CHAPTER

2

Reproductive Anatomy

KEY TERMS

Cervix
Clitoris
Fallopian tubes
Hymen
Labia majora
Labia minora
Mons pubis
Oviducts
Prostate
Semen
Seminal vesicles
Testes
Vagina
Vulva

Historically, the female body and, more specifically, the female reproductive tract, because it is internal and therefore hidden, has always been subject to much romanticism, fantasizing, and descriptive error. Until the publication of the writings and illustrations of the most outstanding anatomist of the Renaissance, Andreas Vesalius, there was virtually no anatomically correct knowledge of female structure. The reason for the lack of information until the sixteenth century has been attributed

to the lack of material for dissection. Even when courses in human anatomy were recognized as part of the curriculum in medical schools all over Europe, corpses for dissection were difficult to obtain because only the bodies of executed criminals who came from an area at least 30 miles away could be used. One or two dissections a year were performed, and female cadavers were rarely available. Vesalius's unprecedented graphic visualization of anatomy, *De Humani Corporis Fabrica,* was not only an accurate representation of the structure of males but was based on the dissections of at least nine female cadavers as well and, therefore, formed the foundation for modern anatomical knowledge of both men and women. In the 400 years since Vesalius, if there were any women physicians and anatomists who contributed to the advancement of knowledge concerning the female reproductive tract, it would not be obvious from the nomenclature. The discoverers of the female anatomical parts; the recognizers of clinical syndromes, signs, tests, and phenomena; the developers of instruments, techniques, operations, and therapies were evidently all men or, at any rate, only men have received acknowledgment (Table 2–1).

Even after anatomical knowledge of the human female was available, there was relatively scant knowl-

TABLE 2–1 Some Contributions to Nomenclature in Gynecology and Obstetrics

Individual	Eponym	Description
Caspar Bartholin 1655–1738	Bartholin's glands	Greater vestibular glands
James Read Chadwick 1884–1905	Chadwick's sign	Color changes in the pregnant vulvovaginal mucosa
Albert Döderlein 1860–1941	Döderlein's bacilli	Lactobacilli of vagina
Gabriele Fallopius 1523?–1562	Fallopian tubes	Oviducts
Regnier de Graaf 1641–1673	Graafian follicle	Preovulatory follicle
Alfred Hegar 1830–1914	Hegar's sign	Softening of the lower uterine segment during pregnancy
John Braxton Hicks 1823–1897	Braxton Hicks contractions	Contraction of the pregnant uterus
Hugh Lenox Hodge 1796–1873	Hodge pessary	Vaginal support of uterine displacement
Max Huhner 1873–1947	Huhner test	Postcoital semen examination
William Fetherstone Montgomery 1797–1859	Montgomery's tubercles	Breast areolar changes during pregnancy

(continues)

TABLE 2–1 *(continued)*

Individual	Eponym	Description
Johannes Müller 1801–1858	Müllerian ducts	Embryonic paired ducts; give rise to uterus and vagina
Martin Naboth 1675–1721	Nabothian cysts	Cervical mucous cysts
Franz Carl Nägele 1777–1851	Nägele's rule	Formula for estimation of date of delivery
Anton Nuck 1650–1692	Canal of Nuck	Inguinal canal
George Papanicolaou 1883–1962	Pap smear	Cervical cancer detection
Isidor Rubin 1883–1958	Rubin test	Tubal insufflation
Alexander Skene 1838–1900	Skene's ducts	Paraurethral ducts
Friedrich Trendelenburg 1844–1924	Trendelenburg position	Elevated pelvic position
Henry Turner 1892–1970	Turner's syndrome	Ovarian dysgenesis
Thomas Wharton 1614–1673	Wharton's jelly	Umbilical cord mucous matrix
Caspar Wolff 1733–1794	Wolffian duct	Embryonic mesonephric duct

edge about her physiology until more recently, and the dissemination of such information to men and women has been minimal. Some of the myths that have arisen concerning the physical and mental abilities of women have had remarkable persistence among educators and physicians who presumably should know better. Fallacies and generalizations about female anatomy, physiology, and sexuality have arisen based more on cultural assumptions than on accurate observations. Even when it is pointed out that insufficient evidence exists for a belief, or that scientific data invalidate a previously held opinion, there is a tendency to cling to outmoded misinformation. The ignorance of men and women concerning the female body has helped to perpetuate the continuation of fallacy and superstition; this chapter provides the anatomical basis to distinguish the myths from the realities.

THE PELVIC GIRDLE

One widely held notion, for example, is that there is greater risk in participation in contact sports for

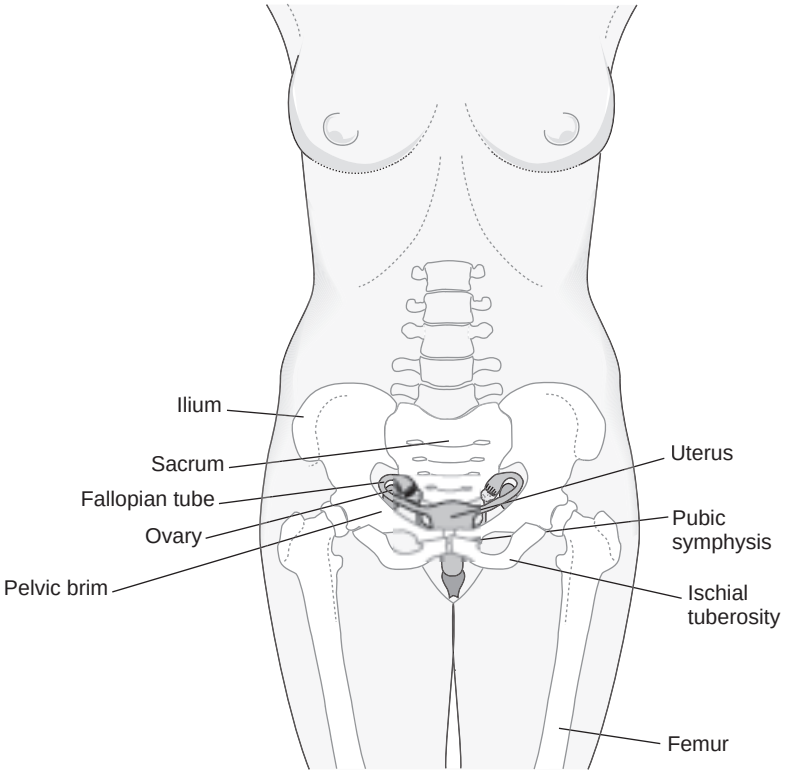

Figure 2–1 Position of the reproductive organs within the pelvic girdle.

females because they are more vulnerable to injury than males and because their internal reproductive organs are more vulnerable to damage. Actually, there are differences in the susceptibility of females and males to the impact of direct contact in sports, but the resultant injuries are to ligaments and muscles, for reasons to be described later, and not to the internal organs. A protective cage for the sexual organs of women is formed by the strong bony pelvic girdle, and the pelvic viscera are seldom damaged, even in the crushing injuries of accidents (see Figure 2–1). The exposed genitalia of the male are far more likely to be injured in contact sports.

The pelvic girdle is the general name given to the two broad, heavy hip bones that provide an attachment for the leg and support the lower spine in order to transmit the weight of the body from the vertebral column to the limbs. Each hip bone, also called the *os coxae,* is composed of three fused bones: the *ilium,* the *ischium,* and the *pubis.* A cup-shaped socket, the *acetabulum* (Latin for little saucer that holds vinegar), receives the head of the thigh bone or femur to form the hip joint (Figures 2–2, 2–3).

Ilium

The large ilium flares upward and outward from the acetabulum. When hands are placed on hips, one is feeling the broad and thick crest of the ilium. Follow it forward along the forefinger. The tip of the forefinger is on the *anterior superior iliac spine.* The tip of the thumb is approximately in the region of the *posterior superior iliac spine,* easily palpable through the skin of a

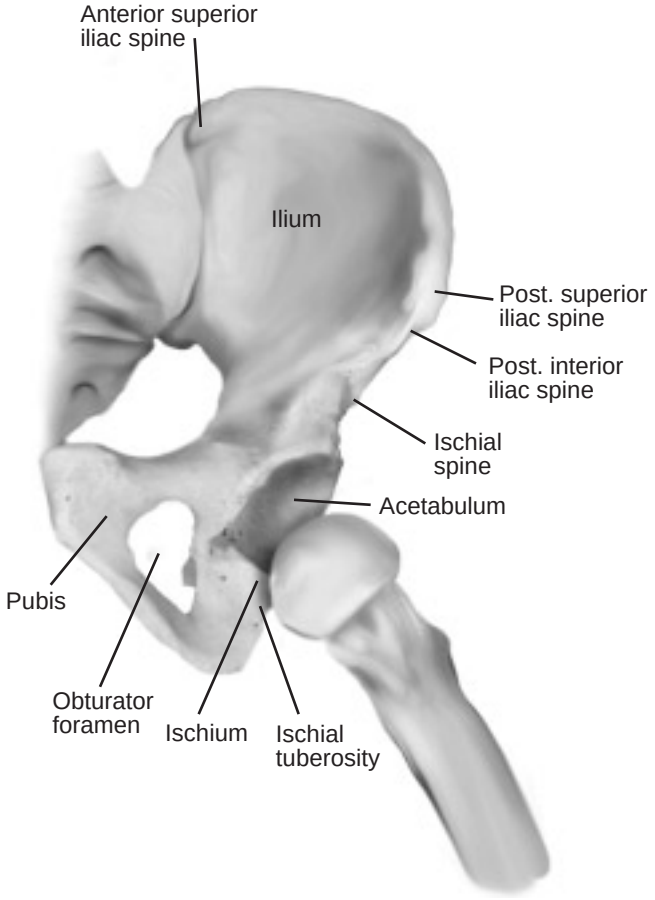

Figure 2–2 Lateral aspect of left os coxae.

thin person and always marked by a dimple. The inner surface of the iliac bones is concave and forms the origin of a powerful muscle of thigh and trunk movement, the *iliacus.* On the right side, the concavity in the iliac bone, the iliac *fossa,* accommodates the *cecum,* which is the pouchlike, blind end of the large intestine formed at its junction with the small intestine. From the cecum extends the vermiform (wormlike) appendix, and because of its anatomical position, the pain of acute appendicitis is felt in the right iliac fossa. The fallopian (uterine) tubes or oviducts are also in anatomical proximity to the concavities of both iliac bones, and pain originating from the tubes when they are inflamed or infected is often referred to (i.e., felt in) the fossae.

The rear or posterior part of the inner surface of each ilium has an *auricular* (ear-shaped) *surface* that forms an articulation or junction with the *sacrum,* the fused vertebrae at the lower end of the spinal column. When one bone articulates with another, a joint is formed, whether or not it is movable. The joint here is the *sacroiliac joint,* one of the most important joints of the body because the body's full weight is transmitted through it to the legs when a person is standing upright. The great load placed on the sacrum by the entire vertebral column would tend to cause it to rock

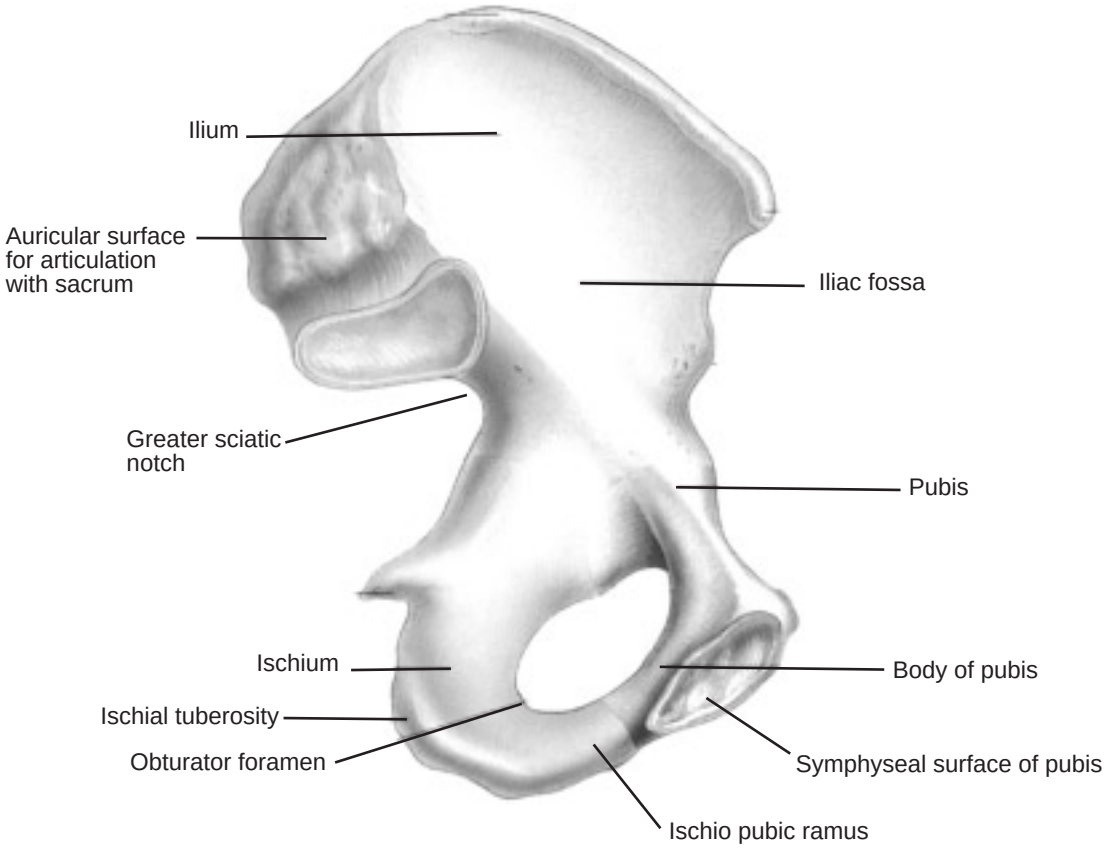

Figure 2–3 Medial aspect of left os coxae.

back and forth between the hip bones if it were not for enormously strong ligaments that surround the sacroiliac joint to form an interlocking mechanism to brace and reinforce it.

Ischium

Below the sacroiliac joint, the rear border of each ilium indents to form a huge *greater sciatic* notch through which pass blood vessels and nerves. The lower part of the greater sciatic notch is formed by the *ischium,* which ends in a large knob, the *ischial tuberosity.* When one is sitting up straight, one sits on the ischial tuberosities, and they, instead of the legs, receive the weight of the body through the sacroiliac joints. The hamstrings, that group of large muscles on the back of the thigh, are attached to the ischial tuberosities.

Pubis

From the tuberosity of the ischium extends a flattened *ischial ramus,* or bar, which meets the flattened ramus of the *pubis.* The ramus of the pubis flares out to form the body of the pubis, which meets the other pubic bone from the opposite side. The union of the two pubic bones is called the *pubic symphysis,* a joint that is united by cartilage and held together by strong ligaments. During pregnancy, both the symphysis and the sacroiliac joints are softened and stretch as a result of the

tremendous amounts of hormones that are produced. The joints become mobile and make delivery easier.

Bony Pelvis

The term bony pelvis refers to the bowl-like structure (pelvis means "basin" in Latin) that is formed by the hip bones at the sides and the front and the sacrum and coccyx at the back. It is divided anatomically into the following:

1. False or greater pelvis, made up of the upper flared parts of the two iliac bones with their concavities, and by the two wings of the base of the sacrum
2. True or lesser pelvis, formed by the rest of the ilium, pubis, and ischium on both sides, and the sacrum and the coccyx

The boundaries of the opening to the true pelvis, or *pelvic inlet,* are called the *pelvic brim.* The diameters of the pelvic brim have particular obstetric significance. The dimensions of the *pelvic outlet,* bounded by the ischial tuberosities, the lower rim of the pubic symphysis, and the tip of the coccyx, are also of great importance obstetrically (Figure 2–4).

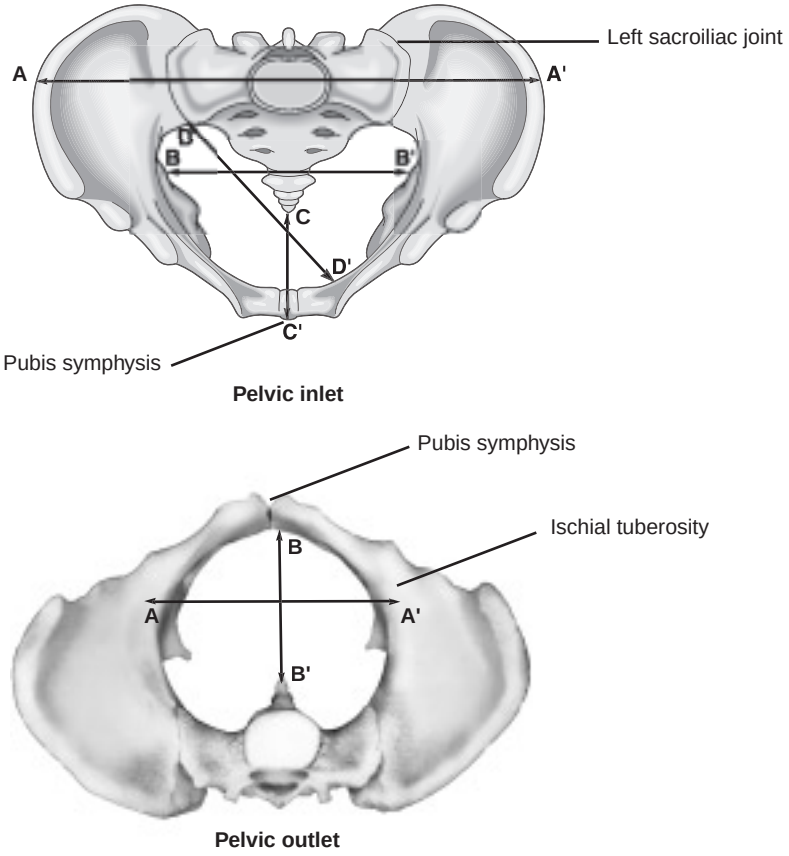

Figure 2–4 Diameters of the pelvic inlet and the pelvic outlet. Inset: A–A' = false pelvis; B–B' = true pelvis, transverse diameter; C–C' = anterior-posterior diameter, from the tip of the coccyx to the pubic symphysis; D–D' = oblique diameter from sacroiliac joint to the iliopubic eminence. Outlet: A–A' = transverse diameter, between inner edges of ischial tuberosities; B–B' = anterior-posterior diameter, from pubic symphysis to tip of coccyx.

At birth, the three parts of the hip bone—the ilium, ischium, and pubis—are composed mainly of cartilage and are separate bones. The ischium and the pubis become bony and fuse at approximately 7 or 8 years of age, but total ossification of all the cartilaginous portions is not completed until sometime between 17 and 25. Although pregnancy is possible after puberty, the pelvic ring may not be as capable of withstanding the stresses and strains of childbearing until all the weaker cartilaginous links among the three bones have fused and become bony.

SEX DIFFERENCES IN THE PELVIS

The body measurements (stature, sitting height, head circumference, and so on) of an adult female average approximately 92% of the body measurements of the adult male. This same proportionality may be applied to skeletal measurements. Generally, the male pelvis as a whole is larger than the female pelvis, except for the dimensions of the *true pelvis,* which has to accommodate the dimensions of the full-term fetal head, since 95% of babies are born head first. Pelvic measurements, however, show considerable variation (as do all other measurements in humans), and there is actually as much variation in the size and shape of the pelvis among women as there is between women and men. No two pelves are alike; it is the individual pelvis and the particular fetal head involved that become important obstetrically.

Sexual differences in the adult pelvis have been studied extensively, and there are different classifications that have been used to describe the normal range of variation in the morphology of the male and female pelvis. The most commonly quoted are those described by W. E. Caldwell and H. C. Moloy, based on x-ray determinations of the dimensions of the pelvic inlet, or superior opening of the true pelvis. These authorities said that female pelves are divided into four main groups:

1. The *anthropoid* pelvis is common in men and occurs in 20%–30% of white women and nearly 50% of black women. The pelvic inlet is oval and the sacrum is long, producing a deep pelvis.
2. The *android* pelvis is also common in men, but one-third of white women and 10%–15% of black women also have this type, in which the inlet is heart shaped and the side walls are narrow. This classification, also called the "funnel" pelvis, produces difficulty in delivery of the baby.
3. The *gynecoid,* or true female, pelvis is less common in males. About 50% of all women have this type. The inlet is round, the outlet is roomy, and the subpubic angle or pubic arch is almost a 90° angle. The gynecoid is the best pelvic type for an easy, normal delivery and is the one selected for contrast with the android pelvis in anatomy books to depict typical male and female pelvic differences.
4. The *platypelloid,* or flat, pelvis is the least common type of pelvic structure among most men and women. In this rare type, the pelvic cavity is shallow but widens at the pelvic outlet, permitting a delivery that is not difficult, as long as the fetal head can pass through the pelvic inlet (Figure 2–5).

Many women have a combination of these four basic types, and the anterior part of the pelvis may be one classification, whereas the posterior segment is another. These classifications are based on average values obtained from skeletal material and, as indicated, are obviously not as important as the individual woman's measurements compared to the measurements of the head of the child she is bearing. Measuring the dimensions of the true pelvis is called pelvimetry, and it is usually performed as part of the physical examination of a pregnant woman to determine whether she will have any difficulty in delivery.

Pelvimetry can be done by x-ray, by external measurements made with a *pelvimeter,* and by internal examination through the vagina. Because of the dan-

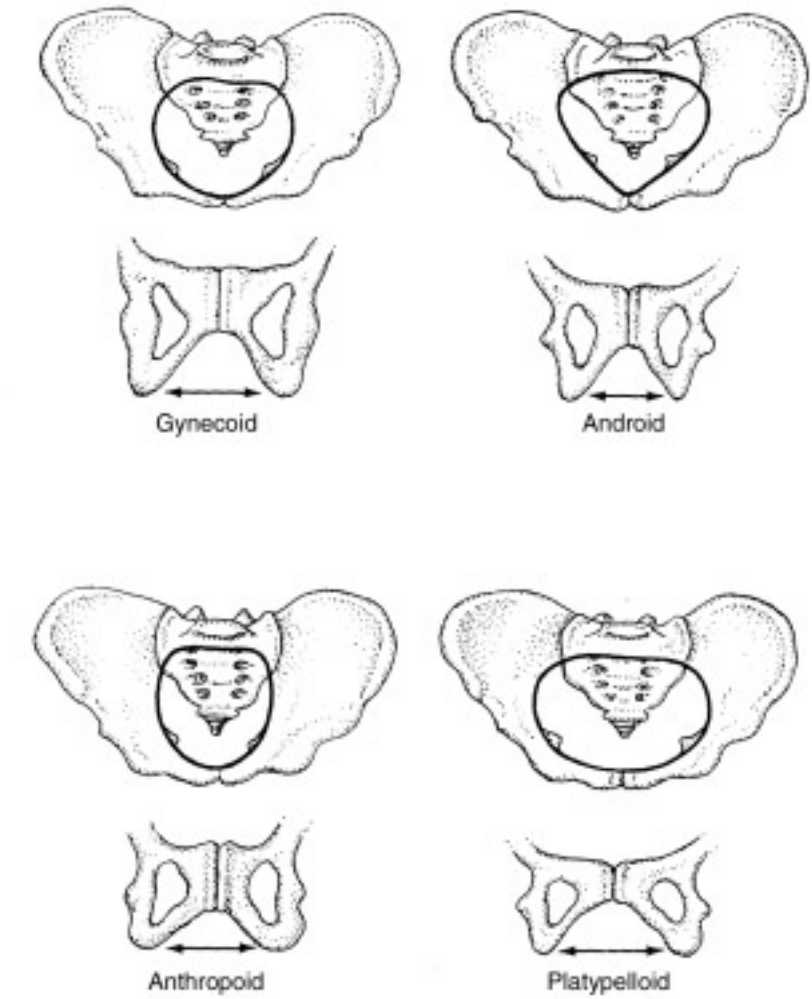

Figure 2–5 Caldwell-Moloy classification of pelves. "Pure" types are shown.

ger of radiation to the ovaries of the mother and the fetus, radiography is used rarely, delayed until the time of delivery, and then done only if there is some apparent difficulty in labor. Most x-ray pelvimetry has currently been replaced by ultrasonography.

If a woman has very narrow pelvic dimensions or if some distortion of the normal pelvis has occurred as a result of poor nutrition, injury, or disease, the decrease in size may be enough to interfere with normal labor. Such a pelvis is said to be contracted and could cause *dystocia,* or long, difficult labor. It may be necessary for the fetus to be removed by an incision into the uterus, or *cesarean section.*

Pelvic Tilt

When we stand in an upright position, the whole pelvis is tipped forward so that the plane of the pelvic brim forms an angle of approximately 50°–60° with the horizontal. The plane of the pelvic outlet, an

imaginary line drawn from the tip of the coccyx to the inferior part of the pubic symphysis, forms an angle of about 15° with the horizontal. This means that the pelvic surface of the pubic symphysis faces upward as much as it does backward, and the concavity of the sacrum is directed both downward and forward. If one were to stand upright, facing flat against a wall, the anterior superior iliac spines and the upper border of the pubic symphysis would both almost touch the wall; that is, they would be in the same vertical plane. This tilt of the pelvis is called the angle of pelvic inclination, and although subject to great individual variation, it is frequently exaggerated in women due to the difference in dimensions of the true pelvis. As a result of the greater tilt of the pelvis in females, the spinal curvature in the lumbar region of the spine is increased in an anterior (forward) direction to compensate and maintain the center of gravity. Otherwise, a woman might fall forward and be unable to maintain an erect posture. Because this forward lumbar curve is greater in some women, their buttocks are usually more prominent than those of men, depending, of course, on the shape of the pelvis and amount of the pelvic tilt (Figure 2–6).

Another general statement, again subject to great individual variation, is that women are more frequently seen with knock-knees than are men. This is true because the head of the femur fits into the cup-shaped acetabulum to form a femural angle of approximately 125° at the neck of the femur so that the shaft of the thighbone can swing clear of the pelvis when the leg moves. That angle determines the position of the knees. The more oblique the angle, the more the shafts of the femur will slope inward, and the closer the knees will meet. In women, the pelvis is generally wider and the femurs shorter, and hence the greater tendency to have knock-knees (Figure 2–7). Some orthopedic physicians have maintained that because of

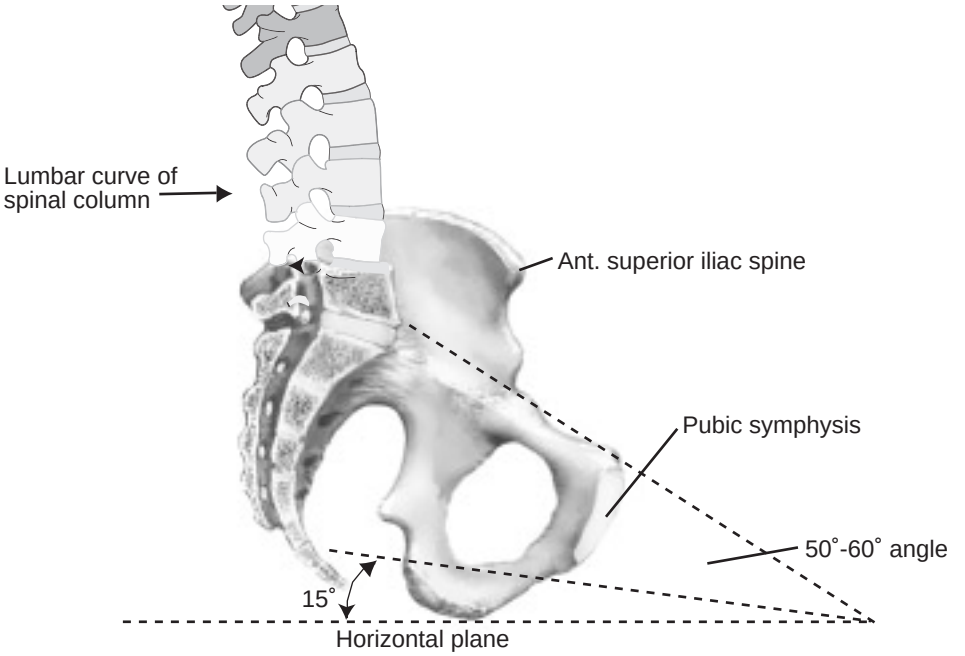

Figure 2–6 Angle of pelvic inclination. When standing erect, the whole pelvis is tilted forward, and the pelvic canal is directed backward relative to the abdominal cavity and the torso. The greater the pelvic tilt of the pelvis, the greater the curve in the lower back.

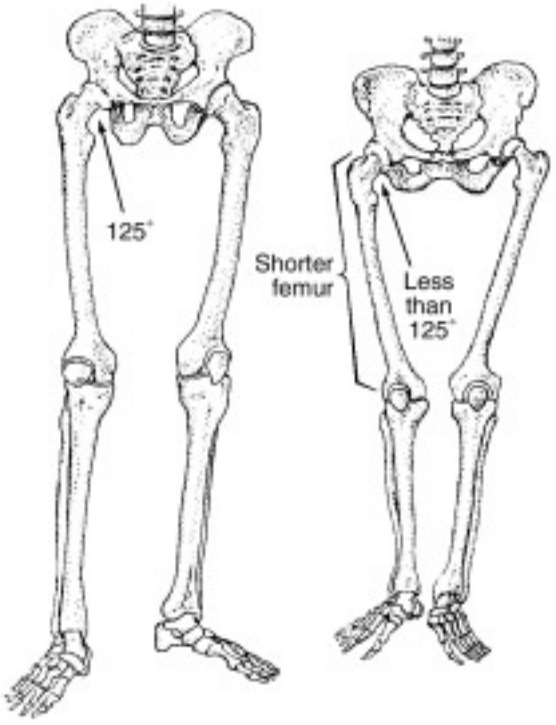

Figure 2–7 The female angle is less than 125° in some women, giving them a greater tendency to have knock-knees.

the above mentioned body mechanics, women's knees are much more vulnerable to injury and that they should, therefore, avoid participation in contact sports. This may be true for some women who have a gynecoid pelvis and a smaller, lighter bone structure. It may be equally valid for some men.

Backache and Its Relation to the Pelvis

If a woman has a greater angle of pelvic inclination, she will also have a greater increase in the curvature of the lumbar spine. Then anything that places further strain on the lumbar area, such as the protruding abdomen of pregnancy or obesity, is almost certain to result in lower back pain. There are estimates that 50%–60% of the population has had back trouble at one time or another, but more females than males suffer with chronic backache.

Sometimes the very process of delivering a baby, particularly if the labor is long and difficult, puts unusual strain on the muscles and ligaments surrounding the sacroiliac joints, which have "unlocked" and stretched under hormonal action to have much more mobility at full term than in a nonpregnant woman. Although these sacroiliac joint changes regress in the period after the birth of the baby, it can take a long time for them to get back to normal, and the woman will have chronic low back pain in the interim.

With the exception of the period of *puerperium* (after delivery of a baby), most backaches in women are muscular aches resulting from poor posture and are not gynecological in origin. If lower back pain is a result of pelvic pathology, it is felt in the area over the sacrum; postural backache is higher—between the top of the sacrum and the bottom of the rib cage.

When one is standing erect with good posture, the weight of the body is passed down the lumbar vertebrae through the sacrum, divided through each sacroiliac joint to the acetabula of the hip bones, and then to the legs. The most important supporting spinal muscles, those that keep the line of gravity in appropriate balance, arise from the front and back of the pelvis. When good posture is disturbed, those muscles are placed under stress, and they become sore and ache. Numerous factors can act to destroy good posture. One, mentioned previously, is the strain on the muscles of the spinal column caused by pregnancy, labor, and the puerperium. Maybe the muscles are weak because of lack of exercise. Or there may be congenital (present at birth) defects in the spine, pelvis, or feet. Sometimes sleeping on the wrong kind of mattress, walking or standing in shoes with high heels or rigid soles, or spending long periods of time in a fixed position—sitting all day in a particular type of chair or driving hundreds of miles without a break—can result in backache. These types of factors, once recognized, should not be difficult to eliminate.

If poor posture and weak muscles are the result of minor defects in the spine, hips, knees, or feet, there are exercises that strengthen the tone and increase the flexibility of abdominal, back, and thigh muscles so that the

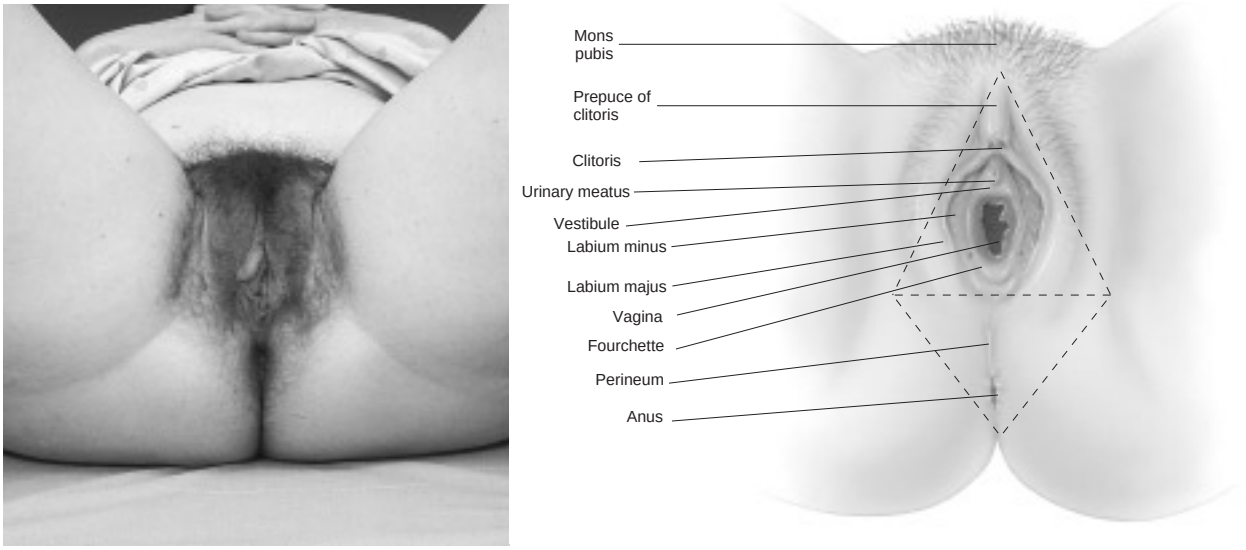

Figure 2–8 Female genitalia.

spine can be supported in a corrected position. Although many cases of low back pain will respond to a home exercise plan, it is important to check with a knowledgeable professional first (orthopedist, neurologist, rheumatologist, physiatrist, physical therapist) and never to continue an exercise that causes pain.

When the ligaments and tendons that support the spinal column are traumatically stretched, the sudden strain can produce muscle spasm and backache. This happens when heavy objects are lifted incorrectly by bending forward with the knees straight. Bed rest and moist heat will relax the muscles and relieve the pain. Another cause of back pain is osteoarthritis or degenerative joint disease, which usually occurs after the fourth decade of life. Should the intervertebral disc between two adjacent vertebrae begin to degenerate, great stress is placed on the surrounding ligaments. If the disc herniates or protrudes it may impinge on the nerves that exit in between the vertebrae. A "slipped disc" may also be associated with numbness or weakness in one or both legs because of the pressure on the spinal nerves. These types of symptoms may require hospitalization, physical therapy, or even surgery for treatment.

The point is, most backaches arise in the back; that is, they are musculoskeletal in origin. They are much more rarely the result of ulcers, kidney disease, or pelvic pathology. Some of the gynecological difficulties that do result in back pain will be covered later.

EXTERNAL GENITALIA

The Vulva

The **vulva,** sometimes called the pudendum, is the term for the visible external genitalia. The name vulva means "covering" in Latin and refers to the area bounded by the *mons pubis* anteriorly, the *perineum* posteriorly, and the *labia minora* and *majora* laterally. The vulva is erotic and highly sensitive to touch; it also serves to protect the urethral and vaginal openings (Figure 2–8).

Mons Pubis

Another name for the **mons pubis** is the *mons veneris,* literally, "the mountain of Venus"—suitably named,

the ancients thought, because Venus was the goddess of love (venereal disease has the same linguistic root). It is the cushion of fatty tissue and skin that lies over the pubic symphysis and, after puberty, is covered with pubic hair. Pubic hair varies in texture, as does the hair on the head, depending on the race of the individual. In many women, the upper border of pubic hair is straight across, forming a triangle, and this is the so-called female escutcheon. In males, the pubic hair supposedly grows upward toward the umbilicus as a result of androgenic activity, thus defining maleness and femaleness in the configuration of pubic hair growth. In actuality, some 25% of women and most men do have an apparent upward continuation of pubic hair to the umbilicus; it is not pubic hair proper, but ordinary body hair. Some people are just genetically hairier than other people. When a woman has this abdominal growth of hair, it is very rarely a sign of some virilizing hormonal influence.

Labia Majora

Extending down from the mons pubis are two longitudinal folds of skin, narrowing to enclose the vulvar cleft, and meeting posteriorly in the *perineum,* that area of skin between the junction of the labia major and the anus.

These **labia majora** (major lips) protect the inner parts of the vulva. The outer surface of the labia is covered with pubic hair. The inner surface is not, but has many sebaceous and sweat glands. The tissue inside the labia majora is loose connective tissue with pads of subcutaneous fat. The fat, like the fat on the hips and in the breasts, is particularly sensitive to estrogen. This is why the labia and the rest of the vulva become enlarged (hypertrophy) from puberty on and shrink (atrophy) after the menopause. Underneath the subcutaneous fat and deep within the substance of the labial tissue are masses of erectile tissue, tissue filled with large blood spaces that engorge with blood during sexual excitement. These masses, which encircle the vaginal opening, are called the *bulbs of the vestibule;* they are equivalent to the *corpus spongiosum* of the male penis.

Under the skin of the labia majora, there are fibers of smooth muscle that are similar to the dartos muscle of the male scrotum. This subcutaneous muscle is temperature sensitive and causes the labia to wrinkle up when exposed to cold and to appear larger and softer in warm weather.

Labia Minora

The **labia minora** are the delicate inner folds of skin that enclose the urethral opening and the vagina. They are also called *nymphae,* from the Greek word for "maiden," referring to the goddesses of the fountain.* The labia minora grow down from the anterior inner part of the labia majora on each side. Each fold joins above and below the *clitoris.* The joining of the folds above the clitoris forms the *prepuce;* the junction below the clitoris forms the *frenulum.* Each labium minus then extends downward to surround the vagina and join again at the posterior end of the vagina, where it blends into the skin of the labia majora. At this junction, there is a slightly raised ridge of skin, the *fourchette.* After the birth of a baby, the fourchette flattens out. There are no pubic hairs on the labia minora, but there are many sebaceous glands that feel like tiny grains of sand when pressed between the thumb and forefinger.

The large numbers of sebaceous glands on the vulvar skin produce sebum, a mixture of oils, waxes, triglycerides, cholesterol, and cellular debris. Sebum lubricates the skin, and in combination with the secretions from the sweat glands and the vagina forms a waterproofing protective layer that enables the vulvar skin to repel urine, menstrual blood, and bacterial infections. Because of the many sebaceous glands, however, the labia minora, particularly in the area of the clitoris, are frequently the site of sebaceous cysts: painful nodules about the size of a pea in the skin. A vulvar sebaceous cyst usually spontaneously drains and

*Everyone knows that a nymphomaniac is a woman with an excessive sex drive. Why is it that hardly anyone knows the same condition in males is satyriasis? Think about it.

disappears within a few days; however, it may become secondarily infected and require treatment or removal.

There are wide variations in the size and shape of the labia minora, and one is generally larger than the other. Sometimes they are completely hidden by the labia majora, or they may be enlarged so that they project forward. Enclosed within the skin of the labia minora are venous sinuses or blood spaces that become engorged with blood during sexual excitement, causing a color change and an increase in the thickness of the labia, sometimes as much as two to three times their diameter.

Vestibule

The vestibule is the area enclosed by the labia minora. Opening into the vestibule are the urethra from the urinary bladder, the vagina, and the two ducts of *Bartholin's glands,* also called the greater vestibular glands. Bartholin's glands produce a few drops of mucus during sexual excitement in the female in order to moisten the vestibule in preparation for intercourse. This amount of secretion is not significant in the lubrication of the vagina. The duct of a Bartholin's gland may become obstructed for no apparent reason, and the gland continues to secrete behind the duct. The result is a large Bartholin's cyst, which usually produces no symptoms, but which occasionally may form an abscess and have to be removed. A gonorrhea infection may sometimes cause a Bartholin's cyst.

Clitoris

The word **clitoris** is from the Greek word for *key,* indicating that the ancient anatomists considered it the key to a woman's sexuality, a perception that had been largely ignored until recently. It is always referred to as the homologue of the penis, that is, similar in embryological origin and structure but not necessarily in function. Some texts describe the clitoris as a *vestigial* homologue of the penis—a vestige being a small, degenerate, or incompletely developed structure. This is a truly erroneous statement except for one thing—the clitoris is smaller than the penis and is usually more easily felt than seen. It has, however, for its size, a generous blood and nerve supply relatively greater than that of the penis. There are more free nerve endings of sensory reception located on the clitoris than on any other part of the body, and it is, unsurprisingly, the most erotically sensitive part of the genitalia for most females.

The clitoris consists of two *crura,* or roots; a *shaft,* or body; and a *glans.* The two crura arise from the lower borders of the ischiopubic rami and join at the pubic symphysis to form the shaft of the clitoris. Within the shaft are the two *corpora cavernosa,* the "cavernous bodies," consisting of erectile tissue that, when engorged with blood, causes the clitoris to become erect and double in size. At the end of the shaft is the rounded glans, extremely sensitive to the touch.

There are two muscles on each side important in clitoral erection. The *ischiocavernosus* muscles arise from the ischium and insert into the corpora cavernosa, and the *bulbocavernosus* muscles arise from the area around the vestibular bulbs of the labia majora and also insert into the corpora cavernosa of the clitoris. During sexual excitement, these muscles contract and compress the dorsal vein of the clitoris, the only vein that drains the blood from the spaces in the corpora cavernosa. The arterial blood continues to pour in and, having no way to drain out, fills the venous spaces until they become turgid and engorged with blood. This mechanism causes the stiffening and erection of the clitoris (Figure 2–9). That there is more erectile tissue associated with the clitoris than generally described in standard anatomical texts was reported by Australian urologist Helen O'Connell and her colleagues (1998). In investigating the relationship between the urethra and surrounding erectile tissue, the researchers performed dissections on the genital anatomy of 10 adult female cadavers who ranged in age from 22–88 years. When they compared the arrangement and amount of erectile tissue in the urethra and genitalia of the cadavers with current anatomical descriptions, they found that the age of the woman made a difference. That is, there was more erectile tissue associated with the

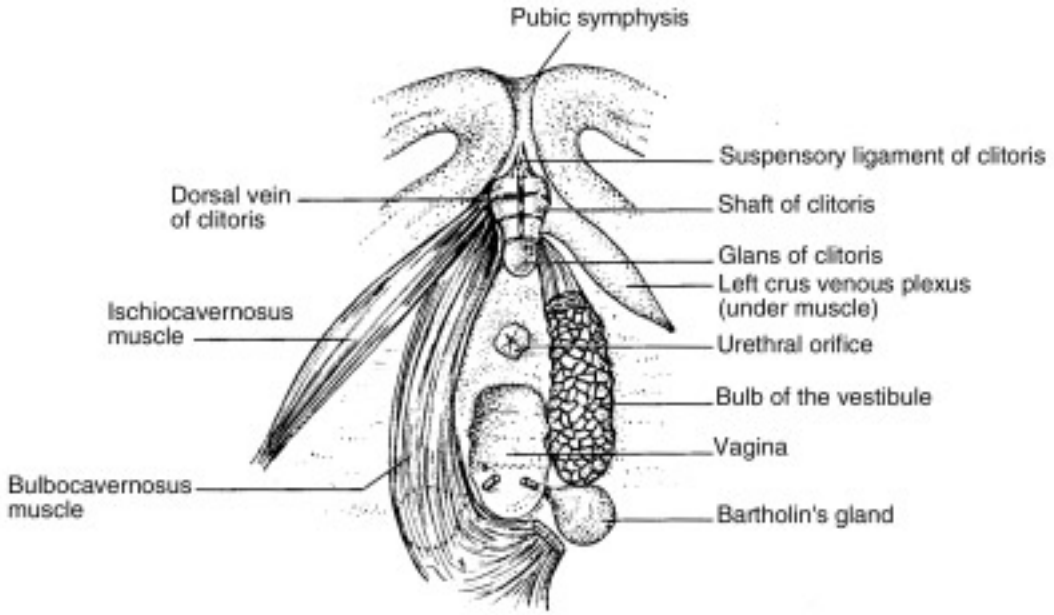

Figure 2–9 Mechanism of clitoral erection. Tactile stimulation of the clitoris results in an increased blood flow to the erectile tissue (corpora cavernosa) in the shaft of the clitoris. The contraction of the two clitoral muscles (bulbocavernosus and ischiocavernosus) compresses the only vein that drains the corpora cavernosa. The blood, trapped in the erectile spaces of the cavernous bodies, causes their engorgement and thus the enlargement and erection of the clitoris.

clitoris in younger women than is described in modern anatomical texts and diagrams. The workers concluded, although the sample size was small, that dissections upon which modern and older anatomical descriptions of female human urethral and genital anatomy relied were inaccurate because they were likely to have been performed on elderly women in which the erectile tissue had shrunk. The investigators recommended that because the erectile tissue of the vestibular bulbs actually is more related to the clitoris and urethra than to the labia majora, the bulbs of the vestibule should be renamed the bulbs of the clitoris. But in addition to calling attention to the inaccuracy of anatomical textbooks, an important implication of this research led by a female urologist (an uncommon specialty for women until recently) is that when women have operations for bladder problems, hysterectomy, or other surgery in the vicinity of the urethra, there could be potential damage to the erectile tissues involved in sexual function unless the findings are considered.

The bulbocavernosus muscles compress the vestibular bulbs during sexual excitement, and they become congested and erect as well, contributing to what Masters and Johnson call the "orgasmic platform" (Chapter 6). Like the penis, the clitoris is suspended from the lower border of the pubic arch by a ligament called the *suspensory ligament*. The prepuce, or foreskin, is a little hood over the glans formed by the anterior junction of the labia minora. As in the male, a sebaceous gland secretion is produced under the prepuce and can cause irritation and itching if not washed away.

Urethra

Approximately 2.5 cm below the clitoris, there is a small elevation like a dimple. In its center is the opening of the urethra, called the *external urethral orifice*. The

urethra is the passageway for urine from the urinary bladder to the outside. When a catheterization is performed to empty the bladder or to obtain an uncontaminated urine specimen, a flexible tube or catheter is inserted into the external orifice and passed upward into the bladder.

On either side of the midline, just posterior to the external urethral orifice, are the openings from the paraurethral or Skene's glands, the female homologue to the prostate glands in the male. They secrete a small amount of mucus and, along with the secretion of other small mucus-secreting glands in the wall of the urethra, function to keep the opening moist and lubricated for the passage of urine.

When Skene announced his discovery of the glands that bear his name in the 19th century, they had already been described by de Graaf 200 years earlier as the producers of "female semen," the lubricating fluid discharged during sexual stimulation. That in some women these glands may produce a secretion emitted from the urethra during coitus was momentously "rediscovered" in 1982 by Ladas, Whipple, and Perry. The three reported in their instant best-selling book, *The G Spot & Other Recent Discoveries about Human Sexuality,* that the secretion, dubbed the female ejaculate, occurred in response to stimulation of the alleged Grafenberg spot, an approximately 2-inch area on the anterior wall of the vagina near the urinary bladder. Ernst Grafenberg, a German gynecologist, had been, until then, better known for the Grafenberg ring, the first widely used intrauterine device. His 1950 description of a "zone of erogenous feeling located along the anterior vaginal wall" was largely ignored, but the publication of Ladas, Whipple, and Perry's book revived controversial inquiry about the phenomenon during the early 1980s and still surfaces occasionally on talk shows and in newspaper and magazine articles about the "G spot."

There is no convincing evidence that the so-called G spot exists, and whether it has profound and wide-ranging implications for female sexual response remains to be demonstrated. In some women there may be a sensitive area on the anterior vaginal wall that produces pleasurable sensations when it is pressed. Other women who look for the G spot with their fingers may find a place that produces a sensation of having to urinate; it is, after all, close to the bladder. But there are women who are concerned about expelling what seems to be a small gush of urine during intercourse, especially at orgasm. They are not urinating but are probably experiencing a greater discharge from the paraurethral (Skene's) glands and the vulvovaginal (Bartholin's) glands—for them, a normal sexual response.

The female urethra, in contrast to that of a male, is short: only about 4 cm in length when a woman is standing erect. This anatomical difference predisposes a woman to bladder infection much more frequently than a man, whose urethra is 18–20 cm in length. Not only is the external opening exposed to vaginal discharges containing bacteria, but organisms like *Escherichia coli* from the rectum can easily ascend up the short urethra and multiply tremendously within hours, leading to a condition called *cystitis,* or urinary tract infection (UTI). For this reason, women should always wipe from front to back after moving their bowels to avoid transferring the bacteria from the anus to the urethra. For similar reasons, internal tampons inserted into the vagina are preferable to external pads as long as they are changed frequently. Although a tampon can be associated with other health problems, a pad can provide a direct link from the anus and vagina to the urethra, as well as an environment in which microorganisms can thrive.

"Honeymoon cystitis," a term that has lost considerable relevance to current lifestyles, is the name given to the bladder infections that occur within a short time after the initiation of regular intercourse in a woman, particularly after a period of little sexual activity. The proximity of the urethra and the base of the bladder to the anterior vaginal wall can cause those structures to become swollen and irritated as a result of repeated coitus, causing an urge to urinate more frequently. Vigorous thrusting movements of the penis can also be responsible for forcing microorganisms up into the urethral orifice and into the bladder to cause cystitis, which must be treated with an antibiotic. One way of prevent-

ing or at least decreasing susceptibility to this cause of bladder infection is to maintain a high fluid intake and to urinate before and after sexual intercourse.

Symptoms of cystitis are burning pain on urination, and an urge to urinate frequently, even immediately after voiding. The urine is cloudy and dark and contains pus cells, red blood cells, and many bacteria. There may be fever, backache, and lower abdominal pain. If the bladder infection is not treated, it can spread to the kidneys and cause a condition called *pyelonephritis,* which is a potentially very serious complication. Additional causes, prevention, and treatment of cystitis and UTI are discussed in Chapter 9.

Hymen

Below the external urethral orifice in the vestibule is the opening to the vagina. Around the vaginal opening there is a small, insignificant membrane with no known function called the **hymen,** after Hymen, the god of marriage in Greek mythology. There are probably few other parts of the female reproductive tract as subject to folklore and misconception as this little membrane. Most people do not even know where it is—they think it is somewhere up in the vagina near the cervix. It is commonly believed that it tears at the first coitus, that copious and visible bleeding occurs, and that the virgin has been "deflowered," defloration being a curious and romantic term for rupture of the hymen. If no bleeding occurs, this is taken as evidence of nonvirginity. Many also believe that the hymen makes it impossible for a virgin to wear tampons during the menstrual period, or that if the attempt is made, this sign of virginity will disappear.

All of this is nonsense. An intact hymen is not proof of virginity; a ruptured hymen is not indicative that sexual intercourse has occurred, and no one, including a doctor, can tell whether or not there has been initial coitus by just looking at the vaginal opening. It is usually possible to determine with accuracy whether or not a woman has had a child but generally impossible to say whether or not she is a virgin. This is because the hymen may be as follows:

- Thin as a spiderweb, or thick and fleshy
- Quite vascular, with a good blood supply, or relatively avascular
- Extremely variable in how much of the vaginal opening is covered
- Sometimes so pliable and flexible that it never ruptures but only stretches, even after childbirth

The hymen very rarely completely occludes the opening to the vagina. This is called an *imperforate* hymen and is usually discovered during adolescence. A girl with an imperforate hymen will menstruate into the vagina month after month, and the discharge will accumulate in the vagina, a condition called hematocolpos. If it is not recognized, menstrual blood may fill the uterus and the fallopian tubes as well. Cutting of the hymen cures the problem, and there is no further difficulty.

Another variation is the septate hymen. If the septum is not too thick and is stretchy enough, intercourse is not hampered. There is usually no problem with insertion of tampons, although there may be some difficulty encountered in removal.

After childbirth, the hymen usually no longer has a continuous rim but remains as isolated remnants with gaps in between. These are referred to as *carunculae hymenales.* The hymen is present throughout life, has no function, and is merely an embryological vestige. Its only significance, if one believes the mythology, is psychological, sociological, or cultural.

Vagina

The **vagina** is a tube that passes upward to the uterus at an approximate 45° angle from the vulva.

The size of the vagina is so variable and so capable of distension that it is difficult to measure its dimensions. This great distensibility enables the vagina to withstand vigorous stresses during intercourse or childbirth. Despite all the stories, a normal vagina can accommodate any size penis with ease. There is no relationship between the size of a woman's vagina and her general body size or shape; the same is true of the size of the penis of a man.

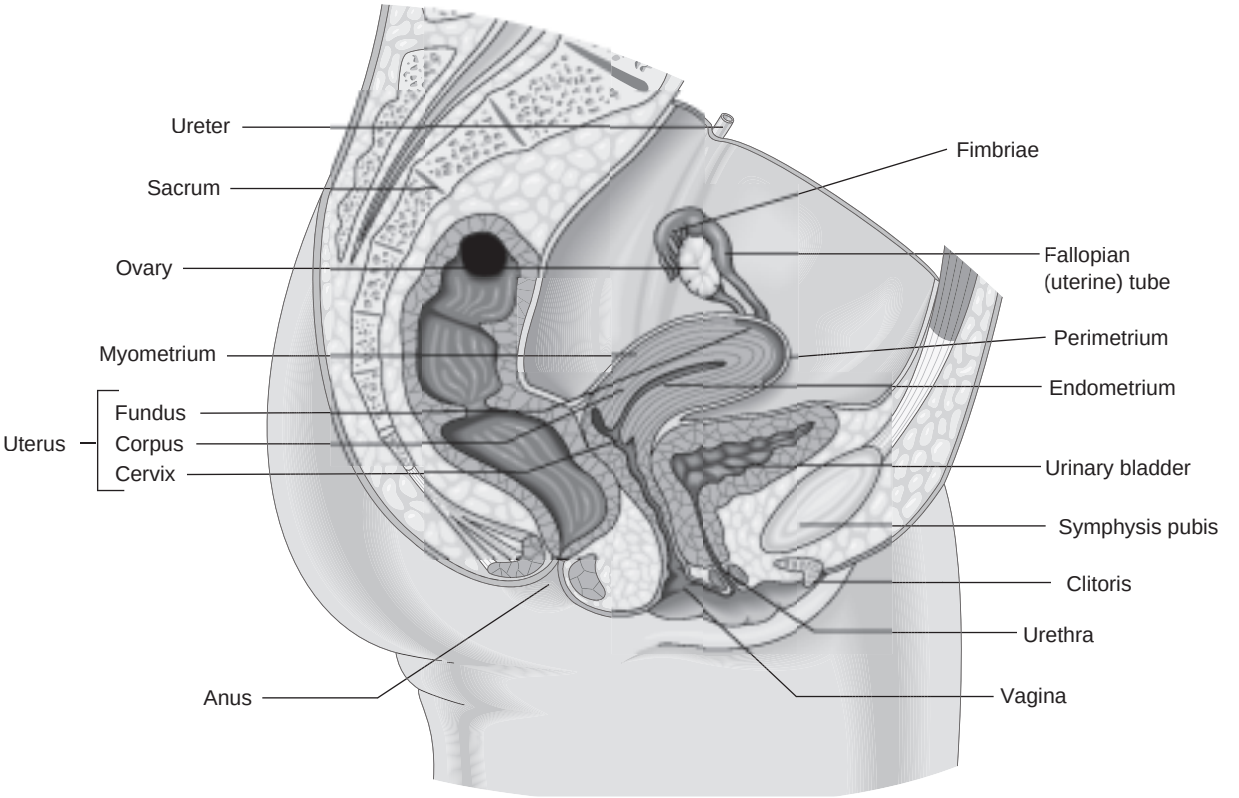

Figure 2–10 Section through reproductive organs showing vaginal fornices.

Actually, the tube of the vagina is only a potential space because its anterior and posterior walls are thrown up into transverse folds that are in close apposition. In a woman who has never had a child, there are many folds and the vaginal walls are firm. After parturition (giving birth), the walls are more or less smoothed out, but they retain their firmness, especially near the opening of the vagina. This is not always true for women who have had many children.

Projecting into the upper part of the vagina is the lower part of the uterus, the conical *cervix*. The circular gutter formed all around the cervix is anatomically divided into the *anterior, posterior,* and *lateral fornices* (Figure 2–10). The walls of the fornices are thin because they consist only of the vaginal wall with the pelvic cavity on the other side. During an internal pelvic examination, the position and relations of the various pelvic viscera can be palpated and outlined through the fornices. Normally, the posterior fornix is empty, and the body of the uterus can be felt through the anterior fornix; the fallopian tubes and the ovaries, through the lateral fornices.

The posterior fornix extends deeper into the pelvis and is, therefore, larger and longer than the anterior fornix. This anatomical arrangement favors the passage of sperm into the cervix during intercourse because when a woman lies on her back, the opening in the cervix is not only directly exposed to the male ejaculation, but the pool of ejaculated semen collects in the posterior fornix and bathes the cervix, which is resting in it (Figure 2–11). The posterior fornix also takes the brunt of penile thrusting during coitus and thus prevents injury or jarring of the cervix.

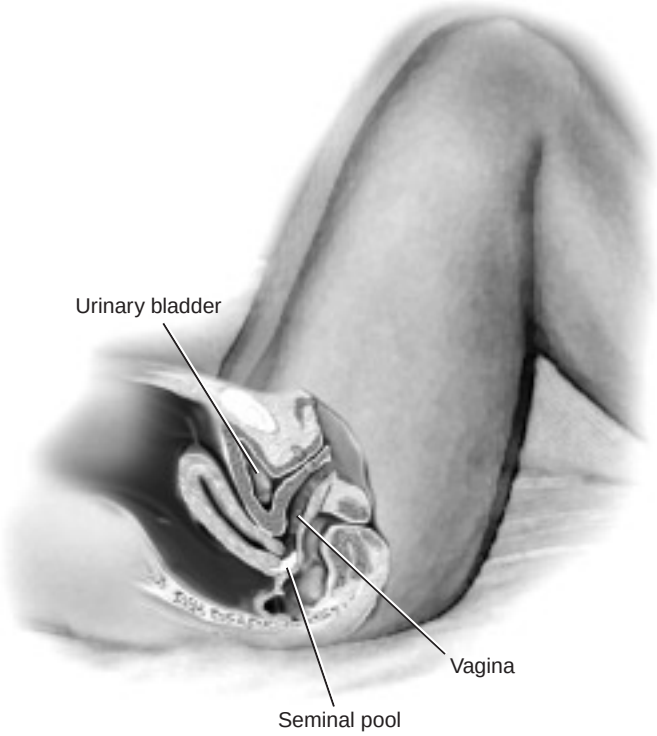

Figure 2–11 When a woman is on her back during intercourse, the semen collects in the posterior fornix, providing sperm with easy access to the cervical opening.

Only a thin partition of vaginal wall separates the posterior fornix from the lining *(peritoneum)* of the pelvic cavity, which dips down to form the *pouch of Douglas,* or the rectouterine pouch. The posterior fornix, therefore, forms the route for several kinds of diagnostic and surgical procedures. In *culdocentesis,* a needle is inserted into the pouch of Douglas to determine the nature of any fluid that might be present—blood, pus, excess tissue fluid. *Colpotomy* is surgical incision through the posterior fornix into the peritoneum of the pelvic cavity. Through this opening, the pelvic viscera can be visually explored by means of a *culdoscope,* which is a tube equipped with optical devices and light—a sort of internal microscope.

The Vaginal Lining. The lining of the vagina is called the vaginal epithelium and consists of layers (as many as 40) of cells resting on connective tissue, containing blood vessels and nerves. This epithelium is like skin but has no hair follicles, sweat glands, or sebaceous glands to weaken it or provide a passageway for entrance of microorganisms. It is, therefore, a very tough, resistant protective lining (Table 2–2). The deeper basal layers of the cells are closer to the blood vessels in the connective tissue underneath and proliferate faster, pushing up to replace the superficial layers that are sloughed off. Estrogen, the female sex hormone, stimulates the growth of the cells. Before puberty and after menopause when there is little estrogen present, the vaginal epithelium is thin and made

TABLE 2–2 Changes in the Vaginal Epithelium with Age

	Newborn Child	One Month Old	Puberty	Sexually Mature Childbearing Years	Post-menopause
Amount of estrogen present (causes changes in)	Much estrogen from placenta	None	Begins to appear	High levels	Relatively very low levels
↓ Appearance of epithelium	Similar to mature	Very thin	Develops thickness	Thick, 20–40 layers	Thinner, may be atrophied
					
Amount of glycogen in cells (causes)	Moderate	None	Goes from none to much	Much	Little or none
↓ Acidity of vaginal secretions (when acted upon by)	Acid, pH 4–5	Alkaline, pH 7	Becomes acid	Acid pH 4–5	Neutral, may be alkaline
Type of bacteria present	Sterile but Döderlein's bacilli present after 12 hours, from mother	Very sparse, some cocci	Goes from sparse varied to Döderlein's bacilli	Döderlein's bacilli and other microorganisms	Various bacteria

up almost entirely of basal cells. When the ovaries are actively producing estrogen during the reproductive years, a smear of cellular material taken from the thick vaginal epithelium will show large numbers of sloughed-off cells, and it is possible to recognize phases of the menstrual cycle by the shape and staining qualities of these cells. An index of estrogenic activity can, therefore, be determined by the relative numbers of basal, intermediate, or superficial cells present in a stained smear of the vaginal lining. The appearance of cells of the vaginal lining is also utilized in tests for cancer detection (Pap test, Schiller test), to be described later.

Vaginal Discharge. The contents of the vagina after puberty and before menopause are normally quite acid, with a pH of approximately 3.5–5.5 (pH is a measure of the acidity or alkalinity of a solution on a scale of 1–14. The lower numbers indicate acidity, the higher numbers, alkalinity, and 7 is neutral). The mechanism for the production and maintenance of this acidity is that the estrogen produced by functioning ovaries during sexual maturity causes rapid proliferation of the basal cells of the vaginal epithelium. These actively growing cells accumulate glycogen granules, the stored form of glucose, in their cytoplasm. Certain bacteria called Döderlein's bacilli (after Albert Döderlein, a German obstetrician) that are normal residents of the vagina are *lactobacilli;* that is, they have the ability to break down the glycogen to form lactic acid. The presence of the lactic acid is responsible for the lowered pH of the vaginal contents.

The normal vaginal discharge is a clear acid material consisting of fluid arising from the capillaries in the vaginal walls with lesser amounts contributed from the cervical glands, the uterine cavity, and the fallopian tubes. In the fluid are mucus; superficial sloughed-off cells; Döderlein's bacilli; other microorganisms (streptococci, staphylococci, yeasts); and various fat, protein, and carbohydrate compounds. The acid discharge combined with the toughness of the thick epithelium protects the vagina from infection by harmful bacteria and makes the vagina much more vulnerable to infection before puberty and after menopause. Döderlein's bacilli are absolutely essential to normal vaginal physiology. If they are disturbed or destroyed by chemical contraceptives, antibiotics, or excess douching, vaginal infections will occur more easily.

Douching. Douching is a procedure of vaginal irrigation in which fluid in a bag is permitted to run through a tube, entering the vagina under slight pressure and ballooning it out slightly. As the fluid runs out or is expelled through muscular action, the vaginal contents are washed out. Douching to prevent pregnancy after intercourse is totally ineffective because it has been determined that sperm can be recovered from the uterus within seconds after being deposited in the vagina—and no woman can get the douche bag apparatus set up and going that fast.

Some women like to douche after their menstrual period because it makes them feel clean. As long as the bag is not suspended too high so that the fluid enters the vagina at too great a pressure, there is no harm in occasional douching for general hygiene. Habitual and vigorous douching may force fluid, and a possible infection, upward into the uterus and into the fallopian tubes. Douching is seldom essential for normal health because the vagina is self-cleansing through the process of normal discharge. But if sexual intercourse is frequent, and gels, foams, or creams are used for contraception, there may be vaginal leakage, which can feel unpleasantly wet. The spermicidal gel used with a diaphragm nightly may have to be douched out weekly, for example. To douche more than every 4 or 5 days is excessive, however, and it will destroy the normal physiology of the vagina.

For a douching medium, plain warm water or water with 1 tablespoon of vinegar (or bicarbonate of soda) to a quart is certainly as effective as the commercial solutions and certainly less expensive. Perfumed, colored, and flavored solutions are not only a waste of money but could cause an allergic reaction. The manufacturers of such products prey on a woman's concern, reinforced by massive advertising campaigns, that natural genital odor is offensive, and that to feel "fresh

and confident" one must use perfumed and deodorizing douches, suppositories, or feminine hygiene sprays.

There is a specific odor produced by the healthy female genitalia that comes from the secretions of the sebaceous and apocrine sweat glands of the vulva, the secretions of Bartholin's and Skene's (urethral) glands, and from the vaginal discharge. It is not an unpleasant odor and is in no way unclean, unless it has been permitted to remain on the skin too long or there is an infection in the vagina causing an abnormal discharge. Feminine hygiene deodorant products, meant to be sprayed on the external vaginal area, are particularly unnecessary and should not be used. If vaginal infection is the source of a perceived malodorous condition, the spray cannot possibly get to the source of the odor and may only cover it up and delay treatment. In some women, allergic sensitivity to the sprays may result in a very painful reaction to their use. Some of the early versions of such products were taken off the market and others were required to include labels with printed warnings about their use. Currently, products are likely to be advertised as hypoallergenic, nonirritating, and completely safe, which may or may not be true for an individual woman. The best "feminine wash" or "intimate cleanser" is neutral, nonperfumed soap and water.

Europeans, particularly in France and Italy, have always been more advanced than Americans in sensible genital hygiene for both men and women. There is, in most home and hotel bathrooms, a bidet. The bidet, which most Americans think is a funny-looking toilet (or perhaps a footbath), is a porcelain basin that one straddles so that a stream of warm water flows over genital and perineal areas after urination or bowel movement. This provides an excellent and convenient method of cleansing the small folds and crevices of the genitalia.

Vaginal Odor. Chemical compounds secreted by an organism into the environment to evoke various developmental, behavioral, or reproductive responses in another member of the same species are called *pheromones.* Sex attractant pheromones have been studied extensively in insects, and synthetic pheromones or their analogues are increasingly being used in biological (rather than pesticide) control of insect pests. Nonhuman mammals have glands that produce a variety of secretions, some odor free and some distinctly malodorous, and the importance of such pheromones in establishing territoriality or in affecting reproductive behavior is well known. Ask anyone with a male dog near an unspayed female in heat. But while the evidence for the existence of sex attractant pheromones in nonprimates is clear-cut, the case for such a phenomenon operating in primates such as rhesus monkeys and humans is controversial and has been studied by scientists for decades. It has been determined that both human women and female monkeys have the same kind of organic acids (short-chain carbon aliphatic acids, such as lactic, butyric, pentanoic, and hexanoic) present in their vaginal secretions and that levels of these acids change during the menstrual cycle. Although the fluctuation of these vaginal acids is reportedly dependent upon fluctuating ovarian hormone levels in the monkeys, any attempts to correlate changing acid levels with hormonal changes in women have, thus far, been unsuccessful. The possibility that vaginal acids may act as sex attractant pheromones in humans was pursued by some workers (Doty, Ford, & Preti, 1975; Keith et al., 1975). Their investigations, although based on small sample sizes, suggested that changes in vaginal odor could be related to the day of the menstrual cycle, with qualities of mildness and pleasantness being perceived around the time of ovulation and objectional odors observed just prior and after menstruation. The evidence for vaginal odors actually having an influence on human sexual behavior was slim, and that line of research appears to have been abandoned. Further intriguing bits of information on "human pheromones" were provided by studies on "bad breath." Although most normal bad breath is related to diet, bad breath is often noted during menstruation and pregnancy. But Tonzetich and colleagues in 1978 studied the volatile sulfur compounds in the mouth ("bad breath") throughout the menstrual cycle in five subjects and determined

that bad breath not only increased during menstruation but also increased fourfold near ovulation. These researchers speculated that increases in the compounds involved in mouth odor could be related to estrogen levels. The paradox of why nature would provide for "good" smells in the vagina and "bad" smells in the mouth at ovulation, the time most conducive to conception, further illustrates how little is known of the role, or even the very existence, of human response to body odors. There have been suggestions that if chemical (pheromonal) communication exists in humans, it may not even involve conscious odor perception but instead may operate via neural pathways that are separate from main olfactory nerves. Many other species have an accessory olfactory system in the nose called the vomeronasal organ with its own neural connections to the brain, which processes the pheromone and directs a response. In the Asian elephant, for example, an identified pheromone chemical in the urine of female elephants who are about to ovulate is detected through the vomernasal organ of the male elephant and tells him that the female is ready to mate. This chemical compound is identical to the sex attractant in more than a hundred species of insects. Some pheromone researchers have postulated the existence of a residual vomeronasal organ in humans that could elicit reproductive physiological or behavioral responses similar to that in other species, but others find such reports highly speculative and controversial (Ben-Ari, 1998).

Laypersons have probably always been aware of the individuality of what has been termed the *olfactory signature* of a person. Even with our relatively underdeveloped olfactory systems, we recognize that different people smell different. Although the existence of human pheromones acting as chemical communicators is unproven, the erotic potential of odor is well known to the manufacturers and advertisers of perfumes and incense. So is the word *pheromone.* An expensive women's fragrance produced in the United States has been named "Pheromone" and sells very well. One enterprising British firm went further in putting sex appeal in a gold-plated bottle by marketing an even more costly scent for men and women that contains a synthetic pheromone. Just what the "synthetic" pheromone is derived from is not disclosed. Perhaps users, who might get amorous advances from insects or dogs, should be cautious.

Musk oil-based scents are very popular with both men and women, and to many people musk smells very much like healthy body odor. Although armpit aroma generally is thought to produce negative behavioral responses, the commercial possibilities have not been ignored. The same product that claims to "mask" or eliminate body odor actually mimics natural body odor, such as musk-scented products. Investigation continues regarding human pheromones, whether they exist, their chemical nature, how they act, and the role of human odors and nonodors in human behavior. Perhaps the "body chemistry" often referred to in sexual attraction is real and genetically determined. See "Menstrual Synchrony" in Chapter 3 for research indicating that women produce compounds that have the ability to affect the menstrual cycles of other women.

Vaginal Lubrication. There is always a certain amount of lubrication of the vagina from vaginal discharge, but sexual stimulation produces considerable wetness, which is usually noticeable. Since the vaginal epithelium has neither sweat glands nor sebaceous glands, where does this moisture come from? Before the observations of Masters and Johnson, it was always incorrectly assumed that Bartholin's glands and cervical mucus from the cervical glands produced the vaginal lubrication. Now it is believed that the blood vessels of the wall of the vagina actually play the essential role. The wall of the vagina is supplied with arterial blood by four branches of the internal iliac artery: the vaginal, uterine, internal pudendal, and middle rectal arteries. They branch into capillary networks, and the blood then drains from the vagina through veins that are large, thin walled, and form an interweaving plexus at the sides of the vagina. This venous plexus ultimately drains through the vaginal veins into the internal iliac vein. Under the conditions of sexual

stimulation, the veins around the vagina become engorged with blood. The resulting congestion of blood in the venous plexus results in pressure that forces a mucoid kind of liquid, or *transudate,* to pass from the veins through the epithelium of the vagina. This liquid at first forms individual droplets and then, as the droplets coalesce, forms a coating for the entire vagina. Because this appeared to sex researchers William Masters and Virginia Johnson as similar to drops of perspiration beading on a forehead, they called this the "sweating phenomenon" of the vagina. This occurs very early in the sexual response of the female and provides sufficient lubrication for intercourse. The vaginal response tends to be prevented when certain kinds of vaginal infections are present, and some women who are on the pill may also find that their ability to lubricate is diminished. Without lubrication, of course, penetration during coitus may be very uncomfortable.

Nerves of the Vagina. The upper two-thirds of the vagina is supplied almost entirely by nerve fibers from the autonomic nervous system, which means that they control the constriction and dilation of blood vessels in the walls of the vagina. There are very few sensory receptors for touch or pain located in the vagina. Sensations of awareness or pressure within the vagina are mainly received by nerve receptors in the rectum or urinary bladder and not in the vagina itself. The upper part of the vagina is hence relatively insensitive. The lower third of the vagina does contain some touch and pain receptors from the pudendal nerve, but such innervation is scanty. In contrast, the vulva has a rich supply of fibers from the pudendal nerve and is very sensitive. If the internal wall of the vagina is inflamed or infected (vaginitis), although the site of the irritation is inside, the itching or pain is referred to the outside on the vulva because of the way that the nerves are distributed. If the area around the vaginal opening itches and burns and an abnormal discharge is present, it very likely means that undesirable organisms are inhabiting the vagina.

Uterus

From the medical records that have remained intact, it is evident that the uterus, a hollow, muscular organ in which a fetus develops, more than all the female reproductive organs, was the most subject to fanciful and erroneous description by ancient physicians. Evidently unwilling or unable to credit women for owning an organ in which the fetus developed, early accounts described the uterus as an independent animal capable of independent activity. A Greek physician in the fourteenth century A.D. wrote:

> *In the middle of the flanks of women lies the womb, a female viscus, closely resembling an animal, for it is moved of itself hither and thither in the flanks . . . and in a word, is altogether erratic. It delights also in fragrant smells and advances toward them, and it has an aversion to fetid smells and flees from them; and on the whole the womb is like an animal within an animal.*★

Centuries earlier, Hippocrates had written that the uterus went wild unless it was often fed with male semen. Even by the 14th century, the descriptions of the uterus were equally inaccurate but perhaps more ingenious. The prevailing opinion of female anatomy was still that it was a poor second to the obviously superior architecture of the male, and a French surgeon compared the uterus to a male organ turned inside out! "It has in its upper part two arms with the testicles . . . like the scrotum," he wrote, and went on to compare the body of the uterus, with a canal in it, to the shaft of the penis with the urethra running through it.

It is not surprising that extravagant errors were made in explaining the "mysteries of the womb"—the uterus is a very unique organ. Every month it prepares to receive a fertilized ovum; if it does not, it sheds its lining and starts all over again. If it does receive a fertilized ovum, it shelters it, nourishes, and protects it dur-

★From *A Pictorial History of Gynecology and Obstetrics,* by H. Speert, 1973, Philadelphia: F. A. Davis Co.

ing its development for 9 months, and then expels it at the end of pregnancy. The actual mechanism for doing all this is still unknown. The uterus has the ability to grow from a weight of about 2 oz when nonpregnant, to 2 lb, its weight immediately after delivery, and then shrink back to its original size by 6 weeks after delivery.

Hollow and muscular, the uterus has an upper expanded portion called the body or *fundus* and a lower constricted part called the neck or *cervix*. The cervix projects down into the vagina and has an opening, the *external os.* As with all other parts of the reproductive tract, there is considerable variation in the size of the normal, nonpregnant uterus, but on average it is 3 in. long, 2 in. wide at the fundus, 1 in. thick at its thickest part, and the wall of the uterus is ½ in. thick. The exact size of the uterus can be measured only with an instrument called a uterine sound, which is inserted through the external os. Clinical impressions of size derived from pelvic examination are very deceptive, making physicians' remarks such as "you have an infantile uterus" not only unnecessarily disturbing but usually erroneous.

The walls of the uterus are solid and made of involuntary smooth muscle. They enclose a cavity that is lined with epithelium called the *endometrium,* which undergoes cyclic changes during menstruation and forms the site for implantation of the fertilized egg if pregnancy occurs.

Positions of the Uterus

The normal uterus is a very mobile organ, and its position between the rectum and the bladder varies, depending on posture, how full the bladder or the rectum is, and how many children have been borne. As seen in Figure 2–12, the body of the uterus is typically inclined forward: When the urinary bladder is distended, the backward movement of the uterus is called *retroversion;* when the rectum is distended, the forward movement of the body of the uterus is called *anteversion*. Further and marked anteversion with relation to the cervix is called acute flexion; marked retroversion is called *retroflexion*. The uterus is normally anteverted and anteflexed. It may also be retroverted and retroflexed and still be normal; a "tipped" uterus is of no clinical significance and results in no symptoms. Backache, constipation, menstrual cramps—none of these can be related to retroversion or retroflexion.

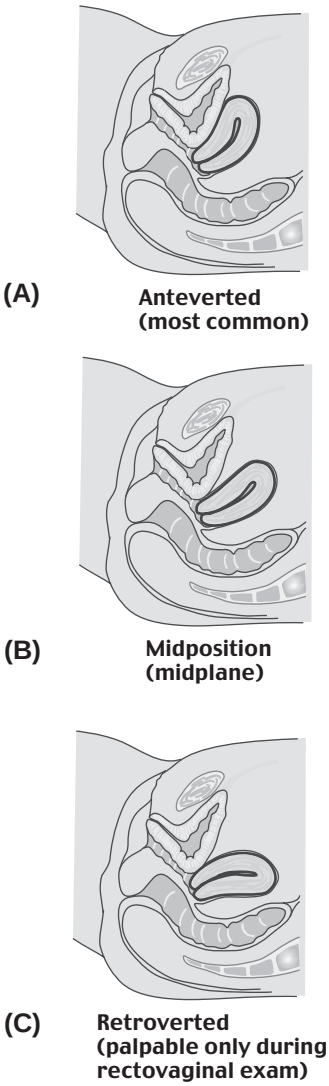

Figure 2–12 The normal uterus can vary in position. (A) Uterus is anteverted. (B) Uterus in midposition. (C) Uterus retroverted.

During the 19th century, gynecologists collected a great deal of money for inserting vaginal pessaries, which are devices used to correct retrodeviations of the uterus. During the early part of the 20th century, there was much unnecessary surgery performed to "correct" the position of the uterus to relieve the symptoms ascribed to its nontypical but perfectly normal position. Of course, it is important for the size, shape, and position of the uterus to be known if any procedure like an abortion or a D and C is to be performed (D and C: *dilatation,* or enlargement of the cervical opening with dilators, to permit *curettage,* or scraping of the uterine lining with an instrument called a curette).* Otherwise, an instrument inserted into a markedly anteflexed or retroflexed uterus may perforate the wall.

The lower part of the uterus, the cervix, projects into the vagina and is circumferentially attached to it, thus dividing the uterus into an upper, or supravaginal part, and a lower, or vaginal portion. The vaginal part of the cervix is called the *portio vaginalis.* In an adult woman who has not delivered any children (nullipara), the cervix comprises approximately one-half the length of the uterus; in a woman who has given birth to at least one child (primipara; more than one child, multipara), it may be only one-third the length of the uterus. In its typical position in most women, the cervix is directed downward and backward, with its long axis making an angle of between 80° and 120° in relation to the forward-inclined body of the uterus. This position is supported and maintained by fibrous muscular bands called ligaments, described later.

External Os

The opening of the cervix into the vagina is the *external os.* The opening into the uterine cavity is the *internal os.* The canal between the external and the internal os is the *endocervical canal,* lined with the endocervical epithelium. It contains many mucus-secreting glands and is approximately 1 in. long.

There is a very visible difference between the nulliparous os and the multiparous one. Before childbirth, the external os is a little round dimple, approximately 3 ml in diameter. It is sometimes called the *os tincae,* or "mouth of a small fish." This tiny canal dilates during labor and delivery to accommodate the passage of the head and body of a full-term infant; after parturition, it never again returns to its previous shape but becomes a transverse slit with irregular margins. Enlarging the cervical opening with dilators to perform an abortion or a D and C has the same effect. Note that although it is not possible to determine whether or not a woman is a virgin, an examiner can tell whether she has had a baby or an abortion. No matter how small the trauma, very minute lacerations and abrasions occur that change the appearance of the os (Figure 2–13).

Cervix

The **cervix** is predominantly composed of fibrous connective tissue with many smooth muscle fibers. It is firm to the touch except after approximately 6 weeks of pregnancy, when it softens, owing to the increased blood supply to the uterus and cervix. The feel of the nonpregnant cervix has been compared to the feel of the tip of the nose, or to the glans of the erect penis.

The epithelium on the surface of the vaginal aspect of the cervix is pale pink, whereas the epithelium of the endocervical canal leading into the uterus from the external os is redder in color. Because of this color difference, inflammations (cervicitis), extensions of the endocervical epithelium onto the vaginal aspect of the cervix (erosions), benign polyps, or cysts are highly visible on the surface of the portio vaginalis, even though these conditions originate on the mucous membrane of the endocervical canal. The glands on the endocervical canal are highly branched and burrow deeply into the recesses and folds of the cervical mucosa. Once organisms get into this desirable envi-

*Dilation and dilatation are synonymous; the dilation of the cervical opening is customarily referred to as dilatation.

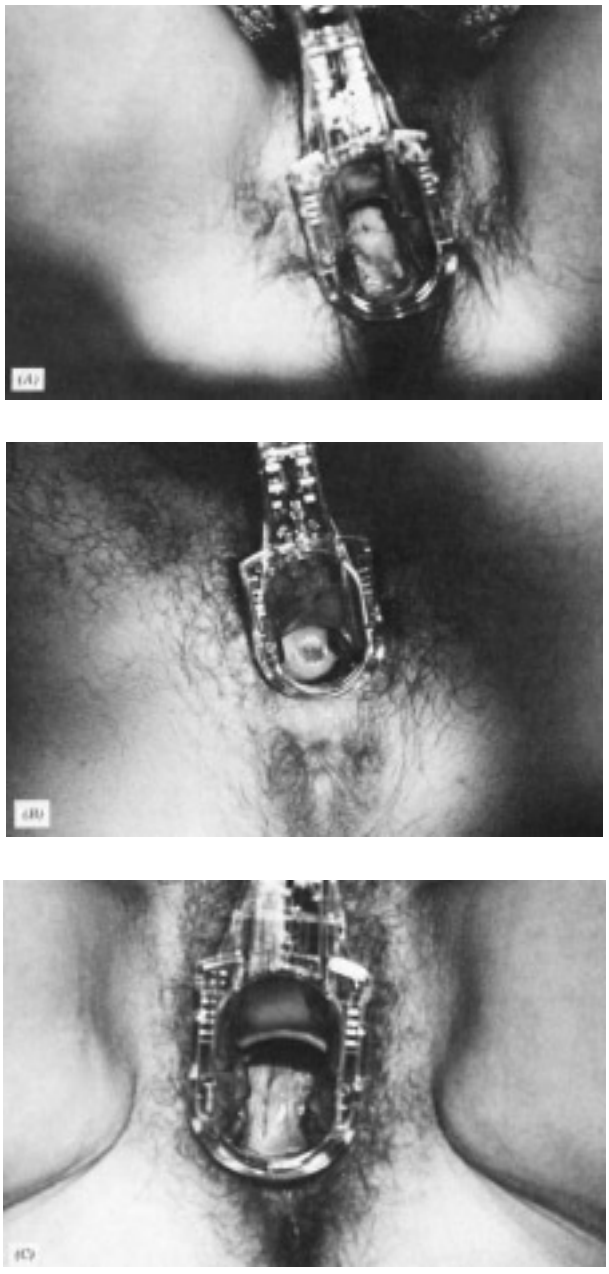

Figure 2–13 Appearance of the cervix and the external os. (A) Nulliparous os. (B) Parous os. (C) Appearance of the vaginal vault after the cervix has been removed in conjunction with a hysterectomy performed through the vagina. The vertical line represents the location of the suturing of the vaginal mucosa.

ronment, they remain hidden and can stubbornly resist most attempts to get rid of them. This is why infections of the cervix tend to become chronic.

Cervical Mucus. The endocervical glands secrete cervical mucus, which is composed mostly of water; electrolytes like sodium and potassium ions dissolved in the water; blood proteins, including immunoglobulins; and mucins, a complex group of glycoproteins. Glycoproteins are compounds made up of carbohydrates and proteins, and in cervical mucus they have been found to contain an extremely high percentage of carbohydrates. During the menstrual cycle, the physical properties of the cervical mucus change as a result of the differing levels of circulating hormones. Before and near the time of ovulation, the mucus is dilute, secreted in greatest quantity, and when it is spread out on a slide it will undergo "ferning" or "arborization"; that is, it forms a distinct pattern as it dries and looks like ferns or tree branches. After ovulation, the mucus becomes much thicker, reaches a gel state, and no longer demonstrates ferning. These changes form the basis for tests of both hormonal activity and determination of the time of ovulation.

The thinner, more fluid cervical secretion enhances sperm migration up to the uterine cavity; the gel-like mucin in the latter half of the menstrual cycle acts as a barrier to sperm motility. It is possible that the cervical mucus may function as a bacteriocide to protect the upper reproductive tract from invasion by harmful bacteria. It has also been suggested that it may form a mechanical protection at the junction of the external os and the endocervical canal against the development of cancer.

OVIDUCTS OR FALLOPIAN TUBES

The **oviducts** or **fallopian tubes** and the ovaries are frequently referred to as the *adnexa* because they are adjacent or next to the uterus. The fallopian tubes

are named after the 16th-century anatomist Gabrielle Fallopius, who thought they resembled tubas or curved trumpets and believed they released noxious fumes from the uterus. More ancient anatomists thought the oviduct looked like a straight trumpet, and they called it the *salpinx* (Greek for tube). That prefix appears in the words describing conditions of the oviducts, such as *salpingitis,* or inflammation of the oviducts, or *salpingectomy,* removal of a tube, among other salpingo-type procedures.

The fallopian tube is anatomically divided into four sections:

1. The *interstitial* or uterine portion: very short, very narrow in diameter, and lying completely within the muscle of the uterus
2. The *isthmus:* the straight part with a thick muscular wall and a narrow lumen (passageway); the section that is the usual site of a tubal ligation, a surgical procedure that prevents the sperm from meeting the ovum by cutting or ligating the oviduct
3. The *ampulla:* occupying about one-half the entire length of the tube, thin walled, with a highly folded lining
4. The *infundibulum:* nearest the ovary, a trumpet-shaped expansion with finger-like projects called fimbriae that wave back and forth through muscular action to attract the ovum into the opening, or *ostium;* one fimbria is longer, closer to the ovary, and is called the ovarian fimbria (Figure 2–14)

The walls of the tubes contain many blood vessels and much longitudinally and circularly arranged smooth muscle. The lining of the tubes is thrown up into folds that almost fill the lumen, but the number of the folds varies with each segment and is most extensive in the infundibulum. The epithelium of the lining consists of those cells that secrete a nutrient fluid to provide an environment necessary for movement, fertilization, and sustenance of the ovum, and other cells that bear cilia, little hairlike processes that beat toward the uterus to create a current to help the egg progress into the uterine cavity. The transport of the egg into the uterus is mainly accomplished by contraction of the circular and longitudinal muscle that creates peristaltic waves, which move the ovum along. This muscular activity is influenced by hormones and is greatest at the time of ovulation.

When an ovum is released from the ovary, it is not in direct contact with the end of the fallopian tube, and the exact mechanisms that keep the egg from falling into the pelvic cavity and getting lost are still not completely known. Culdoscopic observations at the time of ovulation have revealed that the fimbriae are brought closer to the ovary to curve around it by contraction of muscle fibers in the connective tissue, which covers and suspends the fallopian tubes from the abdominal wall. It has also been suggested that muscular contractions in the walls of the fimbriae, coupled with suction action from the ciliary movement of their lining cells, actually actively engulf the ovum, swallowing it up as though the end of the tube were a vacuum cleaner hose.

It is possible that scar tissue resulting from previous pelvic surgery or fallopian tube infection can interfere with the mechanism of picking up the ovum at the time of ovulation, and thereby cause infertility. On the other hand, there are cases on record in which women had a tube removed (salpingectomy) on one side, an ovary removed (ovariectomy) on the other side, and still had several children. Somehow these ova crossed over the uterus to enter the ostium of the opposite side.

Once in the infundibulum of the tube, the egg is rapidly transported through the ampulla until it reaches the ampullary-isthmus junction, where its transport is delayed for about 30 hours. This restraint of movement is referred to as the "tube-locking" mechanism, or the "isthmic block," and if sperm are present, fertilization occurs here. If conception occurs, the new embryo divides and develops, nurtured and sustained by the secretions of the tubal lining, and passes fairly rapidly through the isthmus and interstitial portion into the uterine cavity. No fewer than 45 nor more than 80 hours elapse between the time of ovula-

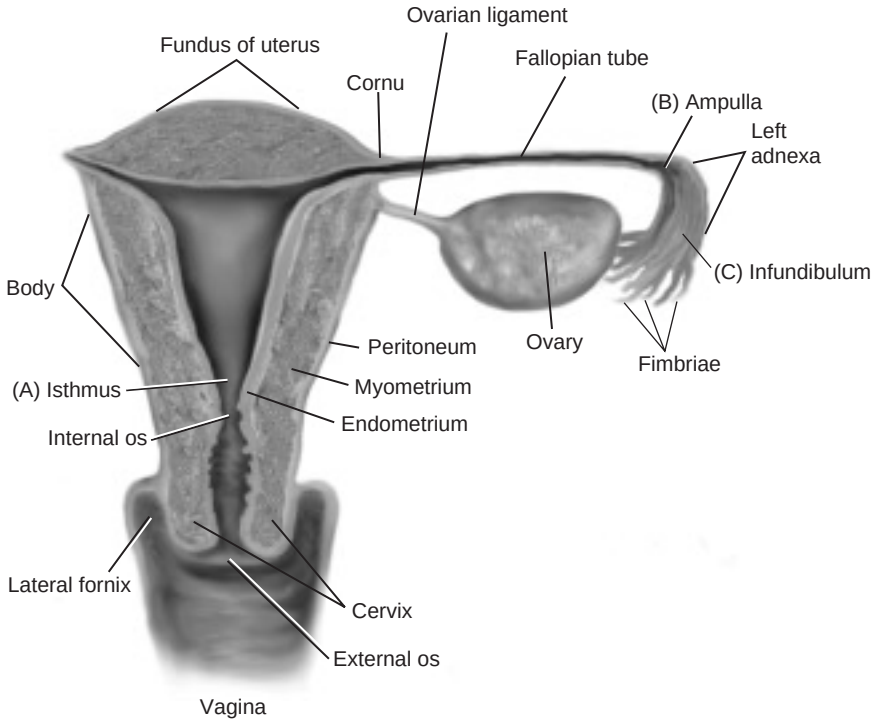

Figure 2–14 The fallopian tube and its relationship to the ovary and the uterus. (A) Isthmus. One-quarter of ectopic pregnancies occur in this area. The thick muscular wall permits little distension, and early rupture is likely. (B) Ampulla. More than half of ectopic pregnancies implant in this portion of the tube, which is more distensible. The pregnancy is further advanced before rupture. (C) Infundibulum. Fewer than 10% of tubal pregnancies occur here or in the fimbriated end.

tion and the ovum's entry into the uterus. Two to three more days pass before the timing is optimal for the joining of the embryo and the uterine lining, the process called implantation.

If the egg is not fertilized, it disintegrates, and its remains are cleaned up by those ubiquitous scavenger cells of the body, the macrophages.

Ectopic Pregnancy

After the conceptus (the collective name for the egg and all its derivatives from the time of fertilization until birth of the baby) arrives into the uterine cavity, it normally implants in the upper part of the cavity. If, for some reason, it fails to get to that destination, it may implant in some other place, like the fallopian tube, the ovary, the cervix, or (rarely) even the abdominal cavity. Such ectopic, or out-of-place, pregnancies are a major public health problem, and their incidence has been increasing dramatically. One in 100 pregnancies is reported to be an ectopic pregnancy, and 98% occur in the fallopian tubes (a tubal pregnancy). The tubes are not distensible enough to permit adequate development of the embryo and subsequent increase in size, particularly the closer the tubal implantation is to the uterus. The embryo, therefore, must always be removed surgically before the tube bursts, which can cause severe hemorrhage and infection in the abdominal cavity. Difficulty and delay in diagnosis and treatment have made ectopic pregnancy the major cause of death during the first 3 months of pregnancy.

Symptoms of an Ectopic Pregnancy. Unfortunately, the early diagnosis of tubal pregnancy is difficult because the early symptoms of an ectopic pregnancy are no different from the symptoms of a normal uterine pregnancy—a missed period, slight uterine enlargement, and softening of the cervix. If the tubal implantation is situated so that fetal tissue is in contact with maternal blood vessels, the hormone tested in pregnancy tests will appear in maternal blood and will yield a positive result. It is possible, however, for the fetal tissue to become separated from the tubal wall, and then a pregnancy test will prove negative, which of course does not exclude the possibility of ectopic pregnancy. A tender and distended tubal mass, palpable on pelvic examination, is a classic symptom, but it is not always detectable. The signs and symptoms of a tubal implantation vary greatly; differentiating it from threatened miscarriage, urinary tract infection, appendicitis, salpingitis, or an ovarian cyst is sometimes very difficult.

Lower abdominal or pelvic pain, with or without vaginal bleeding, is one of the most common symptoms. When there is bleeding or spotting accompanied by the sudden onset of pain after one period has been missed—corresponding to 6–8 weeks of gestation—it certainly warrants investigation. Pain and bleeding may be an indication that the tube has ruptured and that there is hemorrhage into the uterus and body cavity. The pain may be increased when a Valsalva maneuver (increasing abdominal and thoracic pressure by a forced expiration against a closed glottis) is performed. If the internal bleeding irritates the peritoneal lining of the body cavity, the pain may be referred to the shoulder.

Special means for diagnosis, such as laparoscopy, ultrasonic imaging, and immunoassay pregnancy tests, have made earlier determination possible, but it could take all three tests to diagnose a questionable ectopic pregnancy. Ultrasound usually cannot determine whether implantation has occurred in the fallopian tube; it can, however, rule out a tubal pregnancy if a clearly defined gestational sac or even more specifically, a fetal beating heart is seen in the uterus. If a highly sensitive pregnancy test, such as the human chorionic gonadotropin beta-subunit immunoassay, is positive for pregnancy, and there is no uterine pregnancy visible with ultrasonography, laparoscopic examination to permit visualization of the internal organs can make it possible to diagnose ectopic pregnancy before rupture occurs. One other marker is the serum progesterone level, which is considerably lower in an ectopic extrauterine pregnancy than in a normal intrauterine pregnancy. A progesterone level less than 5 nanograms/ml is suggestive of an ectopic pregnancy.

An ectopic pregnancy must always be terminated because there is no way for the embryo to develop to full term without rupturing the tube. In very rare instances, a fertilized ovum escapes through the ostium of the fimbriated end of the tube, implanting itself and developing in the abdominal cavity. Some of these pregnancies have actually been successful, and a nearly full-term baby can be delivered by an abdominal incision. Even more rarely, a fertilized ovum implants itself directly on the surface within the abdominal cavity, without ever having entered the tube.

If the isthmus of the tube is the site of the implantation, however, an early rupture is more likely to take place because here the thick muscle of the tubal wall permits little distension. In the infundibular part of the fallopian tube or in the ampulla portion, it is possible for the pregnancy to continue longer, but it always ultimately terminates in rupture, usually into the pelvic cavity.

Causes of Ectopic Pregnancy. The cause of many ectopic pregnancies is unknown, although endocrine dysfunction has been suggested. In some instances, there are conditions in or around the fallopian tube that prevent the fertilized ovum from getting to the uterine cavity. Thus, a tubal implantation results.

One such condition can occur when a gonorrhea or chlamydia infection that has spread to the fallopian tubes causes a further narrowing, through scar-tissue formation, of the already-narrow lumen. The tiny opening may permit the sperm to get up to the egg, but the fertilized developing egg, larger than a sperm, may not be able to descend to the uterus, and implants in the

tube. Actually, it is more likely that infection of the upper reproductive tract results in infertility because the destructive changes in the lining of the oviducts usually do not permit the passage of sperm at all.

Another cause of ectopic pregnancy may be related to the presence of an intrauterine device (IUD) that has been placed in the uterus for purposes of contraception. It has been observed that tubal pregnancy occurs more often in women with IUDs, and it may result from an alteration in tubal motility, causing a delay in the descent of the conceptus, which then goes ahead and implants in the tube. At any rate, since the function of an IUD is not to prevent the sperm from getting to the egg, but somehow to prevent uterine implantation, any woman with a previous history of sexually transmitted disease (and a possibly narrowed tube) should never have an IUD inserted. It places her in double jeopardy for the possibility of an ectopic pregnancy.

Tubal pregnancy has also been associated with a history of tubal surgery, including sterilization by tubal ligation ("tying the tubes"). The incidence is rare, however, and may be related to the method of tubal occlusion used. Other factors that have been suggested as increasing the risk of ectopic pregnancy include tubal ligation reversal, previous pelvic surgery, ovulation-inducing drugs, and smoking.

It is entirely possible and probable that many tubal pregnancies, like many uterine pregnancies, spontaneously regress or abort at a very early stage, and the woman may never suspect she was pregnant at all.

Treatment of Ectopic Pregnancy. Before 1975, nearly 80% of ectopics ruptured before diagnosis. As a result of the newer diagnostic techniques, currently fewer than 30% rupture before they are recognized, despite the increased incidence of tubal pregnancy. Diagnosed, unruptured ectopic pregnancy allows the surgical procedure of salpingostomy (making an incision in the tube and removing its contents) rather than the former salpingectomy (removal of the entire tube), frequently accompanied by oophorectomy (removal of the ovary on the affected side). Such conservative treatment permits preservation of the fallopian tube for future fertility. An alternative to a major surgical incision through the abdominal wall (laparotomy) is the removal of a small ectopic pregnancy using a laparascope, an internal telescope for viewing the pelvic organs. With laparoscopy, a small incision is made just under the umbilicus. The tubal incision and removal of the contents may be accomplished by electrocautery, scissors, and/or laser surgery. Laparoscopic surgery strikingly decreases hospitalization and recuperation time but should be performed only by gynecologists who have done it many times.

Nonsurgical medical management of tubal pregnancy usually consists of intramuscular injection of methotrexate, a folic acid analogue that prevents synthesis of DNA. The low doses of methotrexate, which can be given only if rupture has not occurred, cause few side effects and have a greater potential for maintaining future fertility. After a single dose, the woman is usually monitored on an outpatient basis. The success rate is said to be 90%–95%.

Despite attempts to preserve the tube, women who have had an ectopic pregnancy have a 12% incidence of recurrence, and 40% are unable to conceive again. Of the 60% who do become pregnant, approximately 15%–20% will miscarry (DeCherney, 1990).

Peritonitis: More Likely in Women

The body cavity is not a cavity at all but is a potential space that exists between the abdominopelvic viscera, which are covered by a membrane called the *visceral peritoneum,* and the body wall, lined by a continuation of that same membrane, which is reflected backward and called the *parietal peritoneum.* When bacteria like gonococci, staphylococci, and streptococci gain access to that space and attack the peritoneum, the resulting inflammation and infection is called *peritonitis,* and it can be life threatening. While one may think that all body openings lead into the body cavity, they actually do not. The mouth opening leads into the long tube of the digestive tract and ultimately exits at the other end in the anus; the urethral opening at the tip of the penis

in males permits exit of spermatozoa from the testis and urine from the urinary bladder. In females, the urethral opening is for the passage of urine only and leads to the bladder. The only way, in both males and females, that harmful organisms can get into the body cavity is through an opening in the body wall by surgery, by accidental perforation, by rupture of an organ (like a ruptured appendix), or through the bloodstream (blood poisoning). In females, however, there *is* another route, which results in a unique anatomical disadvantage. Because the end of the fallopian tube at the ostium opens directly into the pelvic or body cavity, the outside of the body, by way of the vaginal opening, is in contact with the inside of the body cavity via the fallopian tube.

Women, therefore, are much more subject to pelvic peritonitis than men. Fortunately, the acidity of the vaginal secretions and the cervical mucus act as a bacteriocide for most harmful organisms, with the exception of the gonococci of gonorrhea. But whenever the cervix is dilated for procedures such as an abortion, a D and C, a uterine biopsy (a small bit of tissue is taken for examination), or the insertion of an IUD, the possibility of peritonitis exists unless sterile techniques are very carefully observed.

OVARIES

The ovaries are two glands in the pelvic cavity that produce ova and sex hormones. The ovaries are the size and shape of almonds in the shell; that is, they are approximately 3 cm long by 1½ cm wide by 1 cm thick, although the size varies. They are suspended in the pelvic cavity three ways: attached to the peritoneal covering over the back of the uterus (the broad ligament) by connective tissue called the mesovarium; attached to the uterus by the ovarian ligament; and attached to the lateral body wall by the suspensory ligament of the ovary. The actual position of the ovaries is variable, especially after the birth of a child because at that time they are displaced from their original position and may never return to it.

The ovaries are the only organs in the pelvic cavity that are not covered with peritoneum, and they are a dull gray color in comparison to the pink, shiny, smooth uterus. The surface of the ovaries is covered with the *germinal epithelium,* a flattened layer of cells that was misnamed because it was thought that it gave rise to ova throughout life. Under the germinal epithelium is a zone or region called the *cortex,* the area in which the ova develop. Inside the cortex is the region called the *medulla,* with many large blood vessels, lymphatic vessels, and nerves. The connective tissue of the ovary is called the *stroma,* a framework of fibrous cells.

When a female baby is born, her ovaries contain a fixed number of primary ovarian follicles, and the ova she is destined to produce throughout her reproductive life will develop from them. These primary follicles arose from special cells called *primordial germ cells,* which were segregated from the rest of the body cells by as early as 10 days after fertilization. After migrating to the side of the primitive ovary, the germ cells, now called *oogonia,* become surrounded with a layer of cells called follicle cells, and the combination is known as the primary follicle. The primary follicles in the fetal ovary divide at a prodigious rate, and by 20 weeks of fetal life, there are more than 7 million. After that, there is no further division either before birth or after it; from that time on and for the next 50 years or so, the majority of ova undergo a process of regression and degeneration called *atresia*.

Various investigators differ in their estimates of the number of follicles remaining at birth. Some say that 150,000 exist, others maintain that about 1 million are present to form the stock from which all future eggs to be ovulated will be selected. At birth, the primary follicles contain an ovum arrested in the stage of development known as primary oocyte. By puberty, the number of follicles is further decreased to 50,000 (or fewer), and only one of these is ovulated each month—a total of approximately 400 from puberty to menopause.

A woman is, therefore born with all the eggs she will ever have. If she is still ovulating at the age of 50, that ovum has been in her ovary for some 50 years and 4 months. All the rest have become atretic. If this seems like an inordinate waste of cells with talent, consider that when a male ejaculates approximately 3 ml of seminal fluid, each ml contains 40–250 million sperm—yet only one sperm is necessary to fertilize an egg! This apparent overkill is not at all unusual in nature, whose interest is perpetuation of the species.

After puberty, those primary oocytes that will be ovulated go through a monthly scheme of development called the ovarian cycle. The hormones produced by the ovary during its cycle govern the activity of the endometrium of the uterus and result in cyclic menstruation. What is going on in the ovaries and the uterus is determined by hormones released by the anterior pituitary gland, and the anterior pituitary, in turn, is controlled by secretions called releasing hormones from a part of the brain, the hypothalamus. This constitutes the hypothalamic-pituitary-gonadal-uterine axis described in detail in the next chapter.

Anatomically, the ovarian cycle is diagrammed in Figure 2–15. At the beginning of each cycle, a group of follicles begins to undergo development, but only one will completely differentiate and mature. The rest become atretic. The follicle cells around the ovum multiply, form many layers, and become known as the granulosa cells. The stroma cells become organized into two layers, the *thecae interna* and *externa,* which produce hormones. The ovum itself enlarges and becomes surrounded by a membrane, the *zona pellucida,* a noncellular clear zone that lies between it and the granulosa cells. The zona pellucida functions during fertilization, permitting the entrance of only one sperm and blocking all others.

The next stage of follicular development is called the *secondary* or *antral* follicle. The granulosa cells, initially, and later the theca layers, secrete a viscous follicular fluid that accumulates in between the granulosa cells, forming cavities that eventually coalesce to form one large fluid-filled space called the antrum. The primary oocyte stays embedded at one side surrounded by a mound of granulosa cells called the *cumulus oophorus* (Latin for heap of egg cells). When the ovum is ovulated, the two or three adhering layers of granulosa cells shed with it form the *corona radiata,* or crown of cells. Perhaps 20–50 primary follicles reach the antral stage, but only one goes on to ripen fully to ovulation. That dominant one is called the mature *Graafian follicle.* In the follicles that do not fully mature, the granulosa layers become disorganized, the cells deteriorate, the follicular cavity shrinks, and the ovum itself degenerates.

The mature Graafian follicle moves toward the outer part of the ovary and forms a bulge on its surface. It manages to move mostly because of its increased size (2.5 cm or about 1 in. in diameter) and because the theca layers somehow facilitate a pathway. The area on the surface where the bulging follicle has caused a thinning out that looks like a blister is called the *stigma.* At the time of ovulation, the follicle bursts, and the egg, surrounded by its protective and nourishing corona radiata, floats out into the peritoneal cavity on a rush of follicular fluid. There is slight bleeding into the center of the follicle, and some of the blood may escape into the pouch of Douglas to produce the ovulatory pain called *mittelschmerz* (German for middle pain), which some women experience.

The ovulated egg (now a secondary oocyte) is swallowed up by the fimbriated end of the fallopian tube and begins to travel down it. It will die if it is not fertilized within 24 hours. Meanwhile, back in the ovary, the wall of the ruptured follicle collapses and the granulosa cells greatly increase in size, accumulating a yellow lipid-rich pigment called lutein in their cytoplasm. The cells are now called luteal cells, and the former follicle is called the *corpus luteum,* which produces hormones. The corpus luteum reaches its peak of activity approximately 5–7 days after ovulation, and if the ovum is not fertilized, begins to regress on the 10th day. Its life is over by the 15th day. The entire corpus begins to be invaded by connective tissue and, ultimately, is transformed into the *corpus albicans,* the white scar. After puberty, the formation of white scars from previous corpora lutea each

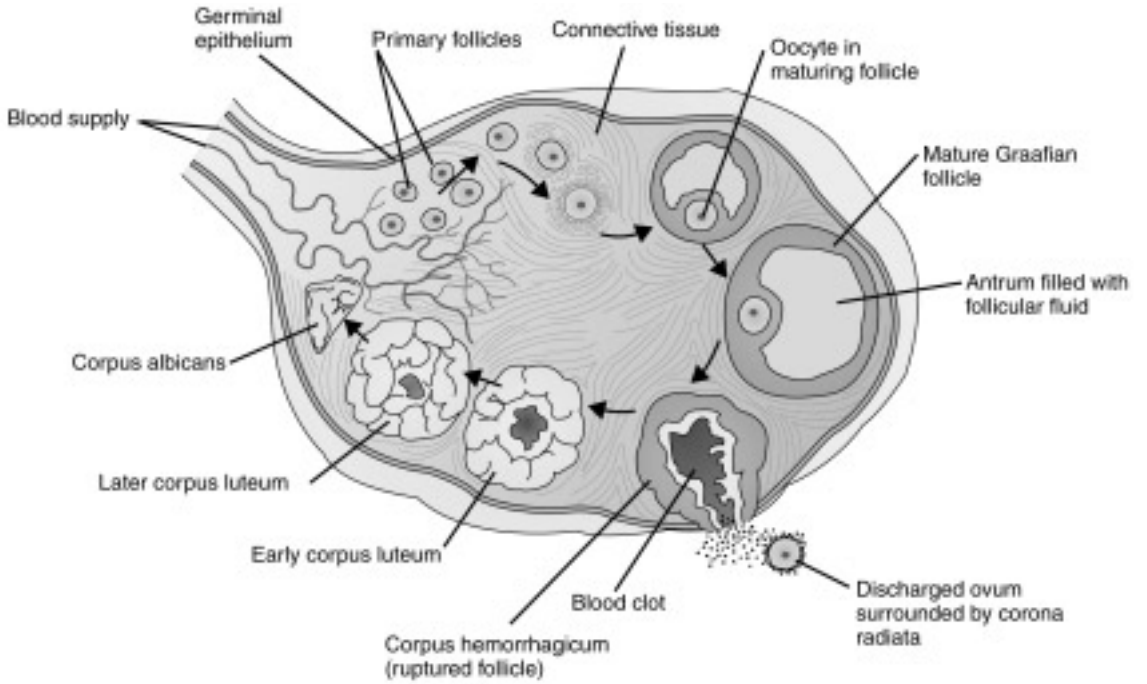

Figure 2–15 The ovarian cycle.

month give the ovary its characteristic pitted, convoluted surface. Before these monthly cycles begin, the ovary in a prepubertal female is smooth; afterward, it looks something like a peach pit. The complete absorption of corpora albicantes takes a year or more, so the ovary always has a few in various stages of disappearance if a microscopic section is examined.

How the one follicle destined for ovulation is chosen while all the others die is not completely known. It takes an estimated 25 days for a small antra follicle to grow into a mature Graafian preovulatory follicle—considerably longer than the period from the beginning of menstruation to ovulation. There must be, therefore, continuous development of a number of primary follicles progressing along to the antral stage independent of hormonal support. Most of them will become atretic, but it is suspected that the follicle most likely to be saved from atresia by the increasing pituitary hormone levels at the onset of a new ovarian cycle is the one best developed at that time. This advanced follicle, rescued by hormones at a later stage than the others because of its increased development, goes on to become the successful ovulatory follicle. The other antral follicles, less mature and lacking the ability to respond to hormones, become atretic.

There must also be some kind of quantitative relationship functioning between antral follicles doomed to atresia and those ordained to ovulate because even one tiny bit of ovarian tissue left after surgery still manages to produce an ovum each month. There is some evidence from animals that in that situation, fewer follicles become atretic than in a woman with two fully functioning ovaries.

When all the follicles are gone from the ovary by atresia or ovulation, ovarian activity ceases, and that period in a woman's life is called menopause. For the great majority of women, the nonactivity of the ovaries in menopause has been highly overrated; it need not be particularly significant to their well-being, sex lives, or general health.

Support of the Pelvic Viscera

That we stand erect and walk on two legs instead of four has been of primary importance in the development and progress of human society. There are many marvelously ingenious evolutionary modifications that have taken place to produce and maintain this posture. These anatomical modifications have significantly influenced our sex lives and the way in which women bear and deliver children. They also have contributed greatly to the development of some human ills, like backaches, sinus trouble, headaches, hernias, impacted wisdom teeth, fallen and weak arches, varicose veins, and hemorrhoids, to mention only a few. Most authorities agree that these malfunctions are signs of how inadequately the human body has adapted to a vertical biped stance instead of a quadruped posture.

The difficulty with standing erect is that gravity is always trying to pull everything down, and the older one gets, the harder it becomes to maintain all structures in their appropriate balanced arrangement of bone, muscle, and soft tissue. The way in which injury or congenital defects can compromise this balance to produce backache has already been discussed. Similarly, there are potential weaknesses that exist in the support of the internal organs. In a four-footed animal, the abdominal and pelvic viscera hang suspended from a horizontal backbone and are supported by the abdominal wall without much trouble, but in humans the abdominal and pelvic organs are constantly subjected to the downward pull of gravity. Even when a person is standing motionless, the viscera exert pressure on the muscles and connective tissue of the pelvic floor. Any movement increases abdominal pressure, as the viscera are squeezed against each other and against the pelvis. When the abdominal pressure is deliberately increased by contraction of the abdominal muscles during such ordinary activities as respiration, urination, and defecation, the stress placed on the pelvic supports that keep the viscera from falling out of the pelvis is enormous.

There are three kinds of supports for the abdominopelvic organs. One is provided by the bony bolstering of the spinal curvatures and the flaring of the ilia of the pelvis. These form shelves to brace portions of the digestive tract. Second, there are folds of the peritoneal lining of the body cavity and packings of connective tissue that attach to the viscera and hold them in place. The major support for the viscera, however, is from underneath—the muscles and connective tissues that make up the *pelvic diaphragm,* which stretches like a hammock across the bones of the pelvic outlet.

The inherent weakness in the pelvic diaphragm is that openings in it must exist for the exits of the urethra and the rectum, and in women, for the vagina. In females, childbearing and childbirth can strain the integrity of the pelvic support systems, and sometimes, after many pregnancies, the organs actually may slide out, or *prolapse* from the pelvis.

Structure of the Pelvic Floor

The pelvic floor consists of all the soft tissues that close the pelvic outlet, from the skin on the outside to the peritoneum on the inside, and all the muscles in between. When skin and superficial connective tissue are removed, the next layer is that of the superficial or *perineal muscles.* They include the ischiocavernosus muscles, important in erection of the clitoris; the bulbocavernosus muscles, which form the external vaginal sphincter and also function in clitoral erection; the superficial and the deep transverse perineal muscles; and the muscles of the external anal sphincter (Figure 2–16).

Underneath the perineal muscles are the *levator ani muscles,* major component (and the largest) of the pelvic diaphragm. In animals, these are the tail-wagging muscles. In humans, because we have no tails to wag, it would be expected that these muscles be diminished and vestigial. Instead, the levator ani muscles are bigger, stronger, and more powerful because their function in us is support, and that makes them the most important muscles in the pelvic floor. They are further strengthened by very strong connective tissue sheaths, the

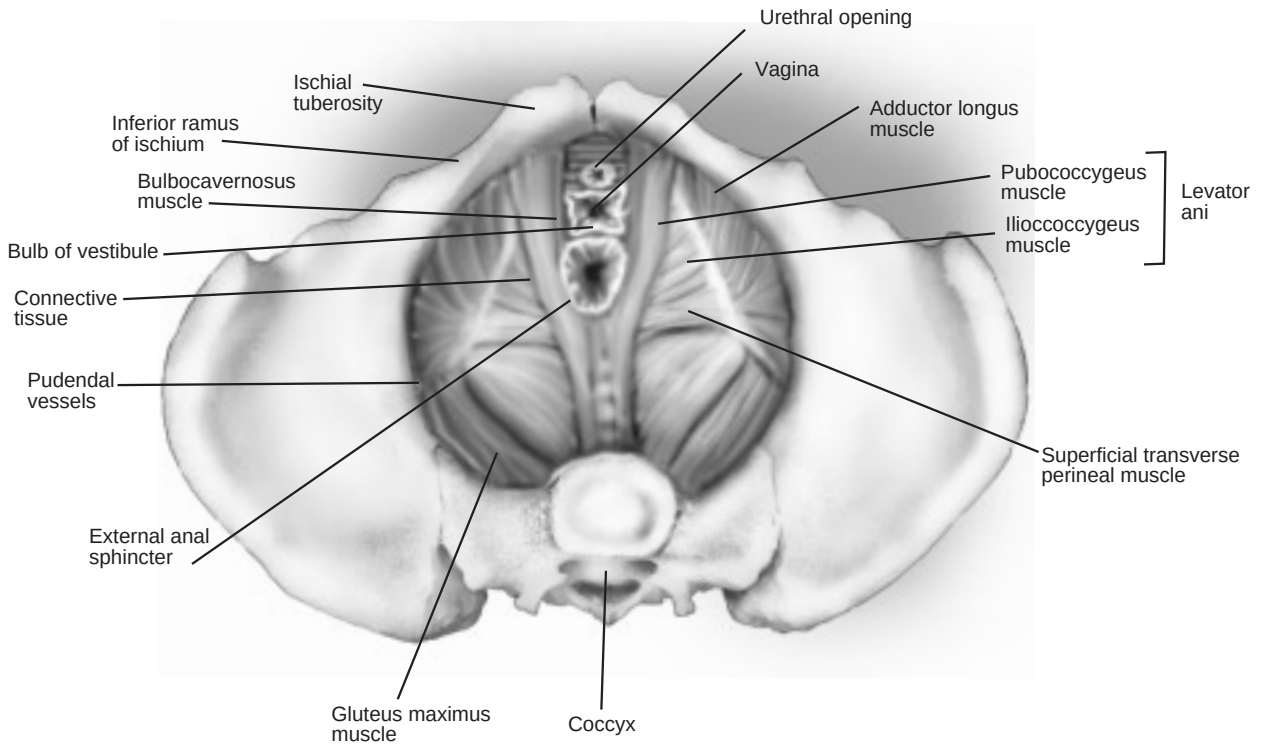

Figure 2–16 Muscles of the pelvic floor, from below.

inferior and *superior levator fascia*. Each half of the levator ani meets its partner from the other side in the midline to surround the urethra, the vagina, and the rectum with fibers that form sphincter muscles, which can powerfully constrict those hollow organs. Of the three component parts of the levator ani, the *pubococcygeus* is the one performing the main sphincteric action.

Sphincter Actions of the Pubococcygeus on Urinary Control

The pubococcygeus muscle fibers around the base (or trigone) of the urinary bladder form a sphincter mechanism that compresses the urethra as it exits and pulls it upward behind the pubic symphysis so that a sharp angle called the urethrovesical angle is formed between it and the neck of the bladder. Even if the bladder is very full and the pressure within it is much greater than normal, urine can be retained. When the pubococcygeus muscle is voluntarily relaxed, the urethrovesical angle can straighten out and descend. Then the bladder muscle, called the *detrusor,* involuntarily contracts to let the urine enter the urethra and proceed until the bladder is empty. If the pubococcygeus is voluntarily contracted during urination, the sharp angle between the urethra and the bladder is restored to its previous elevated position, and urination stops. It is, therefore, possible to repeatedly stop and start urinary flow by contracting and relaxing the pubococcygeus muscle.

However, if the fibers of the pubococcygeus muscle are traumatized, stretched, or torn during childbirth, they no longer meet in the midline around the base of the bladder to maintain the integrity of the urethrovesical angle. Then, any increase in intra-abdominal pressure, like sneezing, coughing, or laughing, pushes the viscera against the bladder and results in

a dribble or even a gush of urine that cannot be controlled by the now lax pubococcygeus muscle. This annoying and embarrassing situation is experienced by some multiparous women to a slight extent at the time of menstruation and is called *stress incontinence.* In a more severe form, it is present throughout the month. Some women never experience incontinence until menopause. There are estimates that nearly 40% of women over 60 are affected.

Although urinary incontinence may also be a result of a neurological disorder or a mechanical obstruction to the bladder or urethra, the most common cause of difficulty is injury to the soft tissues during delivery. The role of the obstetrician present at a delivery is to minimize the possibility of injury to the mother or to the baby, and the doctor's gentle and presumably expert assistance is certainly required in difficult labors. While it is not reasonable to blame all stress incontinence on incompetent or negligent behavior by the obstetrician, there are some procedures performed by physicians that tend to encourage trauma and tissue injury rather than to decrease it. For example, when labor is induced with hormones for no other reason than the convenience of the physician, the result may be a precipitous delivery that can injure both the baby and the mother. Another example is neglecting to catheterize the bladder during labor if the woman is unable to void on her own. The resultant pressure may then injure the bladder neck area. However, many cases of mild and uncomplicated stress incontinence are unavoidable, even with the best and most conscientious obstetrical help, particularly when large infants are delivered through a small bony pelvis. It is likely that the number of births (parity) of a woman is more significant in causing stress incontinence than any perineal damage associated with an individual delivery.

Urinary incontinence produces not only social and psychological distress but also may result in a substantial economic burden for affected women and the nation's health care costs. Obviously, any treatment other than drugs or surgery that can help control incontinence should be considered, especially in older women for whom the risks of surgery and the side effects of drug therapy may be greater.

Kegel Exercises. Most surgical treatment for stress incontinence is aimed at restoring the integrity of the pubococcygeus muscle and the urethrovesical angle. Voluntary contractions of the pubococcygeus, commonly called Kegel exercises, can alleviate and even cure many cases of mild to moderate stress incontinence and are certainly worth trying before resorting to surgery. The exercises, as described by Kegel, the physician who advocated them, are meant to strengthen the pelvic diaphragm. Fifty to 100 times a day, said Kegel, the pubococcygeus should be contracted for at least 3 seconds and the anus and vagina drawn up into the pelvis. No one can observe that these exercises are being performed and they can be done in any position—standing, sitting, lying down. An easy regimen to follow would be to perform the contractions for 15 repetitions, 6 times a day (i.e., first thing in the morning, midmorning, lunchtime, midafternoon, dinnertime, and bedtime). Also, whenever voiding, the flow of urine should be stopped and started several times. For many women Kegel exercises will strengthen the pubococcygeus muscle enough to pull up the neck of the bladder and increase the urethrovesical angle, thereby preventing leakage of urine. Reductions of incontinent episodes by 50%–60% as a result of such pelvic floor exercises have been reported (Burns et al., 1990; Bo, Talseth, & Holme, 1999).

Bladder Training. Another nonmedical possibility to restore urinary control involves "bladder training" or "bladder discipline," a program that involves educating a woman about bladder function and then having her follow a mandatory voiding schedule. A study utilizing bladder training recruited 123 women 55 years or older who had at least one episode of urinary incontinence a week. Sixty of the women formed the experimental group and were enrolled in a 6-week bladder training program. They were educated about how the brain controls urinary tract function and how the bladder and the urethra work. They were also told

to follow a regular voiding schedule that was progressively lengthened and to resist the urge to void at other times by distraction or relaxation techniques. The rest of the women formed the control group. Although the researchers have no real explanation for the physiological or psychological mechanisms of action of the training program, they reported that it was effective. After the program, 12% of the treated women had no incontinent episodes and 75% had at least a 50% reduction in involuntary urine loss (Fanti et al., 1991). Clearly, the use of nonmedical low- or no-cost treatments of urinary incontinence can work for some women.

Action of the Pubococcygeus on the Vaginal Wall

Kegel exercises have also been advocated for the improvement of sexual relations between couples because they increase the ability of the vaginal sphincter to contract. The vaginal sphincter is responsible for the clasping action of the vagina around the penis during sexual intercourse, and the sphincter is formed by the fibers of the pubococcygeus muscles blending into those of the superficial perineal muscles around the walls of the vagina.

The involuntary spasm of the pubococcygeus muscle that may occur during sexual intercourse or perhaps during a pelvic examination in a doctor's office is called *vaginismus.* Here, the constrictive action of the pubococcygeus actually shuts off the vaginal opening so that introduction of the penis during coitus or of a speculum during examination produces pain and makes penetration impossible. Vaginismus can be a result of anticipated pain, or it may be caused by fear, guilt, or nervousness. It sometimes develops in a rape victim, particularly if sexual assault has produced severe lacerations to the genital area. Intercourse may then be severely painful to a woman long after the physical damage has healed.

Sometimes a mild and temporary vaginismus, enough to delay penetration or make it uncomfortable, however, may occur as a result of a previously painful intercourse during an episode of vaginitis. A temporary vaginismus can also be associated with a lack of sufficient lubrication.

It is possible to alleviate mild discomfort during intercourse with a surgical, water-based lubricant like K-Y Jelly, but if vaginismus is the primary response to sexual stimulation, some type of therapeutic counseling may be helpful.

No one has ever seen it happen, but almost everyone has heard the story about the couple that became "locked" together during sexual intercourse as a result of vaginismus and had to be separated in the emergency room of the local hospital. There is no medical basis or case on record to verify this persistent myth, called *penis captivus.* It can occur in animals, most frequently in dogs, and this is probably the source of the fantasy.

Action of the Pubococcygeus on the Rectal Wall

The pubococcygeus muscles also have an effect on the walls of the rectum. When strongly contracted, the pubococcygeus pulls the rectum and anus forward toward the pubic symphysis and supplements the action of the anal sphincter.

Other Muscles of the Levatores Ani

In addition to the pubococcygeus muscles, the lateral components of the levator ani are the *iliococcygeus* muscles, which extend (as their name indicates) from the ilium to the coccyx. Posteriorly, the triangular *coccygeus* muscles complete the pelvic diaphragm. The iliococcygeus muscles and the coccygeus muscles are supportive only; they have no sphincteric action.

Internal Support of the Pelvic Viscera

The uterus, the tubes, the ovaries, the urinary bladder, and the rectum are connected to each other and to the walls of the true pelvis by a number of "ligaments," some of which are not ligamentous structures at all but are merely folds of the peritoneal lining of the pelvic

basin. Others do function as ligaments, combinations of smooth muscles and fibrous connective tissue, that tie the pelvic organs together, or function as ropes to suspend them from the body wall. Some additional support for the viscera is actually accomplished by their positions: being all crowded together provides pressure to hold them in place.

The peritoneum is the membrane that lines the body wall and is reflected back to cover all the viscera. The lining part is the *parietal* peritoneum, and the part that covers the organs is the *visceral* peritoneum. In between is the peritoneal cavity, also referred to as the pelvic cavity. It is actually only a potential space, since the parietal and visceral layers are in close contact.

The arrangement of the peritoneum in the abdominopelvic cavity is complicated. Trying to trace it from one organ to another or to the body wall is frustratingly difficult because in their embryonic development the organs pushed into the peritoneum from behind, acquiring for themselves a visceral peritoneal covering but leaving behind a complex scheme of folds and reflections of the parietal peritoneum. The reflected and folded peritoneal lining forms the route for blood vessels and nerves that supply the organs.

If one imagines the pelvic basin as a huge bowl lined with a membrane, the pelvic peritoneum, it is possible to visualize how the urinary bladder pushes up into it anteriorly, the rectum pushes up into it posteriorly, and the uterus pushes up into it in the middle. The viscera of the pelvis are only partially covered by the peritoneum. They lie mostly underneath it, surrounded by abundant connective tissue, the endopelvic fascia. It is apparent how the two pouches of peritoneum are formed in front and in back of the uterus. The one between the uterus and the bladder is the vesicouterine pouch. The one between the uterus and the rectum is the rectouterine, the pouch of Douglas, or the cul-de-sac, easily reached through the posterior fornix of the vagina.

Each fallopian tube extends laterally from the uterus like an arm, and the peritoneum is draped like a blanket over the uterus and the tubes. Each tube is covered with the blanket except at the ostium, which opens directly into the body cavity. The draped tent of reflected peritoneum is called the *broad ligament*. The ovaries are not covered by the broad ligament but are suspended from its back (posterior) surface by an extension called the *mesovarium*.

Inside the broad ligament is the connective tissue containing the blood vessels and nerves that supply the pelvic organs. Two cordlike condensations of this connective tissue, the *ovarian ligaments* and the *round ligaments,* are found in the apex of the broad ligament; The ovarian ligaments contain smooth muscle fibers and extend between the ovaries and the lateral angle of the uterus. At the time of ovulation, the fibers contract to change the position of the ovaries and bring them closer to the ends of the fallopian tubes. The round ligaments, almost completely composed of smooth muscle, are flat, narrow bands that extend from the lateral angle of the uterus on either side, cross over many blood vessels and nerves, and travel down through the inguinal canal (a passageway through the anterior abdominal wall) to insert into the tissues of the labia majora. The round ligaments hold the uterus forward in its typical anteverted position over the urinary bladder. As they traverse the inguinal canal, these ligaments become surrounded with connective tissue coverings and are accompanied by blood vessels, nerves, and lymphatic vessels. The lymphatics drain from the upper part of the uterus where the tubes enter and connect with the superficial inguinal lymph nodes, providing easy access for the spread of a possible malignancy from the uterus to the nodes.

Inside the base of the broad ligament, near the cervix, are masses or condensations of connective tissue associated with peritoneum, which extend out to the pelvic wall from the cervix and the wall of the vagina like spokes of a wheel. These are the main supports of the uterus, bladder, and vagina. They are the *cardinal* ligaments, extending from the cervix laterally to the pelvic wall, and the *uterosacral* ligaments, extending from the cervix posteriorly to the sacrum.

All the supports that have been described, the muscular components of the pelvic diaphragm and the broad, round, cardinal, and uterosacral ligaments, do their job of retaining the pelvic viscera inside the

pelvis as long as they are strong and firm. If they are repeatedly traumatized in childbirth or if they are lacerated or atrophied, or in any way impaired in their action, they progressively weaken, and the uterus, bladder, or rectum will be displaced downward and begin to protrude or drop out of position. This dropping down or falling of an organ is called *prolapse.* When the urinary bladder prolapses into the anterior wall of the vagina and causes a bulge, it is called a *cystocele.* When the anterior wall of the rectum bulges into the posterior wall of the vagina, it is called a *rectocele.* Even though the uterus has more supporting structures than the other organs, it is the most likely to prolapse.

All the pelvic organs with their associated connective tissue and muscle are sensitive to estrogen. During pregnancy, when hormone levels are at a maximum, all the tissue greatly increases in size (hypertrophies). After menopause, when estrogen levels are low, muscle and connective tissue are likely to shrink (atrophy). The supports are weakened, and there is an increasing predisposition to prolapse, particularly with a previous history of childbirth damage to the supports. Like a stretched-out rubber band, there may be no tension left. The degree of prolapse may be mild, with the cervix only moderately descended into the vaginal canal (first degree), or the cervix may protrude through the vaginal opening (second degree). In extreme or complete prolapse, the cervix and the entire body of the uterus is pushed outside the vaginal opening.

Treatment depends on the extent of the prolapse but it most usually involves surgical correction and shortening and tightening of the cardinal ligaments and repair of the pelvic diaphragm. If the uterus has actually prolapsed out of the vagina, the cervix extends outside the vaginal opening, and the vaginal canal is inside out. A hysterectomy may then be a necessary part of the surgical procedure. In this situation, in which a woman is virtually walking around with her uterus between her legs, there is justification for the removal of a histologically normal uterus.

For the great majority of women, childbearing and delivery are completely normal physiological processes that result in no permanent injury to the reproductive organs or the surrounding soft tissues. Even after several pregnancies, the uterine supports remain firm and intact, having recovered their full functional capacity even though ligaments were stretched and soft tissues lacerated during delivery. Not all women heal as well as others, however, and some may develop subsequent difficulties. There are women who may have what is called a congenital soft tissue deficiency; that is, they were born with a pelvic support mechanism that is just not as strong as it could be. Despite every effort to eliminate trauma during delivery, these women are predisposed to experience some of the problems that have been described, after they have delivered several children. Occasionally, nulliparous women (i.e., those who have never delivered a baby) also experience stress incontinence or uterine prolapse.

THE MALE REPRODUCTIVE TRACT

The reproductive tract of the adult female is adapted for its purpose: to produce ova capable of fertilization by a spermatozoon and then to nourish and protect the rapidly growing conceptus until its birth. The reproductive tract of the adult male is adapted for its purpose: to produce large numbers of spermatozoa capable of fertilizing an ovum and to insert those sperm into the female's body so that one of them may encounter the ovum. What follows is a brief description of the male reproductive structure and function along with some comparisons of the homologues of female and male anatomy. Homologous organs or parts have the same evolutionary or embrylogical origin. They are similar in structure but not necessarily in function (Figure 2–17).

Testes

Spermatozoa are produced in the **testes,** oval smooth organs about 4–5 cm long and 2.5 cm in diameter. The testes are suspended in the *scrotum,* a loose pouch

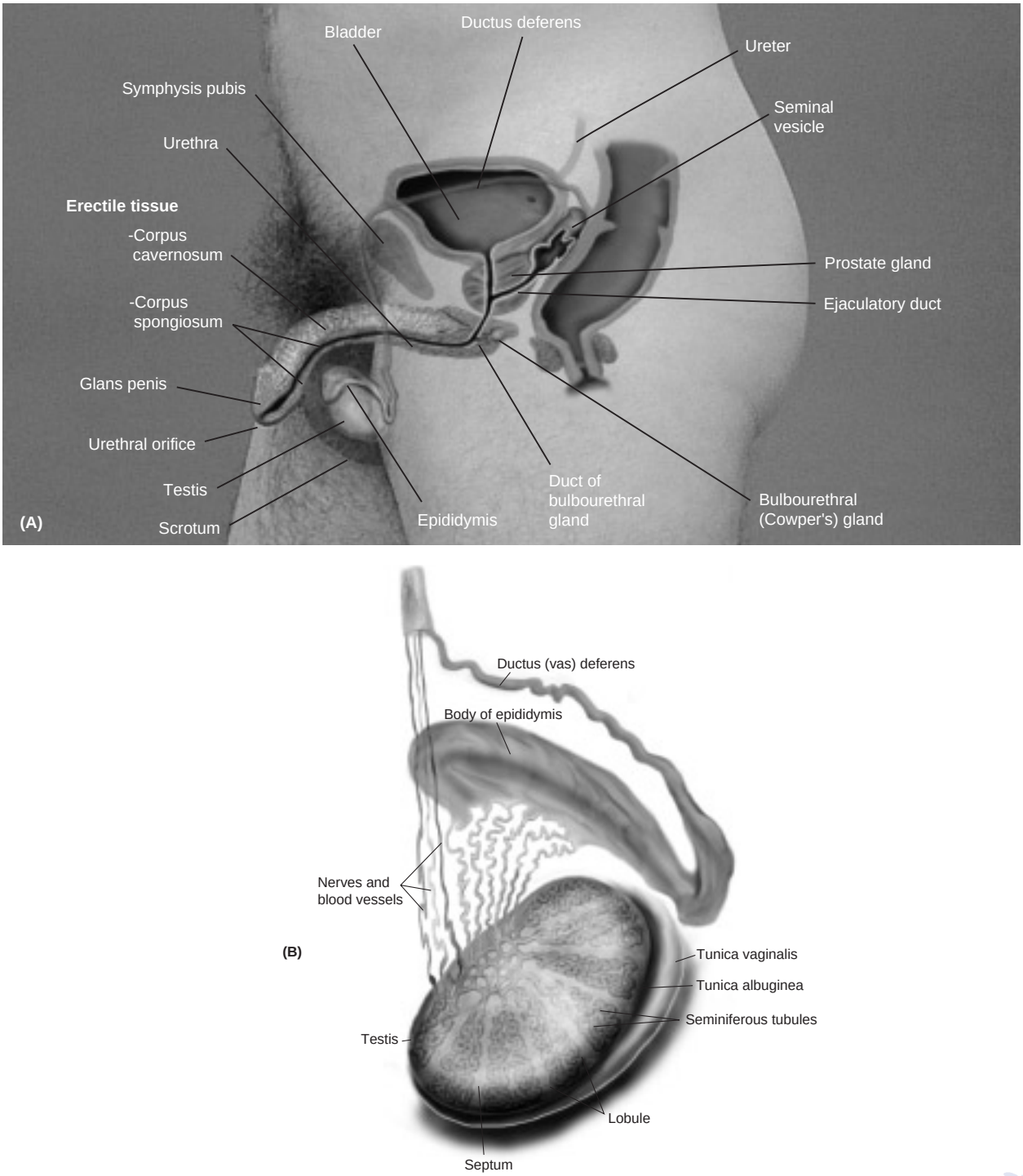

Figure 2–17 (A) Side view of male reproductive tract. (B) Testicle.

of skin divided by a septum into a right and left half, each containing a testis. The right and left scrotal sacs are homologous to the right and left labia majora. As in the labia, a sheet of dartos muscle lying just under the skin causes skin wrinkling in response to cold weather. Contraction of the smooth muscle also can change the closeness of contact of the testes with the body in order to conserve body heat.

Although the testes are carried in the scrotum, they originated during fetal life as the primordial germ cells in the abdominal cavity, just as in the female. In the last months of fetal life, however, the testes descend along with their ducts, nerves, blood vessels, and lymphatics through the inguinal canal, out of the abdominal cavity, and into the relatively cooler scrotal sacs. This is necessary because growth and development of viable sperm can take place only at several degrees less than body temperature. To help maintain the lower temperature, the scrotum lacks insulating fat under the skin and has many sweat glands.

In a small percentage of male babies, one or both testes may not descend and remain in the body cavity, a condition known as cryptorchidism (from the Greek for "hidden testis"). Cryptorchidism sometimes corrects itself during childhood, or hormone administration may be used to encourage testes descent. If uncorrected by the time of puberty, irreversible infertility could result.

Spermatogenesis (the production of sperm) occurs within the long, highly convoluted *seminiferous tubules* of the testes. The differentiation process, from the progenitor germ cell (spermatogonium) to a mature spermatozoon, takes about 74 days (plus or minus 4 days), begins at puberty, and continues throughout the life of the male. Every day a healthy male makes hundreds of millions of sperm. If they are not ejaculated, they die and are disposed of through phagocytosis, the normal scavenger activity of certain white blood cells and the *Sertoli cells,* which are scattered between the cells destined to become sperm. In addition to cleaning up unwanted germ cells, Sertoli cells mechanically support and nurture maturing sperm and produce hormones. Between the seminiferous tubules are clumps of *interstitial cells,* which produce androgens, the male sex hormones. The most potent androgen is testosterone.

Male Accessory Genital Ducts

The accessory duct system transports the sperm from the testes to the outside of the body and includes the epididymis, ductus deferens, and urethra. In each testis the seminiferous tubules lead into straight tubules (tubuli recti), which lead into a network of canals, the rete testis, which lead into about 15–20 efferent ducts that emerge from the upper part of the testis. The *epididymis* is a 20-foot-long coiled tube that receives the sperm from the efferent ducts. It runs alongside the testis and is a storage site for sperm, which may be retained in the epididymis for up to 6 weeks while they acquire motility and fertilizing capacity. The *ductus (vas) deferens* is the continuation of the epididymis on each side. It is a straight tube that leaves the scrotum to ascend upward through the inguinal canal into the body cavity. The end of each ductus deferens expands into an enlargement, which joins with a duct from a seminal vesicle to form a short *ejaculatory duct*. The two ejaculatory ducts from either side penetrate the prostate gland to join the *urethra* as it exits from the urinary bladder. The urethra extends from the bladder to the end of the penis.

Male Accessory Glands

Semen consists of sperm suspended in a semigelatinous fluid that contains substances to nourish and protect the sperm and facilitate their movement. Only about 5% of the volume of semen is spermatozoa; the rest of the ejaculate is a mixed secretion of several accessory glands. The **seminal vesicles,** located at the base of the bladder, produce a viscous, alkaline fluid rich in fructose to provide a direct source of energy for sperm. More than half of the bulk of semen comes from the seminal vesicles. The **prostate** is a single gland that surrounds the urethra as it leaves the bladder. The prostate secretes a milky, alkaline fluid to neu-

tralize the acidity of the vagina during intercourse and enhance sperm motility, which is best at a pH of 6.0–6.5. The prostate is the homologue of the paraurethral or Skene's glands in the female. Although small in childhood, it begins to grow at puberty and reaches adult size at age 20 and remains stationary until about the age of 50. At that age in some men the prostate may slowly begin to grow larger or hypertrophy and may eventually cause urinary obstruction.

The two small *bulbourethral (Cowper's) glands* secrete an alkaline mucus-containing fluid that is lubricating and protective. Their equivalent in the female is the right and left Bartholin's glands.

Penis

The penis and the scrotum form the external genitalia in the male. The penis is the organ for copulation and also serves as the outlet for urine. It has an attached root, a body or shaft, and a glans, the same as in its female homologue, the clitoris. The skin of the penis is thin with no hairs except near the root of the organ. The prepuce (foreskin) is a circular fold of skin that extends over the glans unless it is removed by circumcision shortly after birth, a procedure that formerly was routine and has become much more controversial.

The body of the penis contains three cylindrical masses of erectile tissue—two corpora cavernosa on the top side of the penis and one corpus spongiosum that lies below them and surrounds the urethra. The bulbs of the vestibule are the female homologue to the corpus spongiosum. As the vestibular bulbs contribute to vulvar clasping or "erection," so does the corpus spongiosum contribute to penile erection. The bulbocavernosus muscles in the female and the bulbospongiosus muscles in the male are counterparts and serve a similar function during intercourse. The corpora cavernosa in the male and the ischocavernosus muscles are mainly responsible and behave identically in erection of the penis as do these same erectile tissue masses and muscles in erection of the clitoris.

Ejaculation

Ejaculation is the culmination of the male sex act. Under involuntary nervous control, muscle contractions in the testes and the reproductive ducts move the sperm into the urethra. Simultaneous contractions in the seminal vesicles, prostate, and bulbourethral glands expel seminal fluid along with the sperm. The volume of ejaculate averages 3 ml (about a teaspoon) but can normally range from 1–10 ml. The number of sperm in a single ejaculate is subject to individual variation and may be anywhere from 100 million sperm to half a billion sperm, but the normal average is 300–400 million. The first fraction of ejaculate contains most of the sperm, which have better motility and survival ability than those in the later portions. In addition to the sperm, semen contains many of the substances ordinarily found in blood plasma with the addition of chemicals such as prostaglandins, enzymes, enzyme inhibitors, and hormones that play a role in sperm vitality, motility, migration, and fertilizing capacity. Immediately after ejaculation, the fluid semen coagulates and then spontaneously liquefies within 15–20 minutes. The sperm do not reach their full motility until liquefaction occurs, so the rate of coagulation and liquefaction can be significant in the clinical evaluation of male fertility.

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