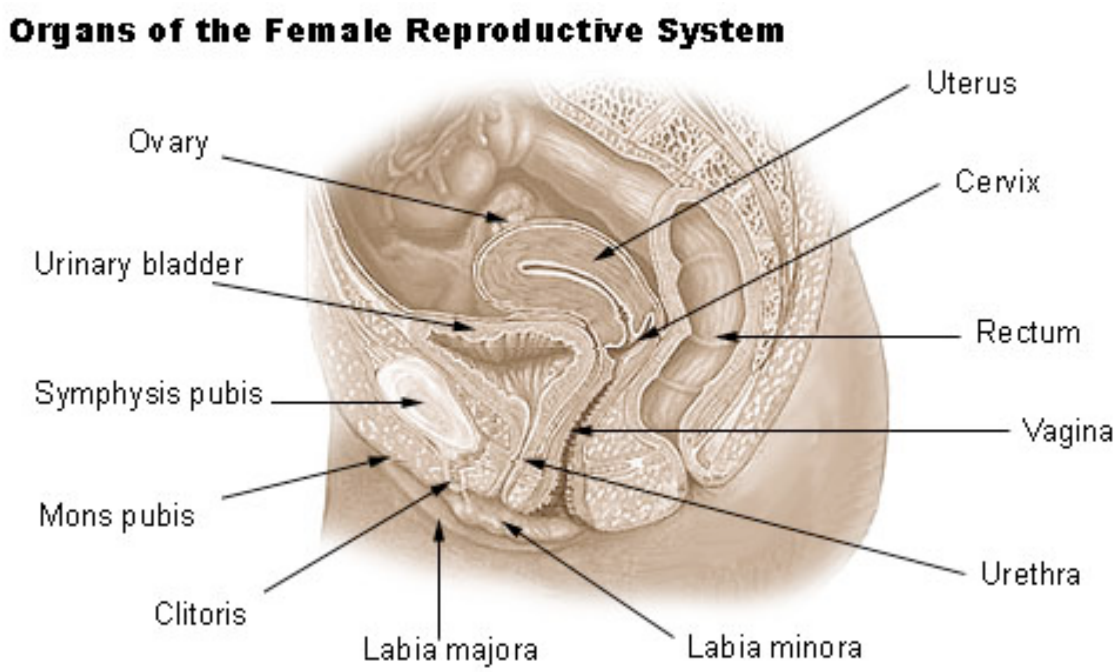


Fig. 101. This is a drawing showing the organs of the female reproductive system except for the fallopian tubes and their anatomic relationship with the rectum. (Wiki).

genital tract and the birth canal, extending from the cervix of the uterus to the vesitbule, opening between the **labia minora** of the vagina (Fig. 102). The upper end of the vagina surrounds the projection of the uterus onto the lumen of the vagina called the cervix. The space between the outer surface of the cervix and the vaginal wall is called the **fornix**; there is an **anterior fornix,**

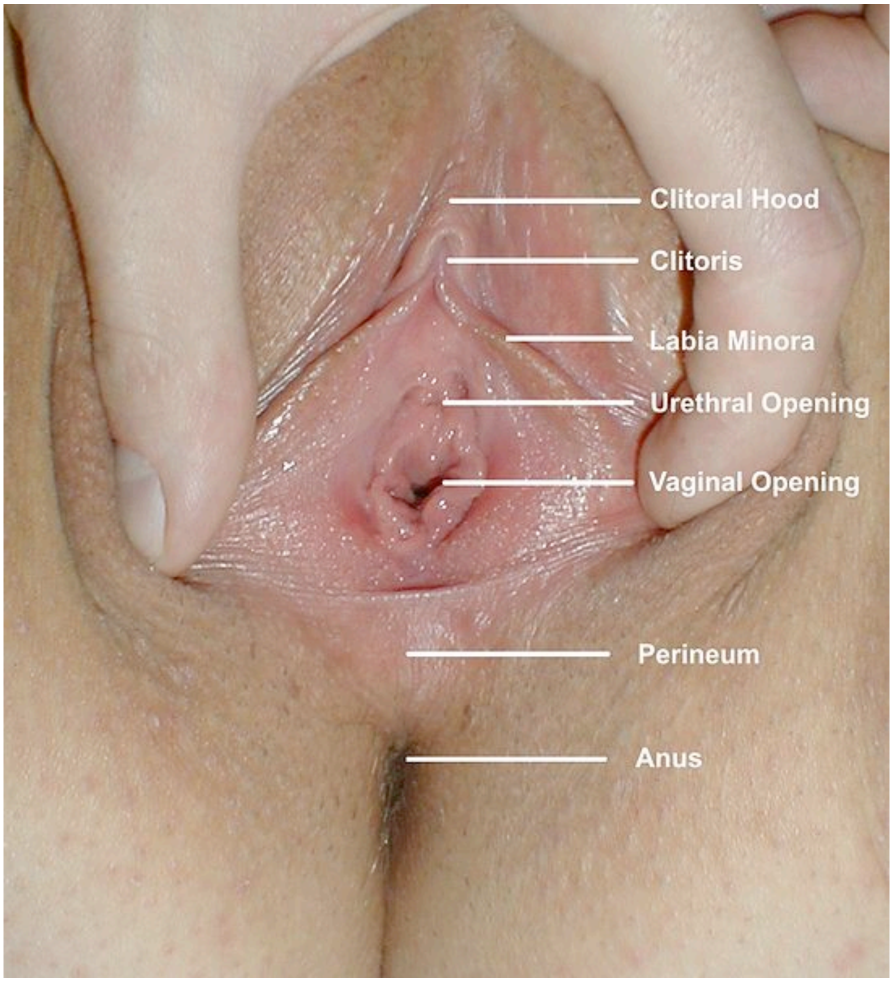


Fig. 102. This image shows the vaginal opening and associated anatomical structures. (Wiki)

posterior fornix and **lateral fornices** (Figs. 60 & 82, p 72 & 103 & Fig. 103). The posterior fornix is deepest and is related to the **rectouterine pouch** (Fig. 104). The lateral fornices may contain cysts referred to as **Gartner's cyst**. These cysts are remnants of the **duct of Gartner**, which embryologically represent the caudal end of the **mesonephric duct**. These cyst when present are seen protruding through the lateral fornices or the lateral walls of the vagina.

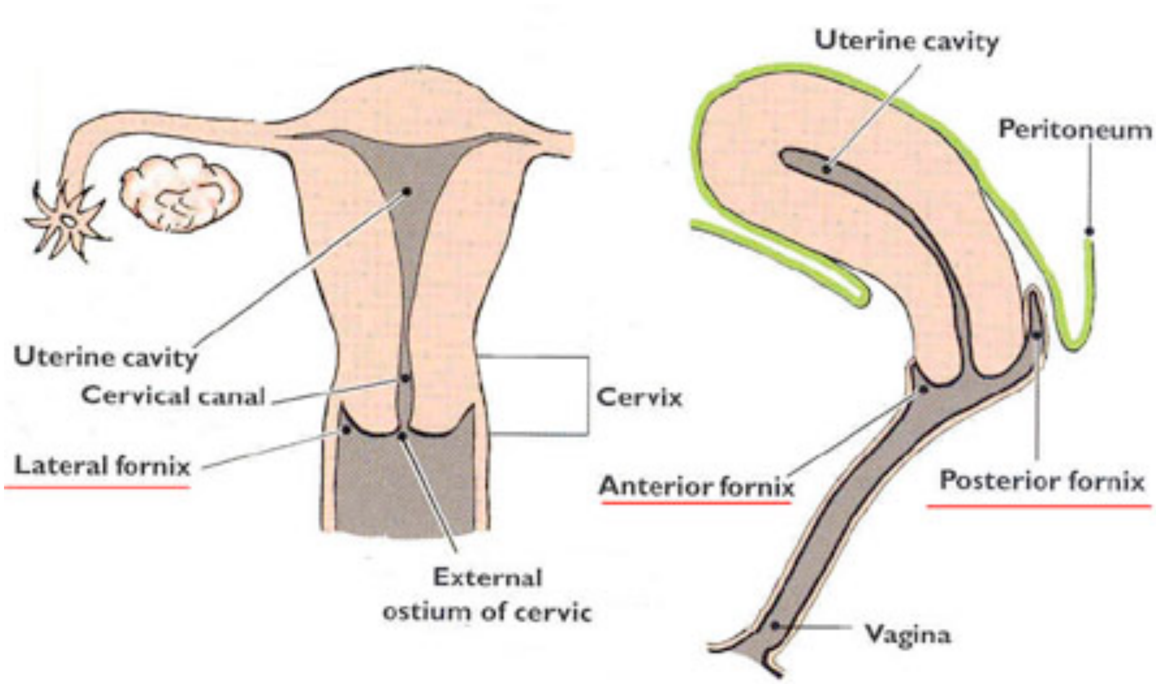


Fig. 103. This is a drawing of the vaginal fornices. The posterior fornix is the larger recess, behind the cervix. It is close to the rectouterine pouch (Fig. 104). The posterior fornix is also clinically significant in that it is the site for culdocentesis (aspiration of fluid from the rectouterine space). The anterior fornix is close to the vesicouterine pouch (Fig. 105). The lateral fornices are to the left and right of the recesses created by the protrusion of the vaginal portion of the cervix into the cervix. (academic.amc.edu)

The walls of the vagina are in contact with except where its lumen is held open by the cervix uteri. The vestibular entrance is a sagittal cleft (Fig. 102); throughout its mid-region the vagina has an H-shaped lumen, the principal dimension being transverse.

As the vagina extends internally from the vestibule it ascends posteriorly and superiorly at an angle greater than 90º (100-110º) to the uterine axis, with the angle varying with the contents of the bladder and rectum. The uterine angle increases as the bladder fills. The width of the vagina increases as it ascends. Also, as it ascends it pierces the **urogenital diaphragm** and the **pelvic diaphragm**. The anterior and posterior walls of the vagina are not of the same length due to the fact the vaginal mucosa is attached to the uterine cervix higher on the posterior cervical wall than on the anterior; the anterior wall is approximately 7.5 cm long with the posterior wall being approximately

9 cm in length.

The superior and middle portions of the anterior wall of the vagina is related to fundus of the bladder, being separated from it by loose connective tissue. Inferiorly, the anterior wall is intimately connected to the urethra. The anterior fornix is also close to the vesicouterine pouch (uterovesical pouch of Meiring or Dunn's pouch) (Fig 60, p 71 & 72 & Fig. 105). The posterior wall is covered by peritoneum in its upper quarter (Fig. 104). *Thus, a penetrating wound of this part of the vagina can involve the peritoneal cavity.* Superiorly, the vagina is separated from the rectum by the rectouterine pouch (Fig. 104), whereas its middle portion is separated from the rectum by loose connective tissue called Denonvillier's fascia (Fig. 36, p 43).

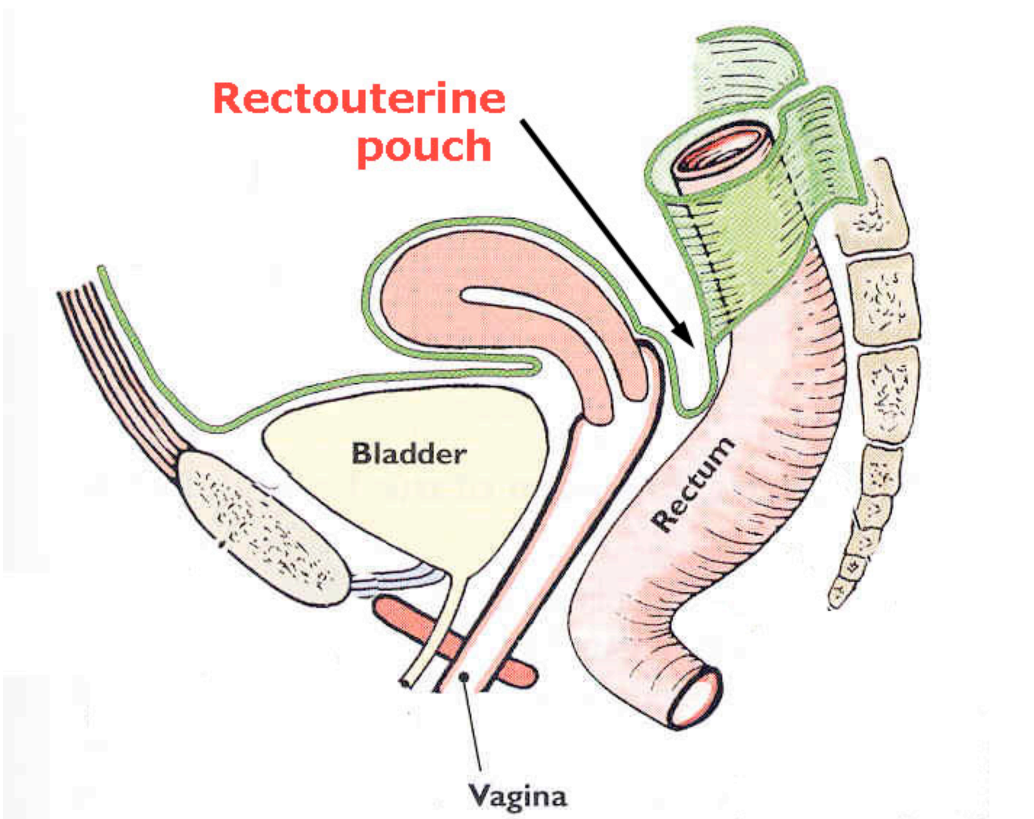
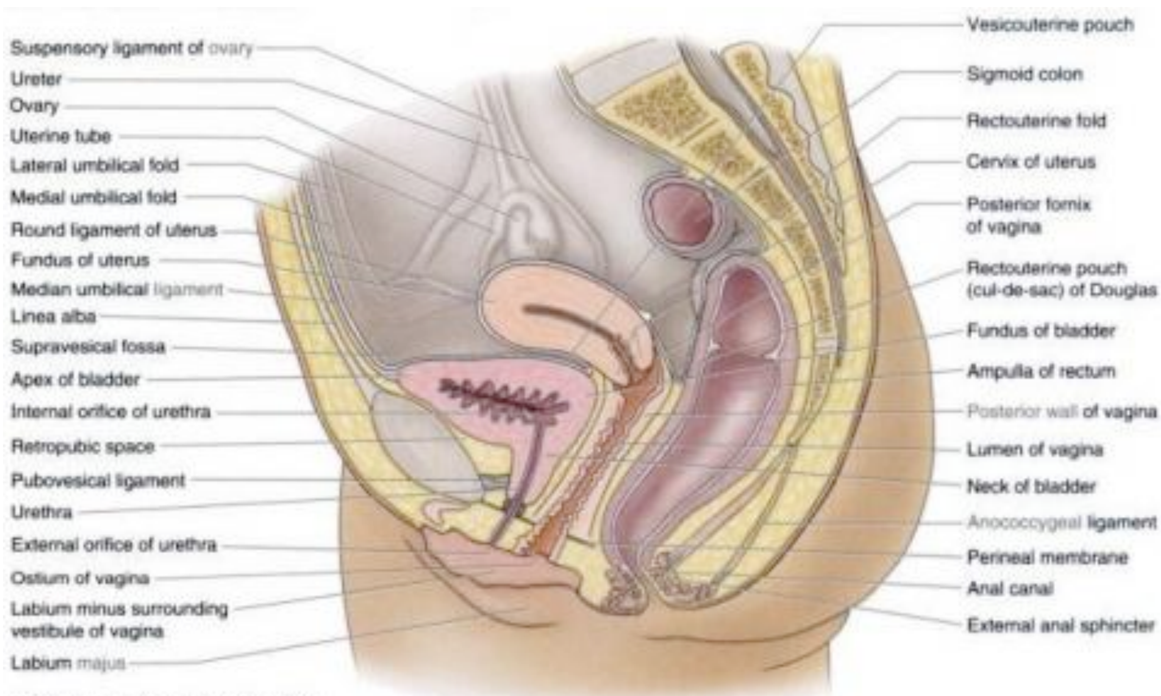


Fig. 104. The above drawing shows the location of the rectouterine pouch. The rectouterine pouch (pouch of Douglas) is formed as the peritoneum of the abdomen extends down over the posterior portion of the uterus and cervix and is reflected back upward covering the upper half of the rectum. This "dip" of peritoneum creates a space above the posterior fornix of the vagina. (academic.amc.edu)



(B) Median section of female pelvis

Fig. 105. As labeled the above drawing is a median section of the female pelvis. All important anatomical landmarks are depicted including the vesicouterine pouch, which is labeled on the top right. This pouch is formed from the peritoneum over the uterus and bladder, continued over the intestinal surface and fundus of the uterus onto its vesical surface, which it covers as far as the junction of the body and cervix uteri, and then to the bladder. It is also referred to as Dunn's pouch, which is an important anatomic landmark for chronic endometriosis. Dunn's pouch is also an important factor in retroversion of the uterus, which can frequently complicate pregnancies. It is close to the anterior fornix of the vagina. (anatomytopics.wordpress.com)

The lower quarter of the posterior wall is separated from the anal canal by the **perineal body** (Figs 69 & 93, p 81 & 115). The narrow lateral walls of the vagina are attached to the **broad ligament of the uterus**. Inferiorly, the lateral walls are in contact with the **levator ani muscles**, **the greater vestibular glands**, and the **bulbs of the vestibule**. Contraction of the **pubococcygeus parts of the levator ani muscles** draws the lateral walls together. *Remember, the vagina is located posterior to the uterine bladder and anterior to the rectum and passes between the medial margins of the levator ani muscles* (Figs. 41 & 43, p 47 & 49). There are three muscles than compress the vagina, acting like sphincters: the **pubovaginalis muscle**, which is the anterior part of the **pubococcygeus muscle** and is inserted into the urethra and vagina (Fig. 106); the **urogenital diaphragm;** and the **bulbospongiosus muscle** (Fig. 43, p 49 & Fig. 107). The pubovaginalis is a U-shaped muscular sling that partially closes the midpoint of the vagina. It is because of this sling the upper portion of the vagina has a greater diameter. The lower vagina is surrounded by the skeletal muscle of the bulbospongiosus (Fig. 107).

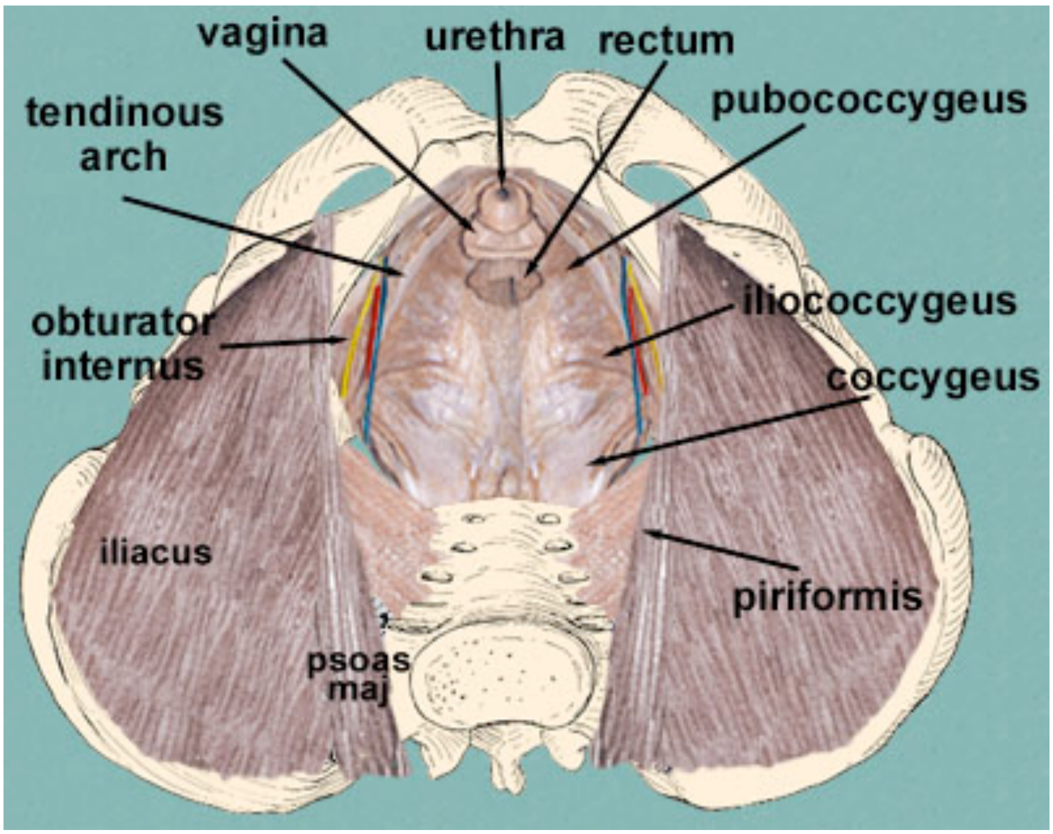


Fig. 106. The above drawing shows the female pelvic diaphragm. The pubococcygeus are the most medial muscle fibers of the levator ani muscle group. The anterior portion of this muscle constitutes the pubovaginalis. These muscle fibers extend from the pubis to the lateral walls of the vagina. The pubovaginalis is the female equivalent of the levator prostatae in the male. (www.gpnotebook.co.uk)

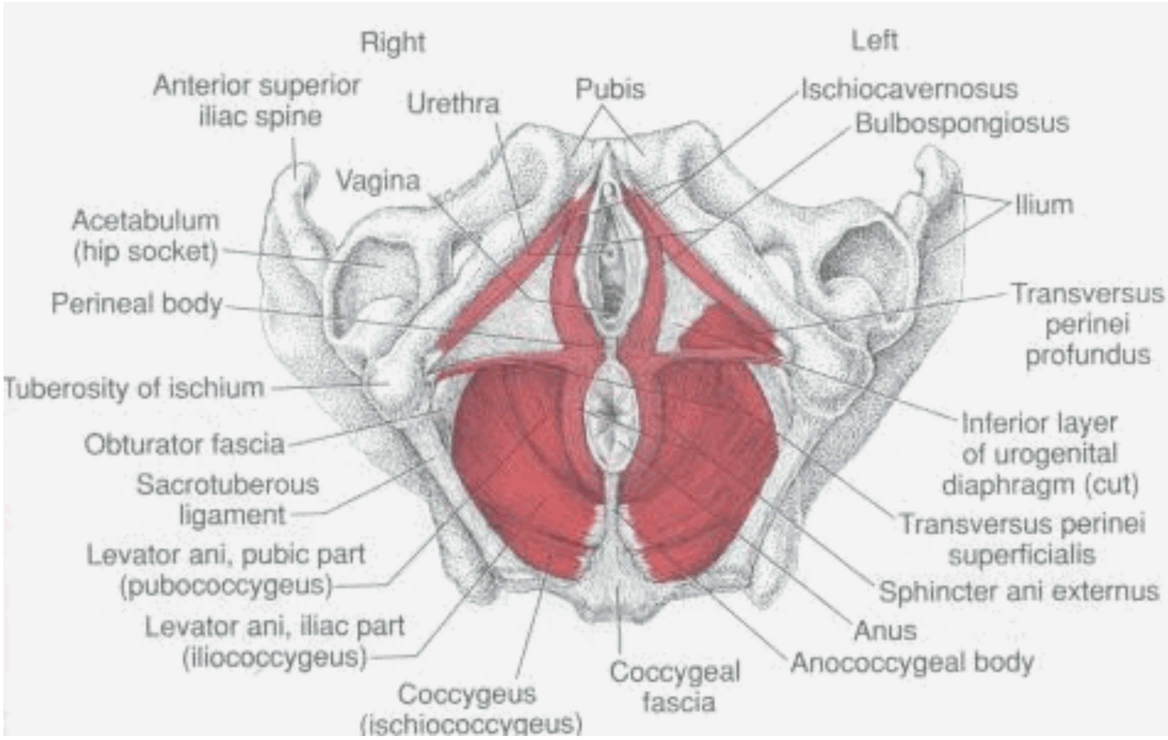


Fig. 107. This is a view of the pelvic floor, inferior to superior. Note the position of the bulbospongiosus muscle. (obgyn.net)

In **summary** the lower third of the vagina is supported by the levator muscles in the pelvic diaphragm, which include the pubococcygeus, iliococcygeus and ischiococcygeus. The middle third is supported by the fibrous attachment to the **arcuate line**, or **arcus tendineus** (Figs. 47, 49 & 69, p 55, 59 & 81, Fig. 108). The rectum supports the middle of the posterior vaginal wall, upon which the anterior vaginal wall rests. In turn, the anterior vaginal wall supports the mid-portion of the bladder. Lastly, the endopelvic fascia that attaches to to the adventitial layer (outer connective tissue layer) of the upper third of the vagina is confluent with the fascia of the cervix, this leads to the formation of the **cardinal (transverse cervical ligament in Fig. 55)** and **uterosacral ligaments** that support the cervix also providing support for the vagina (Fig. 55, p 65 & Fig. 108).

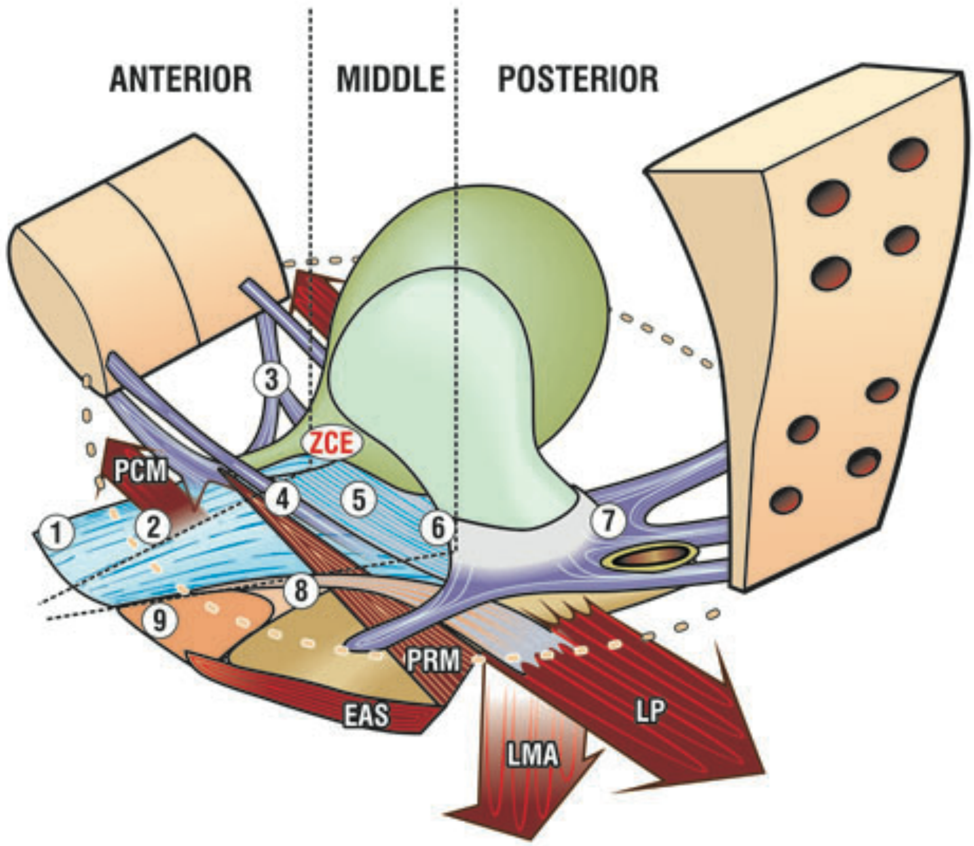


Fig. 108. This figure depicts the key anatomic structures of the pelvic floor, which are divided into three zones, anterior (next to the pubis), middle (includes the anterior portion of the bladder and uterus) and the posterior (includes the posterior portion of the bladder and uterus).
The anterior zone contains (1), external urethral ligament, (2), pubourethral ligament and (3), suburethral vagina (hammock).
The middle zone contains (4), arcus tendineus fascia pelvis, (5), pubocervical fascia and (6), anterior cervical ring (cardinal ligament).
The posterior zone contains (7), uterosacral ligament, (8), rectovaginal fascia and (9), perineal body.
PCM, pubococcygeus muscle direction of applied force; LP, levator ani muscles direction of applied force; LMA, longitudinal muscle of the anus direction of applied force; and ZCE, zone of critical elasticity. (www.integraltheory.org)

The vagina opens externally into the vestibule through the sagittal introitus, which is positioned below the urethral meatus (Fig. 102). The dimensions of the introitus can very greatly to accommodate childbirth and sexual intercourse. Just within the introitus is a thin fold of mucous membrane called hymen (Fig. 103). The internal surfaces of these folds are normally in contact with each other. *The hymenal ring normally ruptures after the first sexual intercourse, but can rupture during non-sexual physical activity.*

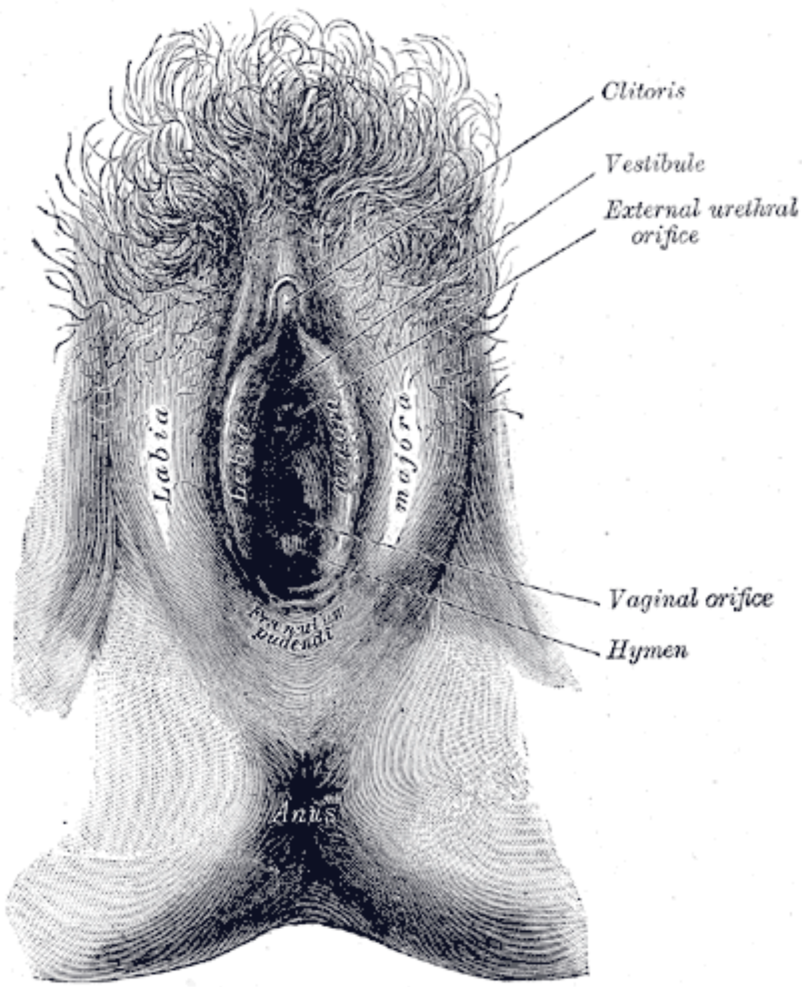


Fig. 109. This image is of the external genital organs of the female. The labia minora has been drawn apart. (Wiki)

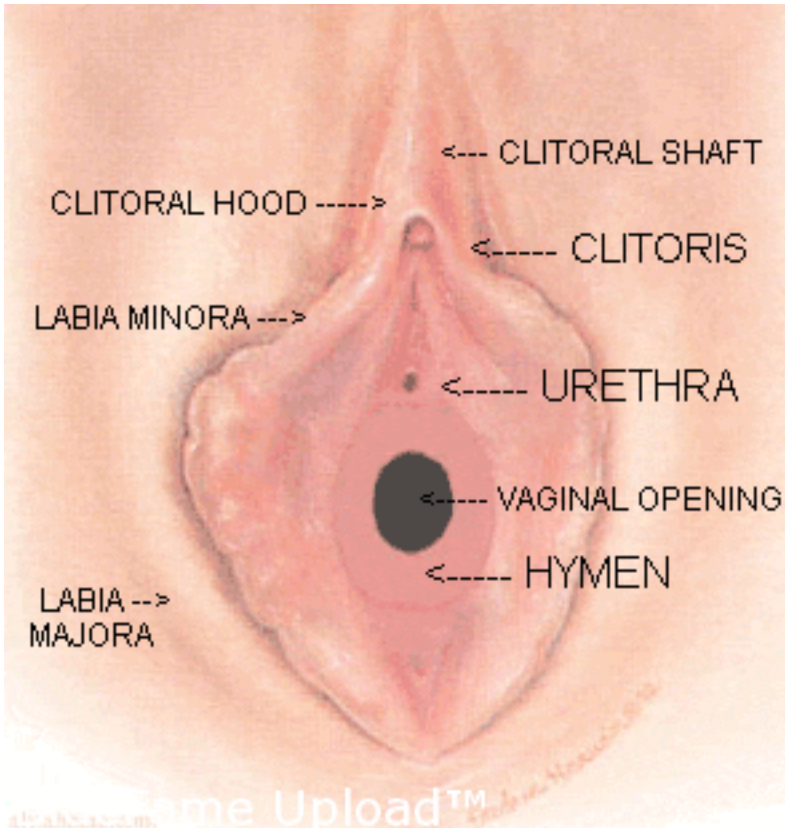


Fig. 110. This image shows the external genital organs of the female with a clearer picture of the hymen. (bf-software.blogspot.com)

Microscopically, the vagina is composed of an **inner mucosal layer**, a **muscular layer (muscularis)** and an **adventitial layer** (Fig. 111).

The **mucosal layer** is continuous with that of the uterus and is firmly adherent to the muscular layer. The mucosa contains two median longitudinal ridges, the **anterior rugal column** and the **posterior rugal column**, and numerous transverse bilateral ridges, the **vaginal rugae**. The vaginal rugae are most numerous on the posterior wall and near the orifice. The vaginal rugal folds contribute to elasticity. The epithelial surface of the mucosa is non-keratinizing stratified squamous epithelium, that is similar to, and continuous with, that of the ectocervix (Fig. 111).

The **muscular layer** the vaginal wall is composed of smooth muscle arranged in two layers, a thick outer longitudinal and an inner circular layer. These two layer are not distinct, being connected by oblique interlacing fibers.

The longitudinal fibers are continuous with the superficial muscle fibers of the uterus. At the introitus there is a sphincter of skeletal muscle, the bulbospongiosus.

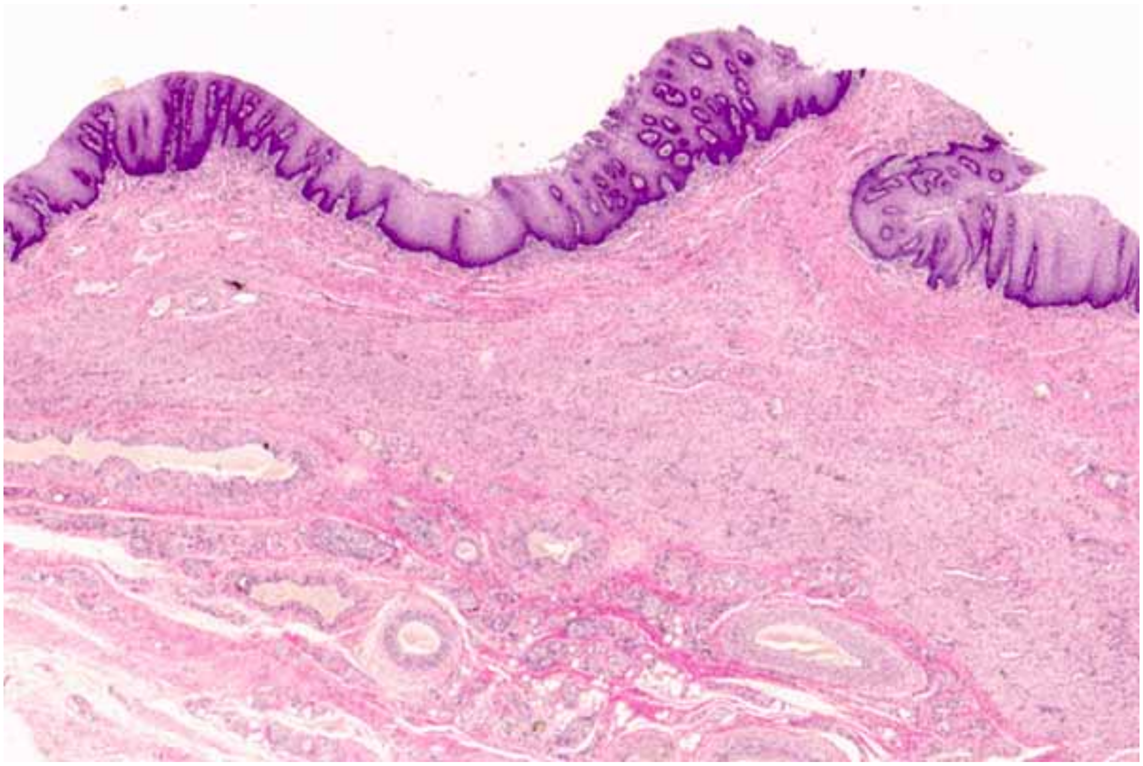


Fig. 111. This is a low power photomicrograph of the vaginal wall. Note the non-keratinizing stratified squamous epithelium lining the mucosa, directly beneath of which is the smooth muscles of the external muscular layer. The adventitial layer is seen in the lower left coroner. (www.siumed.edu)

The **adventitial layer** is external to the muscular layer. It has a high content of elastin which contributes to the elasticity of the vagina. This layer is of variable thickness and is an extension of the endopelvic fascia that provides support for all the pelvic organs.

The **arterial supply** to the vagina is derived from the **internal iliac arteries**. These vaginal arteries form two median longitudinal vessels, the **anterior and posterior azygos arteries,** one of which descends anteriorly to the vaginal wall and the other to posterior wall. They supply both the muscular layer and the mucosal layer. The **uterine, internal pudendal** and **middle rectal**

arteries of the internal iliac artery may also make a contribution to the blood supply to the vagina (Fig. 112).

The **vaginal veins** are two in number, one on each side of the vagina (Fig. 112). They form from a plexus of veins located along the sides of the vagina, which drain the mucosa and muscular layers. The two lateral vaginal veins connect with **uterine, vesicle,** and **rectal plexuses**, ultimately draining to the **internal iliac veins.**

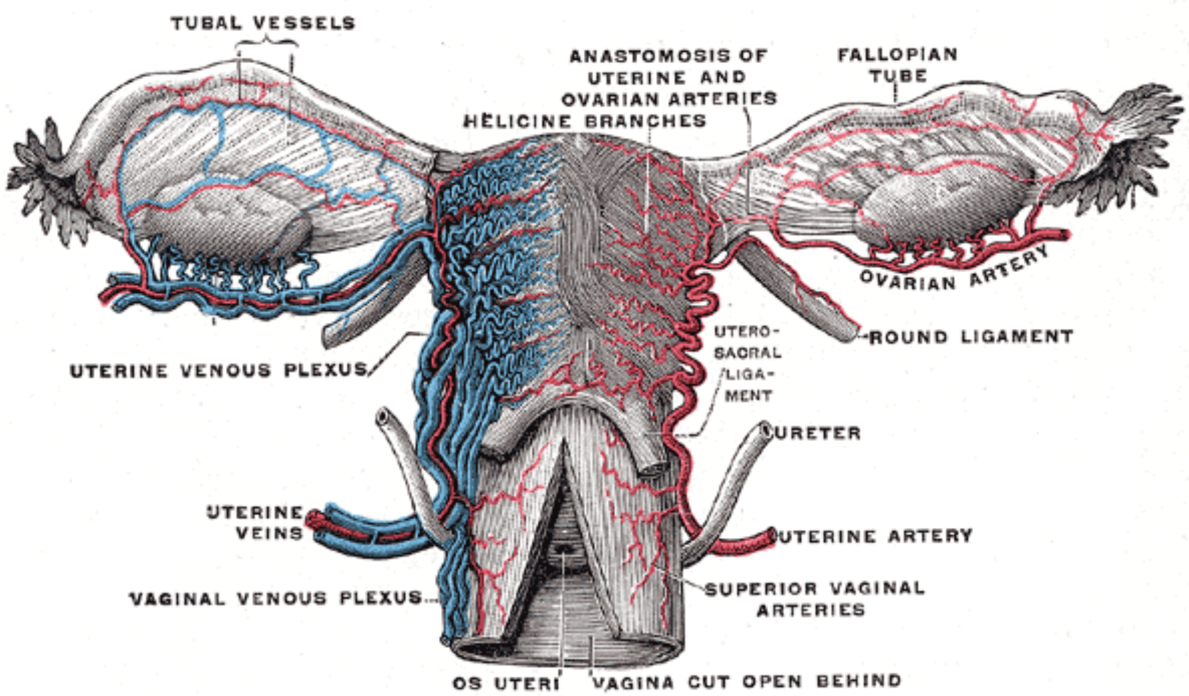


Fig. 112. This image depicts the arterial supply and venous drainage of the internal female reproductive organs. (Wiki)

The **lymphatic drainage** of the vagina is divided into three groups: Those from the superior part accompany the uterine artery and drain into the **internal and external iliac nodes**; those from the middle part accompany the vaginal arteries and drain into the **internal iliac nodes**; and those draining the vagina below the hymen, and from the vulva and perineal skin, drain to the **superficial inguinal nodes**.

Part of the **innervation** of the vagina is derived from vaginal nerves taking their origin from the **uterovaginal plexus** (Fig. 113). This plexus lies in the

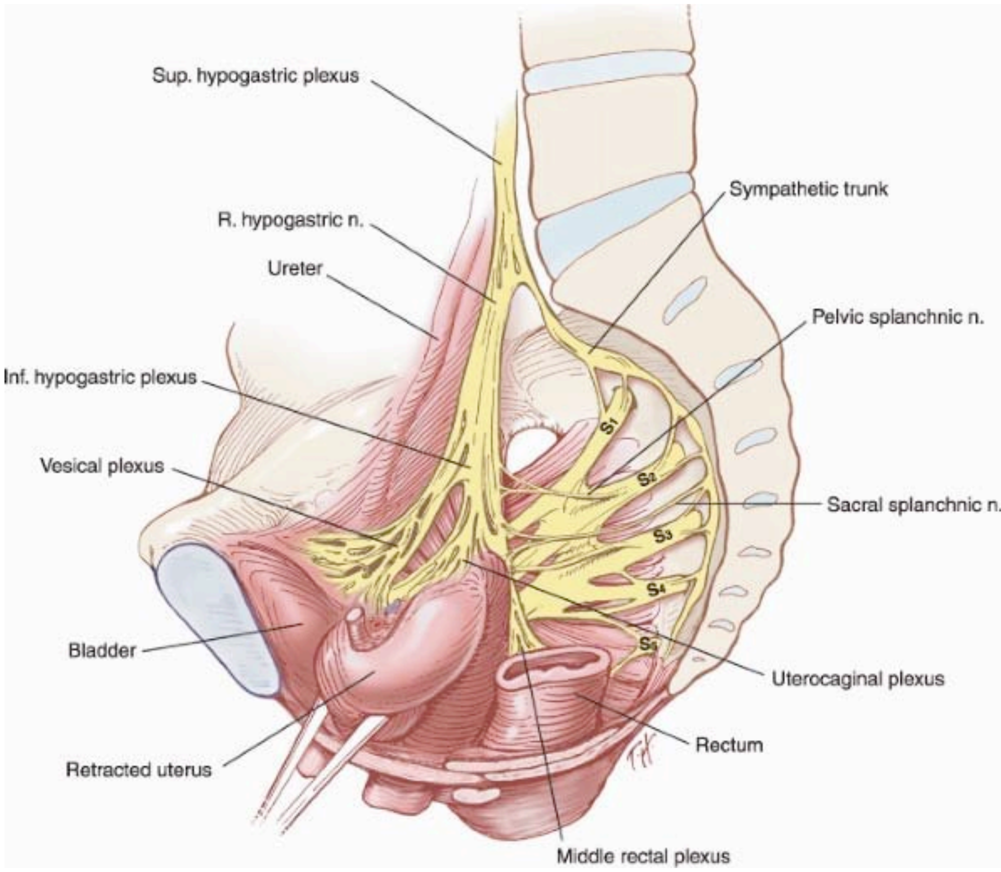


Fig. 113. This drawing shows the location and anatomic relationships between the inferior hypogastric plexus, vesical plexus, middle rectal plexus and the uterovaginal plexus. (www.epubbud.com)

base of the **broad ligament** on each side of the **supravaginal part of the cervix**. The **inferior nerve fibers** from this plexus supply the cervix and the superior part of the vagina.

The remaining upper part of the vagina is supplied by nerves derived from the **inferior hypogastric plexus** and the **pelvic splanchnic nerves**, originating in **spinal segments S2-S3**, and sometimes **S4** (Fig. 113).

The lower vagina is supplied by the **pudendal nerve**, the fibers of which originate in **spinal segments S2-S4** (Fig. 113).

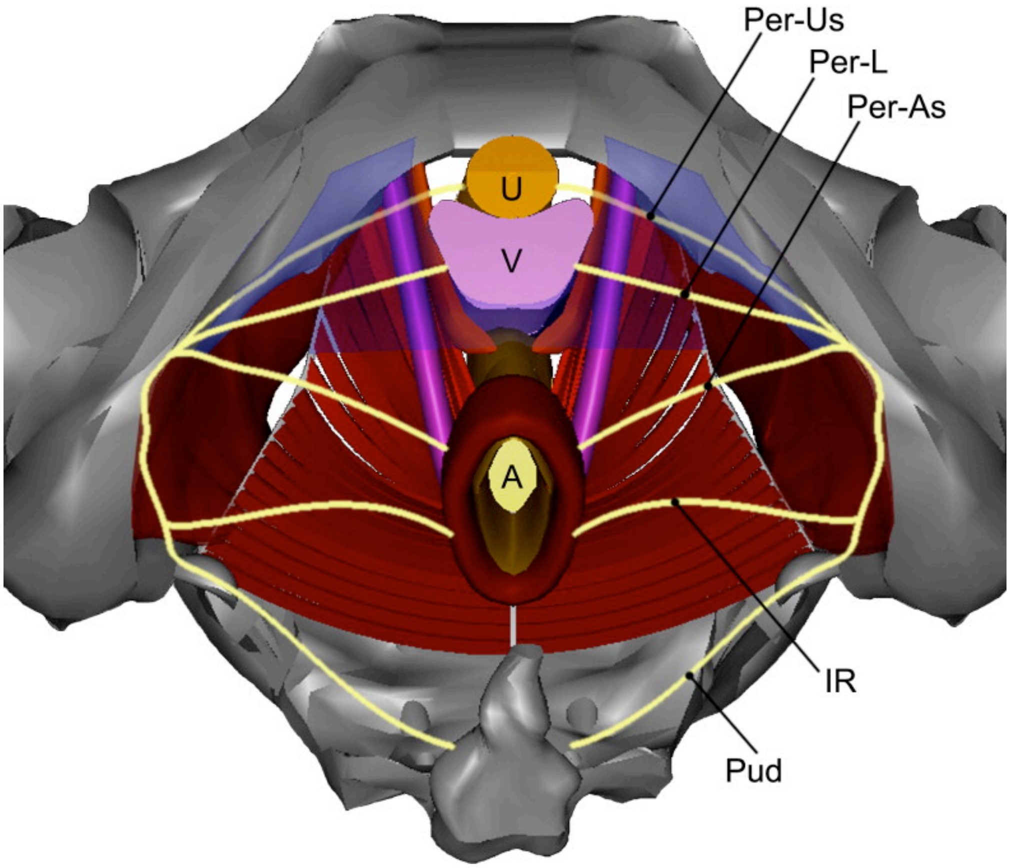


Fig. 114. This image is the inferior view of the pudendal branches and muscular structures of the female pelvic floor. The urethra (umbra), vagina (pink), rectum (light brown), and external anal sphincter (maroon) are shown. Branches of the pudendal nerve (Pud) are also shown: the inferior rectal nerve (IR), the muscular branch of the perineal nerve innervating the external anal sphincter (Per-AS), the posterior labial branch (Per-L), and the muscular branch of the perineal nerve innervating the urethral sphincter (Per-US). The red band-like structures represent the levator ani muscle; the purple band, the puborectal muscle and the semitransparent blue structure represents the perineal membrane. (sciencedirect.com)

Sympathetic impulses produce contraction of the vaginal smooth muscle and the bulbospongious as would occur during intercourse. They also constrict the smooth muscles of the of the arteries and arterioles. Sympathetic nerve fibers arise from **T1-L2** and accompany **sacral nerves of the hypogastric plexus**. The chief importance of the vaginal **parasympathetic fibers** is to mediate sexual response in the lower portion of the vagina. The parasympathetic nerve fibers are derived from **S2-S4** and are found in the **pudendal nerve** and in the **inferior hypogastric plexus**.

The **somatic nerve supply** is mainly to the lower portion of the vagina. **Efferent (motor) somatic supply** is not significant in the vaginal wall since there is no striated muscle. However, there is efferent supply, primarily from the **pudendal nerve**, which controls the **levator ani muscles** that support, and influence function of the lower third of the vagina.

Afferent or sensory supply of the lower ⅔ of the vagina is through the pudendal nerve. Visceral nerve supply is significant for the upper ⅓ muscles and glands. All pelvic visceral nerve fibers course in the endopelvic fascia beneath the pelvic parietal peritoneum. These nerves arise from the **inferior hypogastric plexus**, which has three divisions. One division is the **uterovaginal plexus (Frankenhausen's plexus-mainly consisting of S2-S4)** around the ureter and uterine artery. Fibers from the uterovaginal plexus accompany the vaginal artery and vein to the vagina (Fig. 113). Afferent fibers transmit interoceptive, noxious stimuli from the peritoneum at the **pouch of Douglas**, and from the **cervix** and **upper ⅓ of the vagina to nerve roots S2-S4.**

(b). Uterus: The uterus is a hallow, thick-walled, pear-shaped muscular organ located between the bladder and the rectum in non-pregnant women. The uterus is 7-8 cm long, 5-7 cm wide, and 2-3 cm thick. It is mainly horizontal in orientation, its vesical, or under surface resting on the urinary bladder. Its more rounded intestinal surface faces the cavity of the pelvis and is frequently in contact with the loops of the small bowel. The uterus is not straight, being usually bent anteriorly between the body and cervix; this anterior bending is referred to as **anteflexion**. In anteflexion the mouth of the cervix is pointed directly into the lumen of the vagina. There is another position of the uterus in which its body is bent anteriorly, however the **endocervical canal** forms an an angle with the lumen of the vagina of 90-110 °, this is referred to as **ante-version.** In older women the uterus is typically inclined posteriorly, that is tilted backward, which is referred to as **retroversion**. In retroversion the mouth of the cervix is pointed posteriorly. Lastly, the body of the uterus may be bent posteriorly relative to the cervix thus, forming a sharp angle at the point of bending, which is also referred to as **retroflexion** (Fig. 115). In retroflexion the mouth of the cervix is in normal position, which is due to the sharp angle.

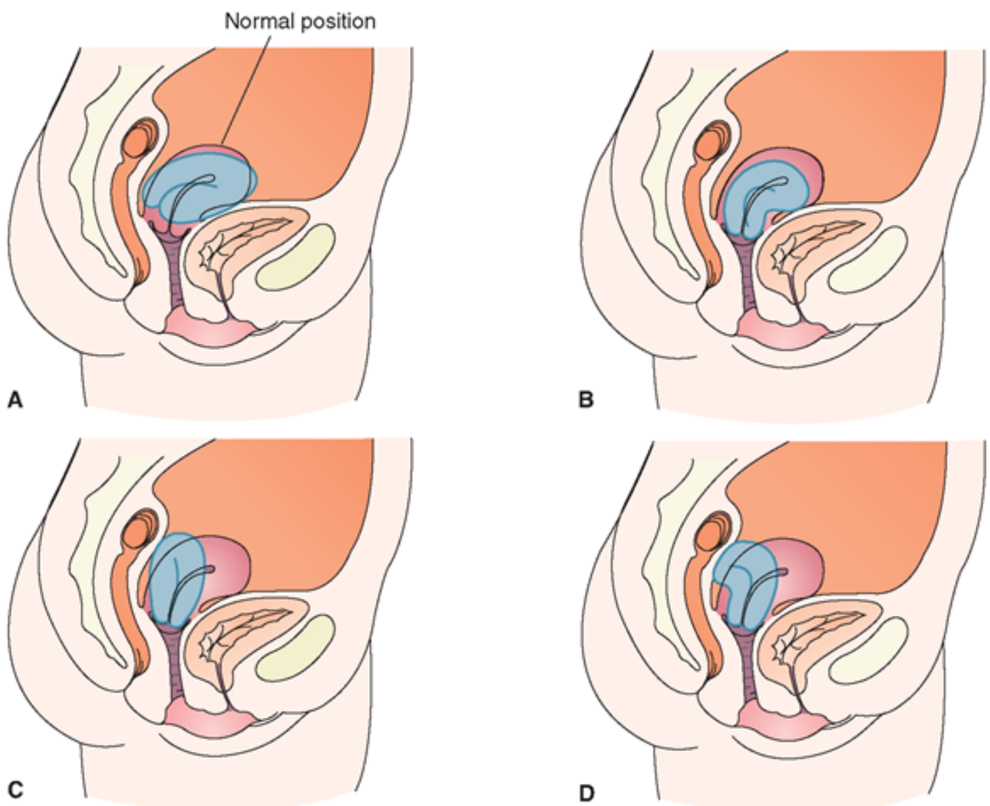


Fig. 115. This figure shows the variations in uterine positions. (A), anteversion; (B), anteflexion; (C), retroversion; and (D), retroflexion. (what-when-how.com)

The uterus is, however, readily displaced upward by elevation of the superior surface of the bladder as urine accumulates, so that angles and relationships change constantly. The uterus can be divided into two main anatomic regions: the **body (corpus uteri)**, which forms the upper two-thirds, and the **cervix (cervix uteri)**, which forms the lower-third. The portion of the body of the uterus, which is above a line joining the points of entrance of the two **uterine**

tubes is called the **fundus (rounded superior part of the body)** (Fig. 116). The regions of the body where the uterine tubes enter are called the **cornua (lateral horns of the uterus)**. Below and anterior to the end of the uterine tubes is where the **round ligament** is attached to the uterus. The round ligaments are 10-12 cm long and leave the abdominal cavity through the **inguinal canal** and insert into the **labia majora**. Behind the point where the uterine tubes enter the uterus is where the **ovarian ligaments** are attached.

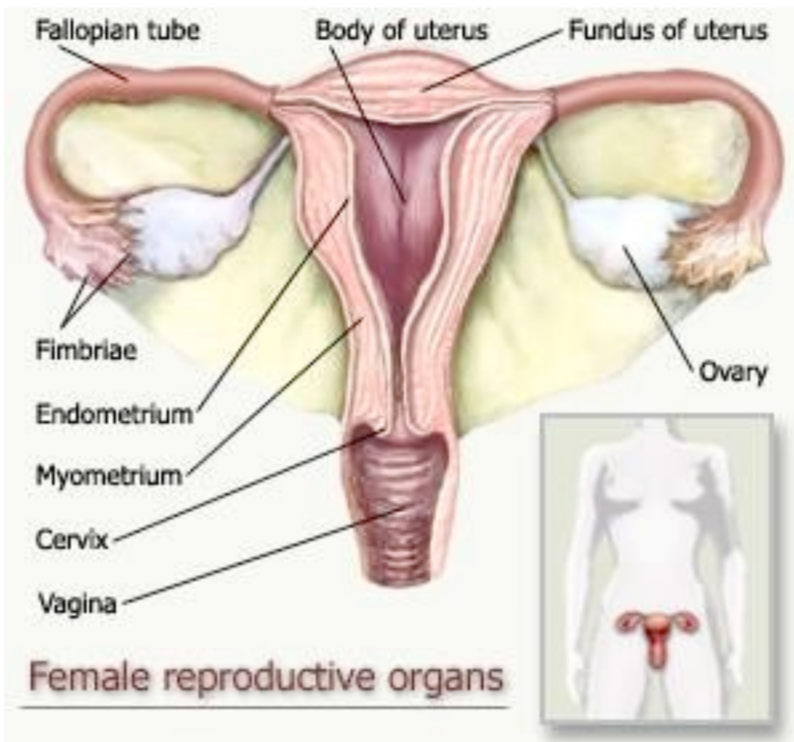


Fig. 116. This figure depicts the anatomy of the female reproductive organs including the body and fundus of the uterus. (natural-fertility-info.com)

The body of the uterus narrows superiorly to inferiorly. The lateral borders of the body is where the **broad ligaments** are attached, which extend from the sides of the uterus to the lateral walls and floor of the pelvis (Fig. 117).

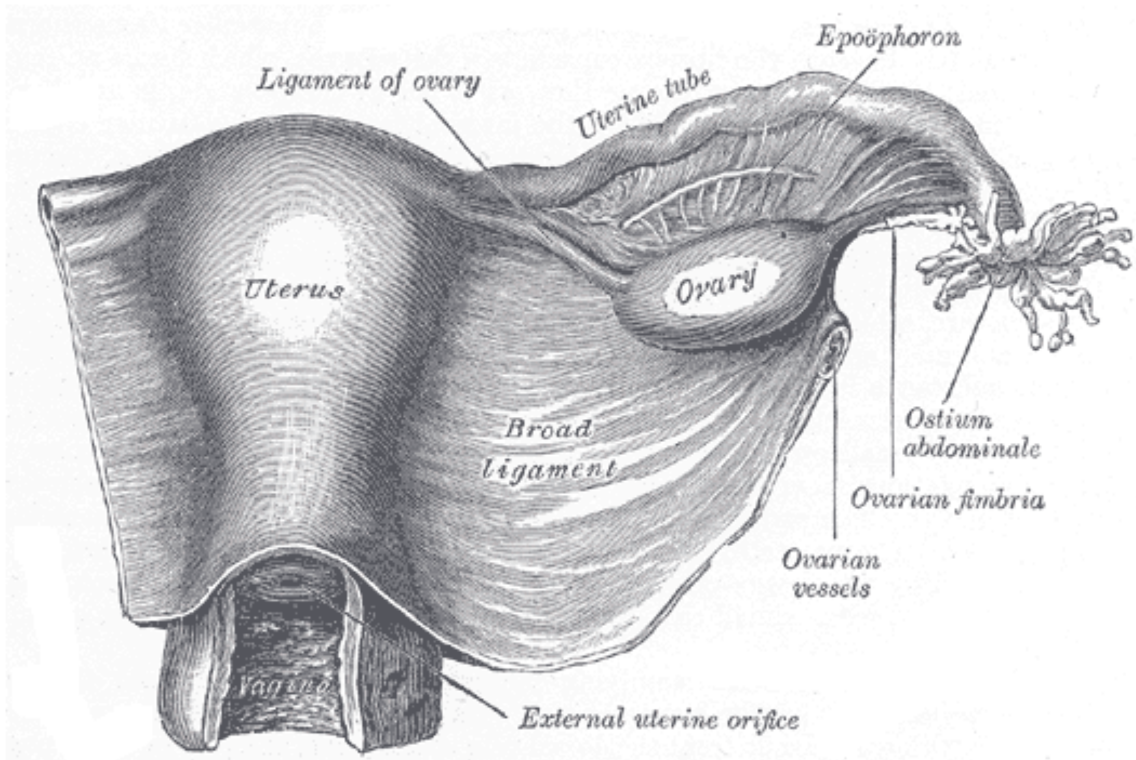


Fig. 117. This figure shows the uterus and right broad ligament from behind (Broad ligament visible at the center). The ligament of ovary (also called the utero-ovarian ligament or proper ovarian ligament) is a fibrous ligament that connects the ovary to the lateral surface of the uterus. This ligament should not be confused with the suspensory ligament at the ovary, which extends from the ovary in the opposite direction. The suspensory ligament, not labeled, surrounds the ovarian vessels. (Wiki)

The **ovarian ligament** lies posterosuperiorly (Fig. 117) and the **round ligament** of the uterus lies anteroinferiorly within the broad ligament (Figs. 118 & 119). The broad ligaments hold the uterus in its normal position.

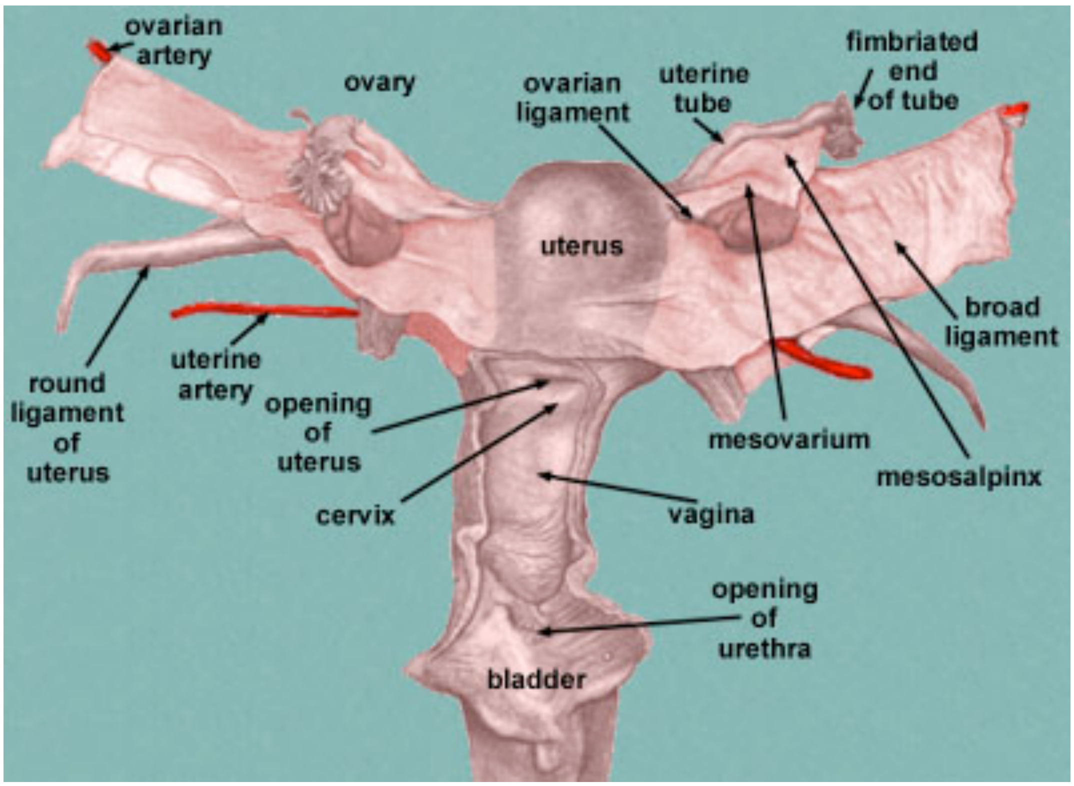


Fig. 118. This image depicts the reproductive organs of the female along with the various ligaments. The uterus is held to the lateral walls of the true pelvis by a double layer of peritoneum, called the broad ligament. The broad ligament encloses the uterine tube in its upper free border, the ovarian artery, the round ligament of the uterus, uterine artery, ovary, and the ovarian ligament. (home.comcast.net)

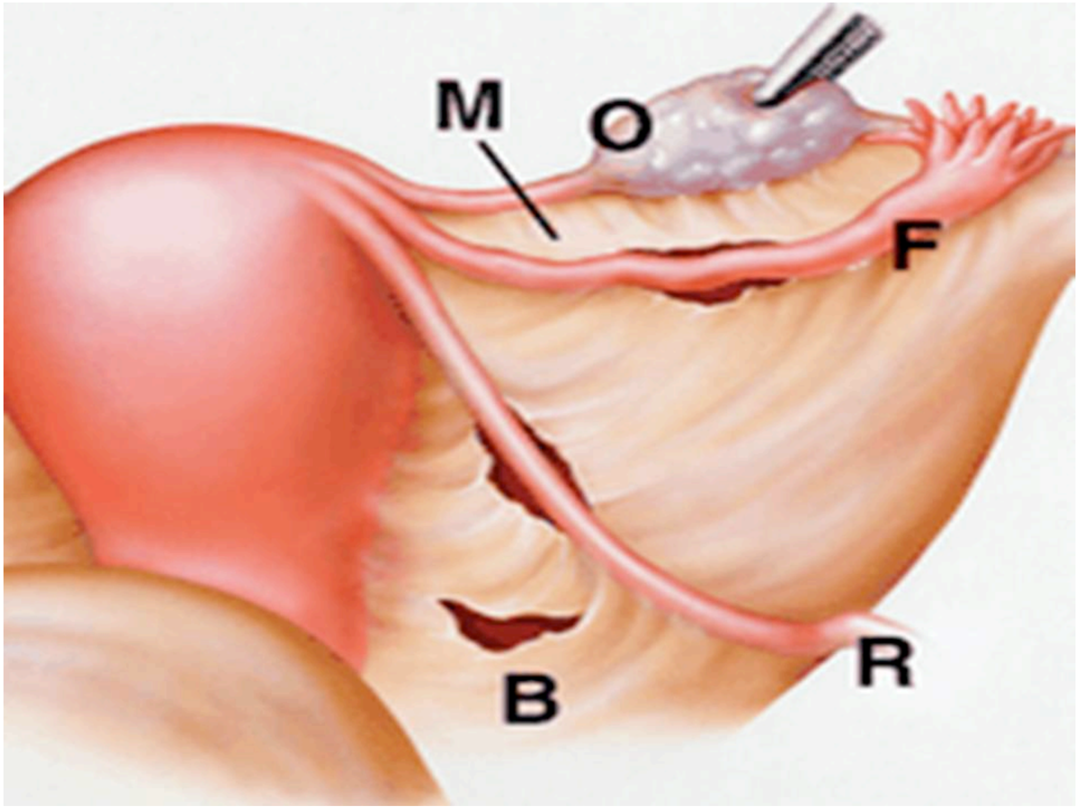


Fig. 119. This is an image taken of the uterus from the back (posteriorly). M, mesosalpinx; O, ovary; F, fallopian tube (uterine tube); B, board ligament; and R, round ligament. (radiographics.highwire.org)

Inferiorly, the body of the uterus joins with the **isthmus** which is a 1 cm long narrow transitional zone between the **body** and **cervix** (Fig. 120). This constricted region is most obvious in **nulliparous women (never given birth to a viable infant)**. This region was referred to as the **upper cervix** in the older literature.

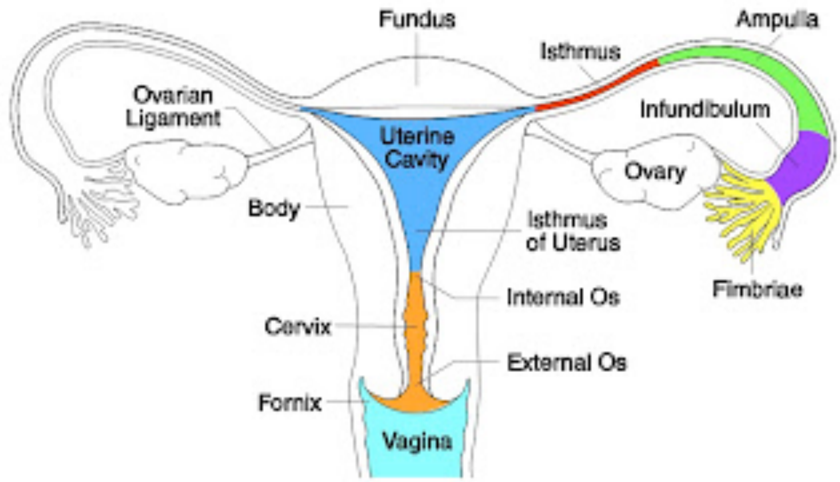


Fig. 120. This image shows the reproductive organs of the female including the location of the isthmus of the uterus. (medicinembbs.blogspot.com)

The cavity of the body of the uterus is about 6 cm long, measured from the **external os** of the **cervix** to the wall of the **fundus** (Fig. 120). In its anterioposterior dimension it is flat and slit-like. In the coronal section (mediolateral) it is triangular.

The **cervix**, or neck of the uterus, is its tapered vaginal end. It is approximately 2-2.5 cm long and nearly cylindrical. On its external surface the vagina attaches to the cervix along an oblique line, dividing the cervix into a **supravaginal** and **vaginal parts** (Fig. 120 & 121). The supravaginal portion is separated from the bladder and adjacent lateral structures by fibrous connective tissue. The vaginal portion projects into the anterior wall of the vagina.

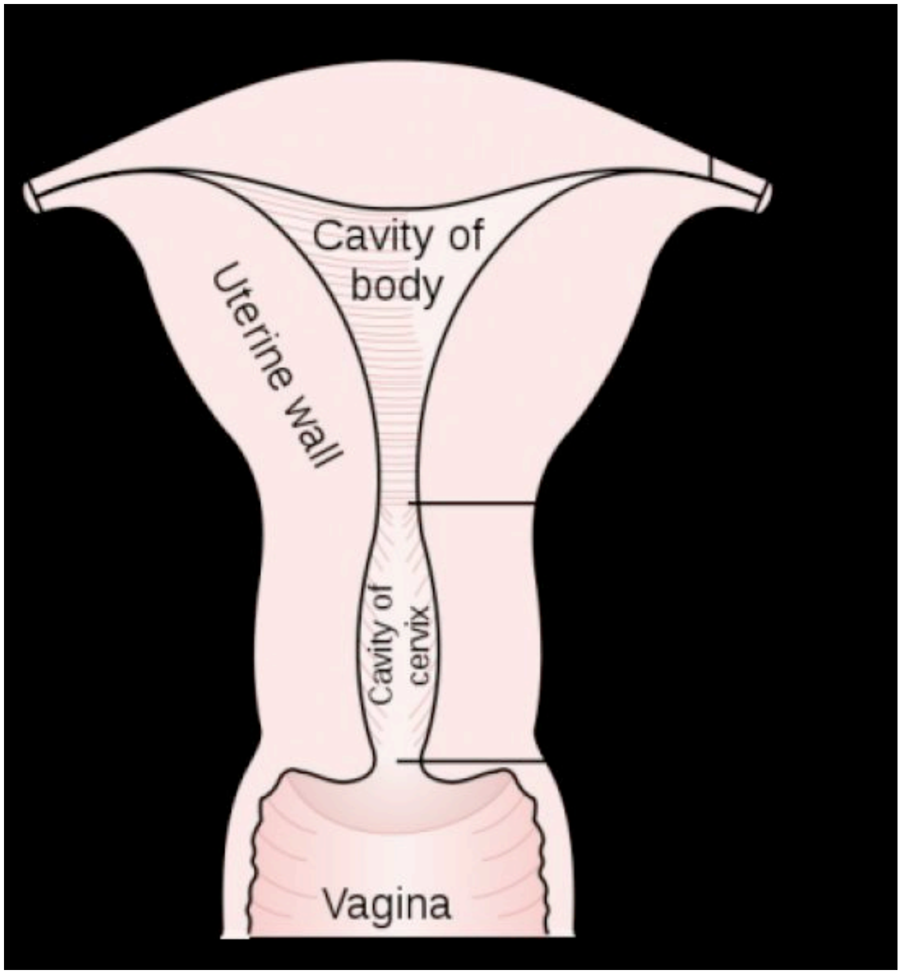


Fig. 121. The supravaginal portion of the cervix is fundamentally between the two horizontal lines, the upper denoting the internal os of the cervix and the lower the external os. The vaginal portion is below the lower horizontal line. (websters-online-dictionary.org)

The cavity of the cervix communicates with the cavity of the uterus through the **internal os** and the lower end communicates with the cavity of the vagina the **external os** (Fig. 120).

The cervix also has attached ligaments. The **transverse cervical ligament (cardinal ligament, ligaments of Mackenrodt's)** extend from the cervix and lateral parts of the vaginal fornix to the lateral walls of the pelvis (Fig. 122).

In some of the literature these ligaments are regarded as important supporting elements of the uterus. However, there is other literature, which suggest these ligaments are no more than the connective tissue around the uterine blood vessels.

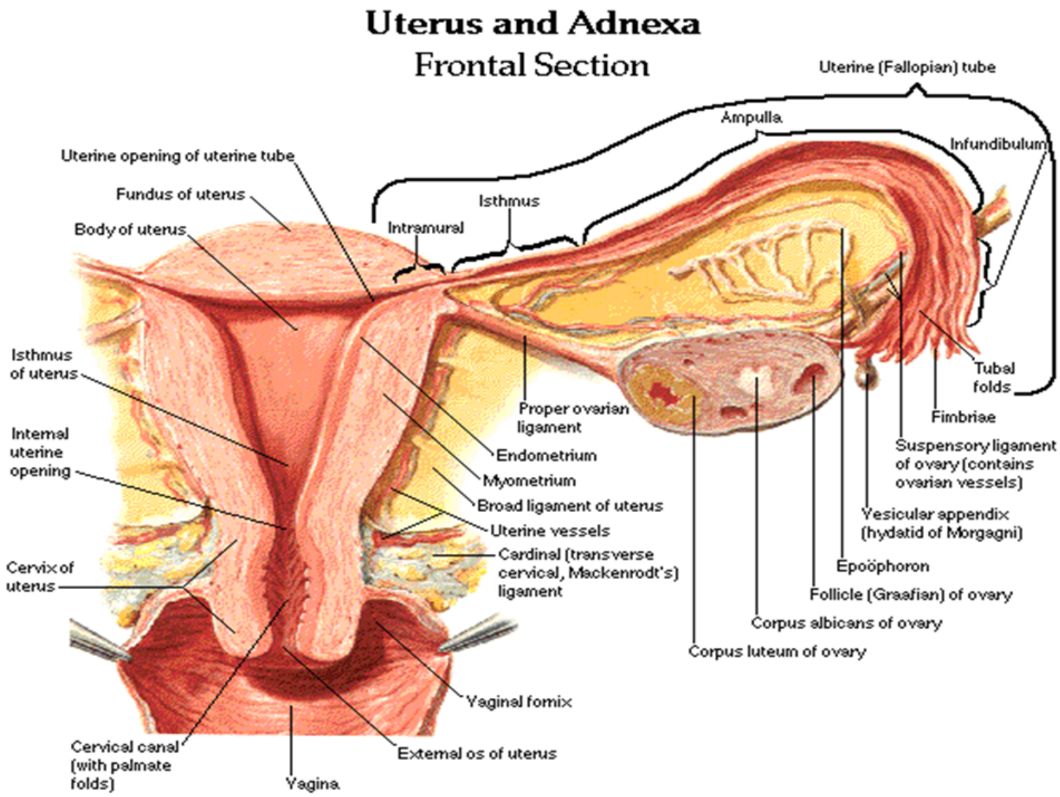


Fig. 122. This image is an anterior (frontal) view of the reproductive organs of the female depicting the Cardinal (transverse cervical, Mackenrodt's) ligaments. (zimbio.com)

The **uterosacral ligaments (rectouterine ligaments)** contain both fibrous tissue and smooth muscle. They pass posteriorly (backward) and superiorly from the sides of the cervix and the body of the uterus on both sides of the rectum and attach to the middle of the sacrum (Fig. 123). When a woman is standing, these ligaments are almost vertically oriented. These ligaments are deep to the peritoneum and superior to the **levator ani muscles**. They tend to hold the cervix in its normal relationship to the sacrum.

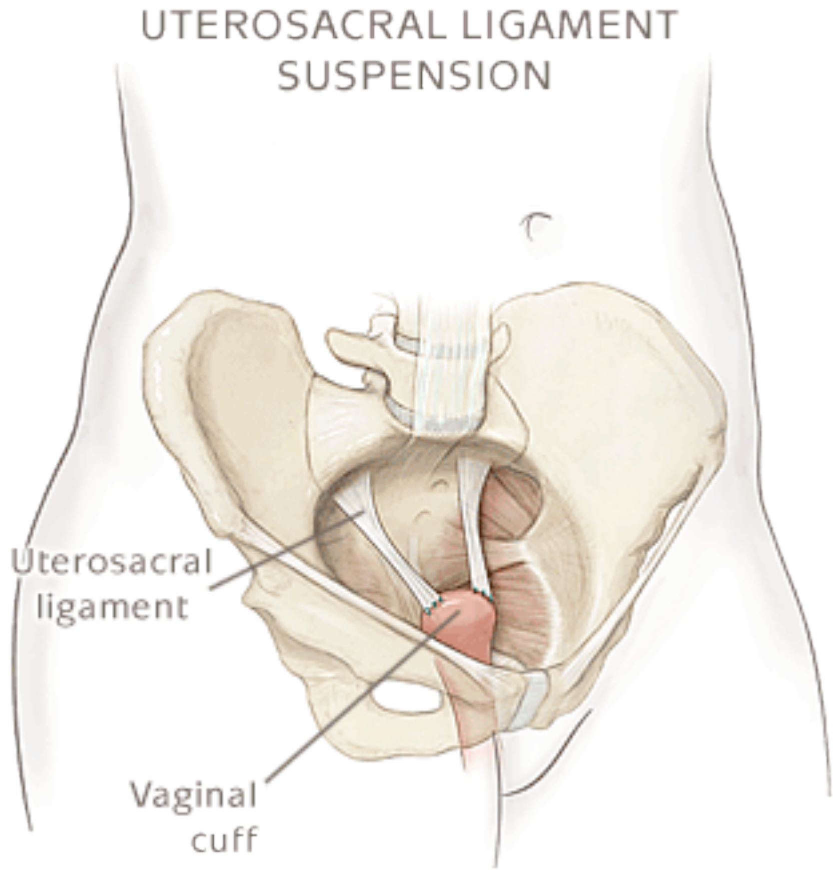


Fig. 123. This image shows the location of the uterosacral ligaments. (wvahealth.com)

The **pubocervical ligament** passes forward from the anterior aspect of the cervix and upper vagina to diverge around the urethra. These fibers attach to the posterior aspect of the pubic bone Fig. 108, p 131 & Figs. 124 & 125). The collagen in the pubocervical ligaments, if reduced, may lead to vaginal prolapse.

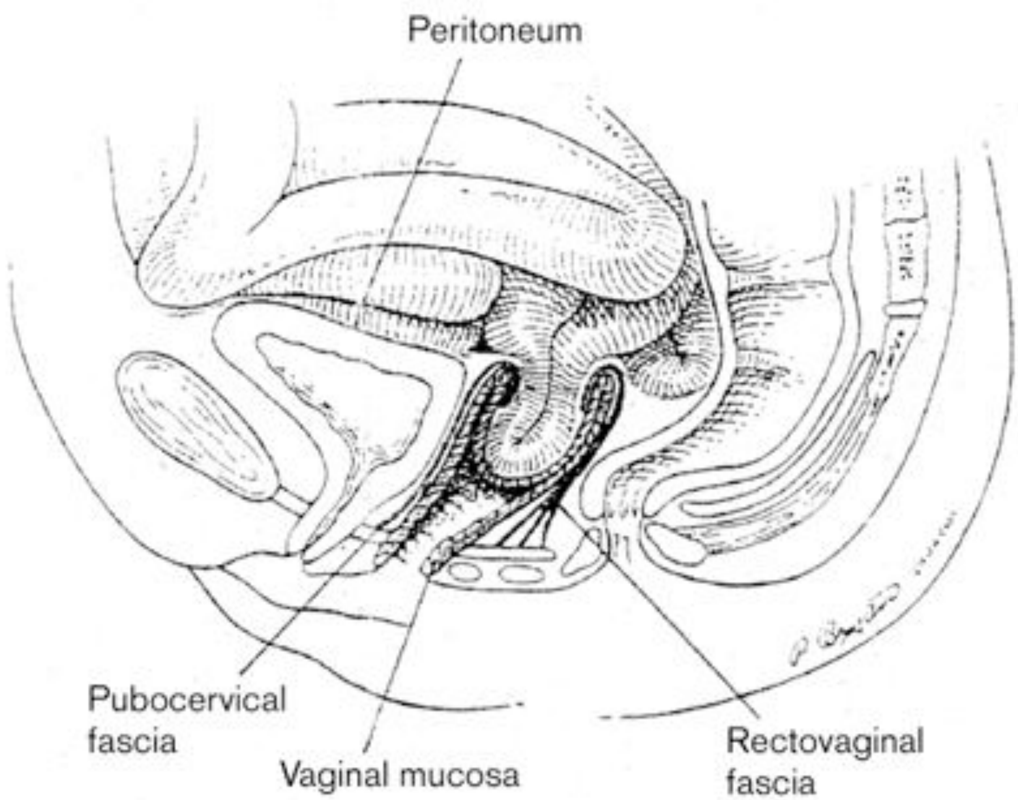


Fig. 124. This image shows the location of the **pubocervical** fascia and ligament as well as the rectovaginal fascia. (obgynundip.com)

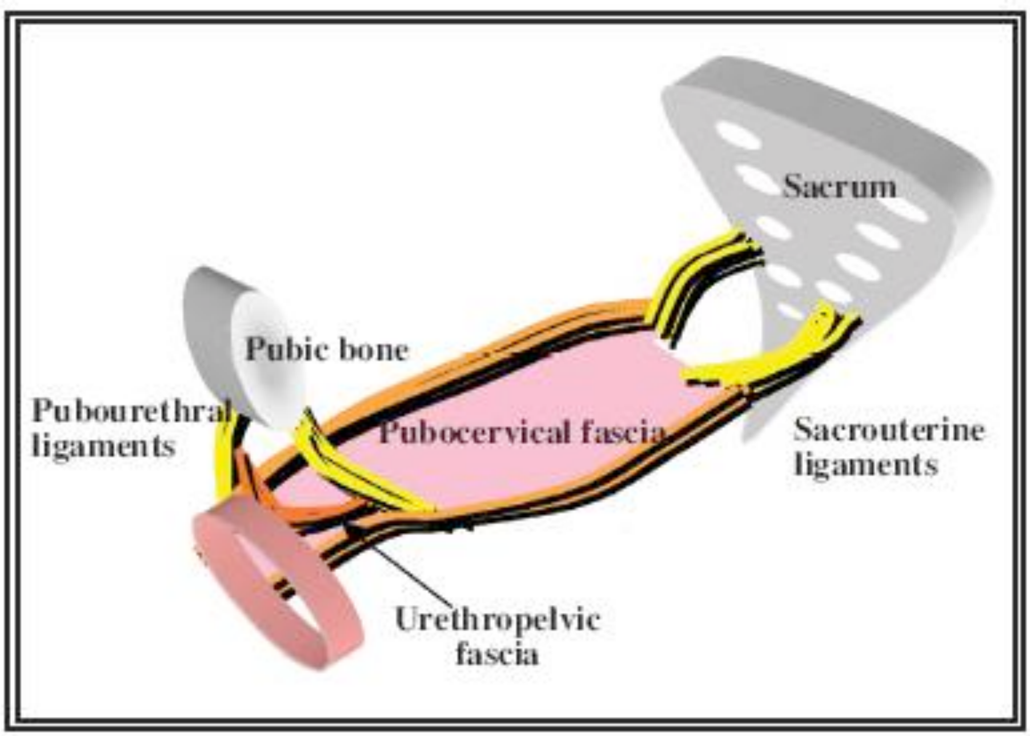


Fig. 125. The above figure depicts another view of the location of the pubocervical fascia and thus, pubocervical ligament and their relationships with the sacrouterine ligaments, urethropelvic fascia and pubourethral ligaments. (actasurologicas.info)

The principle supports of the uterus are the **pelvic floor,** formed by the **pelvic diaphragm**, and the **pelvic viscera** surrounding the uterus and the **visceral fascia (endopelvic fascia),** which bind the viscera together. In addition, the two **levator ani muscles,** the **coccygeus muscles,** the muscles of the **urogenital diaphragm** and the **perineal body** which serves as a central attachment for the **perineal muscles**, are also important in supporting the uterus (Figs. 43, 47, 50, 69, 106 & 107, p 49, 55, 60, 81, 129 & 130, & Figs. 126 &127).

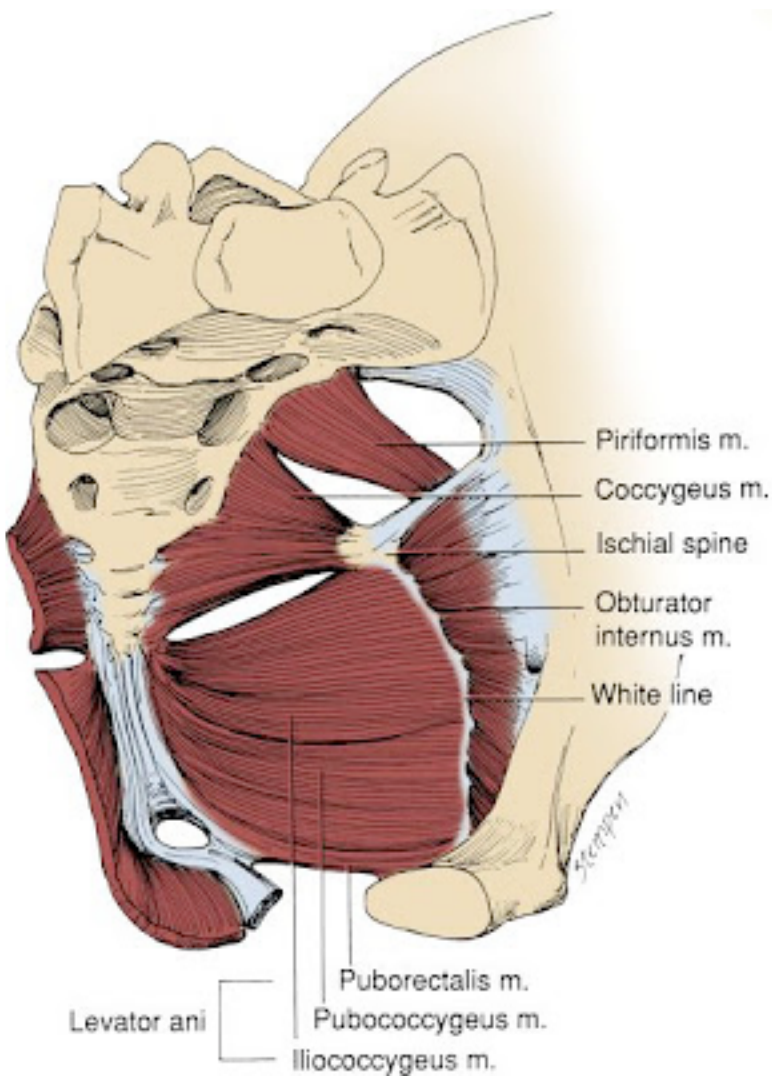


Fig. 126. The above image depicts the contribution of the levator ani, piriformis, coccygeus and obturator internus muscles to the support of the pelvic floor.
The levator ani functions as a unit but is described in two main parts: the diaphragmatic part (coccygeus and iliococcygeus muscles) and the pubovesical part (pubococcygeus and puborectalis muscles). (uronotes2012.blogspot.com)

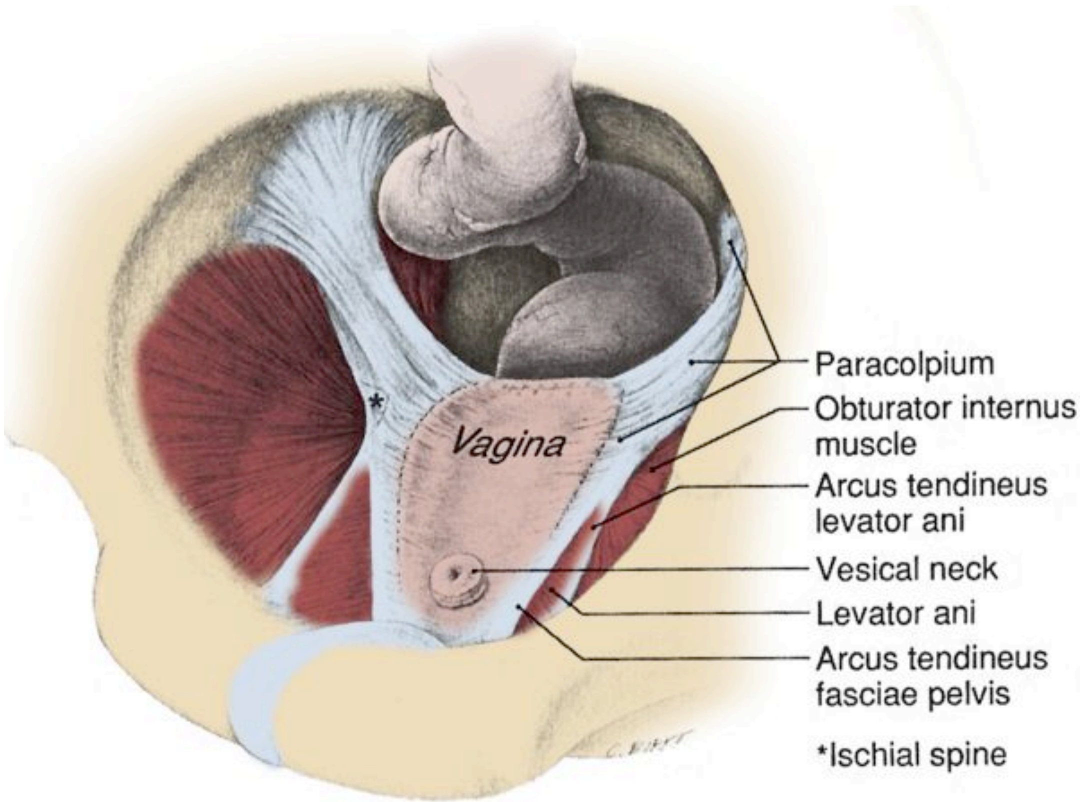


Fig. 127. This image provides a view of the function of the pelvic ligaments and fascia. The pelvic ligaments and fascia serve mainly to keep structures in positions where they can be supported by the muscular activity rather than as weight bearing structures themselves. The lose of normal muscular support leads to sagging and widening of the urogenital hiatus and predisposes patients to developing prolapse.
Pelvic ligaments and endopelvic fascia attach the uterus and vagina to the pelvic side walls so these structures can be supported by the muscles of the pelvic floor.
The entire complex then rests on the levator plate, where it can be closed by increases in intra-abdominal pressure by a “flap-valve” effect. (uronotes2012.blogspot.com)

When a women is standing the uterus lies directly on the superior surface of the bladder, and the cervix and the upper vagina are supported below and behind by the ampulla of the rectum. Although the above described ligaments provide some measure of support for the uterus, their primary function is one of maintaining orientation.

The relationships of the uterus are such that **anteriorly**, the body of the uterus is separated from the urinary bladder by the **vesicouterine pouch (pouch of Meiring or Dunn's pouch)** (Fig. 60, p 71 & 72, & Fig. 82, p 103, Fig. 105, p 127 & 128). Here the peritoneum is reflected from the uterus onto the posterior margin of the superior surface of the bladder. **Posteriorly**, the body of the uterus and supravaginal portion of the cervix are separated from the sigmoid colon by a layer of peritoneum and the peritoneal cavity. The uterus is separated from rectum by the **rectouterine pouch (pouch of Douglas)** (Figs. 82, 104 & 105, p 103, 127 & 128). The inferior part of this pouch is closely related to the posterior part of the fornix of the vagina. **Laterally,** the ureter is crossed superiorly by the **uterine artery** at the sides of the cervix.

Microscopically, the uterus consist of three layers: the **outer layer** referred to as the **serosa** or **perimetrium**; the **middle layer**, the **muscularis**, or **myometrium**; and the **inner layer**, the **mucosa**, or **endometrium** (Fig. 128).

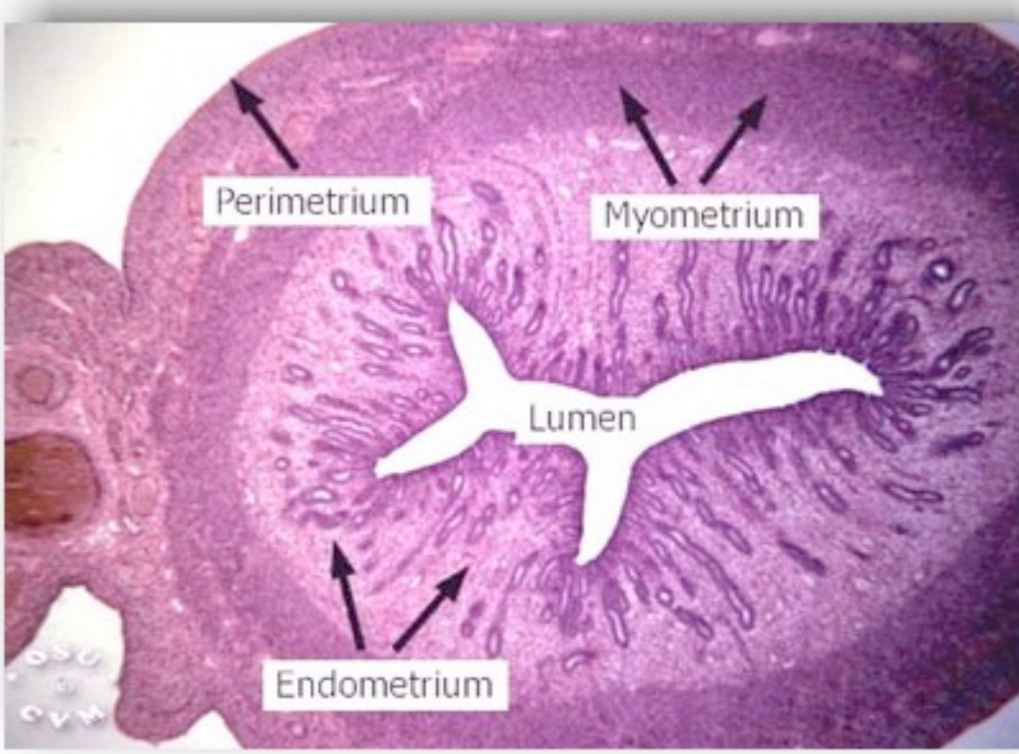


Fig. 128. The above is a low power photomicrograph of a uterus. The endometrium faces the lumen; the myometrium consist of an outer wall of smooth muscle; and the perimetrium is the outer wall of connective tissue that faces the pelvic cavity. (w3.ouhsc.edu)

The **perimetrium** is a typical serosa (peritoneum) consisting of a single layer of mesothelial cells supported by a thin layer of connective tissue. It is continuous on each side of the organ with the peritoneum of the **broad ligament** and is deficient over the lower half of the anterior surface, where the urinary bladder abuts. Posteriorly, it continues downwards to cover the supravaginal cervix.

The **myometrium** consist of smooth muscle and connective tissue with blood vessels, lymphatics, and nerves measuring about 12-15 mm in thickness. The muscle fibers are arranged in bundles, separated by connective tissue. In the non-pregnant state the smooth muscle fibers measure about 40-90 µm in length. In the pregnant state the muscle fibers greatly increase in size and may reach a length of 600 µm or more. There are three layers of smooth muscle, as well as ill-defined interconnecting bundles: an inner muscular layer consisting mostly of longitudinally oriented fibers, referred to as the **stratum subvasculare**; the thick middle layer of circular and oblique muscle fibers with numerous blood vessels, referred to as the **stratum vasculare** (Fig. 129); and a thin longitudinal muscle layer immediately beneath the perimetrium, the **stratum suprvasculare**.

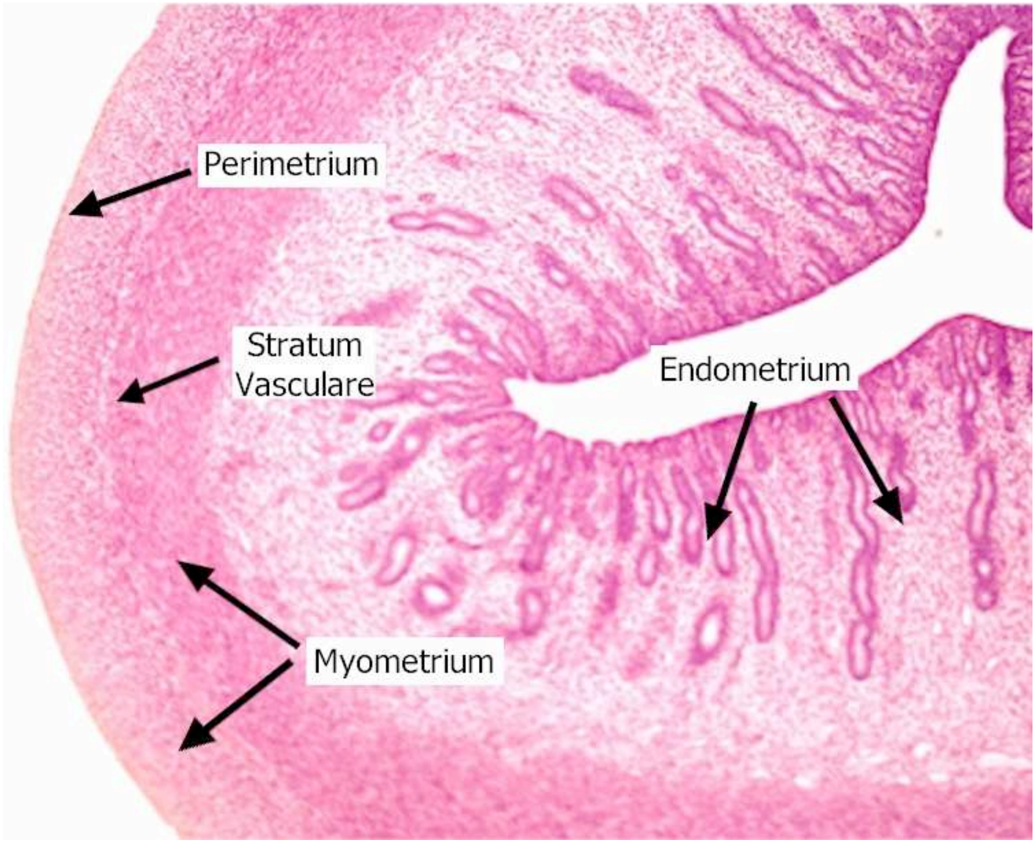


Fig. 129. This is a photomicrograph taken at a slightly higher power than Fig. 122. As in Fig. 122 it depicts the endometrium, myometrium and perimetrium. In addition, it shows the location of the stratum vasculare. (w3.ouhsc.edu)

The **endometrium (mucosa)** is firmly adherent to the underlying myometrium. It is subject to cyclic changes in response to ovarian secretory activity. These cyclic changes ultimately result in partial destruction of the mucosa leading to tissue necrosis and hemorrhage, which is referred to as **menstruation.** Menstruation typically occurs at intervals of about 28 days, although the intervals can vary from 21-35 days and usually lasts for 3-5 days. The first day of menstruation is counted as the first day of the cycle.

Before puberty, the endometrium is lined by **epithelial cells**, which are cuboidal in shape and ciliated (Figs. 130 & 131). After puberty, the endometrium has a lining of columnar epithelium (Fig. 130), which possess scattered groups of ciliated cells (Fig. 132). From this lining epithelium, uterine glands extend through the full thickness of the mucosa (Fig. 133).

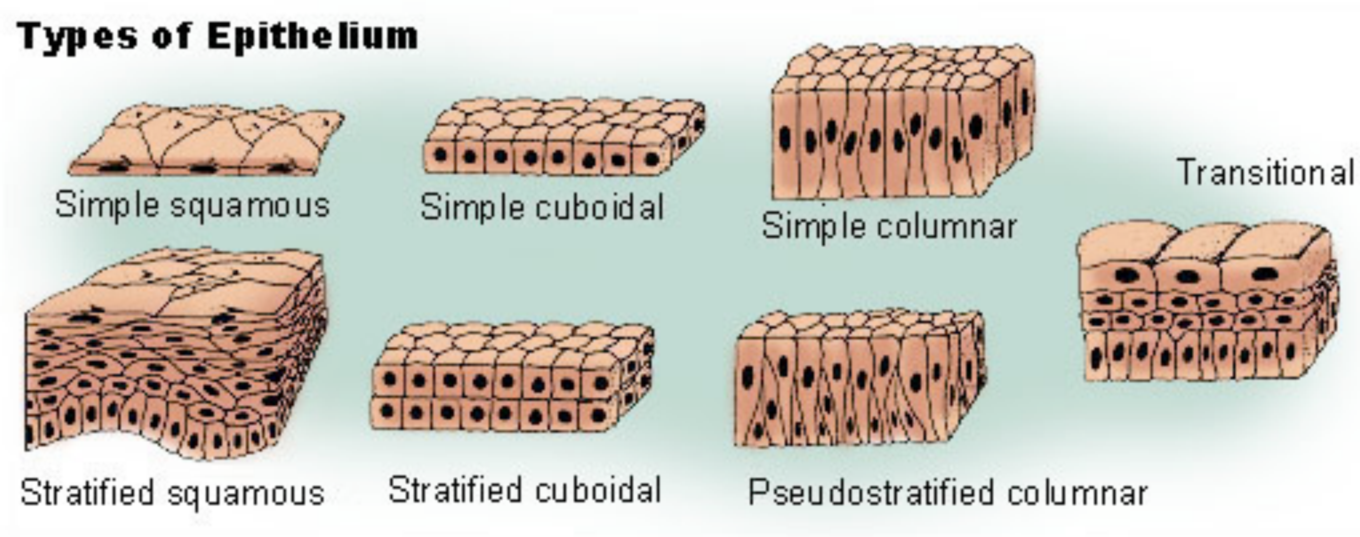


Fig. 130. This image shows the types of epithelial cells including simple cuboidal. (Wiki)

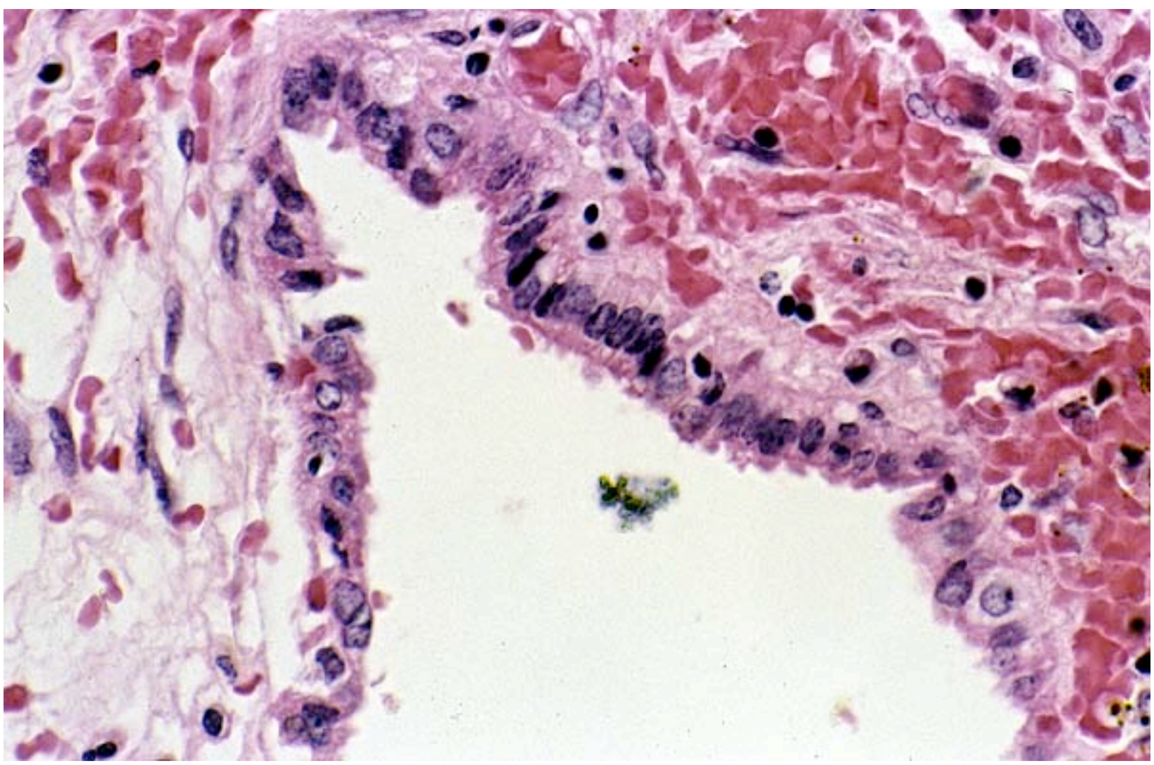


Fig. 131. This is an example of ciliated cuboidal epithelium. It is not however, from the cervix. (path.upmc.edu)

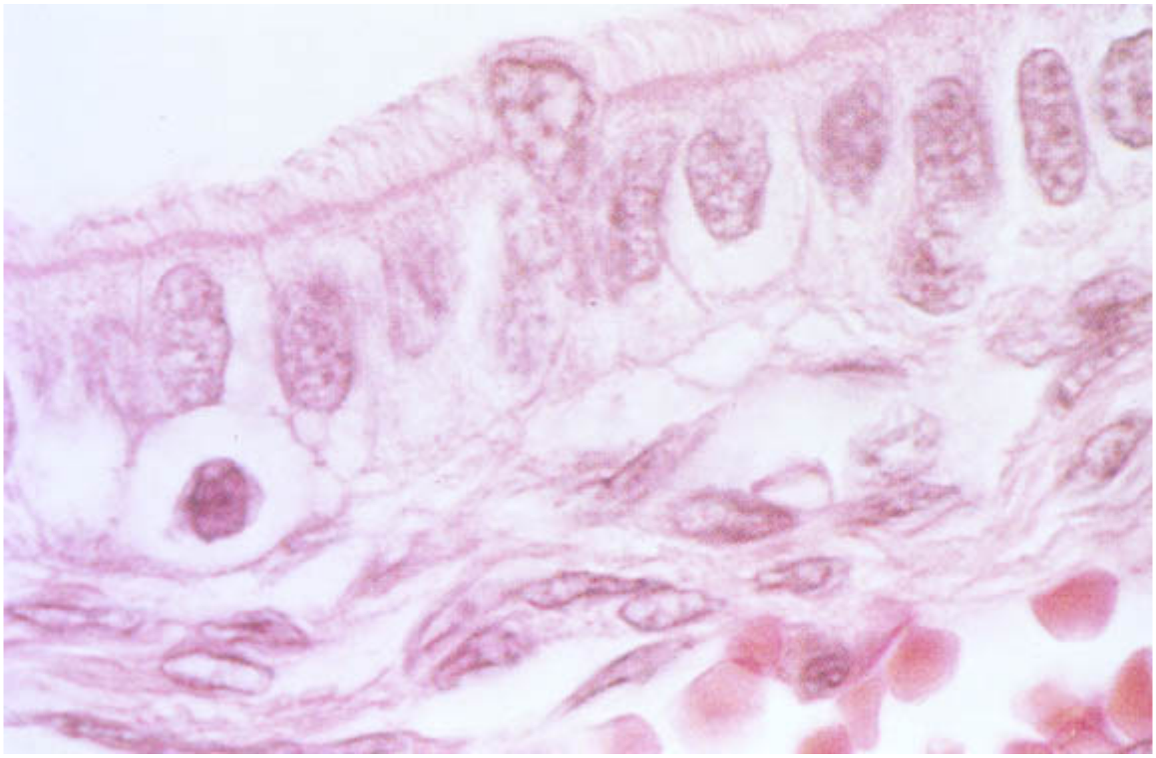


Fig. 132. This is an example of ciliated columnar epithelium. (pathology.mc.duke.edu)

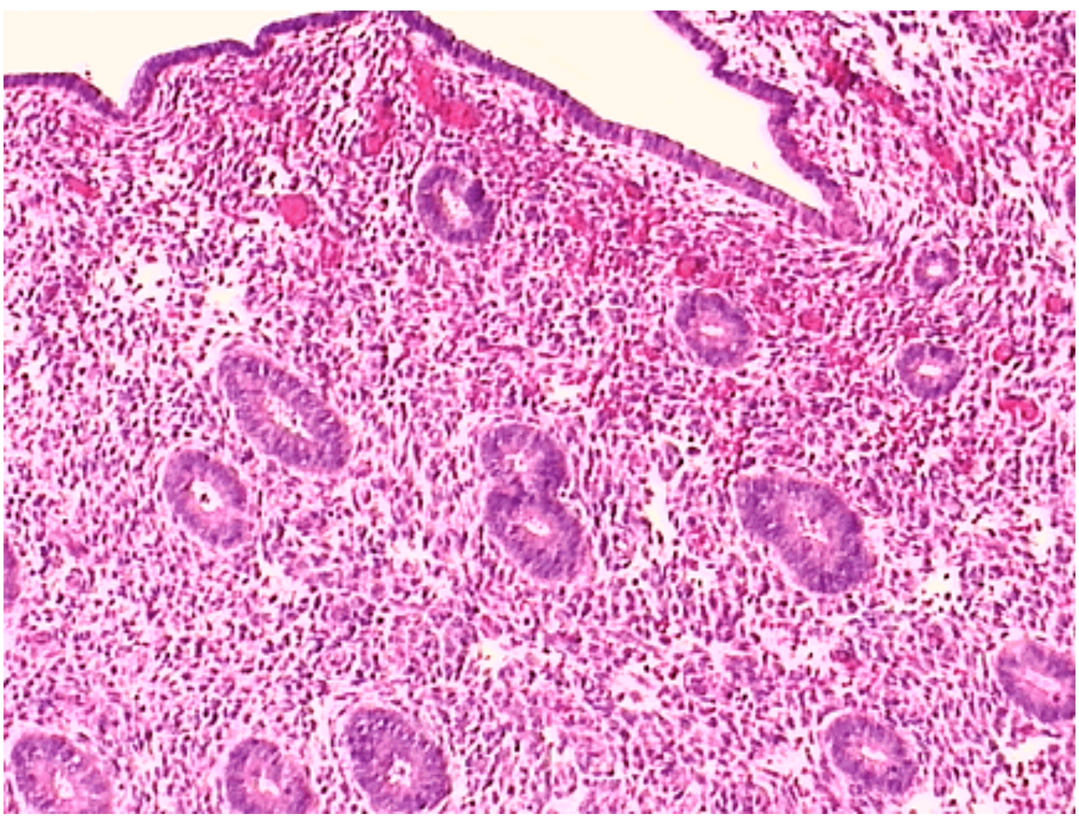


Fig. 133. The above is a photomicrograph of endometrium depicting simple columnar surface epithelium that is in continuity with the glandular epithelium. Note the abundant, very cellular stroma beneath and surrounding the epithelial tissue. (pathweb)

These glands are simple tubules, which may show branching toward their basal ends. They are separated from each other by connective tissue, called **stroma** (Fig. 134). The cells within this connective tissue are called **stromal cells**, which are irregular, stellate cells with large ovoid nuclei. They lie in a frame-work of reticular fibers, which are condensed beneath the epithelium to form a basal lamina. Scattered throughout the stroma are lymphoid cells and leukocytes.

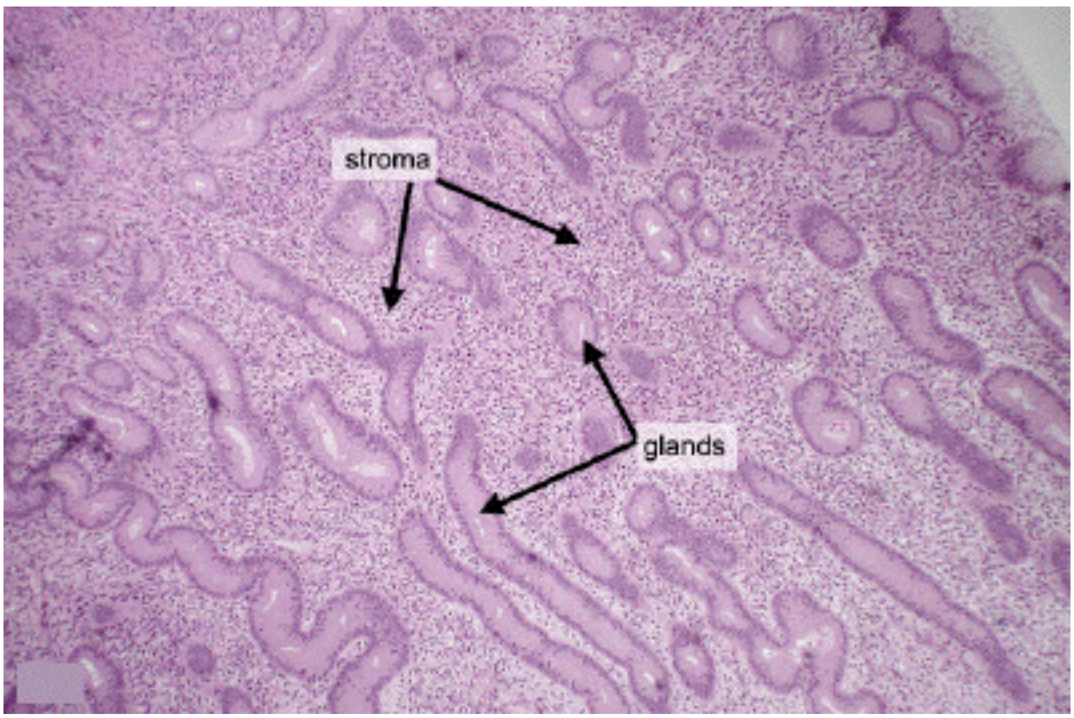


Fig.134. This is a photomicrograph of the endometrium demonstrating sections through the simple branched glands of the endometrium and the abundant stromal tissue surrounding them. Most of the glands exhibit a rather straight tubular morphology and have small, empty lumina. (www.darmouth.edu)

The **cervix** also has an inner **mucosa**, which consist of an epithelial lining resting on a connective tissue base called the **lamina propria**. The mucosa is about 2-3mm thick and contains branching folds, or furrows called **plicae**

palmatae, which appear as large, branching glands. The lining epithelium is varied. The **ectocervix** (more distal, by the vagina) is composed of **non-keratinized stratified squamous epithelium** (Figs. 130 & 135). This is that portion of the cervix, which projects into the vagina. The **endocervix** (more proximal, within the uterus) is composed of **simple columnar epithelium** (Figs. 130, 132, 133 & 135). Some of the columnar cells are ciliated, with the cilia beating toward the vagina. This endocervix is the supravaginal portion of the cevix. The transition between simple columnar epithelial lining of the endocervix to stratified squamous epithelium of the vaginal portion is abrupt and occurs just inside the cervical canal (Fig. 135).

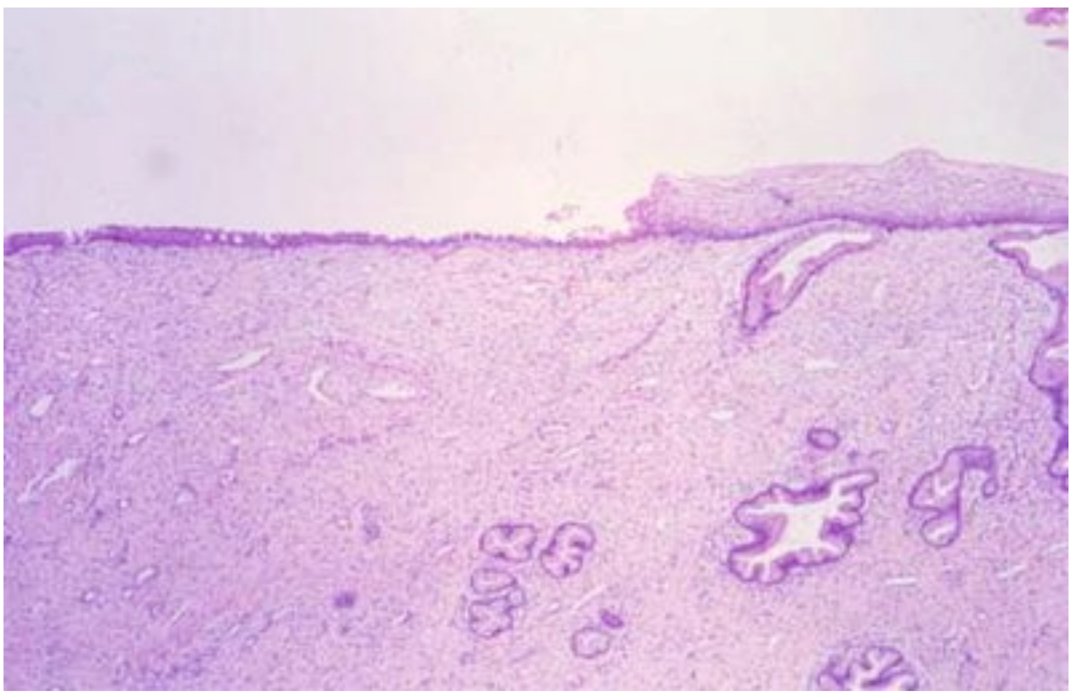


Fig. 135. This is a low-power photomicrograph of the cervix showing the junction of the ectocervix and endocervix (transition zone). The ectocervix is lined by non-keratinized stratified squamous epithelium, the endocervix by columnar cells. Several branched endocerivical glands lined by tall columnar mucus secreting cells are found in the underlying collagenous stroma. (www.histolog-world.com)

The mucosa of the cervical canal, does not desquamate during menstruation, although, minor changes in the structure of the cervical glands do occur.

However, during the menstrual cycle, there are changes in both the quantity and properties of the cervical mucus.

The epithelial lining rest on a connective tissue base called the **lamina propria**. The epithelial lining and the underlying lamina propria constitute the mucosa of the cervix. It is about 2-3 mm thick and contains branching folds, or furrows called **pilcae palmatae**, which appear as large, branching endocervical glands (Fig. 135).

The **arterial supply** of the uterus is derived mainly from the **uterine arteries**, which arise from the **anterior division of the internal iliac arteries** (Figs. 112 & 122, p 135 & 146). The uterine artery approaches the uterus from the lateral pelvic wall. They enter the **broad ligaments** beside the lateral parts of the fornices of the vagina, superior to the ureters. When the uterine artery reaches the side of the uterus at the isthmus (Figs. 120 & 122, p 144 & 146) it divides into a large **ascending branch** that supplies the body and fundus, and and a smaller **descending branch** that supplies the cervix and vagina. The uterus is also supplied by the **ovarian arteries**, which arise from the aorta, and vaginal arteries, which are a branch of the anterior division of the internal iliac arteries. The vaginal artery may also arise from the uterine artery. Although these anastomoses exist, the uterine artery is the dominant artery, which is underscored by its marked hypertrophy during pregnancy.

The **uterine veins** enter the broad ligaments with the uterine arteries. They form a **uterine venous plexus** on each side of the cervix and its tributaries drain into the **internal iliac vein** (Fig. 112, p 135). However, the uterine venous plexus also forms anastomoses with the **vaginal** and **ovarian venous plexuses**, as well as forming an anastomoses with the **superior rectal vein** thus, forming a **port-systemic anastomoses**. Also, the vaginal venous plexus form anastomoses with the **vesical** and **rectal venous plexuses**, as well as the uterine venous plexus. *Remember, the rectal venous plexus drains into the* ***inferior mesenteric vein****, which also drains into the* ***portal vein****, thus forming another* ***portal-systemic anastomoses****.*

The **lymphatic drainage** of the uterus follows three main routes: most lymph vessels from the **fundus** pass with the **ovarian vessels** to the **aortic lymph nodes**, but some lymph vessels drain to the **external iliac nodes**, or run along the **round ligaments** to drain into the **superficial inguinal nodes**; lymph vessels from the **body** pass through the broad ligaments to drain to the external and internal iliac nodes and the **obturator nodes**; lymph vessels from the **isthmus** drain to the superficial inguinal lymph nodes; lymph vessels from the **cervix** drain partly to the internal and external iliac nodes, but also run backwards to drain into the **sacral** and **median common iliac** nodes. The **innervation** of the uterus is mainly from the **inferior hypogastric plexus**, largely from the **anterior** and **intermediate part** known as the **uterovaginal plexus**, which lies in the broad ligament on each side of the cervix (Fig. 113, p 136). The **uterine nerves** end in the **myometrium** and **endometrium**, usually accompanying the vessels (Fig. 136).

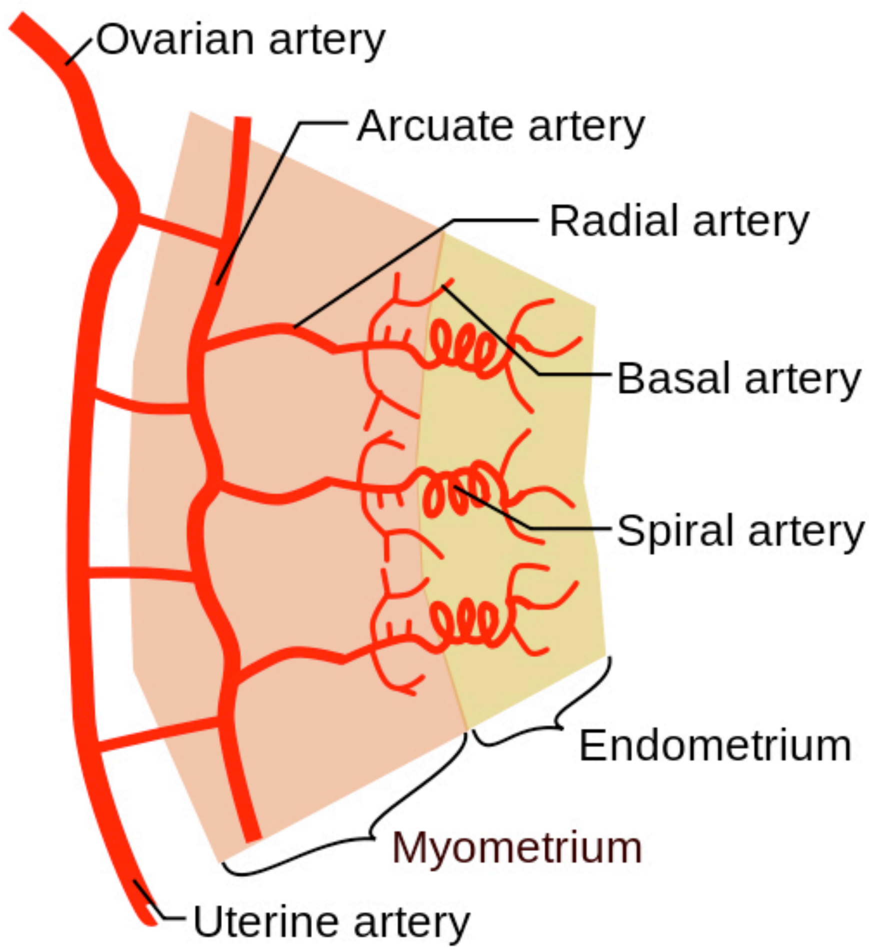


Fig. 136. The above drawing depicts the vascular supply to the endometrium and myometrium of the uterus. Remember, the nerves usually follow the blood vessels. (en.wikipedia)

Nerves to the cervix form a plexus in which are located small **paracervical ganglia**. On occasion one of these ganglion is especially large and is referred to as the **uterine cervical ganglion**.

Efferent preganglionic sympathetic fibers are derived from neurons in **T12-L1 spinal segments**. The sites where they synapse on the **postganglionic sympathetic neurons** are not known.

Preganglionic parasympathetic fibers arise from neurons in **S2-S4 spinal segments**. They form synapses with **postganglionic parasympathetic neurons** in the **paracervical ganglia**.

Sympathetic fiber activation may cause uterine contraction and vasoconstriction. **Parasympathetic** activity may produce uterine inhibition and vasodilation, however, both sympathetic and parasympathetic activity is moderated by **hormonal control of uterine function**.

Most of the **afferent fibers** from the uterus and cervix ascend through the inferior hypogastric plexus and enter the spinal cord through **T10-12** and **L1 spinal segments**.

(c). The Uterine (fallopian) tubes: The **uterine tubes** extend from the **cornua** of the uterus laterally and superiorly to the region of the **ovary**, measuring approximately 10 cm long and 1 cm in diameter. The uterine tubes carry **oocytes** from the ovaries to the uterus. They also carry **sperm cells** from the uterus toward the ovaries. The sperm fertilize the oocyte in the region of the fallopian tube called the **ampulla**. The fallopian tube then conveys the fertilized oocyte, the dividing **zygote** to the uterine cavity (Fig. 137). Each tube opens at its proximal end into the **uterine os at the cornua** or **horn of the uterus**, which is located at the superior angle of the uterine cavity. The lateral end of the tube opens into the **peritoneal cavity** through the **abdominal os**. The fallopian tube is divided into four parts: **infundibulum, ampulla, isthmus,** and **intramural or interstitial/uterine parts** (Fig. 122, p 146 & Fig. 138).

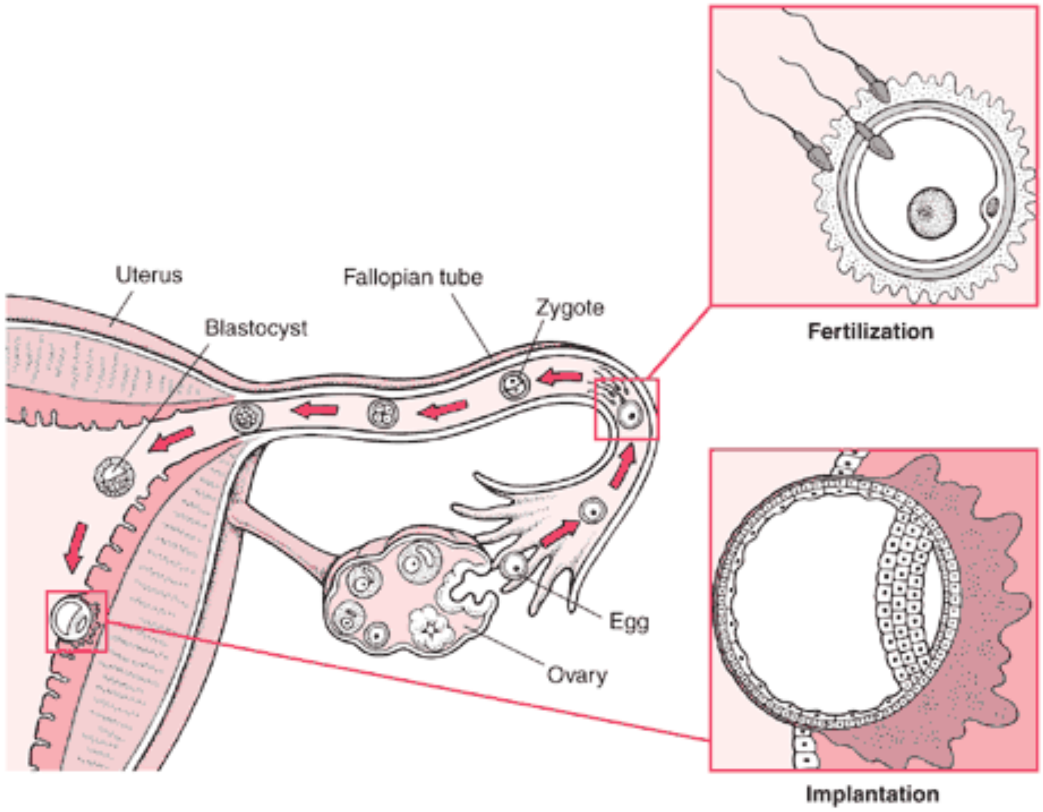


Fig. 137. This image depicts the fallopian tube and egg fertilization and implantation of the blastocyst in the uterus. (daviddarling.info)

Fig. 138. This image shows the anatomy of the fallopian tube. (tubal-reversal.net)

The **infundibulum** of the fallopian tube is its funnel-shaped lateral or distal end. It is closely related to the ovary (Figs. 120 & 122, p 144 & 146, & Fig. 137). As stated above, the opening of the infundibulum into the peritoneal cavity is called the **abdominal os (ostium)**. This opening varies in diameter between 1-2 mm, with the abdominal os lying at the bottom of the infundibulum. The margins of the infundibulum contain 20-30, irregular fringed, finger-like branched processes called the **fimbriae (lateral fringes)**. These finger-like processes spread over most of the medial surface of the ovary (Figs. 120 & 122, p 144 & 146, & Figs. 137 & 138). There is one large fimbria, the **ovarian fimbria**, which is attached to the superior pole of the ovary (Fig. 117, p 141 & Fig. 139).

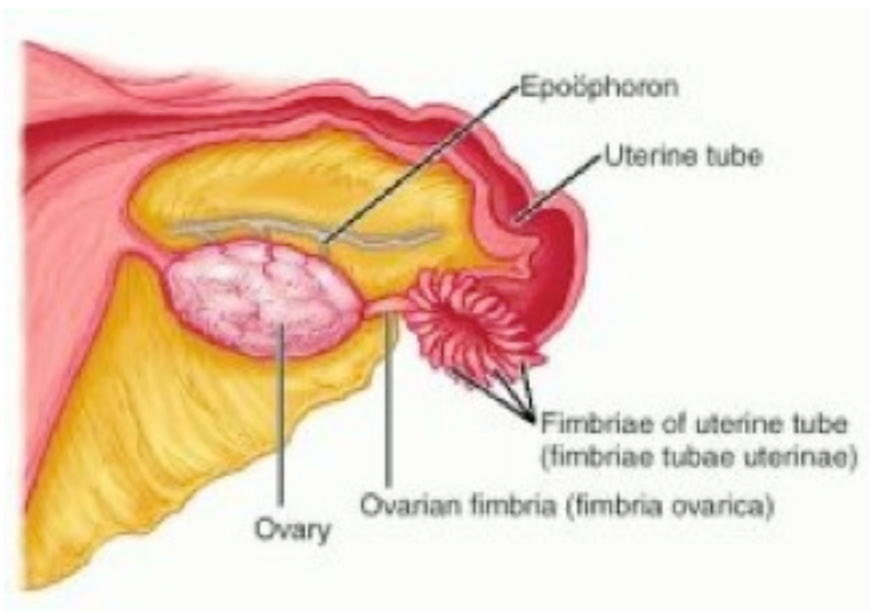


Fig. 139. This drawing shows the location of the ovarian fimbriae. (acubaby.com)

*Remember, the ovaries are intraperitoneal and have a short mesentery, the **mesovarium** (Fig. 118, p 142)*. When the **ovarian follicle** ruptures releasing the oocyte, the oocyte ruptures through the single layer of cuboidal epithelium called the **germinal epithelium** into the peritoneal cavity (Fig. 140). The oocyte is then picked up by the fimbriae and swept into the abdominal os and

and on into the ampulla. What is also important to understand is an oocyte produced by the left ovary may be picked up by, and migrate through either the right or left fallopian tube.

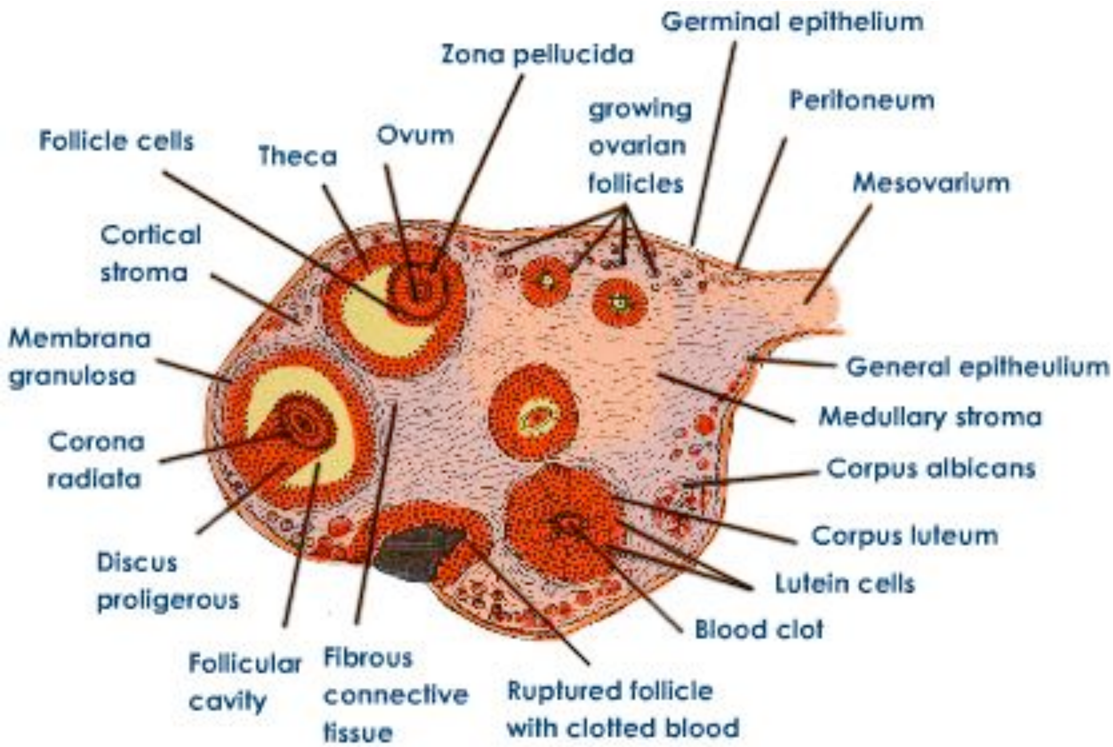


Fig. 140. This is a diagram of an ovary showing what constitutes its microscopic anatomy. Note the germinal epithelium (labeled upper right). (tutorvista.com)

The **ampulla** of the fallopian tube begins at the medial end of the infundibulum. It is slightly tortuous, and is the widest and longest part of the fallopian tube, making up over half of its length, measuring 1 cm in diameter and approximately 5 cm in length. As stated above, it is within the ampulla that fertilization of the oocyte by a sperm usually occurs (Figs. 120 & 122, p 144 & 146, & Figs. 137 & 138).

The **isthmus** of the fallopian tube is the narrow, short and thick-walled part of the fallopian tube that extends medially from the ampulla and enters the cornu of the uterus at its superolateral angle joining the **intramural interstitial/uterine) part** of the fallopian tube. It measure 1-5 mm in diameter and 2.5-3 cm in length (Figs. 120 & 122, p 144 & 146, & Fig. 138).

The **intramural (interstitial/uterine) part** of the fallopian tube is a short segment that passes through the thick myometrium of the uterus, opening into the uterine cavity through the **uterine os**. This opening is smaller than the **abdominal os**. It measures approximately 1 cm long and 0.7 mm in diameter (Fig. 122, p 144 & Fig. 138).

The **Mesosalpinx:** The fallopian tubes lie in the free edges of the **broad ligaments** of the uterus. The part of the broad ligament attached to the fallopian tube is called the **mesentery of the tube or mesosalphinx (salpinx** is Greek for a tube**)** (Figs. 118 & 119, p 142 & 143). The uterine tubes extend posterolaterally to the lateral walls of the pelvis, where they ascend and arch over the ovaries. Except for their uterine parts, the fallopian tubes are covered with peritoneum, in essence, they are **intraperitoneal** as the ovaries.

Microscopically, the fallopian tubes consist of three parts: a mucous membrane, the **mucosa**; a muscular layer, the **muscularis**; and a serosal layer, the **serosa** (Fig. 141).

The **mucosal** lining lies next to the lumen and contains characteristic longitudinal folds. In the **ampulla** the folds branch in a complex manner to divide the lumen into a labyrinth of spaces. In the **isthmus**, the folds rarely branch and in the **intramural portion**, the folds are low. The mucosa consist of an **epithelia surface** which rest on a band of connective tissue called the **lamina propria**. The epithelium lining the mucosa consists of **simple columnar epithelium** which consists of two type of cells, **ciliated cells** and **peg cells** (Fig. 142). The ciliated cells predominate throughout the tube, but are most numerous in the infundibulum and ampulla. Most of the cilia beat toward the uterus and are thought to play a major role in the transportation of the ovum to the uterine os. Interspersed between the ciliated cells are peg cells, which contain apical granules and produce tubular fluid. This fluid contains nutrients for spermatozoa, oocytes, and zygotes. The **lamina propria** is separated from the epithelium by a thin layer called the **basal lamina** (Fig. 143).

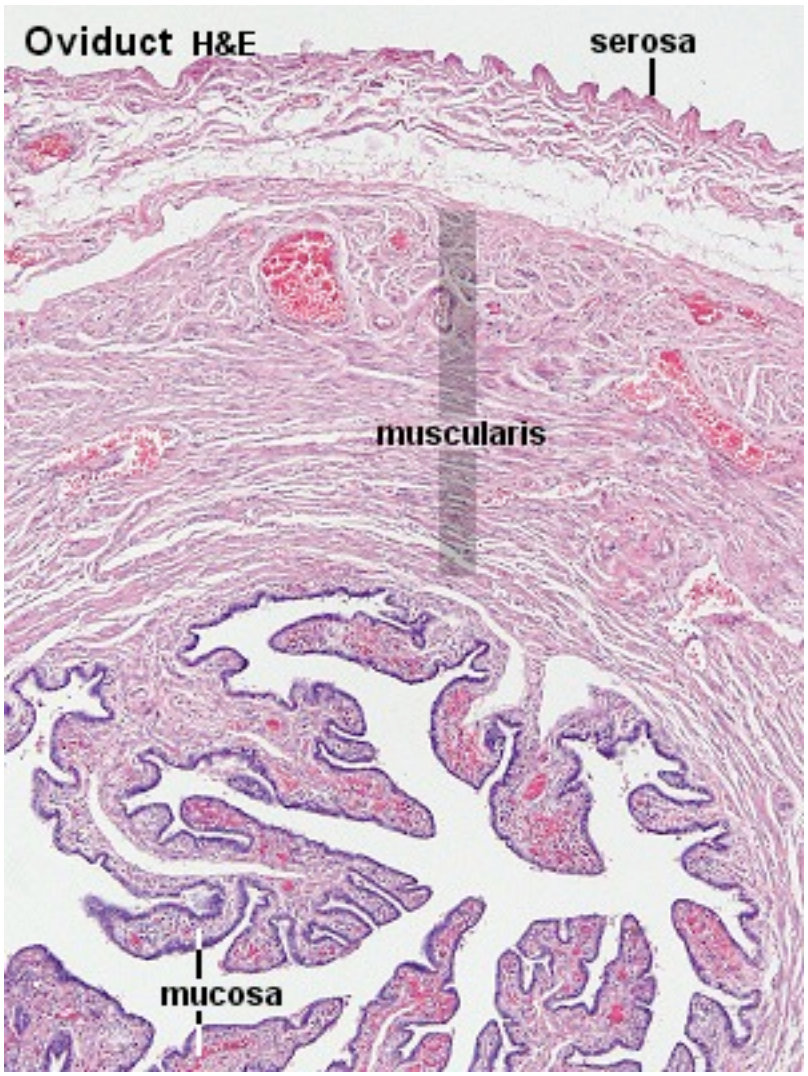


Fig. 141. This image is a low power photomicrograph denoting the components of the fallopian tube's wall. The term Oviduct is another descriptive term for the fallopian tubes. (Wiki)

Fig. 142. This is a higher power photomicrograph of the mucosal surface of the fallopian tube showing the epithelial cells and lamina propria. (Wiki)

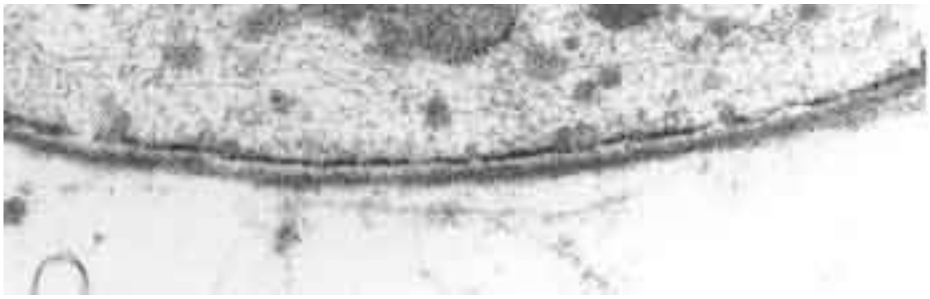


Fig. 143. This image is an electron photomicrograph of the basal lamina. The basal lamina can only be seen by using an electron microscope. This term is often used interchangeably with basement membrane, which is incorrect. A basement membrane is seen using the light microscope, while the basal lamina cannot. (Wiki)

The basal lamina is a layer of extracellular matrix secreted by the epithelial cells, on which the epithelium sits. It is usually about 40-50 nanometers thick. The basement membrane encompasses the basal lamina and typically a reticular lamina secreted by other cells.

The lamina propria provides the vascular connective tissue support and lymphatic drainage vessels. The mucosa lies directly on the muscular coat, the **muscularis**.

The **muscularis** consists of a broad inner circular layer and a thin outer layer (Fig. 141). The outer layer is not continuous, but consists of scattered bundles of smooth muscle fibers, oriented longitudinally. Toward the uterus the muscularis increases in thickness. Contractions of the muscular coat occurs in peristalic waves, which help the movement of the fertilized oocyte down the fallopian tube to the uterine cavity.

The **serosa** is the fold of reflected peritoneum, which covers the fallopian tube (Fig. 141). It consist of loose connective tissue covered by mesothelium. At the rim of the infundibulum, the mucosal lining of the tube becomes continuous with the **mesothelium** of the serosa. The mesothelium is a layer of flat cells derived from the **mesoderm**.

The **arterial blood supply** to the fallopian tubes is derived from the **ovarian** and **uterine arteries**. The lateral third of the tube is supplied by the ovarian arteries with the medial two-thirds being supplied by the uterine arteries.

The tubal branches pass to the tubes between the layers of the mesosalpinx (Fig. 118, p 142).

The **venous drainage** of the fallopian tubes is arranged similarly to the arteries. The lateral third of the tubes drain through the **pampiniform plexus** to the **ovarian veins**, which drain into the **inferior vena cava** on the **right side** and the **renal vein** on the **left side** (Fig. 144). The medial two-thirds of the tube drain through the **uterine plexus** to the **internal iliac vein**.

The **lymphatic drainage** is through the **ovarian vessels** to the **para-aortic nodes** and **uterine vessels** to the **internal iliac chain**. It is possible for lymph to reach the **inguinal nodes** through the **round ligament**.

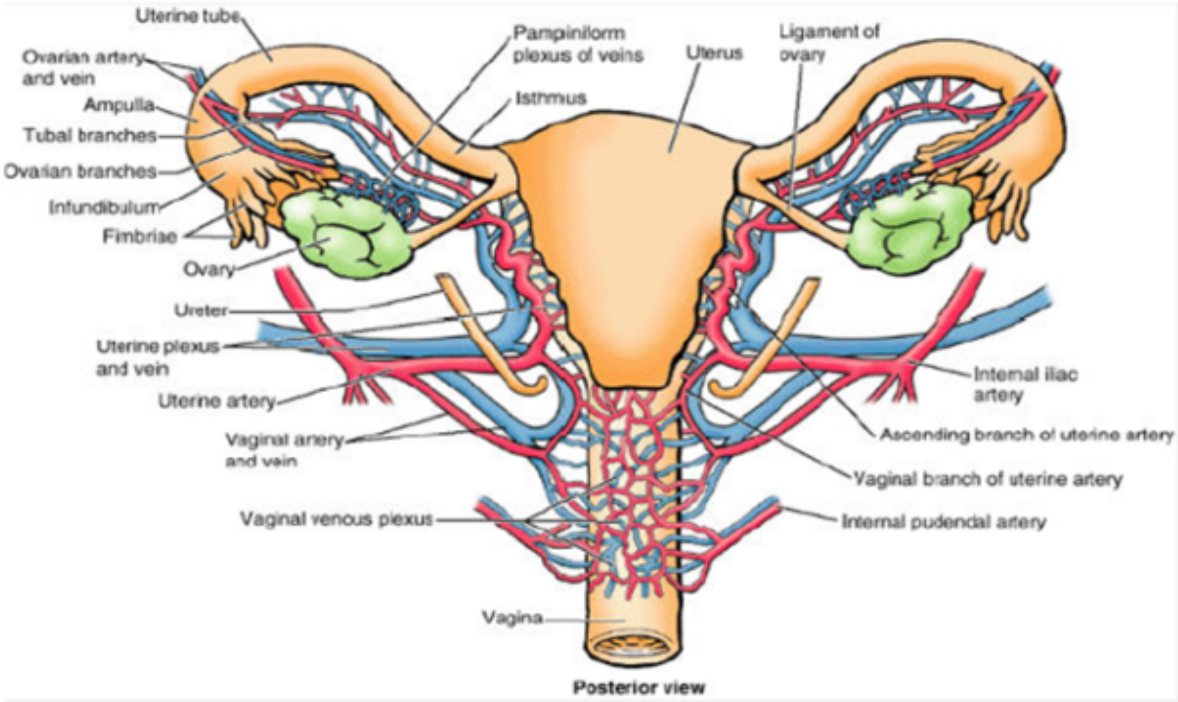


Fig. 144. This drawing depicts the arterial and venous vessels of the female reproductive organs. Note the pampiniform plexus labeled above the fundus of the uterus in the midline. (seisyuhada.wordpress.com)

The **innervation** of the fallopian tubes is **autonomic**, with the **parasympathetic** and **sympathetic fibers** traveling primarily with the ovarian and uterine arteries. Most of the tube has both parasympathetic and sympathetic innervation. The lateral half of the tube receives its **preganglionic parasympathetic fibers** from the **vagus nerves** through the **ovarian plexus**, whereas the medial half receives its preganglionic parasympathetic fibers from **S2-S4** of the **pelvic nerve** and **pelvic plexuses** (Fig. 113, p 136). The ovarian plexus arises from the **renal plexus**, and is distributed to the ovary, and fundus of the uterus. It is carried in the **suspensory ligament of the ovary**.

The **preganglionic sympathetic fibers** are derived from neurons in **T10-L2 spinal segments** and travel to the **inferior mesenteric plexus** (Fig. 145). The **postganglionic sympathetic fibers** from the inferior mesenteric plexus in turn send fibers to the **cervicovaginal plexus**, which send fibers to the **isthmus** and part of the **ampulla**. Some preganglionic sympathetic fibers from T10 and T11 reach the **celiac plexus**, which provides postganglionic fibers to the ovarian plexus, which supplies the **distal ampulla** and **fimbriae**.

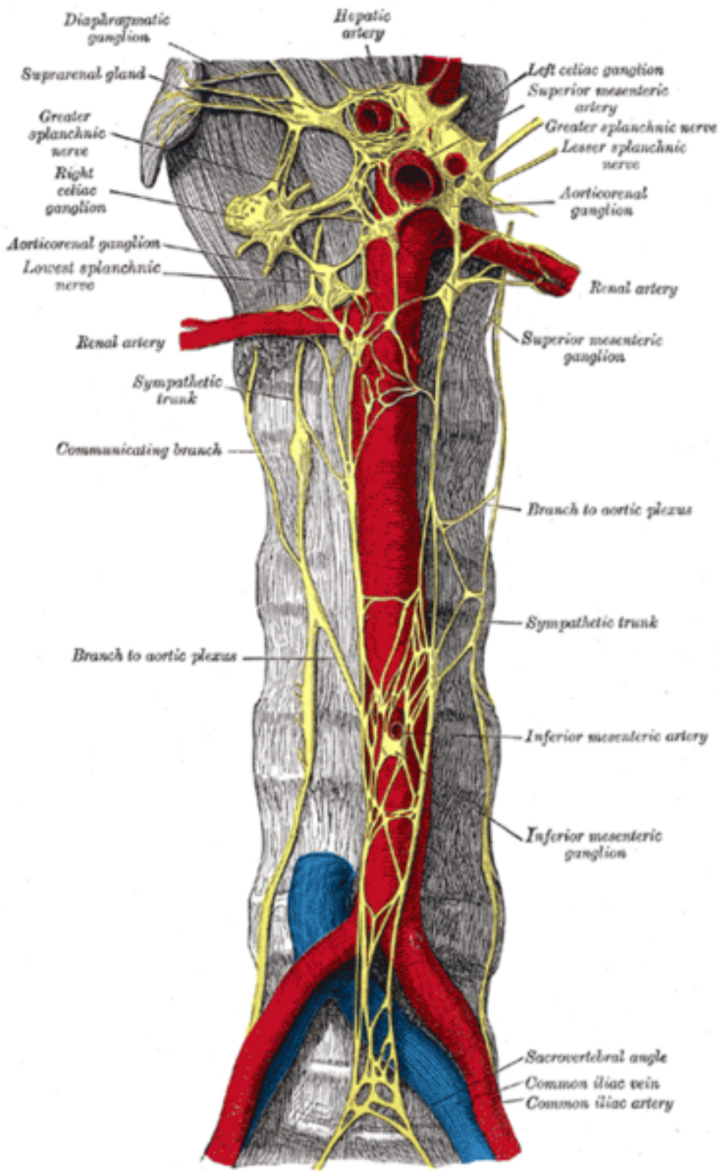


Fig. 145. The above drawing shows the abdominal portion of the sympathetic trunk, with the celiac and hypogastric plexus. (Greater splanchnic and lowest splanchnic labeled at upper left. Greater splanchnic and lesser splanchnic labeled at the upper right). (Wiki)

Visceral afferent fibers primarily follow the sympathetic nerves, and enter the spinal cord through the corresponding **dorsal roots of T10-L2**; they may also travel with parasympathetic fibers. The ampullary submucosa contains

Pacinian corpuscles.

(d). The Ovaries: In the adult nullipara (women who have not borne children), the the ovaries lie on each side of the uterus close to the lateral pelvic wall, enclosed within the double fold of peritoneum, the **mesovarium**, which is attached to the upper limit of the posterior aspect of the **broad ligament** (Fig. 118, p 142). The ovaries have a dull to pinkish-white color, and are typically almond oval in shape, consisting of dense fibrous tissue in which the ova are embedded. It should be kept in mind the size, position, and appearance, depend on the age and reproductive activities of the individual. The ovaries of **normal adult reproductively mature women** are 2.5-5 cm long, 1.5-3 cm thick, and 0.7-1.5 cm wide, with a weight of 3-8 grams. The ovaries more than double their size during pregnancy. In the **neonate**, their typical dimensions are 1.3 x 0.6 x 0.4 cm. Before the **first menstrual period (menarche)** the ovaries are about a third of the normal reproductive adult size; they gradually increase in size with body growth. After **menopause**, the average size of the ovary reduces to 2.0 x 1.5 x 0.5 cm**.** Before **puberty** the surface of the ovaries are smooth. Thereafter, the surface progressively becomes scarred and distorted owing to repeated ovulations.

The ovaries contain 1-2 million oocytes at birth. A woman will release up to 300 ova, on average during her lifetime. As is true of the testes, the ovaries are both **exocrine organs**, secreting ova, as well as **endocrine organs**, secreting **estrogens** and **progestins**. The testes secrete **sperm** and the **hormone testosterone**.

In the **nullipara woman**, the ovaries are located close to the lateral wall of the **true pelvis (lesser pelvis)**, in a recess called the **ovarian fossa** (Fig. 146). Behind the ovarian fossa are the **ureter, internal iliac vessels, obturator vessels and nerve**, and the origin of the **uterine artery**. The **medial surface** faces the uterus and uterine vessels in the broad ligament. Immediately **above the superior extremity** are the **fimbria**. The **inferior extremity** points downwards towards the **pelvic floor**. The **anterior border** is attached to the posterior border of the broad ligaments by the peritoneal fold, the mesovarium.

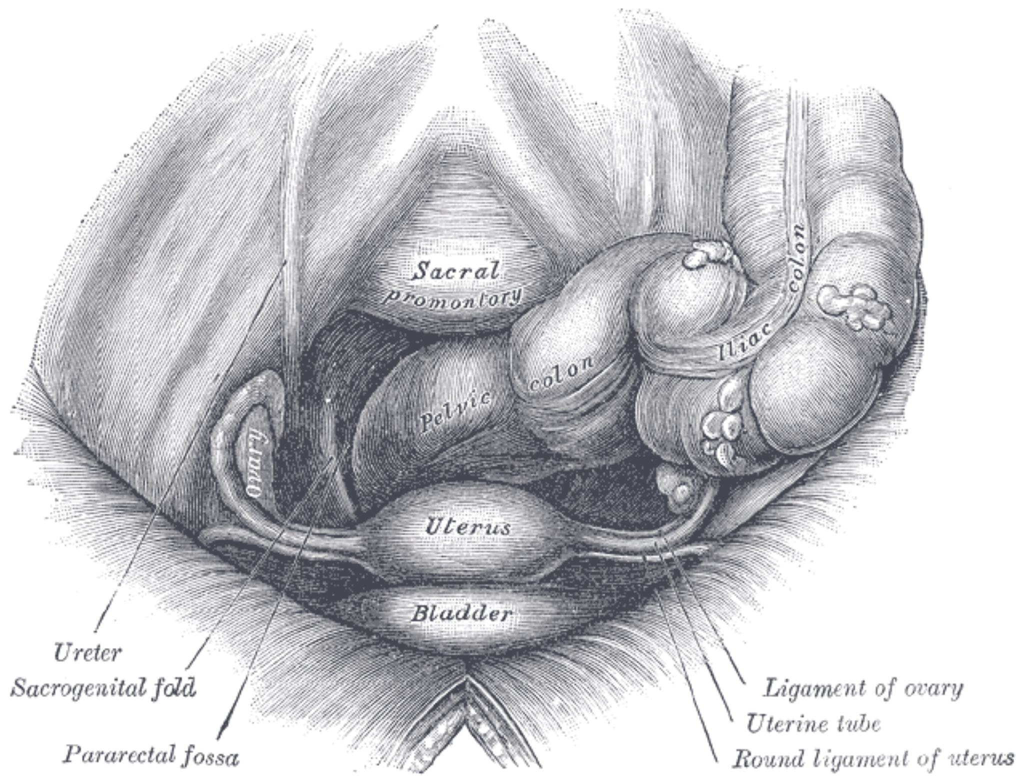


Fig. 146. This image is of the female pelvis and its contents, seen from above and in front. The ovaries lie in a shallow depression, named the ovarian fossa, on the lateral wall of the pelvis, which although depicted above is not labeled. (Wiki)

Each end of the ovary is supported by ligaments. At the tubal pole (superior end), the ovary is attached to the **suspensory ligament**, which is attached to the lateral wall of the pelvis (Figs. 105 & 122, p 128 & 146). The suspensory ligament is a fold of the **posterior peritoneal layer of the broad ligament**. The suspensory ligament contains the ovarian vessels and nerves. These vessels and nerves pass into the mesovarium and then to the hilum of the ovary. The suspensory ligament is often called the **infundibulopelvic ligament**. At the other pole of the ovary is the **utero-ovarian (ovarian) ligament**, which attaches each ovary by a band of fibrous tissue to the uterus (Figs. 117 & 118, p 141 & 142, & Fig. 146). This ligament runs in the mesovarium of the broad ligament.

The hilum of the ovary is its base, and as stated above is the point in which the ovarian vessels enter and leave the ovary.

Microscopically, the ovary has two zones: an **outer zone**, with the **cortex** and an **inner zone**, the **medulla**, which merges with the vascular connective tissue of the mesovarium at the hilum. There is no distinct line of demarcation between the two zones as shown in Fig. 140, page 163 in which the cortex is labeled **cortical stroma** and the medulla, **medullary stroma**.

Before puberty, the cortex forms approximately 35%, the medulla 20%, and the interstitial cells up to 45% of the volume of the ovary. After puberty the cortex forms most of the ovary, and encloses the medulla except at the hilum. The **cortex** consists of a surface layer of epithelium, the **germinal epithelium** beneath which is a compact, cellular stroma, the **tunica albuginea**, which contains the **ovarian follicles** at various stages of development and **corpora lutea** and their degenerative remnants. The **follicles** and structures derived from them are embedded in the dense stroma (Figs. 140, p 163 & Fig. 147). In Fig. 140, tunica albuginea is indicated by the label **corpus albicans**. Tunica albuginea literally means “white covering.” It is used to refer to the connective tissue covering the ovaries.

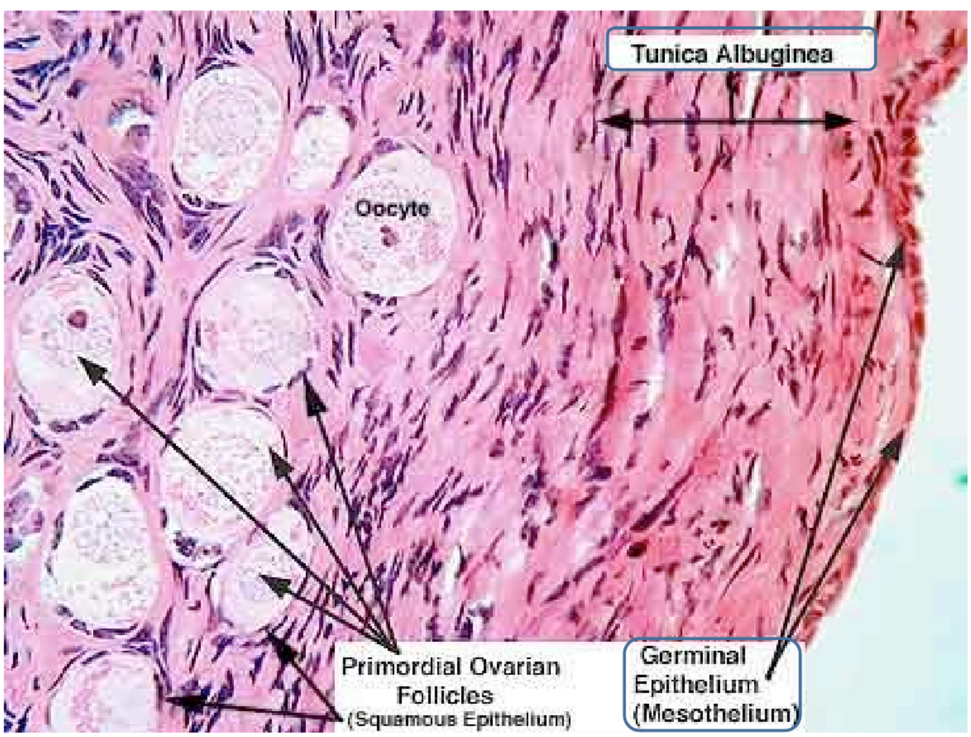


Fig. 147. The above image is a photomicrograph of the cortex of the ovary showing its components. (faculty.une.edu)

*Remember, the ovary is not covered by peritoneum. The **mesovarium** is attached to the base of the ovary, the hilum. At the hilum, the vascular connective tissue of the mesovarium becomes continuous with the medullary stroma. The peritoneal covering of the mesovarium ceases abruptly at the hilum, and is replaced by a layer of cuboidal cells, the **germinal epithelium**. A white line around the anterior mesovarian border usually masks the transition between the peritoneum and the ovarian epithelium.*

The follicles may be seen in all stages of development with the appearance of the cortex depending upon the age of the individual and the stage of the ovarian cycle. Before puberty only primary, or primitive follicles are seen. In Figs. 147 these primitive follicles are labeled primordial ovaries. Sexual maturity is characterized by the presence of **growing follicles** and their end products **corpus lutea**, **atretic follicles** and **corpus albicans** (Fig. 140, p 163 & Fig. 148 & 149).

The **corpus luteum** develops from an ovarian follicle during the luteal phase of the menstrual cycle, following the release of a secondary oocyte from the follicle during ovulation (Fig. 149). The follicle first forms a **corpus hemorrhagicum** before it becomes a corpus luteum, the term referring to the visible collection of blood left after rupture of the follicle.

Once the corpus luteum regresses the remnant is known as corpus albicans. The corpus luteum is essential for establishing and maintaining pregnancy. It does this through the production of progesterone, which is a steroid hormone responsible for the development and maintenance of the endometrium. It the oocyte is not fertilized, the corpus luteum stops secreting progesterone and decays within approximately 14 days. It then degenerates into a corpus albicans, which is a fibrous scar. The cessation of progesterone production ultimately leads to the uterine lining, the endometrium, to slough off and is expelled through the vagina (menstruation). If the oocyte is fertilized and implantation occurs, cells within the developing blastocyst, **syncytiotrophoblast**, begin to secrete a hormone, **human chorionic gonadotropin (hCG)** by day 9 post fertilization. hCH signals the corpus luteum to continue progesterone secretion, thereby maintaining the now thick endometrium of the uterus providing an area rich in blood vessels so that the zygote can develop. Eventually, the developing placenta takes over progesterone production, which results in the degradation of the corpus luteum into the corpus albicans.

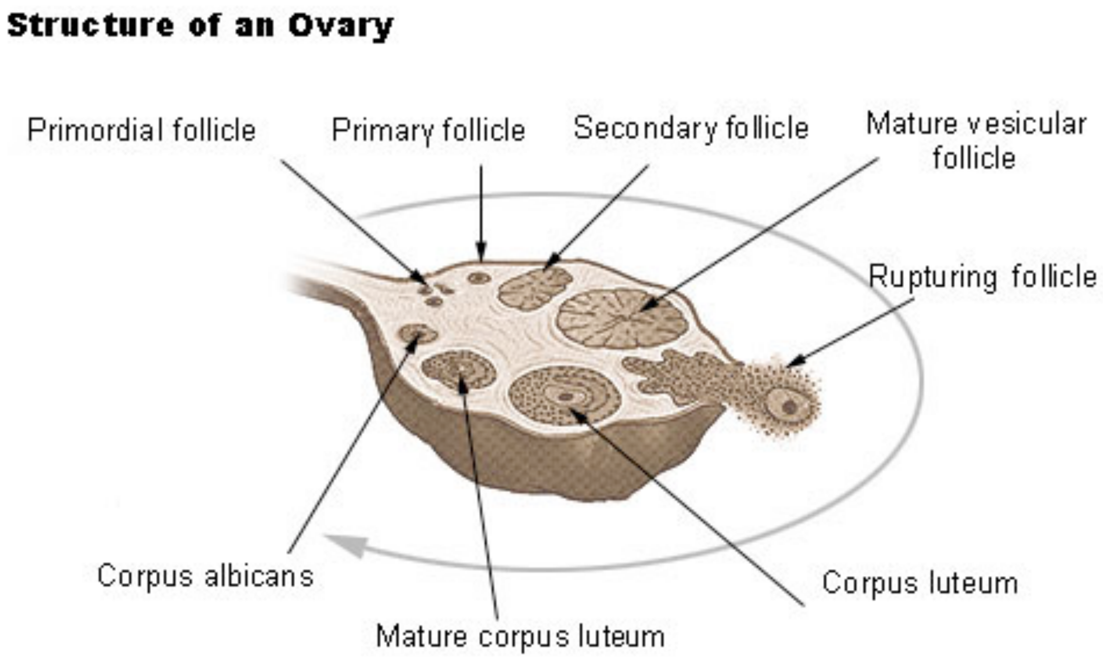


Fig. 148. This drawing depicts the structure of the ovary. (Wiki)

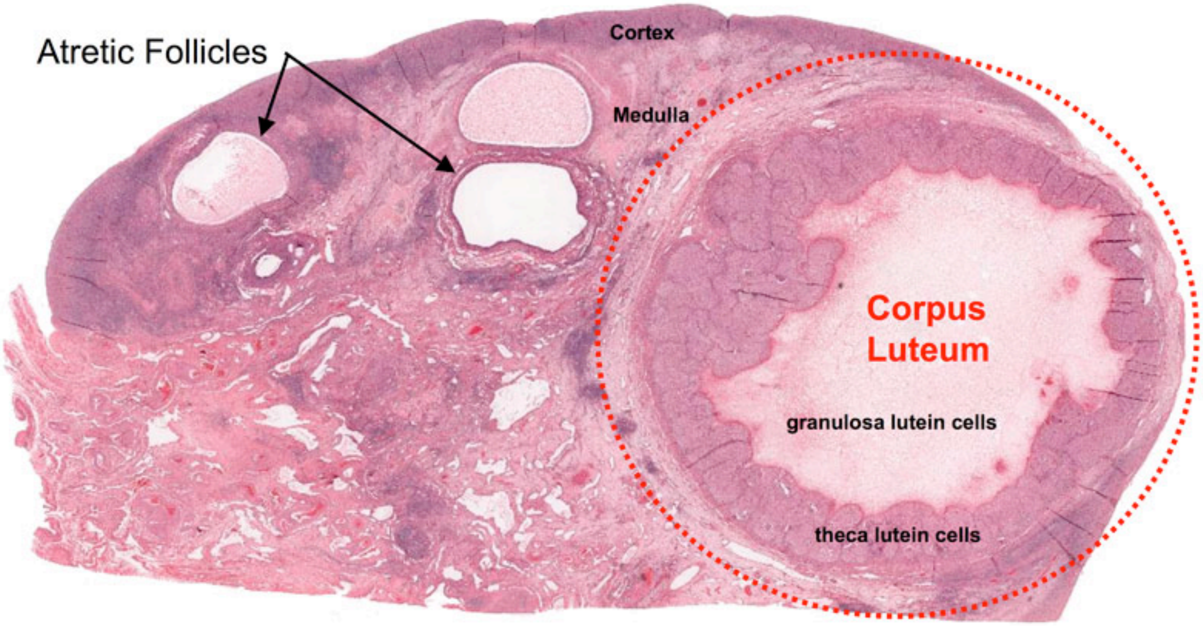


Fig. 149. This is a low power photomicrograph depicting the corpus luteum and atretic follicles. (embryology.med.unsw.edu.au)

After menopause, the follicles disappear and the cortex eventually becomes a narrow zone of fibrous connective tissue.

The **medulla** consists of loose fibroelastic connective tissue containing numerous large blood vessels, lymphatics, and nerves. The stroma also contains scattered strands of smooth muscle fibers. In addition, in the hilar region of the medulla are small numbers of cells, **hilus cells**, which have characteristic similar to the **interstitial (Leydig) cells** in the **testis**. Hilus cells may be the source of **androgens**.

The **ovarian arteries supply** blood to the ovaries Figs. 112 & 144, p 135 & 168). They originate from the **abdominal aorta** below the **renal arteries** approximately at the level of the **L2 vertebra**. They descend behind the peritoneum along the posterior abdominal wall. On reaching the brim of the pelvis, they cross over the **external iliac** vessels to enter the **true pelvic cavity**. Once reaching the pelvic cavity they enter the **suspensory ligaments** and immediately divide into branches, which pass through the **mesovarium,** supplying the ovary; another branch continues medially through the broad ligament to supply the fallopian tube; other branches follow the **round ligaments** through the **inguinal canal** to the skin of the **labia majora** and the **inguinal region**; lastly, there is another branch which passes lateral to the uterus to form an anastomoses with the **uterine artery**.

The **ovarian veins** leave the hilum of the ovary to form a plexus of veins, the **pampiniform plexus** in the mesovarium and suspensory ligament (Fig. 144, p 168). As discussed above, this plexus of veins communicates with the **uterine plexus**. Typically, two ovarian veins leave the true pelvis with the ovarian artery. Before entering the **inferior vena cava** on the right side, and the **renal vein on the left side**, they usually merge into a single vessel.

The primary **lymphatic drainage** of the ovaries is to the **para-aortic lymph nodes** located near the origin of the **renal arteries** by following the ovarian veins. They also may drain through the **pelvic nodes** into the **lower para-aortic nodes**, and occasionally may follow the **round ligament** to the **inguinal nodes** (Figs. 150 & 151).

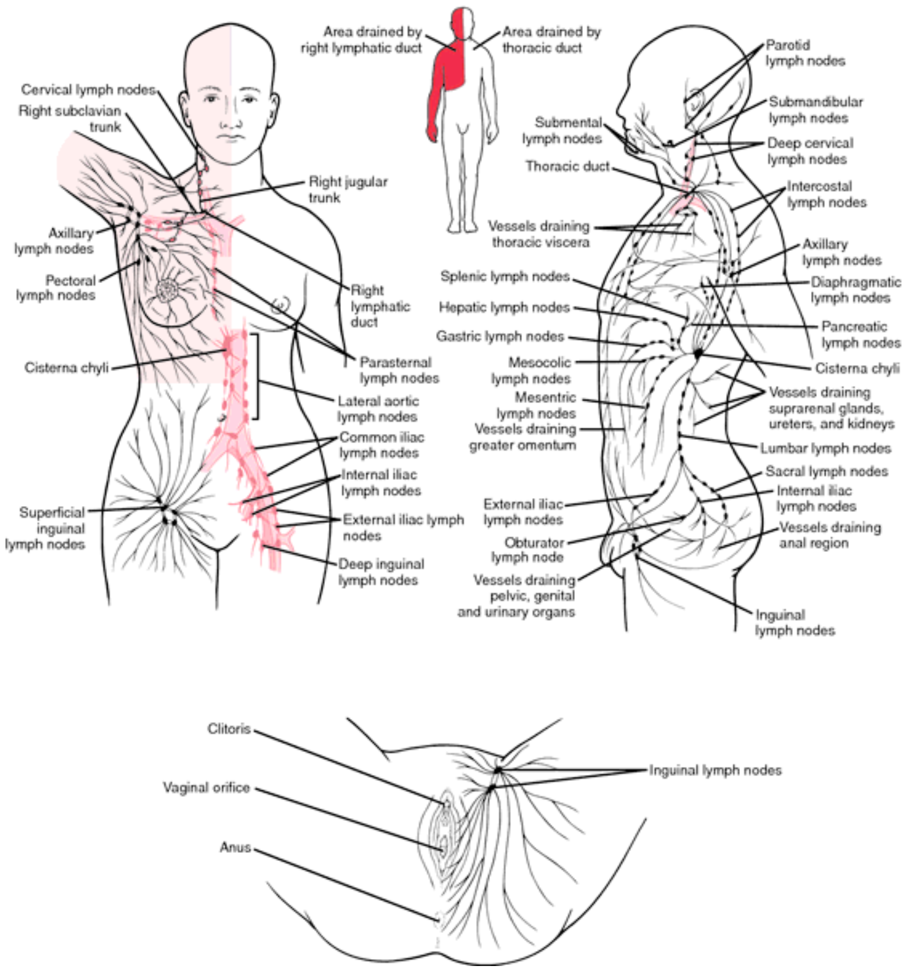


Fig. 150. This is a diagrammatic representation of the lymphatic drainage for the body in general. (medical-dictionary.thefreedictionary.com)

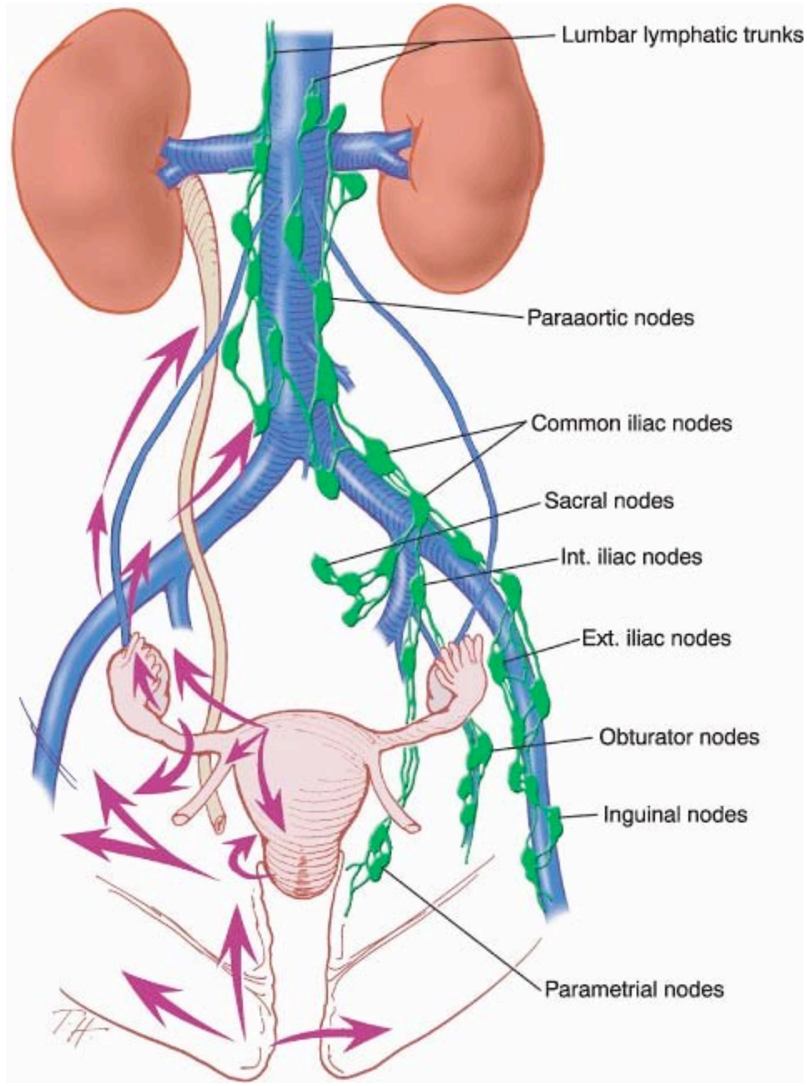


Fig. 151. This diagram shows the lymphatic drainage of the pelvic region including the female reproductive organs. The vulva and lower vagina drain to the superficial and deep inguinal lymph nodes, sometimes directly to the iliac nodes (along the dorsal vein of the clitoris) and to the other side. The cervix and upper vagina drain laterally to the parametrial, obturator, and external iliac nodes and posteriorly along the uterosacral ligaments to the sacral nodes. The lower uterine body drains in the same manner as the cervix. Rarely, drainage occurs along the round ligament to the inguinal nodes. (www.eupbbud.com)

The **innervation** of the ovaries is derived from the **ovarian plexus**. The upper part of the plexus originates from branches of the **renal** and **aortic plexuses**, and the lower part receives branches from the **superior** and

inferior hypogastric plexuses (Fig. 145, p 169). The nerves to the ovary descend along the ovarian vessels from the ovarian plexus. These nerves supply the ovaries, broad ligaments, and fallopian tubes. The nerves consist **postganglionic sympathetic, parasympathetic** and **afferent visceral fibers**. The **preganglionic sympathetic fibers** originate from **T10-11 spinal segments** and are primarily **vasoconstrictor**. The **preganglionic parasympathetic fibers** are derived from the **vagus nerve**. The **postganglionic parasympathetic fibers** take origin primarily in the **inferior hypogastric ganglion** and are probably vasodilator.

C. The Rectum and Anal Canal

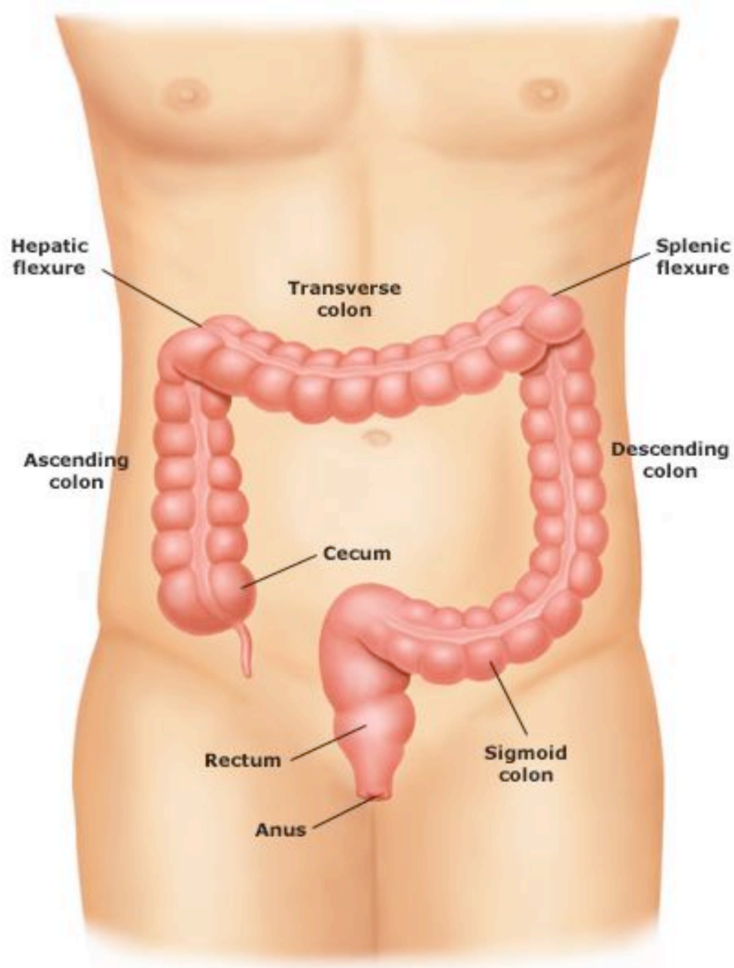


Fig. 152 This image shows the location of the various parts of the colon (drugline.org)

1. **Rectum:** The rectum is continuous with the sigmoid colon, and of the two terminal portions of the gastrointestinal tract, **rectum** and **anal canal**, only the rectum lies in the pelvis (Fig. 152). However, for the sake of continuity they will be considered together. The rectum begins where the complete **peritoneal investment** of the sigmoid colon ends, which is about the level of the third sacral vertebra (Fig. 153).

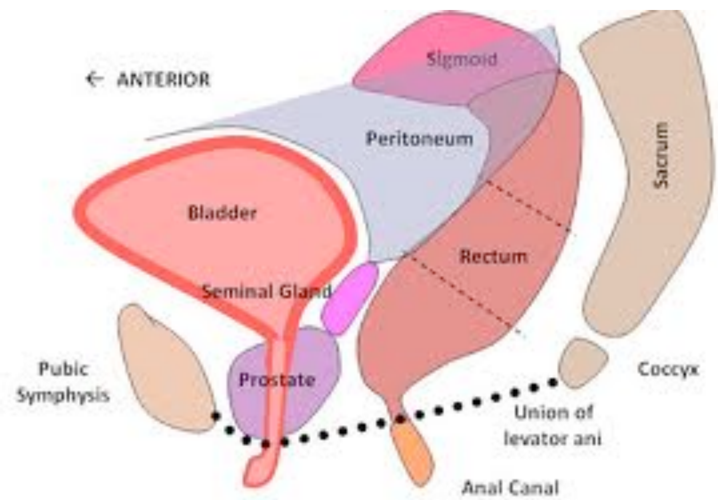


Fig. 153. The above illustration depicts the peritoneum and its anatomic relationships with the organs in the lower abdominal and pelvic cavity of the male. As shown, the peritoneum covers the anterior surface of the superior two-thirds of the rectum. (orzradonc.wikidot.com)

The rectum continues downward and forward, curving first right and then to the left in the concavity of the **sacrum** and **coccyx (sacrococcygeal concavity)**, and onto the **pelvic diaphragm**. Above the pelvic diaphragm the rectum curves to the right. Once the rectum pierces the pelvic diaphragm it becomes the **anal canal** (Fig. 154). The anorectal junction occurs 2-3 cm in front of and slightly below the tip of the coccyx, which in males is opposite the prostate (Fig. 153). The length of rectum varies between 12-15 cm as measured from the **external anal margin**. Immediately above the pelvic diaphragm the rectum dilates to form the **ampulla** (Fig. 154).

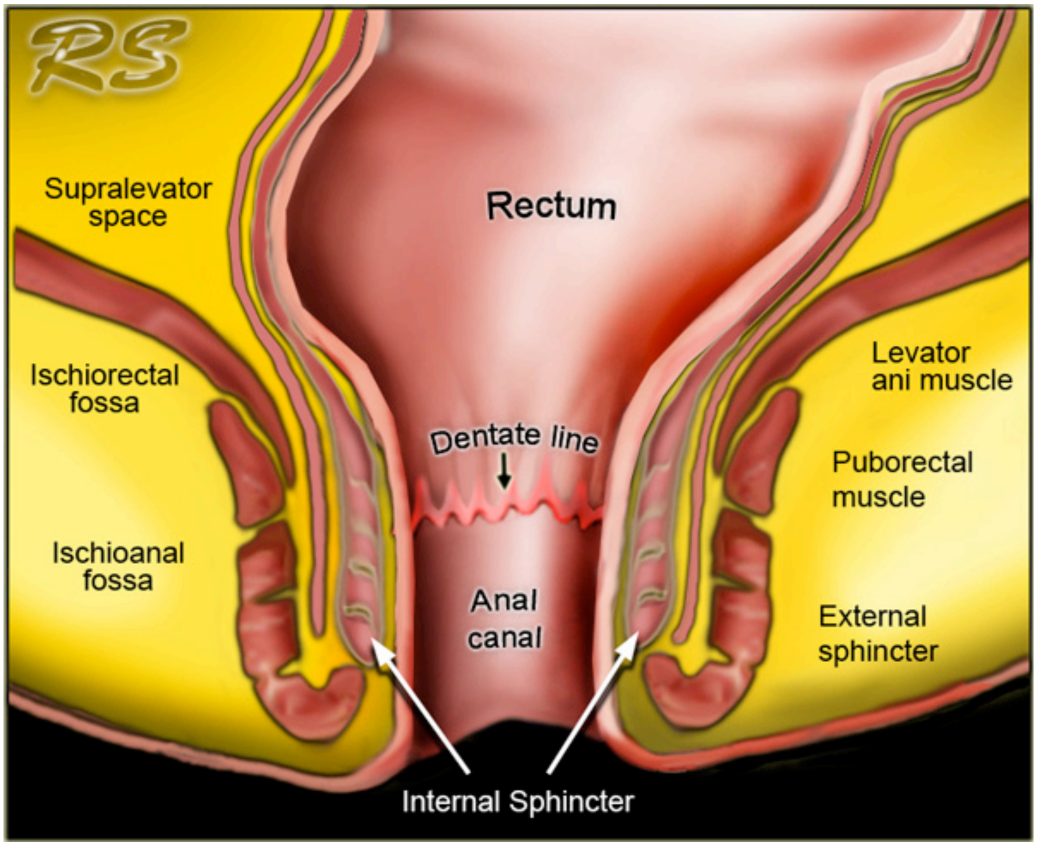


Fig. 154. In this illustration the levator ani muscle constitutes the pelvic floor. Note the dilatation of the terminal part of the rectum, which although not labeled, represents the ampulla. (Wiki)

The initial diameter of the rectum is similar to the sigmoid colon, however, as it descends its diameter increases, ultimately forming the rectal ampulla.

The rectum, unlike the sigmoid colon does not have **sacculations** or **appendices epiploicae**. Also, there is a modification of the three **taeniae coli of the sigmoid colon** (Figs. 155 & 156). Approximately 5 cm above the **rectosigmoid junction** the three taeniae blend to form two wide muscular bands, which descend anteriorly and posteriorly in the rectal wall. These in turn fuse to form an encircling layer of **longitudinal muscle**, which invest the entire rectum. Some of the smooth muscle fibers of the **anterior rectal band** separate just above the pelvic diaphragm and end in the **perineal body** in the **female** and in the back of the **urethra** in the **male.** These fibers form the **rectourethral muscle**. In addition, two fasciculi of smooth muscle may pass anterioinferiorly from the anterior surfaces of the **bodies of the**

second and third coccygeal vertebrae to blend with the longitudinal muscle fibers on the posterior wall of the **anal canal**, forming the **rectococcygeal muscles**.

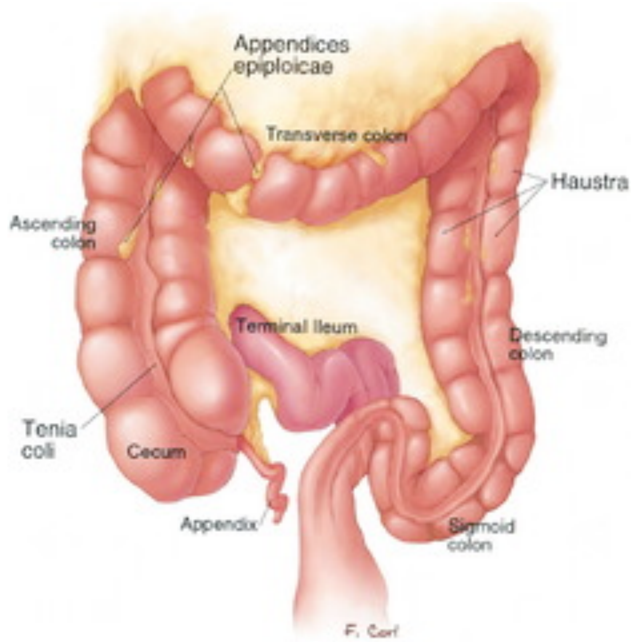


Fig. 155. This illustration shows the terminal ileum appendix and parts of the colon including the appendices epiploicae and taenia coli. (Wiki)

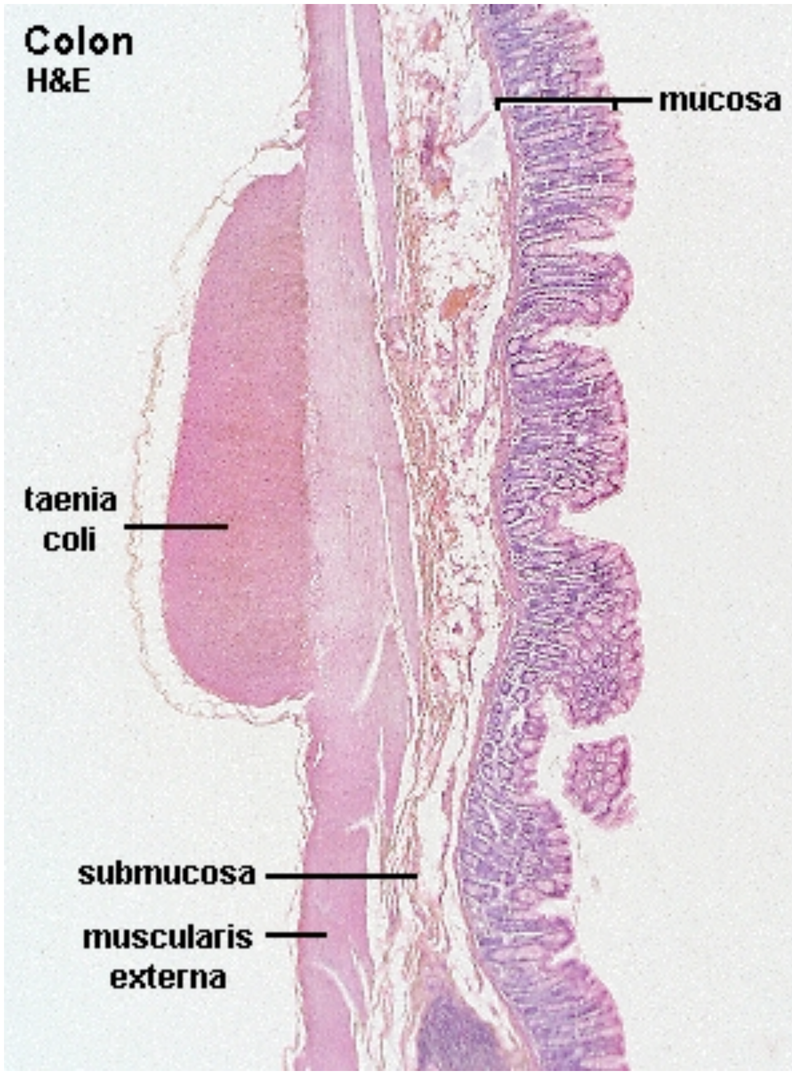


Fig. 156. This image is a low power photomicrograph of the colon showing one of the bundles of longitudinal muscle, the taenia coli. Note also the thin layer of longitudinal muscle between the taenia coli and the inner circular muscle layer. (lecannabiculteur.free.fr)

When viewing the internal surface of the rectum you commonly see three, typically, semilunar, **transverse rectal folds**, which impart a side to side sinuosity to the external surface of the rectum. There are two types of transverse folds: one consist of the mucosa, a circular muscle layer, and part of the longitudinal muscle and can be seen on the external surface of the rectum by an indentation; the other is devoid of the longitudinal muscle layer and has no external indentation. Typically, there is a **superior, middle** and **inferior fold** (Fig. 157).

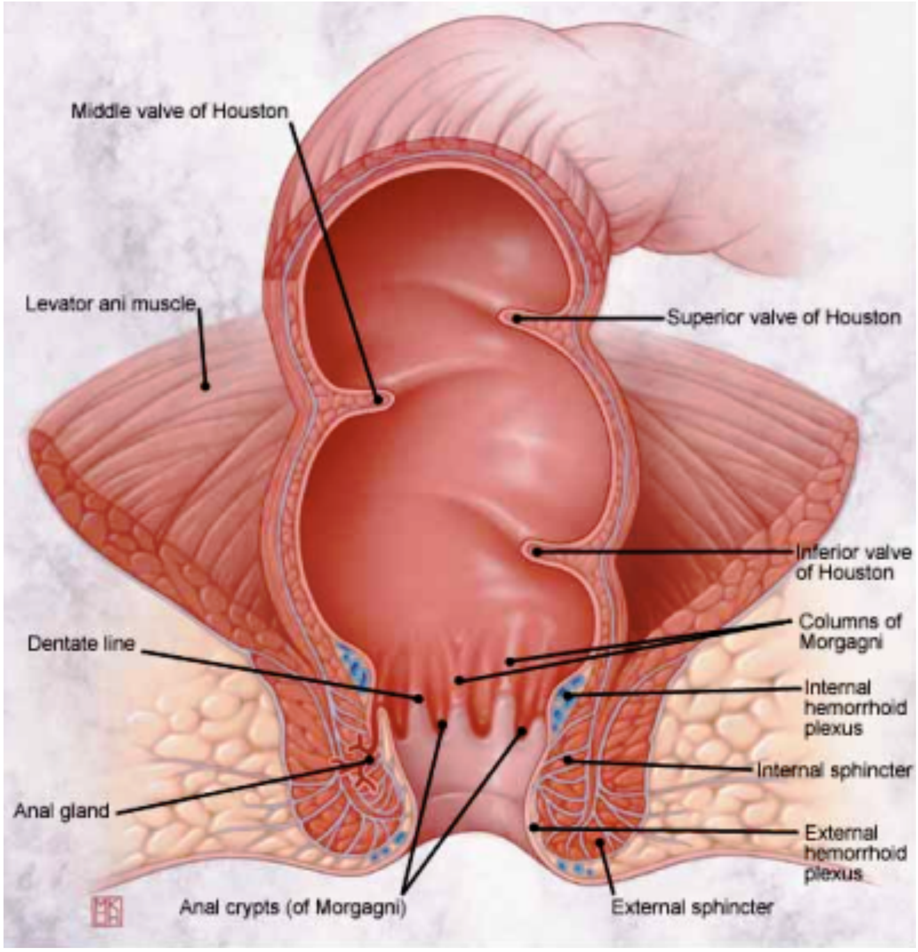


Fig. 157. This illustration shows the location of the semilunar transverse folds of the rectal wall that protrude into the rectum. These valves are also referred to as Houston's valves. These folds were first described by a British anatomist John Houston, a curator of Dublin College of Surgeon's Museum, in 1830. They appear to be unique to human physiology in that they are not found in a number of mammals, including the wolf, bear, rhinoceros, and several primates. They are formed very early in human development, being visible at the 10 week of gestation. (stomaatje.com)

The most prominent and constant fold is the **middle**, which occurs about 8 cm above the anal aperture, projecting from the anterior aspect of the right wall, usually at the **anterior peritoneal reflection**. The **superior fold** occurs 2-3 cm above the middle fold, usually at the beginning of the rectum and may project from either the left or right posterior aspect of the wall. The **inferior fold** occurs 2-3 cm below the middle fold and typically projects from the left posterior aspect. The presence of this fold is variable. Occasionally, there may be a fourth fold located on the left side and a little above the middle fold. These folds are due to the relative shortness of the longitudinal muscular layer which in the rectum are concentrated into the **anterior** and **posterior longitudinal bands** previously discussed. The transverse rectal folds function is to support the weight of fecal matter, and prevent its urging toward the anus, which would produce a strong urge to defecate. As shown in Fig. 153, the rectum does not have a complete peritoneal covering. Its upper one-third is covered on the sides and in front (anterior); in the middle third, it is covered only in front. The peritoneum is reflected superiorly onto the urinary bladder in males to form the **retrovesical pouch** (Figs 36 & 93, p 43 & 115),which is about 7.5 cm above the anorectal junction, or onto the posterior vaginal wall to form the **rectouterine pouch (pouch of Douglas)** (Figs. 104 & 105, p 127 & 128), which is about 5,5 cm above the anorectal junction. The lower third is completely devoid of a peritoneal covering.

In the adult, as pointed out above, the rectum does not reach the pelvic floor, although it did during developmental stages. In the adult the underlying connective tissue upon which the peritoneal epithelial cells rest, becomes apposed once the peritoneal epithelial lining disappears. The apposed connective tissue thus, form the **rectal fusion fascia** (Fig. 55, p 65 & Fig. 158).

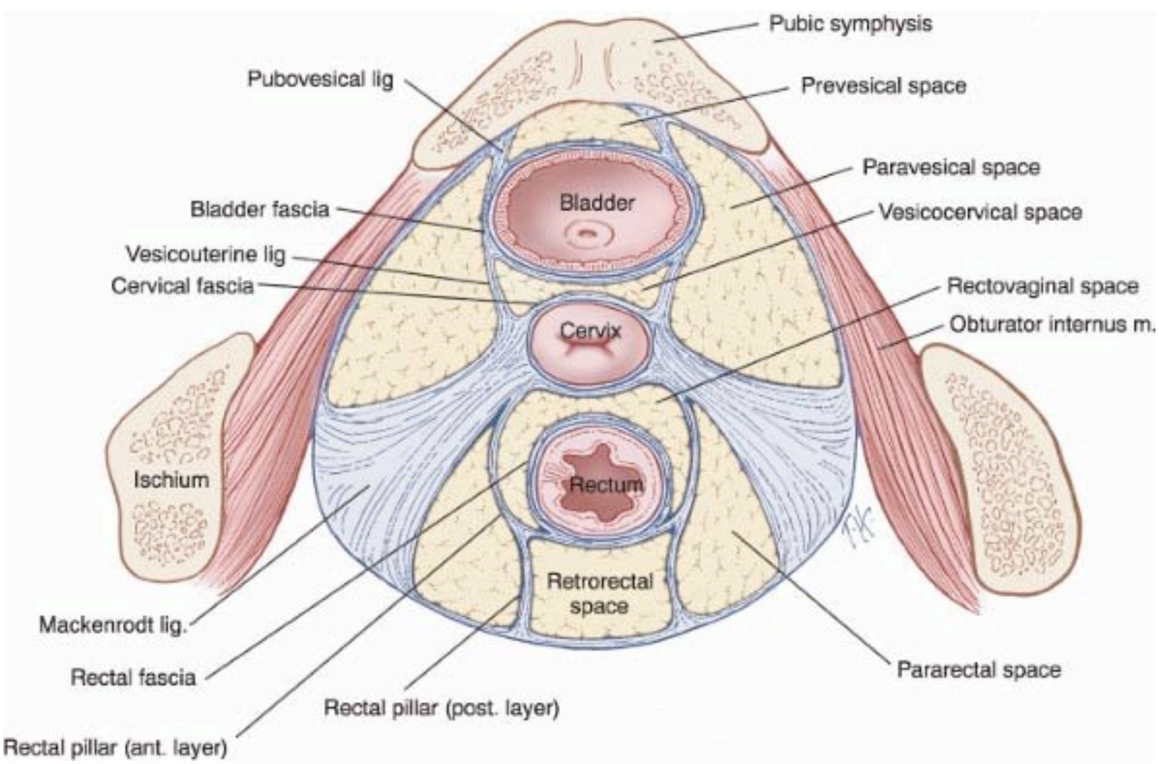


Fig. 158. The above illustration shows the location of the rectal fascia (rectal fusion fascia). (www.epubbud.com)

The rectal fusion fascia lies on either side of the rectum below the peritoneal reflections and assumes the position of the original peritoneum of the rectum. Consequently, the rectal fusion fascia begins on the posterior surface of the upper third of the rectum, expands to include the lateral surfaces of the middle third of the rectum and totally encloses the rectum in its lower third, together with the rectums blood vessels, with the fascia covering the sides ending in a midline attachment over the sacrum. The peritoneum obliterated in front of the lower third of the rectum is the peritoneum of the inferior limit of the **rectovesical pouch** of the male. Here the fusion fascia, continuous behind with the rectal fusion fascia at the sides of the rectum to form the **rectovesical septum** (Fig. 50, p 60). It separates the ampullary portion of the rectum from the fundus of the bladder and from the ductus deferens, seminal vesicles, and the posterior surface of the prostate. The comparable **rectovaginal septum** of the female lies between the ampulla of the rectum and the upper half of the posterior vaginal wall (Figs. 50 & 124, p 60 & 148).

The anatomic relationships of the rectum are such that **posterior** to it are the vertebrae **S3-S5, the coccyx, median sacral vessels, and the lowest portion of the sacral sympathetic chain** (Figs. 72 & 113, p 84 & 113). **Laterally**, the upper part of the rectum is next to the **sigmoid colon** and or the **terminal ileum**. The lowest part of the rectum (that portion below the peritoneal reflection) is **laterally** in relation to the **piriformis, coccygeal and levator ani muscles, the anterior rami of S3-S5 and coccygeal nerves, the sympathetic trunk and the lower sacral vessels** (Fig. 41, p 47). **Anteriorly,** that part of the rectum, which is above the peritoneal reflection, is next to the **sigmoid colon** and or the **terminal ileum** if they lie within the pelvis. If that is not the case, this part of the rectum lies next to the upper parts of the base of the **bladder** in **males**, and in **females** it is in relation to the **cervix and body of the uterus and the upper vagina**. That portion of the rectum below the peritoneal reflection **anteriorly** is adjacent to the lower parts of the **base of the bladder, the seminal vesicles, vas deferens, terminal part of the ureters, and the prostate gland in males, or the lower part of the vagina in females** (Figs. 36, 93 & 105 & p 43, 115 & 128, & Figs. 159 & 160).

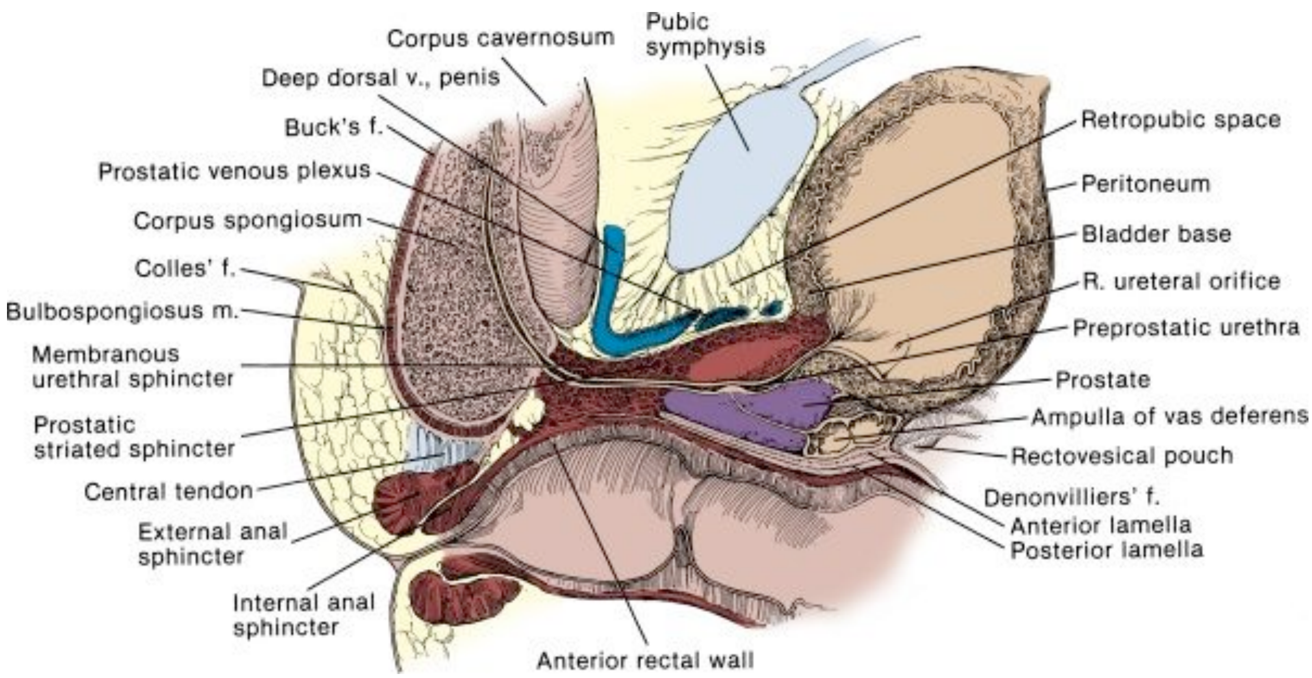


Fig. 159. This illustration depicts the anatomic relationships to the anterior rectal wall in the male. (Wiki)

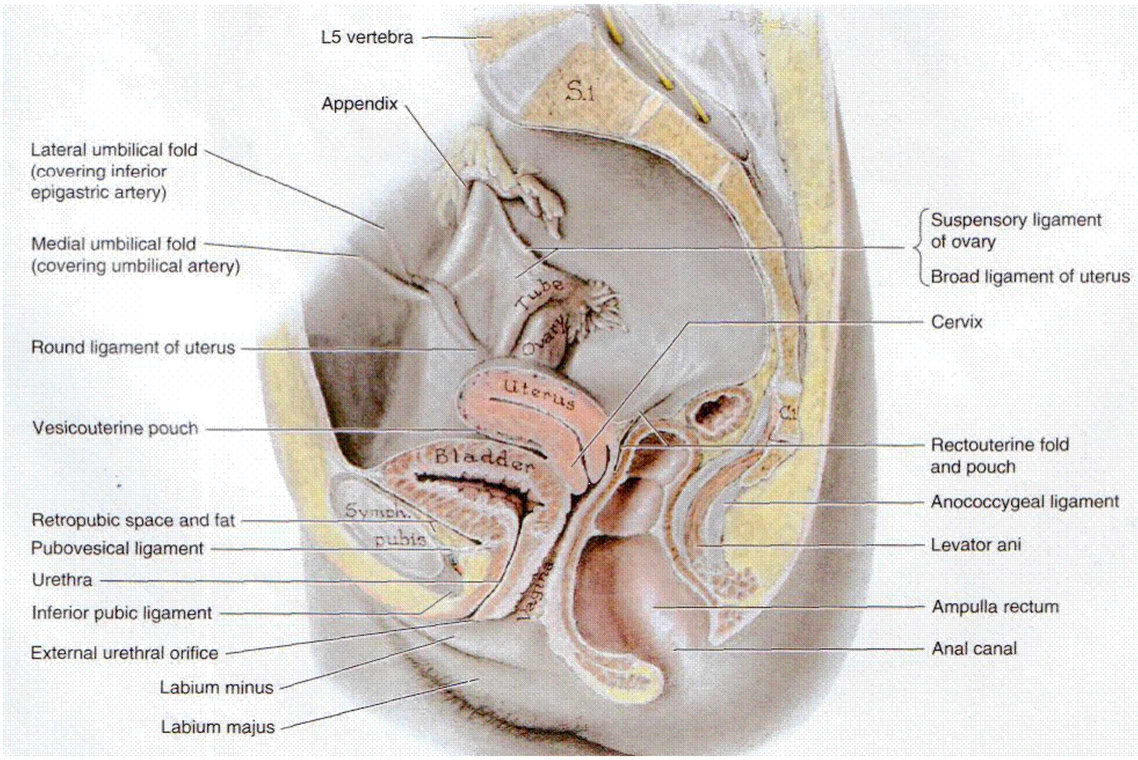


Fig. 160. This illustration depicts some of the anatomic relationships between the rectum and reproductive organs of the female. (Wiki)

Microscopically, the structure of the rectum and anal canal is the same as the rest of the colon being composed of a **mucosa, submucosa, muscularis externa and serosa or adventitial layer** (Fig. 161). However, it differs from the rest of the colon by having **transverse rectal folds** (Fig. 157) and it lacks **tenia coli** in its **muscularis externa** (Figs. 155 & 156).

The **mucosa** appears smooth due to the fact it contains no villi, unlike the small bowel which contains abundant villi (Fig. 162). In the rectum the glands are longer, more widely spaced, and lined, as is the luminal surface of the mucosa, by **columnar cells, mucous (goblet cells), stem cells** and occasional **microfold (M) cells** that are found in the epithelium overlying the **lymphoid follicles** at or near the bases of the intestinal glands. These stem cells divide by mitosis, the resulting cells then migrate towards the luminal surface. **Paneth cells** are usually absent and **neuroendocrine cells** are decreased. The neuroendocrine cells that are present are located primarily at the bases of the glands. They produce a variety of **peptide hormones**. Columnar absorptive cells and goblet cells are abundant. The goblet cells increase in number as you descend in the rectum.

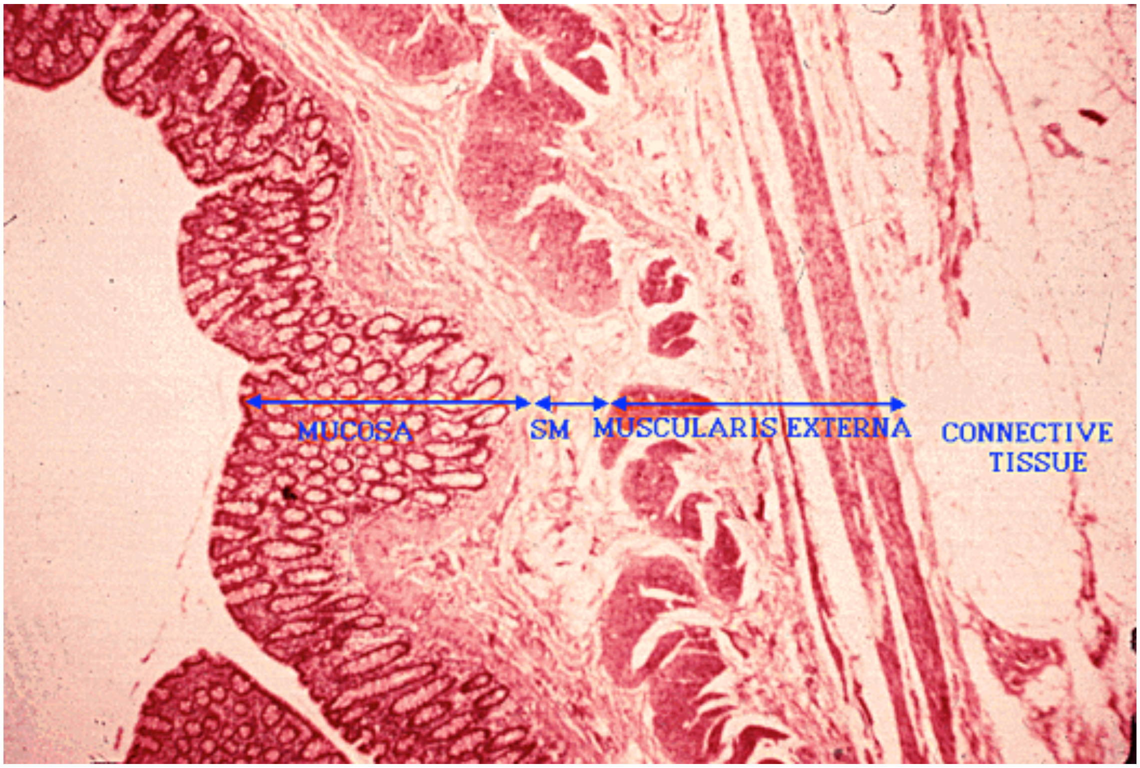


Fig. 161. This is a low power photomicrograph of the rectum denoting the main histologic components. That which is labeled connective tissue is analogous to the adventitial layer. (education.med.nyu.edu)

The epithelial cells rest on a connective tissue layer called the **lamina propria**. The structure of the lamina propria is much the same as in the small intestine; it typically is rich in **eosinophils**. Scattered lymphatic nodules are also present. As compared to the rest of the colon the rectum has more abundant diffuse lymphatic tissue and lymph nodules, which can extend far into the submucosa. The lamina propria forms a specialized **pericryptal myofibroblast sheath** around each gland. Although the lamina propria contains abundant lymphatics, these vessels are absent from the lamina propria core between the crypts.

The final component of the mucosal layer is the **muscularis mucosa**, which is composed of several thin layers of smooth muscle fibers oriented in different ways.

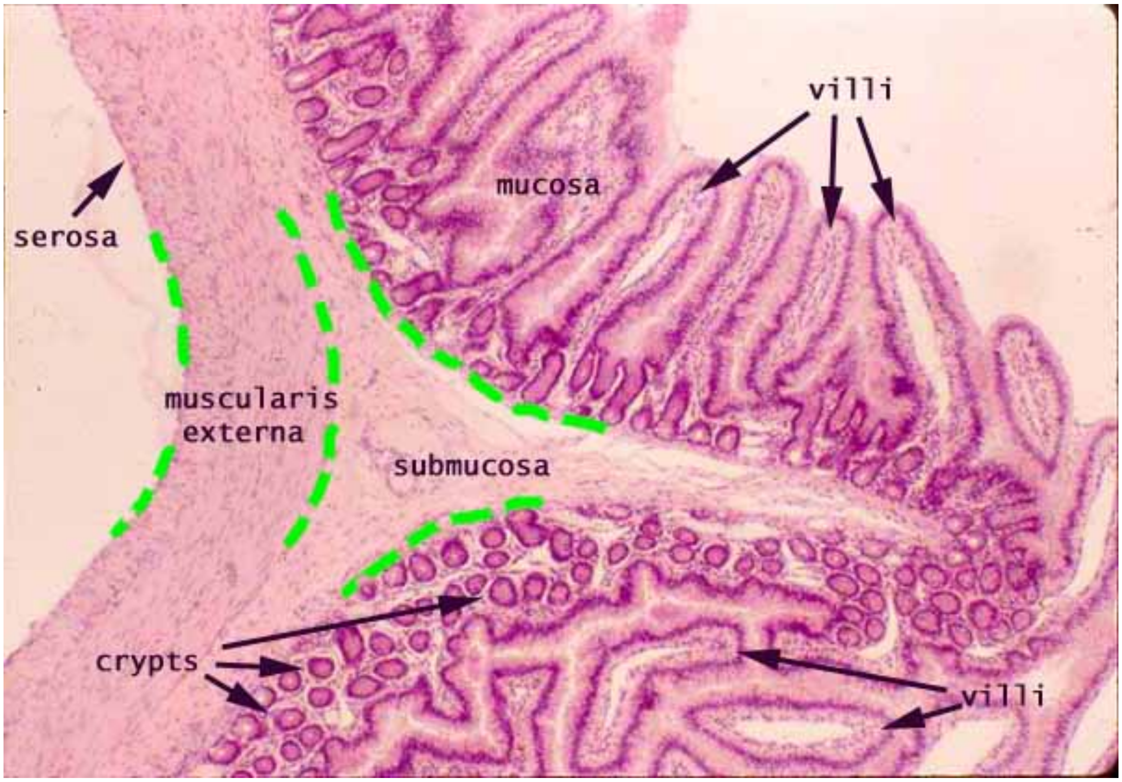


Fig. 162. This image is a low power photomicrograph of the wall of the small bowel. (www.siumed.edu)

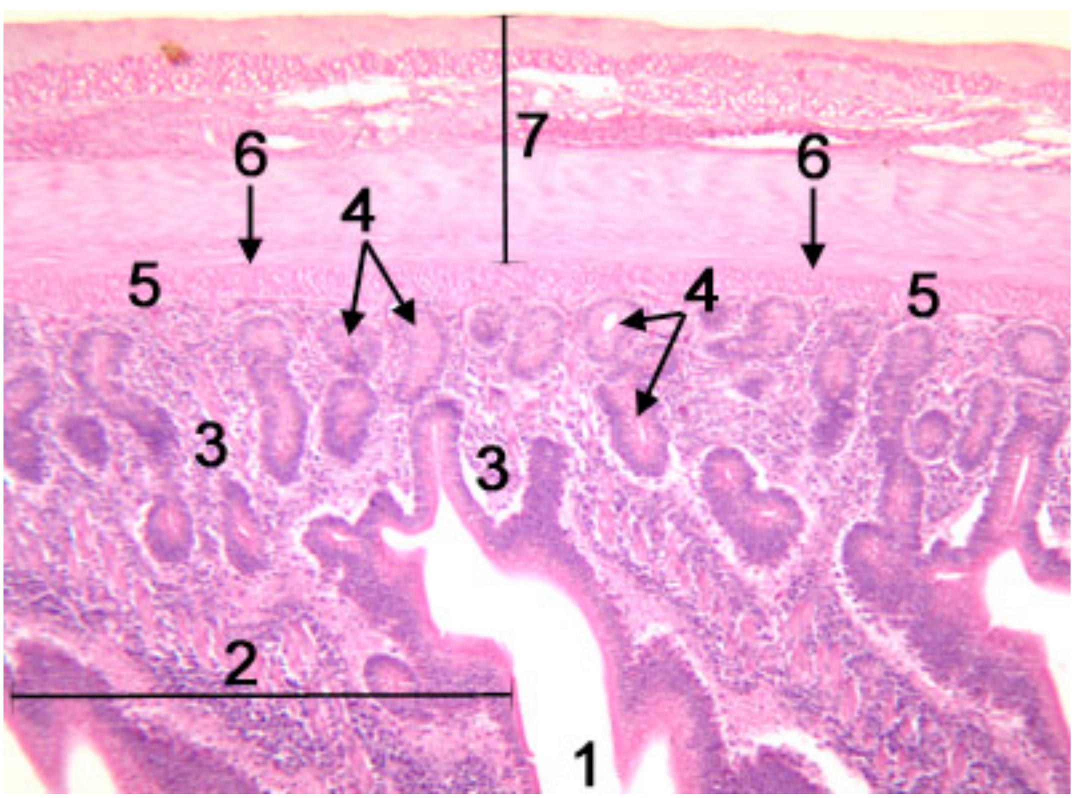


Fig. 163. The above is a low power photomicrograph of the bowel (small bowel, duodenum) showing its components. (1), lumen of the small bowel; (2), Villi; (3), Lamina propria; (4), Crypts of Lieberkün; (5), Muscularis mucosa; (6), Submucosa; and (7), Muscularis externa. (cal.vet.upenn.edu)

The orientation of the smooth fibers in different ways keep the mucosal surface and underlying glands in a constant state of gentle agitation to expel contents of the glandular crypts and enhance contact between the epithelial surface and the contents of the lumen.

The **submucosa** is the next anatomic layer of the intestine (Figs. 161, 162 & 163). It is composed of connective tissue the density of which varies from area to area. Within the submucosa are a network of blood vessels, lymphatics, nerves and ganglion cells, the **submucosal plexus or Meissner's plexus** (Figs. 164 & 165).

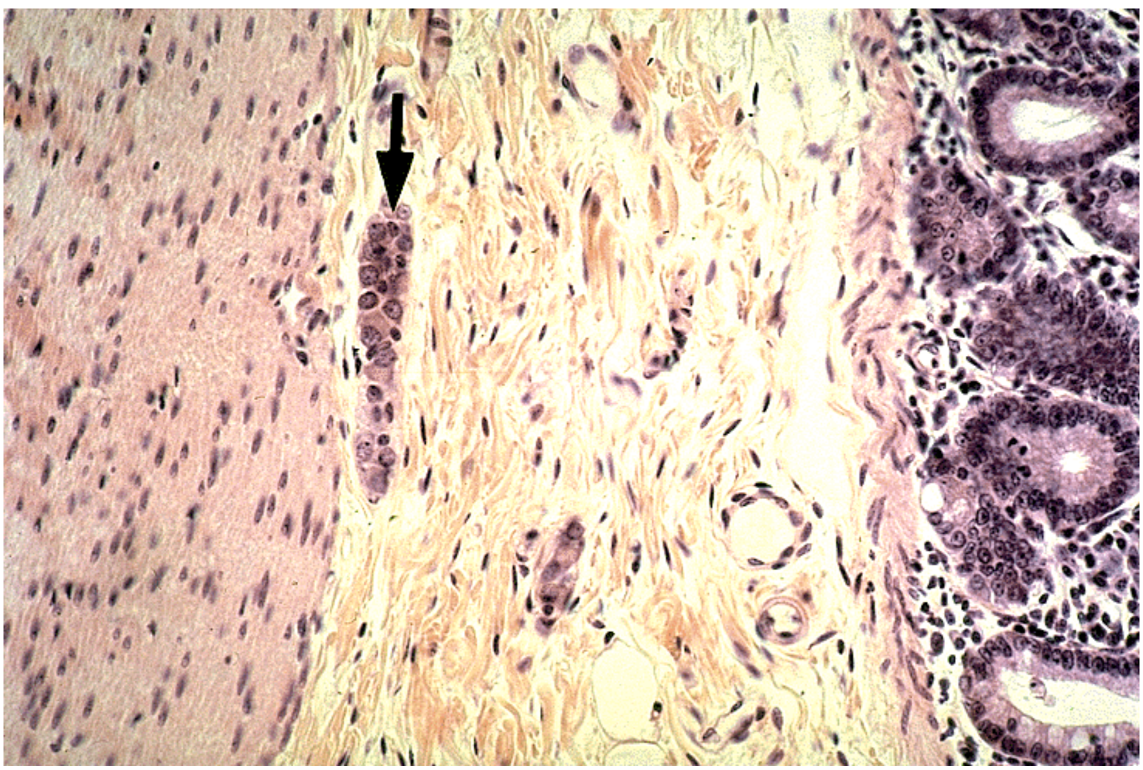


Fig. 164. This is a medium power photomicrograph of the intestine showing the mucosa on the right, submucosa in the middle and the muscularis externa to the left. The arrow points to a collection of ganglion cells, Meissner's plexus. (class.kmu.edu.tw)

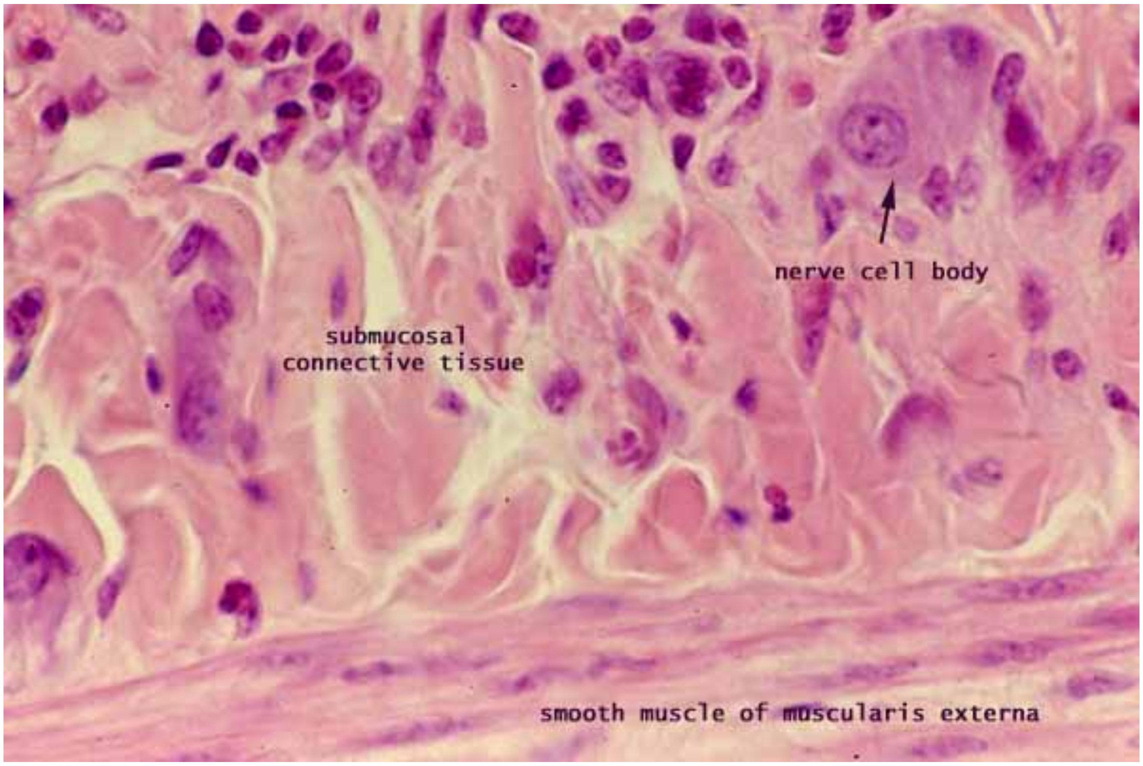


Fig. 165. This is a high power photomicrograph of the intestine showing the submucosal layer within which ganglion cells (nerve cell body) are identified of Meissner's plexus. This plexus consist of parasympathetic nerve fibers and ganglion cells, which influence the smooth muscle of the muscularis mucosae. Immediately inferior to the submucosal layer is the muscularis externa. As can be seen in both Figs. 164 & 165, nerve cell bodies are usually rather conspicuous. Each cell body can be quite large (up to ~50µm), with relatively basophilic cytoplasm and with a large, round, euchromatic nucleus with a single prominent nucleolus. (www.siumed.edu)

The **muscularis externa** consists of an inner circular layer and an outer longitudinal layer of smooth muscle (Figs. 161, 162, 163 & 165). *Remember, in the colon the outer longitudinal layer is thin except for three thick longitudinal bands, the* ***taenia coli****. However, the rectum lacks taenia coli. In the rectum the outer longitudinal is incomplete, being concentrated into an anterior and posterior band on the respective surfaces of the rectum. This is a modification of the three taenia coli of the sigmoid colon.* Also, between the circular and longitudinal smooth muscle layers is another neural plexus, **myenteric plexus or Auerbach's plexus** (Fig. 166). There are neural connections between Meissner's and Auerbach's plexus.

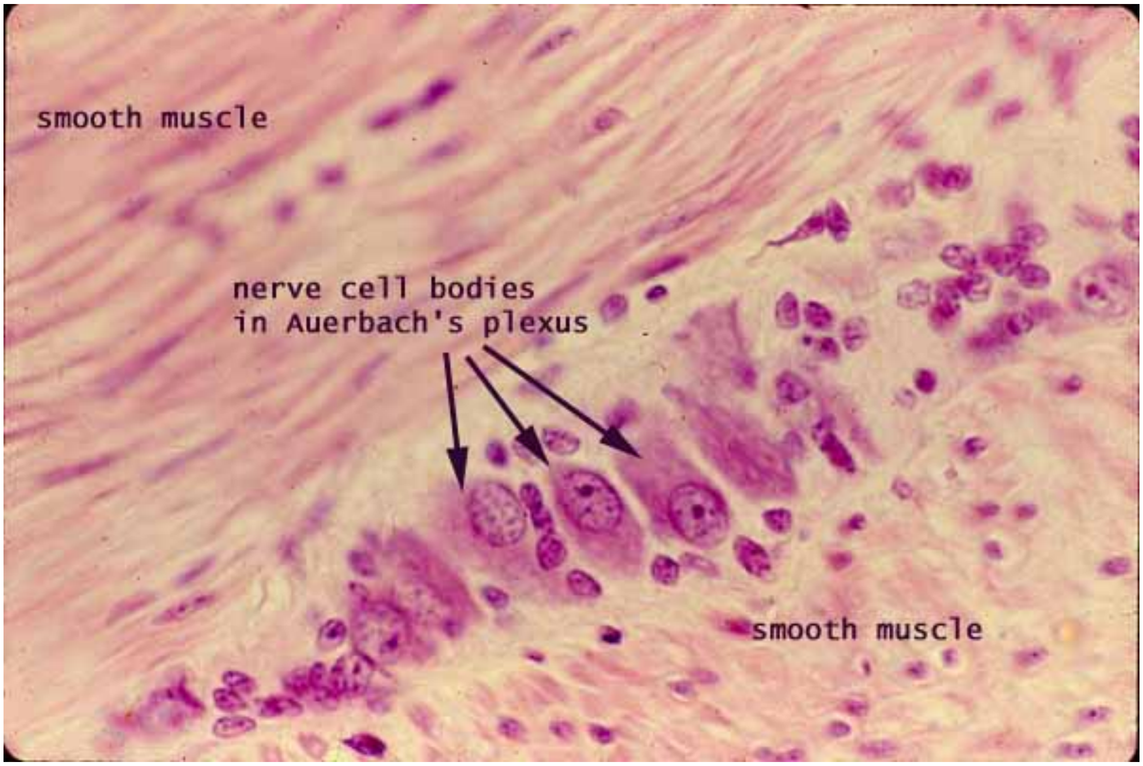


Fig. 166. This image is a high power photomicrograph of the nerve cell bodies forming Auerbach's (myenteric) plexus. It provides motor innervation to both layers of the muscularis externa. It has both parasympathetic and sympathetic input, whereas Meissner's plexus has only parasympathetic fibers. Aurebach's plexus provides secretomotor innervation to the overlying mucosa. It is the major nerve supply to the gastrointestinal tract and controls GI tract motility. (www.siumed.edu)

In the rectum the **serosal layer (visceral peritoneum)** is variable in its presence. In the upper third, the rectum has a serosal layer anteriorly and laterally (Fig. 162). The middle third has a serosal layer anteriorly. All other structures of the rectum contains an **adventitial layer** composed of loose connective tissue (Fig. 161). The **arterial blood supply** to the rectum is through three vessels: the **superior rectal artery, middle rectal artery,** and the **inferior rectal artery** (Fig. 167). The superior rectal artery supplies the upper two-thirds of the rectum. Branches from the middle rectal artery provides an additional supply to the middle third, and ascending branches of the inferior rectal artery supply the inferior third. The superior rectal artery is the primary continuation of the **inferior mesenteric artery**. The middle rectal arteries arise either from the **anterior division of the internal**

iliac artery or from the inferior vesicle artery (vaginal artery in females). The inferior rectal arteries are the terminal branches of the **internal pudendal arteries**.

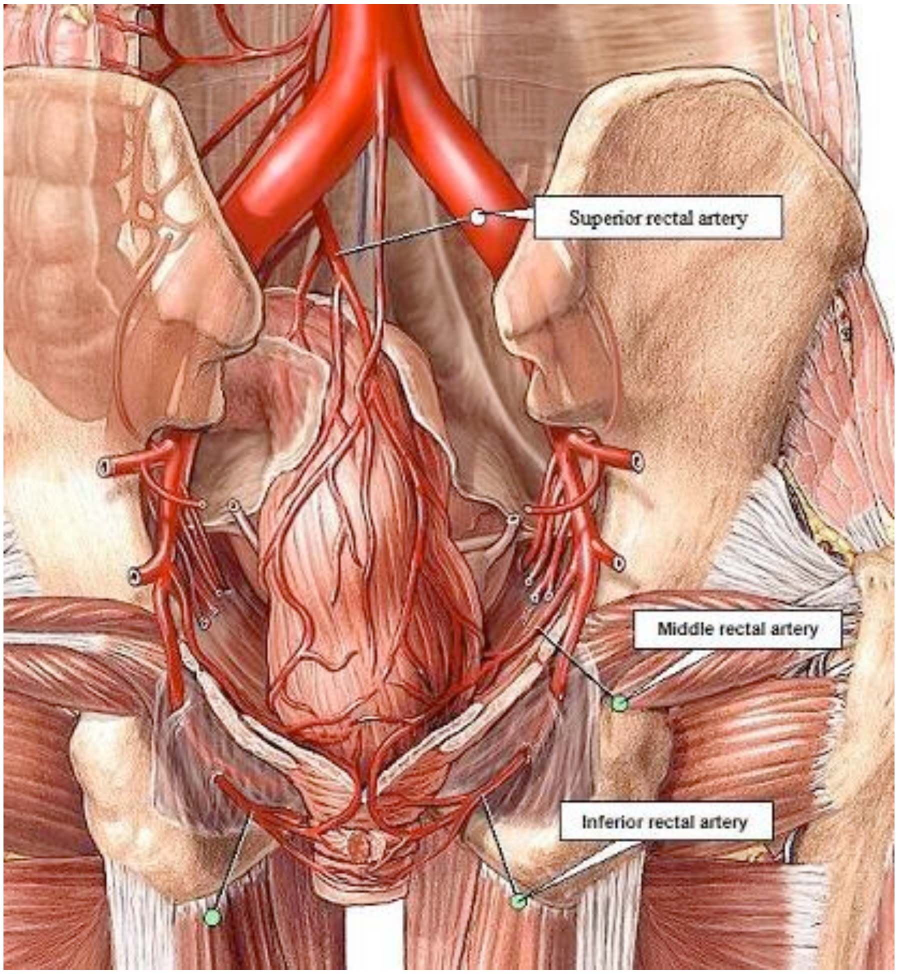


Fig. 167. This illustration depicts the location of the superior, middle and inferior rectal arteries. (fitsweb.uchc.edu)

The **venous drainage** of the rectum is through the **rectal venous plexus**, which envelops the rectum (Fig. 168). In males the rectal venous plexus connects with the **vesicle plexus** and in females with the **uterovaginal plexus**. It consist of two parts, an **internal portion**, which is located under the epithelial surface of the rectum and anus, and an **external portion**, which is outside the **muscularis externa**. The internal and external plexuses communicate with one another. The **internal plexus** drains primarily to the **superior rectal vein**. The inferior portion of the **external plexus** drains to the **inferior rectal vein** then to the **internal**

pudendal vein, which drains to the **inferior vena cava** through the **internal iliac vein**. The middle portion drains by one or more **middle rectal veins** into the internal iliac vein, which drains to the inferior vena cava. The superior part of the external plexus drains into the **superior rectal vein**, which in turn drains into the **inferior mesenteric vein**, which drains to the **portal vein**. Thus, the rectal venous plexus establishes a communication between the **portal** and **systemic venous system**.

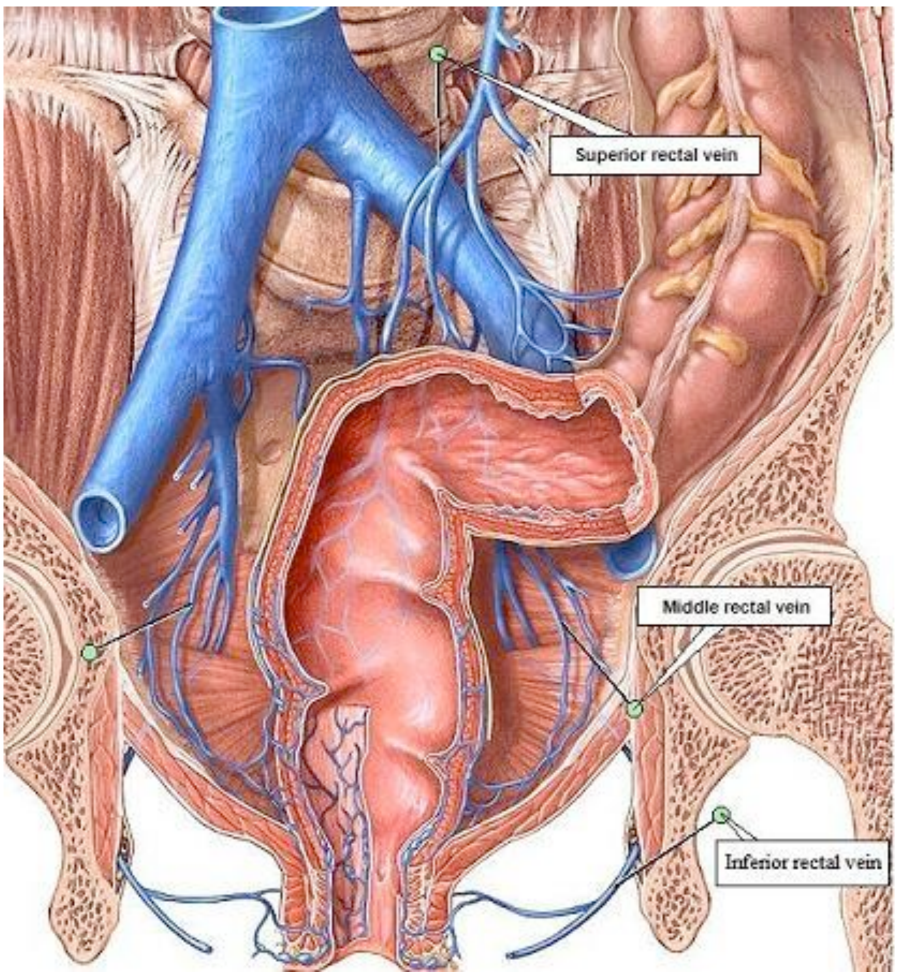


Fig. 168. This illustration depicts the internal and external venous plexus and the superior, middle and inferior rectal veins. (fitsweb.uchc.edu)

The **lymphatic drainage** of the rectum and anal canal takes origin in a plexus of lymphatic vessels in the **mucosal layer**, which is continuous with the cutaneous lymphatic plexus of the **perineum** (Figs. 150 & 151, p 177 & 178 & Fig. 169).

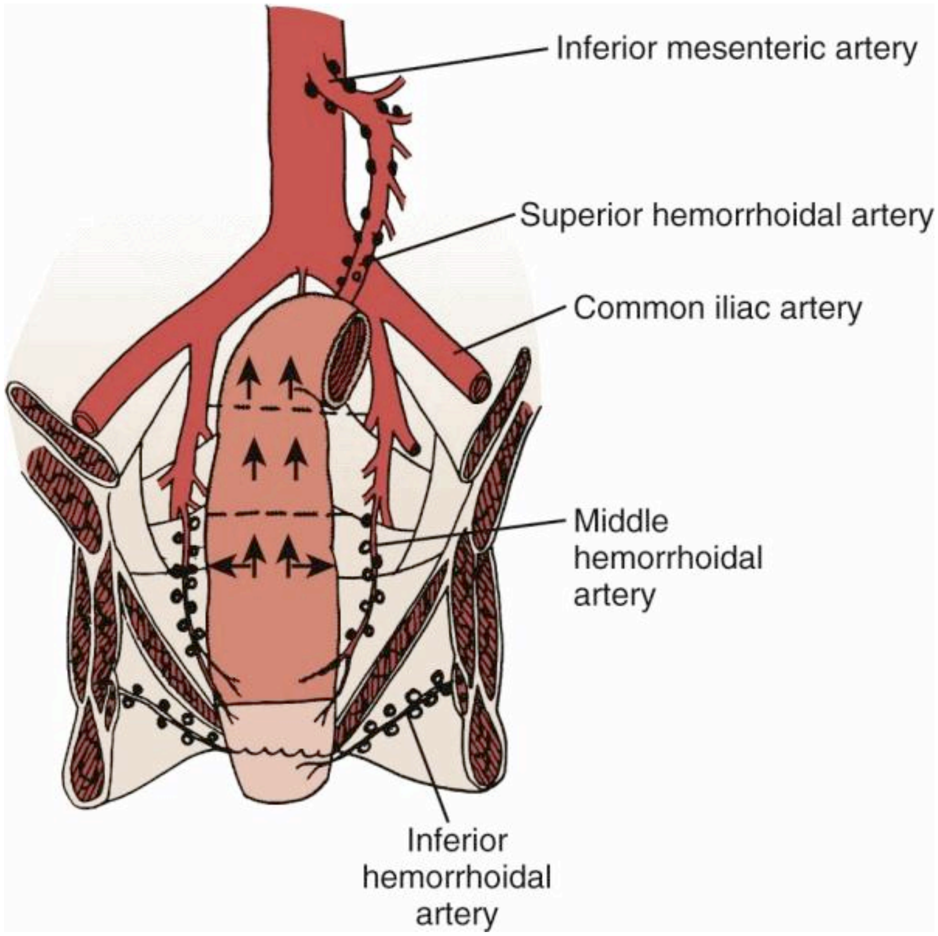


Fig. 169. This illustration depicts the anatomy and lymphatic drainage of the rectum. Anatomically, the classification of hemorrhoidal is analogous to rectal. (health-7.com)

Typically, the collecting vessels follow the blood vessels supplying the rectum and the anal canal. Five lymphatic channels are recognized: (1) The primary drainage is by channels which accompany the **superior rectal (superior hemorrhoidal) vessels** to nodes located in the angle of the division of the superior rectal artery opposite the third sacral vertebra and from there ascend to the **inferior mesenteric nodes** at the root of the **inferior mesenteric artery**. These particular channels drain the entire rectum and anal canal. (2) From the lower part of the rectum, lymphatic channels course lateral ward along the **middle rectal (middle hemorrhoidal) vessels** to the **internal iliac nodes**. (3) Small channels pass under the sacrogenital folds to the **sacral nodes**. (4) Lymphatic channels arising below the pelvic diaphragm follow the **inferior rectal (inferior hemorrhoidal) vessels** across the **ischiorectal fossae**, perforate the lateral edges of the diaphragm, and empty into the **internal iliac nodes**. (5) From the terminal part of the anal canal and from the cutaneous plexus around the anus, lymphatic channels follow the **genitofemoral sulcus** forward to drain into the **superficial inguinal nodes**.

The **innervation** of the **rectum** and **upper anal canal** is **autonomic (sympathetic and parasympathetic)**. The **sympathetic supply** takes origin in the **L1-L2 spinal segments**. These **preganglionic fibers** are distributed through the **lumbar splanchnic nerves** through the **inferior mesenteric plexus** and through the **sacral splanchnic nerves** by the **superior** and **inferior hypogastric plexus** (Figs. 59, 72, 73, 113, & 145, p 69, 84, 86, 136 & 169).

The **lumbar splanchnic nerves** are 3 or 4 short branches of the lumbar trunk, which arise predominantly at the levels of the first, second and third lumbar vertebrae (Fig. 170). The nerve fibers from **L1-L2** go to the **inferior mesenteric plexus**, where they form synapses. The fibers of **L3**, as well as a few fibers from **L2,** travel to the **superior hypogastric plexus**. The lumbar splanchnic nerves supply **sympathetic innervation** for the pelvic viscera and distal large bowel. The superior hypogastric plexus is continuous with the **intermesenteric plexus**. It also receives the lower two splanchnic nerves. The intermesenteric plexus is located between the **superior** and **inferior mesenteric plexuses**. Along with receiving **preganglionic sympathetic fibers** from the upper two lumbar splanchnic nerves, it also receives **parasympathetic fibers**, which represent the distal extent of **vagal innervation** supplying the large intestine to the **left colic (splenic) flexure.** It also should be kept in mind, besides ending here, the lumbar splanchnic nerves have other terminal branches.

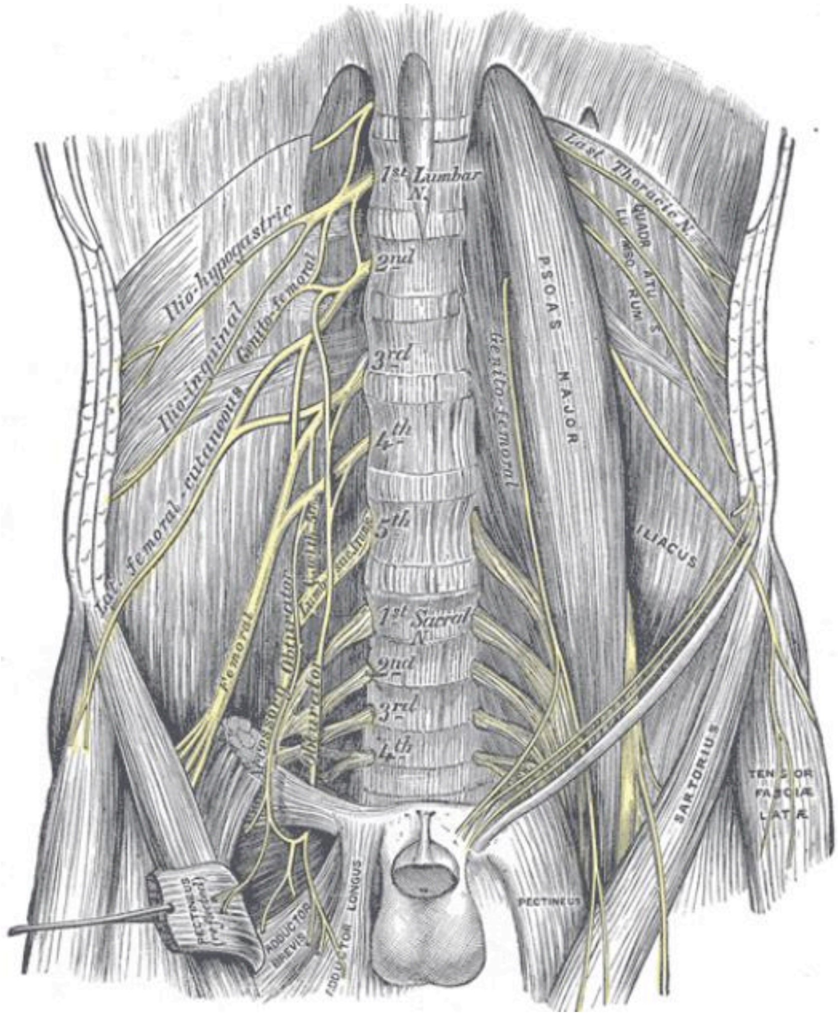


Fig. 170. This image depicts the lumbar splanchnic nerves. It shows the left side of the body with the relationships between the nerves and psoas muscle and inguinal ligament. On the right side the psoas muscle and inguinal ligament have been removed. (www.cambridgeorthopaedics.com)

The **superior hypogastric plexus** divides into the left and right hypogastric nerves at the level of **S1 vertebra** (Fig. 171). The left and right hypogastric nerves diverge on either side of the rectum, descending into the pelvis. They interconnect the superior and inferior hypogastric plexus and are the principal **sympathetic roots** of the latter (Figs. 59 & 113, p 69 & Fig.136).

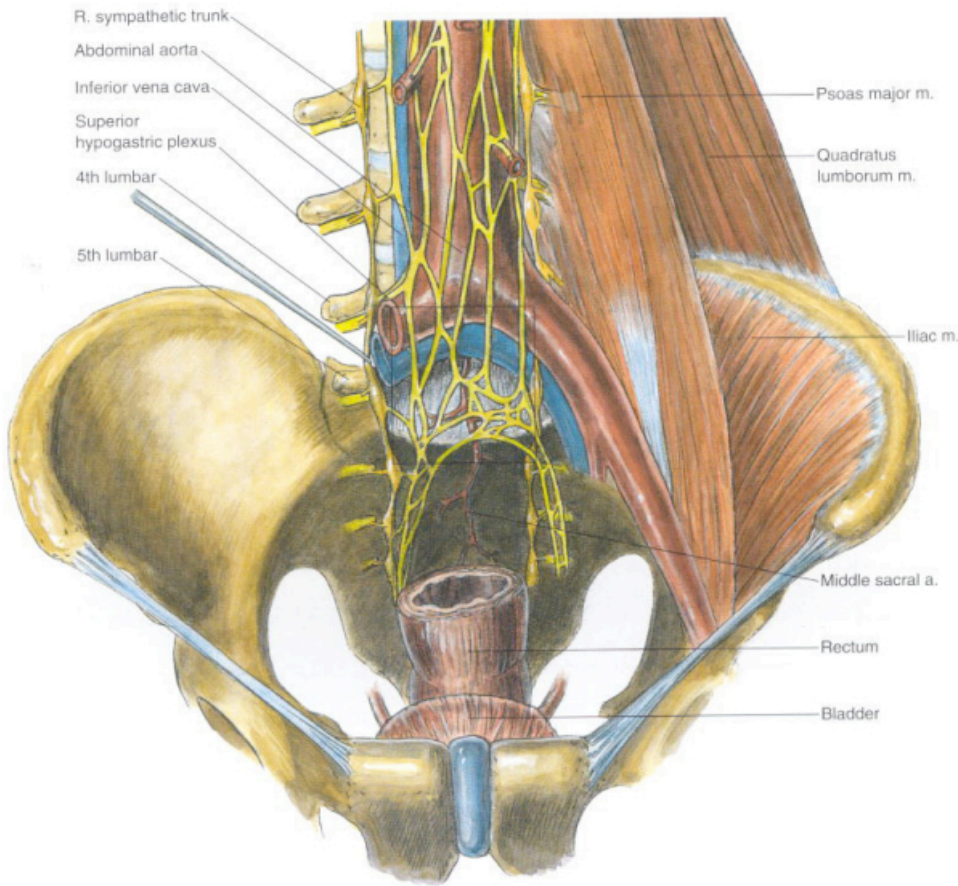


Fig. 171. This illustration is of the anteroposterior anatomy of the superior hypogastric plexus. (polanest.webd.pl)

The **inferior hypogastric plexus** are fanlike expansions of the **hypogastric nerves**, which are located, in the male, on either side of the **rectum, prostate** and **seminal vesicles**, and are against the inferolateral surface of the **bladder** (Figs. 59 & 113, p 69 & 136 & Fig. 172). In the female the relations are similar, the **cervix** and the l**ateral vaginal fornices** replacing the seminal vesicles and the prostate. Although, the hypogastric nerves are the principal source of sympathetic nerves to the inferior hypogastric plexuses, they also receive sympathetic fibers from the **sacral splanchnic nerves** (Figs. 72 & 113, p 84 & Fig. 136). The sacral splanchnic nerves connect the inferior hypogastric plexus to the **sacral sympathetic trunk**. The sacral sympathetic nerves are found in the same region as the **pelvic splanchnic nerves**, the cells of origin are in the **S2-S4 spinal**

segments. These **preganglionic nerves** supply the **parasympathetic innervation** of all pelvic and perineal viscera, and of the abdominal viscera supplied by the **inferior mesenteric artery**. These parasympathetic preganglionic fibers synapse with ganglia of the inferior hypogastric plexus and in minute ganglia in the muscular walls of the pelvic and abdominal viscera.

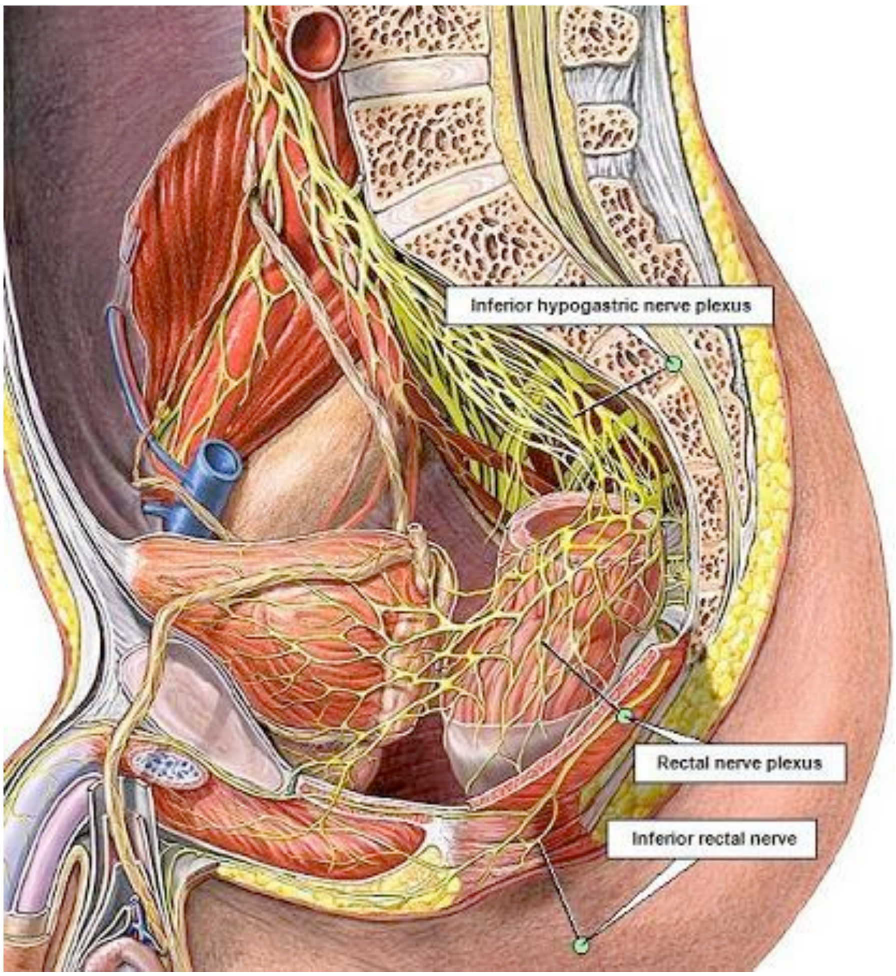


Fig. 172. This illustration depicts the inferior hypogastric plexus and the rectal (middle) nerve plexus, as well as the inferior rectal nerve. (fitsweb.uchc.edu)

The inferior hypogastric plexus give rise to subsidiary plexuses: **the middle rectal, the vesicle, the deferential, and the prostatic (or uterovaginal)**. At this point in our discussion we are interested in the middle rectal plexus.

The middle rectal plexus is derived from the posterior portion of the inferior hypogastric plexus. From 4 to 8 nerves run from the inferior hypogastric plexus to the rectum, mostly directly, however, one or two are in company with the **middle rectal artery**. They penetrate the walls of the rectum, as they do in other parts of the intestines, and synapse with the ganglion cells of the **enteric plexuses**, also referred to as the **enteric nervous system**, of which there are two primary components, the **myenteric (Auerbach's) plexus (outer plexus)** (Fig. 166), and the **submucosal (Meissner's) plexus (inner plexus)** (Figs. 164 & 165).

The **parasympathetic fibers** of the middle rectal plexus are derived from the **pelvic splanchnic nerves** (Figs. 72 & 113, p 84 & 136).

The parasympathetic supply of the large intestine from its **left flexure** to the lower **rectum and anal canal** is separate from the sympathetic supply. The parasympathetic innervation of the distal colon (from the left flexure to the anal canal) is by the long slender pelvic splanchnic nerves, the cells of origin of which are in **S2-S4 spinal segments**. Some of these **preganglionic parasympathetic fibers** synapse in the **inferior hypogastric plexus**, whereas others pass directly to the rectum and sigmoid colon. The separate course of the parasympathetic innervation of the distal part of the colon results in the **superior hypogastric plexus** containing only **sympathetic and afferent fibers**.

The **gastrointestinal tract** has its own nervous system, the **enteric nervous system**. The enteric nervous system is completely contained within the GI tract, beginning in the **esophagus and extending to the anus**. The number of neurons it contains is approximately 100 million, which is almost the same as the number of neurons in the spinal cord. The enteric nervous system is involved in controlling gastrointestinal movement.

The enteric nervous system, as indicated above, has two primary components, the **outer plexus**, which lies between the longitudinal and circular muscles, referred to as the **myenteric (Auerbach's) plexus** (Figs. 166, 173, 174 & 175), and an **inner plexus**, the **submucosal (Meissner's) plexus** (Figs. 164, 165, 173 & 174), that lies within the submucosa. The enteric nervous system is a subdivision of the autonomic nervous system (ANS) that directly controls the gastrointestinal tract.

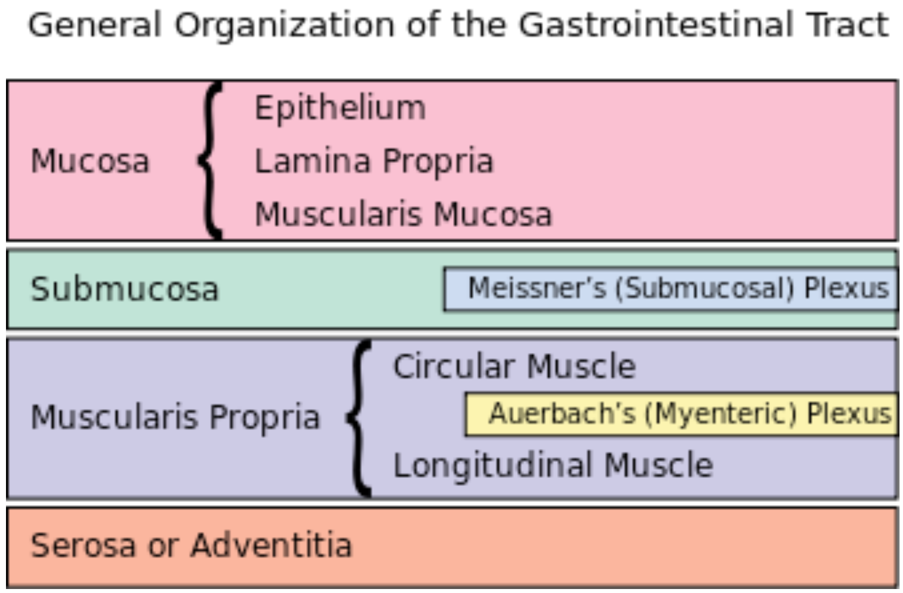


Fig. 173. This illustration shows the general anatomic organization of the gastrointestinal tract including the location of the enteric nervous system. (Wiki)

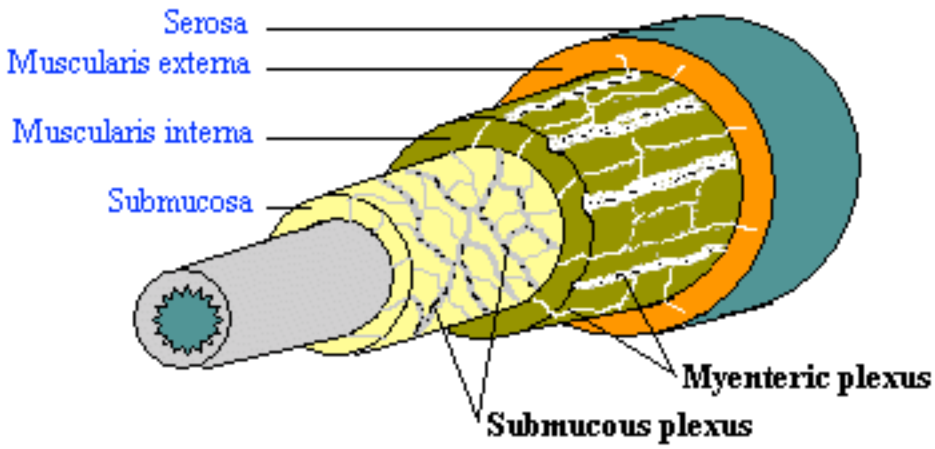


Fig. 174. This image is a drawing showing the anatomic location of the submucosal and myenteric plexuses.

The myenteric plexus is located between the longitudinal and circular layers of muscle of the muscularis externa and, appropriately, exerts control primarily over digestive tract motility.

The submucosal plexus is within the submucosa. Its principle role is in sensing the environment within the lumen, regulating gastrointestinal blood flow and controlling epithelial function. In regions where these functions are minimal, such as the esophagus, the submucosal plexus is sparse and may actually be missing in sections. (www.vivo.colostate.edu)

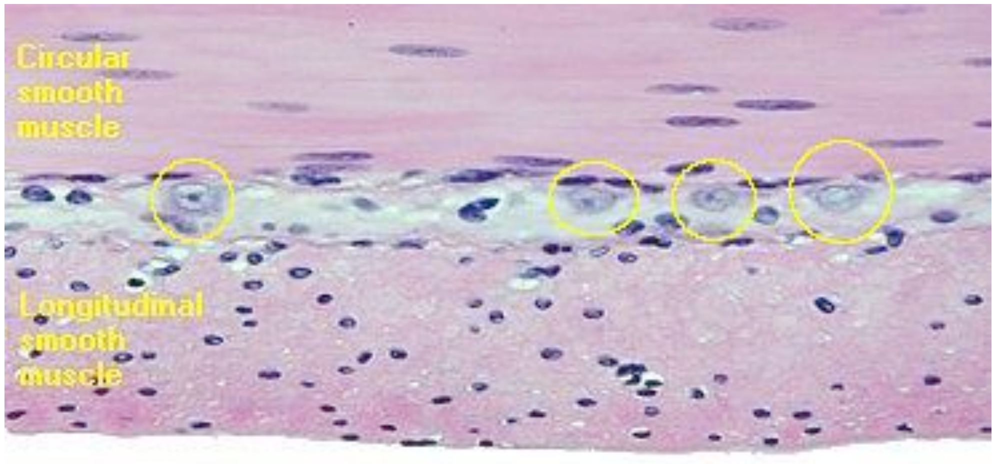


Fig. 175. This is a high power photomicrograph showing the location of the neurons of Auerbach's plexus. (www.vivo.colostate.edu)

Besides the two major enteric plexuses, there are minor plexuses beneath the serosa, within the circular smooth muscle and in the mucosa.

WIthin the enteric plexuses are three types of neurons, most of which are multipolar: **Sensory neurons** receive information from sensory receptors in the mucosa and muscle. At least five different sensory receptors have been identified in the mucosa, which respond to mechanical, thermal, osmotic and chemical stimuli. Chemoreceptors sensitive to acid, glucose and amino acids have been demonstrated, which in essence, allows "tasting" of luminal contents. Sensory receptors in muscle respond to stretch and tension. Collectively, enteric sensory neurons compile a comprehensive battery of information on gut contents and the state of the GI wall; **Motor neurons** within the enteric plexus control gastrointestinal motility and secretion, and possibly absorption. In performing these functions, motor neurons act directly on a large number of effector cells, including smooth muscle, secretory cells (chief, parietal, mucous, enterocytes, pancreatic exocrine cells) and gastrointestinal endocrine cells; and **Interneurons** which are largely responsible for integrating information from sensory neurons and providing it to programming the enteric motor neurons.

The **myenteric plexus** is composed by a linear chain of interconnecting neurons that extends the entire length of the GI tract. Considering its location between the longitudinal and circular layers of intestinal smooth muscle, its primary function is controlling muscle activity along the length of the GI tract. When this plexus is activated it primarily causes: (1) increased tonic contraction or tone, of the GI tract wall; (2) increased intensity of the rhythmic contractions; (3) slightly increased rate of rhythmic contraction; and (4) increased velocity of conduction of excitatory waves along the wall of the GI tract, causing rapid movement of the peristalic waves of the GI tract.

Although the primary function of the myenteric plexus is excitatory when activated, activation of some of its neurons causes an **inhibitory effect**. These **inhibitory neurons** release an **inhibitory transmitter**, such as **vasoactive intestinal polypeptide**, when made active. These inhibitory signals will inhibit the tone of the **intestinal sphincter muscles**, their function of which is to improve the movement of food along portions of the GI tract. For example, impediment of the tone of the **pyloric sphincter**, will allow the partially digested food (chyme) within the stomach to empty into the duodenum. Impediment of the sphincter tone of the **ileocecal valve**, will allow the contents within the small intestine to empty into the cecum.

In contradistinction to the linear chain of interconnecting neurons of the **myenteric plexus**, which extends throughout the length of the GI tract, the **submucosal plexus** is primarily concerned with controlling function within the inner wall of each minute segment. For example, the sensory signals originating from the epithelial surface of the mucosa are integrated in the submucosal plexus to help control local intestinal secretion, local absorption, and local contraction of the submucosal muscle, which in turn causes varying degrees of infolding of the gastrointestinal mucosa.

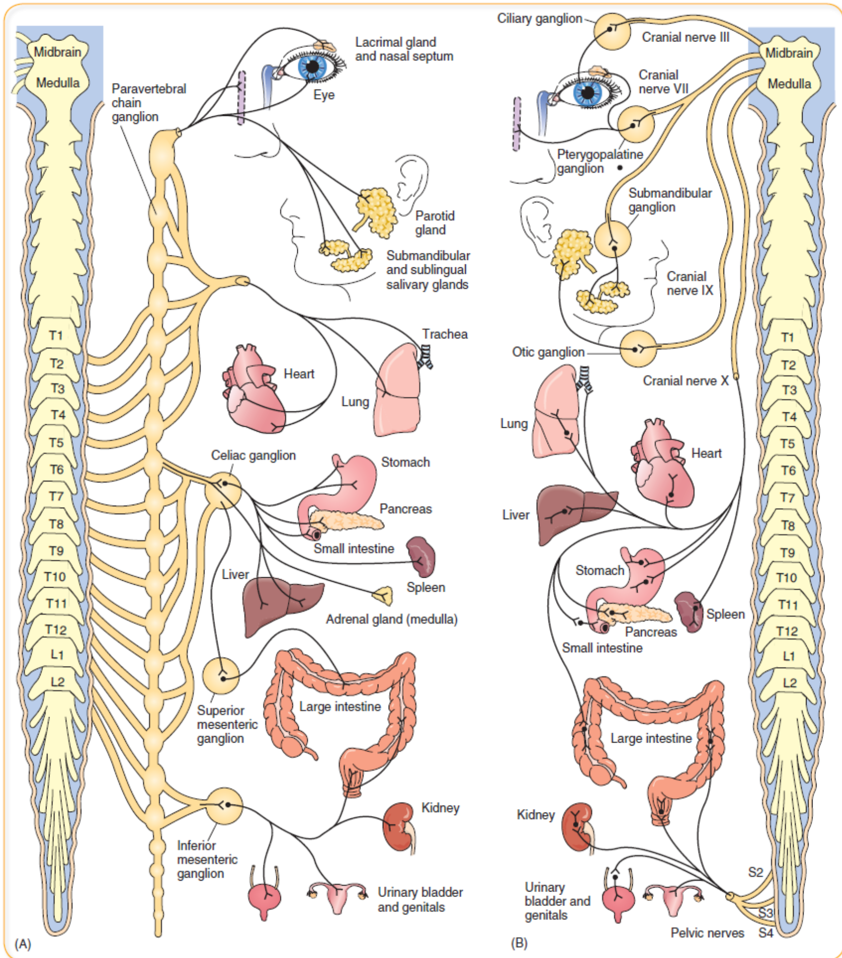
In regard to how the ANS affects the above, typically activation of the **parasympathetic system** increases activity of the enteric nervous system, which in turn enhances the activity of most gastrointestinal functions. On the other hand, **sympathetic stimulation** causes inhibition of gastrointestinal secretion and motor activity, and contraction of gastrointestinal sphincters and blood vessels. Some of the prominent communiques within the ANS enabled by nervous interconnections within the GI tract are referred to as reflexes. For example, the **gastocolic reflex**, where distention of the stomach stimulates evacuation of the colon, and the **enterogastic reflex**, in which distention and irritation of the small intestine results in suppression of secretion and motor activity in the stomach.

*Remember, except for a few parasympathetic fibers to the mouth and pharyngeal regions, the **cranial parasympathetic fibers** are almost entirely in the **vagus nerves.** These nerve fibers innervate the esophagus, stomach, and the pancreas and somewhat less, the intestines to the region of the left colic flexure (Fig. 176).*

The **sacral parasympathetic fibers** originating in **S2-S4 spinal segments** pass the **pelvic nerves** to the distal half of the large intestine, approximately from the **left colic flexure** to the **anus**. The oral cavity, sigmoid colon, rectum, and anal canal receive more parasympathetic fibers than the rest of the GI tract primarily due to their function in defecation (Fig. 176).

The **sympathetic fibers** to the GI tract originate in the spinal cord between **T5-L2**. Most of the **preganglionic fibers** that innervate the GI tract, once they leave the spinal cord, they enter the sympathetic chains that lie lateral to the vertebral column, with many of these fibers then passing on through the chains to outlying ganglion, such as the **celiac ganglia, mesenteric ganglia and the hypogastric ganglia** (Figs. 59, 73, 113, 145, p 69, 86, 136 & 169, & Fig. 176). Most of the **postganglionic sympathetic neurons**, which the **preganglionic fibers** synapse are in these ganglia. The postganglionic sympathetic fibers innervate all parts of the GI tract. Unlike the parasympathetic fibers, they are not concentrated in the region of the oral cavity and the sigmoid colon through to the anus. The sympathetic nerve endings secrete mainly **norepinephrine** and a small amount of **epinephrine**.

Stimulation of the sympathetic nervous system produces two effects: (1) to some extent, the secreted norepinephrine will directly inhibit the smooth muscle of the GI tract except for the smooth muscle within the mucosa, which it excites, and (2) norepinephrine's primary effect is to inhibit the neurons of the enteric nervous system.



(A) The sympathetic division of the autonomic nervous system (B) The parasympathetic division of the autonomic nervous system. http://pharmacology-notes-free.blogspot.com/

Fig. 176. This is an illustration of the sympathetic and parasympathetic division of the autonomic nervous system. (www.about-pharmacology.com)

The GI tract is innervated by many **afferent sensory nerve fibers**, the neuronal cell bodies of which are either located in the **enteric nervous system or the dorsal root ganglia of the spinal cord**. The function of these sensory neurons has been previously discussed on page 203. Stimulation of these fibers can cause excitation or, under other conditions, inhibition of intestinal movements or intestinal secretion.

Afferent impulses generated due to dilation of the GI tract are carried by **visceral afferent fibers**, which travel with the **parasympathetic nerves**. Pain impulses travel in the visceral afferent fibers with the **sympathetic and parasympathetic nerves** that supply the rectum and the upper part of the anal canal.

Remember, sensory signals and the results thereof are not **simple spinal reflexes**. Typically, sensory signals from the GI tract got to multiple areas in the spinal cord and to the brainstem. For example, afferent fibers in the **vagus nerve**, 80% of its nerve fibers are afferent, transmit sensory signals from the GI tract to the medulla within the brainstem, which in turn initiates a vagal reflex signal that returns to the GI tract to control many of its functions (Fig. 176).

2. **Anal Canal:** The **anal canal** begins at the **anorectal junction** and ends at the **anal verge** (Fig. 177). The ampullary portion of the rectum rests on the **pelvic diaphragm** (Fig. 154, p 181). At this point the rectum turns backward and downward at approximately a 90º (80-120º) angle (**anorectal angle**) passing between the medial borders of the **levator ani** to become the **anal canal**. This angle is in part created and maintained by the pull of the sling-like **puborectalis muscle** (Fig. 178).

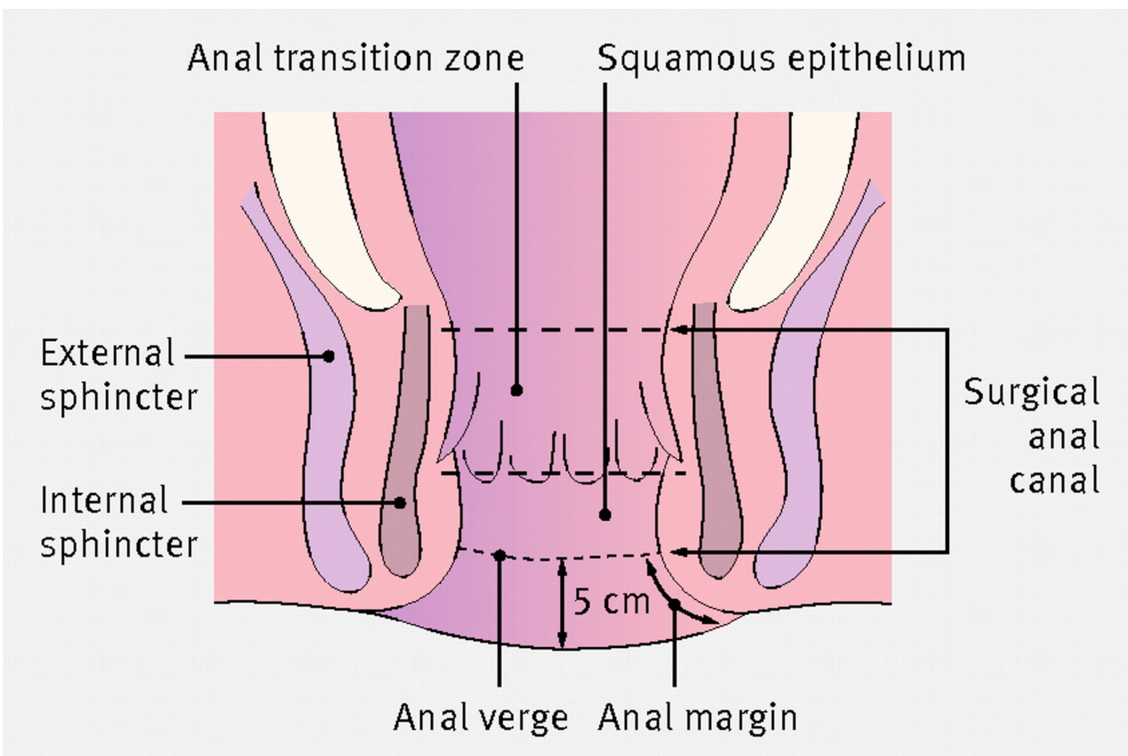


Fig. 177. This illustration represents the cross sectional anatomy of the anal canal. The anus can be divided into the anal canal and the anal margin; the former is 3.5-4 cm long in men and shorter in women. The anal canal begins when the rectum enters the puborectalis sling (Fig. 178) at the apex of the anal sphincter complex (Figs. 154 & 157,

p 181 & 184), and ends with the squamous mucosa blending with the perianal skin. Immediately proximal to the dentate line, a narrow zone of transitional mucosa is variably present-the anal transition zone. Distal to this, the mucosa consist of squamous epithelium devoid of hairs and glands. The anal margin extends distal to the anal verge (the junction of hair bearing skin) to a 5 cm circumferential area from it. (bmj.com)

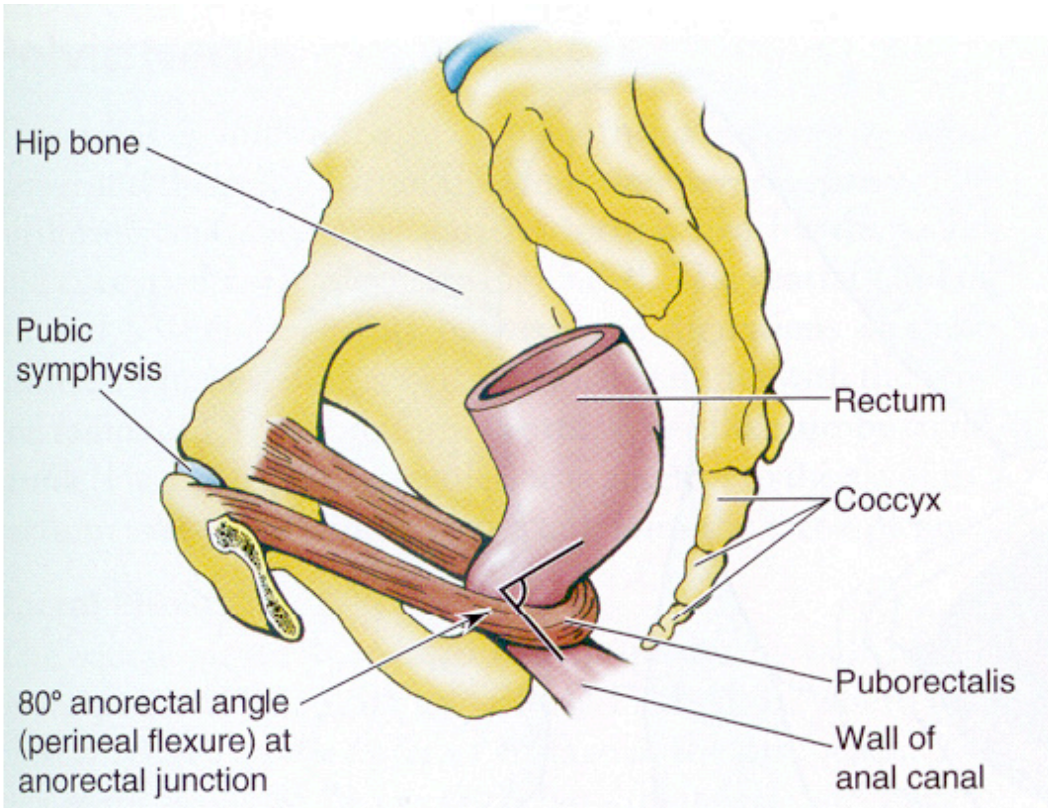


Fig. 178. This is an illustration of the puborectalis sling, which maintains a 80 to 120º angle between the rectum and anal canal. During defecation, the puborectalis muscle relaxes allowing a more vertical orientation of the rectum and anal canal. Failure to maintain this angle can lead to rectal incontinence. (academic.amc.edu)

The anal canal is approximately 3.5-4 cm long in men and 2.0-3.5 cm in women, and is under tonic contraction due to the **external and internal sphincter muscles**, which maintain a contracted collapsed lumen except during defecation. The anal canal ends at the anus, approximately 4 cm in front of and below the tip of the **coccyx** (Fig. 178). It lies below the **pelvic diaphragm** within the **anal triangle of the perineum** (Figs. 154 & 157, p 181 & 184, & Figs. 179 & 180).

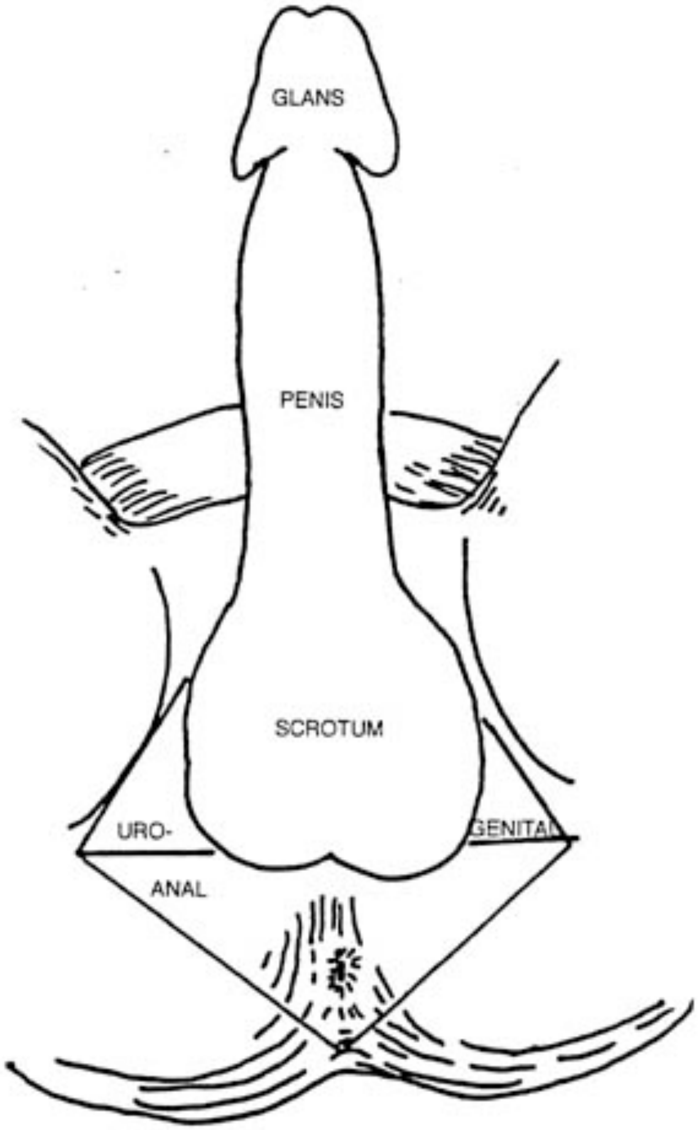


Fig. 179. This illustration is of the inferior view showing the externally visible structures of the male perineal region and its subdivision into anal and urogenital triangles. (www.emory.edu)

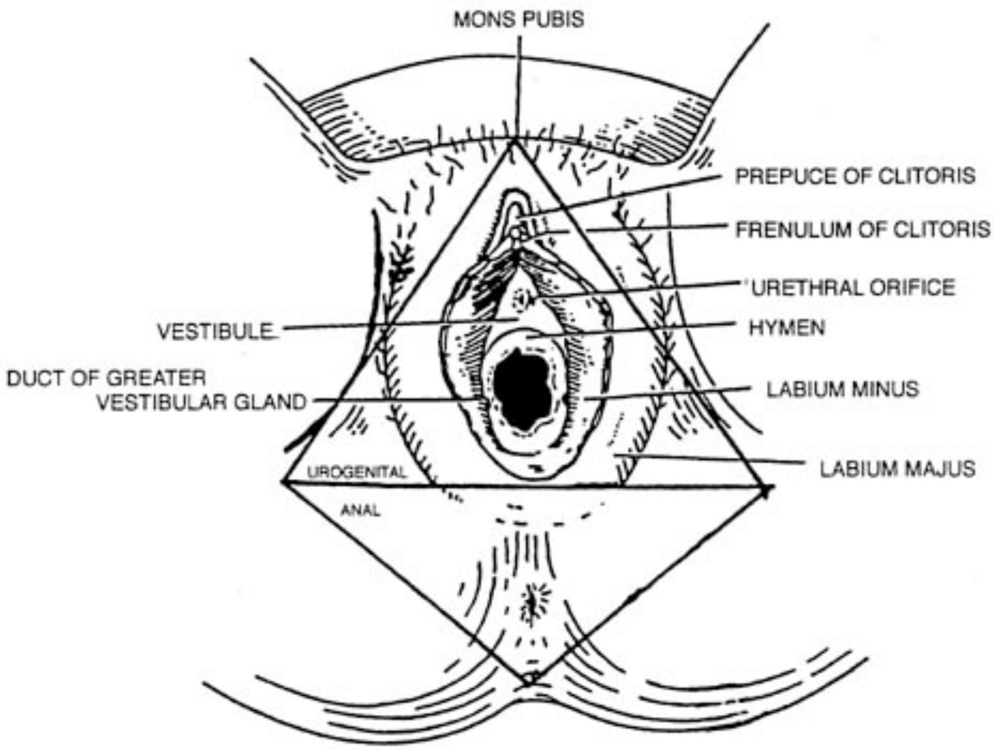


Fig. 180. This illustration is of the inferior view showing the externally visible structures of the female perineal region and its subdivision into anal and urogenital triangles. (www.emory.edu)

The **anal verge** is the distal end of the **anal canal**, forming a **transitional zone** between the skin of the anal canal covered by stratified non-keratinizing squamous epithelium and the perianal skin covered by stratified keratinizing squamous epithelium. This transitional zone is defined by a white line called **Hilton's line (pectin of Jon Stroud)** (Fig. 177).

The **muscles of the anal canal:** The **circular layer of the rectum** continues into the anal canal. When the rectum passes through the diaphragm the circular layer of smooth muscle undergoes immediate and substantive thickening to form the **internal sphincter ani muscle**. This sphincter surrounds the anal canal, ending at the level of the transitional cutaneous zone. It is overlapped distally by the subcutaneous portion of the **external anal sphincter muscle**, which is a voluntary muscle (Figs. 154, 157 & 159, p 181, 184 & 187).

The **external anal sphincter** consist of a **superficial** and **deep portion** (Fig. 36, p

43). The **superficial portion** constitutes the main part of the muscle, taking origin from a narrow tendinous band, the **anococcygeal raphae**, which extends from the tip of the coccyx to the posterior margin of the anus (Figs. 48, 93, 105, & 160, p 56, 115, 128 & 188). It forms two flattened planes of muscle, which encircle the anus, meeting in front, inserting into the **central tendinous point of the perineum**, giving stability for the action of the **bulbospongiosus muscle (bulbocavernosus in the older texts)** (Figs. 43 & 159, p 49 &187, & Figs. 181 & 182).

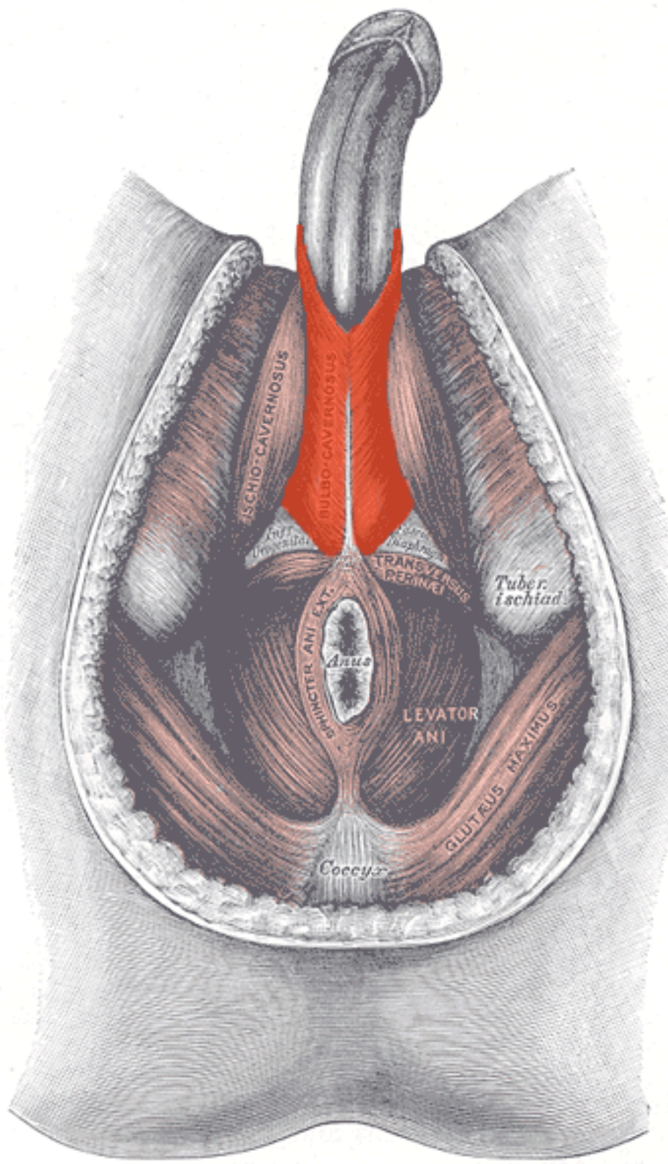


Fig. 181. The above illustration depicts the muscles of the male perineum. The bulbospongiosus is the red colored muscle. As can be seen, in males it covers the bulb of the penis. In males it contributes to erection, ejaculation, and the feelings of orgasm. It serves to empty the canal of the urethra, after the bladder has expelled its contents. It arises from the central tendinous point of the perineum and the median raphé in front. (Wiki)

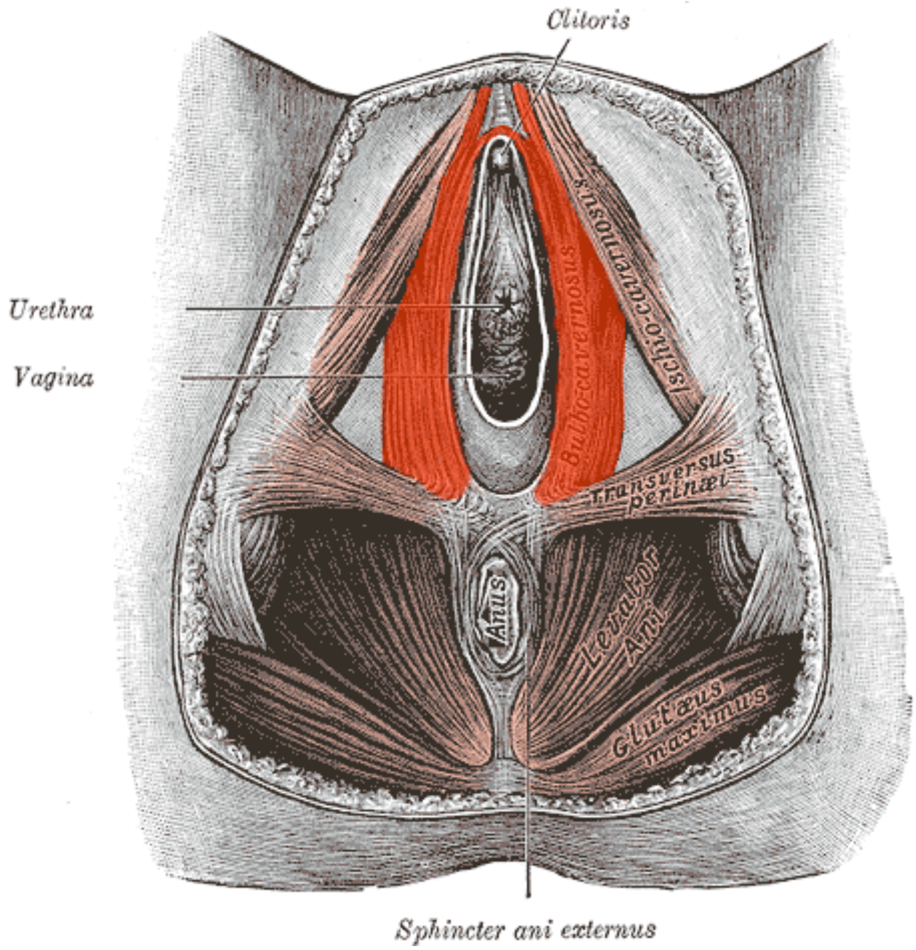


Fig. 182. This illustration depicts the muscles of the female perineum. The bulbospongiosus is the red colored muscle. In females, it covers the vestibular bulb. In females it contributes to clitoral erection and the feelings of orgasm, and closes the vagina. (Wiki)

It also serves as a support of the pelvic floor by joining with the **transversus perinaei superficialis, and the levator ani muscles** (Figs. 52 & 107, p 62 & 130, & Fig. 183). The **superficial portion** caps the distal end of the **internal sphincter ani**, at which point it lies directly under the submucosal layer of the **anal verge**.

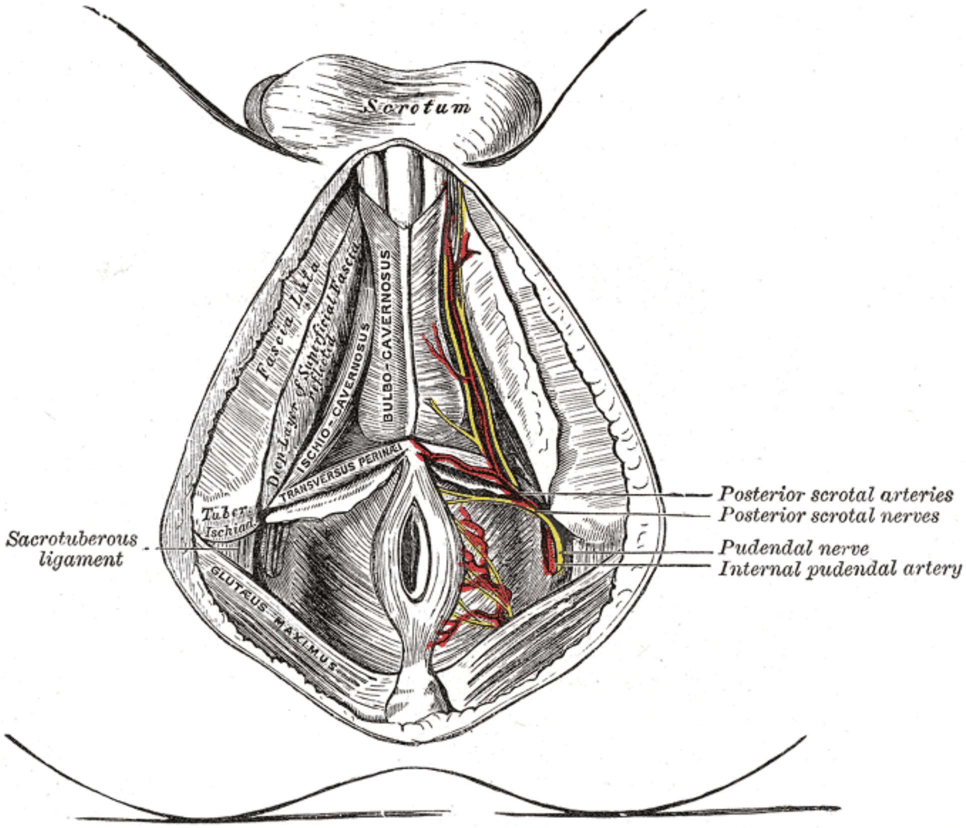


Fig. 183. This illustration depicts the superficial branches of the internal pudendal artery in the male pelvis. It also shows the transversus perinei, which is labeled at the center left. As can be seen, it is a narrow slip of muscle, which passes approximately transversely across the perineal space anterior to the anus. It arises by tendinous fibers from the inner and forepart of the tuberosity of the ischium, and, running medially, is inserted into the central tendinous point of the perineum (perineal body), joining with the muscle of the opposite side. (Wiki).

The **deeper portion of the external ani muscle** is generally circular in disposition (Fig. 36, p 43). It encircles the anal canal both anteriorly and posteriorly, being closely applied to the **internal ani sphincter muscles**. Fibers of the deep portion blend in with the **superficial transverse perineus muscle** and the **bulbospongiosus muscle**.

The **external ani muscles** are in a state of tonic constriction, having no antagonist they keep the anal canal closed.

*Remember, the rectum has an **inner circular layer of involuntary muscle**, which is complete, and an **outer longitudinal layer**, which is incomplete. As the rectum pierces the pelvic diaphragm, the longitudinal muscular layer, after some admixture* *with fibers of the levator ani muscle, continues over the anal canal as far as the anal aperture, separating the **internal and external sphincter ani muscles**.*

The **anatomic relations of the anal canal** are such that **anteriorly**, the middle layer of the anal canal is attached by dense connective tissue to the **perineal body** (Figs. 93 & 107, p 115 & 130). **Laterally** and **posteriorly**, the anal canal is surrounded by loose adipose tissue within the **ischioanal (ischiorectal) fossa** (Fig. 184).

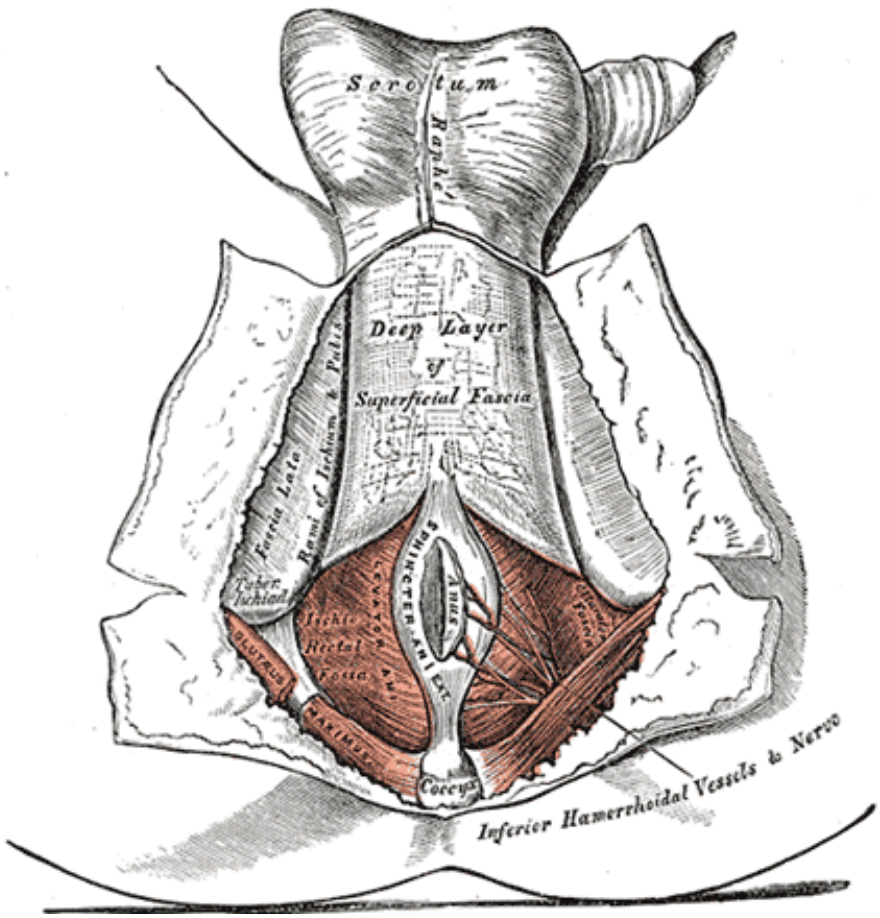


Fig. 184. This illustration depicts the perineum. The skin and superficial layer of the superficial fascia has been reflected. The ischiorectal fossa is labeled at the bottom left. (Wiki)

Posteriorly, the anal canal is attache to the coccyx by the **anococcygeal ligament**, a midline fibroelastic structure, which may possess some skeletal muscle, and which runs between the posterior aspect of the middle portion of the external sphincter and the coccyx (Figs. 48, 93, 105 & 160, p 56, 115, 128 & 188). The **anal canal** is divided into the **upper anal canal**, which constitutes the upper ⅔ and the **lower anal canal**, which represents ⅓ of the anal canal by the **pectinate line (dentate line)** (Fig. 154, p 181). Developmentally, this line represents the **hindgut-proctoderm jundtion**.

*Remember, the **hindgut** forms the left third to half of the transverse colon, the descending colon, the sigmoid colon, the rectum and the superior ⅔ of the anal canal. It also gives rise to the epithelium of the urinary bladder and the majority of urethra.*

*At the terminal end of the hindgut is a region called the **cloaca**, which is continuous ventrally with the **allantois**, which develops as an outgrowth from the caudal end of the **yolk sac** and is seen as a short blind tube running into a connecting stalk. As it grows, its blood vessels persist as the **umbilical vein** and **arteries**. It later fibrosis as the bladder enlarges, with the allantois becoming the **urachus**, which is represented in adults as the **median umbilical ligament** on the interior aspect of the **anterior abdominal wall** (Fig. 63, p 74). The cloaca is a slightly dilated cavity lined with **endoderm**. It is initially connected superiorly with the hindgut, and ventrocaudally it is in contact with the overlying ectodrem at the **cloacal membrane** (Fig. 185). A wedge of **mesenchyme** called the **urorectal spetum**, proliferates and grows into the cloaca from the angle between the allantois and hindgut promoting the movement of endodermal epithelium toward the cloacal membrane (Fig. 186). The cloaca becomes divided into the **ventral presumptive urinary bladder and urogenital sinus and the dorsal presumptive rectum** and **anal canal**, with the cloacal membrane dividing into the **urogenital and anal parts** respectively (Fig. 187). The point at which the cloacal membrane divides becomes the **perineal body** (Figs. 188 & 189). Proliferation of the mesenchyme produces elevations of the surface **ectoderm** around the anal membrane, forming a depression called the **proctodeum or anal pit** (Fig. 187). Eventually the anal membrane ruptures, the site of which in the adult produces an irregular folding of* *the mucosa called the **pectinate line** (Fig. 190). The pectinate line is an important anatomical landmark regarding **arterial, venous and lymphatic drainage, and nerve supply.***

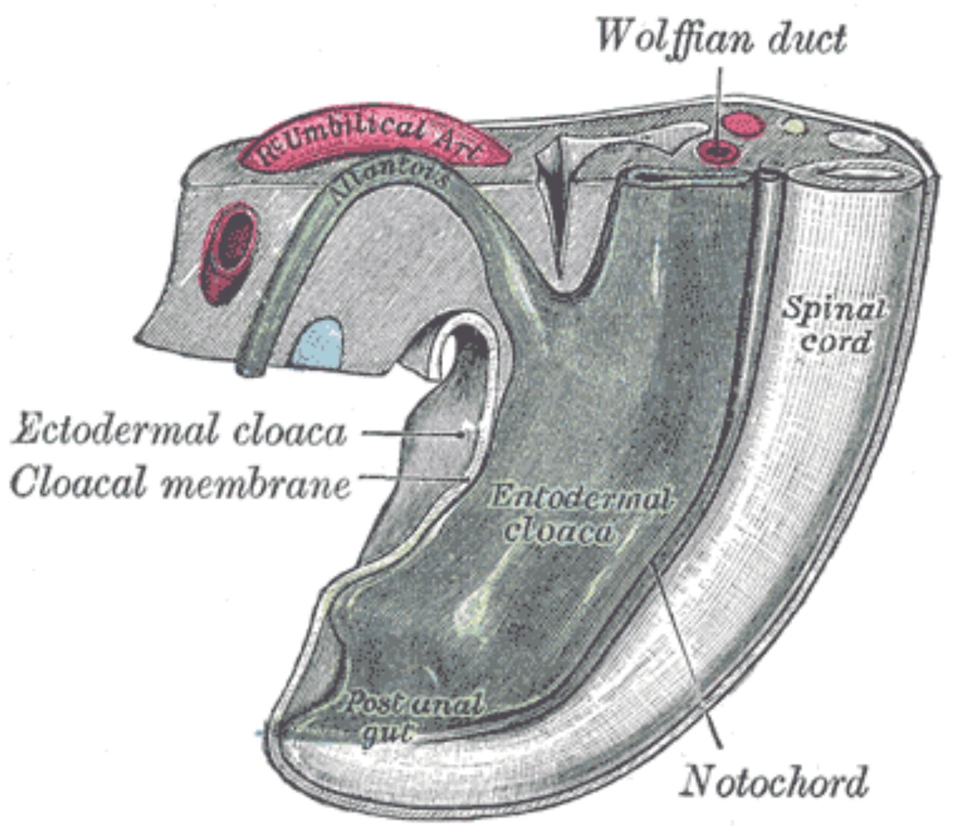


FIg. 185. This is an illustration of the tail end of a human embryo from fifteen to eighteen days old. It shows the cloacal membrane, which covers the embryonic cloaca when still in development of the urinary and reproductive organs. It is formed by ectoderm and endoderm meeting each other. After separation of the cloaca into the urogenital and anal parts, the cloacal membrane, in turn, is separated into a urogenital membrane and an anal membrane. (Wiki)

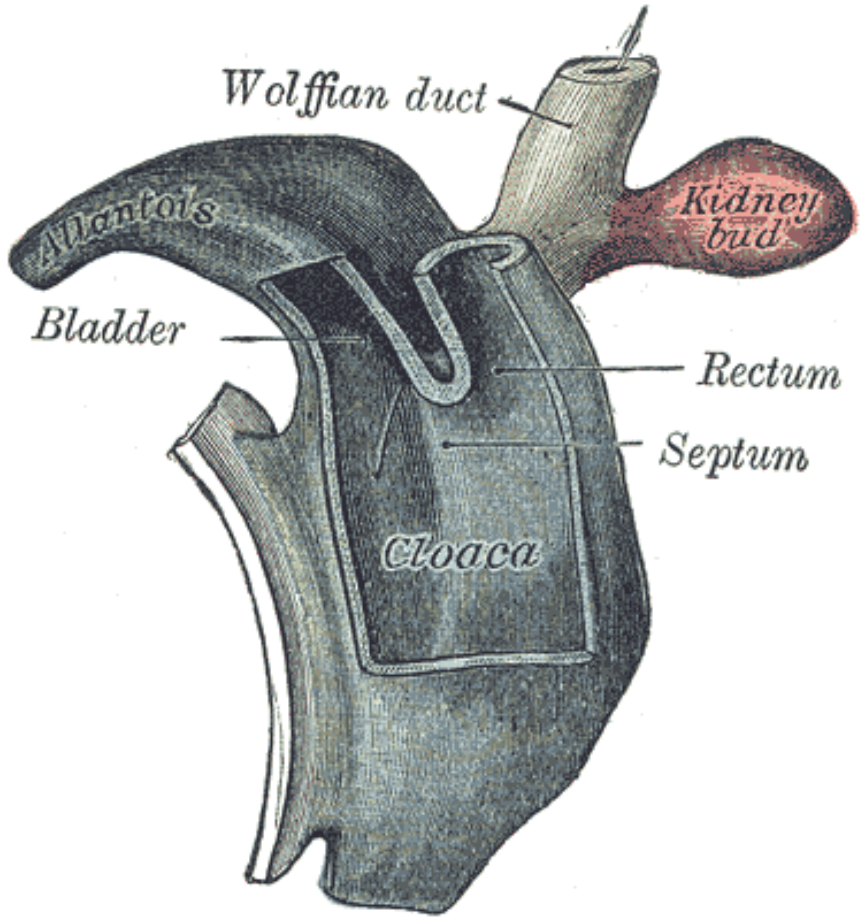


Fig. 186. This illustration is of the cloaca of a human embryo from twenty-five to twenty-seven days old. The entodermal cloaca is divided into a dorsal and a ventral part by means of a partition, the urorectal septum, which grows downward from the ridge separating the allantois from the cloacal opening of the intestine and ultimately fuses with the cloacal membrane dividing it into an anal and a urogenital part (Fig. 187). The dorsal part of the cloaca forms the rectum, and the anterior urogenital sinus, which gives rise to the bladder, pelvic urethra and definitive urogenital sinus. (Wiki)

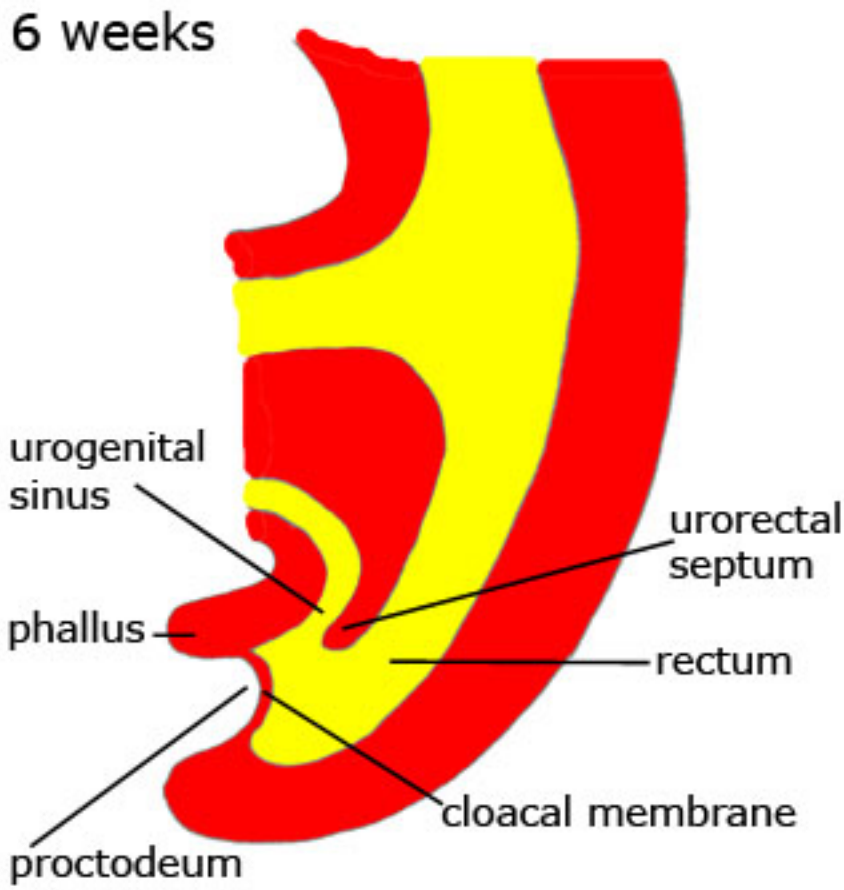


Fig. 187. This illustration depicts a six week old embryo in which a wedge of mesenchyme called the urorectal septum growing into the cloaca from an angle between the allantois and the hindgut, partitioning it into the ventral primitive urogenital sinus and the dorsal rectum. (www.n3wt.nildram.co.uk)

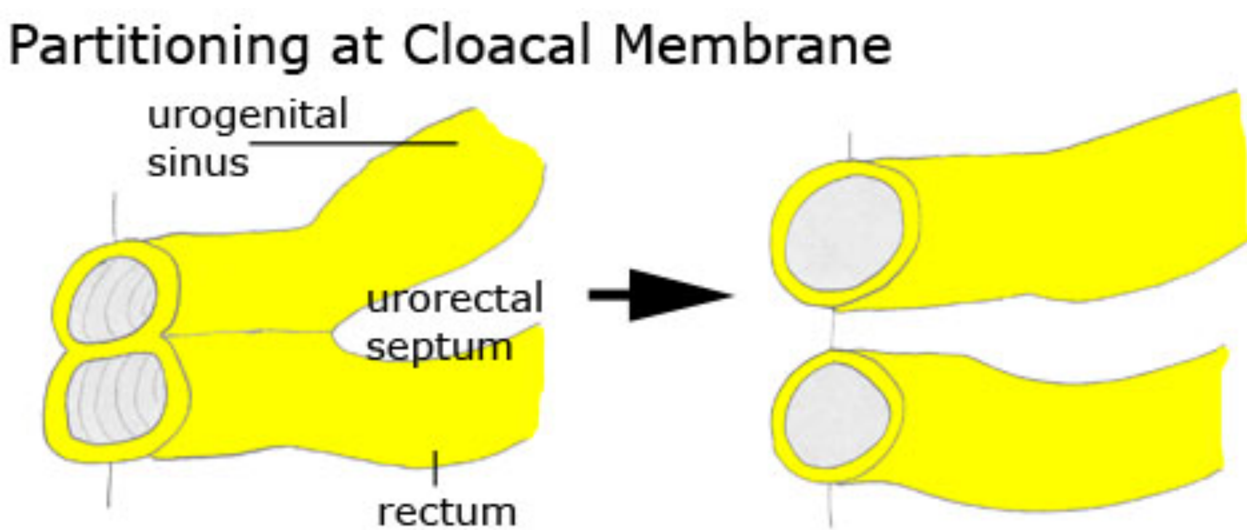


Fig. 188. The above illustration shows the partitioning of the cloaca by a wedge of mesenchyme called the urorectal septum, which grows into the cloaca from the angle between the allantois and the hindgut, partitioning it into the ventral primitive urogenital sinus and the dorsal rectum. (www.n3wt.nildram.co.uk)

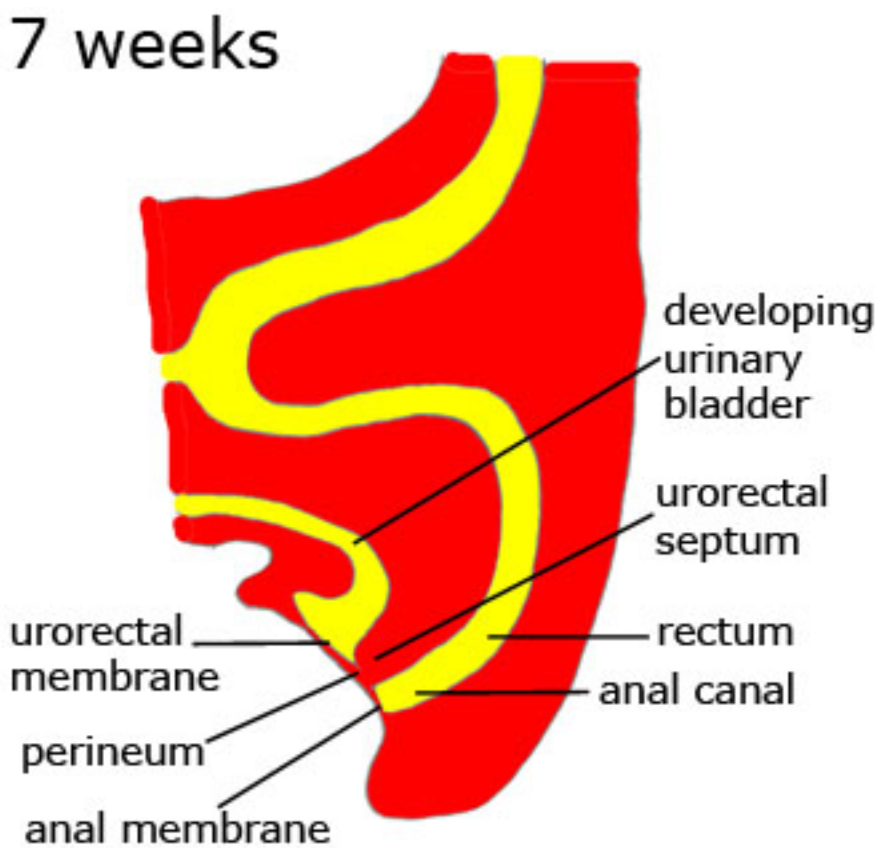


Fig. 189. The urorectal septum fuses with the cloacal membrane, dividing it into the dorsal anal membrane and a larger urogenital membrane (labeled urorectal membrane in the illustration). The areal of fusion is represented in the adult by the perineal body (labeled perineum in the illustration). It also divides the cloacal sphincter into the external anal sphincter posteriorly and the superficial transverse perineal, bulbospongiosus and ischiocavernosus muscles anteriorly. (www.n3wt.nildram.co.uk)

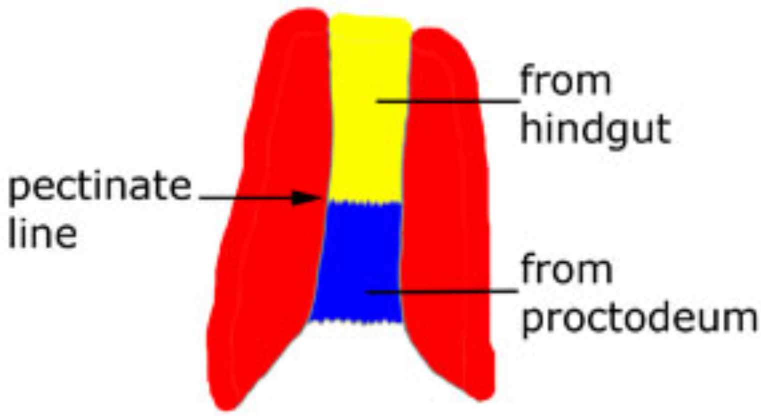


Fig. 190. This illustration shows the anal canal formation following the rupture of the anal membrane, which occurs in the eight week old embryo. The original site of the rupture is marked in the adult by an irregular folding mucosa called the pectinate line. The superior two-thirds is derived from the hindgut, while the inferior third is derived from the proctodeum, their junction marked by the pectinate line. As stated, this gives rise to different arterial, venous and lymphatic drainage, and nerve supply. (www.n3wt.nildram.co.uk)

The **macroscopic (visual with the naked eye) appearance** of the human anal canal was first described by Glisson (1597-1677) and Morgagni (1717), who mentioned the **anal valves** and **anal columns**, respectively. The first detailed **light microscopic description** of the three anal canal zones was by Robin & Cadiat (1874). The present definition of the anal canal, extending from "the pelvic floor to the anal opening" was suggested by Symington (1888). There are no generally accepted names for the three epithelial zones of the anal canal. A review of the literature shows that no less than three different names have been used for the upper zone, fourteen for the middle zone and nine for the lower zone, as well as ten names for the line comprising the anal valves and the base of the anal columns. Traditionally, the middle zone is termed the **anal transitional zone**, and is defined as "The zone interposed between uninterrupted colorectal type mucosa above and uninterrupted squamous epithelium below, irrespective of the type of epithelium present in the zone itself." The line corresponding to the anal valves and anal sinuses is termed the **dentate (pectinate) line**, as this name seems to be employed in more common textbooks. Typically, the anal transitional zone extends from the dentate line to almost 1 cm upward, but it can be observed over a considerably larger area, namely from 0.6 cm below to 2.0 cm above the dentate line, and in some cases may be absent altogether.

The anal canal is typically divided into three zones. The lower ⅓ of the anal canal, that part below the **dentate (pectinate) line**, is divided into two zones by a white line referred to as **Hilton's line** (Fig. 177, p 207). The upper part is referred to as the **zona hemorrhagic**, which is lined by stratified non-keratinizing squamous epithelium (Fig. 191). The lower part, **zona cutanea**, lined by stratified keratinizing squamous epithelium (Fig. 192). Hilton's line is also referred to as the **intermediate zone or transitional zone** as designated in Fig. 177.

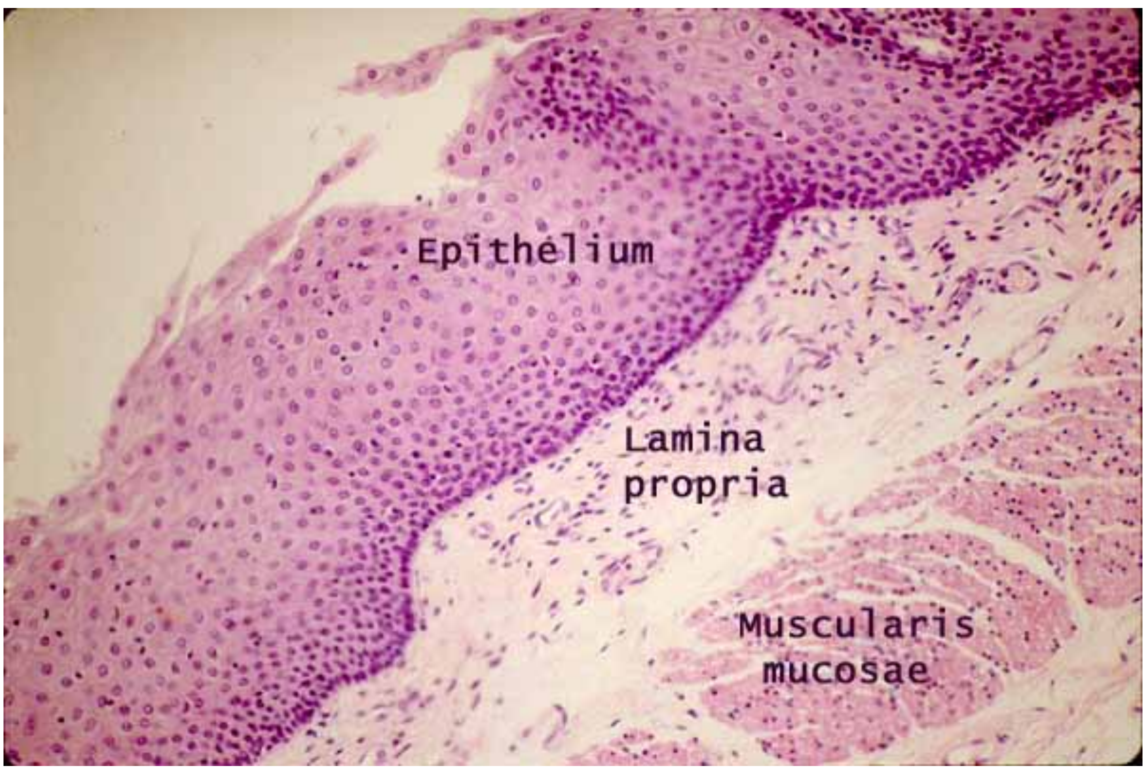


Fig. 191. This is a low power photomicrograph of non-keratinizing squamous epithelium seen in the upper part of the lower ⅓ of the anal canal named the zona hemorrhagica. (learningtosavetheearth.com)

Fig. 192. This is a low power photomicrography of keratinizing squamous epithelium seen in the lower part of the lower ⅓ of the anal canal named the zona cutanea. (baileybio.com)

True mucous membrane begins above the dentate line at the level of the **anal valves** and microscopically is lined by **simple columnar epithelium** (Figs. 130 & 157, p 154 & 184, Fig. 193). The anal valves are the remnants of the **proctodeal sphincter**, which is the end of the anal portion of the **cloaca** (Fig. 187). The mucosa above the anal valves show longitudinal folds or elevation, five to ten in number, separated by grooves, which overlies veins and sometimes small arteries (Fig. 157, p 184). The lower ends of these longitudinal folds are joined together by mucosal folds, the anal valves, under which pass communicating veins. It is at the undersurface of the anal valves the mucous membrane becomes continuous with the **stratified squamous non-keratinizing epithelium of the zona hemorrhagica of the transitional zone forming the irregular line, the dentate line** (Fig. 177, p 207 & Fig. 191).

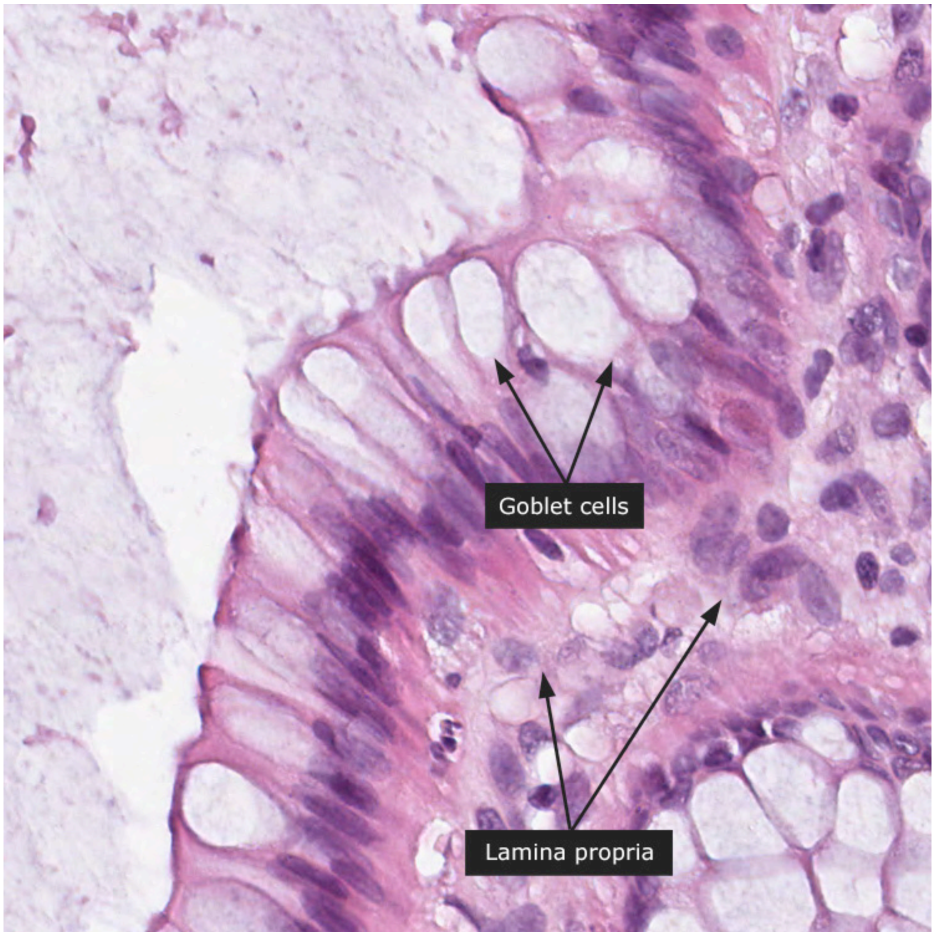


Fig. 193. This is a high power photomicrograph of simple columnar epithelium at the rectum-anal junction. (proteinatlas.com)

The **arterial supply** to that portion of the anal canal above the **dentate line** is from the **superior rectal artery**. Below the dentate line the arterial supply is primarily through the **inferior rectal arteries**. The **middle rectal arteries** also participate in supplying blood through the formation of anastomoses with both the superior and inferior rectal arteries (Fig. 167, p 194 & Fig.194). The **medial sacral artery** is also believed to make a contribution.

The **venous drainage** for the anal canal above the dentate line is primarily to the **superior rectal veins**, which drain to the **inferior mesenteric vein** (Fig. 168, p 195). Typically, the inferior mesenteric vein drains into the **splenic vein** and ultimately the **portal vein**. Below the dentate line the venous drainage is to the **inferior rectal veins**. The **middle rectal veins** drain into the **anterior division of**

the internal iliac vein and ultimately the **inferior vena cava**. The middle rectal veins primarily drain the **external anal sphincter muscles**; they also form anastomoses the superior and inferior rectal veins. The **inferior rectal veins** are a branch of the **pudendal vein**, which in turn drains into the **internal iliac veins** and ultimately the **inferior vena cava**. Thus, the submucosa of the anal canal represents an important area of junction between the veins draining to the **portal and systemic systems**.

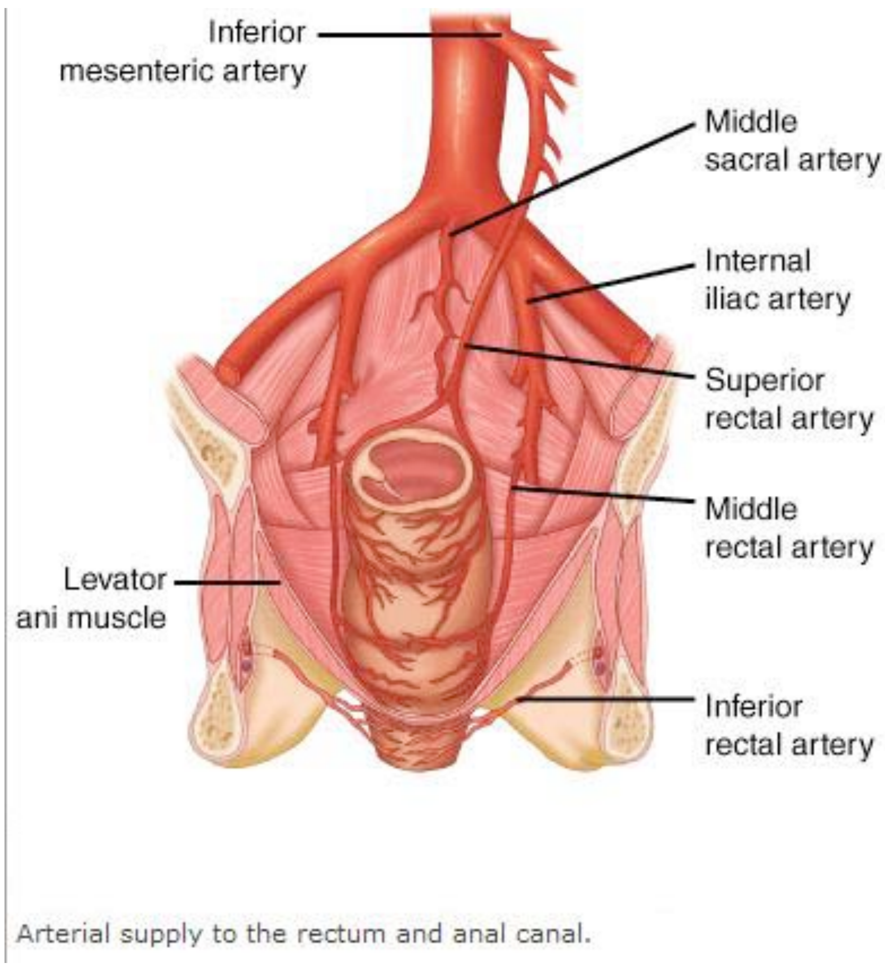


Fig. 194. This illustration depicts the arterial blood supply to the rectum and anal canal. (bedahunmuh.wordpress.com)

The **lymphatic drainage** of the anal canal above the dentate line, including the **internal anal sphincter** and the conjoint **longitudinal coat** is upwards into the submucosal and intramural lymphatics of the rectum. Ultimately, these lymphatic channels drain to the **internal iliac nodes**, and the **inferior mesenteric nodes**. The lymphatic drainage of the anal canal below the dentate line, including the **external anal sphincter** is downward to the **external inguinal lymph nodes (superficial inguinal nodes)** (Figs. 150 & 151, p 177 & 178, & Fig. 195).

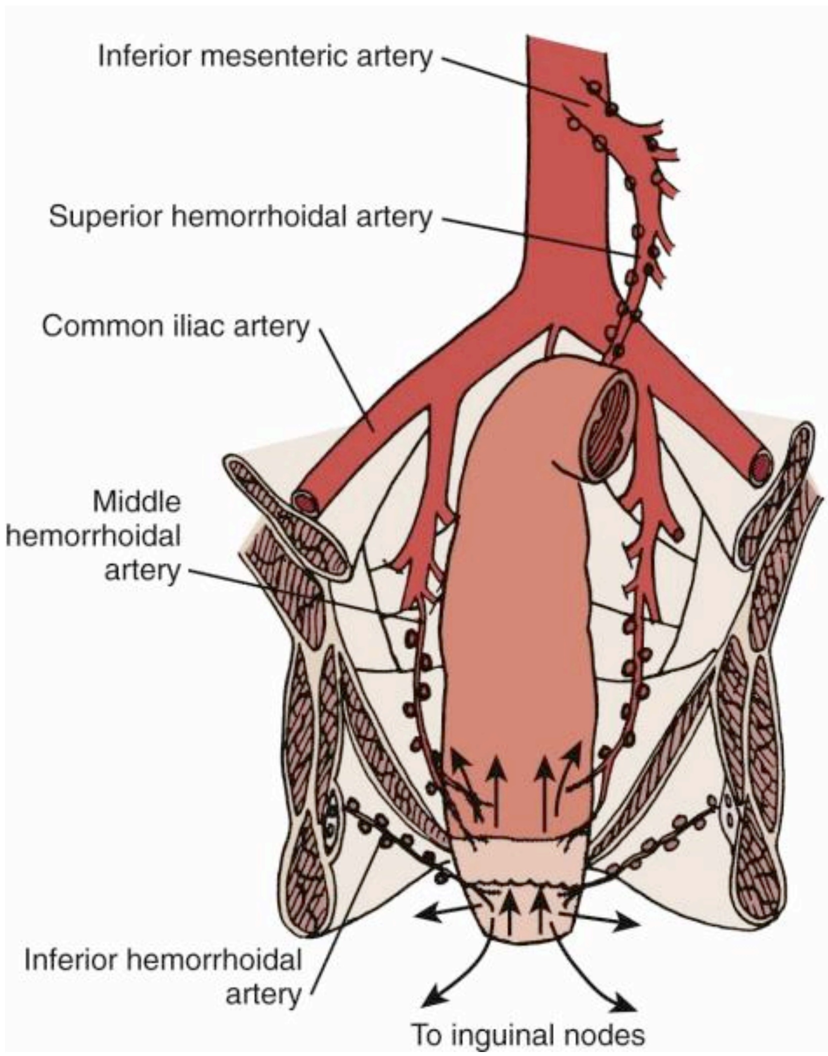


FIg. 195. This illustration shows the lymphatic drainage of the anal canal. (health-7.com)

Much of the **innervation** of the anal canal has been discussed under the innervation of the rectum. To summarize, that portion of the anal canal below the **dentate line** including the **external anal sphincter, the anal mucosa and the**

perianal skin receives **somatic innervation from the anterior divisions (ventral rami) of the second, third, and fourth sacral spinal nerves**, which is primarily distributed through the **inferior branch of the pudendal nerve** (Fig. 114, p 137, & Fig. 196).

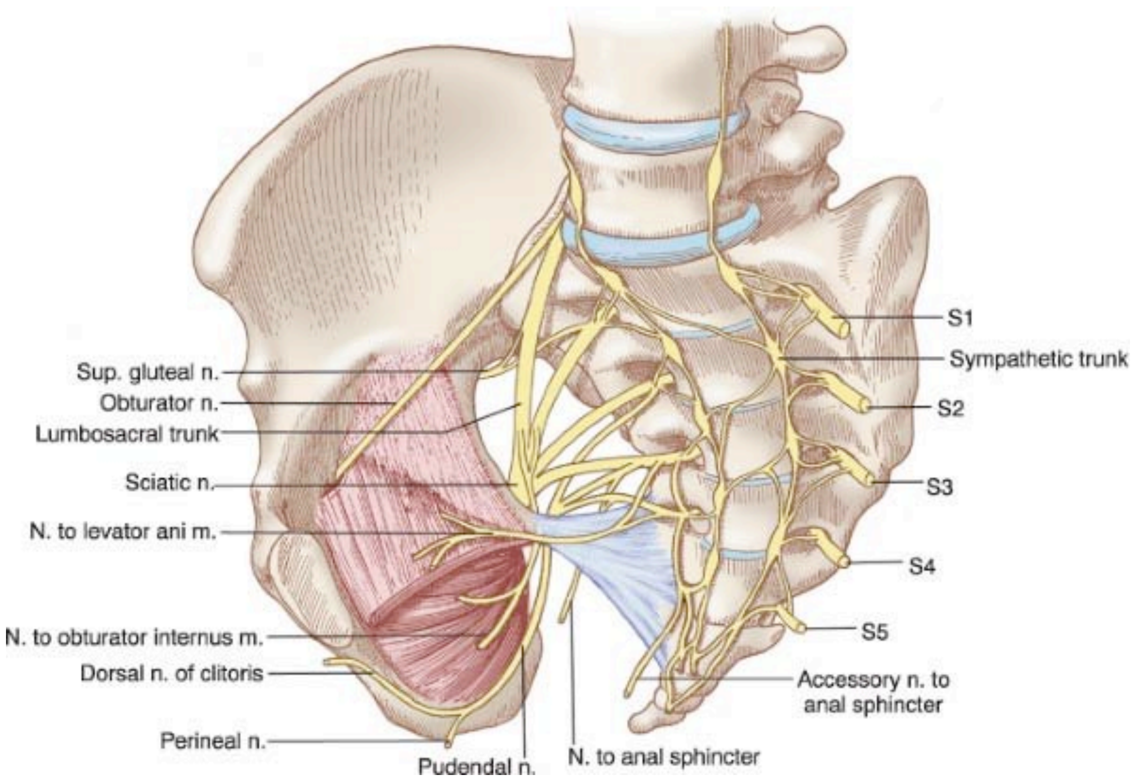


Fig. 196. This illustration shows the components of the sacral plexus of which the pudendal nerve is one. (epubbud.com)

Remember, the pudendal nerve carries somatic (motor & sensory) fibers that innervate the **external anal sphincter.** The **internal anal sphincter** is supplied by **parasympathetic fibers** from the pelvic segments of the spinal cord. There may also be a direct supply to the external anal sphincter, the anal mucosa and the perianal skin through fibers from the anterior division of the second to fourth sacral nerves over-and-above the innervation provided through the pudendal nerve. As this portion of the anal canal is somatically innervated, it is sensitive to pain, temperature, and touch.

Above the dentate line, the nerve supply is **visceral (autonomic)**, coming from the **inferior hypogastric plexus** (Figs. 59, 113 & 172, p 69, 136 & 200, & Fig. 176 p 206). Since it is visceral, the **upper part of the anal canal** is only sensitive to stretch and temperature. The upper anal mucosa is rich in thermo-receptors. The autonomic innervation to this part of the anal canal is to the **anal mucosa, the internal anal sphincter and the conjoint longitudinal smooth muscle coat**.

Sympathetic fibers cause relaxation of the **lower rectal muscles,** but contraction of the **internal anal sphincter and conjoined longitudinal coat** through α-adrenergic receptors.

Parasympathetic fibers cause relaxation of the **internal anal sphincter** through muscarinic receptors, which stimulate release of nitric oxide from intramural nitrergic receptors. The internal anal sphincter relaxes in response to pressure (gas or feces) distending the **ampulla of the rectum**.

IV. Traumatic Injuries of the Organs of the Pelvis: Adult and Pediatric

A. Pelvic Skeleton

Mechanisms of Injury and Risk Factors: Major injuries to the pelvic skeleton are primarily observed when there is high-energy transfer to the victim, such as that occurring following motor vehicular crashes, falls from a height or crush injuries. In one study, adults with significant pelvic fractures were caused by motor vehicular accidents (50-60%), motorcycle crashes (10-20%), pedestrian versus car (10-20%), falls (6-10%) and crush injuries (3-6%). Less serious pelvic injuries can also occur following low-energy transfer events, especially in the elderly who have degenerative bone disease from a simple fall. In the elderly, the most common cause is a fall from a standing position. Other examples of low-energy transfer events leading to pelvic fracture from a simple fall would be those victims who are receiving radiation therapy, those who experience seizure activity and those who are obese. The majority of pelvic injuries do not result in a major disruption of the pelvic ring, i.e. fractures involving the **ilium (iliac wings), ischium** and **pubis**, which form an anatomic ring with the sacrum, but rather involve fractures of the **pubic ramus or acetabulum** (Figs. 197, 198 & 200).

Fig. 197. This image is a 3D CT pelvis showing an iliac wing bone fracture. (faculty.edu.sa)

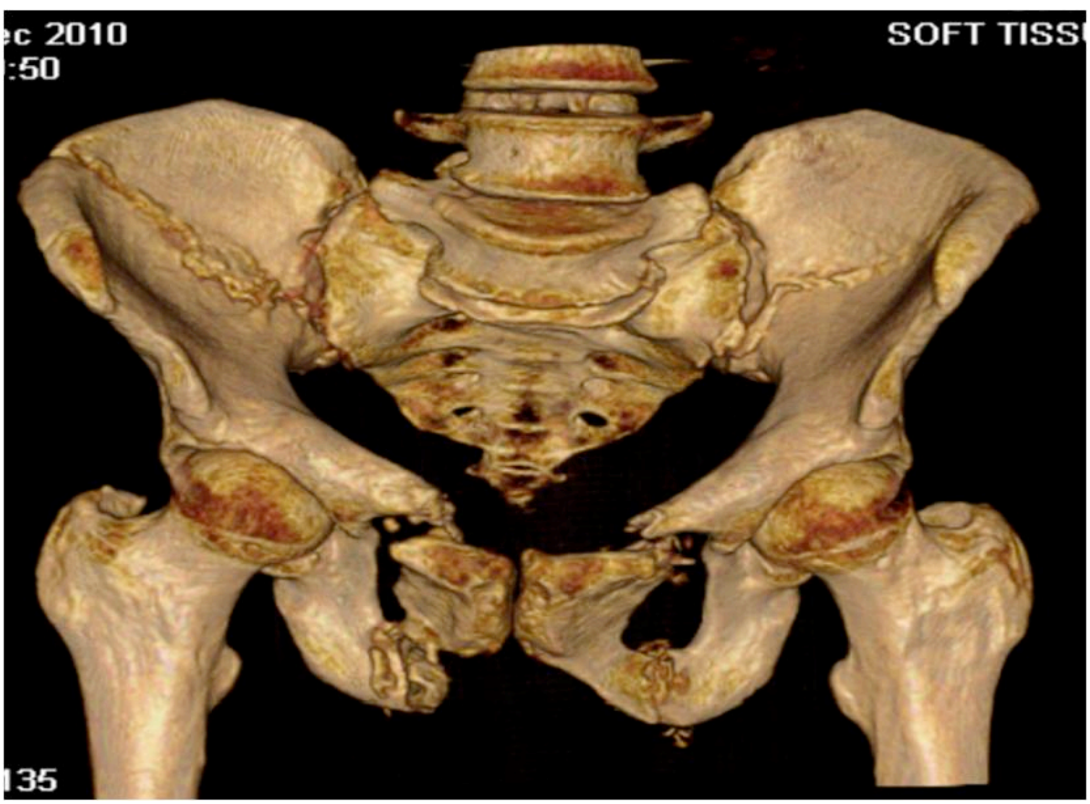


Fig. 198. The above image is a three-dimensional CT reconstruction showing both bilateral crescent and superior and inferior pubic rami fractures. (jscr.co.uk)

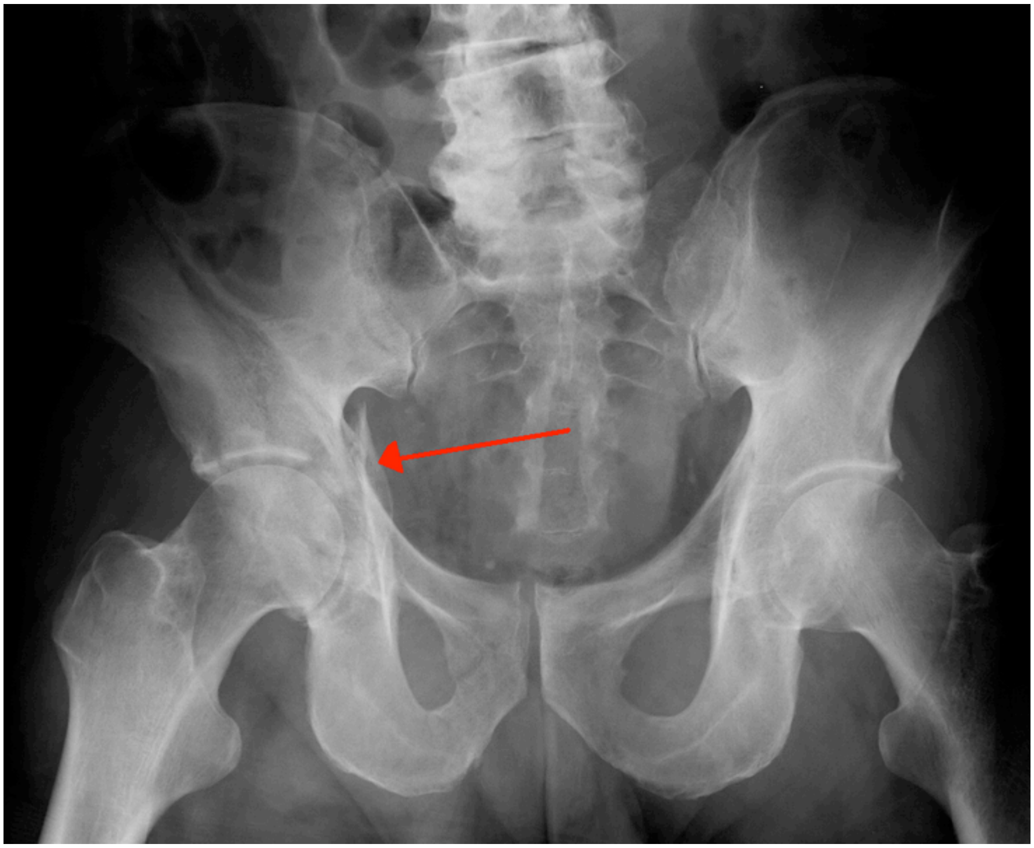


Fig. 199. This is a plane x-ray showing an acetabular fracture. (Wiki)

Because the pelvic skeleton cradles so many internal organs, pelvic fractures, especially those associated with high-energy transfer, are often associated with injuries to the pelvic organs, typically accompanied by significant internal bleeding, which may show no visible external manifestation. In addition, trauma to the extrapelvic organs (abdominal, chest, head, vertebral column and long bones) are common. In one study extra-pelvic associated injuries involved the chest in 63% of cases, long bone fractures in 50%, head and abdominal injuries in 40%, vertebral fractures in 25%, and urogenital injuries in 12-20%. Due to the fact the pelvic organs except for the bladder are generally well protected, injury to these organs is seen typically in severe trauma or high-energy transfer events. Over 50% of all pelvic fractures occur as a result of minimal-to-moderate trauma, such as a fall from a standing position. As stated above, in the elderly, the most common cause is a fall from a standing position. Of these fractures, 95% are minor. The more severe pelvic fractures involve significant organ trauma.

Incidence: Pelvic fractures represent 3-6% of all skeletal fractures in adults and occur in 7-20% of all poly trauma cases. They typically show a bimodal distribution of age with most injuries occurring in the age range of 15-30 years and over 60 years -of-age. In many respects, the age distribution follows that of motor vehicular crashes with car to car injuries more prevalent in adults, especially younger adults, with car-pedestrian injuries more likely to cause injury in children. One to two percent of fractures occurring in children treated by orthopedic surgeons are pelvic fractures. At the other extreme of age, the elderly, they tend to suffer pubic rami fractures (Fig. 198) without internal injuries as a result of falls from a standing position. In a 2007 study of a trauma registry in the United Kingdom, the median age of patients sustaining a pelvic ring fracture was 39 years.

Up to 75% of all pelvic injuries occur in men. In the same referred to 2007 study, 58 percent of patients sustaining a pelvic ring fracture were male. In another 2007 trauma registry review from New South Wales, Australia, most victims sustaining high-energy pelvic ring fractures, such as from motor vehicular crashes, were male, whereas females predominated in low-energy injuries.

Unstable pelvic fractures are estimated to occur in up to 20% of pelvic fractures (Figs. 198 & 200); a further 22% of pelvic fractures will remain stable despite significant damage to the pelvic ring. The remaining 58% of pelvic fractures are **stable**, retaining both hemodynamic and structural stability. A stable pelvic fracture is one in which the pelvis has one break point in the pelvic ring, limited bleeding and the bones stay in place. These fractures are also referred to as minor pelvic fractures. They may vary from an isolated chip off the rim of the pelvis (avulsion fracture) to a single crack through the pelvic ring (Figs. 197 & 201) or fractures of the pubic ramus with minimal displacement (Fig. 202).

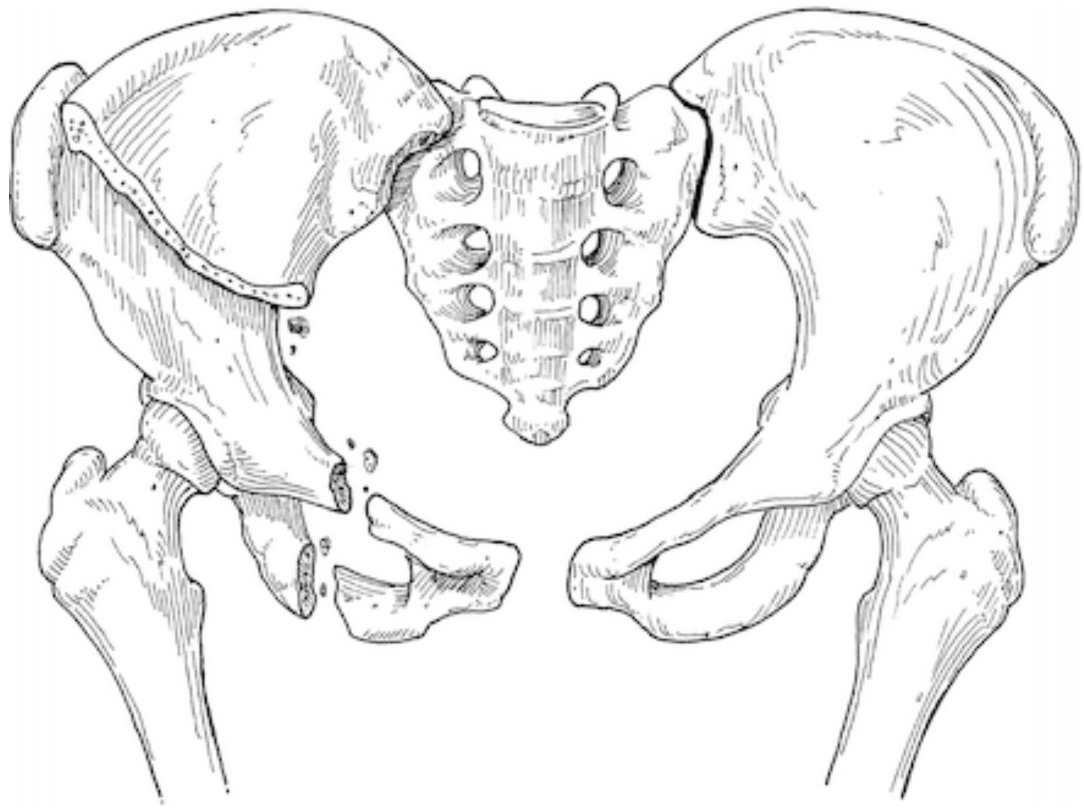


Fig. 200. This is a drawing depicting a Malgaigne injury, which is a complex, unstable pelvic fracture involving one side of the pelvis with both anterior and posterior disruption of the pelvic ring. In this drawing the lateral fragment contains the acetabulum. (radiographics.rsna.org)

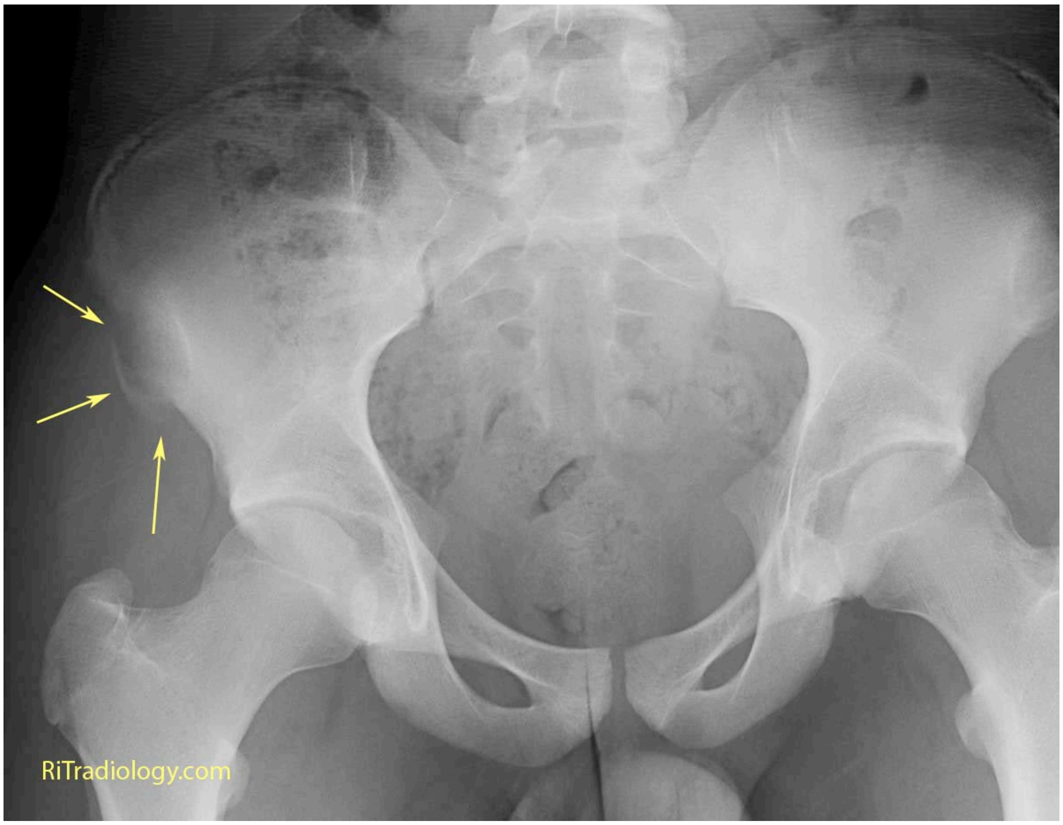


Fig. 201. This image is an x-ray showing an avulsion fracture (arrows) of the right anterior superior iliac spine (ASIS) in a 14-year-old boy. Avulsion fractures of the pelvic bones are usually found in young, skeletally immature athletes. These fractures are due to forceful contraction of the attached muscles while the athlete actively engages in kicking, running or jumping. (radiologyinthal.blogspot.com)

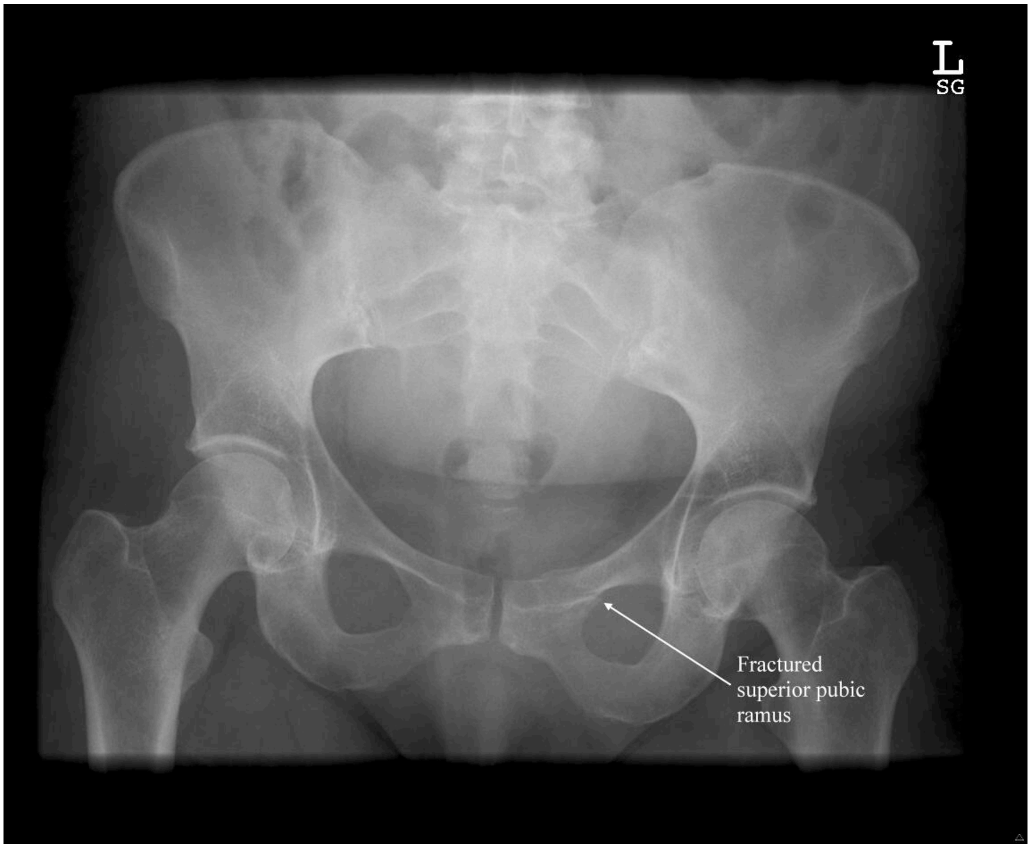


Fig. 202. This image is a plain x-ray depicting a fracture of the left superior pubic ramus (arrow). (imagingpathways.health.wa.gov.au)

Unstable pelvic fractures are those in which there are two or more breaks in the pelvic ring resulting in displacement of part of the pelvis often associated with moderate to severe bleeding and or bladder and urethral injuries and/or sciatic nerve damage (Figs. 198 & 200).

There are two other types of fractures, which primarily occur in athletes, **avulsion fractures**, which was discussed in the caption with Fig. 201 and **stress fractures**. An example of an avulsion fracture would be when a small piece of bone is torn away from the ischium where the hamstring muscle is attached (Figs. 201 & 203). This type of fracture does not make the pelvis unstable or injure internal organs.

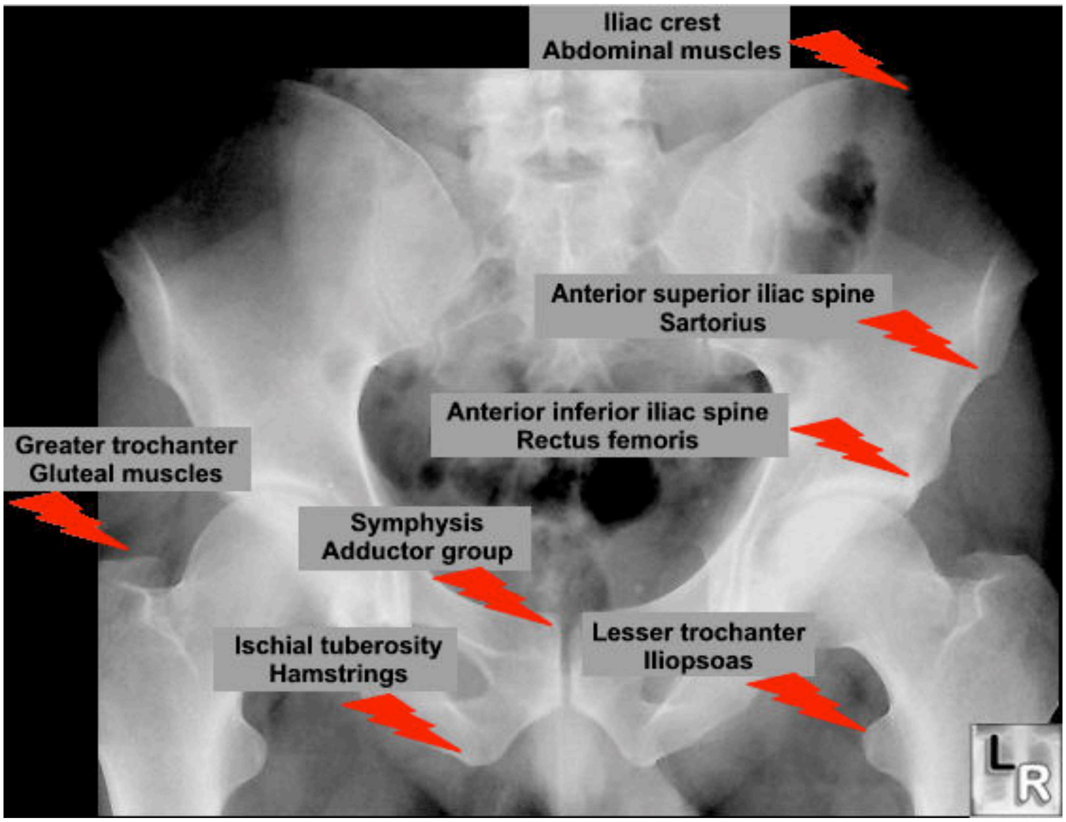


Fig. 203. This image shows where avulsion fractures typically occur in the pelvis. Avulsion fractures result when the fracture fragment is pulled from its parent bone by a forceful contraction of a tendon or ligament. Avulsion fractures are most common in younger individuals engaging in athletic endeavors. Usually, they are uncommon injuries, seen almost exclusively in adolescent athletes with a 2:1 male to female ratio. They occur most often in track events like hurdling and sprinting, or games like soccer or tennis. Most common to avulse is the ischial tuberosity followed by the anterior inferior iliac spine (AIIS) and the anterior superior iliac spine (ASIS) (Fig. 200) about equally. (learningradiology.com)

The stress fracture typically occurs in joggers. Distance running requires athletes to perform the same movements repeatedly, subjecting the same muscles to repeated movements and subjecting the same joints to sustained impact. Making matters worse, runners often condition their minds to ignore pain, driving them to push muscles and joints to the brink of injury. When a runner's, muscles tire, he often forces his bones to compensate by bouncing higher in the air during his stride, forcing the pelvis to absorb more impact. A runner might also be forced to compensate in his stride for imbalances in his posture or leg length, again forcing the pelvis to absorb greater impact. These fractures usually manifest by pain in the thigh or buttock (Figs. 204 & 205).

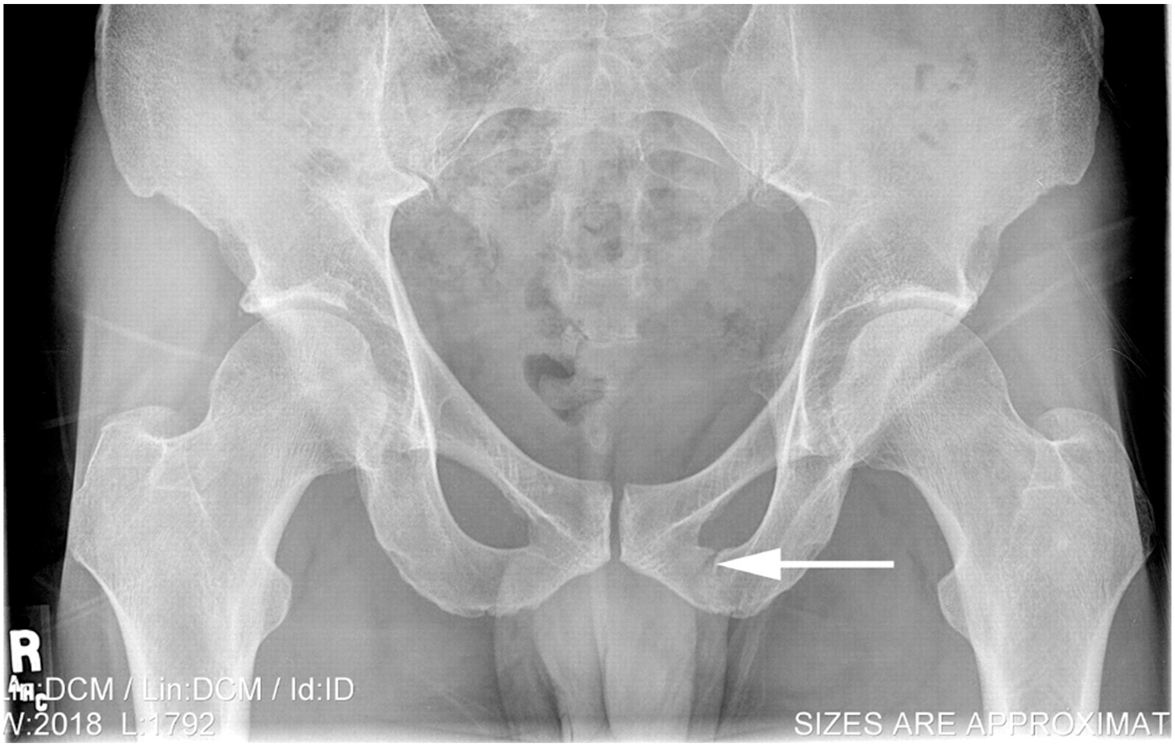


Fig. 204. This plane x-ray depicts a stress fracture of the left inferior pubic ramus shown by the arrow. (joanne-eatswelllwithothers.com)

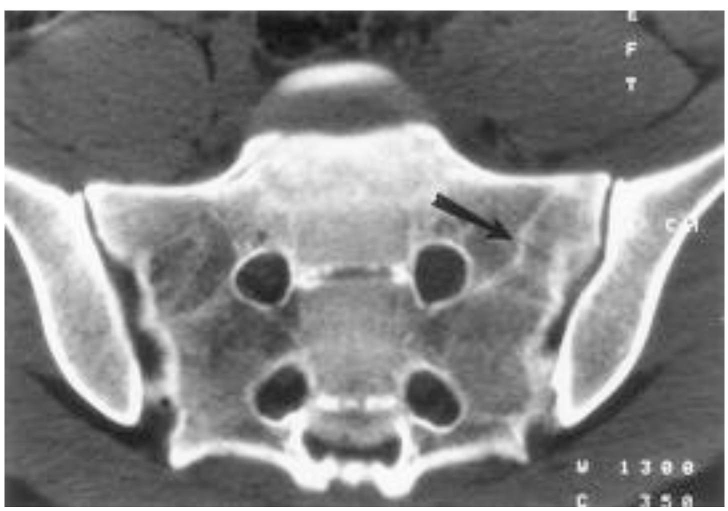


Fig. 205. The above image depicts a stress fracture involving the sacrum shown by the black arrow. (ajs.sagepub.com)

The incidence of pelvic fracture resulting from blunt trauma ranges from 5-11%.

Obese patients are more likely to sustain a pelvic fracture from blunt trauma than non-obese patients. Penetrating trauma is far less frequently associated with pelvic fractures. Open pelvic fractures are rare and account for only 2.7-4% of all pelvic fractures.

Pathophysiology: As discussed under “Relevant Anatomy of the Pelvis,” the pelvis is a ring structure composed by three bones: the **sacrum** and **two innominate bones,** which are composed by the ilium, ischium and pubic bones (Fig. 1, p 2, Fig. 3, p 5 & Fig. 206).

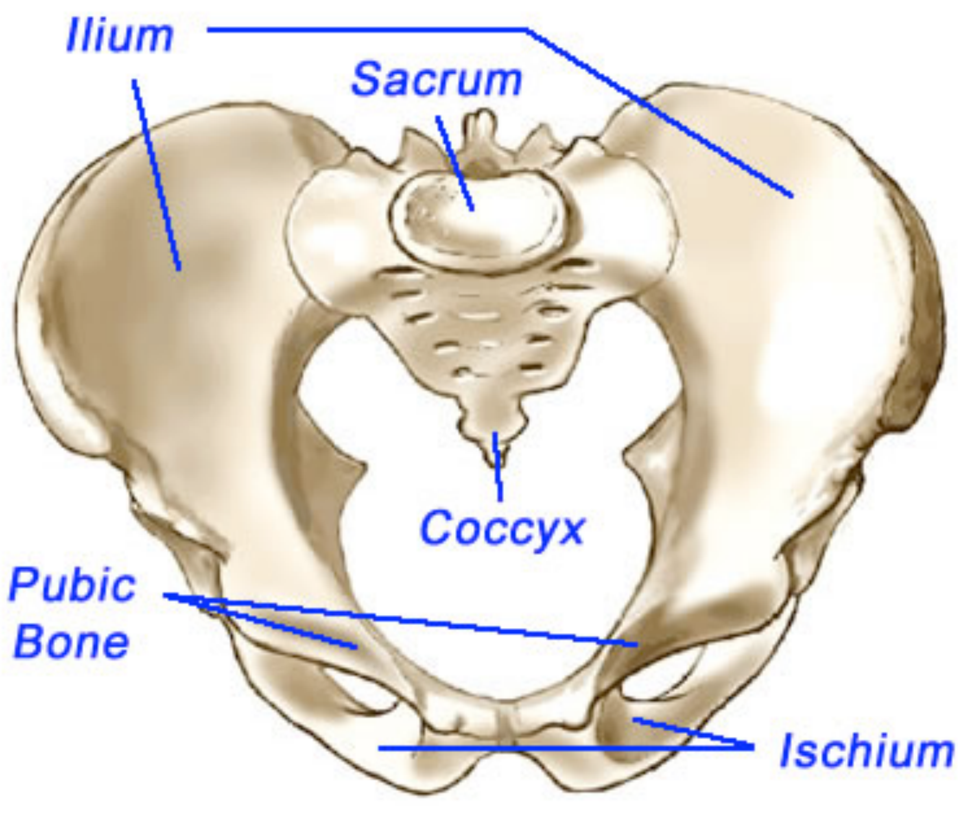


Fig. 206. This drawing is of the anterior or front view of the pelvic bones. (kidport.com)

The pelvic ring is formed by the connection of the sacrum to the innominate bones the **sacroiliac joints** and the **symphysis pubis** (Figs. 13, 15, 16, 23, 27 & 28, p 15, 17, 18, 25, 33 & 34). Stability of this ring is dependent upon strong pelvic ligaments. The strongest and most significant pelvic ligamentous structures occur in the posterior aspect of the pelvis at the sacroiliac joint. It is the posterior ligaments that hold up the weight bearing forces that occur from the lower extremities to the spine and are transferred to the sacroiliac joints. The **posterior sacroiliac complex of ligaments** are considered collectively the strongest ligaments in the body; they are more important then the **anterior sacroiliac ligaments** for pelvic ring stability; the anterior sacroiliac ligaments resist external rotation after failure of the pelvic floor and anterior structures. The single strongest ligaments in the body is considered to be the **interosseous sacroiliac ligaments**, which act to stabilize the sacroiliac joint through resisting anterior-posterior translation of the pelvis; the posterior sacroiliacs resist cephalad-caudal displacement of the pelvis; and the **iliolumbar ligaments** resist rotation and augment the posterior sacroiliac ligaments. The anterior pelvic ligamentous structures are represented by the **symphyseal ligaments**, which resist external rotation (Figs. 15,16, 27 & 28, p 17, 18, 33 & 34 & Figs. 207 & 208).

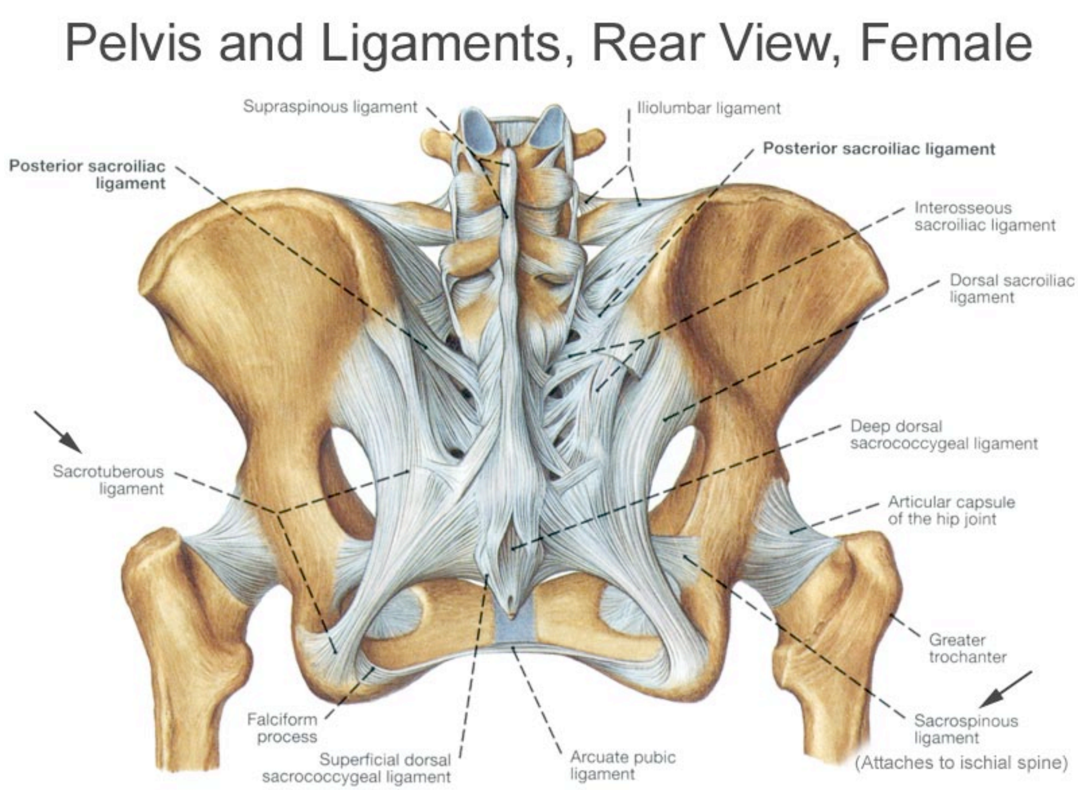


Fig. 207. This drawing shows the ligaments of the posterior female pelvis. (edoctoronline.com)

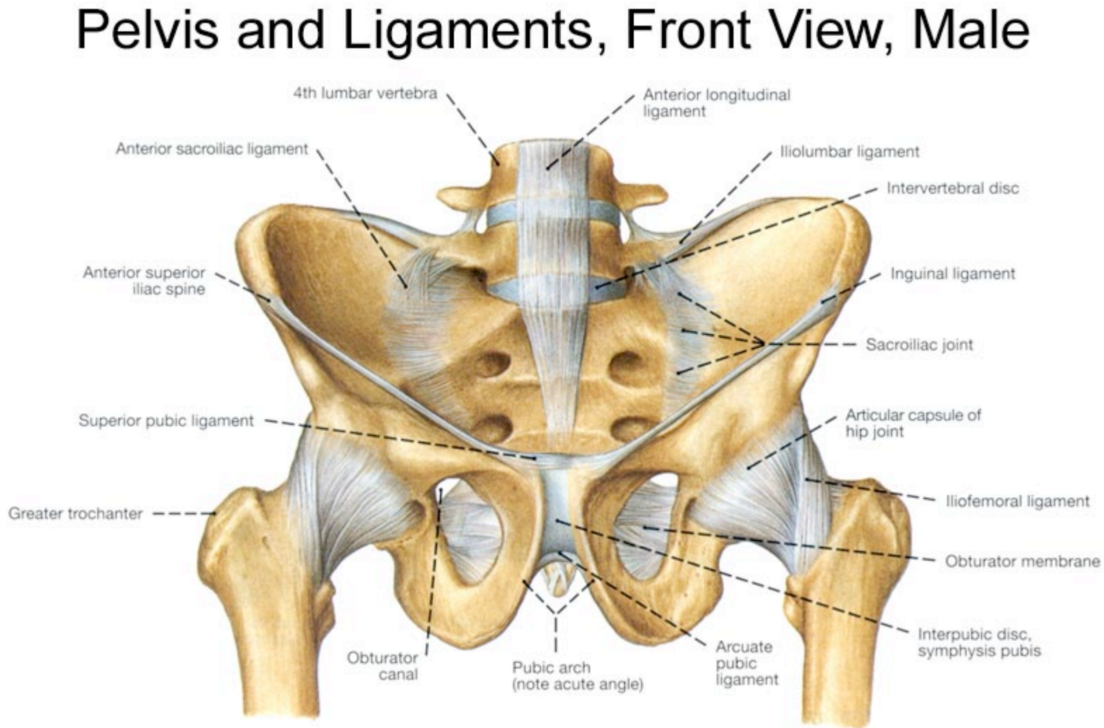


Fig. 208. This drawing shows the ligaments of the anterior male pelvis. (edoctoronline.com)

The symphyseal ligaments act more as a supporting "strut" because it is the ligamentous structures of the sacroiliac joint that provide the stability to the pelvic ring. Destruction of the symphyseal ligaments will not lead to instability of the pelvic ring.

Besides the ligaments of the posterior sacroiliac complex and anterior symphyseal ligaments providing stability to the pelvis, there are also the ligaments in the pelvic floor, the **sacrospinous and sacrotuberous**, which help with stability (Figs. 15, 27 & 28, p 17, 33 & 34 & Figs. 207 & 208). The sacrospinous resist external rotation and the sacrotuberous resist shear and flexion. *Thus, because of the ligamentous structures of the pelvis, displacement of the pelvic ring can only occur if there is disruption of the ring in two places.*

Pelvic fractures are often associated with severe hemorrhage due to the large volume of highly vascular cancellous bone, injured soft tissue at the fractured sites, and the anatomic proximity of major blood vessels. The arteries most frequently injured are the **iliolumbar arteries, the superior gluteal, and the internal pudendal** because of their proximity to bone, the sacroiliac joints and the inferior ligaments of the pelvis. The other major blood vessels which contribute to significant hemorrhage are the **median sacral artery** and the **superior rectal artery** located on the inner wall of the pelvis; and the **common iliac arteries**, which are the terminal branches of the **abdominal aorta**, dividing into the **external and internal iliac arteries**. The internal iliac artery is the **artery of the pelvis**, whereas external iliac supplies the **lower extremities.** The internal iliac artery also gives origin to the **superior gluteal artery**. This artery leaves the pelvis through the upper part of the **greater sciatic foramen** above the **piriformis muscle** and thus, like the iliolumbar, median sacral, superior rectal, external and internal iliac and internal pudendal arteries and associated veins are subject to injuries with pelvic fractures. Bleeding from the venous network after a pelvic fracture is more frequent than arterial bleeding because the walls of the veins are more fragile than arteries. Blood may pool in the retroperitoneal space with hemostasis occurring spontaneously in closed fractures, especially if there is no concomitant arterial hemorrhage. Hemorrhage is the cause of death in approximately 50% of those victims who died following pelvic fractures.

Due to the forces involved, pelvic fractures frequently involve injury to the organs and other structures contained within the pelvis. The organs and structures that can be affected during trauma to the pelvis are the **genitourinary system (lower ureter, bladder, urethra, internal reproductive organs)** and the **gastrointestinal system (primarily the rectum and anal canal).** The **lumbar and sacral plexuses** that are posterior can also be affected during pelvic trauma. Pelvic injury is also commonly associated with concomitant intra-thoracic and intra-abdominal injuries.

The incidence of **genitourinary system injuries** range from 23-57% with **urethral** and **vaginal injuries** being the most common. **Vaginal injuries** result from either penetration of a bony fragment or from indirect forces from diastasis of the symphysis pubis. Injuries to the cervix, uterus and ovaries are rare. **Bladder rupture** occurs in up to 10% of pelvic fractures.

The incidence of **rectal injuries ranges** from 17-64% depending on the type of fracture. Bowel entrapment is rare.

Classification of Pelvic Fractures: At this time there is no universally accepted classification system of determining pelvic fractures, consequently, you will find different descriptions or classifications.

As is true of other fractures, pelvic fractures may be classified as **open or closed**. An open fracture is one in which the skin overlying the fracture was violated, or in which there was injury to the rectum or vagina (Fig. 209). Fractures in which the skin overlying the fracture is closed and/or there are associated injuries to the pelvic ureter, bladder or urethra are considered closed (Fig. 210).

Fig. 209. Open pelvic fracture with laceration of the perineum and rectum. (wheelessonline.com)

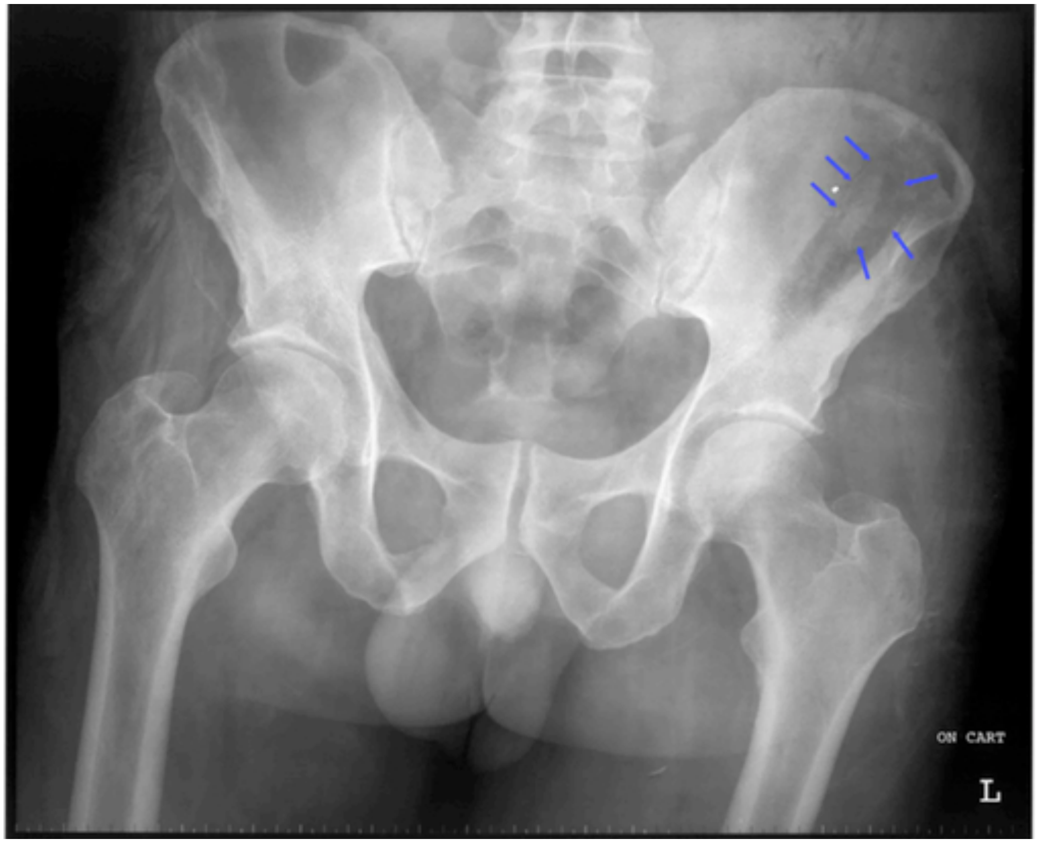


Fig. 210. Closed fracture of the left iliac wing. (ispub.com)

As indicated above fractures may also be classified whether they are **hemodynamically stable or unstable**. A hemodynamically stable fracture is one in which the pelvis has one break point in the pelvic ring (Figs. 199, 201, 202, 204, 205 & 210). Thus, the bones are staying in place and there is limited bleeding.
A hemodynamically unstable fracture is one in which there are two or more breaks in the pelvic ring, consequently, the pelvic ring would not be stable with weight bearing due to involvement of the anterior components (pubis and/or ischium), as well as the loss of integrity of the posterior elements, either osseous or ligamentous, associated with moderate to severe bleeding (Figs. 198 & 200).
Bucholz, Tile, and the Orthopedic Trauma Society developed a classification of fractures based on the stability of the pelvic ring and the integrity of the posterior sacroiliac complex. This classification system is referred to as the Tile's Classification (Fig. 211). His classification begins with minor injuries in which the

pelvic ring is stable and is referred to as a Type A fracture. It increases to more complex injuries. Type B and C with complete instability of the posterior pelvic ring. Type A fractures have an intact posterior sacroiliac complex. There are three subtypes of the Type A fracture: Type A1 fracture does not involve the pelvic ring (avulsion or iliac wing fracture, Figs. 197, 201 & 210); Type A2 fracture is stable or minimally displaced fracture of the pelvic ring; Type A3 is a Denis zone sacral fracture (The Denis three-zone classification system for sacral fractures was developed in 1988 consisting of zone I fractures, which are entirely lateral to the neuroforamina, zone II fractures involve the neuroforamina, but not the spinal canal, and zone III fractures extend into the spinal canal with primary or associated fracture lines) (Fig. 212).

Type B fractures are rotationally unstable but vertically stable (partially unstable fractures). They are always caused by severe trauma, such as from a crushing injury, motor vehicular crash, or fall from a great height. This injury involves complete disruption of the posterior sacroiliac complex, involving vertical shear forces. This fracture can involve one or both sides of the pelvis. There are three primary subtypes and two secondary subtypes of B2: B1 fracture is an open book fracture (Fig. 213) (external rotation) (this type of fracture is typically caused by heavy impact to the groin [pubis], such as can occur in a motorcycle injury. In this kind of injury, the left and right halves of the pelvis are separated at the front and rear, the front opening more than the rear, i.e., like opening a book); Type B2 is a lateral compression fracture (internal rotation) which has two subtypes B2-1 (with anterior ring rotation or displacement through the ipsilateral ramus) and B2-2 (with anterior ring rotation or displacement through the contralateral rami, the so called bucket-handle fracture. When a lateral compressive force combines with an upward rotatory component it produces fractures of both pubic rami on the side opposite the impact, combined with a fracture in the posterior sacroiliac region on the same side as the impact. The resultant displacement of the hemipelvis is superior and medial with rotation like the handle of a bucket) (Fig. 214); and Type B3, which are bilateral fractures. The type B3 also has two subtypes, which include bilateral open book fractures (B3-1), bilateral lateral-compression fractures (B3-2), and combinations of the two.

In Type C fractures, the pelvis is rendered unstable both rotationally and vertically, due to complete disruption of the anterior arch, posterior arch, and pelvic floor (Fig. 211). They are always caused by severe trauma, such as from a crushing injury, motor vehicular crash, or fall from a great height. This injury involves complete disruption of the posterior sacroiliac complex, involving vertical shear forces. This fracture can involve one or both sides of the pelvis. Type C fractures have three subtypes: C1 which are unilaterally unstable; C2 are composed of an unstable pattern on one side of the pelvis and a partially stable (type B injury) contralateral fracture; and C3 which are bilaterally unstable.

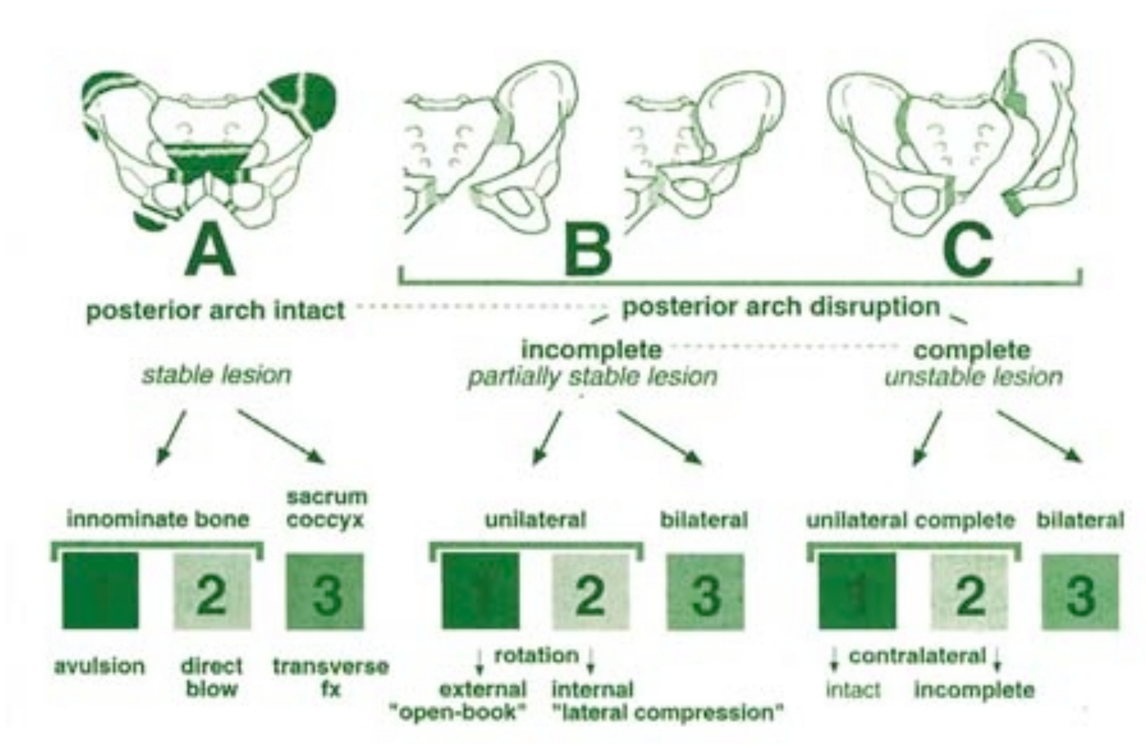


Fig. 211. This illustration is of the Tile classification system.

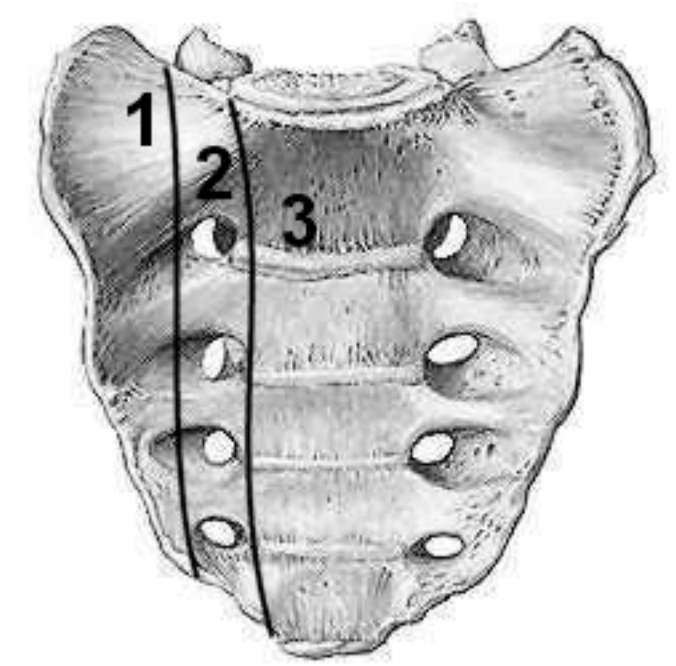


Fig. 212. This drawing depicts the Denis three zone classification system. (rcsed.ac.uk)

Fig. 213. The above plain x-ray is of an open book fracture (arrow). There is diastasis of the symphysis pubis and associated diastasis of the right sacroiliac joint (arrow). There is a subtle fracture of the right inferior pubic ramus (arrow). The sacral arcuate lines (sacral foramina) appear intact. (wikiradiography.com)

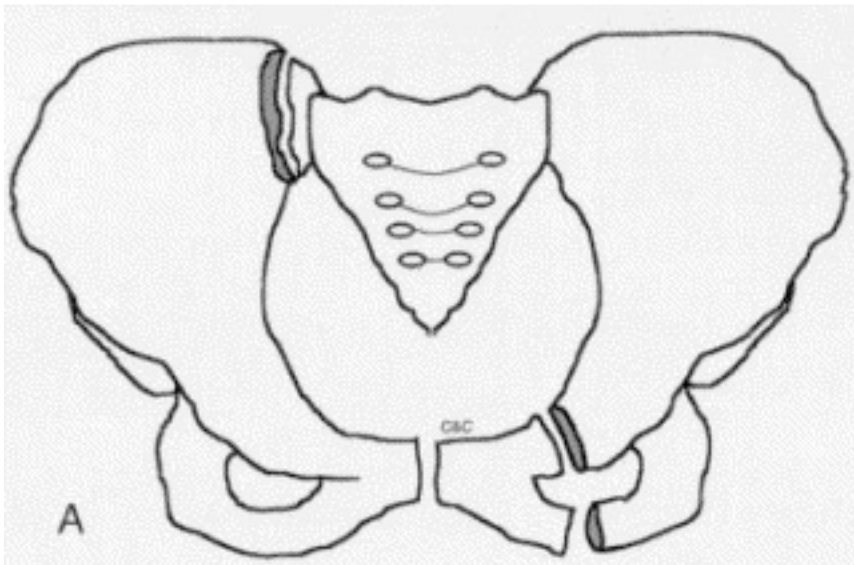


Fig. 214. This drawing is of a bucket handle fracture. (sciencedirect.com)

Young and Burgess developed another classification system of pelvic fractures based on mechanism of injury, in other words, how the injury came about (Fig. 215). The foundation of the mechanism based classification system is determining the vector force that was applied to the victim, most especially their pelvis. There are three vector forces responsible for pelvic injury: **lateral compression (LC), anterior or posterior direction (AP), and vertical shear (VS).**

The **most common vector force** responsible for injury is **LC**. This occurs when the vector force is applied from the lateral side of the pelvic ring, such as would occur in an intersectional motor vehicular accident (T-bone) or when a pedestrian is struck from the side or the victim falls from a great height landing on their side. Typically, the force is applied either to the iliac crest directly or to the greater trochanter by the femoral head's being driven into the acetabulum. Anteriorly, the pubic rami on the side of impact are usually fractured. There also may be a contralateral fracture of the pubic rami or less commonly, fracture of all four pubic rami or in severe cases, disruption of the pubic symphysis. Posteriorly, there is ipsilateral impaction of the sacroiliac joints with the posterior ligaments being intact. If the femoral head is driven into the acetabulum, there are usually associated ipsilateral fractures of the pelvic rami, disruption of the sacroiliac joints with impaction and fractures of the acetabulum. In this type of injury the morbidity and mortality for the victim is mostly determined by the associated injuries of the abdomen, thoracic contents, and the cervical spine. The LC force vector is usually not strong enough to open up the pelvis, however, it can cause great damage to the internal organs from fracture fragments. There is an exception to this and that is when an LC Type III injury is produced (Fig. 215). In this type of injury the lateral force that contacts one side of the pelvis creates an internal rotation, which continues to the opposite side of the pelvis creating an external rotation injury, which is called a "windswept" pelvis. This type of injury is caused by both an initial impact and secondary crush injury. It typically occurs when a pedestrian is struck, then rolled over by a the vehicle. The LC force vector classification is as follows:

LC Type 1: Oblique rams fracture and ipsilateral anterior sacral ala compression fx
LC Type 2: Rami fracture and ipsilateral posterior ilium fracture (crescent fracture)
LC Type 3: Ipsilateral lateral compression and contralateral APC (windswept pelvis)
Common mechanism is rollover vehicle accident or pedestrian vs auto

The next type of vector force, which can impact the pelvis, is either from the **anterior or posterior (APC) direction**. These injuries are mostly ligamentous, such as symphyseal diastasis, with possible longitudinal pubic rami fracture. Typically, there is a direct blow to either the pubic symphysis or the posterior iliac spines, or violent external rotational forces applied to the femurs. Anteriorly, there is separation of the pubic symphysis. Posteriorly, there is bilateral separation of the sacroiliac joints anteriorly, with the posterior sacroiliac ligaments being generally intact. An example of this type of injury is seen when the victim's legs are spread apart in a motorcycle accident. The pelvis is widen from the force of impact. An APC grade III injury is typically called an "open book" pelvis, with complete disruption of all the sacroiliac ligaments, resulting in separate hemipelves. Usually, this type of injury is associated with severe arterial damage involving the **internal iliac artery**, **and adjacent veins**.

These injuries are usually associated with **lumbosacral plexus injuries**. The APC classification is as follows:

APC Type 1: Associated widening of the pubic symphysis < 2.5 cm or of the anterior sacroiliac joint, while the sacrotuberous, sacrospinous, and posterior sacroiliac ligaments remain intact.
APC Type 2: Associated widening of the pubic symphysis > 2.5 cm or widening of the anterior sacroiliac joint caused by disruption of the anterior sacroiliac joint, sacrotuberous, and sacrospinous ligaments; the posterior sacroiliac ligaments are intact.
APC Type 3: Disruption of the anterior and posterior sacroiliac ligaments with lateral displacement. The anterior sacroiliac, sacrotuberous, sacrospinous, and posterior sacroiliac ligaments are disrupted. This type 3 injury is often associated with vascular and nerve plexus injury.

The **third type of vector force** is the **vertical shear (VS)** that causes vertical shear injury. There is application of a shearing force to one or both sacroiliac joints. The force is perpendicular to the trabecular pattern of the posterior pelvic complex, which results in disruption of both the anterior and posterior sacroiliac ligaments, as well as symphyseal, sacrotuberous and sacrospinous ligaments. Anteriorly, there may be disruption of the pubic symphysis, two pubic rami, or all four pubic rami. If the force is violent enough there may be an ipsilateral, hemipelvis avulsion from the body. This usually occurs when a person jumps from a great height and lands on an extended lower extremity. The VS classification is as follows:

VS: Posterior and superior directed force associated with the highest risk of hypovolemic shock (c8%) and a mortality rate up to 25%

There are also combined mechanical (CM) fractures, which involve a combination of these patterns, with LC/VS being the most common.

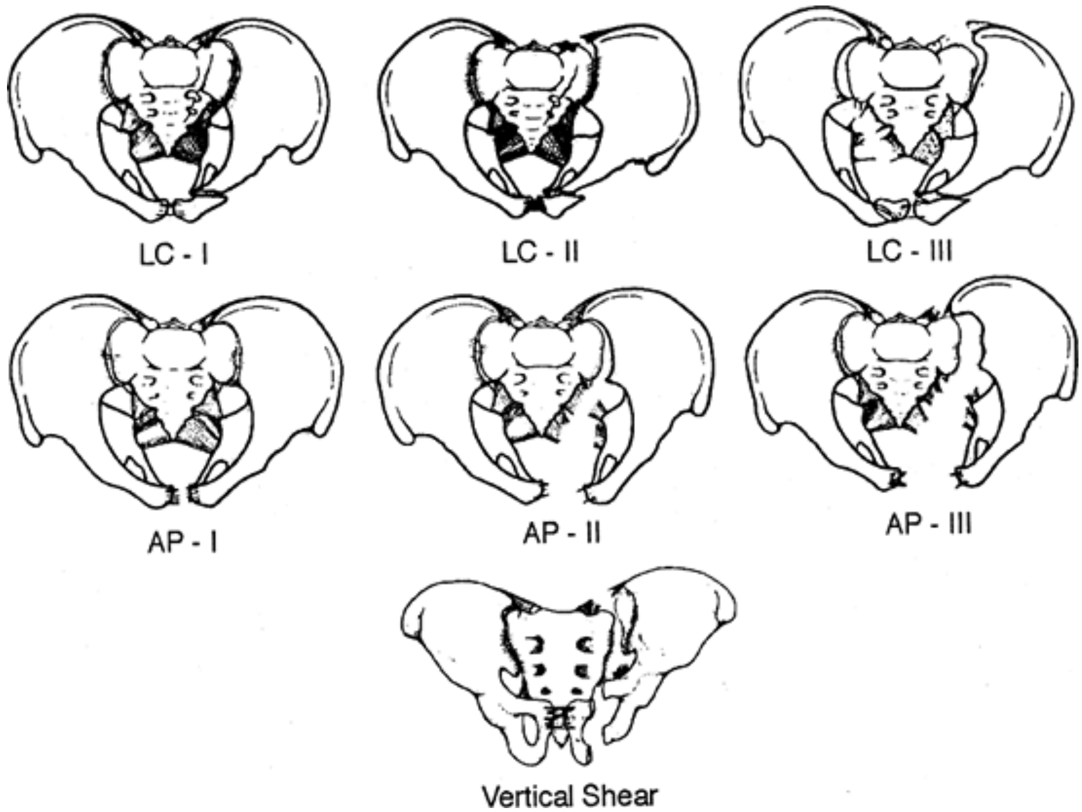


Fig. 215. This is the Young-Burgess classification system. (foamen.com)

Fractures of the acetabulum most commonly involve disruption of the acetabular socket when the hip is driven backward in a motor vehicular accident. Occasionally they occur in a pedestrian struck by a vehicle moving at a significant rate of speed (Figs. 216 & 217).

Falls in the elderly may involve fractures typically of the pubic rami without disruption of the ring (Fig. 204).

Usually, a kick or heavy fall onto the base of the spine may fracture the coccyx or sacrum (Figs. 212 & 218). The sacrum may also show fractures from natural events such as stress fractures in the postpartum period (Fig. 219).

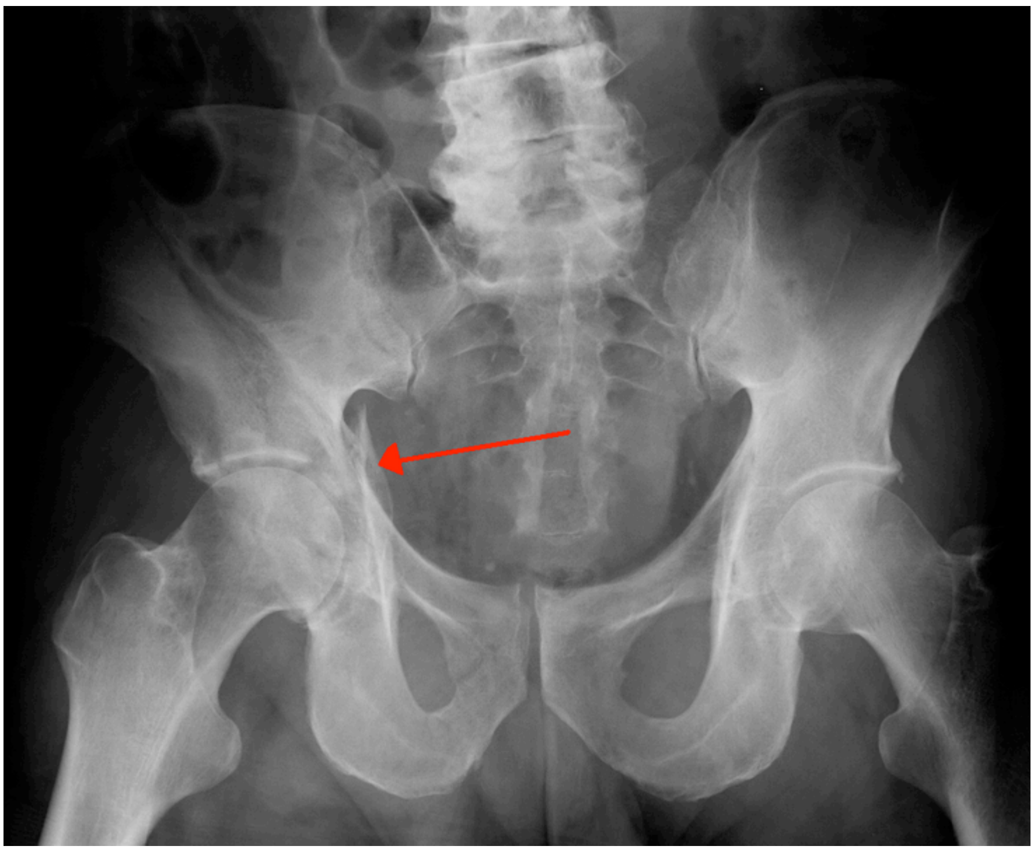


Fig. 216. This image is a plain x-ray depicting a fracture of the acetabulum identified by the red arrow. (radiographics.rsna.org)

Fig. 217. This is a sagittal volume-rendered 3D CT image (anterior projection) showing a fracture of the posterior acetabular wall (arrow). (radiographics.rsna.org)

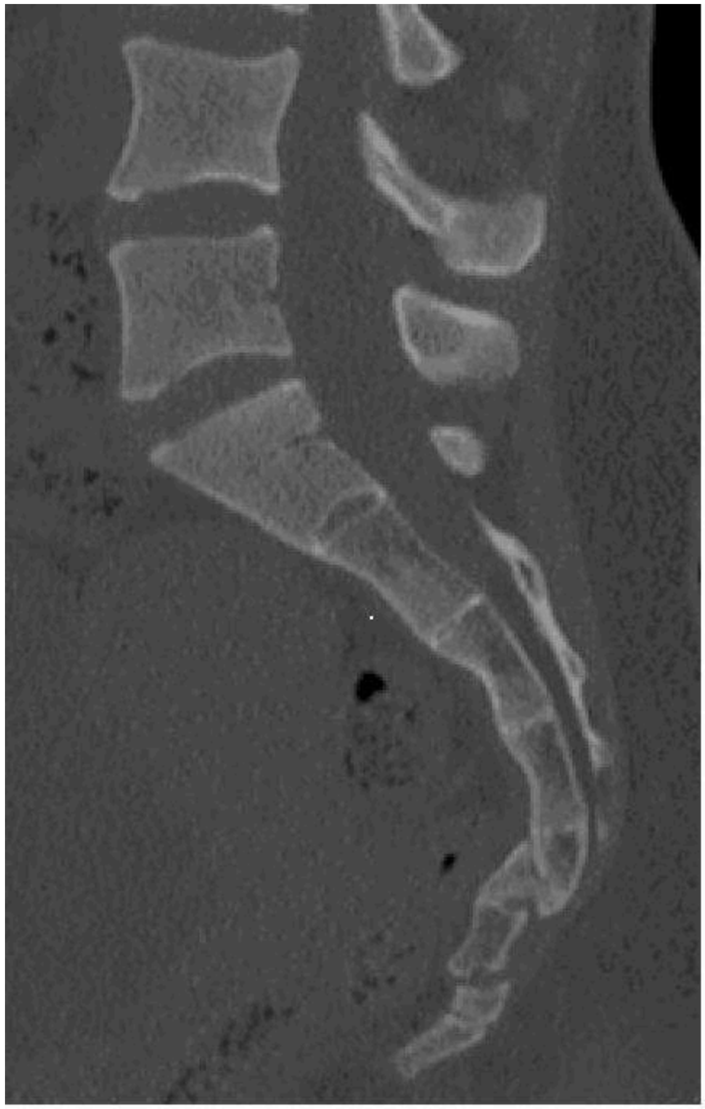


Fig. 218. This is a CT scan of the lumbar vertebrae and coccyx of a 35-year-old female that was riding a bicycle that was broad sided by a SUV. She sustained a type II segmental, angulated compound fracture to the tibia, segmental fractured fibula, a comminuted displaced coccyx fracture shown above and a sacrum fracture. (coccyx.org)

Fig. 219. This is a CT scan of a 30-year-old female who had recently undergone a normal spontaneous vaginal delivery of her first child at 41 weeks gestation. She developed pain in her sacrum and coccyx region that began during pregnancy and increased after delivery. The CT demonstrated bilateral stress fractures of the sacrum. (coccygectomy.org)

Complications of Pelvic Fractures: The considerable forces that are required to fracture the pelvis cannot only cause injuries within the pelvic cavity but also injuries in other areas of the body. The most life-threatening injuries are to blood vessels, which can lead to a loss of large amounts of blood. The source of this bleeding may be intra-abdominal, intra-thoracic, retroperitoneal, extremities, i.e., thigh compartments or pelvic. Common sources of bleeding in pelvic fractures are venous injury (80%), especially shearing injuries which tend to involve the thin walled venous plexus, and from cancellous bone. Uncommon sources of hemorrhage in pelvic fractures are arterial injury (10-20%) with the **superior gluteal** being the most injured vessel in **posterior ring fractures**, typically the result of **anterior posterior compression (APC)**. Two other arteries, which are commonly injured are the

internal pudendal and **obturator**. The internal pudendal is usually injured in **anterior ring fractures**, typically the result of **lateral compression (LC)**. The **obturator artery** is usually injured as the **result of LC**.

Besides pelvic fractures there may be associated **long bone fractures**, which in of themselves can be associated with a large loss of blood. **Aortic lacerations** not uncommonly occur in **APC pelvic injuries**. The **common iliac arteries** are occasionally damaged by bone fragments or they can be completely divided.

In pelvic fractures the blood is usually contained within the pelvis between the parietal peritoneum superiorly and the strong fibromuscular and bony walls of the pelvis. If these barriers are breached by the traumatic forces or at the time of surgery, the bleeding will not be contained and exsanguination can occur. This complication accounts for the high mortality rate associated with open pelvic fractures (Fig. 209).

Closed-head injuries are also common in patients with pelvic fractures. **Visceral injuries, such as a bladder rupture, lacerations of the pelvic ureter or urethra may occur.** Although, urethral injuries occur more commonly in males, they can occur in women. Urethral injuries are usually associated with bilateral pubic rami fractures, significant vertical displacement of the pelvis, and symphyseal disruption (Figs. 198, 213 & 215). Diaphragmatic injury and small and large bowel injury may also occur, however, they are uncommon. The small intestine, colon and rectum are not usually seen because displaced fractures of the sacrum are rare. Paralytic ileus is however common. Other organs which can be injured are the liver, spleen, pancreas, heart, lungs, great vessels and the spinal cord.

Nerve injury, especially **sciatic nerve damage and lumbosacral plexus damage** can also occur, especially in **posterior pelvic injuries** in which nerves may be stretched or damaged. Sciatic nerve damage is usually associated with **vertical force fractures**. **Sacral fractures** may cause damage to the nerves within the **sacral foramina**.

Delayed Complications of Pelvic Fractures: Deep venous thrombosis can occur in pelvic fractures. This complication is because patients with these fractures are immobile for long periods of time thus, becoming highly susceptible to thromboembolism (Fig. 220). As a result such patients may develop **pulmonary emboli (blood clots)** (Figs. 221 & 222).

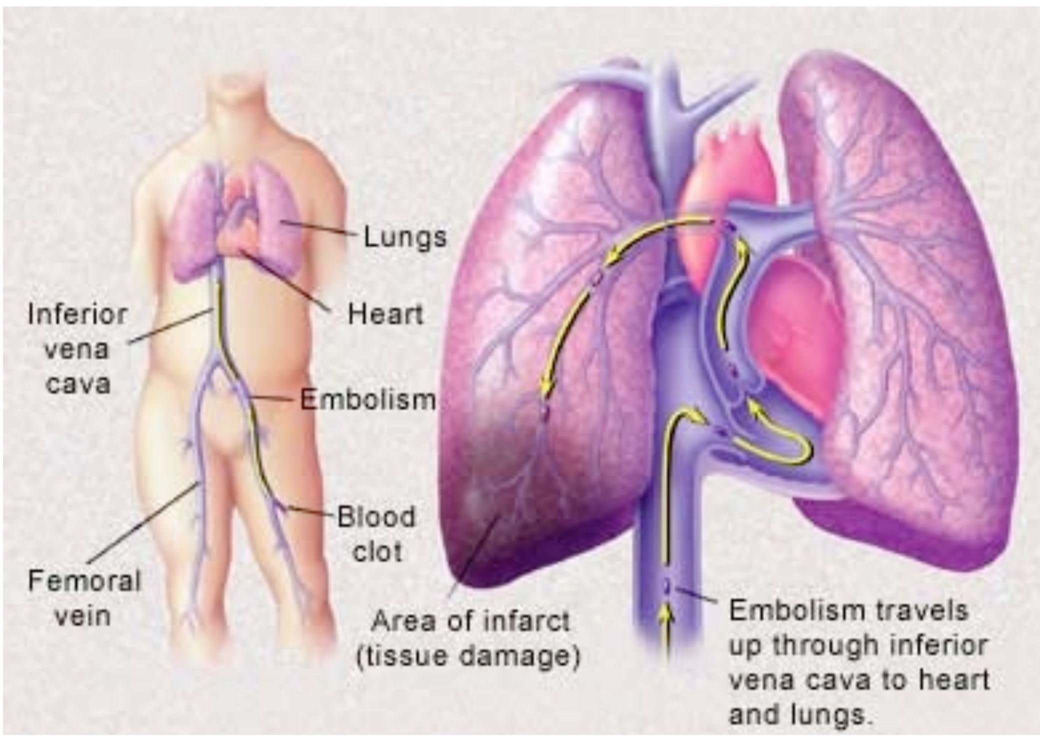


Fig. 220. The above illustration depicts the origin of pulmonary emboli from blood clots (thromboembolism), which typically arises in the major veins of the lower extremities. (doctorrennie.wordpress.com)

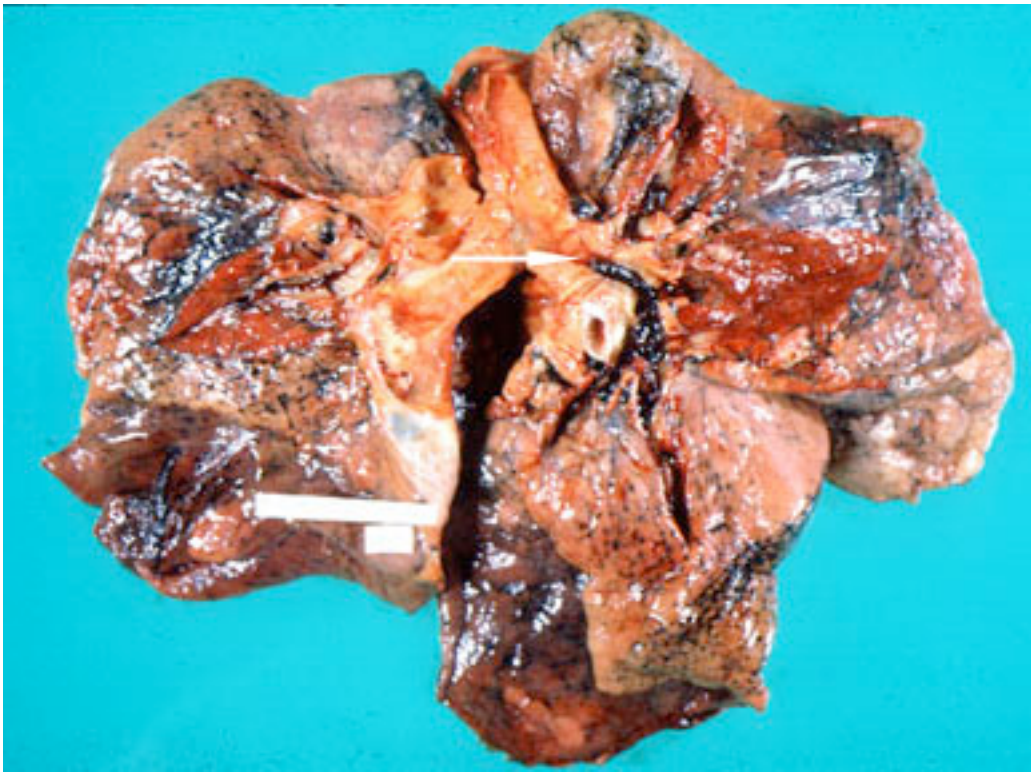


Fig. 221. The above is an autopsy photograph showing pulmonary emboli in the large pulmonary veins identified by the white arrow. (lumen.luc.edu)

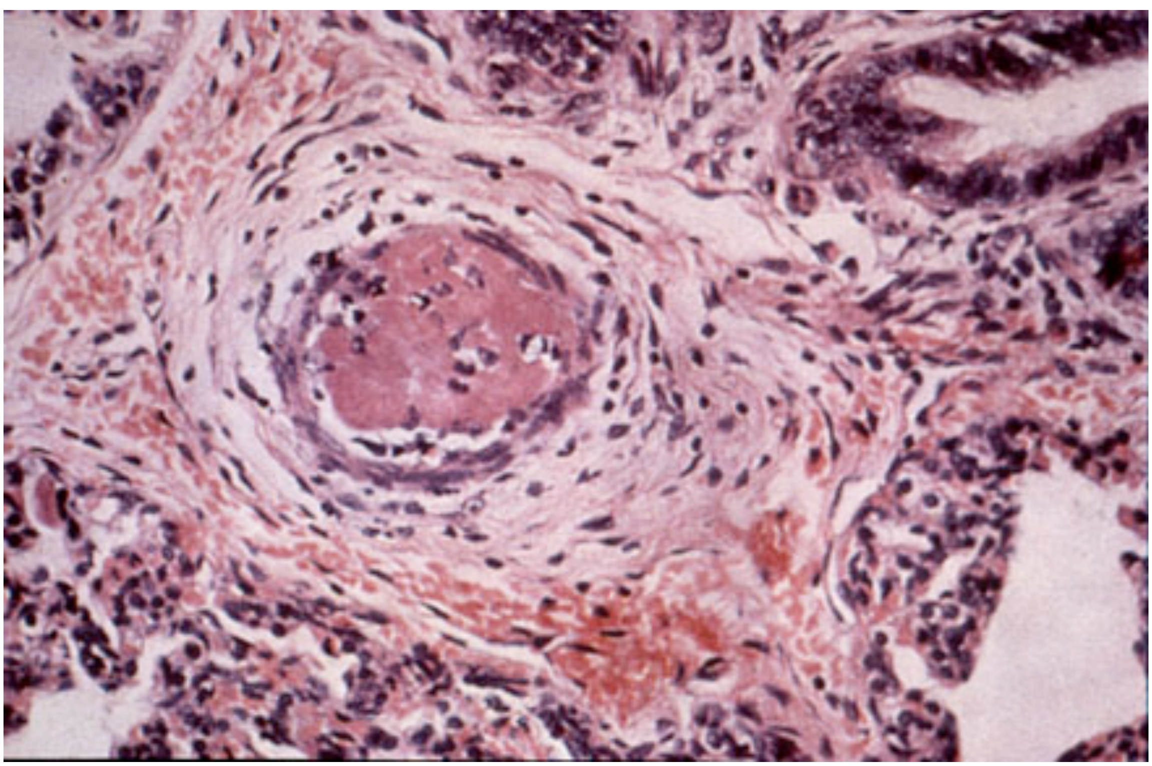


Fig. 222. The above is a photomicrograph of an embolus within a small pulmonary vein. (lumen.luc.edu)

Another form of embolization these patients may experience are **fat emboli**, which are not uncommon in pelvic or long bone fractures (Fig. 223). Usually, fat emboli are due to the mobilization of fluid fat following fractures to the pelvis, long bones or traumatic injuries to adjacent soft tissue. Fat emboli occur in almost 90% of all patients with severe injuries to bones, although only about 10% of these are symptomatic.

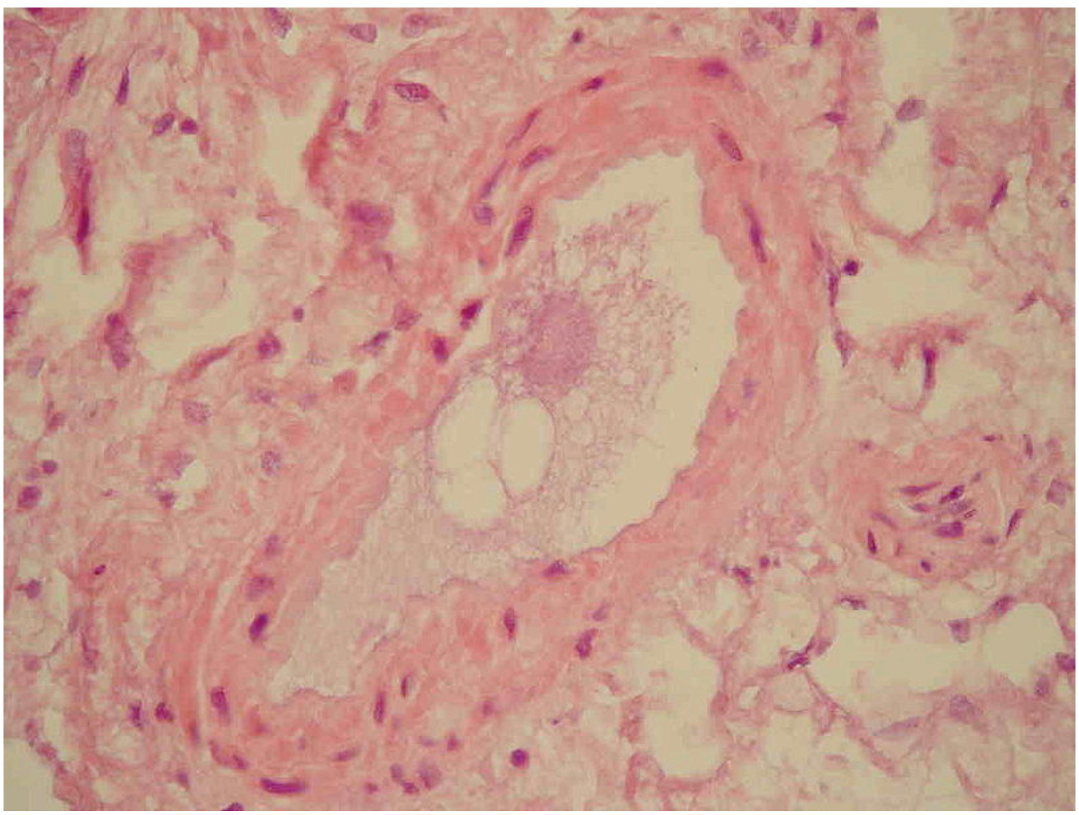


Fig. 223. This is a photomicrograph of a microscopic section of the lung showing a blood vessel with fibrinoid material and an optical empty spaces indicative of the presence of lipid dissolved during the staining process consistent with a diagnosis of fat embolism. (Wiki)

Some patients may develop the **Fat embolism syndrome**, which is distinct from the presence of fat emboli. In this syndrome symptoms usually occur 1-3 days after a traumatic injury and are predominantly pulmonary (shortness of breath, hypoxemia), neurological (agitation, delirium or coma), dermatological (petechial rash), and hematological (anemia and low platelets) (Figs. 224 & 225).

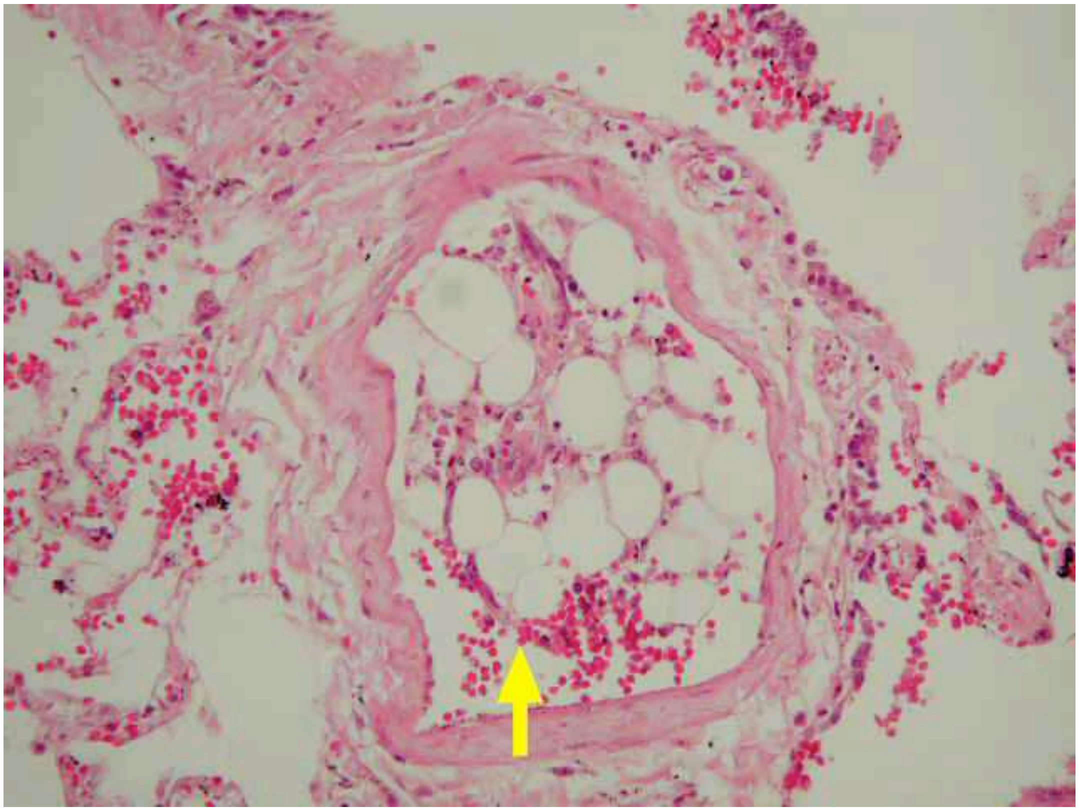


Fig. 224. This is a photomicrograph of a microscopic section of lung from a patient with the fat embolism syndrome (FES). The picture presented is the same as that shown in Fig. 223. The arrow points to the lumen of a small vessel containing fibrinoid material and optically empty spaces. The optically empty spaces are due to the dissolved fat (lipid) material, which occurs during the staining process. FES occurs when embolic fat macro globules pass into the small vessels of the lung and other sites, producing endothelial damage and resulting in respiratory failure, cerebral dysfunction and a petechial rash. (balifreelancewebdesigner.blogspot.com)

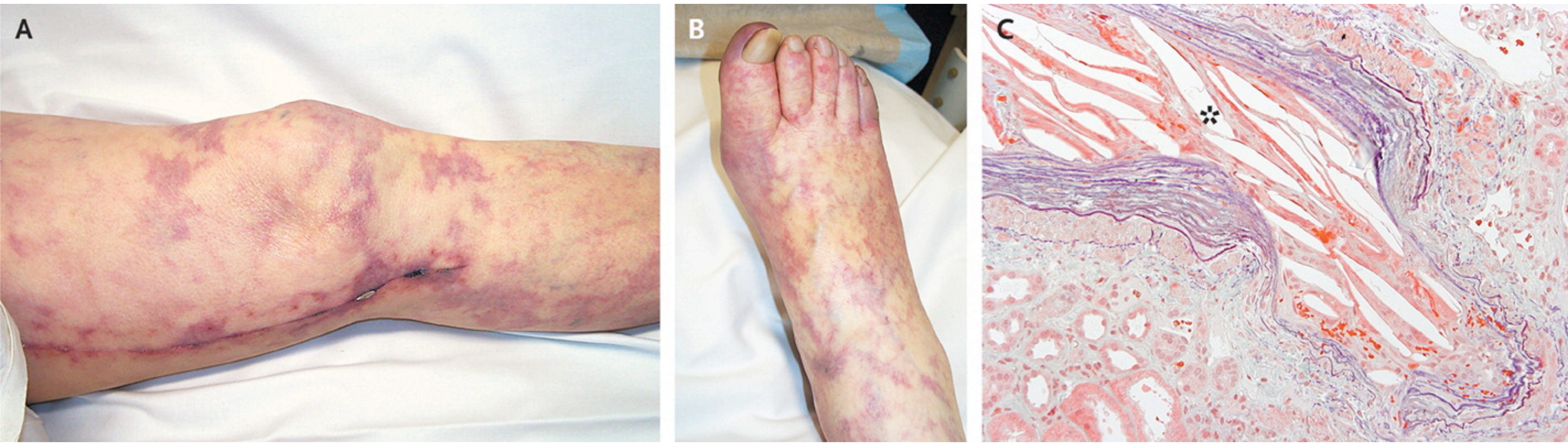


Fig. 225. These images show the diffuse petechial-like rash involving the left lower extremity (A) and the right foot (B) in a patient with FES. (C) shows a small vessel within the lung filled with a fat embolus with multiple optically clear spaces (✡) and fibrinoid material. (wheelessonline.com)

This syndrome manifests more frequently in **closed fractures** of the pelvis and long bones. The petechial rash, which usually resolves in 5-7 days, is said to be pathognomonic for the syndrome, but only occurs in 20-50% of cases. The risk of FES is thought to be reduced by early immobilization of fractures and especially by early operative correction. There is also some evidence that steroid prophylaxis of high risk patients reduces the incidence. The mortality rate of FES is approximately 10-20%.

Atelectasis and pneumonia can also occur from immobilization (Figs. 226, 227, 228 229 & 230). Infections due to open wounds that occurred during the initial injury can also occur, as well as surgical and pin site infections.

Other delayed complications are chronic low backache due to opening out of the sacroiliac joints, sexual dysfunction, impotence, dyspareunia and malunion and non-union of the surgically treated fracture site.

Fig. 226. This image is a plane x-ray showing atelectasis of the right lung. Atelectasis is defined as the collapse or closure of the lung resulting in reduced or absent gas exchange. It may affect part or all of one lung as in this case. It is a condition in which the alveoli are deflated, as distinct from pulmonary consolidation. (Wiki)

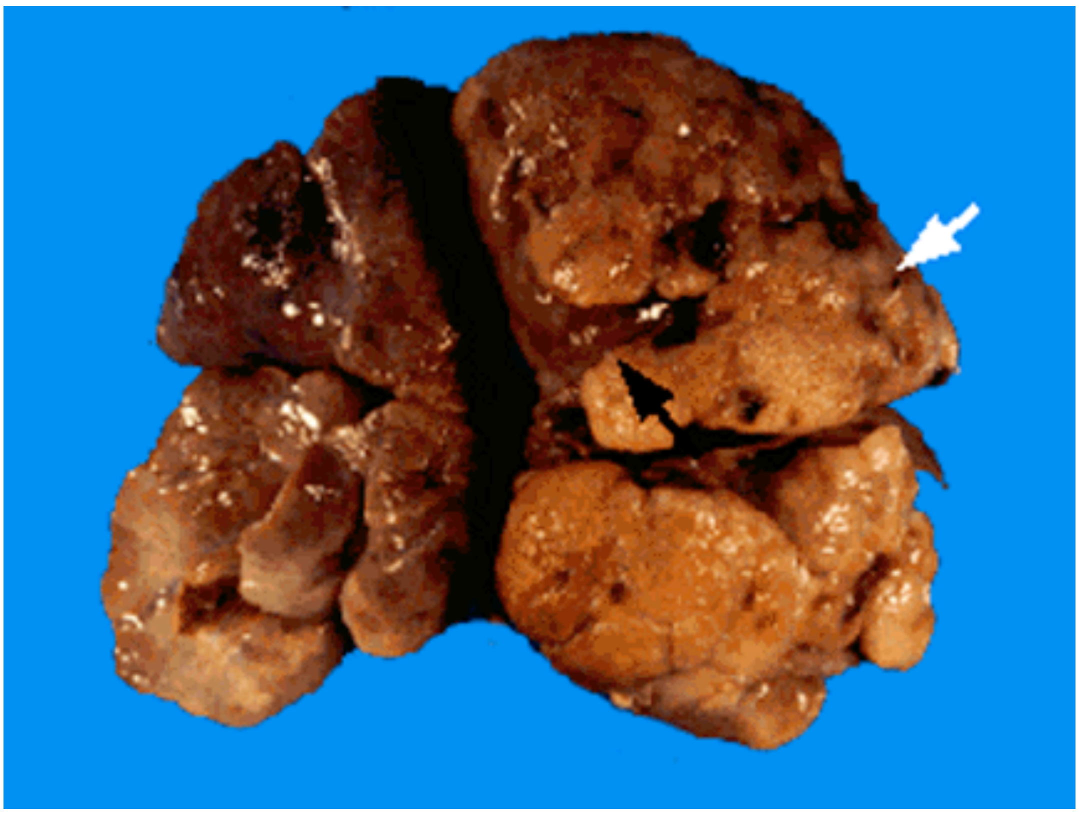


Fig. 227. This image is a autopsy photograph of a lung with areas of atelectasis. The hyperinflated regions are tan (white arrow). The atelectatic regions are deep pink gray and seem to be depressed relative to the tan regions (black arrow). (radiology.uchc.edu)

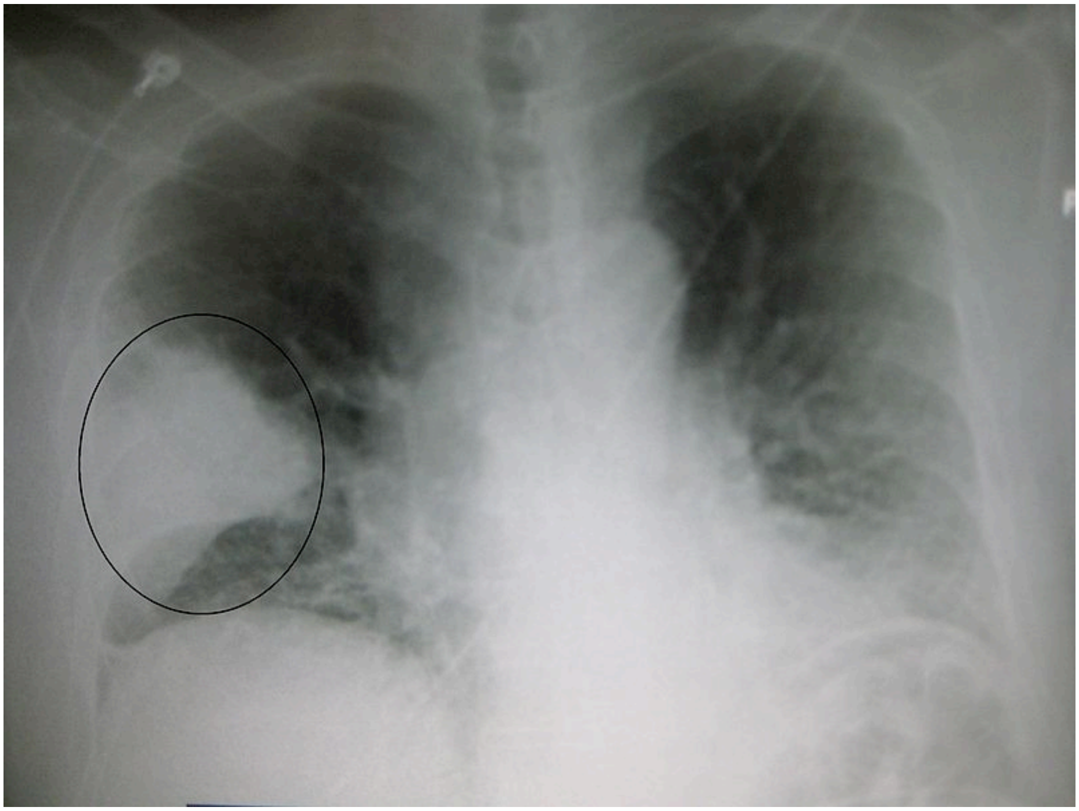


Fig. 228. This image is a plane chest x-ray showing a very prominent wedge-shaped bacterial pneumonia in the right lung. (Wiki)

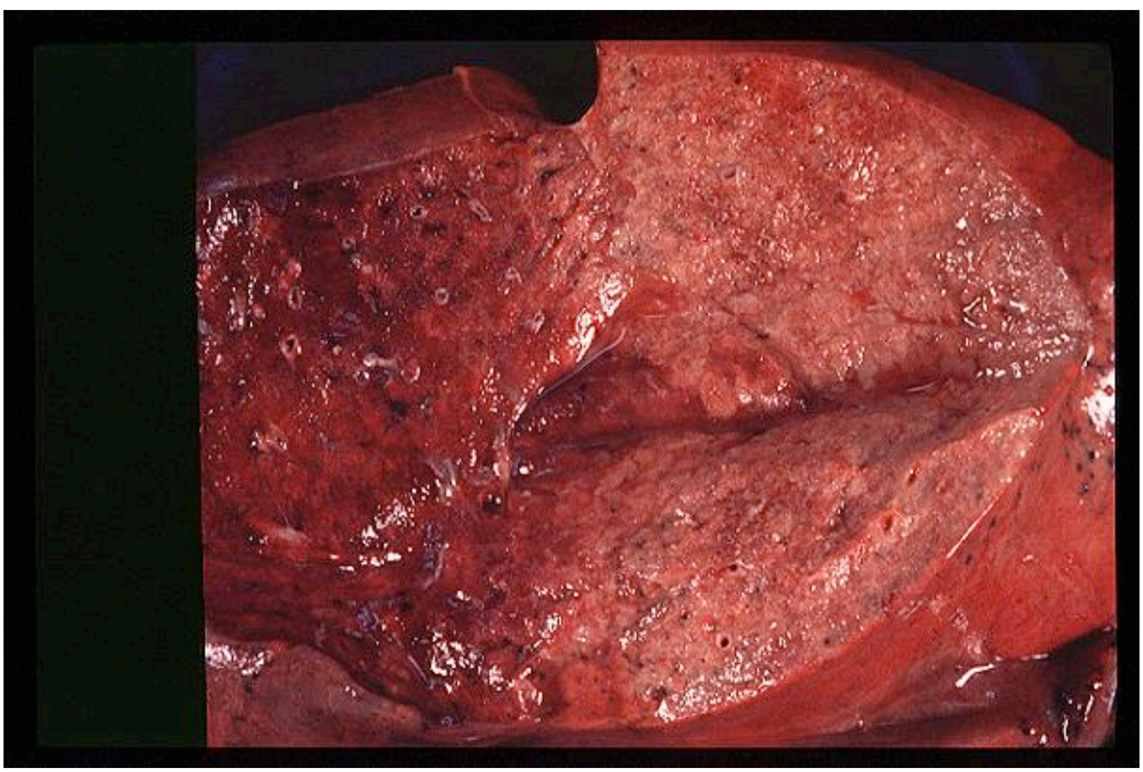


Fig. 229. The above is an autopsy photograph of a lung involved with lobar pneumonia, which is represented by the somewhat sharp demarcation of the pneumonic process on the right and the normal appearing congested lung on the left. (pathguy.com)

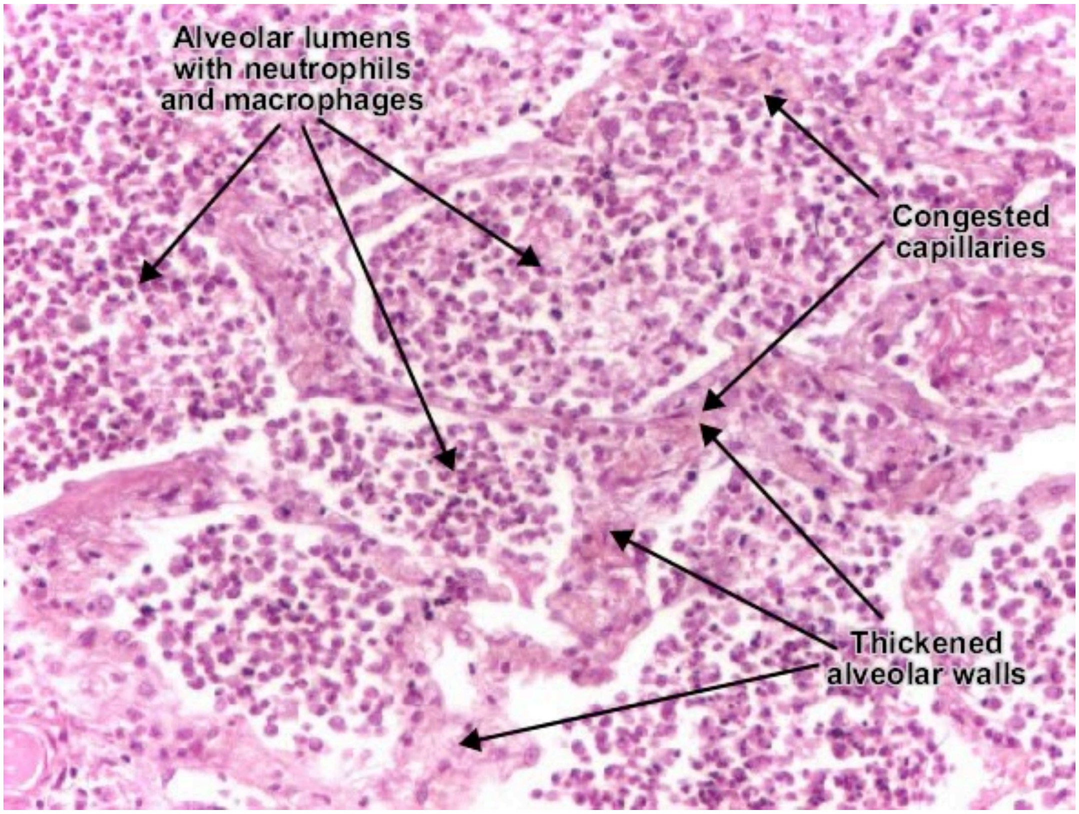


Fig. 230. This is a photomicrograph of a lung involved with an acute pneumonic process. (mdblogger.com)

Mortality and Morbidity of Pelvic Fractures: Trunkey *et al.* showed that more severe pelvic fracture patterns are associated with a greater number and severity of associated injuries. The common determinant of injury severity and morbidity was the instability of the pelvic fracture, but most of the deaths were caused by associated injuries and were not due to pelvic fracture, regardless of its severity. What has been noted in the various studies analyzing morbidity and mortality is that pelvic fractures that involve multiple areas of the pelvis and especially those with greater amounts of displacement of the fractures are associated with more severe injuries to other areas of the body. These more complex fractures are more likely to be mechanically unstable. With the highest correlate of injury severity being the presence of pelvic instability. Loss of stability by disruption of the strong posterior elements of the pelvic arch requires the transmission of major forces to the pelvis, this is associated with the delivery of similar forces to other areas of the body, especially the head, chest, and abdomen. The severity of injuries to these areas determines the outcome from injury in most patients.

Massive hemorrhage from the pelvis usually originates from main arteries. However, such injuries are uncommon and typically are seen with open pelvic fractures. Most pelvic hematomas are due to pelvic hemorrhage from cancellous bone, veins and the surrounding soft tissue.

Over 50% of all pelvic fractures occur as a result of minimal-to-moderate trauma, such as a fall from a standing position. Of these, 95% are minor. Most of these pelvic fractures are relatively straight forward and require no specific treatment other than bed rest and analgesics. These fractures are usually caused by low-intensity forces and are associated with few and relatively minor injuries to other anatomic areas. On the other hand, larger forces from high speed motor vehicular accidents or crushing injuries result in increased pelvic fracture complexity, which is correlated with an increased risk of complications and a greater probability of more severe associated injuries.

Mortality rates for **closed pelvic fractures** range from 3-25% and for **open fractures** range as high as 50%. Hemorrhage is the leading cause of death with increased mortality associated with systolic BP < 90 on presentation, age > 60 years, increases in Injury Severity Score and the need for transfusion of greater than 4 units. Typically, elderly patients with pelvic fractures have a worse outcome than younger patients. Ultimately, the patient's Injury Severity Score, not the nature of the pelvic fracture, best determines the mortality rate.

The **Injury Severity Score (ISS)** is an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury is assigned an **Abbreviated Injury Score (AIS)** of 1 to 6 with 1 being minor, 2 moderate, 3 serious, 4 severe, 5 critical and 6 a non-survivable injury. This scale represents the 'threat to life' associated with an injury and is not meant to represent a comprehensive measure of severity. Each injury is assigned an AIS and is allocated to one of six body regions (head, face, chest , abdomen, extremities including the pelvis and external). Only the highest AIS in each region is used. To calculate an ISS, take the highest AIS severity code in each of the three most severely injured ISS body regions, square each AIS code and add the three squared numbers for an ISS ($ISS = A^2 + B^2 + C^2$, where A, B, and C are the AIS scores of the three most injured body regions). An example of the ISS calculation is as follows:

Region	Injury Description	AIS	Square of Top 3
Head & Neck	Cerebral Contusion	3	9
Face	No Injury	0	
Chest	Flail Chest	4	16
Abdomen	Minor Contusion of Liver	2	
	Complex Rupture of Spleen	5	25
Extremity	Fractured Femur	3	9
External	No Injury	0	
	Injury Severity Score:		**50**

The ISS takes values from 0 to 75. If an injury is assigned an AIS of 6 (unsurvivable injury), the ISS is automatically assigned to 75. The ISS is virtually the only anatomically scoring system in use and correlates linearly with mortality, morbidity, and the length of the hospital stay. A major trauma is defined as an ISS greater than 15.

The weakness of the ISS is that any error in the AIS increases the ISS error, many different injury patterns can yield the same ISS, and injuries to different body regions are not weighted.

Hemorrhage, either pelvic or extra-pelvic, or associated severe head injury are the most common causes of early death, whereas multisystem organ failure and sepsis resulting from soft tissue infection near the fracture site are the main causes of delayed death.

The complication rate associated with pelvic fractures is significant and is related to injury of underlying organs and bleeding. Due to the tremendous force necessary to cause unstable pelvic fractures, concomitant severe injuries are common and are associated with high morbidity and mortality.

Pediatric Pelvic Fractures: Fractures of the pelvis in children are unusual accounting for 1-2% of fractures in children. The most frequent pattern of fractures are those without displacement of the pelvic or iliac ring.

Mechanism of Injury: The pelvis in children differs from that in adults in that their bones are more malleable, their joints have greater elasticity and their cartilaginous structures have greater ability to absorb energy. The elasticity of the joints of the pelvis is substantive, which allows for greater displacement with the application of force thus, often only one area of the pelvic ring is fractured rather than the usual double break in the pelvic ring of adults. Another important point to keep in mind is the cartilage at the apophyses (an apophysis is a normal developmental outgrowth of a bone, which arises from a separate ossification center, and fuses to the bone later in development. An apophysis usually does not form a direct articulation with another bone at a joint, but often forms an important insertion point for a tendon or ligament) is inherently weak compared with bone, so avulsion fractures occur more frequently in children and adolescents then in adults. The apophysis cartilaginous tissue ossifies and turns into bone when skeletal maturity is reached in the adolescent (Fig. 231). During growth spurts apophyses are vulnerable to traction injury (avulsion fractures) (Fig. 232). The most frequent site for avulsion fractures in the child is the tibial tubercle.

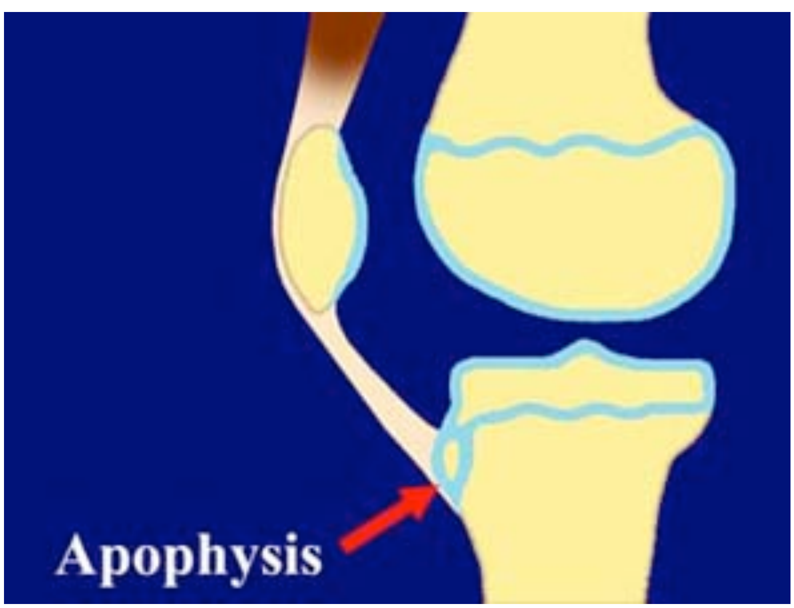


Fig. 231. The above drawing depicts the apophysis of the tibial tubercle. (blog.naver.com)

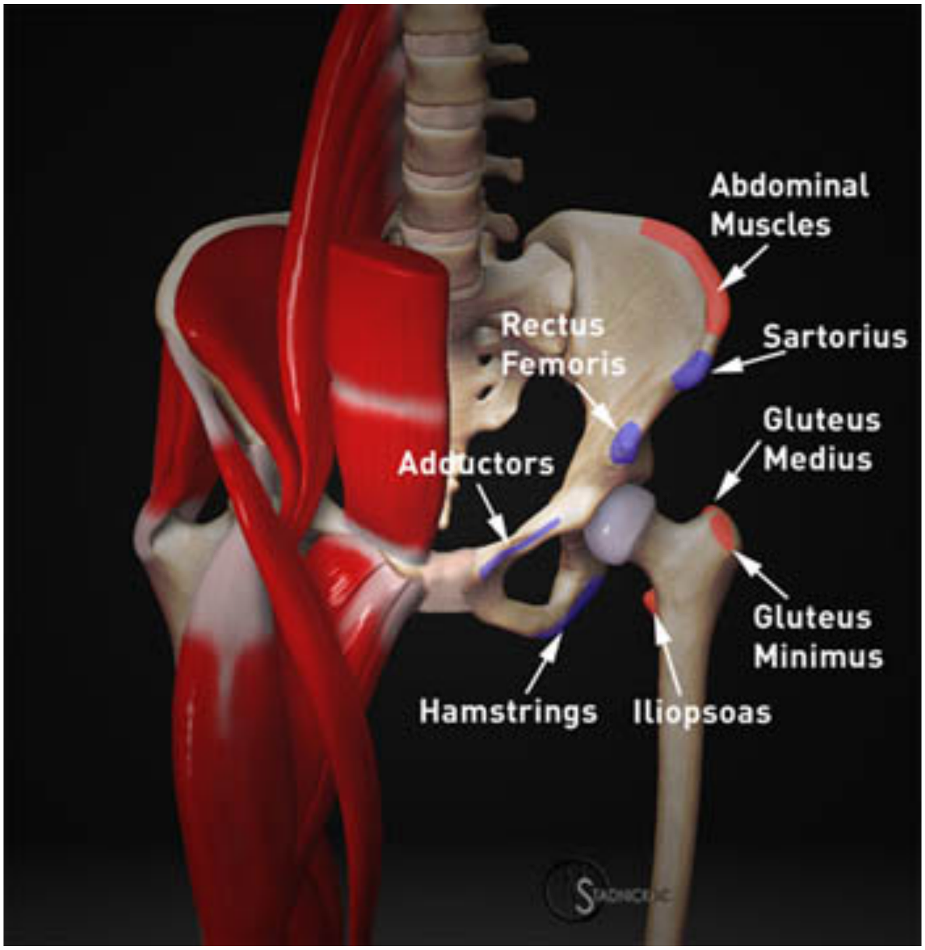


Fig. 232. This is a 3-dimensional model of the pelvis showing the most common sites of apophyseal avulsion injury in the adolescent, which are depicted in blue. Less common sites of apophyseal avulsion are indicated in red. Illustration courtesy of Michael E. Stadnick, M.D. (radsource.us)

Another area that the developing child is prone to show fractures is in the **triradiate cartilage**, which can cause growth arrest, leading to leg length inequality and faulty development of the acetabulum. The triradiate cartilage is the Y-shaped growth plate occurring within the base of the cup-like acetabulum of the pelvis (Fig. 233). This Y-shaped growth plate separates the three pelvic bones - the ilium, pubis, and ischium that form the acetabulum. These three bones typically fuse between 14-16 years of age. Whether the triradiate cartilage is not fused (open triradiate cartilage) as in immature hips or fused (closed triradiate cartilage) as in mature hips, effects the types of pelvic fractures which occur.

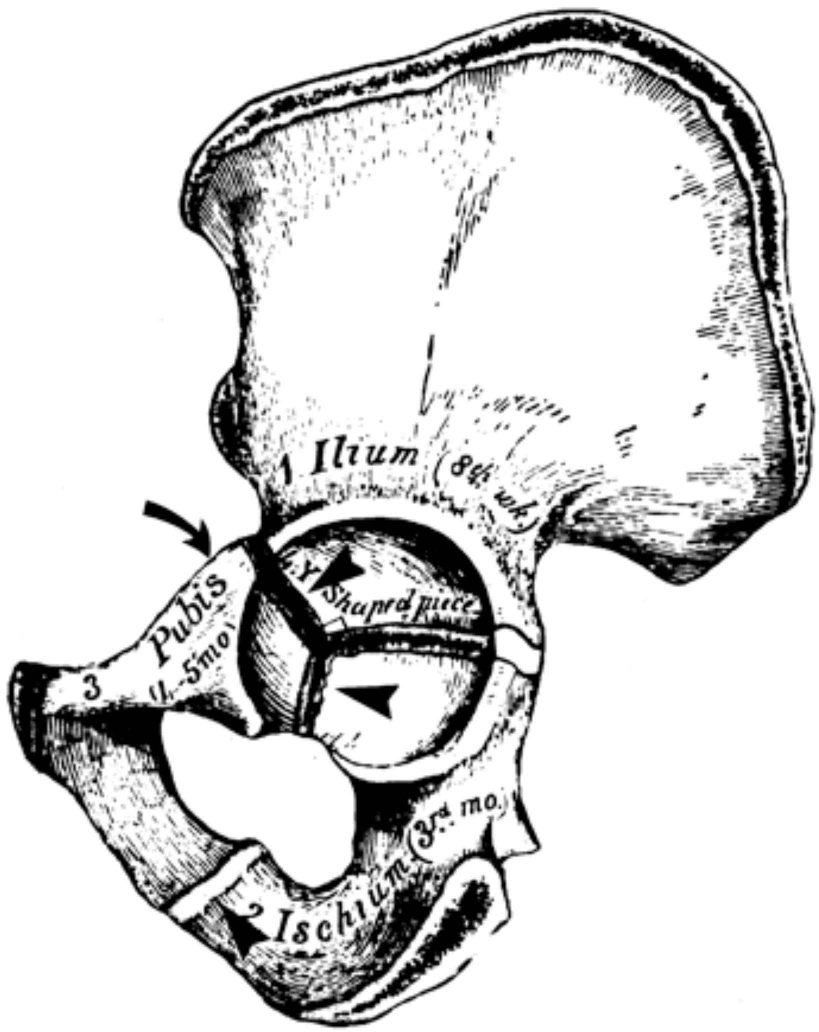


Fig. 232. This is a schematic representation shows the triradiate cartilage at the base of the acetabular cup. (ajronline.org)

In children and adolescents with open triradiate cartilage, pelvic fractures typically isolated pubic rami and iliac wing fractures. However, those with a closed triradiate cartilage, pelvic fractures are often represented by acetabular fractures and pubic or sacroiliac diastasis (Fig. 233).

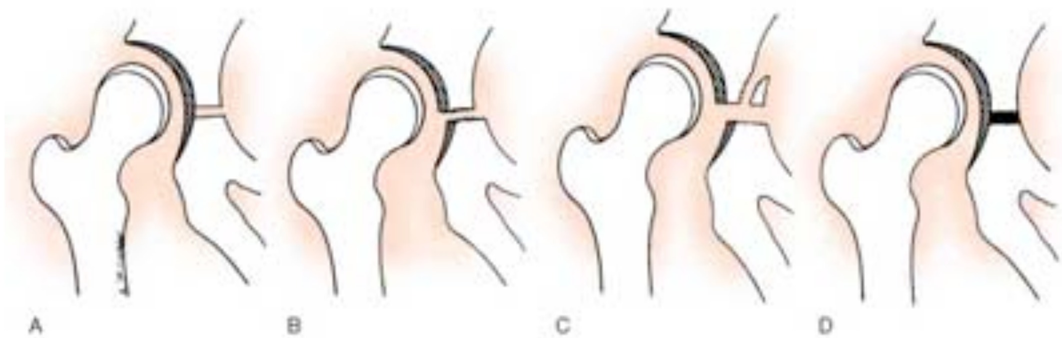


Fig. 233. This illustration shows the types of triradiate cartilage injury in a child. A, normal hemipelvis; B, Salter-Harris type I fracture; C, Salter-Harris type II fracture; and D, Salter-Harris type V fracture. The Salter-Harris fractures are classified based on the extent of fracture involvement through the physis, metaphysis, and/or epiphysis. (ombroecotovelo.net)

Pediatric pelvic fractures are typically associated with high energy trauma, such as children struck by moving vehicles. Associated injuries include the skull, cervical, facial, and long bone fractures; subdural hematomas, cerebral contusions, and concussions; lung contusions; hemothorax; hemopneumothorax; ruptured diaphragm and lacerations of the spleen, liver, and kidney. Injuries that may be associated with and near to pelvic fractures include injury to major blood vessels, retroperitoneal bleeding, rectal tears, and rupture or laceration of the urethra or bladder. In a study conducted by Bond and colleagues, they noted that the location and number of pelvic fractures were strongly associated with the probability of abdominal injury. For example, 1% of isolated pubic fractures had evidence of abdominal injury, 15% of iliac or sacral fractures were associated with abdominal injury, and 60% of those with multiple fractures of the pelvic ring had abdominal injury. These associated injuries account for a mortality of 9-18%. In a study by Rieger and Brug, they noted that 87% of major pelvic fractures were associated with pelvic or extra-pelvic soft tissue injuries; of these 14.8% died. What is evident from these studies and those of Demetriades *et al.* and Silber and Flynn, the death rate from pelvic fractures is quite low in the range of 0-2%, with the underlying causation being pelvic fracture associated hemorrhage. Having said that, massive blood loss in children occurs most commonly from solid viscera injury rather than pelvic vascular disruption. There are numerous classification systems for pelvic fractures in children. Torode &

Zieg developed a four-part classification of pelvic fractures: type I, avulsion of the elements of the pelvis; type II, iliac wing fractures; type III, simple wing fractures, including fractures involving the pubic rami or disruptions of the pubic symphysis; and type IV, ring disruption fractures, which create an unstable segment of the pelvic ring including bilateral pubic rami (straddle) fractures, fractures involving the right or left pubic rami or the pubic symphysis and a fracture through the posterior elements or disruption of the sacroiliac joint, and fractures involving the anterior structures and acetabular portion of the pelvic ring (Fig. 234). This classification system does not include acetabular fractures.

Acetablular fractures in children and adolescents are very rare. These fractures are typically classified according to Letournel and Judet (1981) (Figs 235 & 236), with additional classification of triradiated cartilage fractures (Salter and Harris 1963) (Fig. 233). An important point in understanding Letournel and Judet's classification of acetabular fractures is the idea of what makes up the acetabular columns (Fig. 236). They are bone massifs, one anterior, which extends from the anterior portion of the iliac crests to the pubic symphysis, and a posterior massif that contains the ischium, extending up to the angle of the greater sciatic notch. Another important concept is that Judet and Letournel classified fractures as simple or elementary, and complex or associated (Fig. 235). Simple fractures owe their name to the fact that they have only two fragments, while complex fractures present more than two fragments. This classification does not cover all the possible types of fracture, as there are transitional forms between the types described that are not as common (Fig. 237). A point to remember is that acetabular fractures in children differ from those in adults in that they can be caused by trivial trauma.

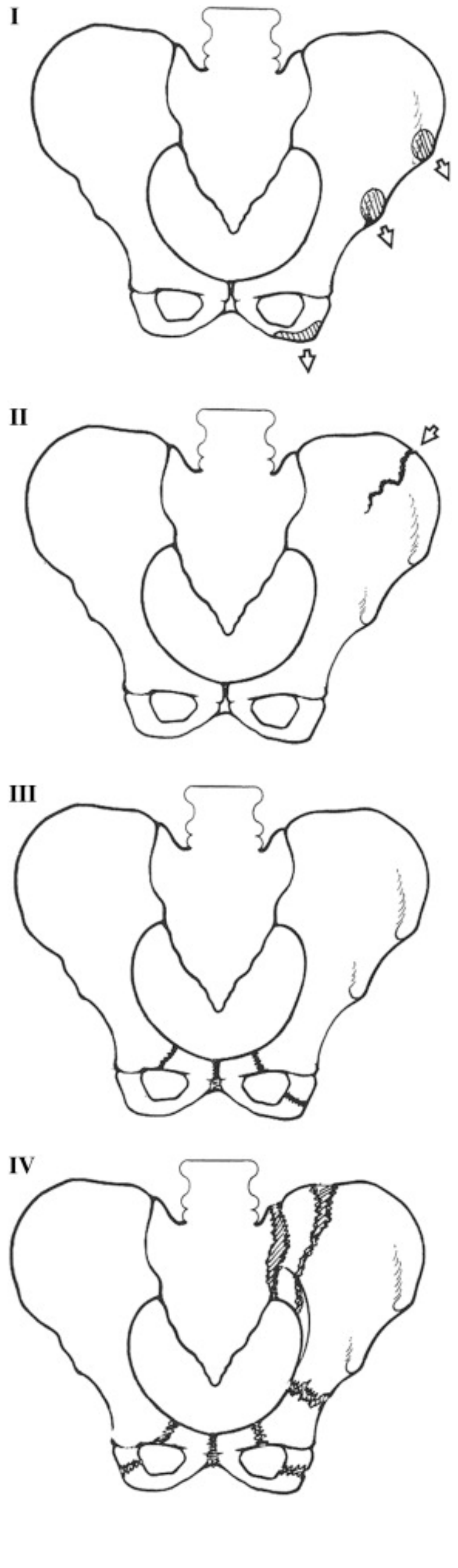

I
II
III
IV

Fig. 234. The above illustration shows the four types of pelvic fractures in children according to Torode and Zieg. Type I - avulsion fractures of the boney elements of the pelvis; Type II - iliac wing fractures; Type III - simple ring fractures, including those involving the pubic ramus or disruptions of the pubic symphysis; and Type IV - ring disruption fractures. (ombroecotovelo.net)

Table 1. *Classification of acetabular fractures according to Judet and Letounnel.*[4,5,7]

Elementary fractures	Associated fractures
Posterior wall	T-shaped
Anterior wall	Posterior wall and posterior column
Posterior column	Posterior wall and transverse
Anterior column	Posterior hemitransverse and anterior column
Transverse	Two-column

Fig. 235. This table is a basic representation of the acetabular fractures according to Judet and Letournel. Fig. 237 shows what these fractures look like. (scielo.br)

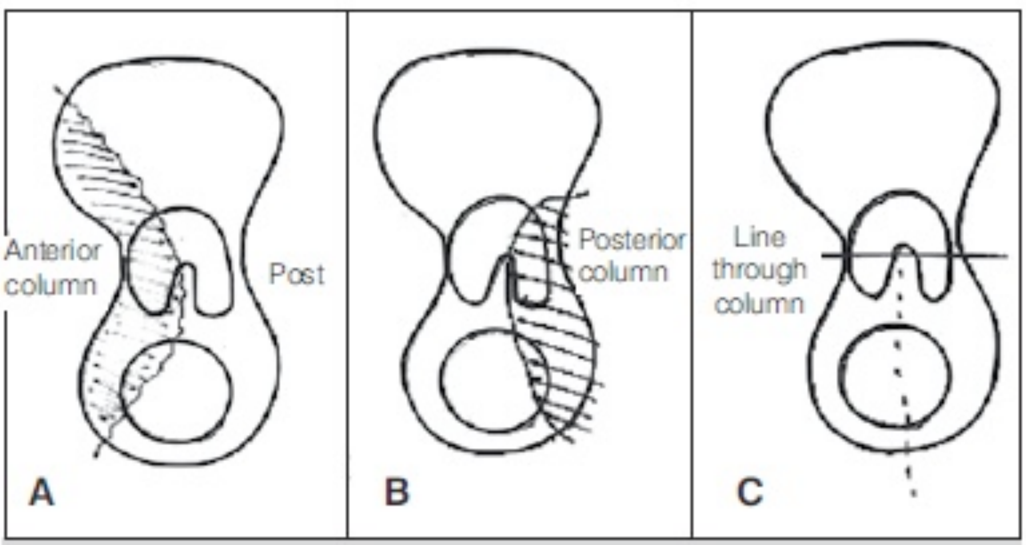


Figure 4. *Drawings representing acetabular fractures. (A) Anterior column, (B) Posterior column, (C) T-shaped.*

Fig. 236. This image depicts what makes up the acetabular columns or bone massifs. (scielo.br)

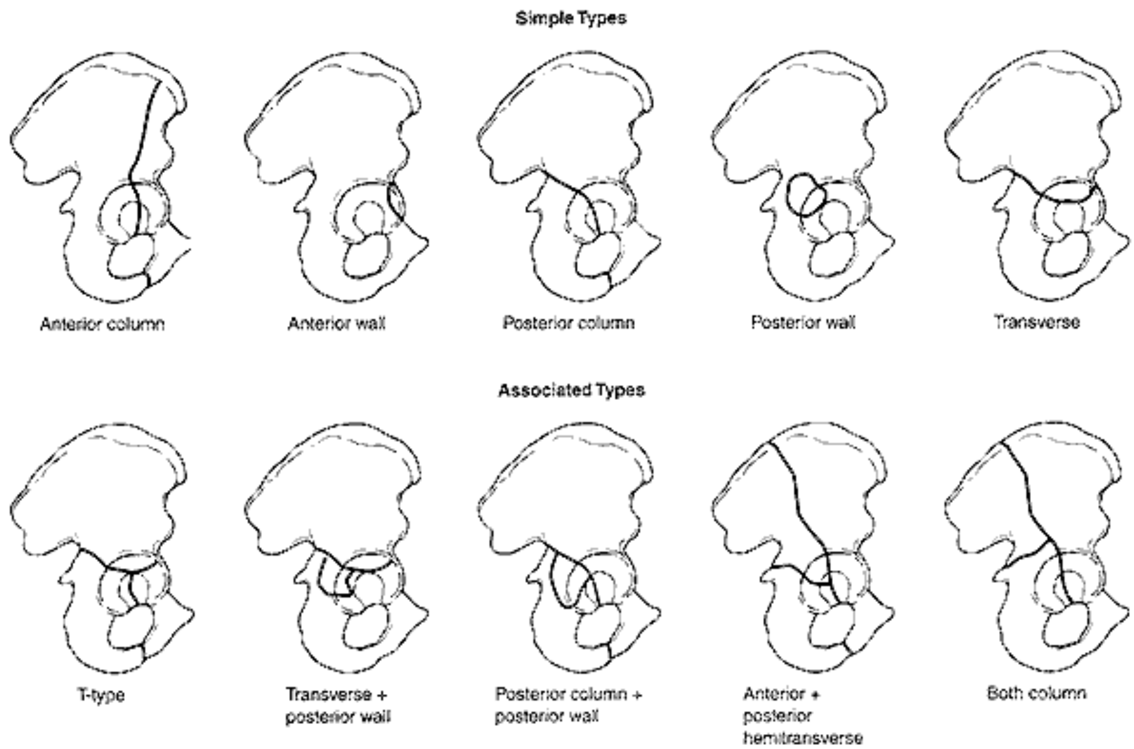


Fig. 237. This image depicts the classification of fractures of the acetabulum according to Judet and Letournell. (scielo.br)

There are other classification systems for pediatric pelvic fractures. Quinly and Rang's classification system for pelvic fractures has three categories: uncomplicated fractures; fractures with visceral injuries requiring surgical exploration; and fractures associated with acute massive hemorrhage. Their classification system emphasizes associated soft-tissue injuries, rather than the pelvic fracture itself. Young-Burgess classification system (Fig. 215, p 245-248) can also be used to categorize pediatric pelvic fractures. If you remember, this system classifies pelvic fractures according to the direction of force: lateral compression, anteroposterior compression, vertical shear, and combined mechanisms. As also discussed above, the Tile classification system (Fig. 211, p 242-245) can be applied to pediatric pelvic fractures. There is another classification system for pelvic fractures, Conwell's classification, which is based on the number of fractures in the pelvic ring. This system includes acetabular fractures and is applicable to adults and children.

In analyzing all of these classification systems, the most useful information is whether a fracture is stable or unstable. Most pelvic fractures in children are stable.

Avulsion fractures were briefly discussed on page 265 and in Figs. 203 and 231. To reiterate, avulsion fractures occur most commonly in adolescent athletes, usually boys, typically occurring in those sports requiring sudden, explosive bursts of speed. Large muscles contract and create force greater than the strength of the attachment of the muscle to the apophysis. The most common sites of avulsion fractures (and muscles that attach there) are the iliac crests (abdominal muscles), anterior superior iliac spine (sartorius), anterior inferior iliac spine (rectus femoris), lesser femoral trochanter (iliopsoas), and ischial tuberosities (hamstrings). In one series 13% of pelvic fractures occurring in adolescent athletes were avulsion fractures.

There are three physical signs commonly associated with pelvic fractures the knowledge of which can help the forensic pathologist during their external exam: (1) Destot sign, which is a large superficial hematoma beneath the inguinal ligament, upper thigh (Morel-Lavalle lesion), perineum and the scrotum (Fig. 238); (2) Roux sign, a decrease in the distance of the greater trochanter to the pubic spine on the affected side in lateral compression fractures; and (3) Earle sign, a bony prominence or large hematoma and tenderness (living patient) on rectal examination, indicating a significant pelvic fracture.

Fig. 238. The above is an illustration of a patient with Destot sign. When such a hematoma occurs in the upper thigh it is also referred to as Morel-Lavalle lesion. It is frequently associated with acetabular fractures and other pelvic trauma. (crashingpatient.com)

Although uncommon, a child may also experience sacral and coccyx fracture dislocations (Fig. 239).

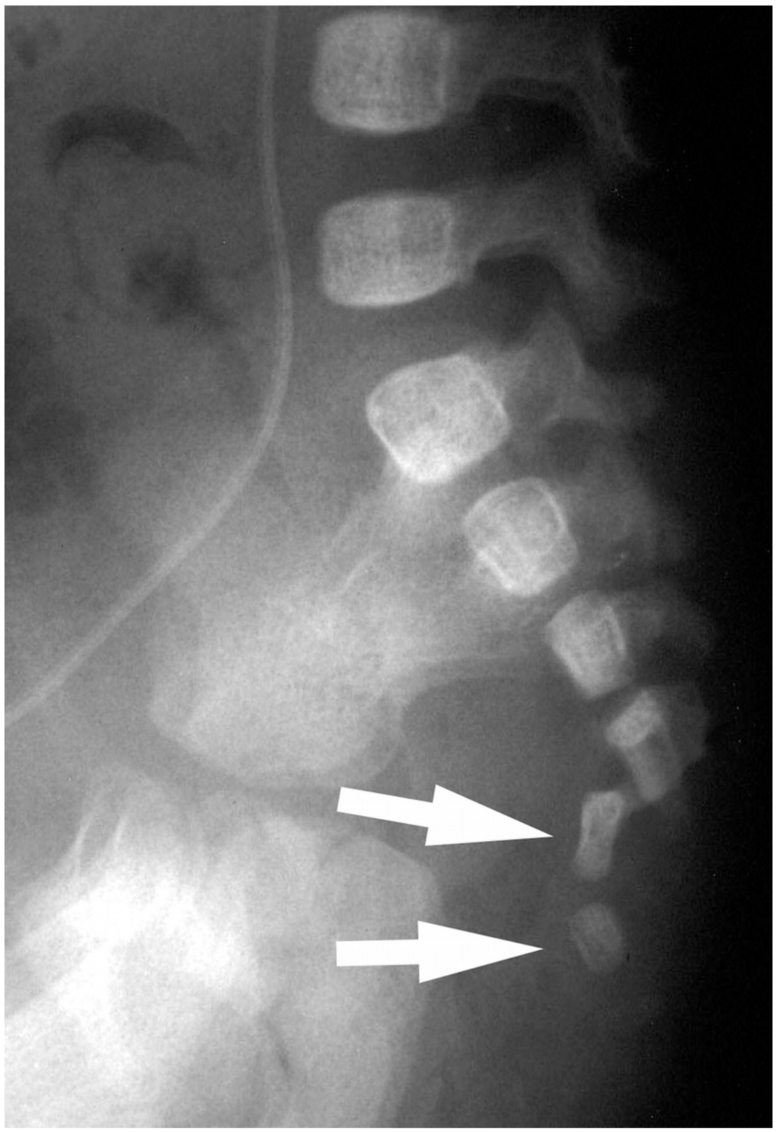


Fig. 239. This is an image of a sacral and coccyx fracture dislocation in an abused 2-month-old girl. Lateral radiograph depicts a fracture between the fourth and fifth vertebrae, through the intervertebral disk space. The fifth sacral vertebra and coccyx (arrows) are anteriorly displaced. The injury was originally explained as resulting from a

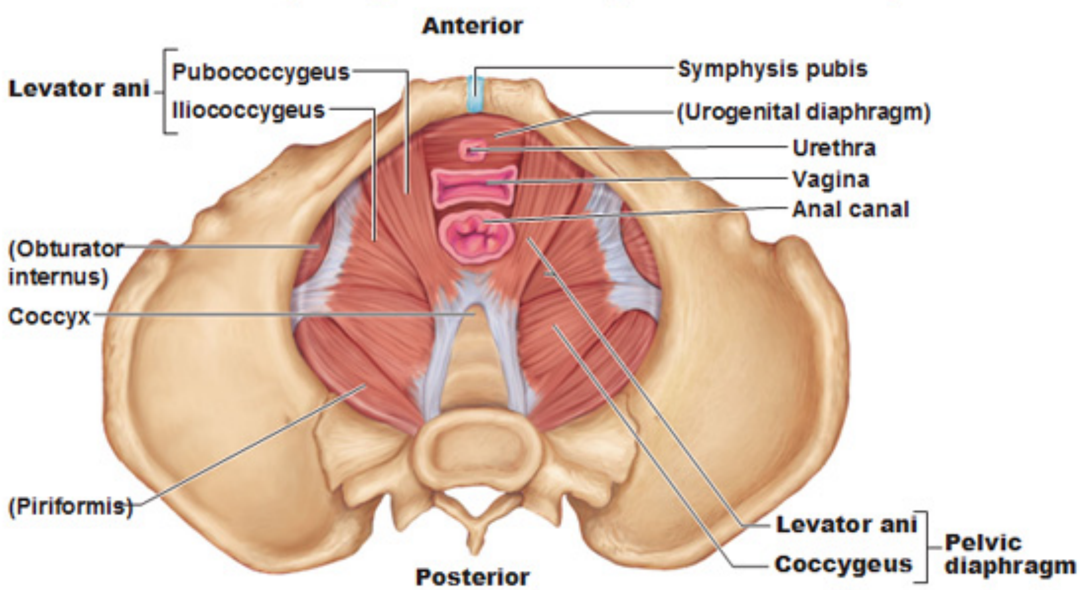
changing table fall; the mother's boyfriend later confessed to slamming the child down in a sitting position. (radiographics.rsna.org)

Mortality and Morbidity of Pediatric Pelvic Fractures: Overall mortality in those children with pelvic fractures with associated injuries varies between 8-18%. Traumatic brain injury (TBI) in such poly trauma patients was the first cause of death followed by pelvic fractures, which occur in approximately 1% of all patients with blunt force traumatic injury. The overall mortality for patients with pelvic fractures including those with associated traumatic lesions is 3.5-5%, with the most common underlying causation being hemodynamic instability. In one series the associated lesions were neurological in 80%; musculoskeletal 73%; thoracoabdominal 35%; and genitourinary 9%. As previously pointed out the mortality rate from pelvic fractures alone varies between 0-2.3% depending on the series reviewed.

B. Pelvic Floor

To reiterate the pelvic floor (pelvic diaphragm) is composed of muscle fibers of the **levator ani, the coccygeus,** and the **associated connective tissue,** which span the area beneath the pelvis (Figs. 47 & 48, p 55 & 56 & Fig. 240).

The Pelvic Diaphragm = the deepest muscle layer



Superior View of Female Pelvis

Fig. 240. The above illustration is a superior view of the female pelvis (looking downward from inside the abdominal and pelvic cavity) depicting the muscles of the pelvic diaphragm. (antranik.org)

Although the terms “pelvic floor” and “pelvic diaphragm” are used interchangeably, some sources believe the “diaphragm” consist only of the levator ani and coccygeus muscles, while the “floor” also, includes the **perineal membrane and deep perineal pouch**.

During the course of **pregnancy or childbirth** the levator ani muscles or their supplying nerves can be damaged. Childbirth often leads to pelvic floor dysfunction, most especially if the pelvic floor has sustained a traumatic injury during delivery, which was not treated appropriately. For example, third and fourth degree perineal lacerations and forceps extraction can lead to pelvic organ prolapse, such as the vagina, bladder, rectum, or uterus protrude into or outside the vagina (Figs. 241, 242, 243, 244 & 245). Similar prolapses can be the result of vaginal delivery. Even a cesarean section does not ensure that pelvic floor dysfunction can be avoided. There is also some evidence that the musculature of the pelvic floor can be injured during a hysterectomy. In addition, pelvic surgery involving the perineal approach can cause injury to the pelvic floor, including a coccygectomy.

Fig. 241. Complete vaginal prolapse. (2womenshealth.com)

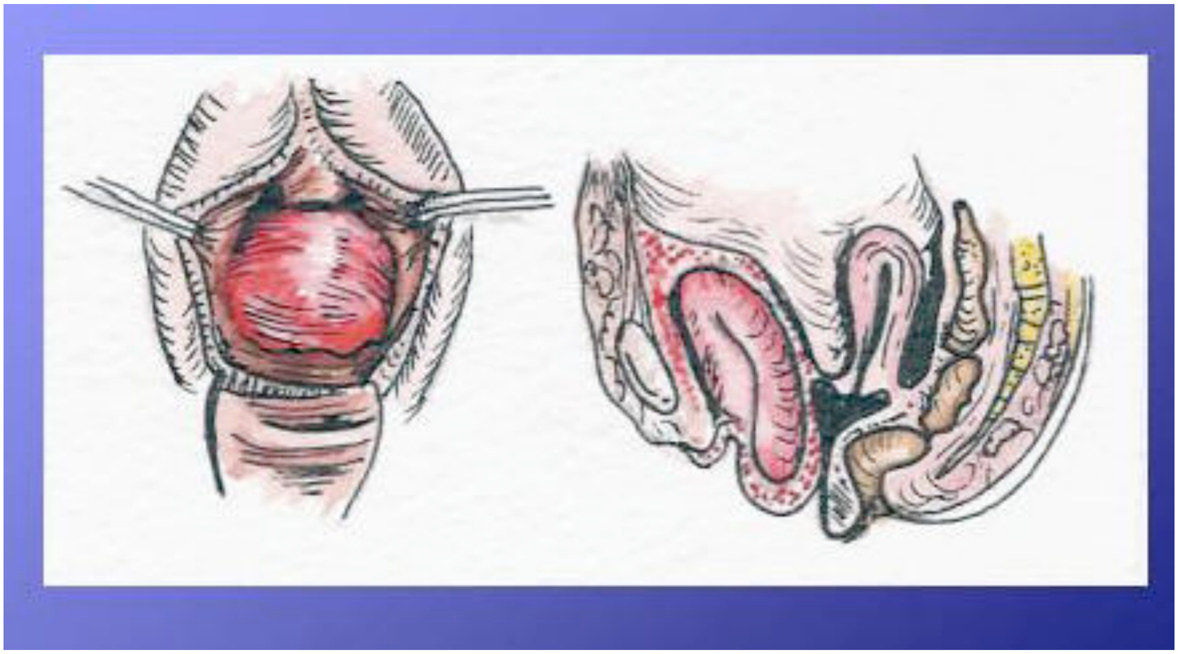


Fig. 242. This is an illustration of a bladder prolapse. (2womenshealth.com)

Fig. 243. This image is of a full-thickness rectal prolapse. (emedicinehealth.com)

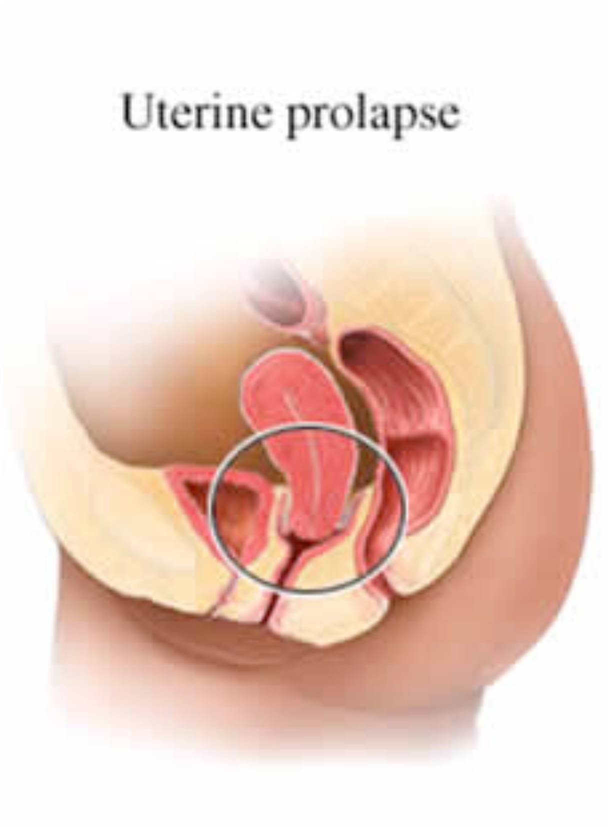


Fig. 244. This is an illustration of a uterine prolapse into the vaginal. (Wiki)

Fig. 245. The above is an image of a patient with a uterine prolapse and a suprapubic scar. (ttmed.com)

Those female athletes who participate in water-skiing, bicycle racing, and equestrian sports can experience perineal trauma. Although we tend to view pelvic floor dysfunction as primarily a female issue, pelvic floor dysfunction in males is much more common than once believed. The leading causes of male pelvic floor dysfunction include trauma, surgery, poor posture, heavy weightlifting combined with straining of the pelvic floor, poor motor control, water-skiing, bicycle riding, equestrian sports and sitting on hard surfaces for prolonged periods. Trauma is typically associated with fractures, often due to motor vehicular accidents.

Repetitive minor trauma, such as, chronic cough, constipation and straining to void can lead to pelvic floor dysfunction as can chronic hip and back pain.

Disorders of the posterior pelvic floor can lead to rectal prolapse, rectocele, perineal hernia, anismus (contraction of the pelvic floor muscles instead of normal relaxation when a person strains to defecate thus causing constipation; also called pelvic floor dyssynergia).

Constipation occurs in approximately 15% of adults in the western world, and over half of these cases are related to pelvic floor dysfunction.

Pediatric Pelvic Floor Dysfunction is typically related to abnormalities in neurodevelopment. By the age of two years the child has control of sphincter and pelvic floor musculature due to the maturation of the descending pathways from the pontine micturition center and to a lesser extent from the frontal cortex.

Abnormalities in neurodevelopment can lead to genitourinary issues in the child. For example, children with Williams syndrome (Williams-Beuren snydrome) on a rare occasion can develop bladder prolapse (Fig. 246). Williams syndrome is a rare neurodevelopment disorder characterized by a distinctive, “elfin” facial appearance, along with a low nasal bridge, an unusually cheerful demeanor and ease with strangers; developmental delay coupled with strong language skills; and cardiovascular problems, such as supravalvular aortic stenosis and transient hypercalcemia. It is due to the deletion of about 26 genes from the long arm of chromosome 7. This syndrome was first identified by Dr. J. C. P. Williams of New Zealand.

Fig. 246. This image is of a child with Williams Syndrome who presented with bladder prolapse. (sciencedirect.com)

From a clinical perspective, 30-35% of children with enuresis have pelvic floor dysfunction.

C. Urinary System

1. Pelvic Portion of the Ureter: Although the anatomy of the ureter has been previously discussed, pages 65-70, I will give a brief summary. The ureters are peristaltic tubular structures that course from the kidney to the bladder in the retroperitoneal space. Anatomically the ureter is 22-30 cm in length, with the pelvic portion comprising 12.5 cm. It is divided into three portions: the proximal ureter (upper) is the segment that extends from the ureteropelvic junction to the area where the ureter crosses the sacroiliac joint; the middle ureter courses over the bony pelvis and iliac vessels; and the pelvic or distal ureter (lower), which extends from the iliac vessels to the bladder (Fig. 56, p 66).

Ureteral injuries due to trauma are rare as the ureter is well protected in the retroperitoneum by the bony pelvis, psoas muscles and vertebrae. The left ureteropelvic junction is posterior to the pancreas and ligament of Treitz. The inferior mesenteric artery and sigmoidal vessels cross in front of the left ureter in its inferior pole. On the right side, the ureter lies posterior to the duodenum and just lateral to inferior vena cava, with the right colic and ileocolic vessels crossing in front. Due to this protection, traumatic injuries to the ureters are typically accompanied by significant collateral damage with the resultant morbidity and mortality being determined by the management of the associated injuries. Most commonly, the ureter is injured in the **ovarian fossa** near the infundibulopelvic ligament and where the ureter courses posterior to the **uterine vessels**.

The **renal pelvis and ureter** have three major functions: absorption, dynamics, and tonus. Absorption is minimal and is unaffected by repair of traumatic injuries and its consequent functions. The dynamics refer to the synchronous and progressive contractile movement the ureter shows from the ureteropelvic junction to the ureter-vesicle orifice, which is produced by the intrinsic automaticity of the ureteral musculature. Tonus of the ureter is the degree of contraction that the ureteral wall assumes for a given rate and volume of urinary output. It is the tonus that initiates the **detrusor muscles** action of the urinary bladder at a certain volume thus, perpetuating the cyclical undulations. When the ureter is damaged by **penetrating trauma or blunt force trauma**, peristalis beyond the injury ceases. Tonus is decreased in the ureter, proximal to the injury, due to stretching from the increased volume of urine in this segment. This increased volume of urine is the result of detrusor action being halted at the damaged segment of the ureter.

Despite the protected anatomical position of the ureters they can sustain injuries from trauma, the most common of which are the result of **abdominopelvic surgery or ureteroscopy** (Fig. 247). The resulting intraoperative injuries include ligation, transection, electrocautery, and avulsion.

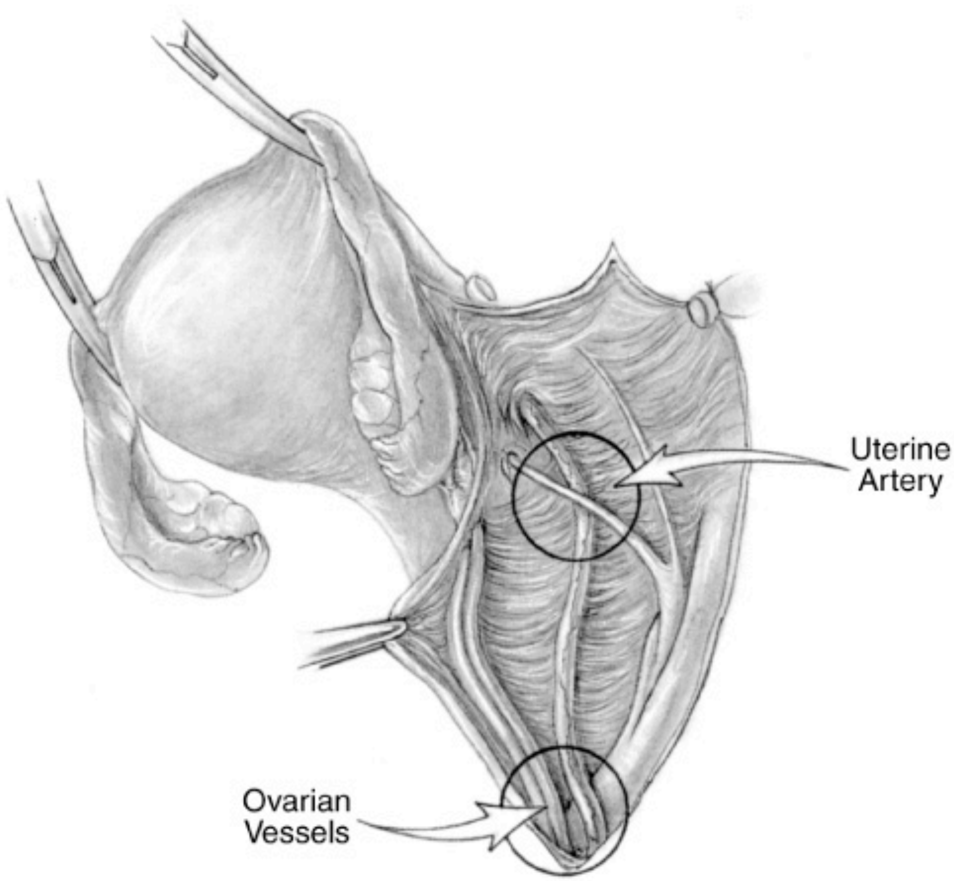


Fig. 247. This illustration shows the anatomic relationships of the uterine artery and ovarian vessels to the ureter. These relationships explain why the ureter is especially liable to injury during hysterectomy. (5minuteconsult.com)

The American Association for the Surgery of Trauma has classified ureteral injuries as follows:

Grade I : Hematoma; contusion or hematoma without devascularization

Grade II : Laceration; less than 50% transection

Grade III : Laceration; 50% or greater transection

Grade IV : Laceration; complete transection with less than 2 cm of devascularization

Grade V : Laceration; avulsion with greater than 2 cm of devascularization

Note: for bilateral lesions up to Grade III you advance one grade.

Traumatic injuries other than iatrogenic can be either **penetrating (i.e., gunshot or stab wounds) or due to blunt force**. When examining all penetrating and blunt force traumatic injuries, the ureter was damaged in less than 4% and 1% of cases, respectively. Also, the type of external traumatic injury matters; although fewer than 3% of gunshot wounds involve the ureters, they account for 91% of all penetrating injuries, with stab wounds and blunt trauma accounting for 5% and 4% respectively (Fig. 248).

Fig. 248. This image is a CT scan of a penetrating injury of the left ureter due to a shell fragment. (openi.nlm.nih.gov)

The relative predominance of ureteral injury associated with **gunshot wounds** is related to the mechanism of injury. Gunshot wounds affect the ureters in two ways: First, the missile can damage the ureter directly with varying degrees of severity causing a contusion through partial to complete transection as shown in Fig. 248. Such injury is due to the permanent cavity due to the trajectory of the missile. Secondly, the kinetic energy released by the missile causes a blast effect, which creates a temporary cavity, often 10-40 times the diameter of the permanent cavity. This blast effect may disrupt the intramural blood supply of the ureter, resulting in ureteral necrosis. Such ureteral necrosis may extend as far as 2 cm above and below the point of direct missile injury (Fig. 249).

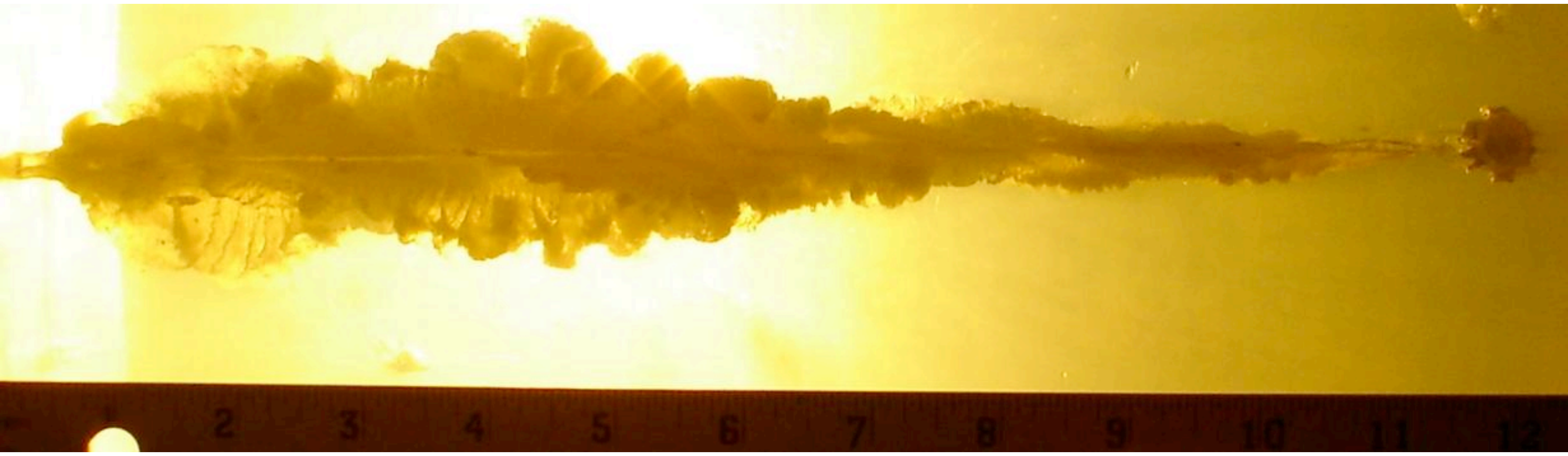


Fig. 249. This is a block of gelatin into which a missile has been fired to demonstrate the permanent cavity, shown as a horizontal yellow-orange straight line and the secondary (temporary) cavity, which represents the blast effect of the released kinetic energy of the missile. Remember, the degree of the released kinetic energy is determined by the square of the velocity of the missile hence, its greater diameter as compared to the permanent cavity of the missile path. (thegunforum.net)

Typically, most gunshot injuries are low velocity thus, the blast effect (temporary cavity) severity and size, which is determined by the square of the velocity of the missile, is much more localized. In contradistinction to this, the kinetic energy released by high velocity missiles, as demonstrated in Fig. 249, is such that there is extensive damage to the surrounding tissues due to the larger temporary cavity, which are 10-40 times larger than the permanent cavity.

Stab wound related injuries to the ureter are less common than penetrating gunshot wounds, 5% and 91% respectively. However, long-bladed knives or stab wounds posterior to the midaxillary line should always raise suspicion for possible ureteral involvement (Fig. 250).

Fig. 250. This radiograph shows the result of a stab wound to the flank, which resulted in the division of the right ureter, that was primarily surgically repaired over a small-bore stent. (radiographics.rsna.org)

When assessing penetrating trauma, the proximal ureter is injured at rate of 59.7% (± 37%), with the mid and distal ureters sustaining injuries at a rate of 25.6% (± 30.4%) and 20.8% (± 24.4%) respectively.

Blunt force trauma can cause ureteral injury through several mechanisms. Typically, they involve deceleration or acceleration mechanisms with sufficient force to disrupt the ureter from either the **ureteropelvic or urterovesical junctions**. Such injuries can result from a high speed motor vehicular collision, a fall from a significant height, or a direct blow to the region of the L2-3 vertebrae.

Usually, most traumatic injuries to the ureters involve males, 83.4% (± 28.5%), with an average of 23.2 years (± 12.1).

Associated injuries were present in 90.4% (± 26.2%) of patients. Small and/or large bowel injuries were most commonly involved in conjunction with external ureteral trauma (96% ± 21.5%).

Complications occurred in 36.2% (± 34%) of cases, including retroperitoneal abscesses, infected urinomas and fistulas. Missed ureteral injuries were reported in 38.2% (± 39.5%) of cases.

In one study the mortality rate was 17%, which included the associated injuries.

Iatrogenic Injuries

Gynecologic surgery: Approximately 52.82% of surgical ureteral injuries occur during gynecologic procedures with hysterectomy accounting for most of these cases. In-point-of-fact abdominal hysterectomies account for 1.3-2.2% of ureteral injuries with laparoscopic and vaginal hysterectomies accounting for 1.3% and 0.03% respectively. The injury typically occurs in the distal ureter around the infundibulopelvic or as the ureter crosses inferior to the uterine artery (Fig. 247), usually from blind clamping and ligature placement to control hemorrhage.

Colorectal surgery: Following gynecologic procedures, colorectal surgery is the next most common cause of iatrogenic ureteral injuries. The two most common colorectal surgeries causing ureteral injuries are **low anterior resection** and **abdominal perineal resection**, which together account for 67% of general surgical injuries. The **left ureter** is more commonly injured than the right.

Vascular surgery: The ureters are injured in 2-4% of vascular surgeries. Patients undergoing repeat aortoiliac surgery are at greatest risk for ureteral injury. Another complication of aortic vascular surgery is the development of aortoureteric or graft-ureteric fistula, which can cause substantive hemorrhage as hematuria.

Urologic procedures: These procedures account for 42% of all iatrogenic injuries. Endoscopic procedures account for 79% of injuries, while open surgery accounts for 21%, with most of the injuries occurring in the distal ureter (87%).

Additional iatrogenic causes: The ureters may be injured during spinal surgery for disc disease, vaginal surgery for pelvic prolapse, and appendectomy.

Mortality and Morbidity: The mortality and morbidity from ureteral injuries, as is true of lower genitourinary trauma in general, is typically due to associated injuries, especially **pelvic fractures.**

Pediatric Traumatic Ureteral Injuries: Injuries to the ureters are uncommon in children, accounting for less than 1% of all urologic trauma. The ureter is protected by its close approximation to the vertebral column and paraspinal muscles, and its course within the bony pelvis. It is also protected by the fact it is a small target and is inherently flexible and mobile. Although the ureters may be injured either from external trauma or surgical procedures (Figs. 251 & 252) in children most ureteral injuries are due to trauma, whereas in adults most ureteral injuries are due to surgical procedures. **In children most traumatic injuries to the ureter occur in the upper portion, usually involving the ureteropelvic junction**. **Disruption of the ureter from the renal pelvis is typically due to stretching of the ureter by sudden hyperextension of the trunk.** Trauma of the ureter should be suspected in children presenting with a **fracture of the transverse process of the lumbar vertebra**. Other **traumatic injuries associated with ureteral injuries are pelvic fractures, hip fractures, lower rib fractures, splenic and or liver lacerations and diaphragmatic rupture**.

Penetrating injuries may occur at any point along the length of the ureter with the most common being gunshot wounds, which account for 95% of all penetrating injuries. Up to 50% of children with gunshot wounds to the abdomen have injury to the ureters. Penetrating injuries to the ureter are associated with injuries to other intra-abdominal regions in up to 90% of cases.

Fig. 251. This image is a preoperative CT scan (transverse view) showing a right iliac wing fracture in a 11-year-old girl who also sustained a pelvic ring fracture, C1-1 in the Tile modified AO classification (Fig. 211, p 243). The mechanism was a skiing accident. (sciencedirect.com)

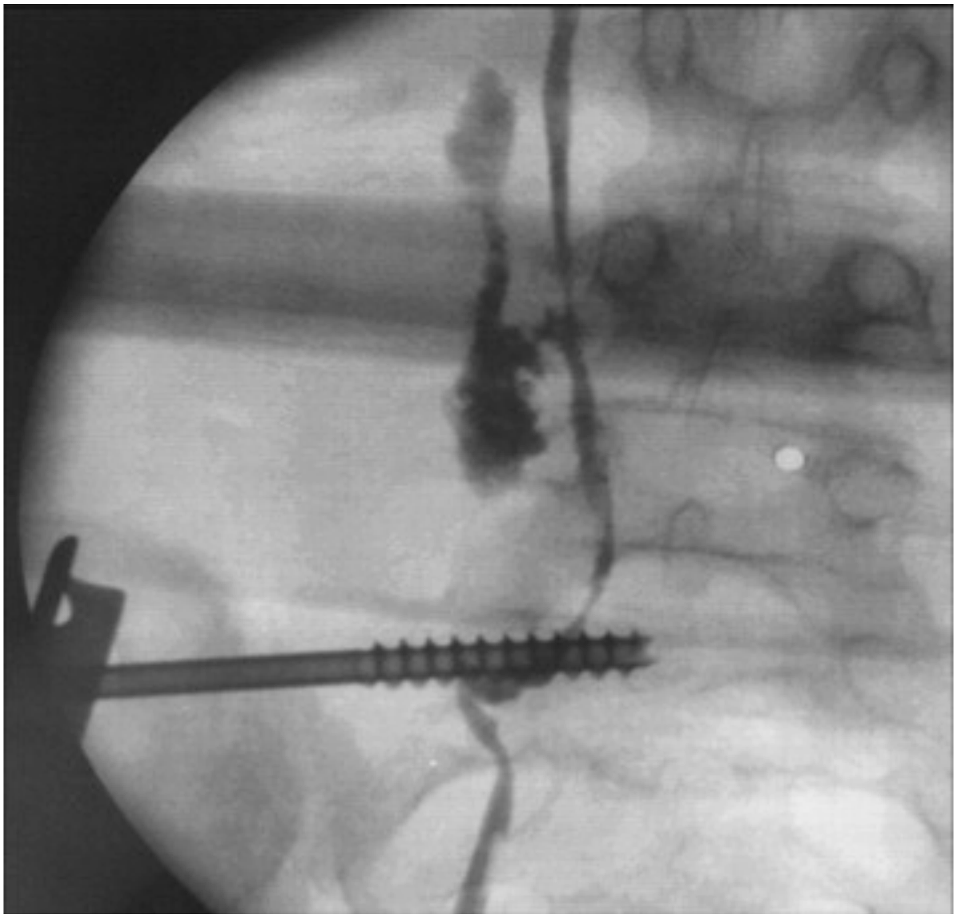


Fig. 252. This is a retrograde ureteropyelography (anterior-posterior view) showing ureteral leak with opacification at the L4-5 disc level. The ureter is twisted in front of the screw. This is the same case shown in Fig. 251. The injury to the right ureter occurred after a percutaneous iliosacral screwing with non-computer-assisted fluroscopic guidance. This procedure was done to stabilize the right iliac wing fracture shown in Fig. 251. (sciencedirect.com)

2. **Urinary Bladder:** Most bladder injuries occur in association with **blunt trauma**. Eighty-five percent of these injuries occur with pelvic fractures, with the remaining 15% occurring with **penetrating trauma**.
   Remember, 3-10% of all trauma patients have injuries involving the genitourinary tract, while 10-15% of trauma patients with abdominal injuries have associated genitourinary involvement, with bladder injuries constituting 40% of injuries.
   During their external examination of the body, the forensic pathologist should have a high index of suspicion of bladder injury if there are contusions (bruising) or edema of the lower abdomen, perineum, or genitalia.

Traumatic injuries to the bladder are typically classified as **extraperitoneal**, **intraperitoneal**, **and combined**. **Extraperitoneal** bladder injuries typically occur when the bladder is empty or contains only a small amount of urine (Fig. 253).

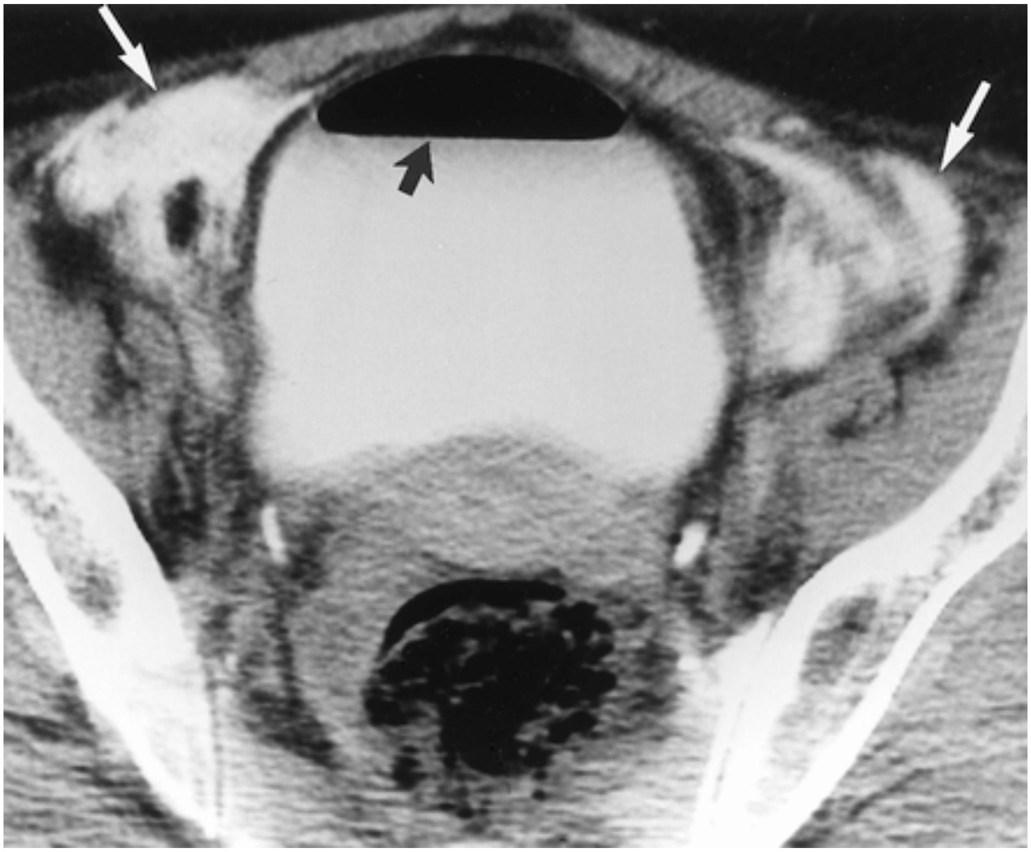


Fig. 253. This is a CT cystogram obtained after retrograde filling of the bladder shows an intravesicle air-contrast level (black arrow) and contrast material in the perivesicle extraperitoneal space (white arrow). The patient was a 77-year-old woman who sustained blunt abdominal trauma with injury to her bowel, mesentery and bladder. (radiographics.rsna.org)

In the extraperitoneal rupture, the bladder lies within the pelvis and thus is somewhat protected by the bony pelvis. Thus, **extraperitoneal bladder injuries** are usually associated with **pelvic fractures**, especially fractures of the pubic ramus (95%). The most common site of injury is near the bladder neck thus, the resulting extravasation is usually extraperitoneal. Typically, the laceration occurs in the direction of the long axis of the bladder and corresponds to the direction of the heaviest muscle bundles. Only rarely will extraperitoneal bladder injuries occur without pelvic fractures. Such an injury can occur when blunt force is applied to the lower abdominal wall in a downward direction.

There are occasions in which due to violent blunt force compression of the bladder a rupture will occur low in the posterior wall with the result that an extra-or subperitoneal extravasation of urine takes place. In such instances the urine may follow the retroperitoneal space as high as the kidneys or it may follow the spermatic cord in the scrotum.

Extraperitoneal bladder injuries account for 65-85% of injuries to the bladder.

Intraperitoneal bladder injuries account for 15-35% of all bladder injuries (Fig. 254).

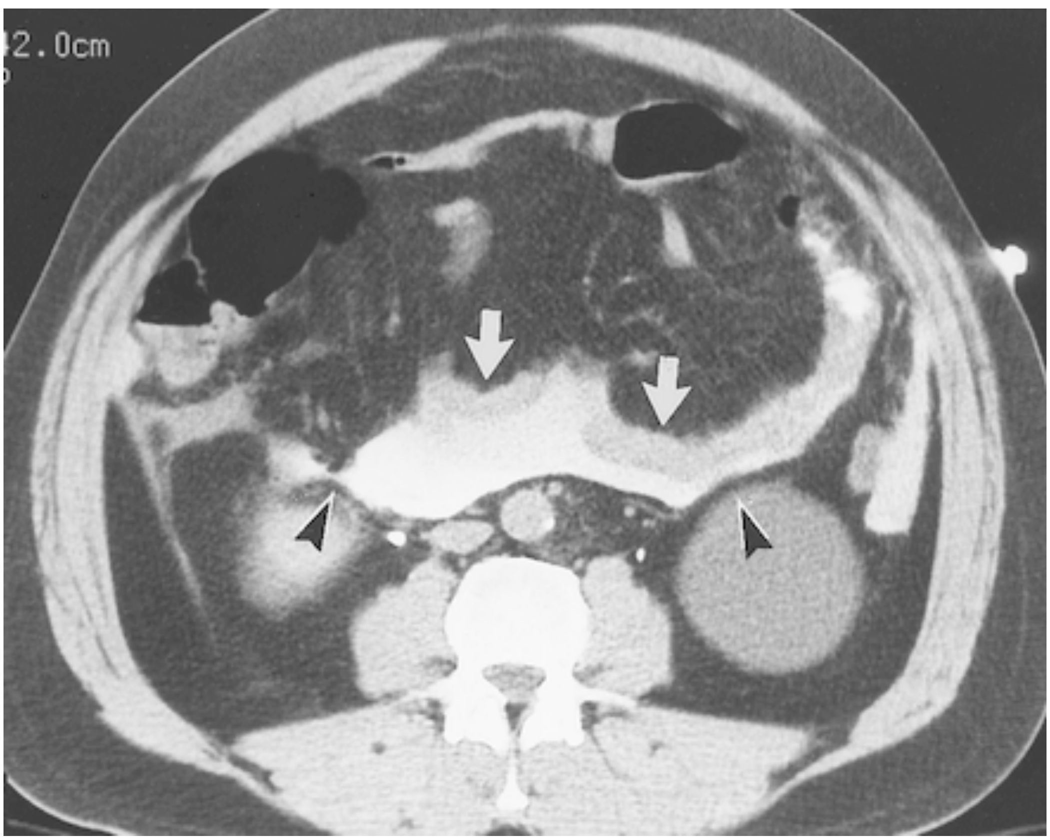


Fig. 254. This is a CT cystogram of a 53-year-old man who was involved in a motor vehicular accident. The cystogram demonstrates the classic appearance of an

intraperitoneal rupture, with extravasated contrast material between the loops of small bowel (arrows) and the anterior pararenal fascial (arrowheads). (radiographics.rsna.org)

These injuries typically occur when the bladder is distended or as the result of penetrating trauma. If due to blunt force trauma, the trauma, whether in the form of a kick or blow, is delivered to the lower abdominal wall, which results in the posterior wall of the bladder being compressed against the sacrum. Such sudden compression creates an explosive hydraulic force, which affects all parts of the bladder wall with equal intensity with the rupture of the bladder occurring at the site of least resistance. In the distended bladder the peritoneum over the dome is already under considerable tension thus, due to its poor elasticity, it is the first tear. This is followed by rupture of the bladder which usually occurs in the superior or posterior part of the dome. The resulting tear may be longitudinal, oblique, or transverse, depending upon the direction of the fibers in the middle stratum of the tunica muscularis. Such ruptures lead to urine entering the peritoneal cavity.

Combined injuries are usually seen with gunshot wounds, however, they can also occur as the result of a motor vehicular accident (Fig. 255).

Bladder injuries may range from contusions to rupture. E. E. Moore *et al.* developed a bladder organ injury scale, which is as follows:

Grade I : Hematoma - contusion, intramural hematoma
: Laceration - partial thickness

Grade II : Laceration - extraperitoneal bladder wall laceration < 2 cm

Grade III : Laceration - extraperitoneal (> 2 cm) or intraperitoneal (< 2 cm) bladder wall laceration

Grade IV : Laceration - intraperitoneal bladder wall laceration > 2 cm

Grade V : Laceration - intra-or extraperitoneal bladder wall laceration extending into the bladder neck or urethra orifice

Note: advance one grade for multiple injuries.

Fig. 255. This is an Axial CT cystography of the bladder of a 29-year-old woman who was in a motor vehicular accident. The cystographic image shows a small amount of fluid lateral to the bladder, but no contrast extravasation is seen (arrows). This CT cystogram was interpreted as intraperitoneal rupture with a probability of extraperitoneal rupture, which was confirmed by surgical bladder exploration. (ajronline.org)

Traumatic rupture of the bladder occurs more frequently in men than women and is rarely seen in children.

Other Mechanisms of Blunt Force Traumatic Bladder Injury: A substantive proportion of blunt force traumatic injuries of the bladder occurs in victims who are intoxicated. It is believed the susceptibility of the intoxicated person to bladder rupture is because most have distended bladders.

There is an uncommon situation of delayed rupture of the bladder seen in women who have had a pelvic operation, which has resulted in the blood supply to the posterior wall being compromised.

Spontaneous rupture of the bladder does occur but it is rare. The bladder can rupture due to a slight fall, straining at the stool, sneezing, or a sudden exertion during lifting a heavy weight. Such ruptures are typically **extraperitoneal** and usually occur in a person with chronic cystitis with chronic urinary obstruction, especially bladder neck obstruction. Rupture may also occur through the base of an ulcer, tumor or an infected diverticulum, either congenital or acquired. The acquired diverticula are more common and most often seen in men with prostatic enlargement (hyperplasia or neoplasia), resulting in obstruction to urine outflow with its consequent marked muscle thickening of the bladder wall. The increased intravesical pressure causes out-pouching of the bladder wall and the formation of diverticula (Fig. 256). These are frequently multiple and have narrowed necks located between the interweaving hypertrophied muscle bundles.

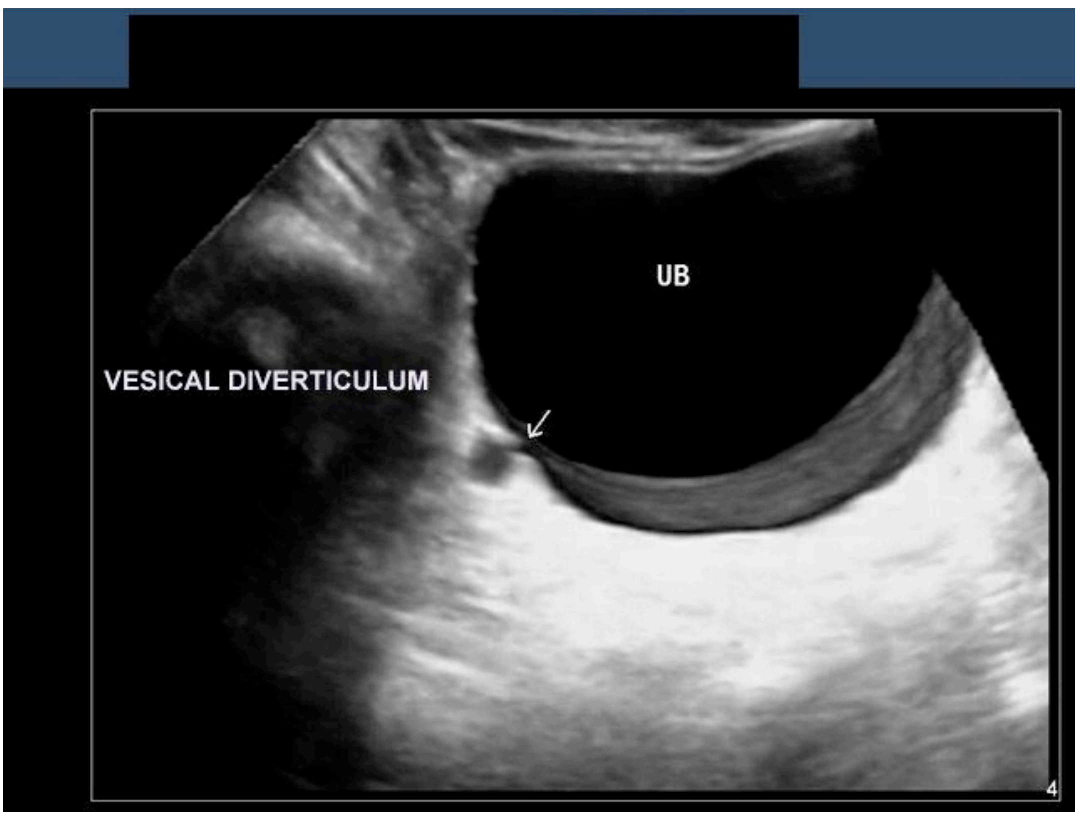


Fig. 256. This is an ultrasound of the urinary bladder (UB) showing a diverticulum. (cochinblogs.blogspot.com)

The congenital form are much more infrequent and are either due to a focal failure of development of the normal musculature or to some urinary tract obstruction during fetal development.

Although most diverticula are small and asymptomatic, they may become clinically significant, since they constitute sites of urinary stasis and thus, predisposed to infection, formation of bladder calculi and rupture.

An unusual cause of spontaneous bladder rupture is weakening of its wall by extrinsic disease, such as pelvic osteomyelitis.

The bladder can be injured during childbirth. Lacerations of the vagina incident to precipitate delivery occasionally extend into the posterior wall of the bladder with the development of vesicovaginal fistula. Obstetrical contusion of the bladder mucosa occurs infrequently, but when it does occur it manifest as hematuria.

Penetrating Injuries: The bladder may be penetrated by a bullet or stab wounds to the abdomen or perineum (Fig. 257). Such injuries are usually associated with other serious injuries.

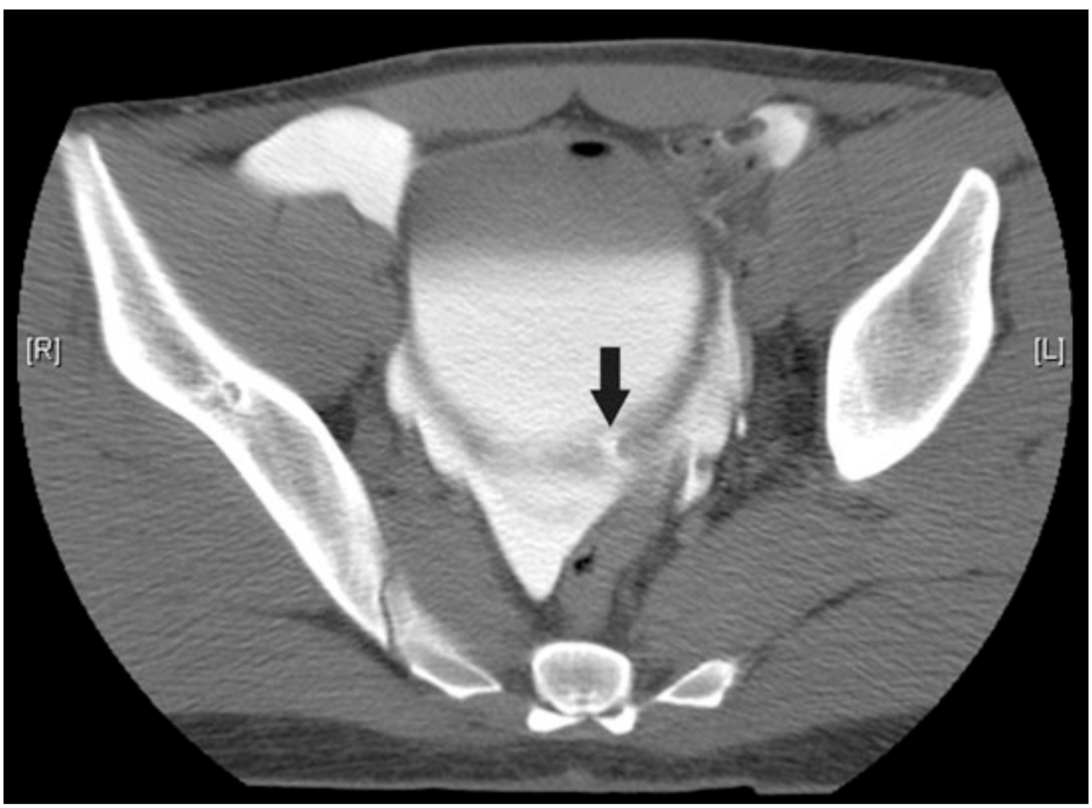


Fig. 257. The above image is from a 22-year-old man with scrotal gunshot wound. Axial image of the pelvis during CT cystogram demonstrates contrast extravasating through a perforation in the posterior wall of the bladder (arrow). (radiology.casereports.net)

Often the development of massive fatal hemorrhage or peritonitis masks the penetration to the bladder. On occasion, the bladder may be the only pelvic organ injured by a penetrating wound. Penetrating wounds of the trigone can lead to permanent derangement of detrusor muscle function.

Perforation of the bladder from within can be accomplished through instrumentation (cystoscope) or by some other foreign body introduced by way of the urethra. Psychiatrically disturbed individuals have been known to introduce a myriad of foreign objects including snakes through the urethra into the bladder. Such foreign objects can lead to severe ulcerative cystitis, as well as spontaneous perforation. Foreign objects within the bladder may serve as a nidus for the development of a urinary calculus (Fig. 258). Calculi have been observed to form around bullets and fragments of shrapnel.

Fig. 258. Plain x-ray showing a radio-opaque bladder calculus. (sciencedirect.com)

Pediatric Traumatic Injuries to the Bladder: Bladder injuries may occur after blunt or penetrating trauma. Blunt force traumatic injuries secondary to motor vehicular accidents is the leading cause of bladder injuries in children. More than 80% of bladder injuries are associated with pelvic fractures and penetration of the bladder by bony fragments. However, only 10% of patients with pelvic fractures sustain lower urinary tract injury. The probability of having an associated bladder injury increases proportionally with the number of fractured pubic rami. Mortality rate associated with bladder rupture may be as high as 40%. Death is usually caused by associated head injuries rather than the bladder injuries themselves.

Remember, during childhood, the bladder has a higher abdominal location, which renders the organ more susceptible to injury than in adults. Also, as in adults, the bladder is more easily damaged when full. The risk of injury is especially increased in the setting of improperly fastened seat belts and lap belts. Bladder neck injuries are uncommon, but when they occur are typically serious. Such injuries have been reported to be more common in children than adults, especially in male children, due to the undeveloped prostate and are often in association with pelvic fractures. The injury may be due to longitudinal lacerations or lacerations that extend to the proximal urethra.

As in adults, bladder injuries in children are classified as **extraperitoneal, intra-peritoneal or combined**. **Extraperitoneal injuries** are more frequently associated with pelvic fractures of the anterior ring and may be related to either lacerations or penetration from bone fragments, irrespective of bladder volume and the time of injury (Fig. 253). In contrast, **intraperitoneal injuries**, which account for approximately two-thirds of major bladder injuries, are usually caused by blunt force trauma resulting in a burst mechanism to a full, distended bladder (Fig. 254). **Combined injuries** are usually seen with gunshot wounds (Fig. 255). Bladder injuries may range from contusions to rupture as in adults. Contusions are described by same as incomplete, non-perforating tears of the mucosa. Technically, contusions represent bleeding into the mucosa from the rupture of venules, capillaries and arterioles; there is no laceration, superficial or otherwise. Complicated injuries may involve the bladder, urethra, sacral plexus, and supporting structures of the anorectal region.

Iatrogenic bladder injuries may occur during herniorrhaphy, cystoscopy, and umbilical artery cutdown. Patients with myelodysplasia who have undergone bladder augmentation may experience spontaneous bladder rupture in the presence of infection, bacteremia or over distention.

3. **Urethra:** Urethral injuries constitute 10% of all injuries to the genitourinary tract. Blunt force trauma is responsible for 60% of urethral injuries with penetrating and iatrogenic etiologies accounting for the other 40%. Traumatic injuries to the urethra occur more commonly in males than in females. Urethral trauma affects

all age groups but appears to have a higher incidence in persons aged 15-25-years-of-age.

Urethral injuries present with **blood at the meatus**. With injuries to the **anterior segment** you can also see **penile and/or perineal edema and/or a contusion**.

To understand urethral injuries you must have a comprehension of urethral anatomy. As was previously discussed in the review of urethral anatomy, pages 92-102 and Figs. 76-80, the adult male urethra is 18-20 cm long, extending from the internal orifice in the urinary bladder to the external opening (meatus) at the end of the penis. In the adult female the urethra is 4 cm long, extending from the internal orifice in the urinary bladder to the external urethral meatus 2.4 cm behind the glans clitoris.

In the male the urethra is divided into two parts, the **anterior** and **posterior urethra**. The **anterior urethra** is approximately 15-16 cm long and lies within the the perineum (proximally) and the penis (distally), surrounded by the **corpus spongiosum**. The **posterior urethra** is approximately 3-4 cm long and lies in the pelvis proximal to the corpus spongiosum. The division point between the anterior and posterior urethra is the **perineal membrane** (Fig. 259).

The anterior urethra is subdivided into a proximal component, the **bulbous urethra**, surrounded by the **bulbospongiosus** and is entirely within the perineum, beginning proximally at the level of the inferior aspect of the **urogenital diaphragm.** The distal component is composed of the **pendulous urethra** and the **fossa navicularis**, which is the most distal aspect of the anterior urethra lying within the **glans penis**.

The posterior urethra is subdivided into the **preprostatic urethra,** which is approximately 1 cm in length, extending from the base of the bladder to the prostate; the **prostatic urethra**, which is 3-4 cm in length and lies within the prostate; and the **membranous urethra**, which is approximately 2-2.5 cm, extending from the prostate to the bulb of the penis, passing through the perineal membrane.

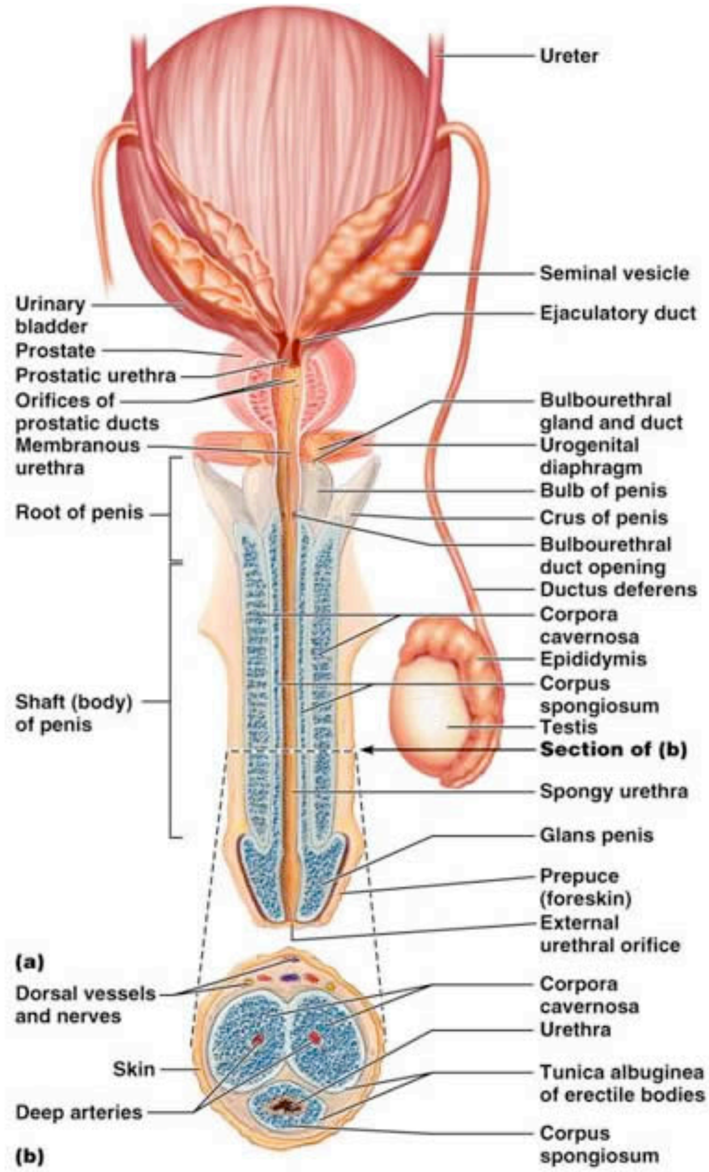


Fig. 259. This illustration depicts the male genitourinary system including the various components of the urethra. (classes.midlandstech.edu)

Most urethral injuries result from blunt force trauma, with penetrating injuries occurring more commonly in a military setting. Usually, the main causes of urethral injuries are gunshot wounds, stab wounds, wounds sustained by falling on sharp objects, lacerations incident to pelvic fractures, motor vehicular accidents mutilation (self-inflicted or otherwise), iatrogenic and crushing wounds, which produce straddle type injuries, such as occurs with bicycles, skateboards and falls onto the perineum.

Of the above, the **straddle type injury** is one of the most common (Fig. 264). In such an injury the urethra is likely to be contused or lacerated without the production of an external wound. Typically, it is the fixed part of the cavernous portion that is injured.

Posterior urethral injuries usually occur in close to proximity to the **external urethral sphincter** and are typically initiated by a massive shearing force that results in pelvic fracture and disruption through the **membranous urethra**. Membranous urethral disruptions are usually associated with multiple organ injury whereas anterior urethral injuries usually occur in isolation. An example of an **anterior urethral injury** would be a straddle type traumatic injury caused by crushing of the immobile **bulbous urethra** against the pubic rami, or rupture of the corporal bodies (remember, the penis is composed by three cylindrical masses of cavernous tissue bound together by fibrous tissue. Two of these cylindrical masses, the **corpora cavernosa penis [corporal bodies**], lie side by side on the dorsum of the penis, whereas the third cylindrical mass, the **corpus spongiosum** lies ventrally in the median plane), also referred to as a penile fracture, leading to a laceration through the adjacent urethra (Fig. 259). **Iatrogenic injuries** affect both anterior and posterior segments of the urethra.

Traumatic posterior urethral injuries are usually the result of blunt force trauma. Urethral disruption occurs in approximately 10% of pelvic fractures, however, almost all membranous urethral disruptions related to blunt force trauma have an associated pelvic fracture. The pelvic fractures that lead to urethral disruption are usually secondary to motor vehicular accidents (68-84%) or falls from heights and pelvic crush injuries (6-25%). Pedestrians are far more at risk than passengers in sustaining pelvic fracture urethral disruption injuries in motor vehicular accidents. Other unusual causes of pelvic fracture and membranous urethral injury include forceful kicks to the perineum, such as riding a mechanical bull (urban cowboy syndrome) (Fig. 288).

The most common classification system currently in use for blunt force posterior urethral injuries was originally described by Colapinto and McCallum in 1977. It was modified recently by Goldman and colleagues to include all common types of blunt urethral injuries. This classification uses radiographic findings to sort blunt urethral injuries, which is as follows:

Type I : Rupture of the puboprostatic ligaments and surrounding periprostatic hematoma stretch the membranous urethra without rupture (Fig. 260).

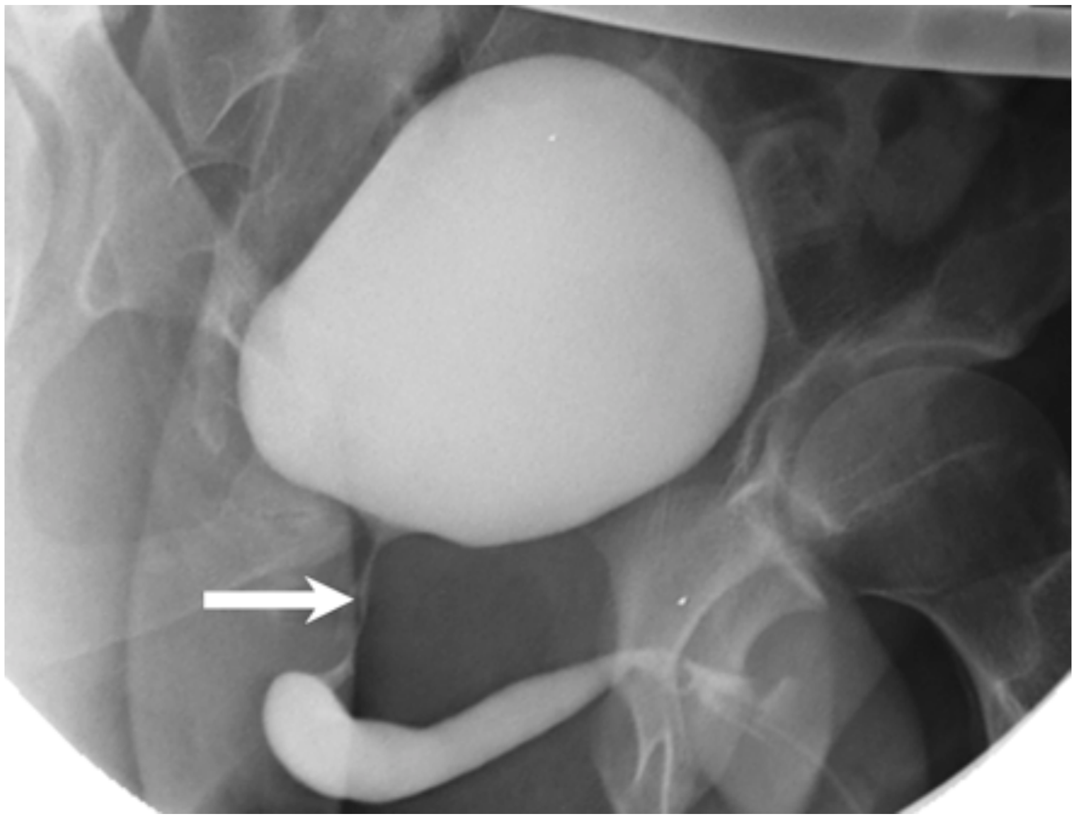


Fig. 260. Image from ascending urethrography in a male patient with an open book pelvic fracture showing the posterior urethra (arrow), which appears to be stretched but intact (Goldman type I injury), with no evidence of contrast material extravasated. (radiographics.rsna.org)

Type II : Partial or complete rupture of the membranous urethra above the urogenital diaphragm or perineal membrane (Fig. 261).

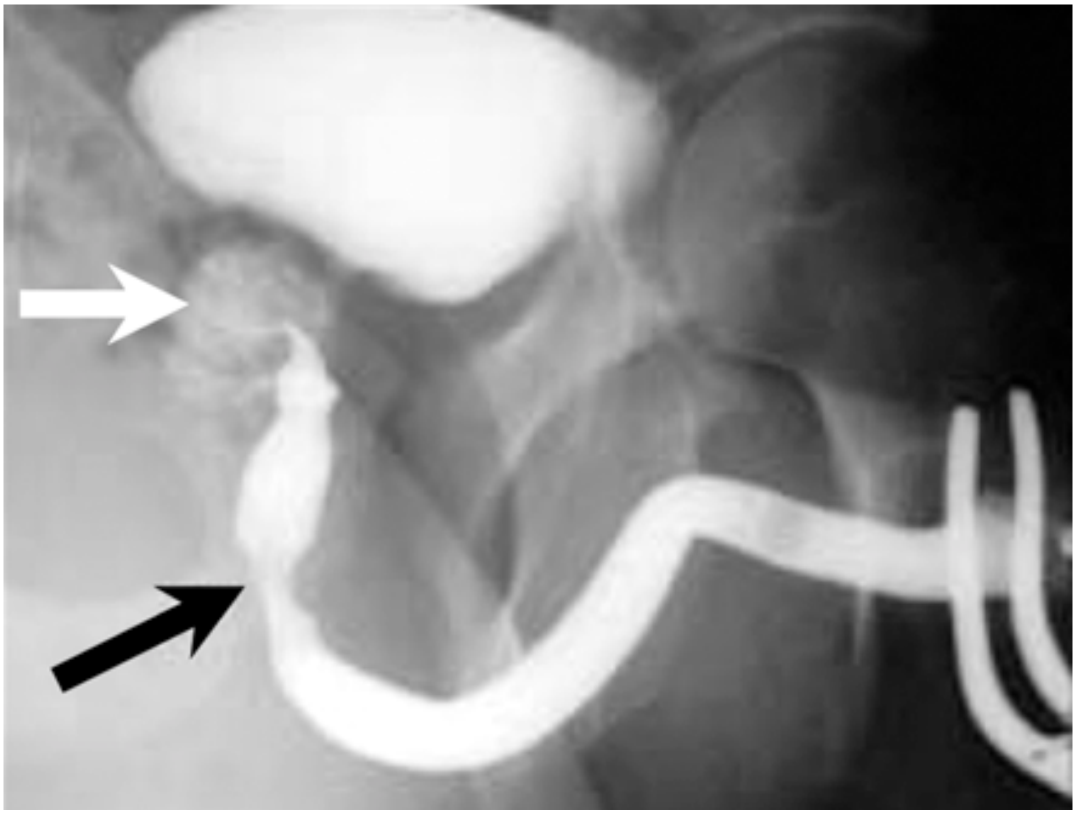


Fig. 261. Image from ascending urethrography showing an area of contrast material extravasation (white arrow) indicative of injury to the posterior urethra, with an intact urogenital diaphragm (black arrow). (radiographics.rsna.org)

Type III : Partial or complete rupture of the membranous urethra with disruption of the urogenital diaphragm (Fig. 262).

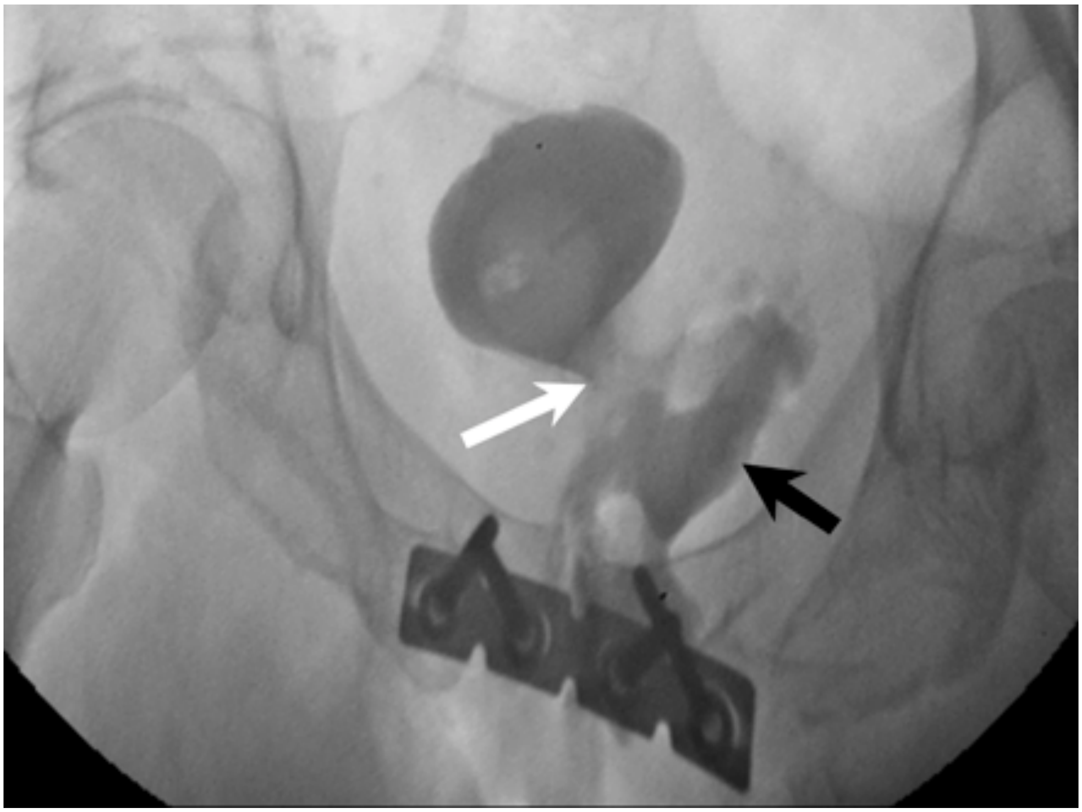


Fig. 262. This image is from a male patient after pelvic fixation for trauma sustained in a road accident, showing a complete posterior urethral transection that extends through the urogenital diaphragm to the anterior urethra, with resultant extraperitoneal contrast material extravasation (black arrow). Because the bladder neck (white arrow) is intact, the injury is classified as a Goldman type III. (radiographics.rsna.org)

Type IV : Bladder neck injury with extension into the urethra. There is an extension of the type IV injury referred to as the type IVa, which shows extraperitoneal bladder rupture at the bladder base with periurethral extravasation, simulating a type IV injury (Fig. 263)

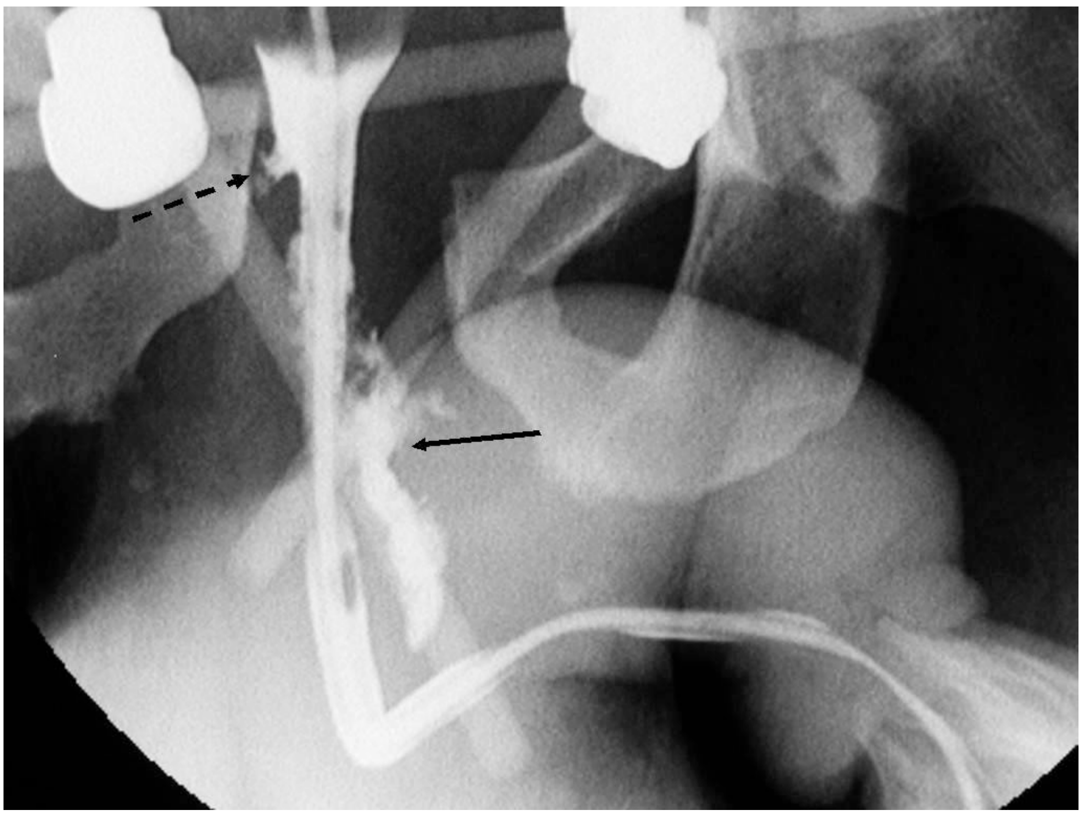


Fig. 263. This image is of a retrograde urethrogram showing a type III urethral tear at the urogenital diaphragm (solid arrow) and a type IV urethral disruption at the bladder neck (dashed arrow). (emedicine.medscape.com)

Type V : Pure anterior urethral injury (Figs. 264 & 265)

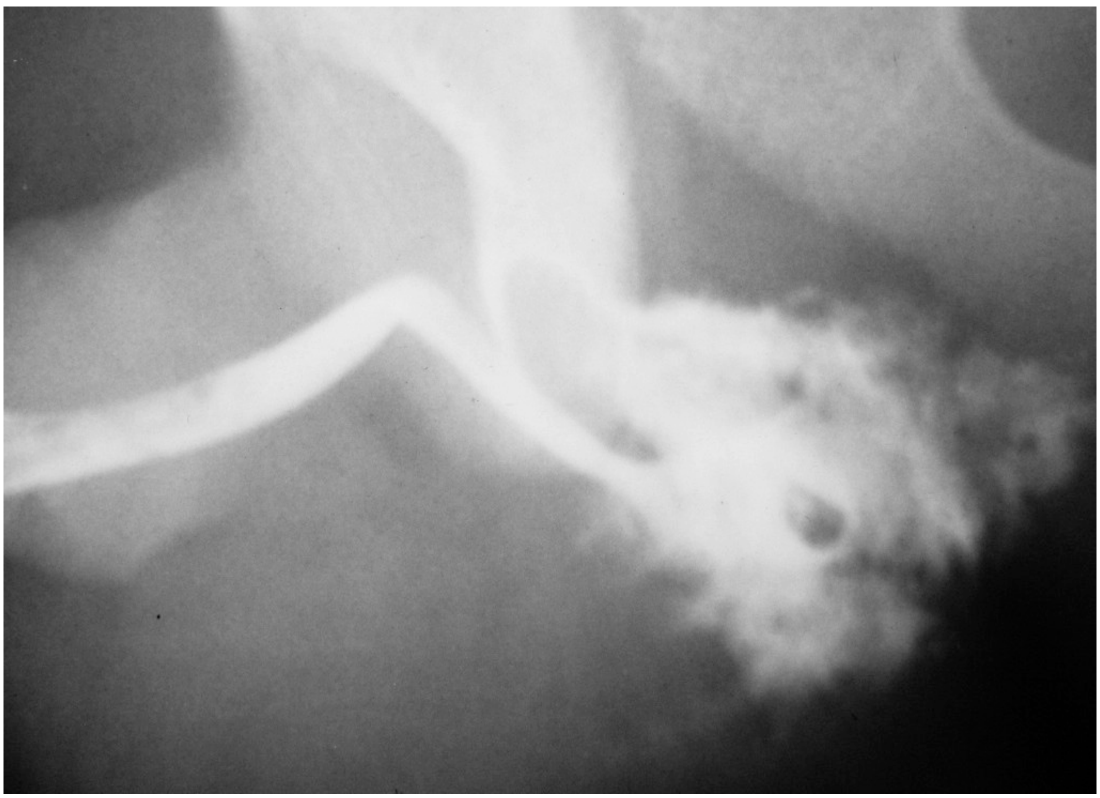


Fig. 264. This is a retrograde urethrogram showing a type V urethral injury with extravasation of contrast material from the distal bulbous urethra. It is an example of a straddle type injury. (emedicine.medscape.com)

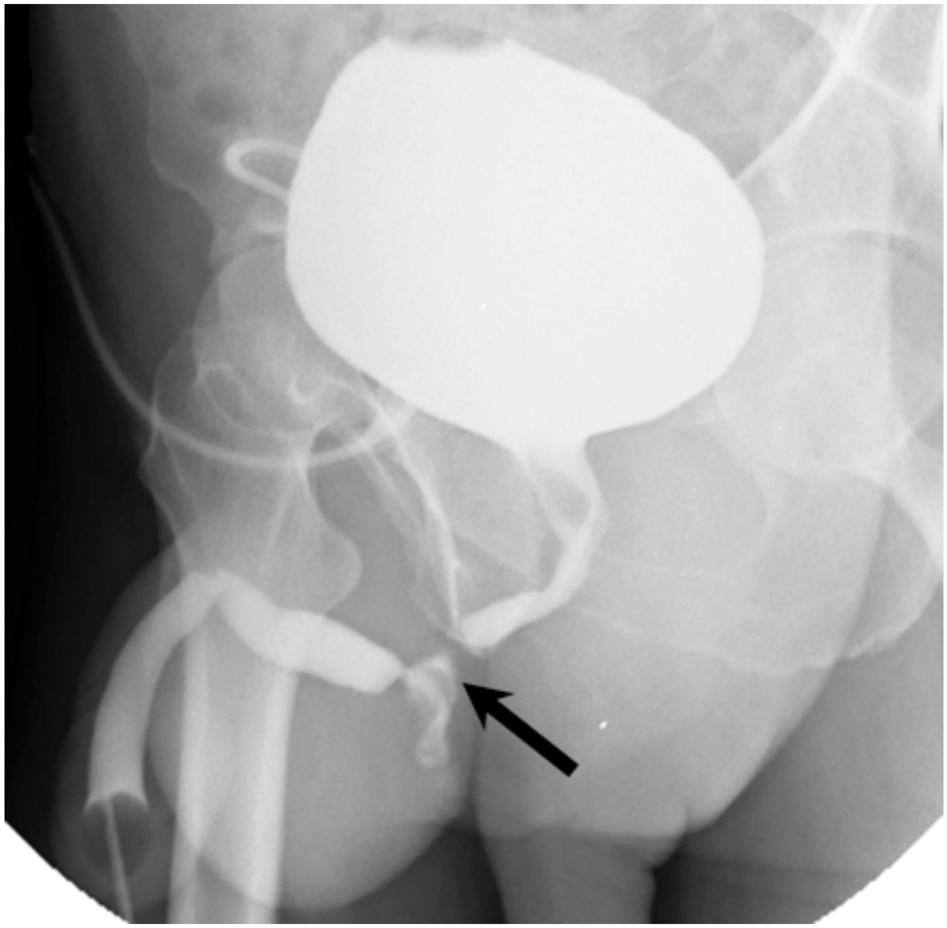


Fig. 265. This image is from a simultaneous ascending and descending urethrography, performed with the balloon catheter still in place in the distal urethra to maintain distention below the level of transection and with voiding through the posterior urethra, depicting a complete urethral transection consistent with a Goldman type V injury. (radiographics.rsna.org)

Type I and II injuries are uncommon, each representing approximately 10-15% of posterior urethral injuries. Either type II or type III injuries may be classified as complete or partial ruptures. The relative incidence of complete to partial tears is approximately 3:1. Type III injuries are the most frequent, occurring in 66-85% of all cases. Type IV injuries are rare.

Pelvic fractures with urethral injuries are far less common in females. This is due to the shortness of the female urethra and its greater mobility in relation to the pubic arch. Although, pelvic fracture urethral injuries are less common in females, they do occur and when the do they predominate in the prepubertal and pubescent age group. The underlying foundation for the susceptibility of this age

age group is believed to be do to younger females have thinner and less mobile tissues along with compressible pelvic bones.

Female urethral injuries frequently have associated vaginal lacerations and rectal tears, the incidences of which are 76% and 33% respectively. Labial edema, hematuria and urethrorrhagia may also be seen.

The blunt force required to cause pelvic crush injuries leading to urethral disruption are of such magnitude that they commonly produce associated neurologic injuries include head and/or spinal cord injuries, injuries to the organs of the chest, abdomen and pelvis and other musculoskeletal injuries. Bladder rupture occurs in approximately 5-10% of pelvic fractures. When pelvic fractures cause urethral disruption, the rate of associated bladder rupture is usually an extraperitoneal rupture (56-78%) (Fig. 253), however, intraperitoneal ruptures occur in 17-39% (Fig. 254). On occasion you may see combined extra- and intraperitoneal rupture (Fig. 255). Prepubertal males may experience extension of the disruption up into and through the prostatic urethra. This is due to the prostate being smaller thus, it is less protective.

Traumatic anterior urethral injuries: Blunt force trauma or penetrating injuries may cause anterior urethral injuries, with blunt force trauma being more common. The **bulbous urethra** is the most frequently injured segment (85%), due to the fact it is fixed beneath the pubic bone. Blunt force trauma to the bulbous urethra is typically caused by straddle type injuries (i.e., motor vehicular accidents, bicycle accidents, falling astride onto a fence, railing or saddle) or kicks to the perineum. Blunt force delivered to the perineum crushes the bulbous urethra up against the **inferior pubic rami**, leading to contusion or urethral laceration (Fig. 264). Traumatic anterior urethral injury, in contradistinction to prostatomembranous urethral disruption, rarely has associated organ trauma.

Traumatic anterior urethral injury may also be related to penile fracture in 10-20% of cases. The mechanism of such an injury is a direct blow applied to the erect penis during intercourse, with the erect penis striking the female pubic rami.

The most widely used classification system for anterior urethral injuries was described by McAninch and Armenakas and is based on radiographic findings:

Type I : Contusion: Clinical features suggest urethral injury, but retrograde urethrography is normal (Fig. 266)

Type II : Incomplete disruption: Urethrography demonstrates extravasation, urethral continuity is partially maintained. Contrast is seen filling the proximatl urethra or bladder (Fig. 267)

Type III : Complete disruption: Urethrography demonstrates extravasation with absent filling of the proximal urethra or bladder. Urethral continuity is disrupted (Fig. 266)

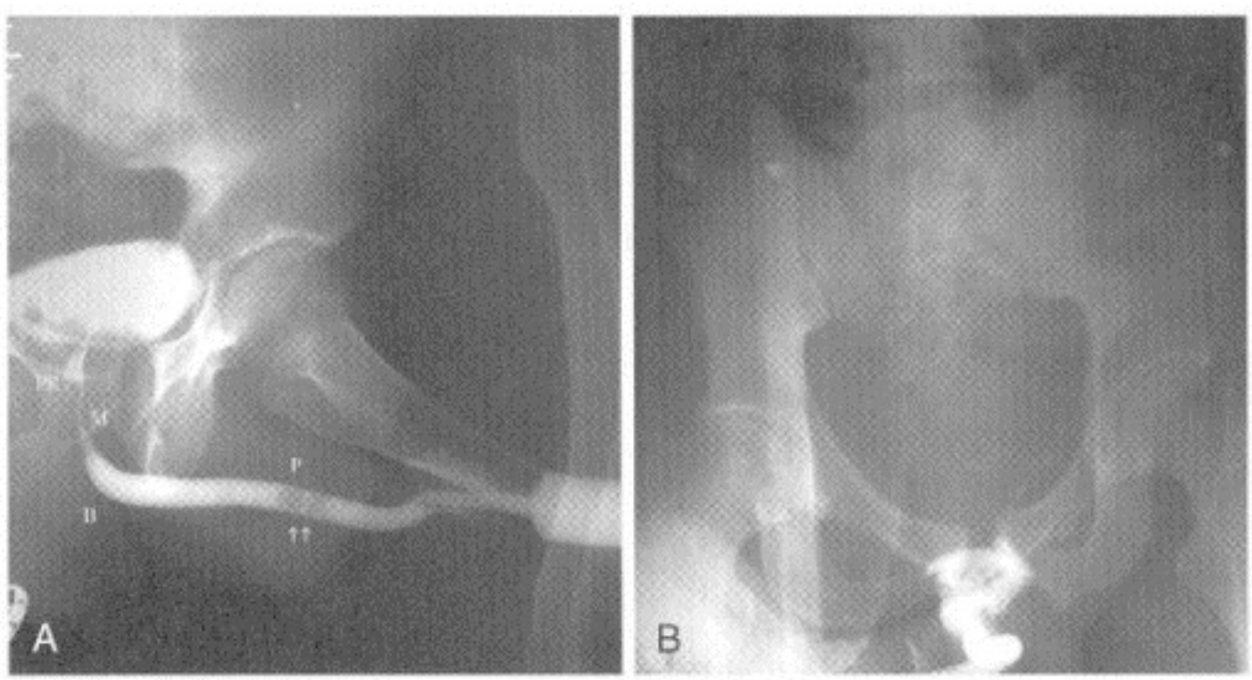


Fig. 266. A. This represents a normal urethrogram with air bubbles (arrows) within the anterior urethra. The characteristic normal anatomy includes the penile (P), bulbous (B), membranous (M), and prostatic (PR) urethra. Bladder filling is demonstrated as well.
B. This image demonstrates trauma to the anterior urethra at the level of the urogenital diaphragm and bulbous urethra showing extravasation of contrast at and below the urogenital diaphragm and pubic symphysis. Sacroiliac joint diastasis is also seen. (sciencedirect.com)

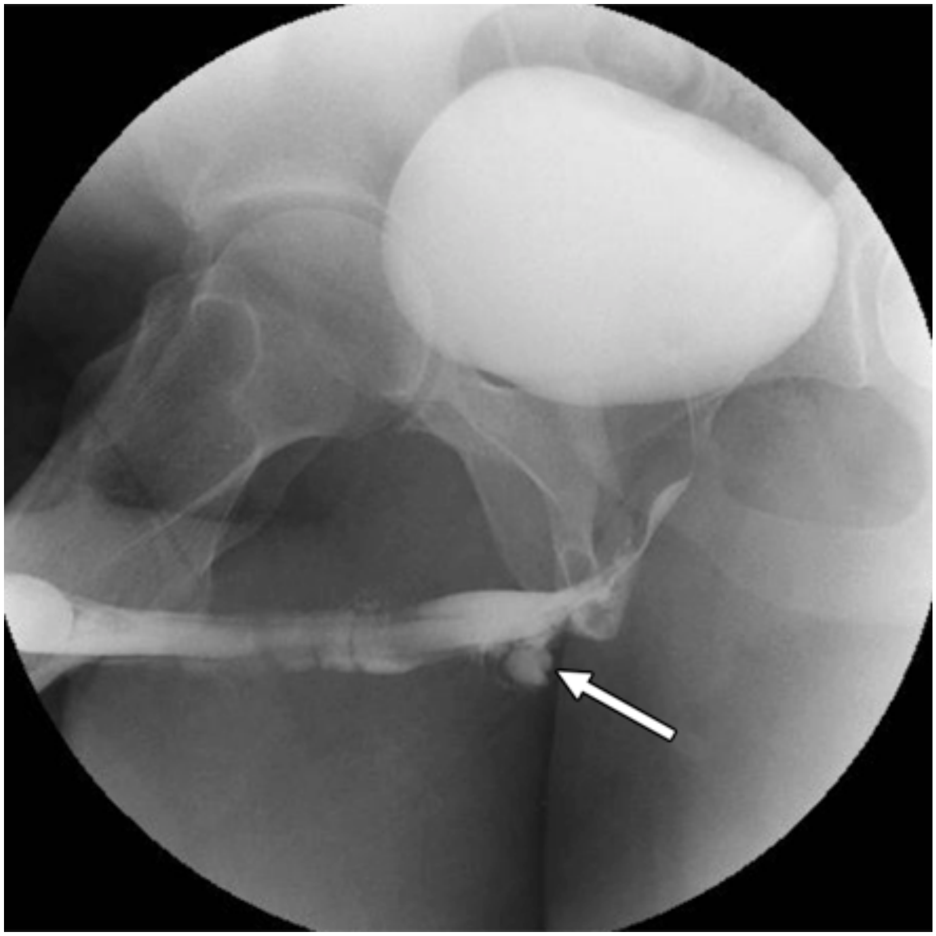


Fig. 267. This image is from a 54-year-old male with a straddle injury. The voiding cystourethrogram shows a partial urethral transection and extravasation at the bulbar urethra. (ajronline.org)

Penetrating trauma to the urethra is most often caused by firearms, however, such trauma can be caused by stab wounds, industrial accidents, self-mutilating injuries and bites.

Mechanism of Injury: It is believed the mechanism of membranous urethral disruption involves a shearing force that avulses the apex of the prostate from the membranous urethra, where the membranous urethra is fixed in place by the urogenital diaphragm. There are three generally accepted mechanisms proposed which may generate this shearing force. The first involves upward displacement of the one hemipelvis and symphysis causing a laceration of the urethra. The second involves a straddle fracture whereby a free floating central symphyseal fragment is displaced posteriorly, causing a disruption. The third mechanism involves pubic symphysis diastasis, whereby the membranous urethra is stretched until it ruptures. Along with these three mechanisms some have suggested the urethral disruption represents partial or complete avulsion of the membranous urethra off the fixed bulbous urethra at the bulbomembranous junction.

Iatrogenic urethral injury: Iatrogenic urethral injuries most commonly result from prolonged or traumatic urethral instrumentation, whereby the delicate mucosa may be partially disrupted. The most frequent cause of acute iatrogenic urethral trauma is related to traumatic foley catheter removal without prior ballon deflation (Fig. 268).

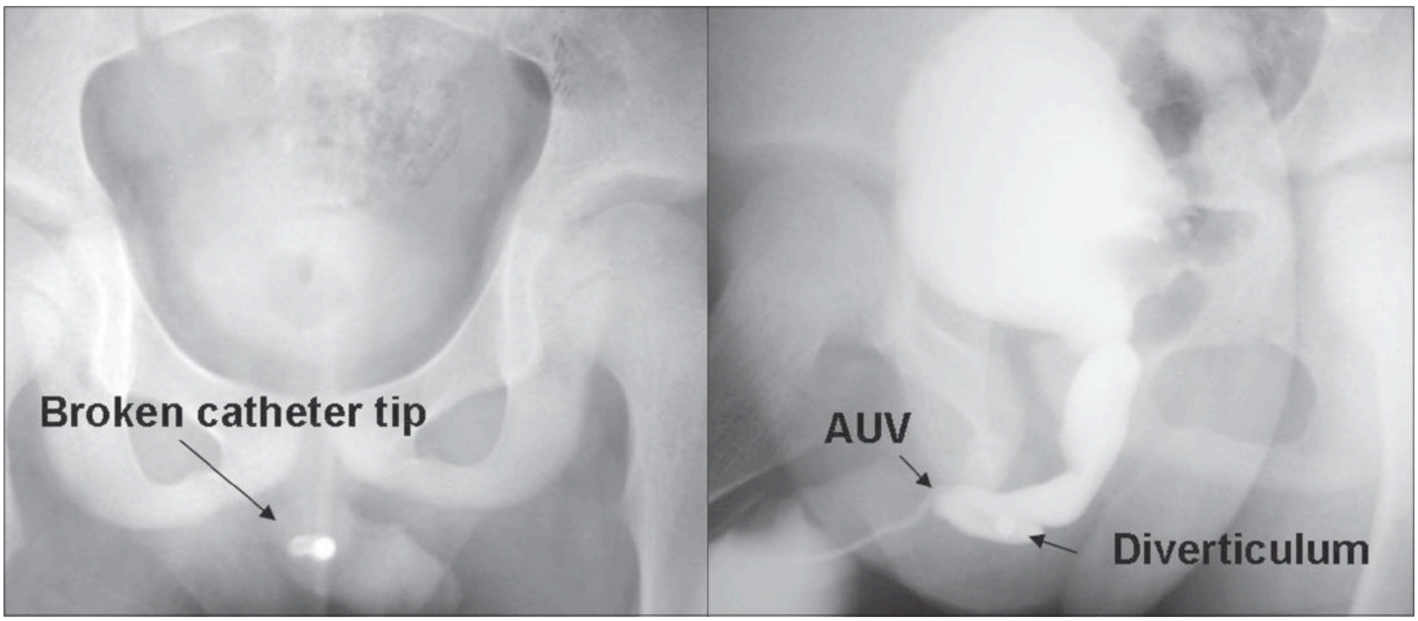


Fig. 268. Voiding cystourethrogram showing a foreign body within the urethra, which was a broken catheter tip, in a boy with anterior urethral valve pathology and a diverticulum. (afijpaedsurg.org)

Urethral injuries have also been attributed to complications of extracorporeal circulation during cardiac revascularization surgery. Urethral injuries can occur as a complication of bladder drained pancreas transplantation and pancreas-kidney transplantation.

Iatrogenic injuries of the posterior urethra can occur as a result of treatment for benign prostatic hyperplasia, prostatic cancer and during a vasectomy (Fig. 269)

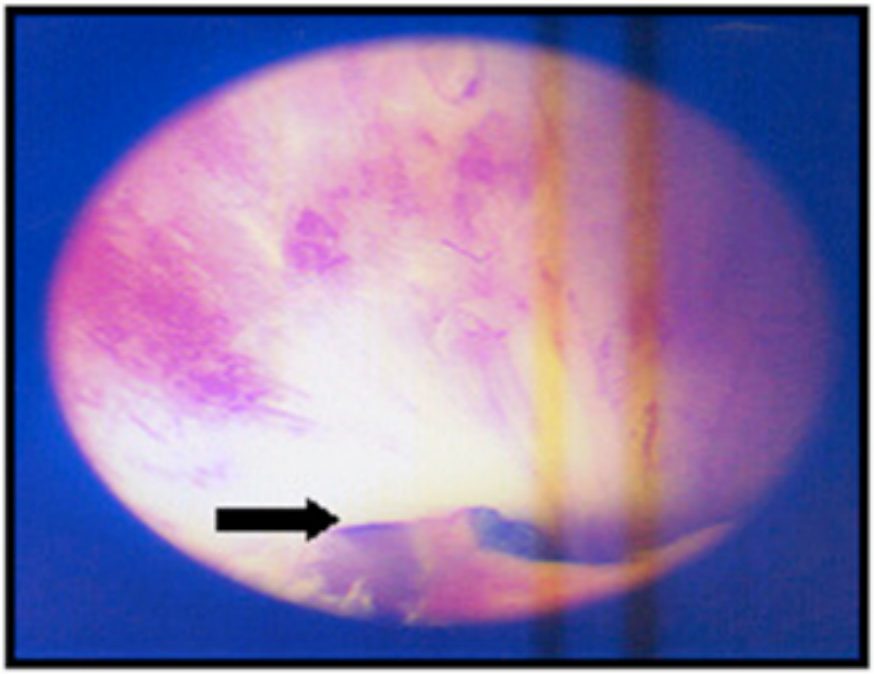


Fig. 269. This is an endoscopic view of an iatrogenic urethral injury during a vasectomy due to a suture denoted by the black arrow. (ispub.com)

Pediatric Urethral Traumatic Injuries: Blunt trauma due to motor vehicular accidents, falls from considerable height on to the perineum, and straddle injuries, accounts for most urethral injuries sustained during childhood. Injuries due to instrumentation (iatrogenic) (Fig. 268), and penetrating injuries, such as gunshot wounds, are less common. Urethral injuries in children, as happens in adults, occur primarily in males. As is true in adult males, in boys the urethra is divided by the urogenital diaphragm into an anterior urethra (pendulous and bulbous) and a posterior urethra (membranous and prostatic).

Anterior urethral injuries result from direct trauma, are often isolated, and are associated with low mortality. The pendulous urethra may be damaged by blunt or penetrating forces. Bulbar injuries are commonly caused by straddle mechanisms, as the urethra is compressed between the symphysis pubis and or a solid object. The major sign of acute anterior injury is bleeding from the urethra with blood being seen at the meatus in 90% of cases. Perineal ecchymosis in the shape of a butterfly is typical for these injuries. An important point to remember is improper placement of a urethral catheter can convert a partial tear into a complete transection.

Posterior urethral injuries occur with severe trauma and are usually associated with other injuries, most especially pelvic fractures. The mortality rate with a fracture of the pelvis has been reported as high as 30%. As reported above, there is an association between pubic arch fractures and urethral injuries, with higher risk as the number of broken rami increases. The higher death rate in these patients is attributed primarily to associated injuries.

The **urogenital diaphragm** located between the pubic rami fixes the membranous urethra and makes it vulnerable to rupture when the pubic arch is fractured. Tears may also result from shearing of the prostatic urethra at the superior border of the urogenital diaphragm. Injuries to the prostatic urethra may extend to the bladder neck. Posterior urethral injuries in men as compared to boys almost invariably occur distal to the prostate. Remember, in adults, the mature prostate, puboprostatic ligament and bladder stabilize the prostatic urethra, making it less susceptible to trauma.

Because the female urethra is relatively mobile and short, trauma to the urethra is uncommon. As discussed above, it is reported in less than 6% of cases with associated pelvic fractures in one series of women and girls. When urethral trauma occurs, it is found more commonly in girls than in women. Female urethral injuries are typically divided into avulsions and longitudinal tears. These injuries occur most often from blunt abdominal trauma in motor vehicular crashes and in association with pelvic fractures.

Iatrogenic injuries may occur during instrumentation or surgical procedures (Fig. 268).

B. Internal Reproductive Organs

1. Male Internal Reproductive Organs

(a). Ductus Deferens: The anatomical course of the ductus deferens (vas deferens) makes it vulnerable to traumatic injuries to the scrotum and perineum. The anatomy of the ductus deferens was discussed on pages 104-106, Figs. 81-84). To summarize, the ductus deferens is a fibromuscular tube that is continuous with the **epididymis**. It begins at the bottom (tail) of the epididymis then turns sharply upward along the posterior margin of the testes. The ductus deferens enters the abdominopelvic cavity through the **inguinal canal** and passes along the lateral pelvic wall. It crosses over the ureter and posterior portion of the urinary bladder, and then descends along the posterior wall of the bladder toward the prostate gland. Just before it reaches the prostate gland, each ductus deferens enlarges to form an ampulla (Fig. 270). Sperm are stored in the proximal portion of the ductus deferens, near the epididymis, and peristalic movements propel the sperm through the tube. The proximal portion of the ductus deferens is a component of the **spermatic cord**, which will be discussed in the next chapter under "**Male External Reproductive Organs**."

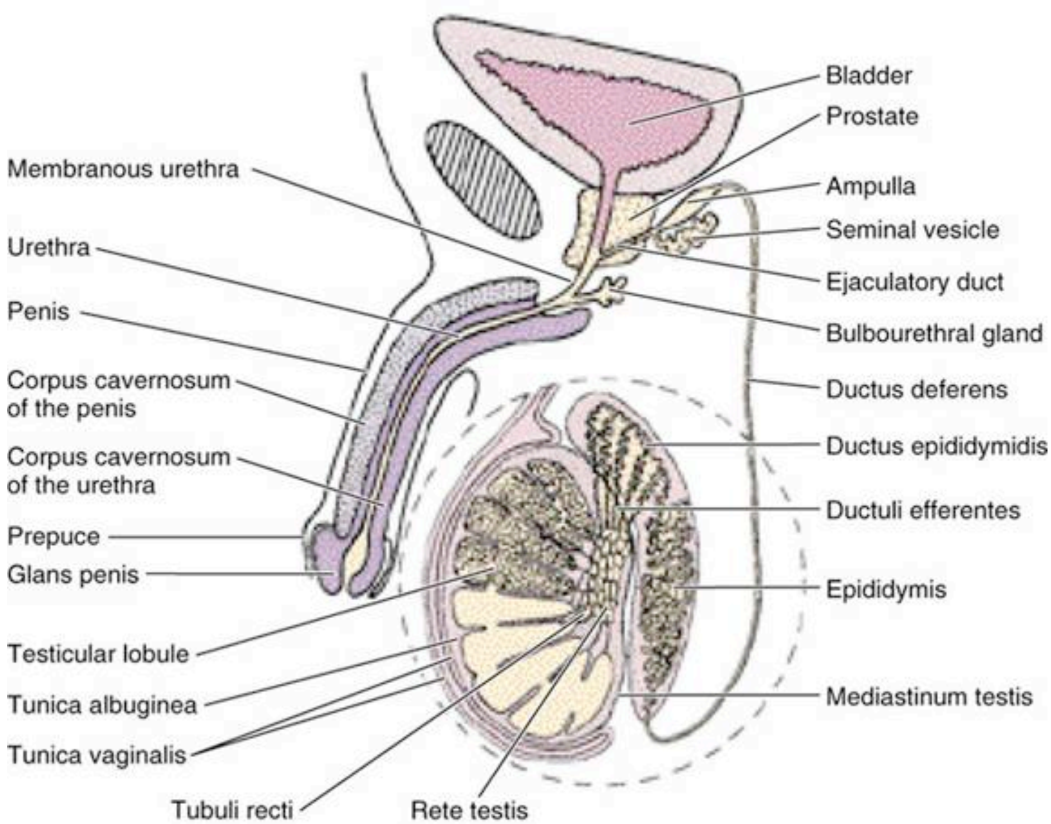


Fig. 270. The above illustration is of the male reproductive organs. (intranet.tdmu.edu.ua)

Direct trauma to either the epididymis and or the vas deferens can occur at the same time as injury to the testicle, perineum or pelvic region. The most common testicular blunt force trauma is sports injuries, such as those incurred while playing rugby and football (Fig. 271). The second most common cause of testicular trauma is a kick to the groin. Less common etiologies include motor vehicular and motorcycle accidents, falls and straddle type injuries.

Fig. 271. This image shows a tackle by Italian defender Chiellini resulting in injury. (arsenalarsenal.wordpress.com)

The most common cause of **penetrating injuries** to the vas deferens are gunshot wounds to the inguinal area (Fig. 272). Stab wounds can also cause penetrating injuries, such as a division of both vas deferens due to a cross stab wound to the root of scrotum.

Fig. 272. This image is of a soldier sustaining a gunshot wound to the genital area. It resulted in extensive injury to his penis, scrotum and internal reproductive organs including the vas deferens and ejaculatory ducts. (wartimegenitaltrauma.wordpress.com)

The ductus deferens may also be injured iatrogenically, such as during inguinal or lower ureteral surgery. The blood supply of the ductus deferens may be injured or ligated at the time of a hydrocelectomy and variococelectomy. The distal aspect of the ductus can be injured during ureteral re-implantation.

(b). Ejaculatory Ducts: As is true of the ductus deferens, the anatomic position of the ejaculatory ducts makes them vulnerable to traumatic injuries to the scrotum, perinuem or pelvic region as shown in Fig. 272. Although the anatomy of the ejaculatory ducts was discussed on pages106-109, Figs. 84-87, we will briefly review the subject. Each ductus deferens, at the ampulla, joins the duct from the adjacent seminal vesicle (one of the accessory glands) to form a short ejaculatory duct. Each ejaculatory duct passes through the prostate gland and empties into the urethra (Figs. 270 & 273).

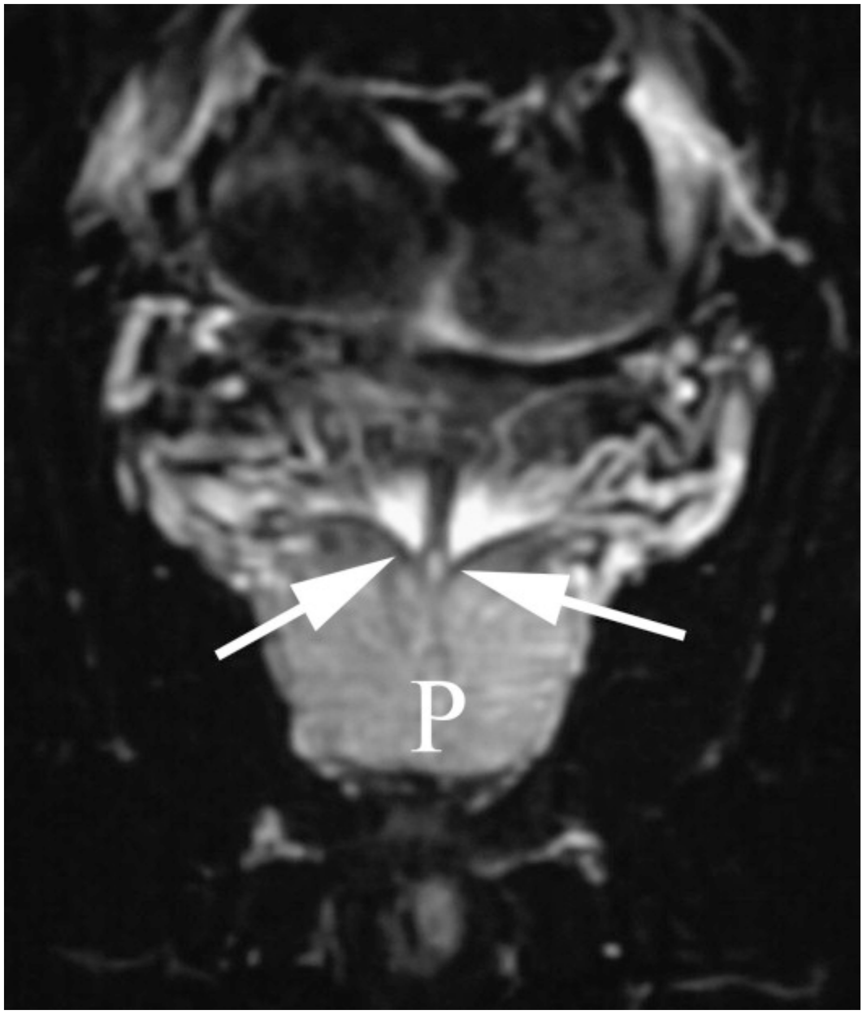


Fig. 273. This is a coronal T2-weighted MR image showing the very narrow ejaculatory ducts (arrows) and prostate (P). (sciencedirect.com)

Traumatic injury to the pelvic region, scrotum, and perineal area, such as shown in Fig. 272, as well as motor vehicular and motorcycle accidents can lead to injury to the ejaculatory ducts. Something as apparently benign as chronic constipation can also lead to ejaculatory duct injury.

Trauma to the spinal cord causing sympathetic nerve injury or T10-12 neuropathy can cause ejaculatory duct dysfunction.

Obstruction of the ejaculatory ducts can also be due to congenital and acquired causes. The congenital form is typically caused by paramesonephric (Mullerian) duct cysts. Acquired forms can be linked to inflammation of the ejaculatory duct due to secondary extension from prostatitis, orchitis, seminal vesiculitis, and urethritis. These inflammatory diseases can be due to common urinary pathogens as well as sexually transmitted diseases like chlamydia.

The ejaculatory ducts can also be injured iatrogenically, such as would occur as a complication of surgical operations on the urethra including men who have undergone a transurethral resection and after urethral valve operations conducted early in childhood. Obstruction of the terminal ends of the ejaculatory ducts can follow either prolonged catheterization or insertion of an intra-urethral device (i.e., “Memokath”) inserted into the prostatic urethra to facilitate bladder drainage in men with severe detrusor instability.

In older men, benign prostatic hypertrophy can occasionally block ejaculatory ducts, as is also true of the presence of chronic prostatitis. When you examine Fig. 273 and note the narrowness of the ejaculatory ducts it is not surprising how easily they can be injured.

(c). Accessory glands: The accessory glands of the male reproductive organs are the seminal vesicles, prostate gland, and the bulbourethral glands.

(1). Seminal vesicles: Injuries to the seminal vesicles probably occurs much frequently than is generally accepted, especially if you consider its anatomic location. Both the seminal vesicles and prostate are located above the soft tissue between the genitals and anus, the area of which is called the **perineum**. Located on either side of your perineum are the **ischial tuberosities**. I will briefly review the anatomy of the seminal vesicles, which has been previously discussed in greater detail on pages 110-113, Figs. 92-99.

The paired seminal vesicles are saccular glands posterior to the urinary bladder. Each gland has a short duct that joins with the ductus deferens as the **ampulla** to form an ejaculatory duct, which then empties into the urethra (Figs. 270, 274 & 275).

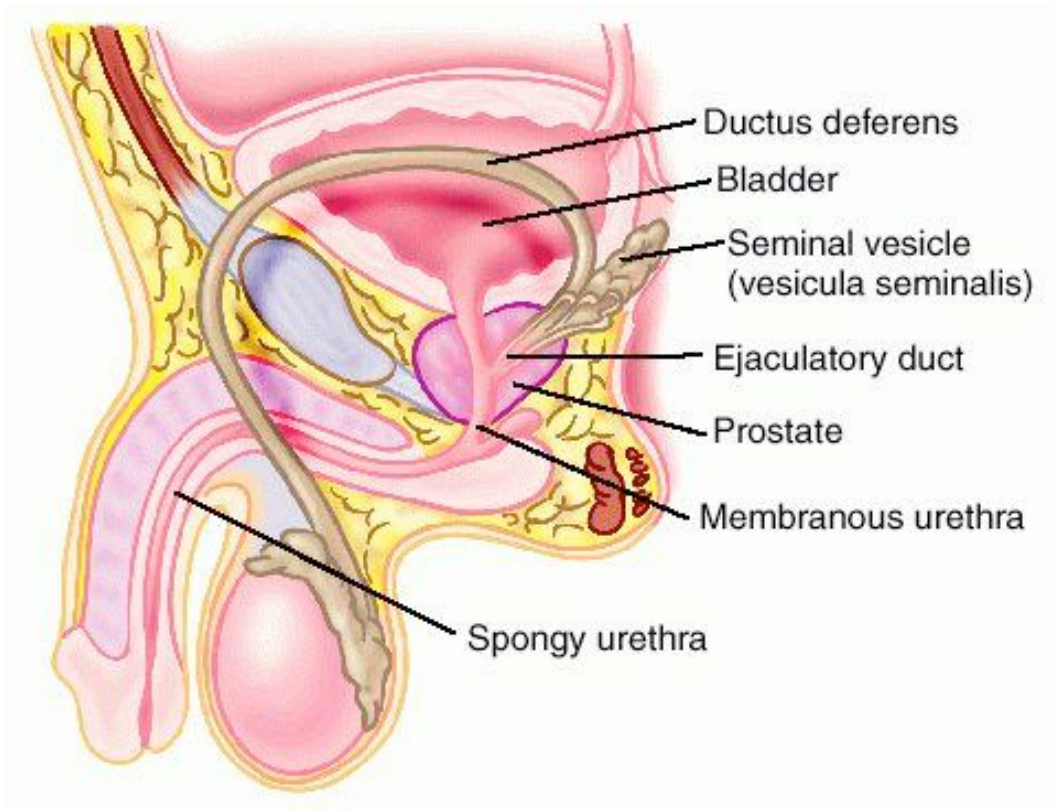


Fig. 274. Male reproductive organs including seminal vesicle. (studyblue.com)

Fig. 275. The above image depicts the anatomic relationship between the rectum, which is surrounded by mesorectal fat within the mesorectal fascia (red arrows). P, prostate and V, seminal vesicles. (radiologyassistant.nl)

The fluid from the seminal vesicles is viscous and contains fructose, which provides an energy source for the sperm; prostaglandins, which contribute to mobility and viability of the sperm; and proteins that cause slight conglutination reactions in the semen after ejaculation.

Due to the anatomic location of the seminal vesicles as depicted in Figs. 270, 274 & 275, they can sustain traumatic injuries due to either blunt force or penetration (Fig. 272) to the scrotum, perineum or pelvic region. Such injuries can be due to motor vehicular or motorcycle accidents, kicks to the perineal region, saddle type injuries, falls with impact to the groin and ports related injuries including bicycling.

Because bike seats are very narrow, the middle of the seat often becomes pressed against the soft tissue just below the prostate and seminal vesicles.

Fig. 276. Note the narrowness of the seat. Bicycle riding can cause repeated trauma to a man's prostate, chronic prostatitis and male infertility, according to the Tulane School of Medicine. Rarely in can also injure the seminal vesicles. (livestrong.com)

It is unusual for the seminal vesicles to be injured directly, since they are slightly higher than the prostate and thus, do not receive directly the blunt pressure (Fig. 276).

The seminal vesicles may be injured by either gunshot wounds (Fig. 272) or stab wounds, typically in association with penetrating injuries to other pelvic and or abdominal organs.

The seminal vesicles may be injured iatrogenically, such as through the development of a seminal vesicle-perineal fistula following an abdominal perineal resection (Fig. 277). Seminal vesicle-rectal fistulas have also been reported.

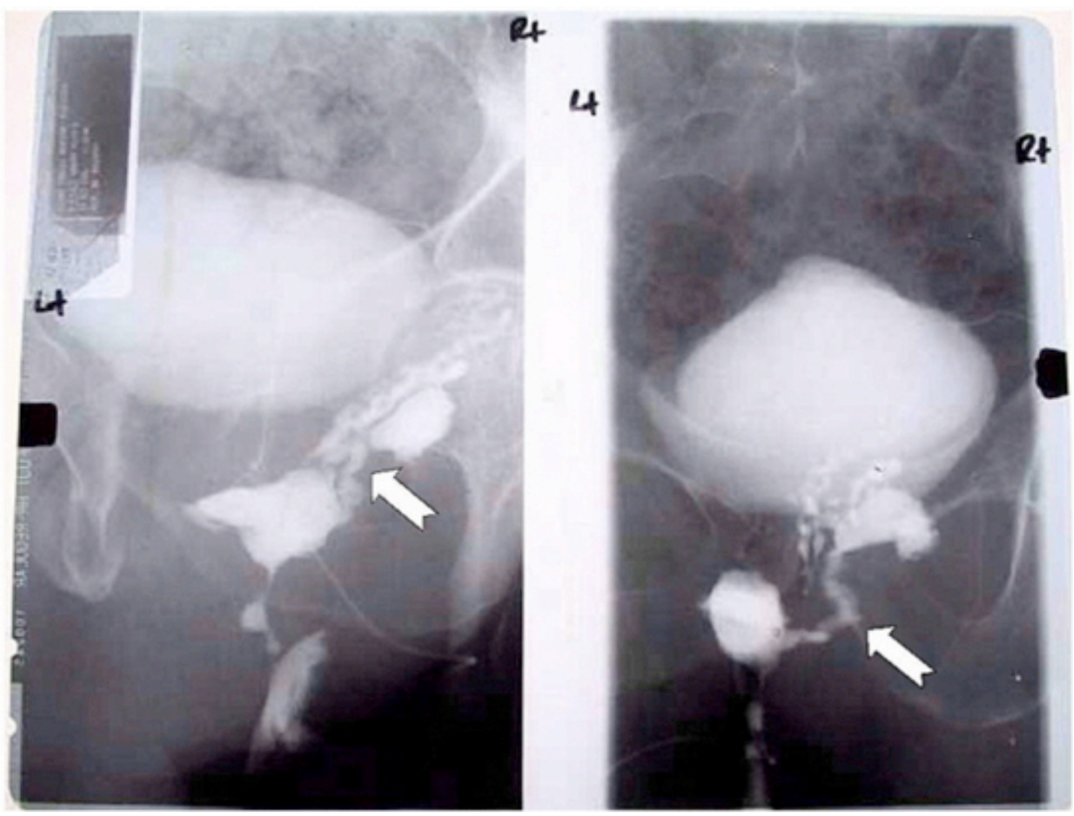


Fig. 277. This is a sinography showing a complex seminal vesicle-perineal fistula (arrowed), which developed in a 61-year-old male who had an abdominal perineal resection for carcinoma of the rectum. (ispub.com)

(2). Prostate: The prostate is located deep within the pelvis, and is closely adherent to the posterior aspect of the anterior pubic arch at the level of the paired **puboprostatic ligaments**. The posterior urethra begins as the **periprostatic urethra** at the level of the bladder neck and extends as a channel through the prostate, anterior to the midline. The **prostatic urethra** ends distal to the **verumontanum**, which is a o 0.5 cm long protuberance found on the ventral wall of the urethra. The paired ejaculatory ducts empty into the prostatic urethra at the level of the verumontanum (Fig. 273).
The prostate gland is a firm, dense structure located just inferior to the urinary bladder. It is about the size of a walnut. Numerous short ducts from the parenchyma of the prostate gland empty into the prostatic urethra (Fig. 278).

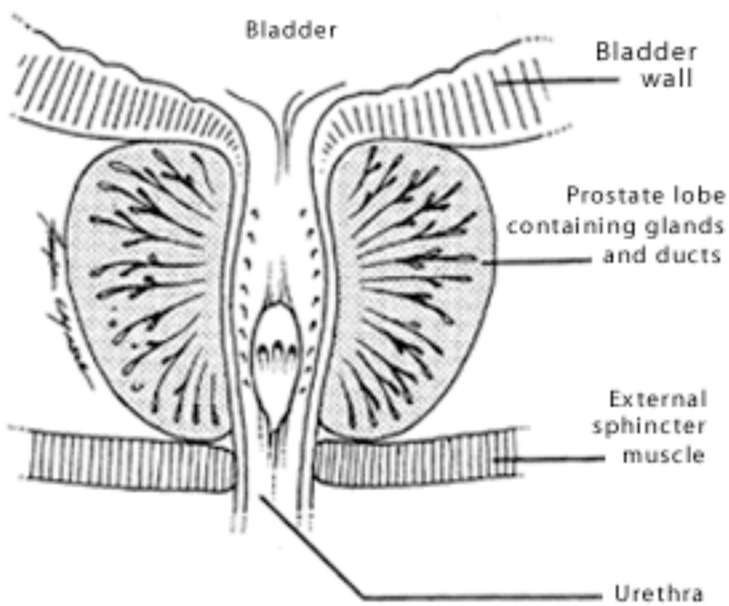


Fig. 278. This drawing shows the ducts of the prostate gland and their entrance points into the prostatic urethra. The verumontanum is located in the center of the prostatic urethra as an oval shaped structure. (duanereade.com)

The secretions of the prostate are thin, milky colored, and alkaline. They function to enhance the motility of the sperm. A more detailed discussion of the anatomy of the prostate can be found on pages 113-122, Figs. 92-99.

Due to the anatomic location of the prostate it can sustain traumatic injuries, whether of a blunt force or penetrating nature delivered to the scrotum, perineum or pelvis.

Blunt force trauma causing pelvic fractures can cause an anterior midline rupture of the prostate and prostatic urethra with secondary involvement of the bladder neck and the subprostatic urethra (Fig. 279).

Fig. 279. This image is of a retrograde urethrogram, which shows a large amount of contrast material extravasation without flow into the prostatic urethra or bladder. The patient had sustained a fracture of the right pubic ramus. (radiographics.rsna.org)

Blunt force trauma to the perineum can also cause a high riding prostate, were the prostate and bladder become detached from the membranous urethra and reach a higher than normal position (Fig. 280). As discussed above, bicycle riding can lead to the development of a traumatic induced prostatitis. It has also been reported that excessive exercise with a leg press machine can indirectly cause a nonbacterial traumatically induced prostatitis due to pelvic to pelvic floor muscle strain.

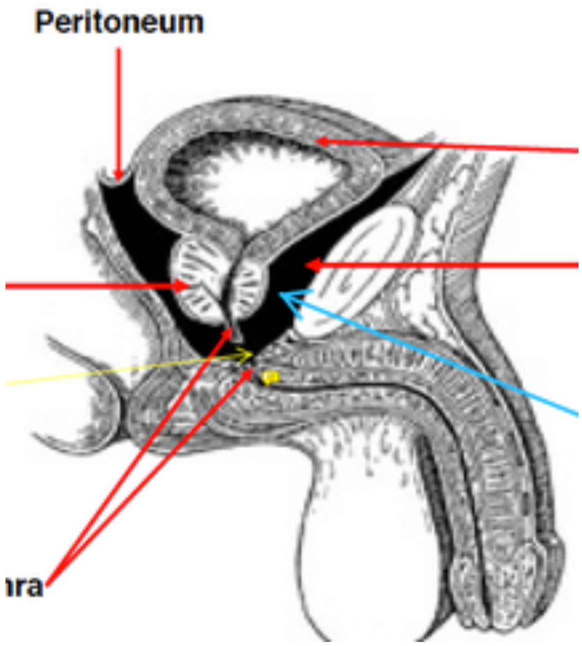


Fig. 280. This is an illustration of a high riding prostate due to the prostate and bladder becoming detached from the transected membranous urethra. Urine accumulates (black space) below the peritoneum and above Colles fascia. There will be associated erectile difficulties because the cavernous nerves are in the same location. (quizlet.com)

Most **penetrating injuries** of the prostate are due to gunshot wounds (Fig. 272). As is true of gunshot wounds in general, low velocity gunshot wounds are much like stab wounds, whereas high velocity gunshot wounds produce marked destruction.

(3). Bulbourethral (Cowper's) Glands: The two bulbourethral glands are small, round, yellow, somewhat lobulated masses approximately 1 cm in diameter. They lie lateral to the **membranous urethra** above the **perineal membrane** located at the base of the **penile bulb** (Fig. 281). A short duct from each gland enters the proximal end of the penile urethra. Additional discussion of the anatomy of the bulbourethral glands can be found on pages 122-124, Fig. 100.

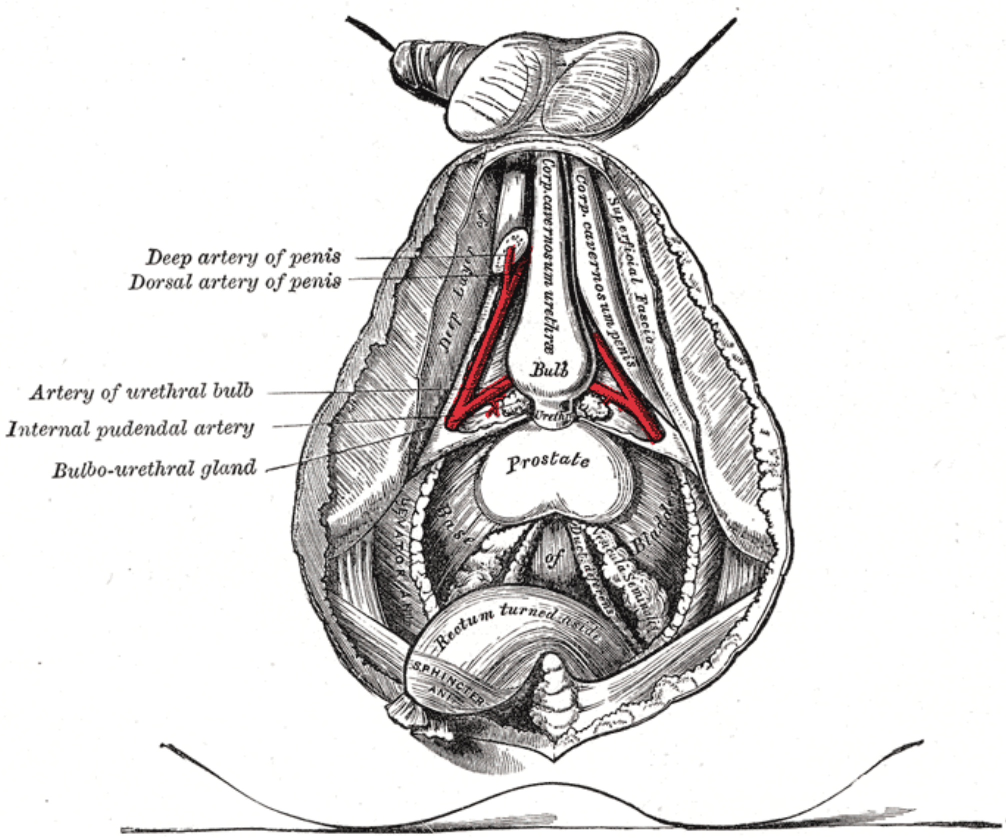


Fig. 281. The bulbourethral gland is labeled at center left. (Wiki)

In response to sexual stimulation, these glands secrete an alkaline mucus like fluid. This fluid neutralizes the acidity of the urine residue in the urethra, helps to neutralize the acidity of the vagina, and provides lubrication for the tip of the penis during intercourse. Due to its anatomic position it can sustain traumatic injuries from either blunt force trauma or penetrating injuries to the scrotum, perineum or pelvis.

Blunt force traumatic injuries are typically caused by straddle type injuries (i.e., motor vehicular and motorcycle accidents, bicycle accidents, falling on to a fence or similar structure, or kicks to the perineum Fig. 282).

Penetrating trauma is most often caused by gunshot wounds, but also can be caused by stab wounds and industrial accidents (Fig. 272).

These glands can also become infected, develop calculi, cysts and become cancerous (Fig. 283).

Fig. 282. This patient sustained an open pelvic fracture with extensive soft tissue destruction of the perineum, scrotum and internal reproductive organs including the bulbourethral glands due to blunt force trauma (msdlatinamerica.com)

FIGURE 1. Scrotal wall edema and skin discoloration.

Reprinted with permission from 'Aho T, Canal A, Neal DE. Fournier's gangrene. *Nat Clin Prac Urol.* 2006;3(1):54-57. doi:10.1038/ncpuro0353. ©2006. Macmillan Publishers Ltd.

Fig. 283. This is an example of Fournier's gangrene (necrotizing fasciitis) involving the deep and superficial fascia of the perineum. The rate of fascial necrosis in Fournier's is reported to be 2 to 3 cm/h. Thrombosis of subcutaneous and cutaneous blood vessels produce gangrene, but the fascial necrosis is usually more extensive than the visible gangrene suggests. Anorectal abscess, genitourinary infection, and **traumatic injury** are the most common causes. (jappa.com)

Pediatric Traumatic Injuries to the Male Internal Reproductive Organs: As in male adults, the internal reproductive organs of a male child may sustain injury following trauma to the scrotum, perineum or pelvic region, whether of a blunt force or penetrating nature. In a male infant who shows evidence of trauma to the genital/perineal area before walking, child sexual abuse should be considered. Once a child begins to walk, which is typically around 12 months of age, injuries to the male genitalia are usually the result of an accident or nonaccidental trauma as in sexual abuse. The latter may be in the form of a bite mark or forceful retraction of the foreskin causing dehiscence of the tissues (Figs. 284 & 293). Remember, findings of acute abrasions, lacerations or bruising of the penis, scrotum or perineum are not considered diagnostic of sexual abuse, however, they are suggestive with their true meaning being interpreted on assessment of all aspects of the investigation. *In pragmatic terms for the forensic pathologist doing the examination, they must be objective, leaving their bias at the door to the morgue. If you walk into a case thinking child abuse, there is going to be a good chance that is the light in which you are going to interpret your findings.*

Fig. 284. There are bit marks at the root of the penis and on the penile shaft and medial side of the left thigh. The victim was an eight-year-old male child who was attacked by a pet dog when the dog was disturbed while eating. (urologyanals.com)

Injuries to the male genital area (scrotum, penis and perineum) is typically in the form of bruises with swelling or minor lacerations. Typically, these injuries occur from falling on an object that is being straddled, such as playground equipment, crossbars of a bicycle, fence, horseback riding, etc. (Figs. 285, 286 & 287) or participating in sports (Fig. 288).

Fig. 285. This image is of a male child who sustained contusions to his penis, scrotum, perineal and suprapubic region due to a straddle injury. (accessemergencymedicine.com)

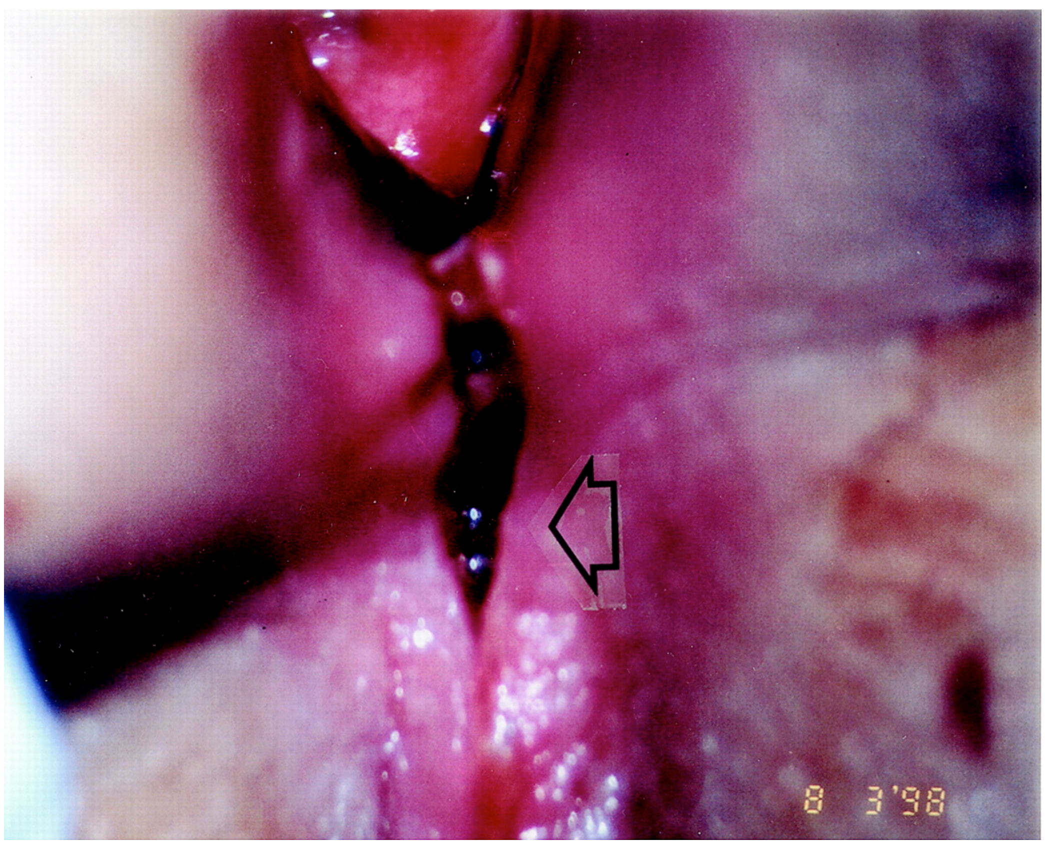


Fig. 286. This image shows a laceration to the perineal region due to a straddle injury in a 5-year-old. (pediatrics.aappublications.org)

Fig. 287. This is an AP radiograph of the pelvis showing bilateral superior and inferior rami fractures. This injury was originally described in horseback riders. Urethral injuries are very common. (pic2fly.com)

Fig. 288. This is an example of how a straddle type injury can occur in soccer. (poweryogasports.com)

Fig. 289. This picture is of Morgan Dennis straddle-mounting bars. You can readily appreciate what would occur should there be a miscalculation. (gymtide.com)

Straddle injuries are further classified as non-penetrating and penetrating. Non-penetrating injuries are typically unilateral and superficial, causing minor trauma to the external genitalia manifested as contusions and at most superficial lacerations of the scrotum or penis (Fig. 285). However, penetrating injuries, those involving the internal reproductive organs and rectum, are more serious and extensive and often indicate sexual abuse. If sexual abuse is suspected, besides the examination of the penis, scrotum and perineum the thighs, suprapubic region and perianal area should be examined looking for bruises, scars, bite marks, and discharge (Fig. 290). A discharge is an important diagnostic feature which raises the question of sexual abuse, most especially if on laboratory examination, one of the sexually transmitted diseases, such as chlamydia and gonorrhea, is identified in a prepubertal child. However, with the possible exception of identifying a sexually transmitted disease in a prepubertal child, and as discussed above, even when physical signs suggestive of child abuse are present, the diagnosis should rarely be made on these alone (Fig. 291). *Confirmation depends on a multidisciplinary investigation. If the child is still alive or before death was able to make a statement how they got these injuries, this is by far the most important single feature. This statement may be supported by any or all the following: medical and forensic evidence, an admission by the abuser, and a comprehensive assessment of the child, family, and social background. In my experience, family members and friends of the family, who the family knows to be responsible or strongly suspect them, are typically protected by the same. It should never be forgotten that all of these are fallible guides to a diagnosis, which should be approached with caution and humility, knowing the serious consequences of diagnostic error in either direction.*

Fig. 290. This is a case of sexual child abuse. Note the bruising of the suprapubic region, right upper thigh and penis. There are therapeutic needle puncture sites in both inguinal regions. (anilaggrawal.com)

Fig. 291. This is case of perianal dermatitis caused by group A beta-hemolytic streptococci and not blunt force trauma. The differential diagnosis of perianal streptococcus dermatitis includes diaper rash, psoriasis, seborrheic dermatitis, sexual abuse, pinworm infestation, non sexual blunt force trauma and inflammatory bowel disease. A rapid strep test or a culture of the perianal area establishes the diagnosis. (aafp.org)

On occasion, boys may suffer non sexual assaults to their genitals, which may lead to trauma of their internal reproductive organs. The largest percentages of boys reporting genital violence were in the seventh and eight grades, with the percentages rapidly declining in grades 9, 10 and 11. Being kicked in the genitals was the most frequently reported event (43%), being hit the next most common (86%), and being hit with an object relatively uncommon (8%). The assailants against boys were primarily other children who they knew and were younger than 18-years-old. On occasion family members may be the assailants (Fig. 292). Eighteen percent of the assaults involved multiple assailants. Forty percent of the perpetrators of genital violence against boys were girls. The assaults against boys tended to take place at school or around the school. Most of the assaults were isolated events, but 20% were part of a series (bullying). Approximately 25% of these non sexual genital assaults against boys resulted in some injury, typically not severe.

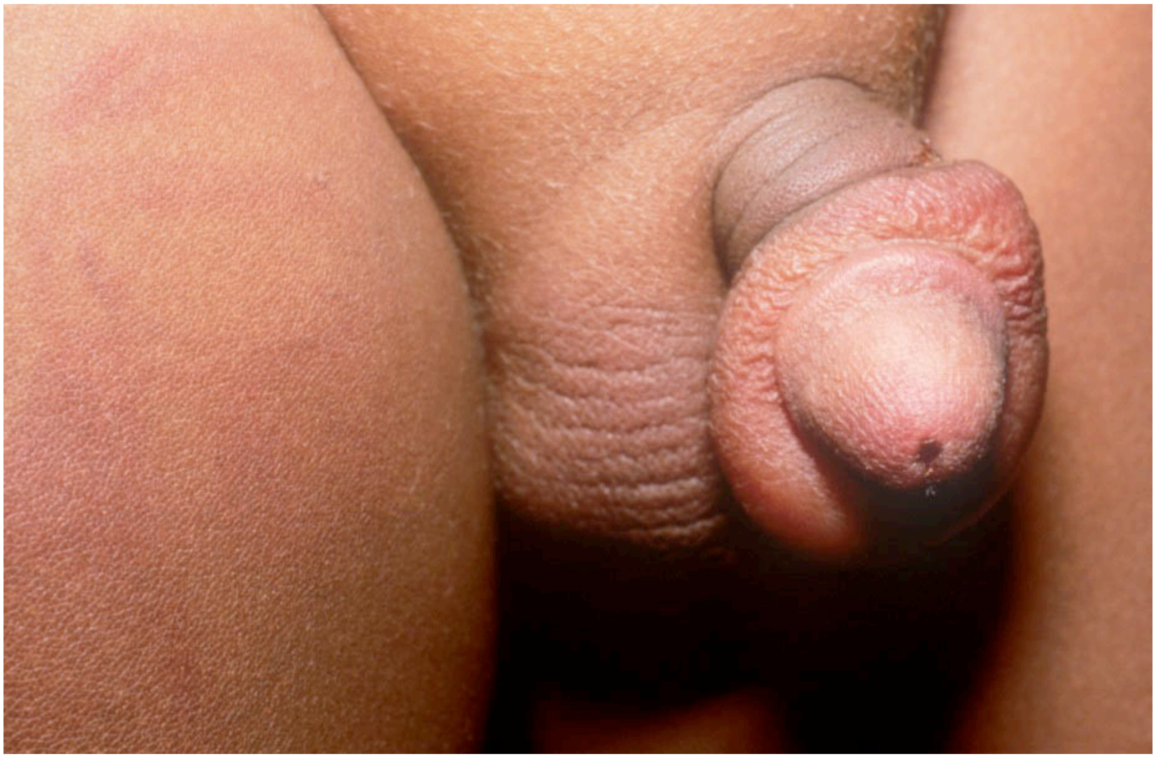


Fig. 292. This picture is of a toddler who was beaten with a belt on and around the genital area. Note the edema of the penis and the imprint of the belt buckle on the right upper thigh. (dermatlas.med.jhmi.edu)

In males, the urethra is more external and thus, it can be compressed between a hard object and the bony pelvis. The urethra can be bruised or torn. The most reliable sign of a damaged urethra is a drop of blood at the opening of the urethra. Other findings are blood in the urine, difficulty starting or painful urination.

Although uncommon, male children can sustain dog bites to the scrotum and or the penis (Figs 284 & 293).   In a case similar to that in Fig. 293, not only was there a traumatic injury of the right testicle but there was also a traumatic resection of the right testicular vas deferens.

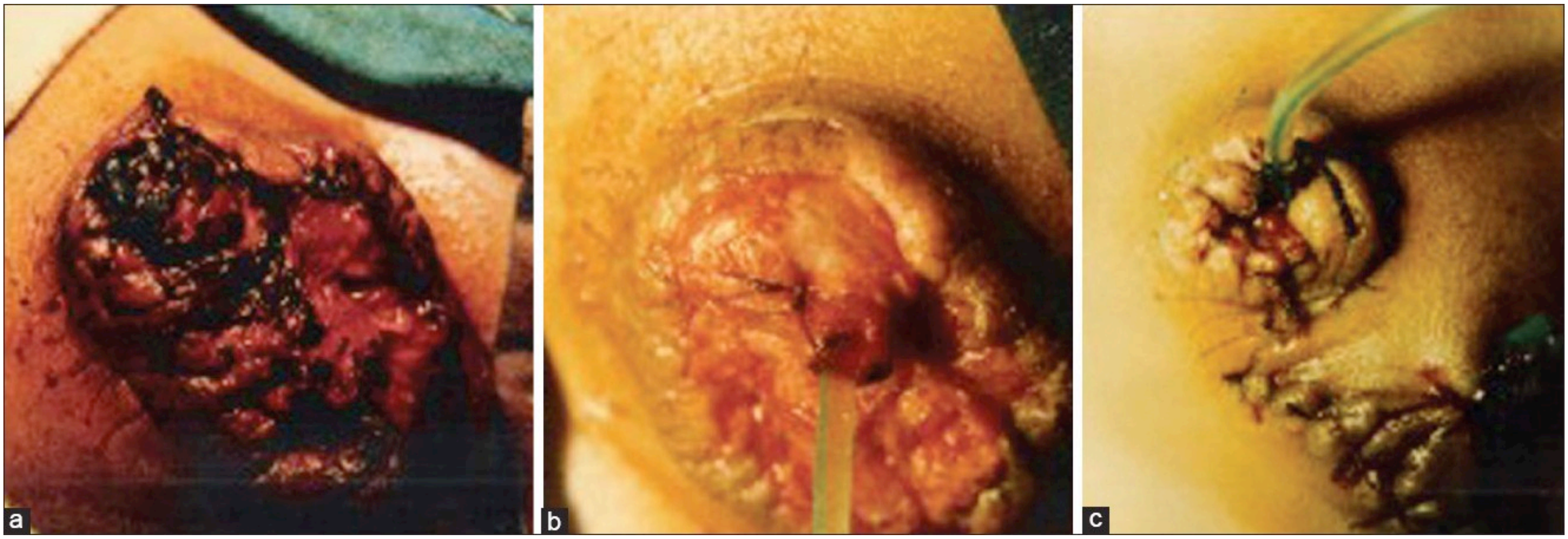


Fig. 293. These images are of a 9-month-old male infant who was brought to the emergency room 6 hours after being attacked by puppies while he was lying in a roadside hut. Clinical examination revealed absence of the glans, most of the shaft of the penis, and both testes. The A image show marked destruction of the penile shaft, testes, and scrotum. B represents the wound after thorough washing and debridement. C represents the reconstructed scrotum and meatus on a very small penile stump after meatoplasty. (urologyannals.com)

There are 1.5 to 2 million dog bites reported in the United States every year. The primary victim of dog bites are children less than 9-years-of-age. Children with dog bites account for up to 1% of all pediatric emergency department visits during the summer months. The offending animals are usually neighborhood or family pets. Injuries from dog bites to the external genitalia as shown in Fig. 293 are rare. In one series, six were to children, of whom 5 were 2-years-of-age or younger, and still in diapers. Three were male and 2 were girls. All involved dogs were family pets. The injuries ranged from avulsion of the external anal sphincter, laceration of the vagina, loss of the testes, loss of the glans penis, and loss of the external genitalia and anus.

Lastly, the male urethra may be injured through self-instrumentation. This occurs because the male urethra curves, however, the object inserted typically does not. Body piercing can also result in unintended penetration of erectile tissue with undesired consequences.

Children may also sustain **operative trauma** to the genitourinary tract, such as in the treatment of anorectal malformations. In one series involving male infants with high anorectal malformations, the incidence of genitourinary trauma was 11%; in those with a low anomaly, the incidence was 2%. There were 3 urethral tears, 4 urethral strictures, 5 urethral diverticula, 2 vas deferens injuries, and 1 ureteric injury.

2. **Female Internal Reproductive Organs**

(**a). Vagina:** The vagina is a fibromuscular tube, approximately 10 cm in length (the vaginal walls have an unequal length, approximately 7.5 cm for the anterior wall and 9 cm for the posterior wall), that extends from the cervix to the vaginal vestibular entrance. It is located between the rectum and the urinary bladder. Because the vagina is tilted posteriorly as it ascends and the cervix is tilted anteriorly, the cervix projects into the vaginal at nearly a right angle (Fig. 294).

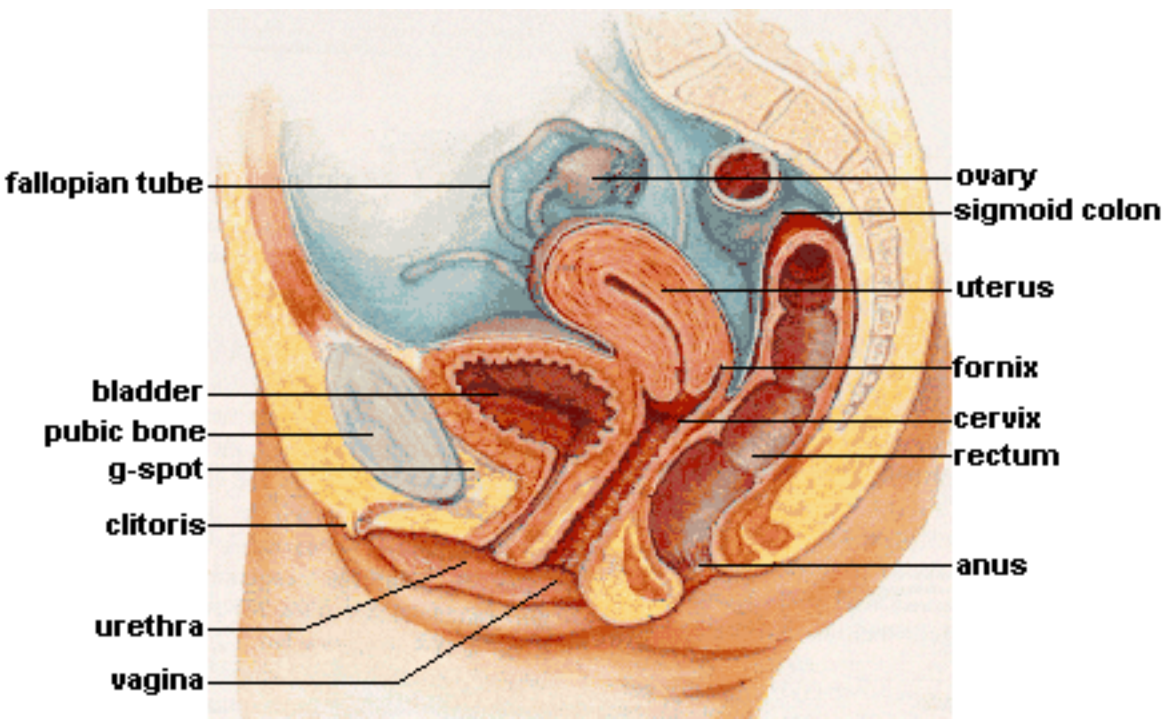


Fig. 294. This is an illustration of the female pelvic anatomy. (vaginal-health-guide-remedy.com)

This spatial orientation of the cervix to the long axis of the vagina predisposes the posterior fornix, as depicted in Fig. 294, to injuries, especially during coitus.

Dickinson pointed out the relative weakness in the structure of the posterior fornix, which is supported by only a few bundles of connective tissue. Also, the right fornix is more prone to injury due to slight variations of the uterocervical axis. There is one report which suggest the possibility of tears in these structures resulting from levator ani muscle spasms along with direct injury.

The vagina serves as a passageway for menstrual flow, receives the erect penis during intercourse, and is the birth canal during childbirth. A more detailed discussion of the anatomy of the vagina can be found on pages 124-138, Figs. 101-114.

Accidental contusions, lacerations, or perforations of the vagina are uncommon. The most common cause of **traumatic injuries** to the vagina are **obstetrically related**. **Non obstetric vaginal lacerations** differ greatly from lacerations sustained during childbirth and typically are classified into two types. The first type is relatively minor and is usually associated with normal intercourse or the first experience of sexual intercourse (FIg. 295).

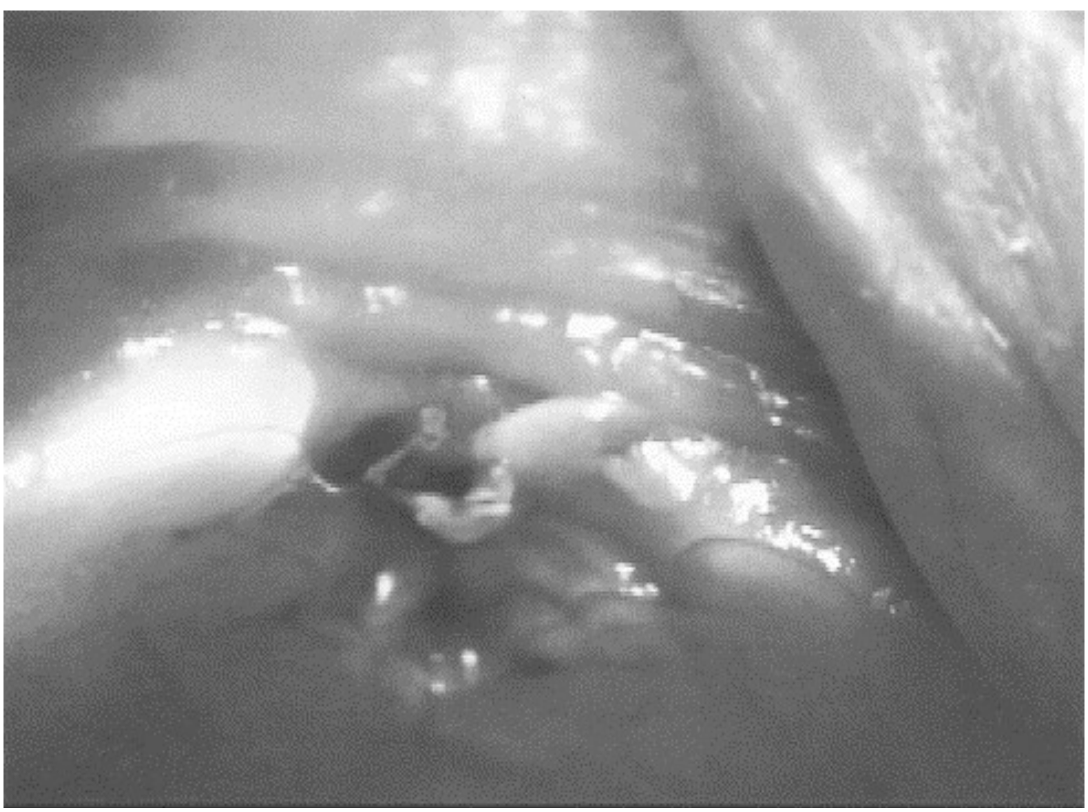


Fig. 295. The above image depicts a superficial vaginal mucosal laceration from digital penetration. (sciencedirect)

The second type is deeper and more extensive, often resulting in copious vaginal bleeding. In these patients, hemorrhagic shock is present in approximately 15%. The lesions associated with this degree of pathology are typically in the distal vagina and usually 3-5 cm in length. They are most commonly located posteriorly and to the right (Fig. 296).

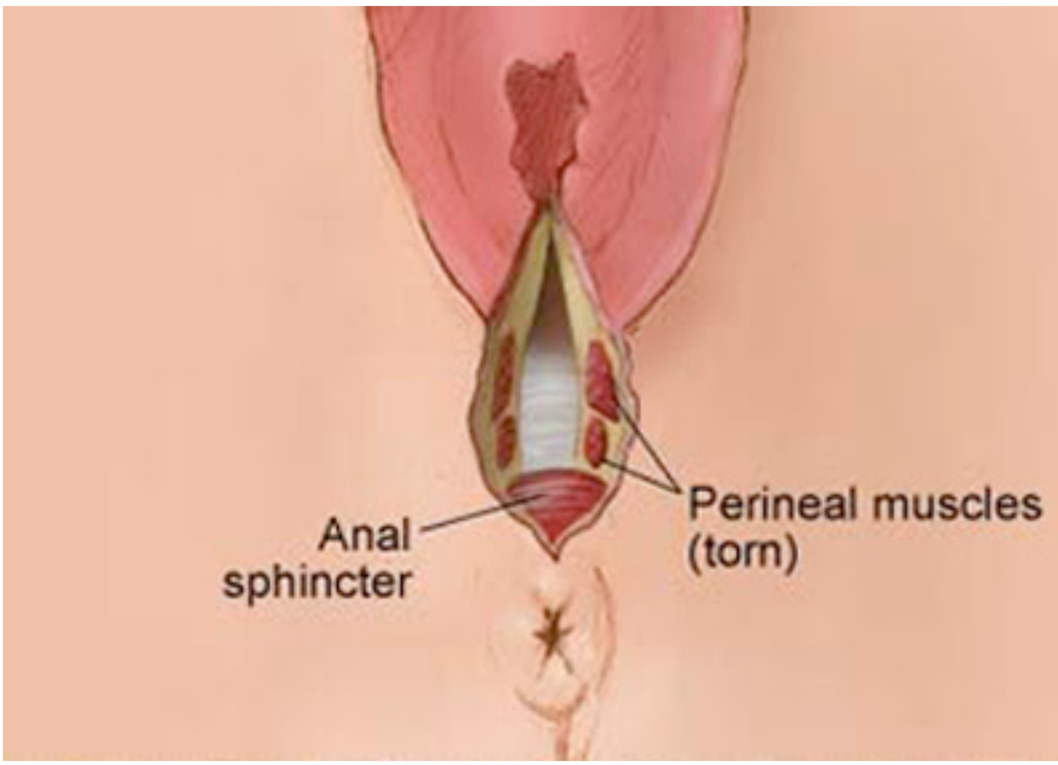


Fig. 296. This is a more severe tear extending into the muscles that surround the vagina. Such tears require sutures for proper closure. (skepticalob.com)

The actual statistics for vaginal trauma is not known because a substantive number of these injuries are not reported. However, in one study conducted by Geist, 75% of women who came to the emergency department with vaginal lacerations require repair. According to Geist's review, these patients usually have marked vaginal bleeding (80%) and perineal and/or lower abdominal pain

(10-20%). Lacerations extending into the peritoneal cavity occur in less than 1%. E. E. Moore *et al.* developed an organ injury scale for vaginal injuries, which is as follows:

Grade I : Contusion hematoma

Grade II : Laceration superficial (mucosal only)

Grade III : Laceration, deep into fat and muscle

Grade IV : Laceration complex extending into the cervix or peritoneum

Grade V : Injury into adjacent organs (anus/rectum/urinary bladder)

Note: advance one grade for multiple injuries up to grade III

As discussed above, the most common mechanism of non obstetric injury to the vagina is coitus. Predisposing and etiologic factors that can account for such injuries include virginity, dis proportion in the size of the male and female genitalia, atrophic vagina in postmenopausal women, friability of tissues, stenosis and scarring of the vagina because of congenital abnormalities, previous surgery, or pelvic radiation therapy. Other factors include rough and violent thrusting of the penis during intercourse, insertion of foreign bodies, and sexual assault (Fig. 297).

Fig. 297. The above image shows a hymenal laceration due to violent penile thrusting. (koronfelsforensicmedicine.blogspot.com)

Coital positioning, especially in the case of dorsal decubitus, with hyperflexion of the thighs and sitting positions have also been suggested as predisposing factors. Women with significant coital injuries may experience significant morbidity and mortality due to the fact they may present late and thus, have significant blood loss. This delay may be due to embarrassment because of the nature and cause of injuries or fear of spousal or parental knowledge. In addition, partner abuse may have played a roll.

There are also **non-coital** causes of vaginal traumatic injuries. Such injuries often occur in a setting of multiple severe injuries and typically require operative intervention. Vaginal lacerations may be a consequence of blunt or penetrating abdominal or pelvic trauma, especially as a result of pelvic fractures. Vaginal lacerations have also been reported in association with injuries sustained while straddle and astride positions (Fig. 298).

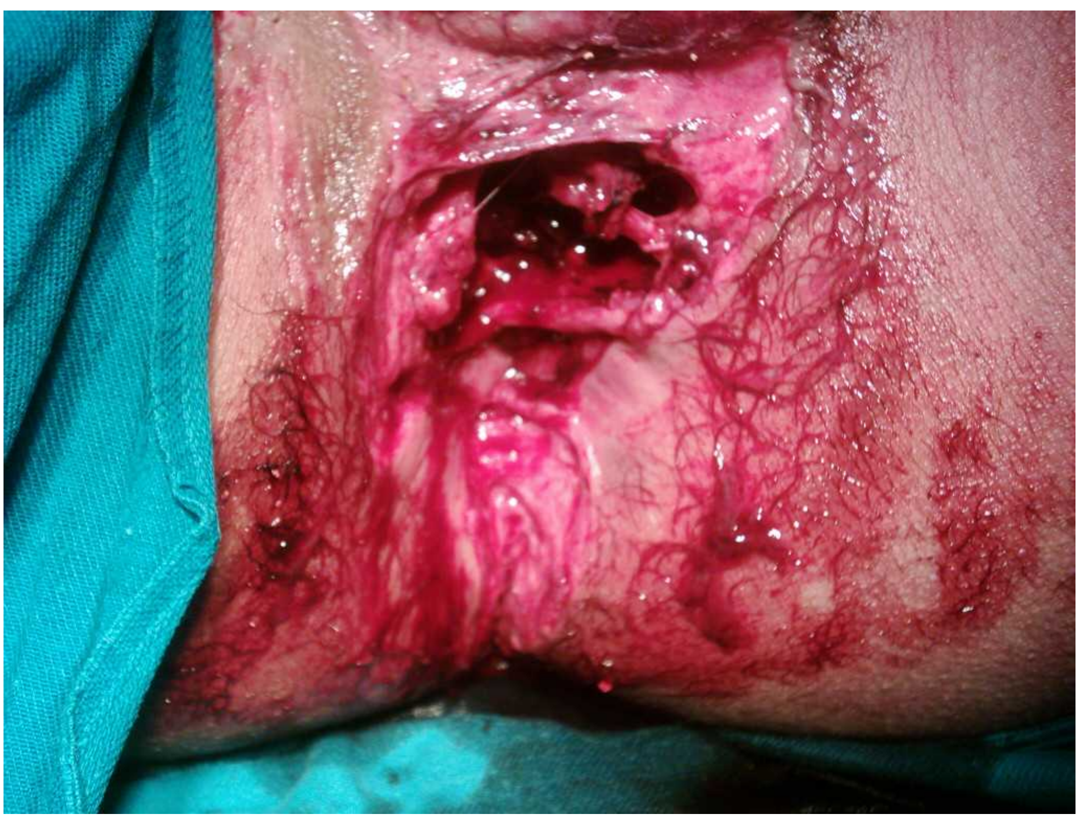


Fig. 298. The above image depicts a vaginal laceration which extends into the perineal region. This injury was due to blunt force trauma. There was no associated pelvic fracture nor was there involvement of the anal sphincter mechanism. (documentingreality.com)

Straddle injuries are more common in young girls and are usually limited to the lower vagina. Genital tract injuries have also been reported in association with water sports, such as water and jet skiing. These injuries range from vulvar hematomas to minor lacerations to life-threatening vaginal lacerations with extension into the perineum (Fig. 298), peritoneum or rectum. Such injuries are typically limited to the lower vagina.

The vagina may sustain **penetrating injuries** from gunshot wounds or stab wounds to the perineal, pelvic or lower abdominal regions. In attempted auto induction of abortion the instrument, which may be a knitting needle, semirigid catheter, paper knife, wirer, elm stick, etc, may be passed directly into the peritoneal cavity through the posterior vaginal fornix (Fig. 294, discussion p 337). Vaginal bleeding has been reported following a substantive blow to the perineum, which forces the vagina up into the uterus, especially a uterus involved with a tumor, such as a leiomyoma.

Vaginal bleeding following either psychological or physical disturbances can also occur. It is not uncommon for either police officers or ambulance personnel on arriving at the scene of a motor vehicular accident to find copious discharge of blood on the clothing of women even though they do not otherwise appear to have been injured. It is believed that menstrual flow may be precipitated or augmented in such circumstances.

Childbirth in of itself can cause lacerations of the vagina, which may be minor or of such a severe nature that the vaginal perforation extends to the bladder or rectum (Fig. 299). If such injuries are survived, but improperly repaired, the may create vesico-vaginal or recto-vaginal fistula. Such severe communicating lacerations, if improperly treated can also lead to an acute onset of sepsis. Remember, the vagina may contain a variety of organisms including streptococci, staphylococci and on occasion Clostridium welchii.

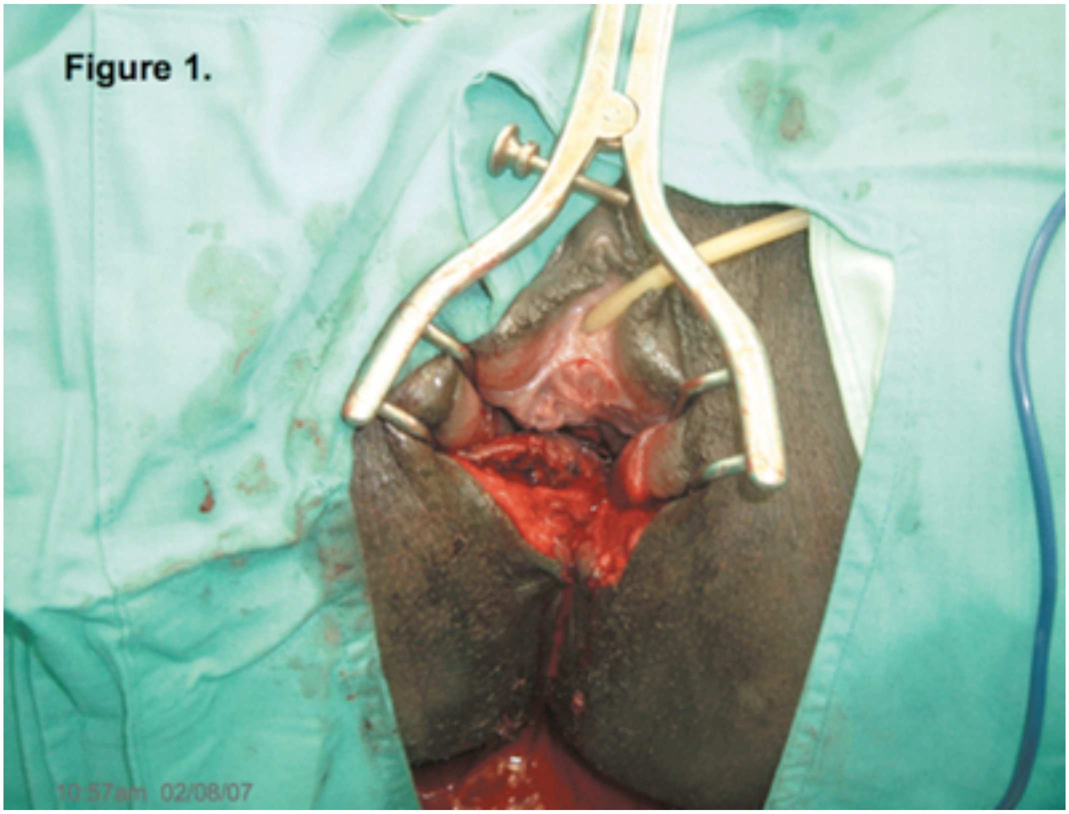


Fig. 299. This image is of a severe perineal laceration sustained during a vaginal delivery. There is a wide communication between the rectum and vagina. The laceration extended 9 cm proximally into the pelvis. (ispub.com)

(b). Uterus: The uterus is a muscular organ that receives the fertilized oocyte and provides an appropriate environment for the developing fetus. Before the first pregnancy, the uterus is about the size and shape of a pear, with the narrow part (isthmus) being directed inferiorly (Fig. 300). After childbirth, the uterus is usually larger, then regresses after menopause. The uterus is lined with **endometrium**. The **stratum functionale** of the endometrium sloughs off during menstruation. The deeper **stratum basale** provides the foundation for rebuilding the stratum functionale. For a more detailed discussion of the anatomy of the uterus see pages 138-160, Figs. 115-136.

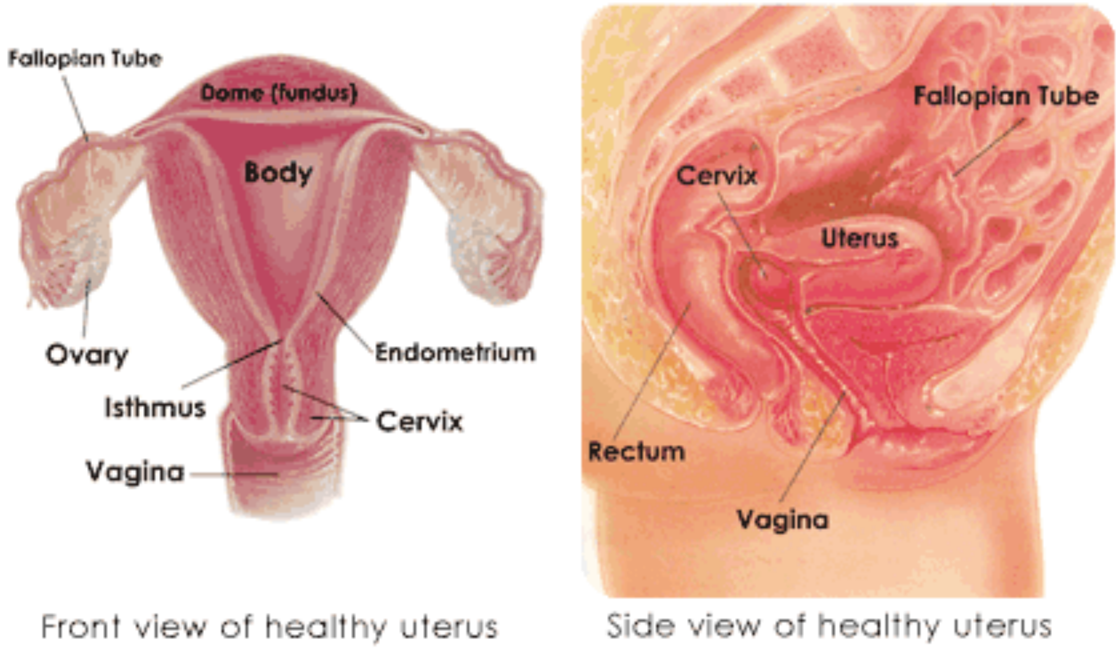


Fig. 300. These images show the front and side views of the uterus. The uterus appears as an inverted pear shaped muscular organ located in the middle of the female pelvis. (alternativesurgery.com)

Overview of Traumatic Injuries to the Uterus

The female internal reproductive organs, including the uterus are rarely injured by blunt force trauma except for the **pregnant uterus** or a uterus involved in an extensive disease process. When blunt force trauma does involve the non pregnant uterus it is usually associated with severe crushing injury with extensive fractures of the pelvis. E. E. Moore *et al.* developed an organ injury scale for the non pregnant and pregnant uterus; that for the non pregnant uterus is as follows:

Grade I : Contusion/hematoma

Grade II : Superficial laceration (< 1cm)

Grade III : Deep laceration (> 1cm)

Grade IV : Laceration of the uterine artery

Grade V : Avulsion/devascularization

Note: advance one grade for multiple injuries up to Grade III.

In regard to the pregnant patients, trauma is the leading cause of non obstetric maternal mortality, as well as a significant cause of fetal loss. Usually, pregnant trauma patients are more likely to sustain serious abdominal injury than non pregnant trauma patients, with most obstetric complications of trauma occurring in third trimester. Accidental injuries occur in 6-7% of pregnancies.

Penetrating trauma accounts for as many as 36% of maternal deaths.

Causes of trauma in pregnancy include motor vehicular accidents (49%), falls (25%), assaults and domestic violence (18%) and gunshot injuries (4%). The incidence of domestic violence increases sharply during pregnancy. Although maternal mortality is quite low in gunshot wounds, fetal mortality is quite high, ranging from 40-70%. Figs. 301, 302 & 303 are of a case in which a mother in her third trimester was shot in the abdomen, however, both her and the baby survived. Overall, the fetal mortality rate due to trauma ranges from 1-34% depending on the series reviewed. The fetus is at significant risk, especially if **placental abruption, placenta previa or uterine rupture** occurs.

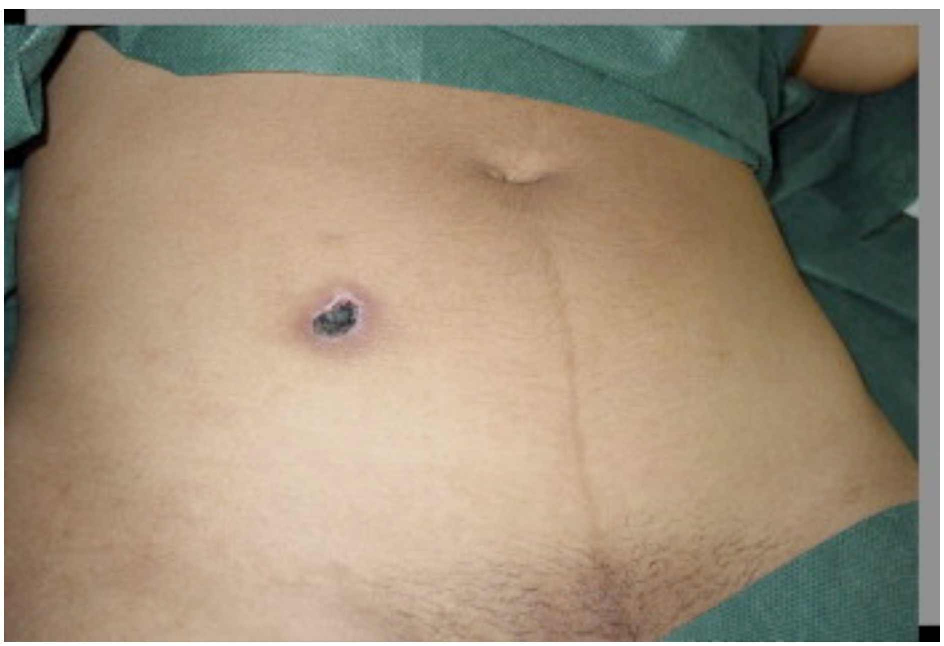


Fig. 301. This image shows a healing gunshot wound of entrance in a women who at the time she sustained the gunshot wound was in her third trimester. The fetus sustained a superficial injury, with survival of both the mother and fetus. (sciencedirect.com)

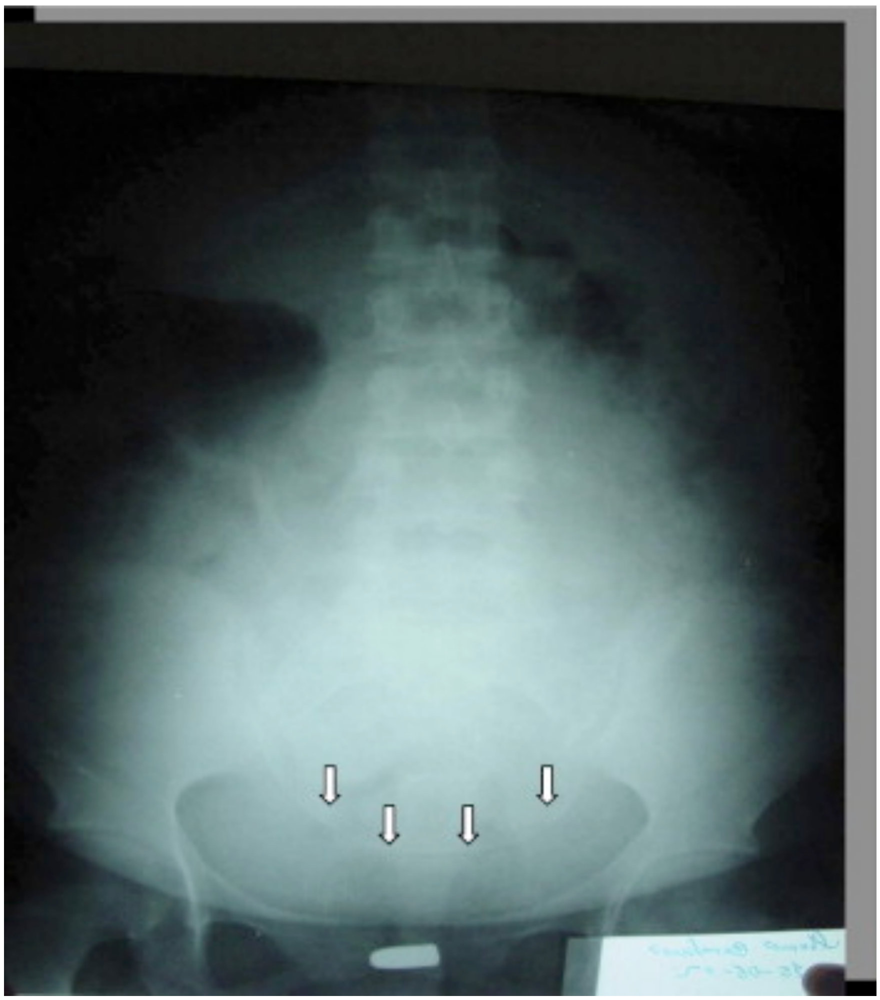


Fig. 302. This is a CT scan of the women depicted in Fig. 301 showing a missile in her uterine cavity; the head of the fetus is in the vertex position denoted by the arrows. (sciencedirect.com)

Fig. 303. This image is of the fetus after delivery, alive and well, except for the superficial, tangental, gunshot wounds on the babies left scapular region and left shoulder (arrows). Note the missile inferior to the baby’s head. (sciencedirect.com)

E. E. Moore *et al.* developed an organ injury scale for the pregnant uterus which is as follows:

Grade I : Contusion/hematoma (without placental abruption)

Grade II : Superficial laceration (< 1 cm) or partial placental abruption < 25%

Grade III : Deep laceration (> 1 cm) occurring in the second trimester or placental abruption > 25%, but < 50%

Grade IV : Laceration involving the uterine artery
Deep laceration (> 1 cm) with > 50% placental abruption

Grade V : Uterine rupture - second trimester
Uterine rupture - third trimester
Complete placental abruption

Maternal deaths usually results in fetal death (Fig. 304 & 305). Head injury and hemorrhagic shock account for the majority of maternal deaths. Although there are reports of late third trimester pregnancies delivered by emergency cesarean section despite lethal maternal injuries, such cases are rare.

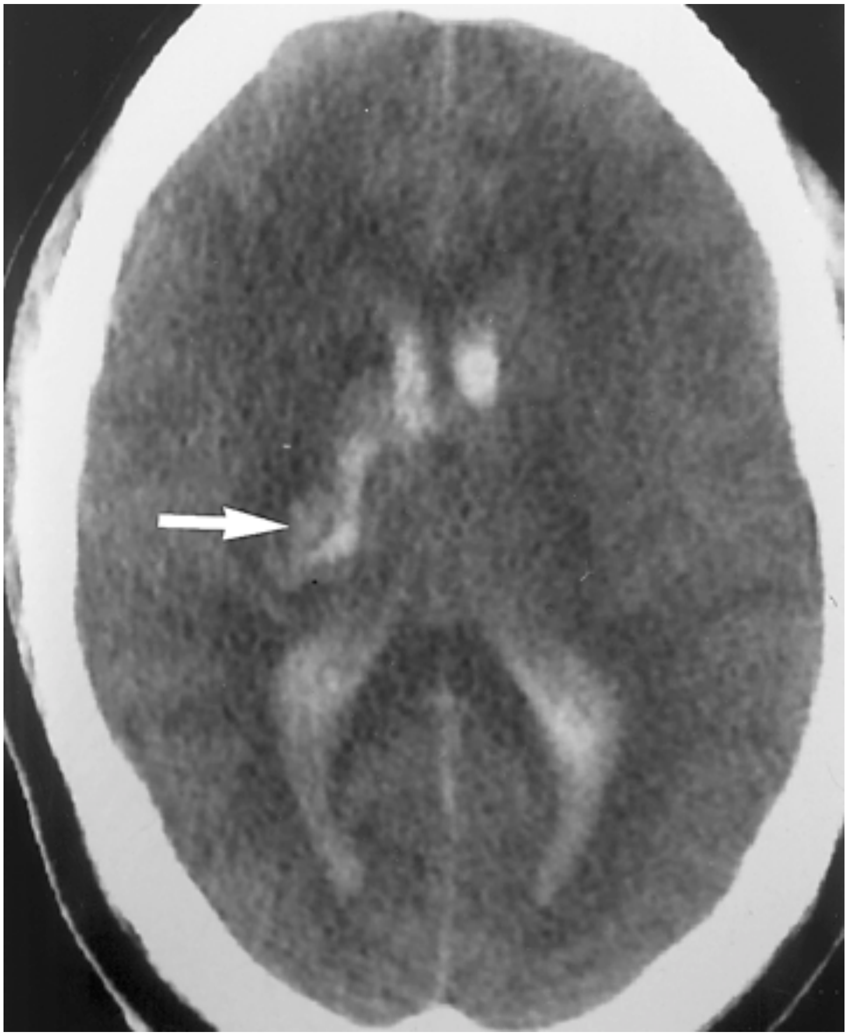


Fig. 304. This is a CT scan of the head of a women who was an unrestrained driver in her first trimester (10 weeks). She sustained a closed head injury due to a motor vehicular accident. The above CT scan shows diffuse axonal injury with an intraparenchymal hematoma and intraventricular hemorrhage. She died as did her baby. (radiograpahics.rsna.org)

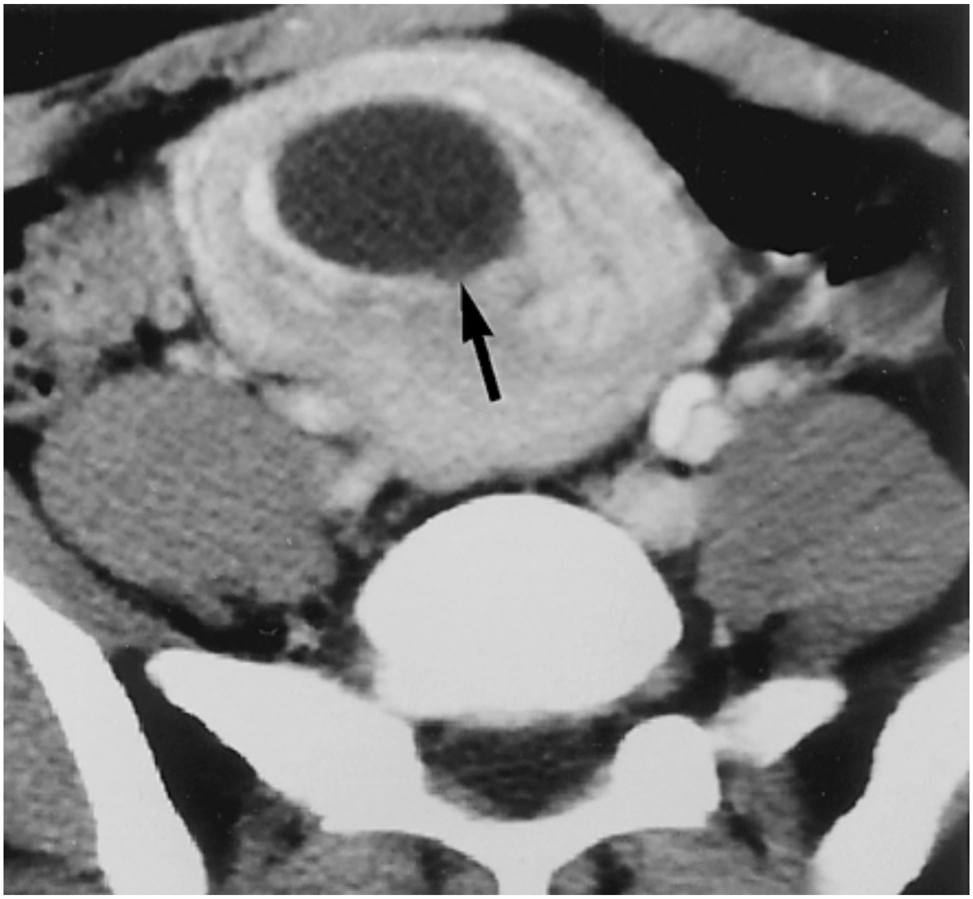


Fig. 305. This is the pelvic CT scan of the women depicted in Fig. 304. It reveals an enlarged uterus with a "bulging," peripherally enhancing, fluid collection that fills the endometrial cavity (arrow). Fetal parts are not seen. Fetal parts are usually not seen on CT until the late first trimester or early second trimester. Both the fetus and mother died. (radiographics.rsna.org)

The best chance for fetal survival is maternal survival (Fig. 306). When the mother survives, the most common cause of fetal loss are **placental abruption and maternal hemorrhage** (Fig. 307).

Fig. 306. This is a pelvic CT scan of a women who was an unrestrained driver in a motor vehicular accident during her 31st.-week of pregnancy. The CT reveals a peripheral area of placental infarction or abruption that does not enhance (arrow). The results of the fetal ultrasound were normal, and the patient's only other injury was an ankle fracture. She was discharged home and had a normal delivery at term. L = fetal liver, P = normal placenta. (radiographics.rsna.org)

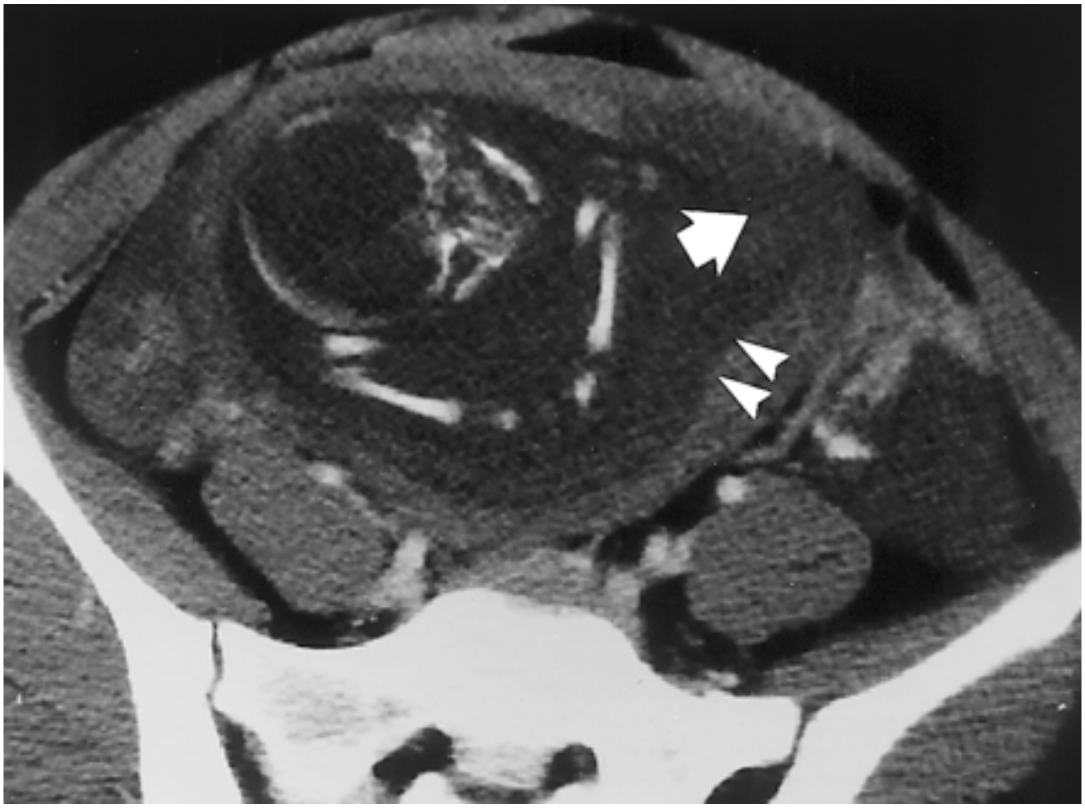


Fig. 307. This is a pelvic CT scan which shows lack of placental enhancement (arrowheads), and a focal uterine wall defect (arrow). Because of these findings and those of the screening ultrasound, which revealed no fetal heart tones or movement, complete abruption with possible uterine injury was suspected. The mother became coagulopathic with both the mother and fetus dying. (radiographics.rsna.org)

In order to fully comprehend the effects of trauma, blunt force or penetrating, on the pregnant patient and her fetus there needs to be an understanding of the physiologic changes of pregnancy. Regarding **maternal physiology**, during the course of pregnancy, the cardiac output increases from 4.5 to 6.0 L / min, with uterine blood flow increasing from 1-10% of the cardiac output. The increases in cardiac output and blood volume begin early in the first trimester and are 30-40% above the non pregnant state by 28 weeks. This relative hypervolemic state and hemodilution is protective for the mother because fewer red blood cells are lost during hemorrhage. The hypervolemia prepares the mother for the blood loss that accompanies vaginal delivery (500 cc) or cesarean section (1000 cc). However, almost 40% of maternal blood volume may be lost before showing signs of maternal shock.

The pelvic and ovarian veins enlarge, the latter approaching the size of the inferior vena cava. The spleen enlarges as much as 50% during pregnancy. Maternal hypertrophy (greater on the right) is common in pregnancy with kidneys enlarging by 1.5 cm. The kidneys enlarge by hypertrophy and hyperemia, which can be seen as early as the tenth week of gestation. This enlargement is to accommodate maternal and fetal metabolic and circulatory requirements, which results in renal blood flow increasing 25-50% during gestation. Such an increase results in blood urea nitrogen and serum creatinine being reduced.

Despite the increase in blood volume and cardiac output, the pregnant patient is susceptible to hypotension from aortocaval compression in the supine position. Although, only about 10% of pregnant patients at term develop symptoms of shock in the supine position, fetal compromise can occur even in asymptomatic mothers. As the uterus enlarges, the diaphragm rises about 4 cm and the diameter of the chest enlarges by 2 cm, increasing the substernal angle by 50%.

There are also important respiratory changes during pregnancy, the most important of which is a decrease in functional residual capacity (FRC). Beginning in the second trimester, there is a 20% decrease in FRC coupled with a 21% increase in oxygen consumption. In addition, 30% of patients have airway closure during normal tidal ventilation in the supine position. All of these changes predispose to rapid falls in PaO2 during periods of apnea or airway obstruction. Along with the spleen enlarging, the gravid uterus displaces the liver and spleen upward against the ribs and elevates the bladder out of the pelvis, making these organs more prone to injury. Moreover, as the kidneys and spleen enlarge, this in of itself makes them more prone to injury. Also, as the uterus enlarges it displaces the intestines upward and laterally. These changes in anatomy and anatomic position must be kept in mind when assessing traumatic injuries and their relationship to morbidity and mortality either of the mother or fetus.

In addition, the increased levels of progesterone and estrogen during pregnancy inhibit gastrointestinal motility. This is associated with a decrease in competency of the gastroesophageal sphincter, which increases the potential for aspiration. Lastly, due to the neurologic changes which occur during pregnancy there is a

25-40% decrease in anesthetic requirement. This means that even with what one would normally consider a “sedative” dose, can result in substantive respiratory depression and even death, both of the mother and fetus. Should the mother survive a significant respiratory depression, there is the concern for the neurologic development of the fetus.

Concerning **fetal physiology** the effect of trauma on pregnancy depends on the gestational age of the fetus, the type and severity of the trauma, and the extent of disruption of normal uterine and fetal physiology. The survival of the fetus depends on two things, uterine perfusion and delivery of oxygen. The uterine circulation has no auto-regulation, which implies that uterine blood flow is related directly to maternal systemic blood pressure, at least until the mother approaches hypovolemic shock. At that point, peripheral vasoconstriction occurs, which further compromises uterine perfusion. Once hypovolemic shock develops in the mother, the chances of saving the fetus are about 20%.

If fetal oxygenation or perfusion are compromised by trauma the first manifestation will be an abnormal fetal heart rate. This may manifest as a **bradycardia or tachycardia**, a decrease in the baseline variability of the heart rate, the absence of normal acceleration in the heart rate, or recurrent deceleration. **The normal range for the fetal heart rate is 120-160 beats per minute.**

The **fetus** is usually considered **viable** when it has a **50% chance of extrauterine survival**. If neonatal facilities are available, this usually means at **25-26 weeks gestation** or an estimated weight of **750 grams**. More aggressive institutions use 24 weeks gestation or an estimated weight of **500-600 grams** as the cut off point, although chances of **survival are then reduced to 20-30%**. It should be understood, even with the best ultrasound dating criteria, the assignment of gestational age is subject to 1-2 weeks of uncertainty. Thus, decisions on fetal viability are made on the basis of the best gestational age available.

Traumatic Injuries Involving the Pregnant Uterus

Maternal Injury: The pregnant patient is predisposed to the same spectrum of injuries met with in the non pregnant trauma patients. However, there are some distinct differences. For example, retroperitoneal hemorrhage is more common in pregnant patients because of increased blood flow.

Certain injuries in pregnancy are associated with an increased risk of fetal loss. Pelvic and acetabular fractures occurring in pregnancy are associated with a high maternal (9%) and higher fetal (35%) mortality, increasing to 75% for severe fracture patterns (Fig. 308 & 309). In penetrating abdominal trauma, uterine and fetal injury increase as the gravid uterus enlarges, while offering greater maternal protection.

Fig. 308. This is a CT scan showing a right acetabular fracture (arrows) in a woman who was an unrestrained driver in a motor vehicular accident during her 22nd-week of pregnancy. She also had a right sacroiliac joint diastasis which is not shown. No fetal heart tones were heard on a screening ultrasound. (radiogrpahics.rsna.org)

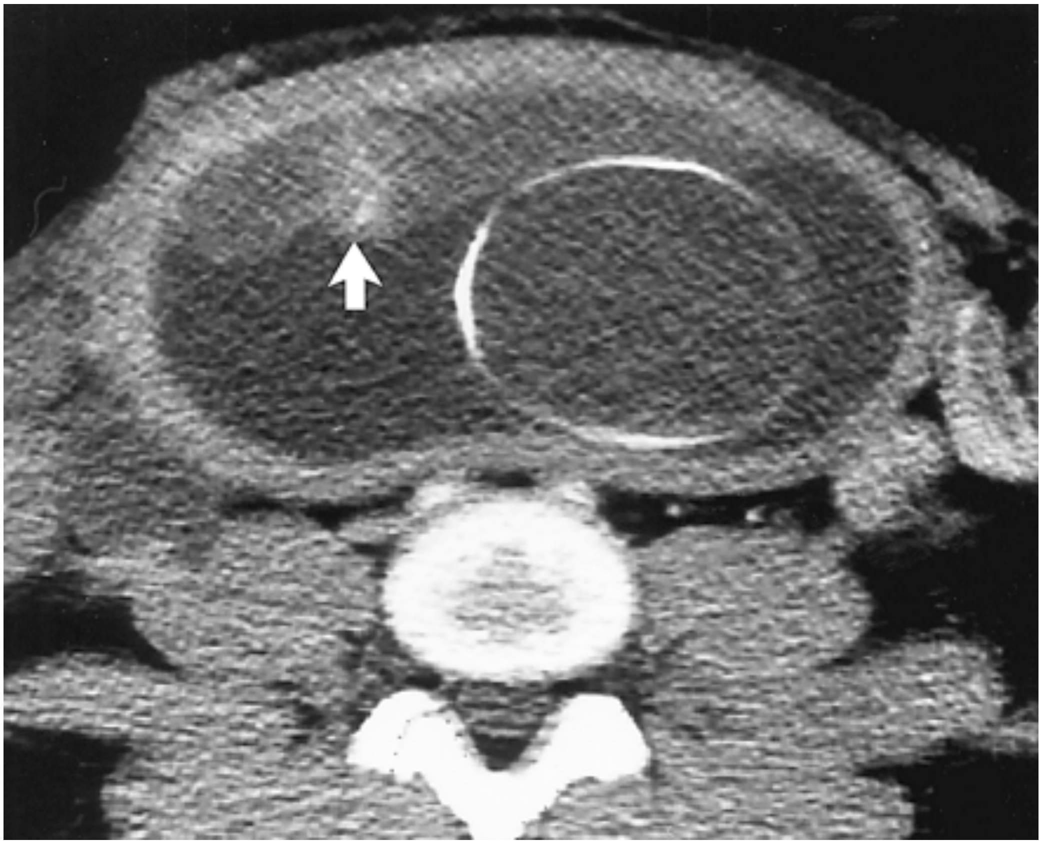


Fig. 309. This is the abdominal CT scan on the mother in Fig. 308. It shows that only a small part of the placenta enhances (arrow). The patient had a spontaneous stillbirth the next day. Pathology examination of the placenta revealed an acute placental infarction. The mother recovered from her skeletal injuries. (radiographics.rsna.org)

When the mother survives, the most common cause of fetal death are placental abruption and maternal hemorrhage (Fig. 307). As previously discussed, a pregnant women can lose 30-40% of her blood volume before her vital signs change. Because there is no uterine auto regulation, maternal blood pressure does not accurately reflect uterine blood flow. Maternal hemorrhage causes pronounced uterine vasoconstriction, that while protective to maternal hemodynamics, leads to fetal hypoxia, acidosis, and even death. Severe maternal head injury is associated with an increased risk of fetal loss thought to be due to alteration in the hypothalamic-pituitary-adrenal axis.

Injury to the Pregnant Uterus: Complications of trauma to the pregnant uterus include spontaneous abortion, preterm labor, premature rupture of membranes, placental abruption (Figs. 306 & 307), placental laceration and infarction (Fig. 309) and uterine laceration and rupture (Fig. 307). As previously indicated, most injuries occur in the third trimester.

The **most common obstetric problem** caused by trauma is uterine contractions. Trauma to the uterus can injure the myometrial and decidual cells, which in turn can destabilize myometrial and decidual lysosomes. These lysosome can release prostaglandins and arachidonic acid, which can cause uterine contractions leading to premature labor. Progression to premature labor depends on the size of uterine damage, the amount of prostaglandins and arachidonic acid released, and the gestational age of the pregnancy.

The **most common injury** to the pregnant uterus after receiving blunt trauma is **placental abruption** (Figs. 310 & 311). This is due to the shearing between the relatively elastic uterus and the rigid placenta. Abruption can occur with little or no external signs of injury to the abdominal wall. The incidence of placental abruption is 1-5% with minor trauma and 30-50% with major trauma. **Risk factors for placental abruption** apart from trauma include **advanced maternal age, tobacco use, cocaine use, maternal hypertension, and pre-eclampsia**. Clinical findings that indicate abruption include vaginal bleeding, abdominal cramps, uterine tenderness, amniotic fluid leakage, maternal hypovolemia, a uterus larger than normal for the gestational age, or a change in the fetal heart rate. Fetal distress is associated with placental abruption 60% of the time and should be treated with immediate intervention.

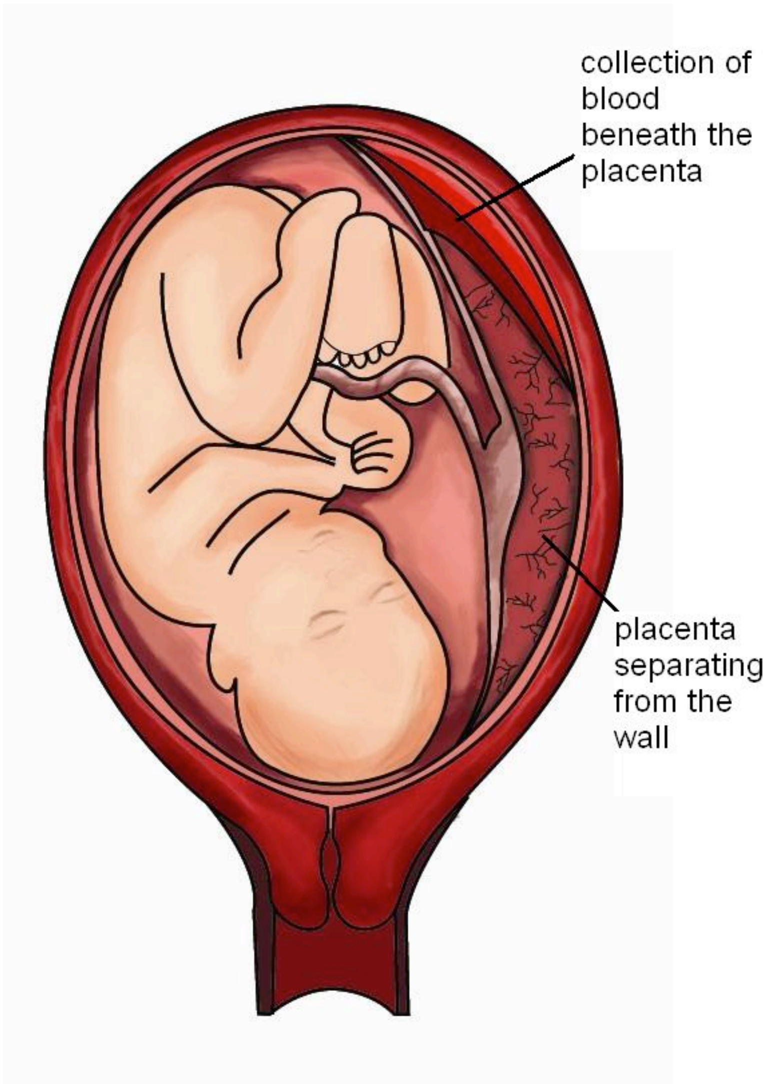


Fig. 310. This is an illustration of placental abruption. Blood is collecting beneath the placenta. This is a condition where a normally situated placenta abnormally separates from the wall of the uterus before the baby is born. It occurs in about 1 in 200 pregnancies. Placental abruption usually occurs in the third trimester, but can occur at any time after 20 weeks. (pitterpatter.com)

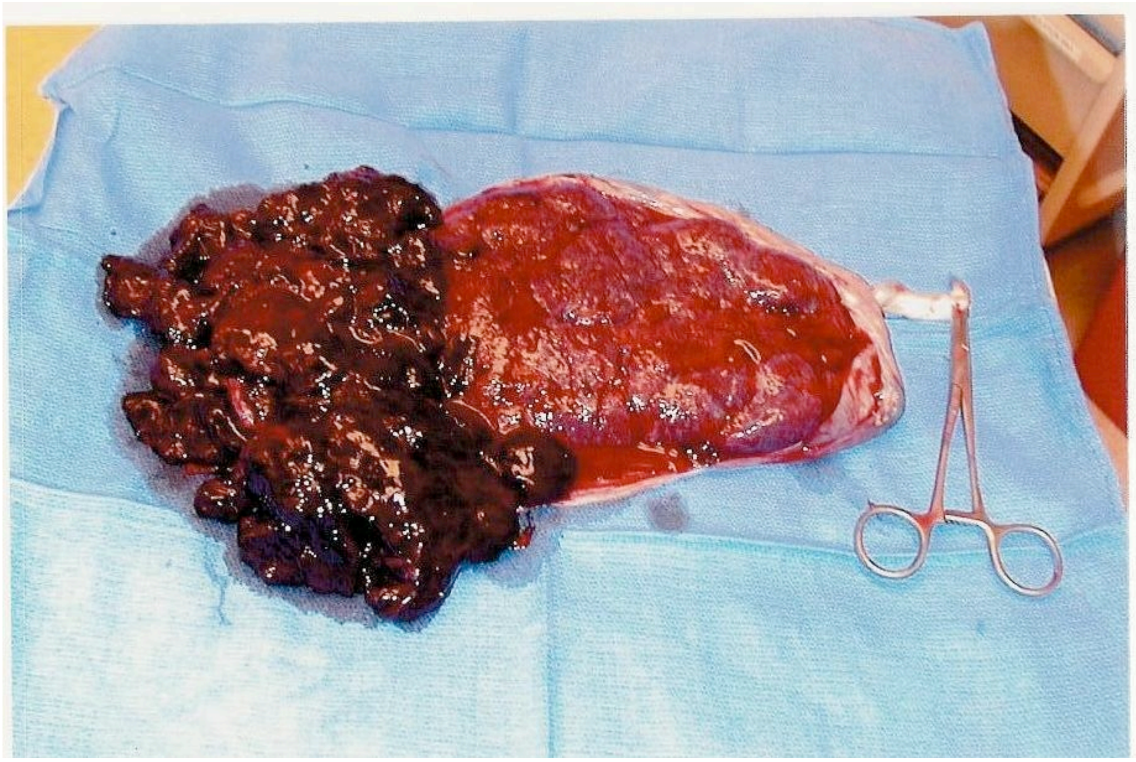


Fig. 311. This is an actual placenta from a delivery in which placental abruption took place. The marked hemorrhagic area on the left is the abruption. (gfmer.ch)

There are several types of placental abruption. **Marginal placental abruption** occurs when there is utero-placental separation at the placental margin (Fig. 312). **Retroplacental abruption** involves the central placenta and carries a worse prognosis (Fig. 311). Placental abruption can lead to preterm labor, fetal distress, low birth weight, oligohydramnios, fetal death, and maternal coagulopathy due to the release of thromboplastin substances from the placenta (Fig. 307). Small placental abruptions may be well tolerated. The larger the abruption the worse the prognosis, with **greater than 50% abruption of the placental surface leading to 75% fetal mortality.**

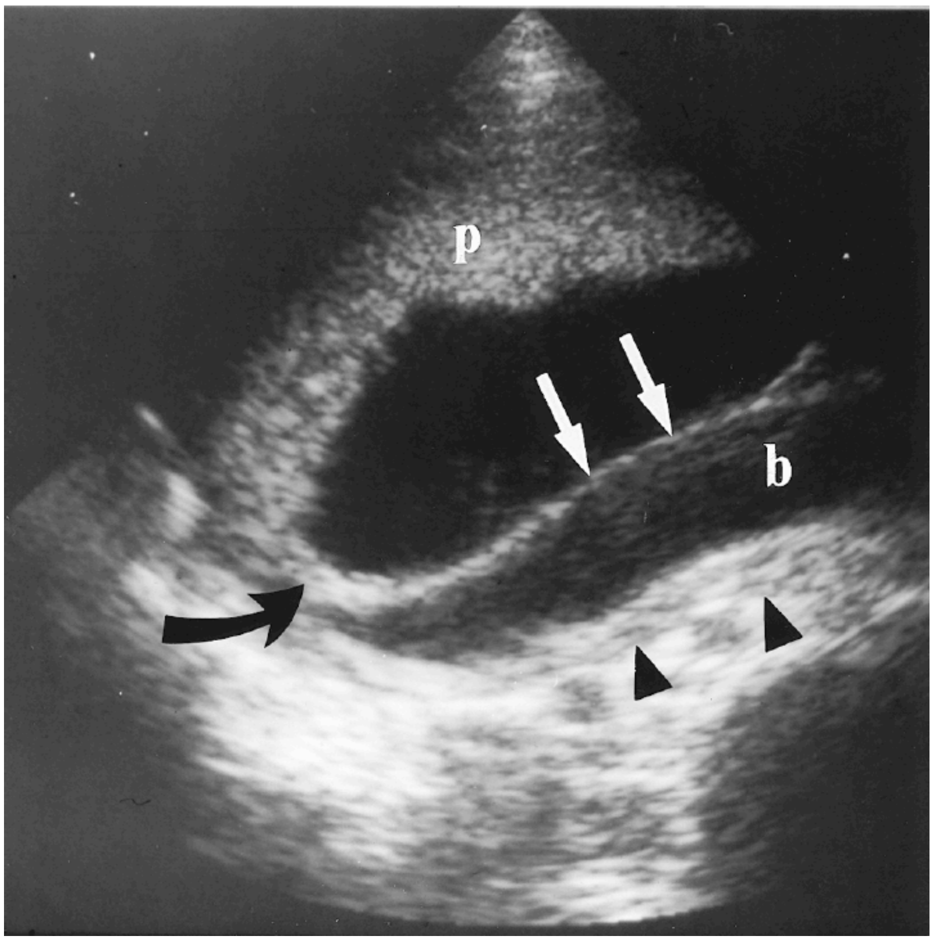


Fig. 312. This is an example of subchorionic hemorrhage (marginal placental abruption). This results from venous bleeding caused by detachment of the margin (curved arrow) of the placenta (p). Low pressure bleeding (b) dissects beneath the chorion (white arrows) separating it from the myometrium (black arrowheads). (radiographics.rsna.org)

There is another condition referred to as **placenta previa**, which can also lead to complications for the mother and fetus. Placenta previa is an obstetric complication in which the placenta is attached to the uterine wall close to or covering the cervix (Fig. 313), which can lead to the placenta shearing off and bleeding. **It is the leading non traumatic cause of antepartum hemorrhage (vaginal bleeding)**. However, due to the placentas precarious anatomic position, blunt force trauma to the lower abdomen, pelvis or perineum can cause that portion of the placenta overlying the lower segment of the uterus (isthmus) or cervix to shear off and lead to vaginal hemorrhage.

The risk factors for the development of this condition are: abnormal vascularization of the endometrium due to scarring or atrophy from previous trauma; surgery or infection; alcohol use during pregnancy; women who have had previous pregnancies, especially closely spaced pregnancies; smoking during pregnancy; cocaine use during pregnancies; women who are younger than 20 or older than 30 are at increased risk as they get older; and women with a large placenta due to twins or erythroblastosis are also at a higher risk.

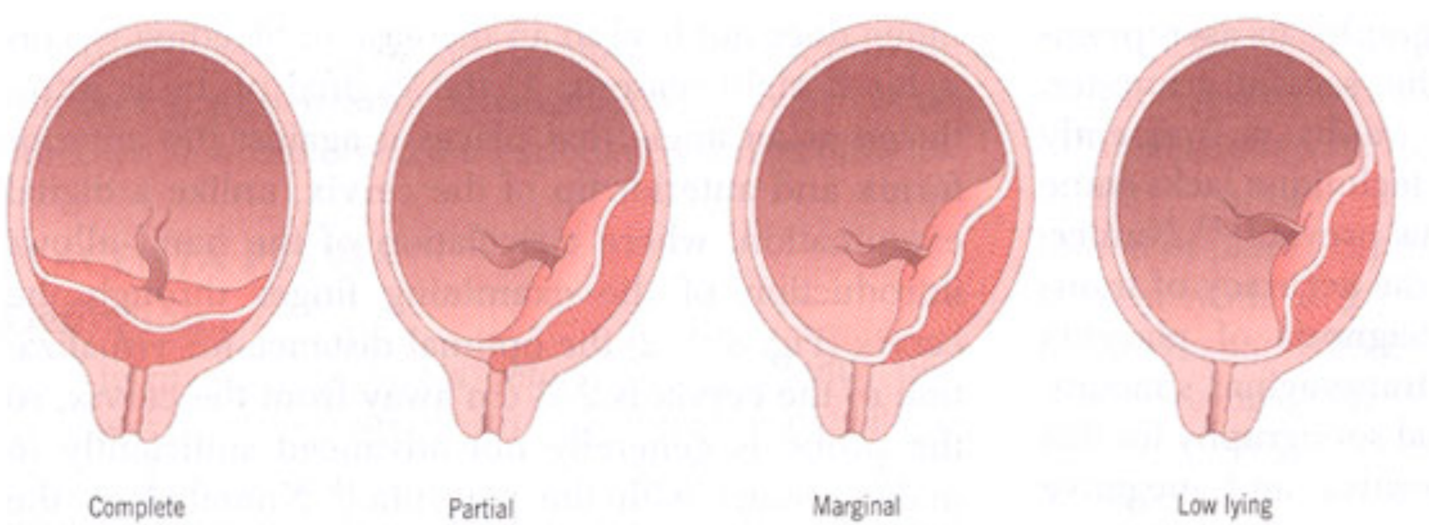


Fig. 313. The above illustration shows the various types of placenta previa. With placenta previa, the placenta is implanted in the lower uterine segment, where it encroaches on the internal cervical os. This disorder, one of the most common causes of bleeding during the second and third trimesters of pregnancy, although it can occur in the latter part of the first trimester, occurs in approximately 1 in 200 pregnancies, more commonly in multigravidas than in primigravidas. Generally, termination of pregnancy is necessary when placenta previa is diagnosed in the presence of heavy maternal bleeding. Maternal prognosis is good if the hemorrhage is controlled; fetal prognosis depends on the gestational age and amount of blood lost. (familymedicinehelp.com)

Uterine lacerations and rupture are uncommon blunt force traumatic injuries, occurring in less than 1% of those sustaining major trauma. Uterine rupture is one of the most life-threatening emergencies in obstetrics, associated with almost 100% fetal mortality (Fig. 307). Maternal mortality occurs in fewer than 10% of cases and usually results from associated injuries. Prior cesarean section, previous uterine surgery and congenital uterine anomalies increase the risk for uterine rupture in blunt trauma. Penetrating trauma is an independent risk factor. **Injury to the Fetus:** Direct fetal injury is uncommon in the pregnant trauma patient because the fetus is afforded protection by the maternal body wall, uterus, and amniotic fluid. By the late third trimester, the volume of amniotic fluid relative to the volume of the fetus is decreased, providing less of a cushioning effect. The most common injuries to the fetus are **skull fracture and head injury,** seen late in third trimester with cephalic presentation, often in the setting of maternal pelvic fracture. Fetal head injury is almost universally lethal to the fetus. It should also be also pointed out that not all fetal intracranial pathology is trauma related (Figs. 314 & 315).

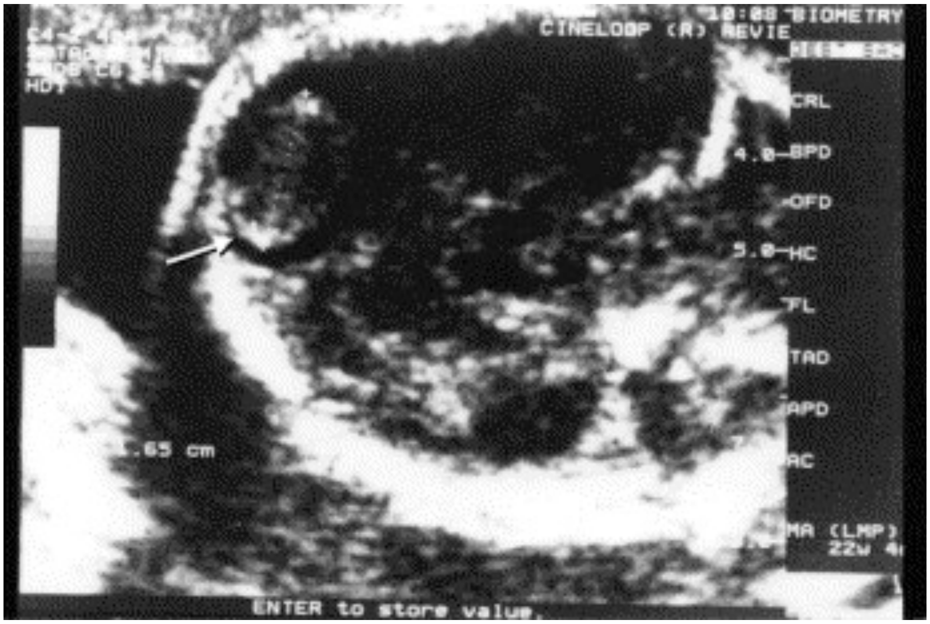


Fig. 314. This is an ultrasound of a pregnant women at 22 weeks gestation. The arrow denotes a rounded hyperechogenic mass in the posterior fossa suggesting a subdural hematoma. There was no history of trauma. (sciencedirect.com)

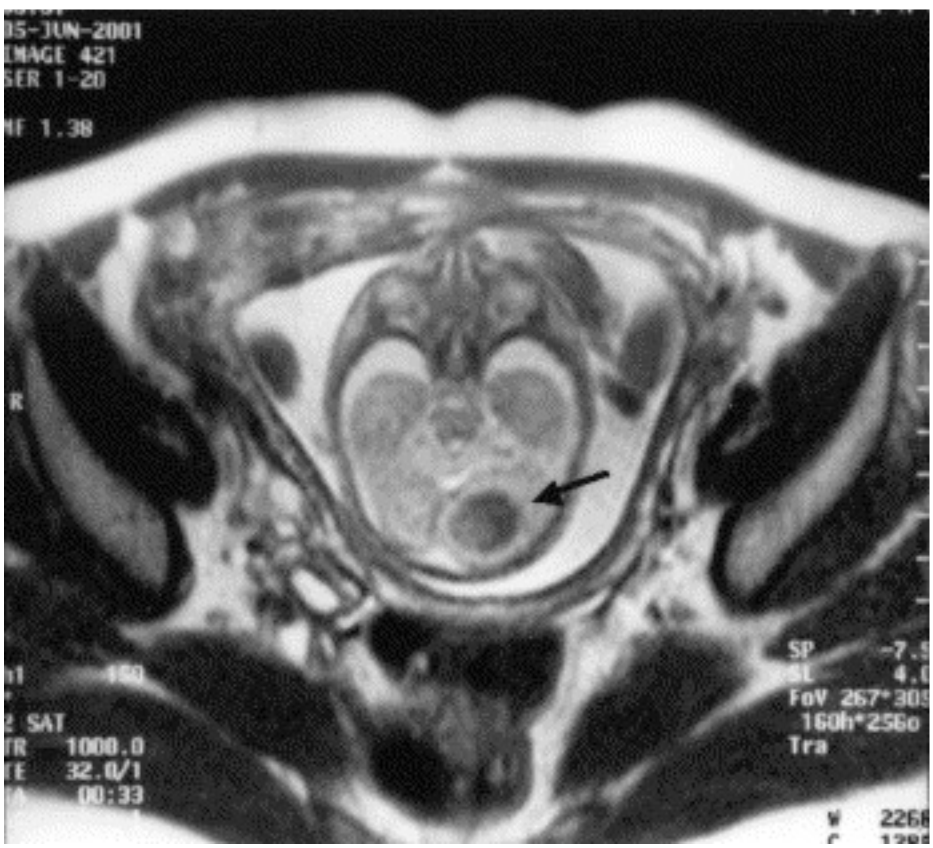


Fig. 315. The above image is an MRI on the case depicted in Fig. 314. It shows the fetal head with a subdural hematoma in the posterior fossa. The mother elected to terminate the pregnancy. (sciencedirect.com)

There is an unusual complication of trauma during pregnancy called **Feto-maternal hemorrhage (FMH)**, which is the trans-placental hemorrhage of fetal blood into the normally separate maternal circulation. The reported incidence of FMH following trauma is 8-30%. There is no real correlation between the severity of the trauma, gestational age, and frequency and volume of FMH. Complications of FMH include Rh sensitization in the mother, fetal anemia, fetal paroxystic atrial tachycardia or fetal death from exsanguination. In theory FMH is possible by the 4th week of gestation; some say FMH becomes a concern after 12 weeks gestation when the uterus rises above the pelvis and becomes an organ susceptible to direct trauma.

Penetrating Trauma: As previously discussed, as pregnancy progresses, intra-abdominal organs change position, which has important consequences. Because the bowel is pushed upward by the enlarged uterus, penetrating injury to the upper part of the abdomen is more likely to be associated with multiple gastrointestinal injuries. Organs involved in decreasing order of frequency are the small bowel, liver, colon, and stomach. During the third trimester, injuries to the lower quadrant of the abdomen almost exclusively involve the uterus. This may be advantageous to the mother because the uterus and amniotic fluid absorb most of the energy of the missile, resulting in less destruction to other organs (Figs. 301-303). Penetrating trauma in pregnancy is less common than blunt trauma, accounting for 9% of abdominal trauma in pregnancy in one series. Most result from gunshot wounds. As pointed out above, the gravid uterus offers protection to the mother; however, direct uterine and fetal injuries are increased. If the uterus is involved in penetrating trauma, fetal injury may occur in 60-90% of cases. Gunshot wounds to the uterus carry a maternal mortality of 7-9% and a fetal mortality of 40-70%. **Fetal mortality is higher if the injury is caused before 37 weeks of gestation**. **Stab wounds** to the abdomen are managed similarly in pregnant and non pregnant patients if signs of obvious intra-abdominal injury are present (shock, peritoneal signs, evisceration). Fetal mortality for stab wounds varies between 27-42%.

Electric Burns: In the case of electrical burns, fetal mortality is high at 73% even with a rather low electric current because of the fetus' lack of resistance to electrical shock. This is probably related to the fact the fetus is floating in amniotic fluid with a low resistance to current.

(c). Fallopian tubes: Contusions or lacerations of the fallopian tubes typically occur with similar injuries to the uterus and ovaries. This is primarily due to the anatomical relations with these structures. Although the anatomy of the fallopian tubes has been discussed in detail on pages 160-169, Figs. 137-145, I will briefly review their anatomic and functional features.

There are two fallopian tubes, one for each ovary. The end of the tube near the ovary expands to form a funnel-shaped infundibulum, which is surrounded by finger like extensions called **fimbriae**. Because there is no direct connection between the infundibulum and the ovary, the oocyte enters the peritoneal cavity before entering the fallopian tube. At the time of ovulation, the fimbriae increase their activity and create currents in the peritoneal fluid that help propel the oocyte into the fallopian tube. Once inside the fallopian tube, the oocyte is moved along by rhythmic beating of cilia on the epithelial lining and by peristalic action of the smooth muscle in the wall of the tube. It typically takes the oocyte about 7 days to traverse the length of the fallopian tube. Because the oocyte is fertile for only 24 to 48 hours, fertilization usually occurs in the ampulla of the fallopian tube (Fig. 316).

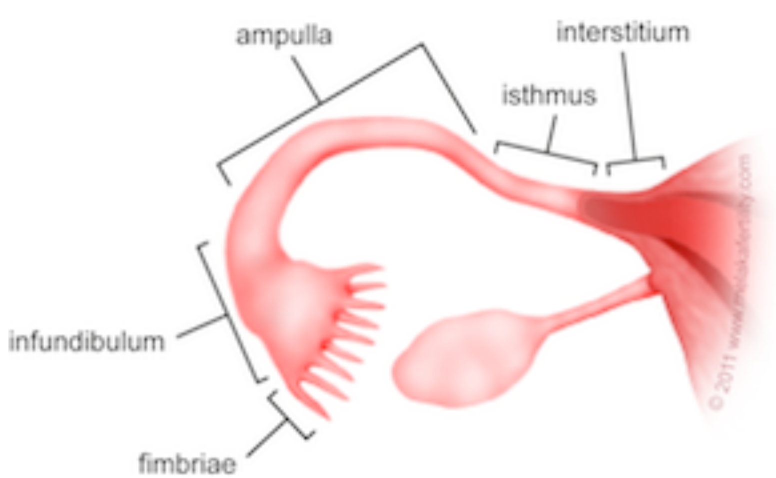
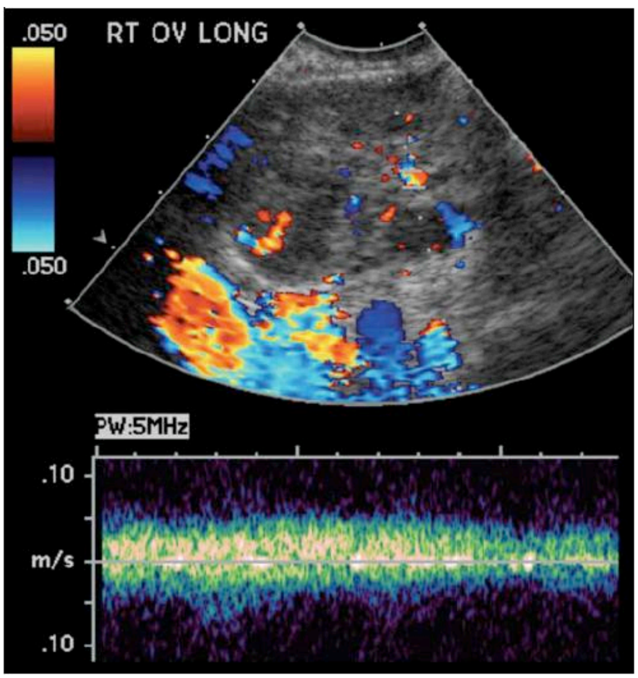


Fig. 316. The above illustration depicts the anatomy of the fallopian tube. (melakafertility.com)

Blunt unintentional trauma, including pelvic fractures and straddle injuries, often not only result in perineal and vaginal injuries but also cervical, uterine, fallopian tubes and ovary injuries. Enlargement of any of these organs enhances their chances of blunt force traumatic injury. Although unusual, there have been case reports of isolated blunt force traumatic injury to the fallopian tubes, such as in the case of an 18-year-old female who sustained minor trauma of the pelvis, which resulted in an isolated torsion of the right fallopian tube due to herniation of the tube through a tear in the broad ligament (Fig. 317).



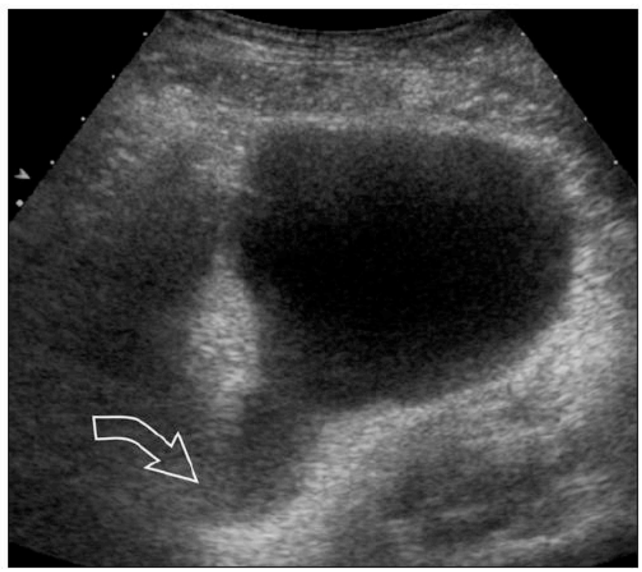


Fig. 317. The left image is a color doppler sonographic image and the right an ultrasound image. These images show a dilated adnexal tubular structure that flares at one end, with thickened echogenic walls, suspicious initially for hydrosalpinx. A beaked, tapering appearance of the tube, with its vertex pointing toward the affected adenxa. On further examination it was believed these findings indicated a fallopian tube torsion. Fallopian tube torsion may result from adhesions, adnexal venous congestion adjacent ovarian or paraovarian masses, uterine masses, gravid uterus, **trauma**, and sudden body position changes (Sellheim theory). Other factors which may cause torsion of the fallopian tube are long mesosalpinx, tortuous dilated tube (hydro-or hemao-salpinx), tubal mass, tubal ligation, PID, abnormal peristalsis/periovulatory spasm. (dailyem.wordpress.com)

E. E. Moore and colleagues developed a fallopian tube organ injury scale:

Grade I : Hematoma/contusion

Grade II : Laceration < 50% circumference

Grade III : Laceration > 50% circumference

Grade IV : Transection

Grade V : Vascular injury; devascularized segment

Note: advance one grade for bilateral injuries up to grade III.

Genital trauma involving both external and / or internal reproductive organs has been reported in 20-53% of sexual assaults.

Penetrating injuries, either gunshot wounds or stab wounds account for almost all injuries to the fallopian tubes, the ovaries, and the non gravid uterus.

The fallopian tubes may be **iatrogenically injured** as a complication of urologic and gynecological surgery (Fig. 318).

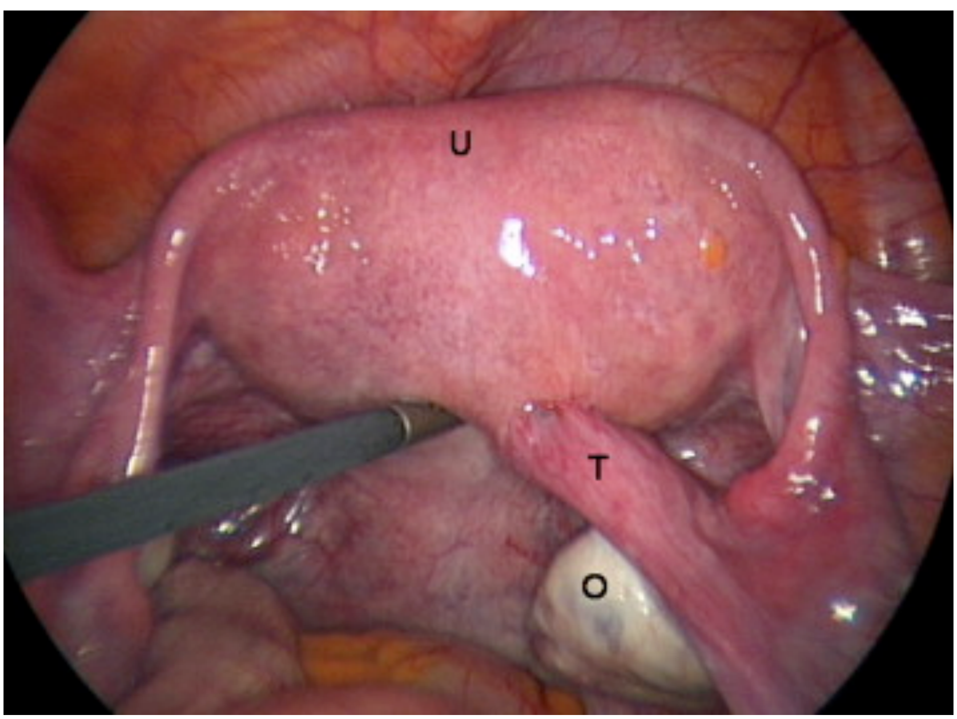


Fig. 318. The above is a laparoscopic view of the pelvis showing fallopian tube incarceration. This was a complication of the termination of a pregnancy by vacuum aspiration. (sciencedirect)

Bleeding from the fallopian tube into the peritoneal cavity may have non traumatic causes in females of reproductive age, such as a ruptured fallopian tube occurring in a setting of an extrauterine pregnancy (Figs. 319 & 320).

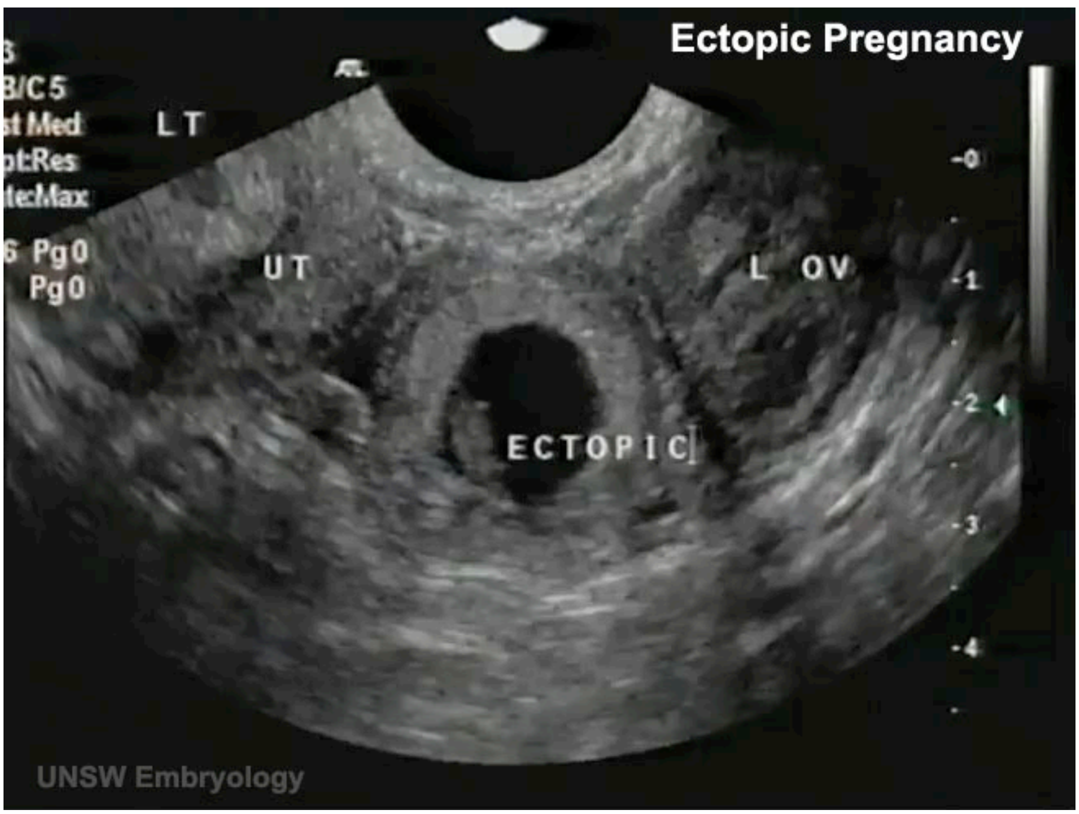


Fig. 319. This is an abnormal ultrasound showing a tubal pregnancy. (embryology.med.unsw.edu.au)

Fig. 320. This is an example of an actual pathology specimen of a ruptured fallopian tube ectopic pregnancy causing hemoperitoneum with acute abdominal pain. (meduweb.com)

(d). Ovaries: Although the anatomy of the ovary has been discussed in detail on pages 170-179, Figs. 146-151, I will briefly review the subject. The ovaries are covered on the outside (outer surface) by a layer of simple cuboidal epithelium called the germinal (ovarian) epithelium. This layer is derived from the mesoderm during embryonic development and is closely related to the mesothelium of the visceral peritoneum, however, it is **not** the same as the visceral peritoneum, i.e., the visceral peritoneum does not cover the ovaries. A white line around the anterior mesovarian border usually marks the transition between the peritoneum and ovarian germinal epithelium. Underneath the germinal epithelium is a tough connective tissue capsule, the **tunica albuginea**. The ovarian tissue the tunica albuginea surrounds is divided into an **outer cortex**, which contains the ovarian follicles, and a **medulla**, which contains the loose connective tissue, with blood vessels, lymphatic vessels and nerves (Fig. 321).

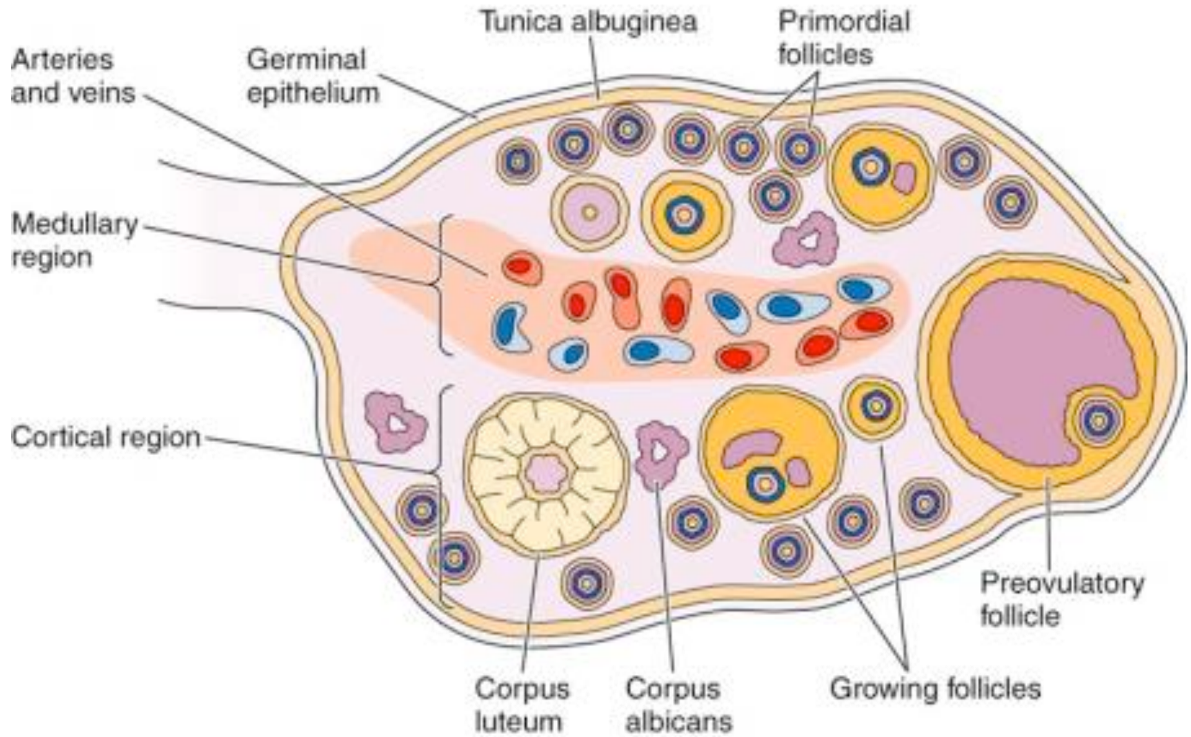


Fig. 321. This is an anatomic illustration of a normal ovary. (drmmkapur.blogspot)

Contusions and / or lacerations of the ovaries, typically occur in conjunction with similar injuries to the fallopian tubes and uterus. They are usually the result of crushing injury with fracture of the pelvis.

E. E. Moore and associates developed an ovary organ injury scale:

Grade I : Contusion/hematoma

Grade II : Superficial laceration (depth < 0.5 cm)

Grade III : Deep laceration (depth > 0.5 cm)

Grade IV : Partial disruption of the blood supply

Grade V : Avulsion or complete parenchymal disruption

Note: advance one grade for bilateral injuries up to grade III.

An ovary may suddenly undergo rupture, commonly at the site of a cyst, leading to hemorrhage into the ovarian tissue and / or intra-peritoneal bleeding (Fig. 322 & 323). This is especially likely to occur in women with underlying bleeding disorders. The pathogenesis of a sudden rupture in the ovary (ovarian apoplexy) is often due to dystrophic and sclerotic changes in ovarian tissue, polycystic ovary syndrome, acute and chronic inflammatory processes in the uterus, and some other diseases. It can also occur as the result of medication that stimulates ovulation. All of these processes can create irregularities in the ovulation process and corpus luteum formation. As a result, blood vessels in the ovary become dilated, and thus are prone to intra-ovarian bleeding. As a result, a hemorrhage can occur in the corpus luteum due to the fragility of the blood vessels, causing a hematoma. Other possible causes of ovarian rupture include abdominal trauma, excessive physical stress, vigorous sexual intercourse, horseback riding, etc.

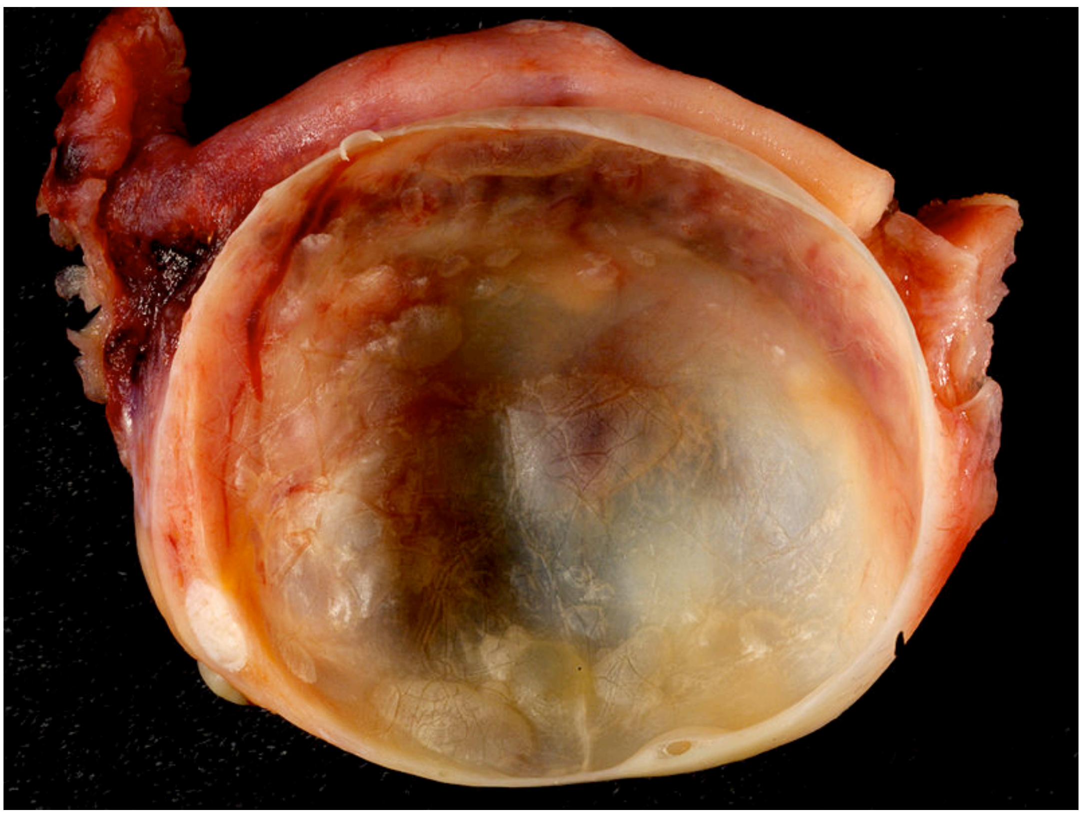


Fig. 322. This is a picture of a benign ovarian cyst, which is a collection of fluid, surrounded by a very thin wall, within an ovary. Any ovarian follicle that is larger than about 2 cm is termed an ovarian cyst. In the United States, ovarian cysts are found in nearly all premenopausal women, and in up to 14.8% of postmenopausal women. (ovariancystsandpcos.blogspot.com)

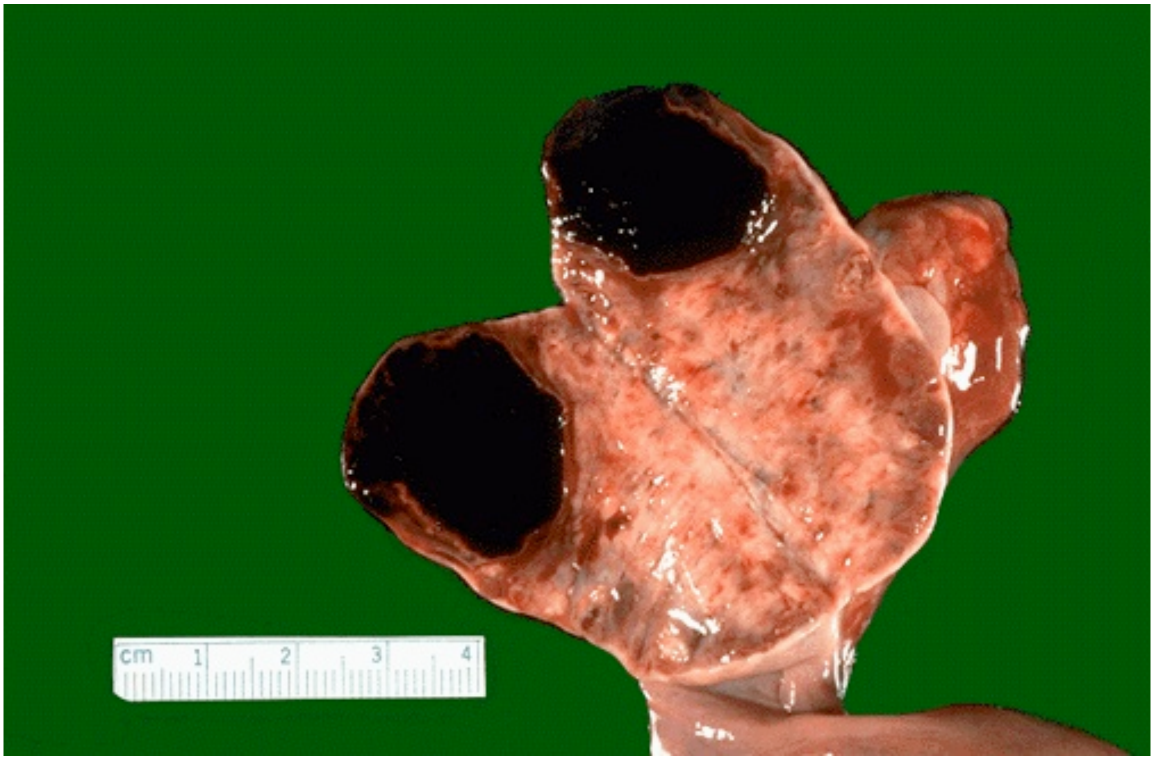


Fig. 323. This is a picture of a hemorrhagic corpus luteum cyst, which may rupture at the time of menstruation, and take up to three months to disappear entirely. This type of functional cyst occurs after an egg has been released from a follicle. The follicle then becomes a new, temporarily little secretory gland that is known as the corpus luteum. The ruptured follicle begins producing large quantities of estrogen and progesterone in preparation for conception. If a pregnancy doesn't occur, the corpus lutem usually breaks down and disappears. It may, however, fill with fluid or blood, causing the corpus luteum to expand into a cyst as in this image. Typically it stays within the ovary. However, it can grow to almost 4 inches in diameter and has the potential to bleed into itself or twist the ovary, causing torsion and thus causing pelvic and abdominal pain. If it fills with blood, the cyst may rupture, causing internal bleeding. (meduweb.com)

Like the fallopian tubes the ovaries can undergo torsion, which is the twisting of the ovary on its ligamentous supports, which can result in a compromised blood supply. Concomitant ovarian and tubal torsion has been shown to occur in up to 67% of cases of adenxal torsion.

Ovarian torsion can occur in females of all ages; however, women in their reproductive years have the highest prevalence, with 17-20% of cases occurring in pregnant women. This is probably due to the increased occurrence of physiologic and pathologic ovarian masses, therapy for infertility, and pregnancy. Initially, the twisted vascular pedicle in the suspensory ligament of the affected ovary compromises venous and lymphatic outflow. However, arterial inflow is sustained because the arteries have thick, muscular walls and are less collapsible. This results in diffuse ovarian edema and enlargement, which over time cause the capsule to stretch and increase pressure on the ovary. Arterial thrombosis and ultimately ischemia and infarction ensue (Figs. 324, 325, & 326).

Large, heavy cysts and cystic neoplasms, such as benign mature cystic teratomas, hemorrhagic cysts, and cystadenomas, commonly predispose the ovary to swing on its vascular pedicle.

Fig. 324. This image is of a transverse sonogram of the left ovary showing a central hemorrhagic cyst (cursors) with the classic "fishnet" appearance in a 32-year-old woman with ovarian torsion. (radiographics.rsna.org)

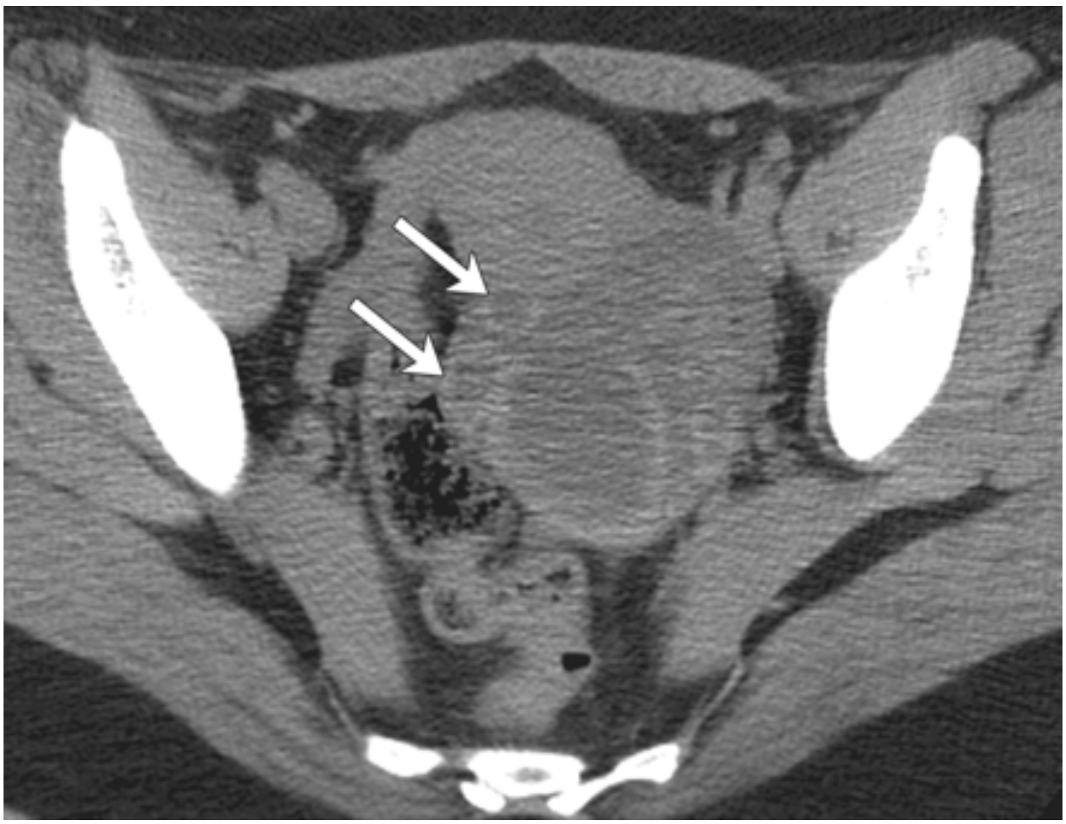


Fig. 325. This is the correlative CT image to the image presented in Fig. 324. It shows a large septated cystic lesion in the pelvic midline with minimum enhancement and possible peripheral cysts (arrows). A hemorrhagic necrotic appearing ovary was removed at surgery much like that in Fig. 326. (radiographics.rsna.org)

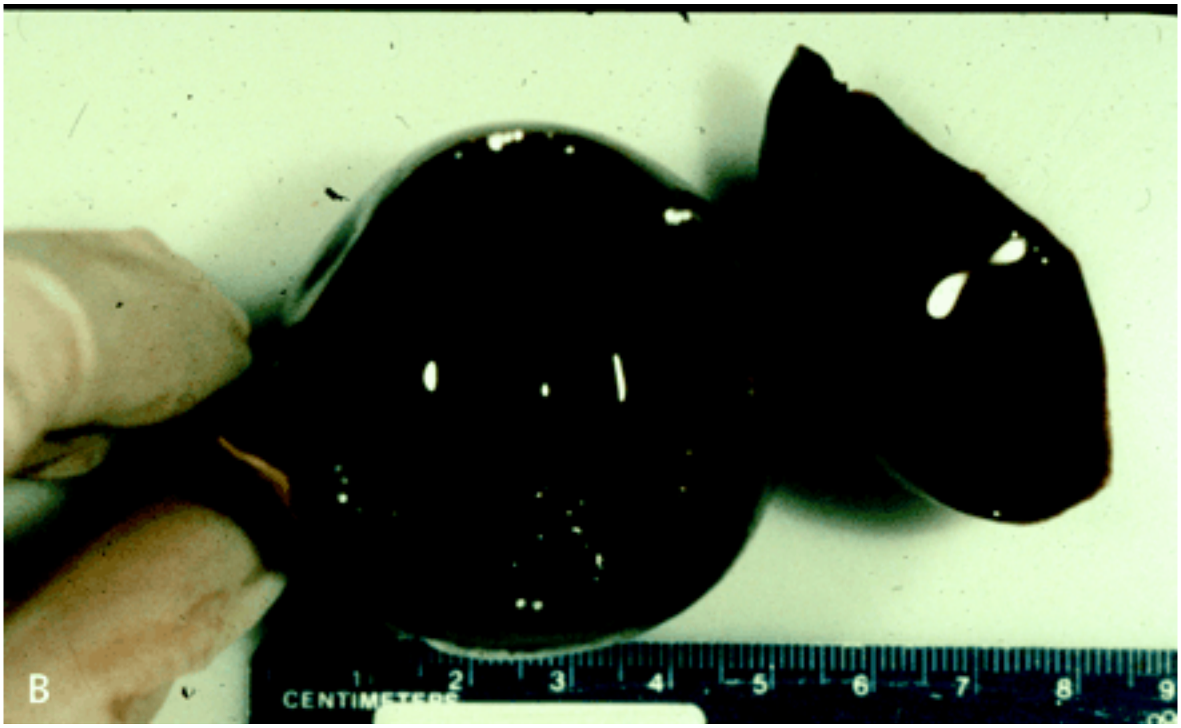


Fig. 326. This is a hemorrhagic infarcted ovary due to torsion. (jultrasoundmed.org)

In terms of traumatic injuries, **penetrating injuries** account for almost all injuries to the fallopian tubes, ovaries, and the non gravid uterus.

Pediatric Traumatic Injuries to the Female Internal Reproductive Organs: The perineal, pelvic and external genitalia can sustain traumatic injuries in the form of blunt force or penetrating, accidental and non accidental. **Pediatric urogenital injuries** can result from motor vehicular accidents, physical assaults, participation in sports, accidents within the home or outside, and sexual assault with an object or penile penetration, and iatrogenic trauma (Fig. 327). In both accidents and blunt penetrating trauma, the hymen, perineum or vagina may be injured. The hymen rarely is injured in accidents because it is protected not only by bone, but also its recessed position.

A B C

Fig. 327. The above images are examples of superficial blunt trauma. A, Superficial abrasions and bruising are seen anteriorly on either side of the clitoris and urethra in a 3-year-old who presented with dysuria (painful urination). B, This is another toddler in which superficial abrasion or laceration is seen between the left labia minora and majora following a straddle injury. C, These healing superficial abrasions involving the posterior fourchette and perianal area were the result of sexual abuse. (A and B, Courtesy Janet Squires, M.D., Children's Hospital of Pittsburgh) (nodba.ir)

Straddle injuries are one of the most common accidental injuries in girls (Figs. 327 B, 328, 329 & 360)). They occur during riding bikes due to impact with the bicycle bar, water skiing, snow skiing and in accidental falls. There may be accompanying damage to the urinary tract or abdominal and pelvic organs. However, visceral injury is rare and when it occurs is typically due to high impact, such as occurs in a motor vehicular accidents. If a fracture of the pelvis occurs, the internal reproductive organs, as well as the bladder and bowel, may be injured by a bony fragment or a fat embolism.

Fig. 328. The above image shows a straddle injury with bruising to the left labia majora and clitoral hood. (accessemergencymedicine.com)

Fig. 329. This image is of another straddle injury with severe bruising, swelling of the left labia with bilateral extension into the perineum. (accessemergencymedicine.com)

The **perineum** is highly vascular, hence large hematomas can be seen involving injuries to the internal reproductive organs. If a torn vessel in the perineal area retracts under the pelvic floor muscles, a severe retroperitoneal hemorrhage may result (Fig. 330). For example, a 13-year-old girl, who after giving birth, had a hematoma of the labia minora, but went into shock from a torn vessel and retroperitoneal bleeding. Another case involved a girl who fell resulting in a small laceration of her labia, as well as a torn vessel in the perineal area, which retracted beneath the pelvic floor muscles, leading to retroperitoneal hemorrhage. Sever falls from heights onto flat surfaces can produce major perineal lacerations simulating penetrating injury. In addition, they occasionally disrupt the pelvic vessels, mesentery, and intestines, with or without pelvic fracture (Fig. 330). Similarly, severe penetrating injury may produce tears that extend through the cul-de-sac, rupturing pelvic vessels and tearing intra-abdominal structures. External injuries in these cases are usually extensive and associated with significant bleeding, but on occasion can be deceptively minor in appearance. Children with peritoneal extension of injury complain of lower abdominal and perineal pain, which may radiate down one leg. Abdominal examination should reveal at least mild direct tenderness early on. Later, guarding and rebound tenderness may be noted. Patients with pelvic bleeding ultimately tend to develop signs of hypovolemia, although this may not be evident immediately after the injury.

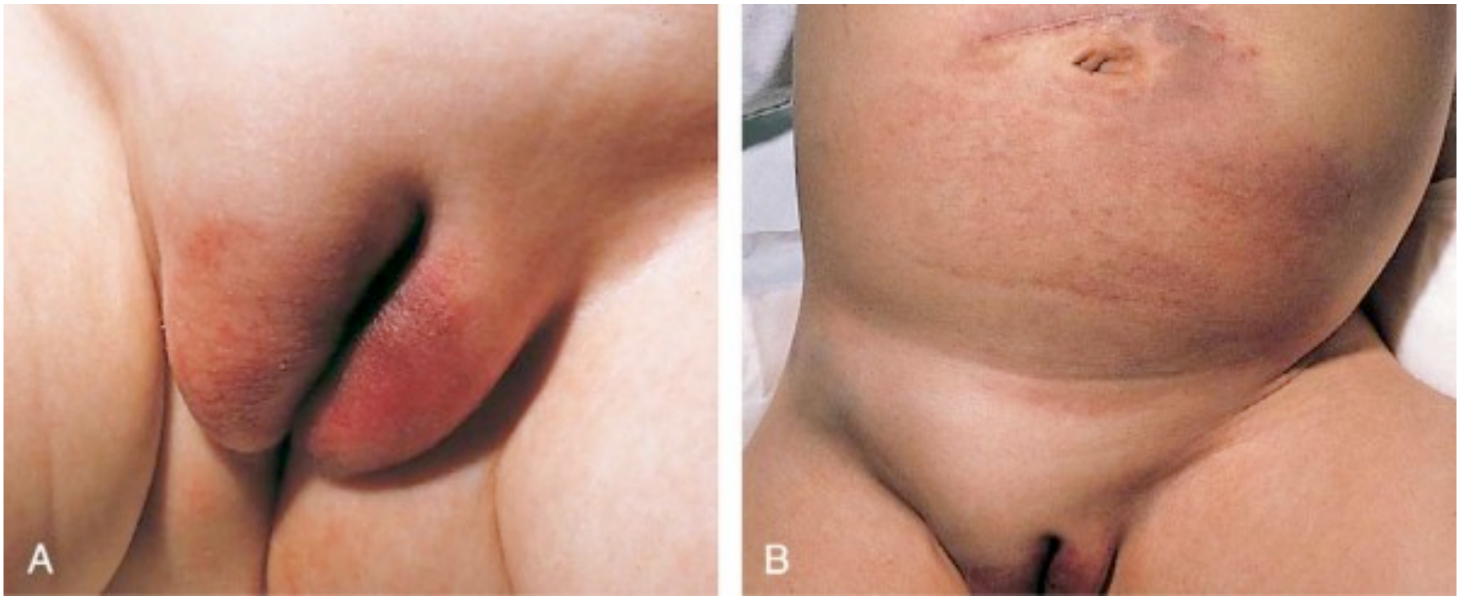


Fig. 330. These images are of severe blunt perineal trauma. A, Following a fall from a second story window in which she landed on her bottom, this child had labia contusions and hematomas, lower abdominal tenderness, and signs of hypovolemia. B, The force of the fall ruptured pelvic vessels, resulting in retroperitoneal bleeding that ultimately extended along the anterior abdominal wall. These photographs were taken several days after the injury. (Courtesy Marc Rowe, M.D., Sanibel, Fla.)

Sharp penetrating injuries can damage not only the hymen and / or the perineum, but also the internal reproductive organs. Such injuries can be accidental or non accidental. An example of an accidental penetrating injury is a girl who landed on a toy (the chimney of a toy locomotive) at the bottom of a slide with penetration of the hymen and adjacent tissues (Figs. 331 & 371).
Digital or penile penetration usually causes bruising of the posterior fourchette, tears of the hymen that progress from the posterior hymen to the posterior vaginal wall (Fig. 331 D) or from the perineal body to the anterior wall of the anal canal. Vaginal tears can involve the bladder, rectum, broad ligament, and peritoneal cavity. The bowel may prolapse through a vaginal tear (Fig. 332). The swelling that results from hymenal injuries can cause tissue necrosis with disappearance

of the hymen within three weeks of the injury. This should not be interpreted as an indication of a second assault. You may also see superficial lacerations of the cervix from digital penetration (Fig. 333)

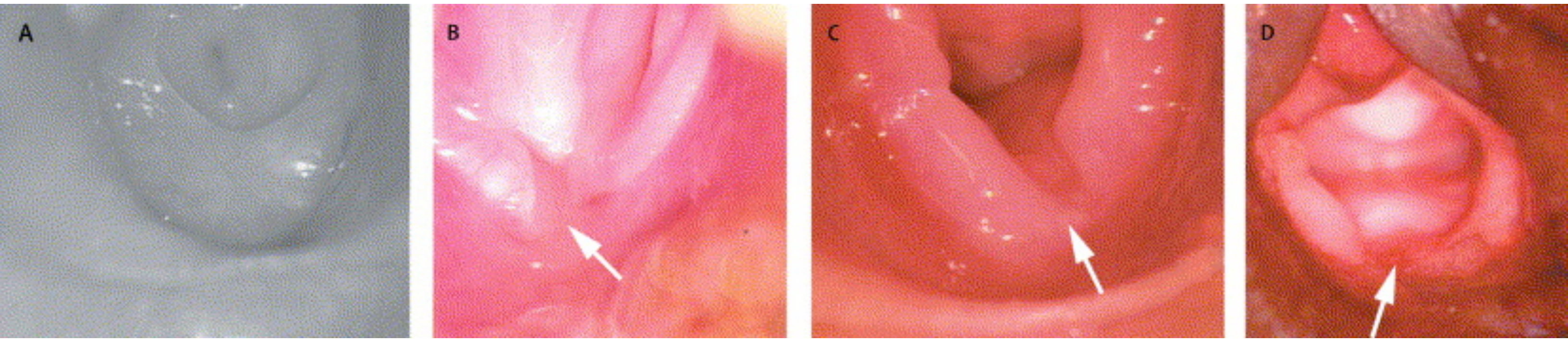


Fig. 331. These images depict a normal hymen (A) and hymenal injuries (B-D). A, represents a normal hymen of a preadolescent 5-year-old girl. Note the delicate hymen membrane has a right and left wall and a base. Trauma to the hymen generally causes tears in the 3 to 6 o'clock position. B, is a complete tear of the hymen (arrow). Some estrogen effect is seen as white thickening of the hymen. The hymen is torn to the floor of the vagina. C, shows a healing tear in the hymen (arrow), represented as a U-shaped notch. Shallow U-shaped indentations in the hymen are normal. The traumatized hymen may heal completely over a few weeks to months. D, depicts an acute hymen tear. This 11-year-old girl has sustained penetration of the hymen, which is torn to the floor of the vagina. Blood is seen coming from the hymen walls and vaginal floor. This trauma may heal completely over time, or a V-shaped notch may remain in the hymen edge. (sciencedirect)

Fig. 332. The above image is an example of prolapse of the small bowel through a vaginal tear in a premenopausal woman following coitus. (pssjournal.com)

Fig. 333. This image shows a superficial laceration of the cervix from a fingernail. (sciencedirect.com)

Pelvic floor injuries can result from impalement, crush injuries, or sexual assaults. Internal reproductive organs, bladder, urethral and the bowel may also be injured. The mortality rate may be as much as 11% if the injuries are not recognized and treated within 6 to 12 hours. The mortality rate increases to 50-100% in delayed recognition. To illustrate this point a girl impaled herself on a bedpost with the injury occurring posterior to the hymen. There was no injury to the vagina but the bowel was torn. After treatment, the injury healed in about 6 weeks.

Urethral injuries can result from straddle accidents, crush injuries, urethral intercourse, impalement, criminal abortion, and insertion of foreign objects (Fig. 334). The injuries can range from transections to urethritis, with the latter being more common. Should you see anterior lacerations at the side of the urethra, they can indicate forced separation of the labia from a sexual assault or they can occur during examination by a doctor (iatrogenic) (Fig. 327 A).

Fig. 334. This image is of a closed-off vestibule with anterior perineal scarring following urethrovaginal disruption injury. (sciencedirect.com)

There is a condition, which is referred to as **urethral prolapse**, that you need to be aware of because it is sometimes misinterpreted as evidence of sexual abuse. The misinterpretation comes about due to the protrusion of purplish-red mucosal tissue between the labia minora, that bleed easily and often overlies the vaginal orifice, simulating edematous, traumatized, redundant hymenal folds (Fig. 335). The condition is often first discovered when blood or a serosanguineous discharge is found on the diaper or underwear (Fig. 383). With magnification, the urethral orifice can be seen at the center of the mass, which is soft and markedly tender to to touch. This condition is unusual and tends to occur only in children younger than 12-years-of age; two-thirds of affected girls are African American.

Fig. 335. This image is of urethral prolapse. This child was referred for evaluation for possible sexual abuse when blood was noted on her underwear, and traumatized tissue was seen on examination. On close inspection, this was found to be edematous, friable prolapsed urethral mucosa. (nodba.ir)

Bladder injuries can be contusions, intraperitoneal rupture (especially when the bladder is full), or extraperitoneal rupture (Figs. 253 & 254, p 290 & 291). The ruptures typically occur on the anterior and lateral walls. Penetrating injuries of the genital/perineal region can result in injuries to the bladder (4-25%).

Vaginal and cervical injuries can result from accidents, masturbation, coitus, chemicals, assaults, and criminal abortions. They can manifest as abrasions, lacerations, “blowout” injuries (through the vagina into the abdominal cavity, uterus, bladder or rectum) and bleeding into the ischiorectal fossa or retroperitoneum (Figs. 295, 298, 331 D, 333 & 334). Foreign bodies in the vagina can be from accidents, self-insertion, or assaults (Figs. 336 & 337).

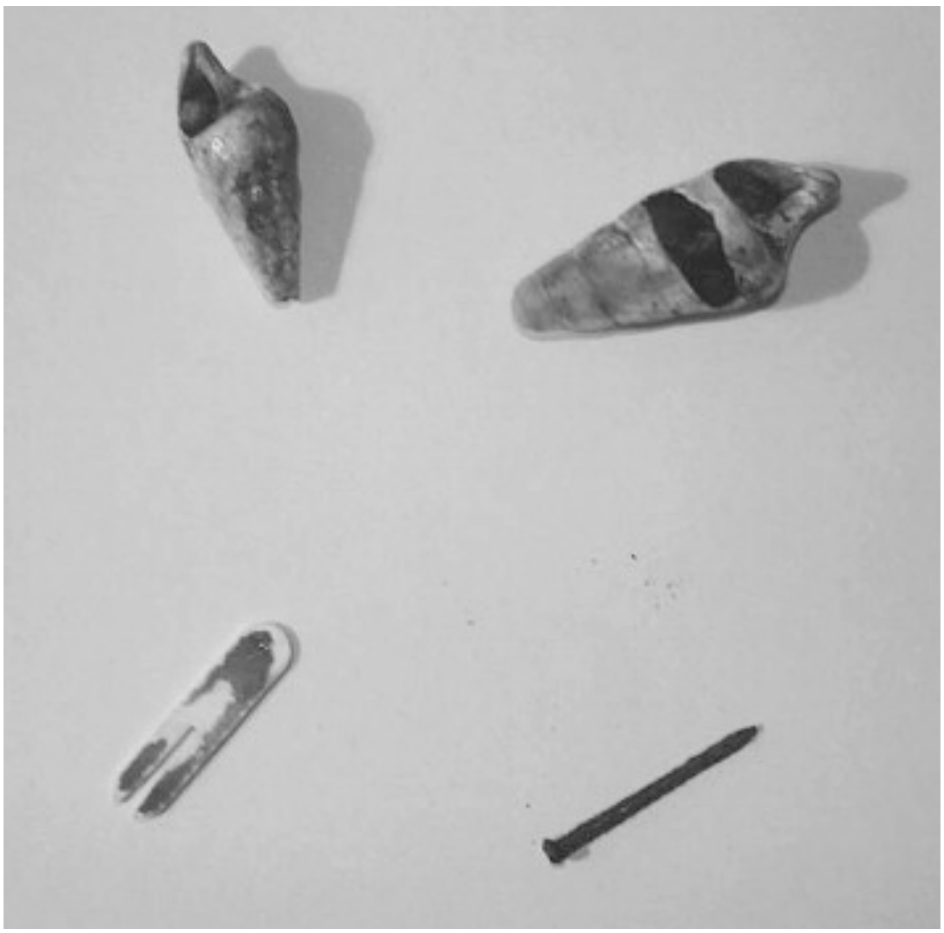


Fig. 336. These are foreign bodies which have been removed from the vagina in the pediatric age group: 1 nail, 2 seashells and one plastic item, most probably a toy. (sciencedirect.com)

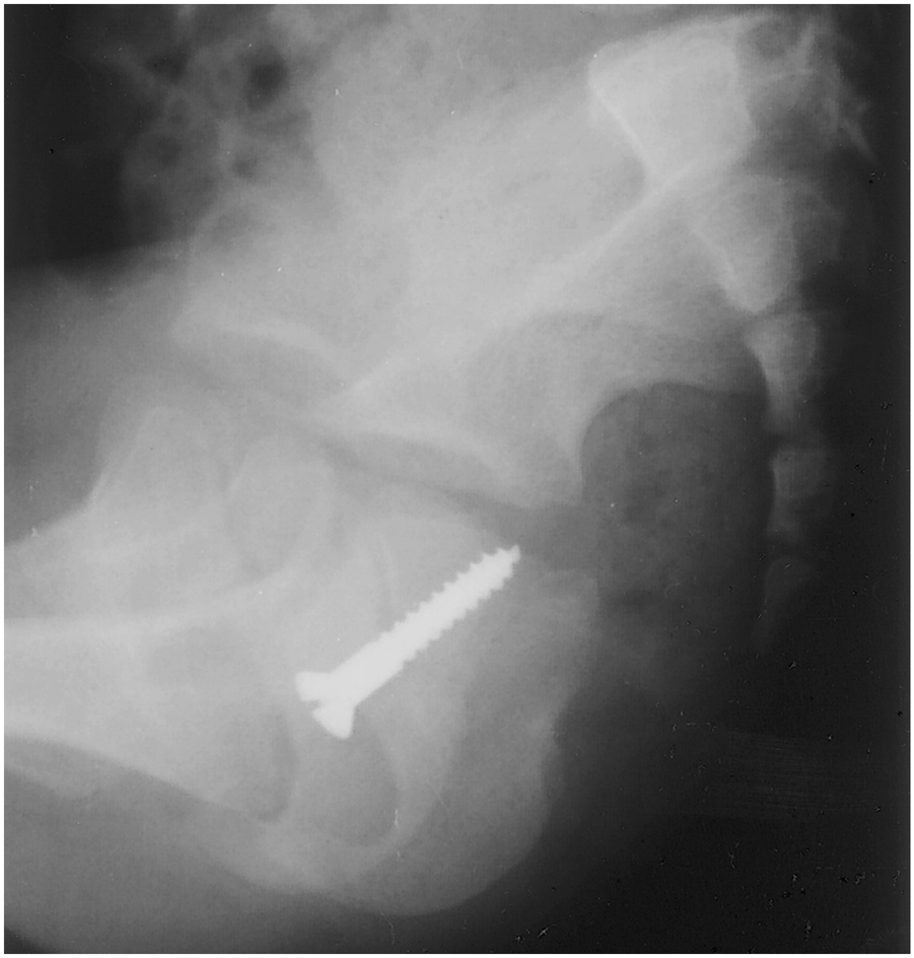


Fig. 337. This is a radiograph of a young child showing a screw that she had inserted into her vagina. (radiogrpahics.rsna.org)

Self insertion can be from play, but some children will insert something to “plug the hole” to try to prevent further assaults. The foreign object may lead to inflammation or trauma depending on the object used, the location, and the force applied. Trauma is more likely if an assailant inserted the object. An object left in the vagina for a long period may erode into the bladder. Objects may also be inserted into the urethra.

Injuries to the uterus can result from either blunt force or penetrating objects. There can be lacerations, hemorrhage or other visceral injuries. Non pregnant uterine injuries are rare as the uterus is in a protected region. However, high impact forces can cause shearing at the cervix, avulsion at the isthmus or other injuries. Injuries to the uterus during pregnancy are more common and can be caused by domestic abuse or accidents, such as motor vehicular accidents. The damage that results from criminal abortion will depend on the stage of gestation and the method used (Figs. 338 & 339). Visceral injuries can also occur (Figs. 340, 341 & 342).

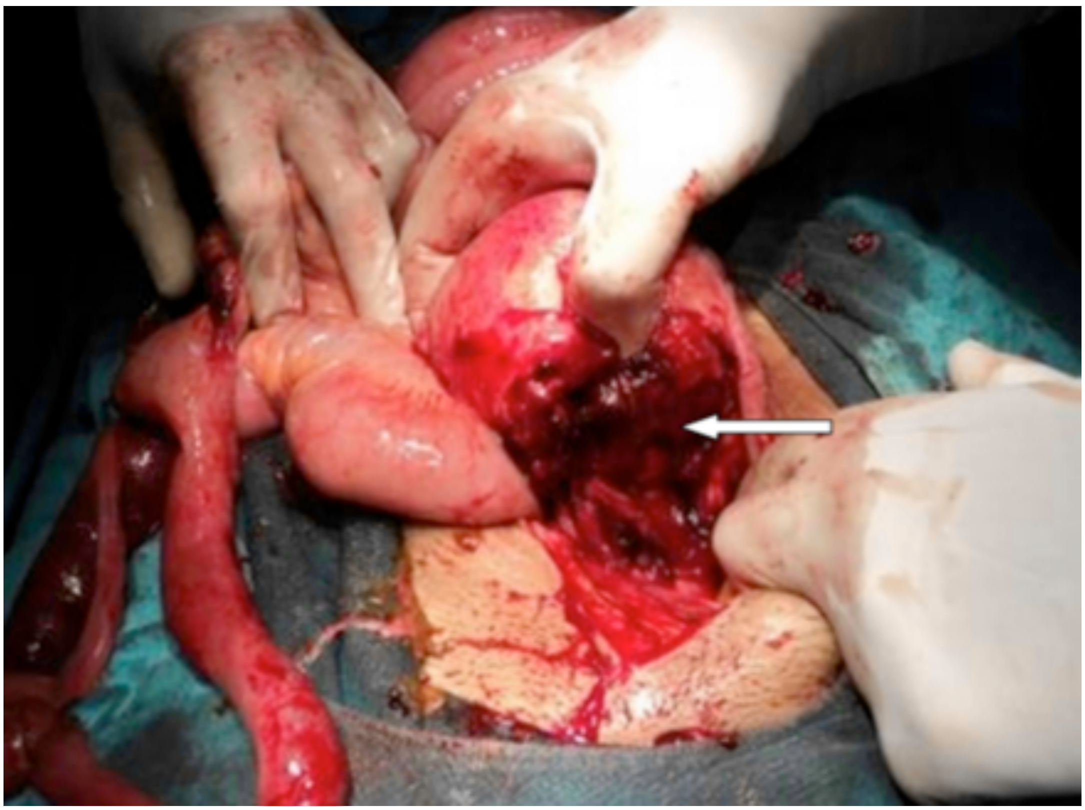


Fig. 338. The above image shows a tear in the uterus (arrow), which occurred during an illegal abortion. (ispub.com)

Fig. 339. This is the fetus removed during the illegal abortion shown in Fig. 338. Note that both hands have been amputated and the chest wall has been injured. (ispub.com)

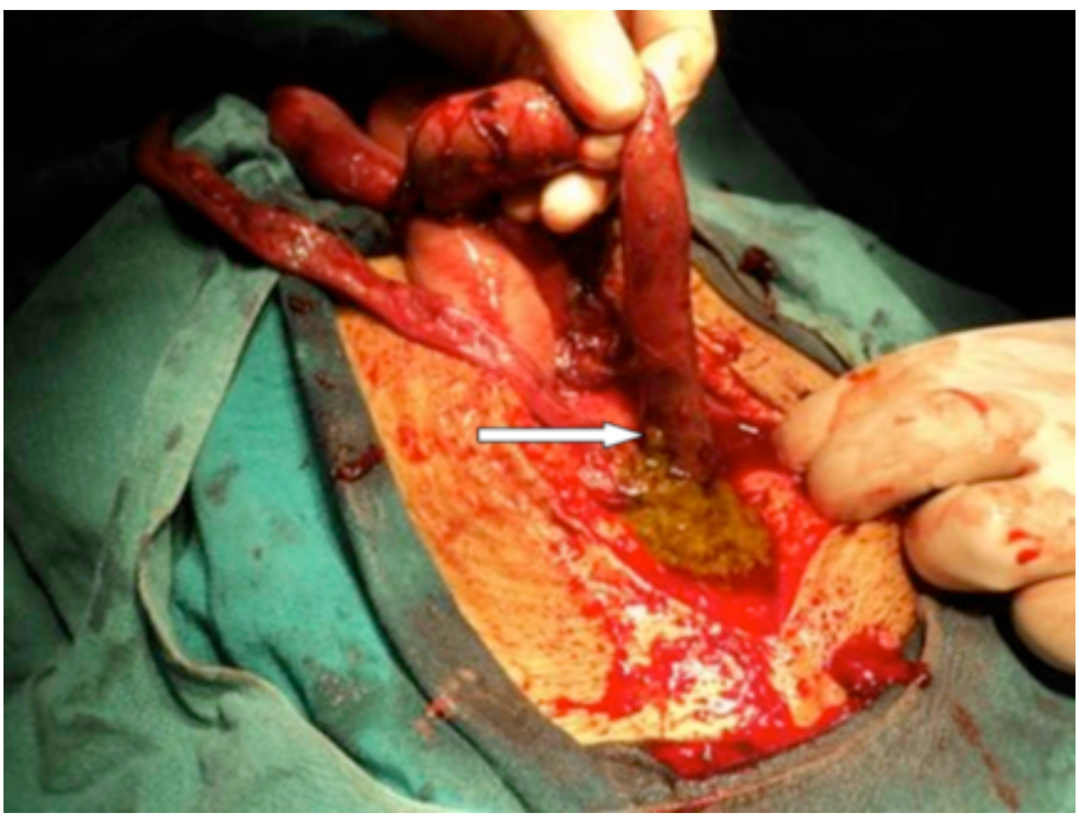


Fig. 340. The above image shows the perforated small bowel (arrow) with leakage of fecal matter that occurred as the result of the illegal abortion shown in Figs. 338 & 339). (ispub.com)

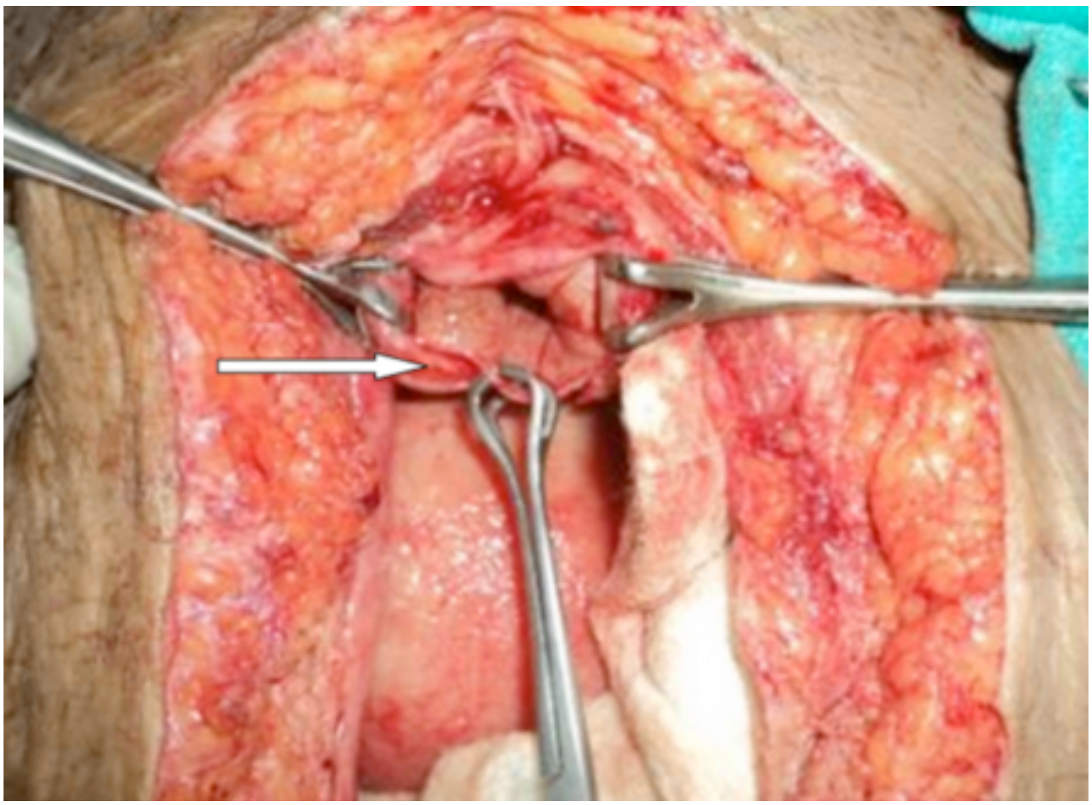


Fig. 341. This image shows a tear in the dome of the urinary bladder (arrow) which occurred during the illegal abortion shown in Figs. 348, 349 & 340). (ispub.com)

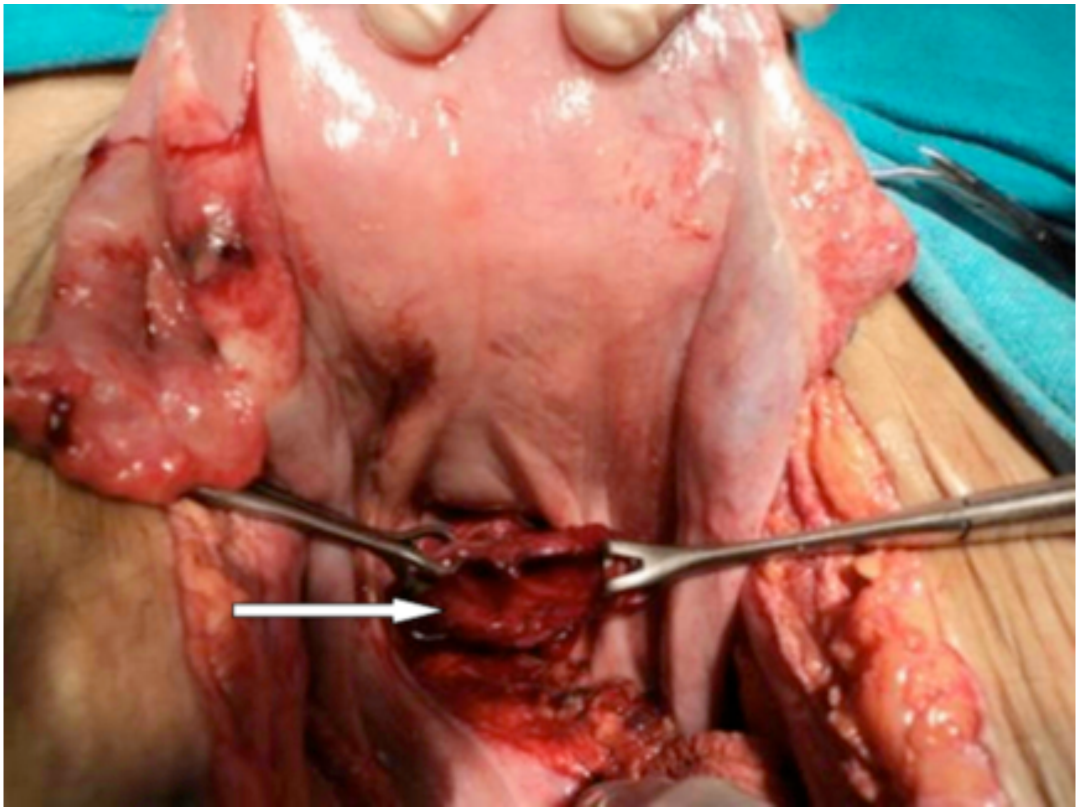


Fig. 342. This image shows the lower end of the transected rectum (arrow) which occurred during the illegal abortion shown in Figs. 348-341. (ispub.com)

Burns are not uncommon in the genital region of children. The genital region of children may have burns due to dunking the child in hot water (Figs. 343 & 344). There are also some inflammatory dermatologic conditions which can mimic burns such as contact dermatitis, bacterial dermatitis due to organisms like streptococcus (Fig. 355) and candidal diaper dermatitis (Fig. 345). Cigarette burns to the posterior fourchette causing third degree burns have also been reported. There is also a reported case of gasoline being poured onto the abdominal and genital region then lit.

Fig. 343. These are images of inflicted scalds. A, After getting his hands into something he was not allowed to touch and making a mess, this child's hands were held down in hot water, resulting in severe second degree burns. Note the sharp line of demarcation just above the wrist joint and the uniform depth of the burn. B, This toddler was dipped in a tub of scalding water while being held under the arms and knees, as an object lesson following a toilet accident. C, Close up of severe second degree burns of the foot and lower leg of the same child. (health-7.com)

Fig. 344. This is another example of an inflicted scald burn in which the child was held in the “jackknife” posture and forcibly immersed in a sink or bathtub partly full of very hot water. These burns are typically symmetrical with severe involvement of the buttocks, perineum, and feet, along with sparing of the knees and nearby areas of the legs. There are typically few or no splash marks, and there is a usually well-demarcated “high-water” mark on the ankles or lower legs. (utmb.edu)

Fig. 345. This image is of a case of candidal diaper dermatitis, which can be easily misinterpreted as a scald burn. Between 40-75% of diaper rashes that last for more than 3 days are colonized with C. albicans. Candida has a fecal origin, and is not an organism normally found on perineal skin. (learnpediatrics.com)

Bites to the genital region of children are from fights, sexual abuse or dogs. (Figs. 284 & 293, p 328 & 335). Hepatitis, herpes or other sexually transmitted disease should be considered when bites are present. Hickeys on and around the genital area are another indication of assaults. Remember, petechial hemorrhages (pin point size hemorrhages) can be found on the palate (upper surface of the mouth) after oral sex. However, they can also be found in newborns after vigorous suctioning at birth to clear the mouth and throat. The lesion to be learned here, as is true of many injuries suggestive of sexual child abuse, be certain of the circumstances before reaching conclusions.

When considering a determination of sexual assault on a female child it is very important on your external exam that you inspect the medial aspects of the thighs, labia majora and minora, clitoris, urethra, periurethral tissue, hymen, hymenal opening, fossa navicularis, posterior fourchette, perineum and perineal tissue. Remember, some children will have evidence of both sexual and other physical abuse (Figs. 327 C, 331 B-D, 333, 334 & 346).

Fig. 346. These are examples of abusive bruises. Remember, bruises are strongly related to mobility. Once children are mobile they sustain bruises from everyday activities and accidents. Bruising in a baby who is not crawling, and therefore has no independent mobility, is very unusual.
The shins and knees are the most likely places where children who are walking, or starting to walk, get bruised.
Abusive bruises often occur on soft parts of the body, for example cheeks, abdomen, back and buttocks. The head is by far the commonest site of bruising in child abuse. Clusters of bruises are common feature in abused children. These are often on the upper arm, outside of the thigh, or on the body. As a result of defending themselves, abused children may have bruising on the forearm, face, ears, abdomen, hip, upper arm, back of the leg, hands or feet. Abusive bruises can often carry the imprint of the implement used or the hand as in Fig. 347. (online-procedures.co.uk)

Fig. 347. This image shows a handprint bruise on the lateral aspect of the hip. (referencemedscape.com)

Violent sexual abuse may be associated with bruising around the knees, thighs, and genitalia. Also, making a diagnosis on a single physical sign is very rarely possible in forensic medicine. With child sexual abuse it is especially dangerous to do so because of the devastating social consequences of an incorrect diagnosis.

We will now address **accidental perineal injuries in preteen girls**. Thirty-nine percent of accidental perineal injury in preteen girls were associated with bicycle or tricycle use. Twenty-five percent occurred outdoors in association with climbing apparatuses, falls to the ground or while straddling an object. Thirty-six percent of injuries occurred indoors, most while children were climbing on counters or furniture. The age range was 3-12 years for bicycle related injuries, 2-11 years for for other outdoor injuries, and 1-8 years for indoor injuries. In this study only one child had a hymenal injury (Fig. 331). That child was a 2-year-old who fell, abducting (to draw away from the median plane) her legs in a splits-type mechanism (Fig. 348). She was playing in a park. She had a pinpoint abraded area on the hymenal surface at the three o'clock position (Fig. 349, the pin point hemorrhage shown is not at the 3 o'clock position). The only associate injury was erythema (reddening) on the right labia minora.

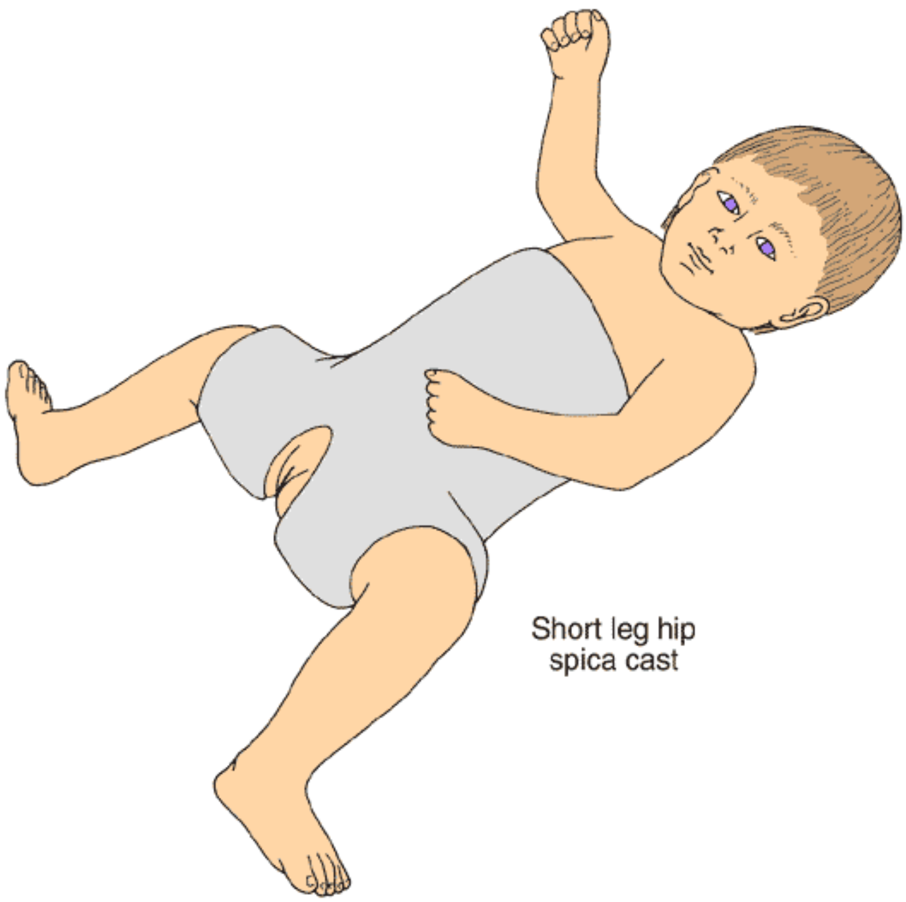


Fig. 348. This is an example of what is meant by the legs being in an abducted position. (chew.org)

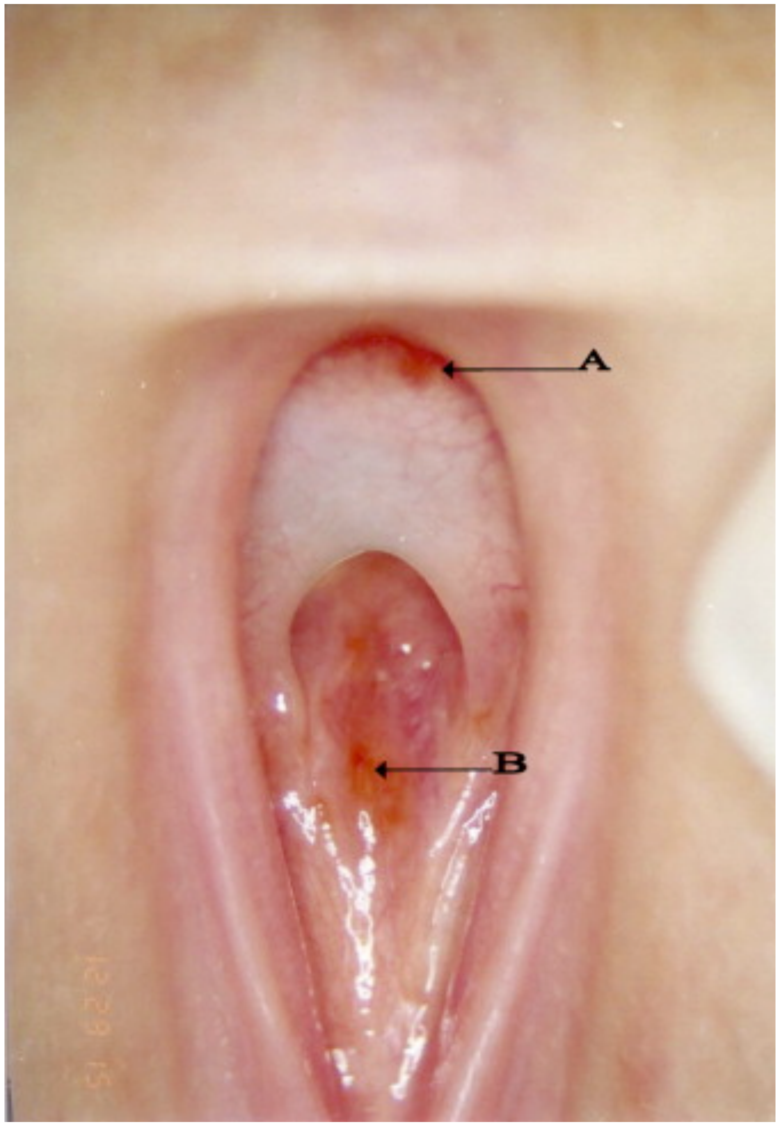


Fig. 349. This picture shows an anterior vaginal wall submucosal hemorrhage (arrow A) and a small hymenal submucosal pinpoint hemorrhage (arrow B). Prone knee-chest position. (sciencedirect.com)

In each group in this study, the labia minora was the most frequent structure injured. Except for the hymen, each structure (thigh, clitoris, urethra, labia majora, and posterior fourchette) was involved in at least 5 patients. In 73% of the cases some or all injuries were anterior and in 19% some or all injuries posterior. Seven patients in this study had injuries to both anterior and posterior structures, including 4 of 10 indoor injuries to girls 3-years-of-age or less. Two patients had injuries to the thigh.

Non accidental perineal injuries considered to be diagnostic of **sexual abuse** are lacerations or scars of the hymen and attenuation of the hymen with loss of tissue, however unintentional trauma must be ruled out (Figs. 350 & 366).

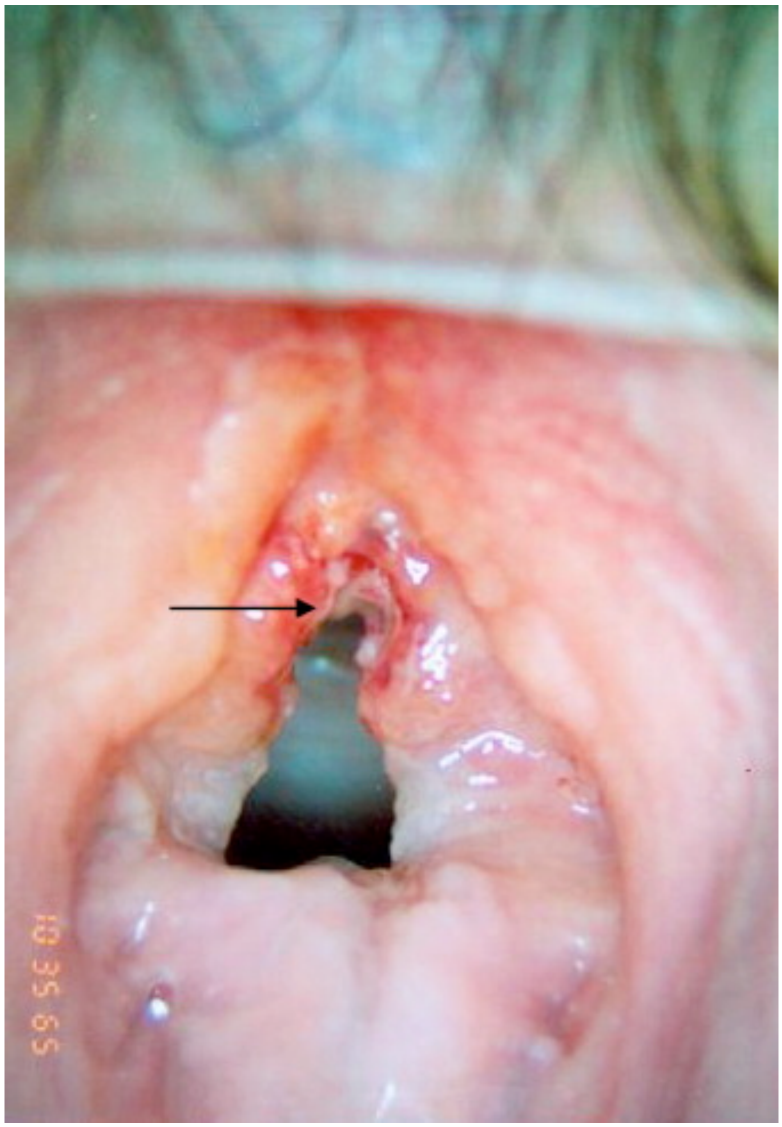


Fig. 350. This image shows a deep midline laceration of the posterior hymenal rim (arrow) in a 15-year-old victim of a sexual assault. Prone knee-chest position. (sciencedirect.com)

Other signs, such as an enlarged hymenal opening (more than 1 cm in horizontal diameter in a prepubertal girl), notches or bumps in the hymen (Fig. 331 D) or localized erythema or edema, may support a diagnosis of sexual abuse.

Remember, all of these signs must be interpreted with caution in light of normal variation (Figs. 351, 352 & 353).

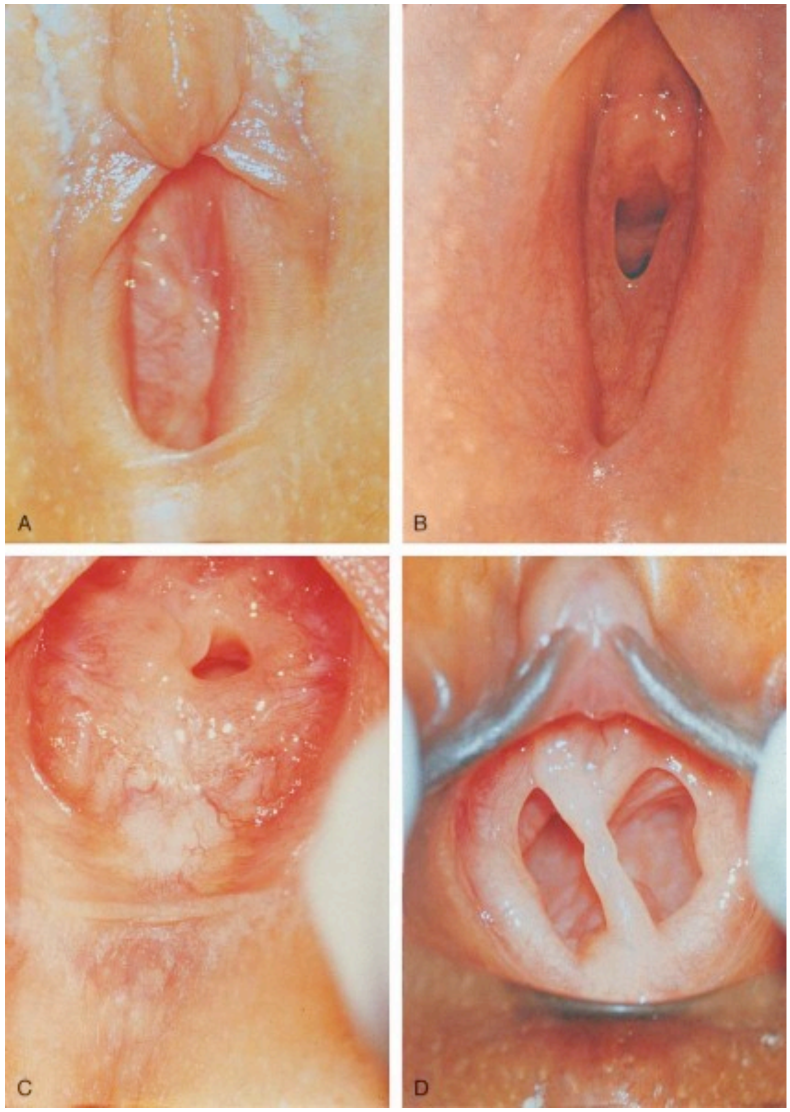


Fig. 351. These images show variations in normal hymenal configuration. A, redundant hymen. B, crescentic hymen with smooth edges. C, somewhat redundant hymen with an annular orifice. D, septate hymen resulting from a failure of lysis of the embryonic hymenal septum. (nodba.ir)

Fig. 352. This is an image of a septal remnant. This skin tag at 6 o'clock is a remnant of the vaginal septum present earlier in fetal development and constitutes a normal finding seen in about 5% of girls. (nodba.ir)

Fig. 353. This is an image of a hymenal flap. This child has a redundant hymen with an everted anterolateral flap, another normal variant. (nodba.ir)

The following are physical genitoanal findings that are listed according to the strength of evidence for sexual abuse ranging from normal to definitive: **Normal and nonspecific vaginal findings:** hymenal bumps, ridges and tags (Figs. 331 D, 351, 352 & 353); V-shaped notches located superior and lateral to the hymen, not extending to the base of the hymen; vulvovaginitis; and labial agglutination (adhesions). Labial agglutination can be due to frictional vulvovaginitis (inflammation of the vagina and surrounding skin), seborrheic dermatitis, possibly pinworms, or it may be a normal finding (Fig. 354). In one series 3% of the girls undergoing examination for sexual abuse had labial adhesions.

Fig. 354. This is an image of labial adhesions. The labia are fused in the midline because of prior inflammation. They are separated by a thin lucent line, and the epithelium of the labia is normal. (health-7.com)

In one series involving 10 cases (ages 2 months to 2½ years) of labial adhesions, none had a history of trauma, 1 had a history of masturbation, and 3 had urinary tract symptoms (incontinence, infection). Labial adhesions are considered a normal finding in girls. They are often seen in the newborn period and are not necessarily due to poor hygiene or diaper rash. They are found in girls from the newborn period to puberty.

Normal and nonspecific anal changes include: erythema (Fig. 355); fissures; midline skin tags or folds (Fig. 356); venous congestion; minor anal dilatation (Fig. 380); and lichen sclerosis (Figs. 357 & 358). We will cover these features in detail in the next chapter. They are mentioned now only for continuity.

Fig. 355. This perianal redness suggest sexual abuse in this child. It is in actuality a case of perianal streptococcal dermatitis. (jfponline.com)

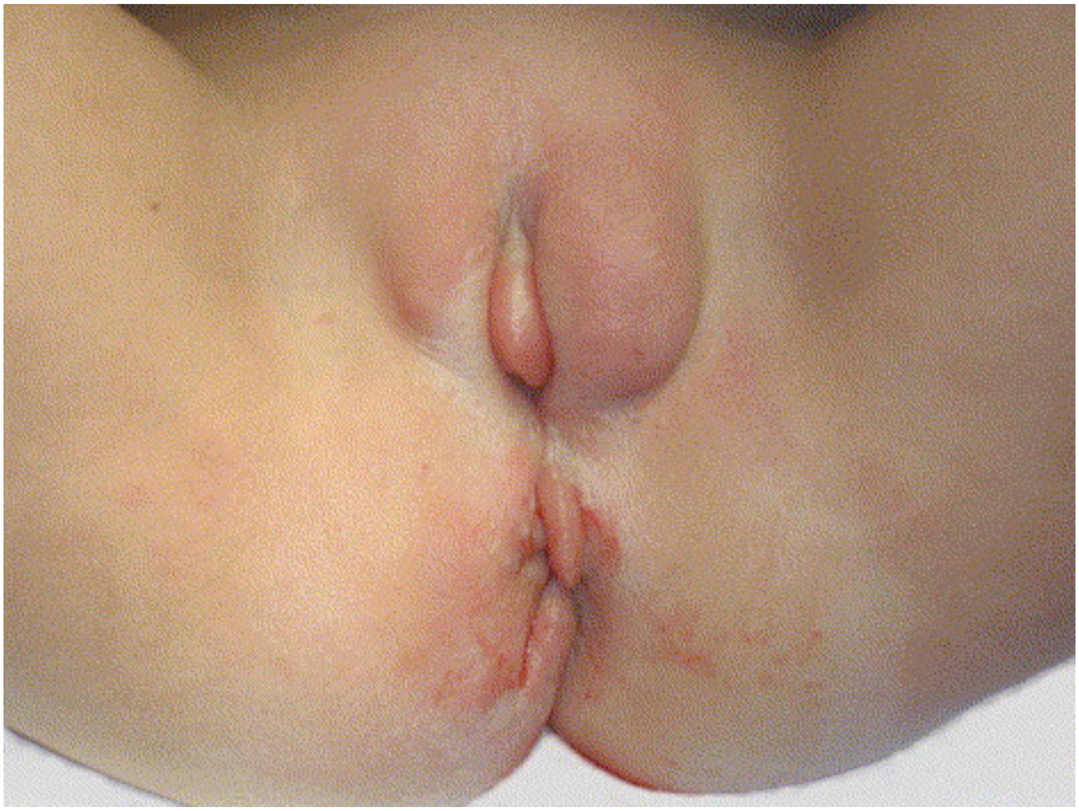


Fig. 356. This is the perianal region of a 7-year-old girl who was suspected of being a victim of sexual abuse. This image shows perianal fissures extending from the anus at 2, 5, 8 and 10 o'clock, as well as two skin tags at 12 and 6 o'clock. These are accompanied by swelling of the labia majora, especially on the left, together with edema and enlargement of the clitoris. Initially it was not realized the child had a diagnosis of Crohn' disease in which the above findings are consistent. (sciencedirect.com)

Anatomical variations or physical conditions that may be misinterpreted as sexual abuse include: lichen sclerosis (Figs. 357 & 358); vaginal and / or anal streptococcal infection (Fig. 355); failure of midline fusion; nonspecific vulva ulceration; urethral prolapse (Fig. 335); female genital mutilation; unintentional trauma (straddle injuries, Figs. 327 B, 328, 329 & 360); labial fusion (adhesions) (Fig. 354); about one-third of girls have asymmetry of the vaginal and or hymen orifice; and a V-shaped groove in the posterior fourchette of girls, without signs of acute trauma, is normal. (Fig. 359 shows the location of the posterior fourchette).

Fig. 357. This is the perianal and vulvar region in a girl showing hypopigmentation and atrophy due to lichen sclerosis et atrophicus. This disease is a chronic dermatosis characterized by an initial short inflammatory phase followed by chronic scarring and skin atrophy. It is more common in females, with 2 peaks in age distribution: (1) prepubertal children and (2) postmenopausal women. It is one of the most common causes of chronic vulva symptoms in adult females. When this disease occurs in men it tends to do so in those who are uncircumcised. (your-doctor.net)

Fig. 358. This image is of the perianal region and posterior midline of the sacrum-coccyx in a patient with lichen sclerosis et atrophicus. (see.visualdx.com)

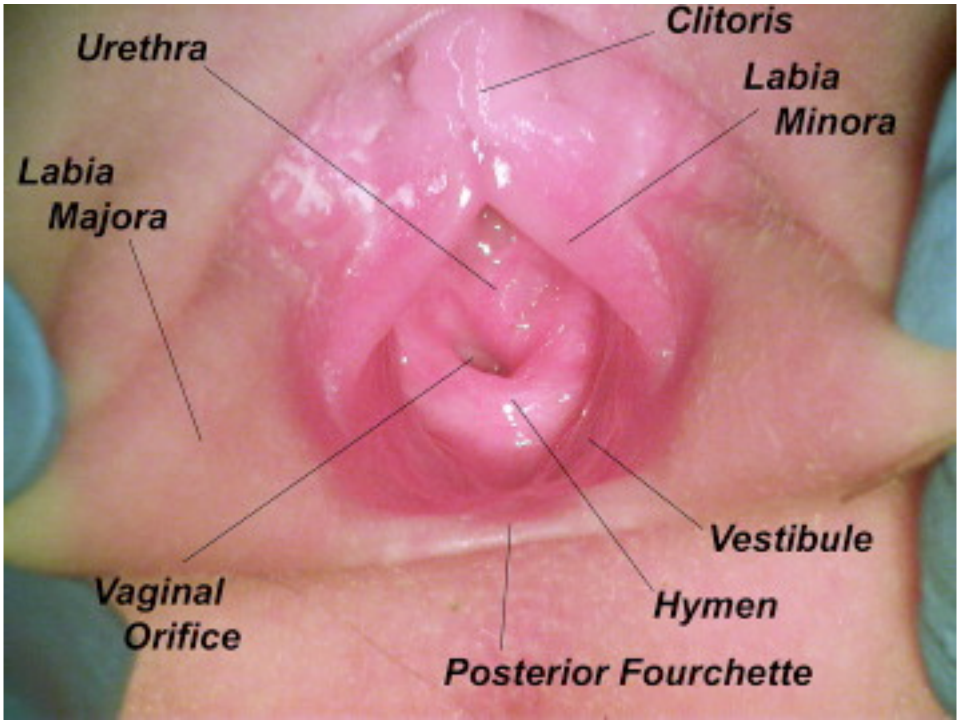


Fig. 359. This image shows you the components of the genital region of the female including the posterior fourchette. (sciencedirect.com)

Findings suggestive of abuse include: acute abrasions, lacerations or bruises of the labia, perihymenal tissues (Fig. 360); hymenal notch or cleft extending through more than 50% of the width of the hymenal rim (Fig. 331 B & D); fresh laceration or scarring of the posterior fourchette not involving the hymen (but unintentional trauma must be ruled out) (Fig. 361); condyloma in children over 2-years-of age, however this must be interpreted with caution (Figs. 362 & 363); and significant anal dilatation (Figs. 364 & 365). The child abuse literature suggests that hymenal injuries to the **anterior portion** of the hymenal ring are more commonly caused by digital penetration and those to the **posterior portion** more often are due to penile penetration. The specificity of such findings however, have been questioned. It has also been suggested that posterior perineal injuries are uncommon except as a result of intentional trauma (Fig. 366). There are a number of studies, which do not support this assumption as the posterior fourchette can be injured in accidental trauma, as shown by a 6-year-old who tore her posterior fourchette in a bicycle accident.

Fig. 360. This image is an example of moderate genital trauma. This 9-year-old girl presented with vaginal bleeding. Inspection revealed a hematoma of the anterior portion of the right labia majora, contusions of the clitoris and anterior labia minora, and a hematoma protruding through the vaginal opening. A small superficial laceration is present on the left, between the labia majora and minora. There was also a vaginal tear of the right lateral wall. Although these findings suggest sexual abuse, they in actuality are the result of a straddle injury on a diving board. (nodba.ir)

Fig. 361. This infant presented for examination due to blood spotting on her diaper (Fig. 383). Inspection revealed a perineal tear just posterior to the hymenal ring. There was no evidence of internal extension on vaginoscope. These findings suggest a superficial penetrating injury. Sexual abuse was suspected. (nodba.ir)

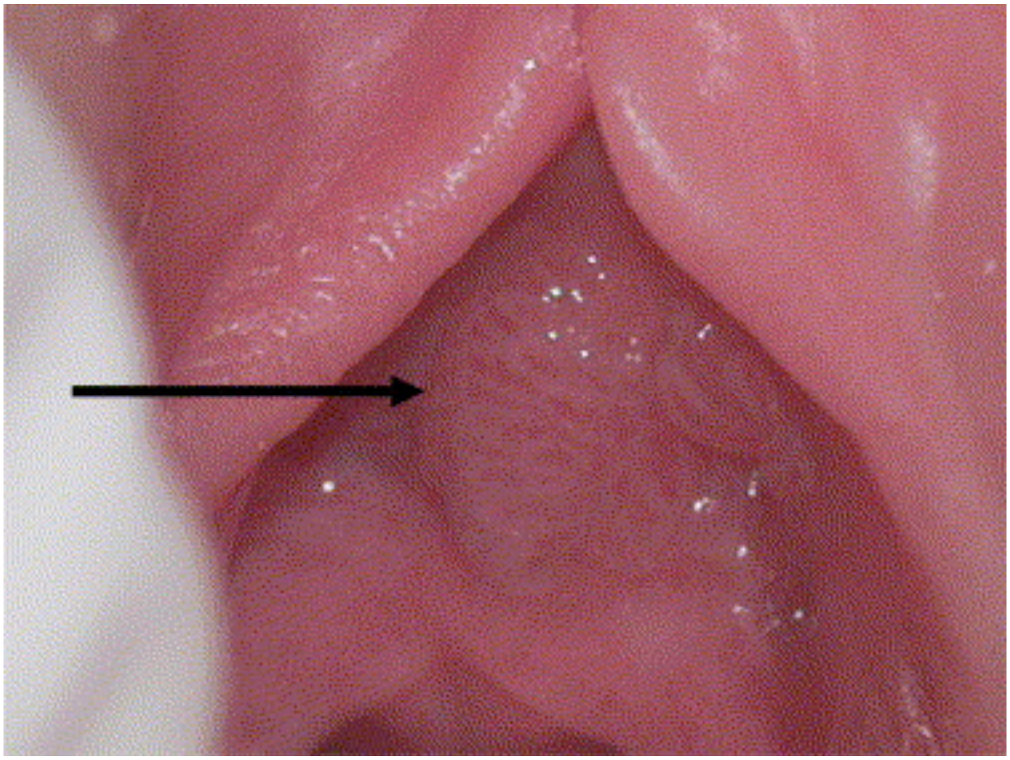


Fig. 362. This image shows a large strawberry-like condyloma (arrow) above the urethral meatus in a young girl. (pediatrics.aappublications.org)

Fig. 363. The above image shows condyloma (warts) on the perineal or perianal skin region. These lesions tend to be more flat and papular in appearance then the condyloma on or near a mucosal surface. This is the same child as presented in Fig. 362. (pediatrics.aappublications.org)

Fig. 364. This image show evidence of acute anal dilatation complicated by an acute laceration. This is an example of recent anal sexual abuse. The tear indicates the violent nature of the act. (revespcardiol.org)

Fig. 365. This image shows definitive anal sphincter dilatation and suggest chronic anal sexual abuse. (revespcardiol.org)

Fig. 366. This image shows a V-shaped deep hymenal laceration at the 6 o'clock position (arrow) and fossa navicularis and posterior fourchette lacerations. This case is that of an 8-month-old who had been sexually assaulted 3 days before. (pediatrics.aappublications.org)

Regarding condyloma (anogenital warts) there are a number of facts that must be kept in mind as to their interpretation. The latency period for warts in general is not known. The incubation period of warts can be lengthy (2-3 years), however, warts have been seen in newborns. The method of transmission are numerous and warts are often seen in young children.

Anogenital warts in children can be transmitted through perinatal (around the time of birth) infection, digital inoculation (self, family members), casual non-sexual contact, sexual contact, and possibly fomites (objects such as books and clothing). This is much unlike in adults where more than 90% with anogenital warts are from sexual contact and where anogenital warts in women are restricted to sexual experiences. Condylomata can be present at birth, including babies born by cesarean section. The perianal region is the most common anogenital site.

Non-sexual contact appears to be the most common route of spread of anogenital warts in young children. Remember, there is a prolonged latency period. There is vertical spread (mother to child in the womb), children can self-inoculate, or family members may spread the disease to their children by non-sexual contact.

Findings that are definitive evidence of abuse or sexual contact include: sperm or seminal fluid in, or on, the child's body; positive culture for N. gonorrhoeae or serologic confirmation of acquired syphilis or other sexually transmitted diseases (when perinatal and iatrogenic transmission can be ruled out); intentional, blunt penetrating injury to the vaginal or anal orifices (Figs. 366, 367 & 368).

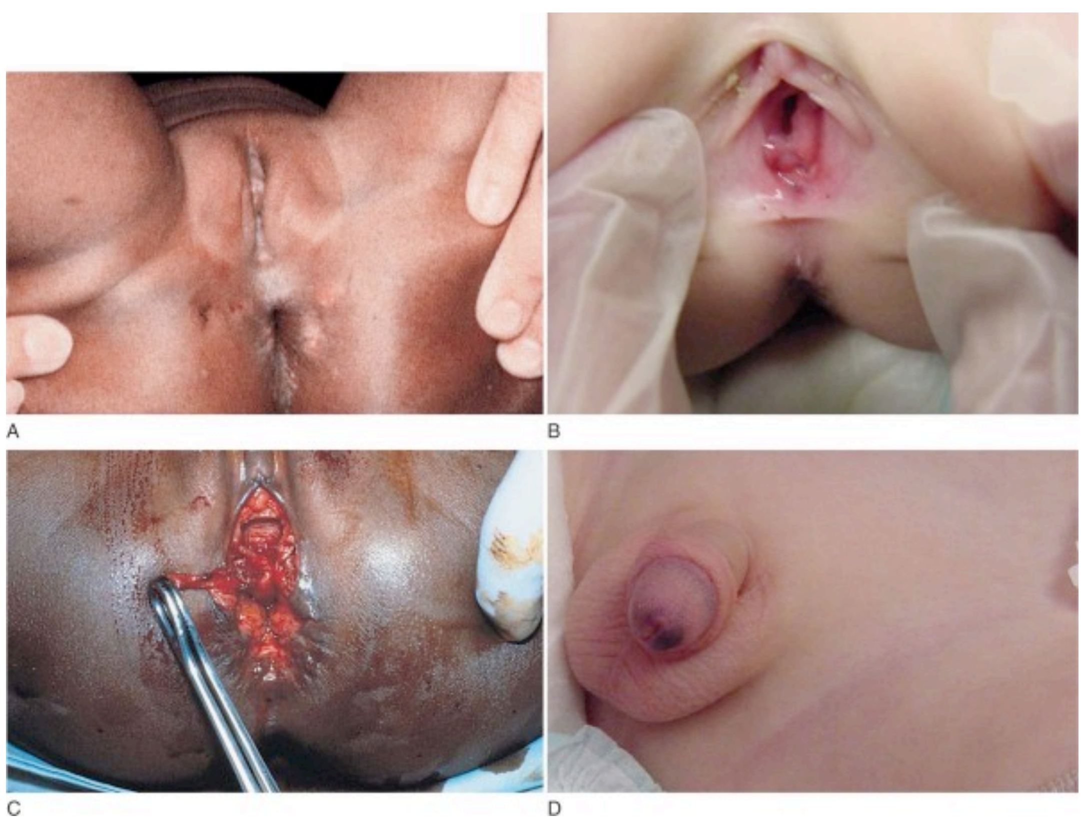


Fig. 367. These images and those of Figs. 366 & 368 are those of acute traumatic findings seen in victims of sexual abuse and assault. In A, of the above images there are abrasions, contusions, and punctate tears of the perineum and perianal areas in a prepubescent girl. B, This image is of a 21-month-old infant, sexually assaulted by the mother's paramour, erythema and edema of the entire hymen are evident, along with bruising of its inferior aspect and of the posterior fourchette. A laceration is at 5 o'clock. C, This image shows severe genital trauma in a prepubescent girl after being sexually assaulted. Inspection revealed a hymenal tear at 6 o'clock, extending posteriorly through the perineal body to the rectum. There was also a 1-inch (2.54 cm) vaginal tear, along with a rectal tear and complete disruption of the external anal sphincter. D, This image depicts acute bruising of the glans of a baby, who also had a femur fracture. (, Courtesy Kamthorn Sukarochana, M.D.; D and E, courtesy Janet Squires, M.D., Children's Hospital of Pittsburgh, PA) (nodba.ir)

E

F

G

Fig. 368. The image in E is that of an older boy, who shows penile and scrotal bruising along with multiple small bruises over the lower abdomen. F, This image contains perianal laceration, abrasions, and burns in a prepubescent boy. The examiner suspected that the burns were inflicted to coverup evidence of sodomy. G, On examination of this 3-year-old boy there was evidence of prominent perianal ecchymoses. (nodba.ir)

Blunt penetrating trauma to the vaginal orifice produces a characteristic pattern of injury; bruising, lacerations and or abrasions are typically seen between the 4 and 8 o'clock positions of the hymen. Such injuries often extend to the posterior commissure, fossa navicularis and the posterior hymen. Any interruption in the integrity of the hymenal membrane edge that extends to the posterior vaginal wall is likely to be a healed laceration.

Genetic and defect conditions that can mimic child abuse: There are connective tissue disorders classified as **Ehlers-danlos type I to X**, which involve laxity of the skin and joints. Some of the subtypes have a propensity for poor healing with thin, cigarette-paper-like scar formation, as well as bruising, prolonged bleeding, and occasional vascular disruption. Ehlers-danlos syndrome type I and II are inherited as an autosomal dominant disorder.

Some infants, especially those of pigmented races, will show blue **Mongolian pigmentary marks** over the back, buttocks, upper thighs, especially posteriorly. They usually have a consistent color, defined borders, and tend to disappear with age (Fig. 369).

Fig. 369. The above image is of a baby with widespread slate gray-blue patches indicative of Mongolian spots. Note their prominence on the posterior aspect of the trunk. (newborns.stanford.edu)

Shwachman-Diamond syndrome is a autosomal recessive disorder associated with short stature, developmental delay, exocrine pancreatic insufficiency, short ribs with metaphyseal dysplasia, and isolated or combined decreases in red cell, white cell, or platelet counts. Lowered platelet counts lead to increased bruising. **Hemangiomas** (collection of blood vessels) can be present in the genital area, such as in a young girl who had a hemangioma limited to her labia making them appear red, large and irregular. This appearance however does not change in the short term (Fig. 370).

Fig. 370. This genital mass in a 6-month old led to concerns of sexual abuse. The mass was circumscribed, compressible, and warm. It was diagnosed as an infantile genital hemangioma, deep variety. (pediatricsconsultantive.com)

There is an interesting anatomic change in the brain of those who have been subjected to severe, repeated sexual abuse in the child. This finding was presented at an annual meeting of the American Psychiatric Association, as well as in another study done by Yale, which addressed Vietnam Combat Veterans suffering from **Post-Traumatic Stress Disorder (PTSD)**. In both of these studies they noted a significant decrease in the size of the **hippocampus**. Most sexually abused women had PTSD symptoms, such as recurring nightmares about their trauma, emotional numbing, dissociation, exaggerated reactions when startled and a decrease in verbal short-term memory.

Dissociation is an altered state of consciousness induced by terror. It includes absorption in one's thoughts to the exclusion of the external world, feeling of detachment from one's body or self, and memory lapses. It is believed the dissociation may have a role in repressed memories of abuse.

It is thought that severe trauma, both psychological and physical, unleashes a a cascade of stress hormones that harm the hippocampus and related brain areas over time.

Sexual Homicides of Children: Typically, these occurred between birth and 4 years and between 13 and 17. From birth to 4 years, the most likely perpetrator was a family member and the least likely was a stranger. From 13 to 17, the most likely perpetrator was an acquaintance and the least likely was a family member. One study showed that all murder victims under the age of 12 years, their death was preceded by child abuse in 57% of the time, with 79% suffering abuse by the assailant before their death. Sexual assault preceded the death of 6% of all murder victims under 12 years of age.

The most common method of death in the sexual homicides was strangulation for victims less than 12-years-of age and cutting or stabbing for victims between 13 and 17.

C. Traumatic Injuries of the Rectum and Anal Canal

Traumatic anorectal injuries are relatively uncommon. By far the most frequent cause of anal trauma are **iatrogenic sources**. These include obstetrical injuries, as well as injuries caused by anorectal procedures (Fig. 299). They may be due to penetrating injuries to the pelvis and perineal area, such as impalement, blast or gunshot wounds, as well as severe blunt traumatic injuries, often associated with pelvic fractures (Fig. 371). Blunt trauma to the perineum can result in extensive tissue loss and even disruption of the levator sling. Other caused of injury are from enema tips and rectal thermometers, insertion of foreign bodies, and even fist fornication (Figs. 372 & 373).

Fig. 371. This image is from an adolescent who fell while roller skating downhill and slid on her bottom for several feet over the sidewalk, tearing her perineum on an object projecting up between two of the cement plates. A laceration involving the right labia majora and minora, extending through the perineal body to the anus, is evident on inspection. Further examination revealed vaginal and rectal extension of the tear with complete transection of the external anal sphincter. The peritoneum was intact. (nodba.ir)

Fig. 372. This image is of a rectal foreign body, which is a vibrator self-inserted. (accessemergencymedicine.com)

Fig. 373. This image shows a 7-oz beer bottle within the rectum, which required surgical removal. (accessemergencymedicine.com)

Fist fornication is also referred to as “fisting” or “hand balling.” Fist penetration of the anus and rectum as a sexual practice was first described in detail in the medical literature by Navin in 1981. First fornication is a sexual act that involves introducing heavily lubricated, clenched fist through the anus into the rectal ampulla. Insertion may continue past the upper rectum, and reach the sigmoid colon or even the descending colon. Amyl nitrate, marijuana, LSD, mescaline, and alcohol have been used before engaging in fist penetration, since they are believed by the participants to relax the anal sphincter.

In 1984, Reay and Eisle reported the first fatality due to “Fisting.” This was a female victim who was assaulted by a ship's crew member who escorted her to her stateroom after a shipboard partly. She had a blood alcohol level of 180 mg/dl. A second death from "Fisting" was reported by Orr *et al* in 1995. This was also a female who was found dead in a bathtub. The autopsy showed her vagina to be lacerated. The anus and rectum also showed extensive lacerations that were especially prominent on the posterior and lateral aspects. On internal examination she had massive retroperitoneal hemorrhage. Her boyfriend was subsequently convicted of sexually assaulting her by forcing his fist into her vagina and rectum. He had placed her in the bathtub in an attempt to revive her.

The American Association for the Surgery of Trauma (AAST) developed a rectal organ injury scale, which is typically used for blunt and penetrating trauma, however, its use for injury secondary to anorectal foreign bodies is considered appropriate. It is as follows:

Grade I : Hematoma/ contusion or hematoma without devascularization and or partial-thickness laceration

Grade II : Laceration < 50% circumference

Grade III : Laceration > 50% circumference

Grade IV : Full-thickness laceration with extension into the perineum

Grade V : Devascularized segment

There is another classification involving anorectal foreign bodies, which categorizes them as **voluntary versus involuntary** and **sexual versus nonsexual**, which is as follows:

Voluntary - sexual: vibrators (Fig. 372), dildos, varied other objects (Fig. 373)

Voluntary - nonsexual: body packing of illicit drugs

Involuntary - sexual: rape or assault (e.g. the Abner Louima case where 4 New York City Police Department Officers assaulted/ sodomized him with a broom stick in 1977) (Fig. 374)

Involuntary - nonsexual: the mentally ill or children: retained thermometers; enema tips; oral ingestion, such as bones, tooth-picks, plastic objects

Fig. 374. This image is of a victim of an assault in which a stick was forced into his anal canal and rectum. This is not the Abner Louima case. (accessemergencymedicine.com)

By far the most common category of rectal foreign bodies is objects that are inserted voluntarily and for sexual stimulation. Numerous objects have been described in the literature some of which include: vibrators, dildos, a turkey baster, Billie club, cucumbers, apples, light bulbs, Christmas ornaments, camping stove, knives, trailer hitch, nails, bottles, utensils, pill bottles, cans, jars, pipes and tubing, balls, balloons, umbrellas, stones, flashlights and scissors. (Figs. 372 & 373)

The second most common type of rectal foreign body is best known as body packing and is commonly used by drug traffickers. A person known as a mule swallows several packages of drugs, typically heroin or cocaine, wrapped in plastic bags and / or condoms (Figs. 375 & 376). The potential complications from body packing include impaction, perforation, and even rupture of the packages resulting in systemic absorption of the drugs, which can result in overdose and even death of the mule. Involuntary nonsexual foreign bodies are generally found in the elderly, children, or the mentally ill (Figs. 377 & 378). The objects are usually retained thermometers and enema tips; aluminum foil wrapping from pill containers; and orally ingested objects, such as tooth picks, chicken bones, plastic objects, such as erasers or pill bottle caps, and even coins or small plastic toys. Any of these mechanisms or objects can cause severe injury. Most foreign objects are retrieved from the stomach (46%) and esophagus (13%).

Fig. 375. This is a radiograph of a typical body packer with a multitude of cocaine packets throughout the small and large bowel. (auntiminnieeurope.com)

Fig. 376. These are packets of cocaine from a body packer who swallowed them carry them within his intestines. (casereports.bmj.com)

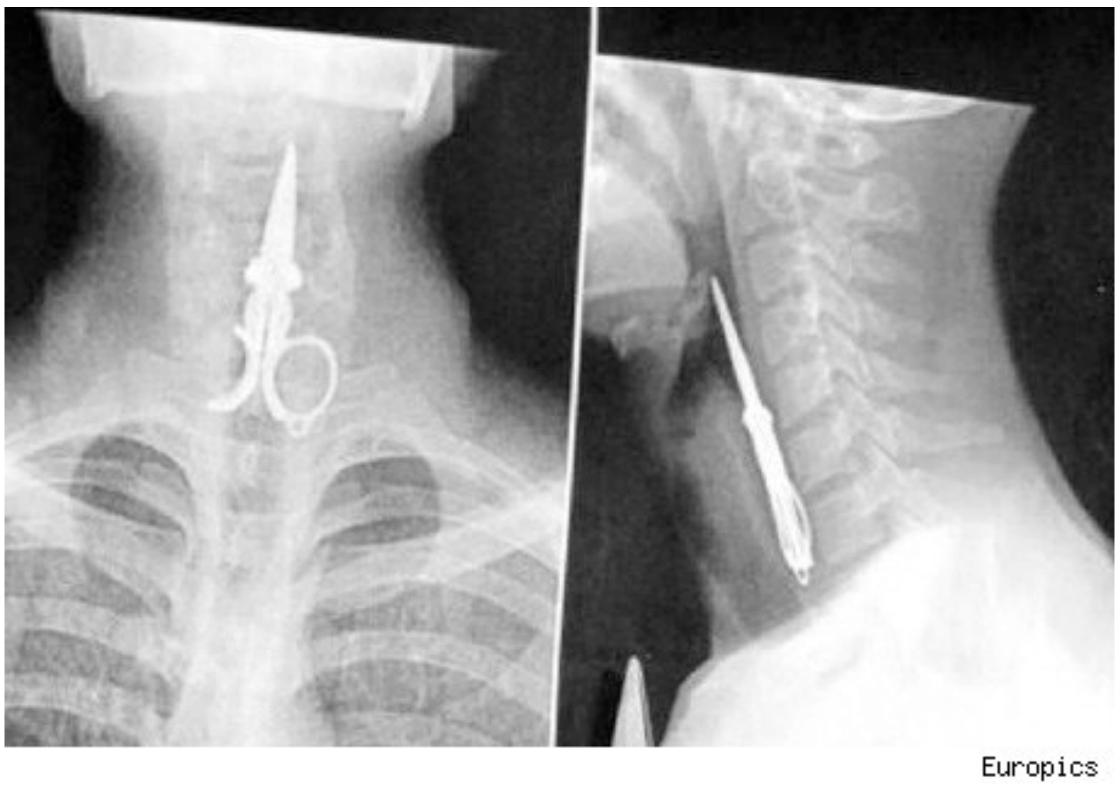


Fig. 377. These radiographs show scissors within the esophagus of an elderly person. (hospitalstay.com)

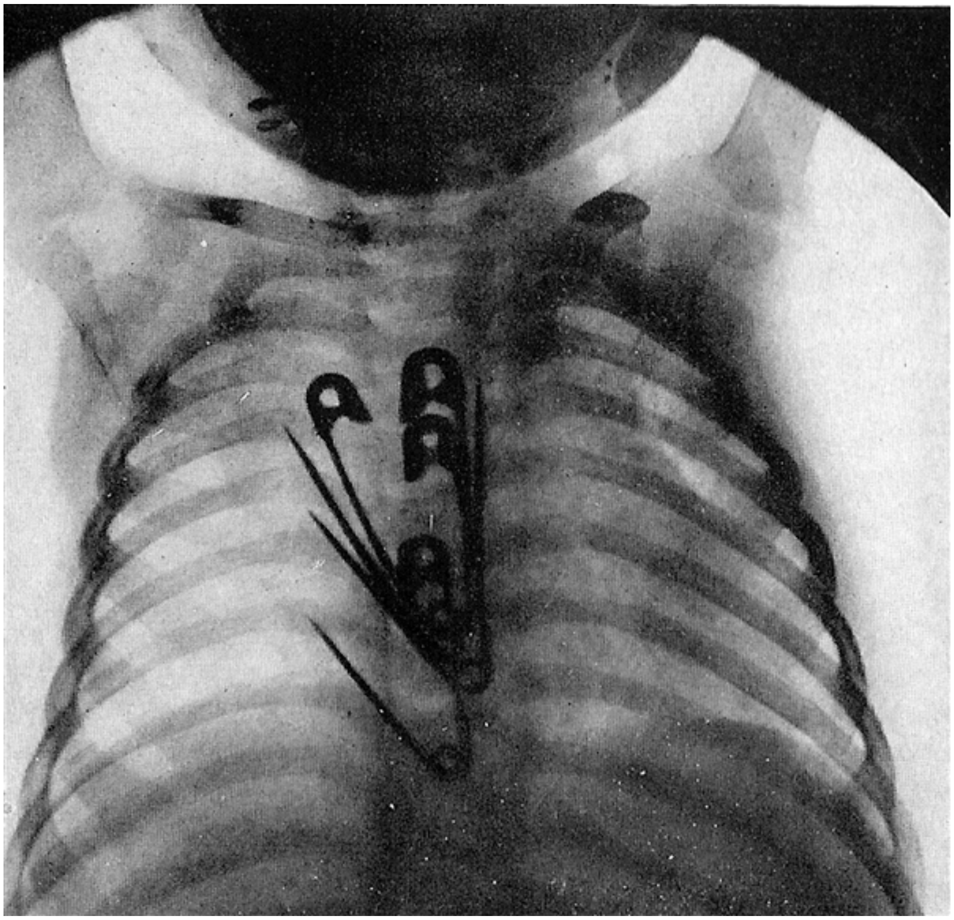


Fig. 378. This is a radiograph of a child who had swallowed multiple safety pins. The swallowing of foreign objects by children occurs typically between 1-3 years. (hi9.in)

There is another alternative classification system, which reflects the extent of the injury caused by the object. This system stratifies injury into four categories:

Category I : retained foreign body without injury

Category II : non-perforative mucosal laceration

Category III : sphincter injury

Category IV : rectosigmoid perforation

Pediatric Traumatic Injuries of the Rectum and Anal Canal: Traumatic injuries to the anorectal region in children is uncommon. They may occur as the result of blunt force trauma sustained in a motor vehicular accident, falls from heights, straddle injuries (Figs 371 & 379). They may also occur due to accidental penetration or penetration due to a sexual assault (Figs. 342, 364, 367 C & 368 F).

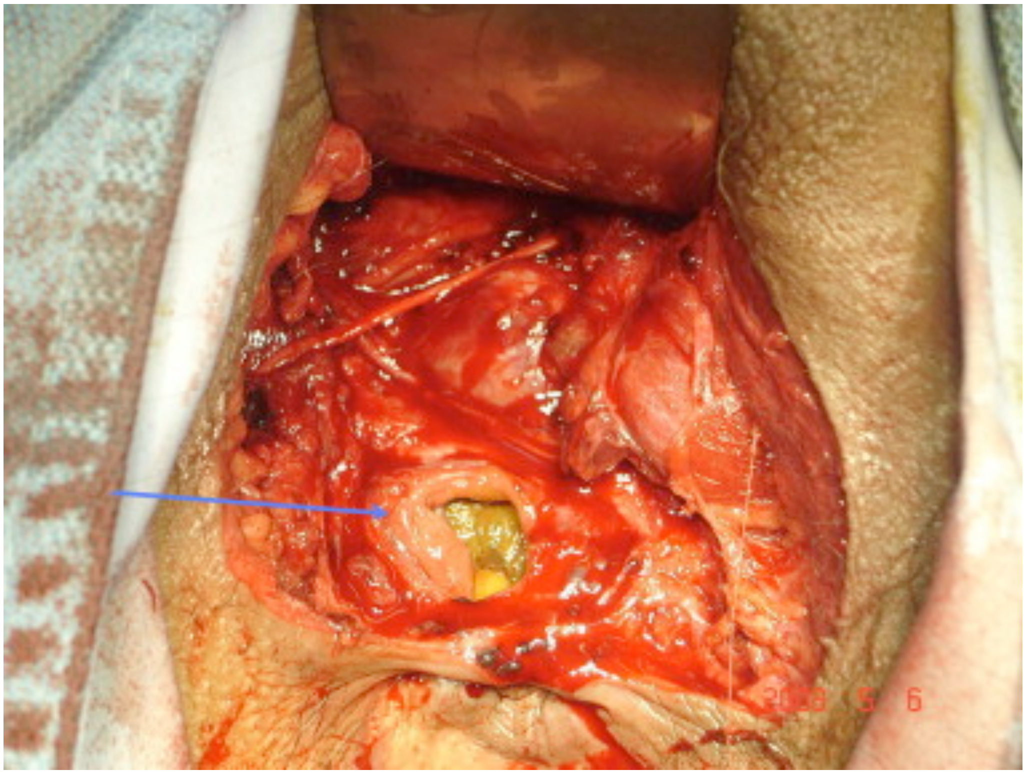


Fig. 379. This image shows a large laceration with perineal involvement, rectal perforation, and stool contamination (blue arrow) in a 18-year-old male following a motor vehicular accident. The open book fracture of the pelvic symphysis (Type BI_ is not seen. (sciencedirect.com)

Penetrating traumatic anorectal injuries in children are rare. They are more commonly noted in boys, which may reflect their more active life style. The commonest cause of penetrating anorectal injuries in children include falls on pointed objects (impaling), sexual abuse (Figs. 364, 365, 368 F & G & Figs. 380 & 381), firearm injuries, road traffic accidents, especially those with a fractured pelvis, forceful enemas, swallowed foreign bodies and the use of rectal thermometers. Many of these penetrating injuries were due to impalement while riding bicycles. The mechanism of impalement included falls onto the pointed unprotected pedal or the pointed disconnected spoke of the bicycle, and impalement by the metal bar that normally would be supporting the bicycle seat.

The most common presentation is rectal bleeding, however, in girls, there may be vaginal bleeding or discharge with or without rectal bleeding.

Fig. 380. This image is of the normal anal dilatation and venous pooling of the anus in a child. (accessemergencymedicine.com)

Fig. 381. This image shows perianal acute contusions (blue-gray color) and acute lacerations in a child who was sexually abuse. (accessemergencymedicine.com)

What is very important to remember is any child presenting with an anorectal injury due to penetration should be suspected of being a sexual assault victim until proven otherwise. The physician, if the child is alive, or the forensic pathologist should the child have died, should be prepared to submit swabs, aspirates and washings of all cavities. Detailed notes, diagrams and photographs should be accomplished in the event it is determined a sexual assault took place. In the developed countries the most common causes of anorectal injuries in children are sexual abuse and firearms.

Death of a child as a result of intercourse is rare. Marti's *et al.* article "Traumatic lesions of the Rectum" evaluated 337 children for sexual abuse. In that article only one patient, a 6-week-old girl presented with rectal rupture and peritonitis who was successfully treated. In 1982, Block *et al.* published an article “Anorectal Trauma in Children,” in which they evaluated 147 children for sexual assault. Only 16 of this group suffered significant anal injuries. Again, there were no deaths. Muram *et al.* published an article “Anal and Perineal Abnormalities in Prepubertal Victims of Sexual Abuse,” in which they evaluated 310 children for sexual abuse. In this series 104 children had evidence of anal injury, however, there were no deaths. Orr *et al.* published an article “Fatal Anorectal Injuries: A Series of Four Cases” in 1994. One of the of the four cases involved a 21-month-old white female who at autopsy was found to have an anus measuring 1.5 cm in diameter along with two radial lacerations from the anus into the perineum somewhat like that seen in Fig. 381. There was also an ulceration at the anal verge (Fig. 177, p 207). Internal examination showed diffuse peritonitis and a ¾ inch in diameter, transmural area of perforation and necrosis on the anterior wall 2 inches above the pectinate line (Figs. 154 & 157, p 181 & 184).

Although **sodomy** is a relatively common finding in sexual assaults (Figs. 364, 365, 368 E & G & 381), typically penetration of the anal orifice tends to leave few, if any, physical findings. Even a young child can pass large stool without causing injury to the anus.

Normal or nonspecific anal findings include: fissures, excoriation, redness, which may be seen after sexual abuse but there are other causes; anal tags, which are protrusions of tissue typically at the 6 o’clock and 12 o’clock midline positions (Figs. 382, 383, 384 & 385)); diastasis ani, smooth anal skin at the 6 o’clock or 12 o’clock midline positions; increased skin pigmentation and thickened anal skin folds; venous congestion, pooling of blood in the veins around the anus and gaping (wide open) anus is considered normal if stool is present in the ampulla of the rectum or dilated anal canal (Fig. 380).

Fig. 382. This image shows an anal fissures, which are the most common cause of fresh rectal bleeding in children, which is recognized typically by fresh blood staining diapers (Fig. 383). (cal.md.chula.ac.th)

Fig. 383. Fresh blood staining diapers. (cal.md.chula.ac.th)

Fig. 384. This image shows an anal fissure and an acute shallow tear of the anus (arrow) at the posterior side. (cal.md.chula.ac.th)

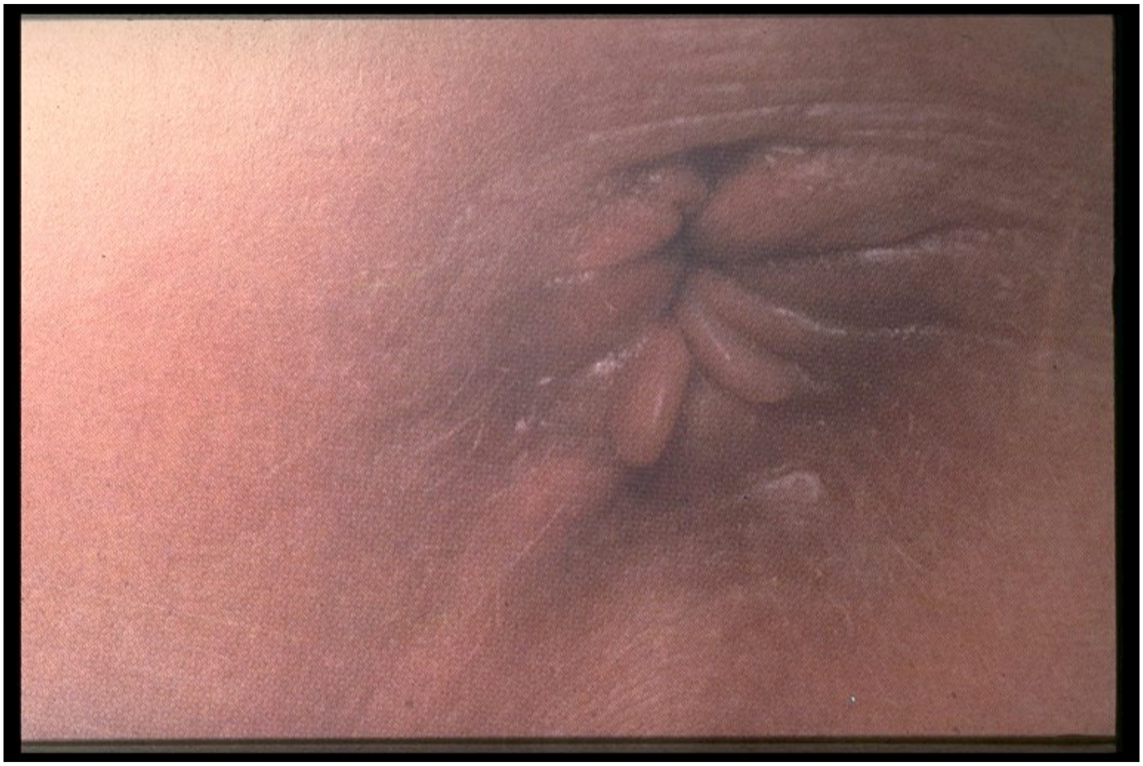


Fig. 385. This image shows a skin tag resulting from chronic anal fissures. (cal.md.chula.ac.th)

Findings that may or may not indicate sexual abuse include: acute anal injury manifested by bruising, lacerations, abrasions and swelling. Most of these injuries heal without leaving any lasting signs. Acute injury is always suspicious for sexual abuse (Figs. 364, 365, 367 B & C, 368 F & G, & 381); Scars may result from deep lacerations after sexual abuse occurred. Skin tags away from the midline of the anus may indicate healed injury; and chronic sexual abuse may result in funneling (loss of subcutaneous fat around the anus), changes in the anal skin, and decreased muscle tone (Figs. 383 & 384)). Decreased tone is defined as at least > 15 mm (some use > 20 mm) anal dilatation with no stool in the ampulla or the distal anus. In the **prepubertal child**, perianal abnormalities resulting from sexual abuse are uncommon. Prepubertal children who were sexually assaulted show perianal laceration and anal laxity similar to adults (Figs. 367 A & C, 368 F & G, 386 & 387). The resulting laxity of the anal sphincter muscles created an opening that did not return to normal for 7-10 days. However, the irregular appearance of the anus in such cases differed from the smooth contour of a normally dilated one (Fig. 380).

Fig. 386. This image shows a perianal wound accompanied by anal dilatation in a 3-year-old girl after anal penetration. (accessmedicine.net)

Fig. 387. This image shows acute anal trauma with dilatation due to anal penetration in a prepubertal child. (accessmedicine.net)

In the adolescent, a sexual assault is likely to include sodomy. Forced anal penetration may result in erythema and swelling of the tissues even if the assailant used a lubricant. In some cases you may also see multiple perianal lacerations and or contusions (Fig. 388). In the most severe cases, penetrating injury extended into the peritoneal cavity. The latter is more likely to occur if a foreign object was used during the assault.

Fig. 388. This image is of an acute rectal laceration in a young boy who was sexually abused by a relative. Note the redness (erythema) and perianal laceration. (accessmedicine.net)

Healed perianal injuries leave little evidence of past trauma. The erythema and edema of an acute injury tend to resolve in a matter of hours to one to two days. Most lacerations appear to heal without development of scar formation, and the anal laxity that resulted from the injury to the anal sphincter muscles disappeared in 7-10 days. In the living patient, an anterior-posterior diameter of 20 mm (2 cm) or greater appearing within 30 seconds with no stool present in the rectal ampulla is thought by many to be evidence of repeated anal penetration. While this finding has been noted in male prostitutes and other victims of sexual abuse, it is considered by others to be only a “marker” for further investigation. Their argument has been whether reflex anal dilatation is usually a sign of repeated anal penetration or whether it occurs normally (studies quote incidences of 4-15%) or as a result of conditions such as chronic constipation or Crohn’s disease. *To date the evidence suggest that reflex anal dilatation of more than 2 cm is more likely than not to be associated with abuse, most especially if accompanied by perianal acute or resolving contusions, while dilatation of more than 1 cm is a possible supporting sign. As previously stated making a diagnosis of sexual abuse based on a single physical sign is very rarely possible. With child sexual abuse it is particularly dangerous to try do do so because devastating social consequences of an incorrect diagnosis.*

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