1 The male reproductive system

1.1 Structure and function of the male reproductive system

The male gametes (spermatozoa) are produced in the seminiferous tubules of the paired **testes** contained in the **scrotal sacs**. Although the testes originate high in the abdominal cavity, they descend and pass outside through the **inguinal canal** before birth. A spermatic cord remains to show the path they have taken. Occasionally in baby boys the descent of the testis may not be complete, the inguinal canal stays open and hernias may result, as the intestines are pushed out through the openings.

The scrotum, being suspended outside the body cavity, has a slightly lower temperature than the rest of the body and this may favour the development of the spermatozoa. During cold weather, the muscles of the scrotal wall contract bringing the testes closer to the body wall to retain heat. Higher environmental temperatures cause the muscles of the scrotum to relax removing the testes further from the body heat.

The mature spermatozoa pass from the seminiferous tubules to the **epididymis**, a series of coiled tubes where they may be stored before passing to the **vas deferens** or sperm duct. A complex process of sperm maturation occurs in the epididymis and requires numerous chemicals secreted from the glands

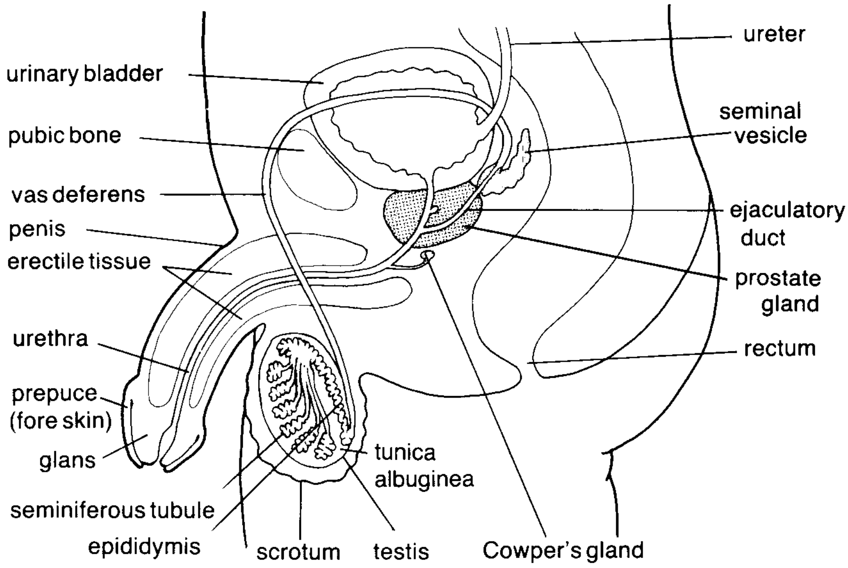

Figure 1.1 Sectional view of the male reproductive system

for this process. The vasa deferentia are muscular tubes (one from each testis) which pass into the abdomen through the inguinal canals, then up over the bladder, looping over the ureters. The two vasa deferentia now join with each other and the tube from the bladder to form the **urethra**. The urethra passes down inside the **penis** and consequently serves to transport both spermatozoa and urine at different times. The spermatozoa are suspended in **seminal fluid** composed of secretions from the two **seminal vesicles**, the **prostate gland** and **Cowper's gland**. (See Figure 1.1.) These fluids contain nutrient (fructose), mucin and enzymes which activate the spermatozoa and provide a medium for swimming when they enter the female tract. Prostate fluid is needed before the sperm are motile. Seminal fluid is slightly alkaline to protect the sperm from the acidity of the female vagina.

The sensitive end of the penis called the **glans** is covered by a double fold of skin. Should this skin fit too tightly it is cut during a minor operation called **circumcision**. This may also be more hygienic, preventing the breeding of micro-organisms in the moist warm conditions under the skin folds. Circumcision may also be performed as a religious custom.

1.2 The testis and spermatogenesis

The gross structure of the testes is shown in Figure 1.1. Note the position of the **tunica albuginea** which forms a white inelastic capsule for support and protection. Thin septa from the tunica albuginea divide the testis into about 250 lobes which contain the highly coiled **seminiferous tubules**. Histological sections of the walls of the seminiferous tubules show cells in various stages of spermatogenesis (sperm production). (See Figure 1.2.) Undifferentiated stem cells are found on the basement membrane around the periphery of the tubule, while cells at various stages of development are seen across the wall, with the mature spermatozoa into the central lumen.

Starting at puberty the **spermatogonia** on a basement membrane divide rapidly, so that cells showing chromosomes in various stages of mitosis are often visible. (At this stage it would be useful for you to read a full account of mitosis and meiosis in a standard A-level text.) Some of these cells enlarge to form **primary spermatogonia**, each of which undergo the first and second stages of meiosis, to form four haploid spermatids. It is well known that even though this planet is inhabited by 4 000 000 000 people, no two humans are identical. The differences between individuals are partly produced by the fundamental process of sexual reproduction, when gametes fuse to form the zygote. Each gamete contributes one set of chromosomes, so that the zygote receives one set from the mother and one from the father. Meiosis serves to reduce the number of chromosomes by half (haploid) in the gametes, so that when they fuse during fertilisation, the normal (diploid) number of chromosomes is restored in the zygote. Meiosis contributes to variation by ensuring that the genetic constitution of the gametes is changed during their development, so that all gametes differ. These variations are made during meiosis in the leptotene stage of prophase I, when crossing over occurs between homologous chromosomes. Further variation is ensured by the random separation of each pair of chromosomes at anaphase I and anaphase

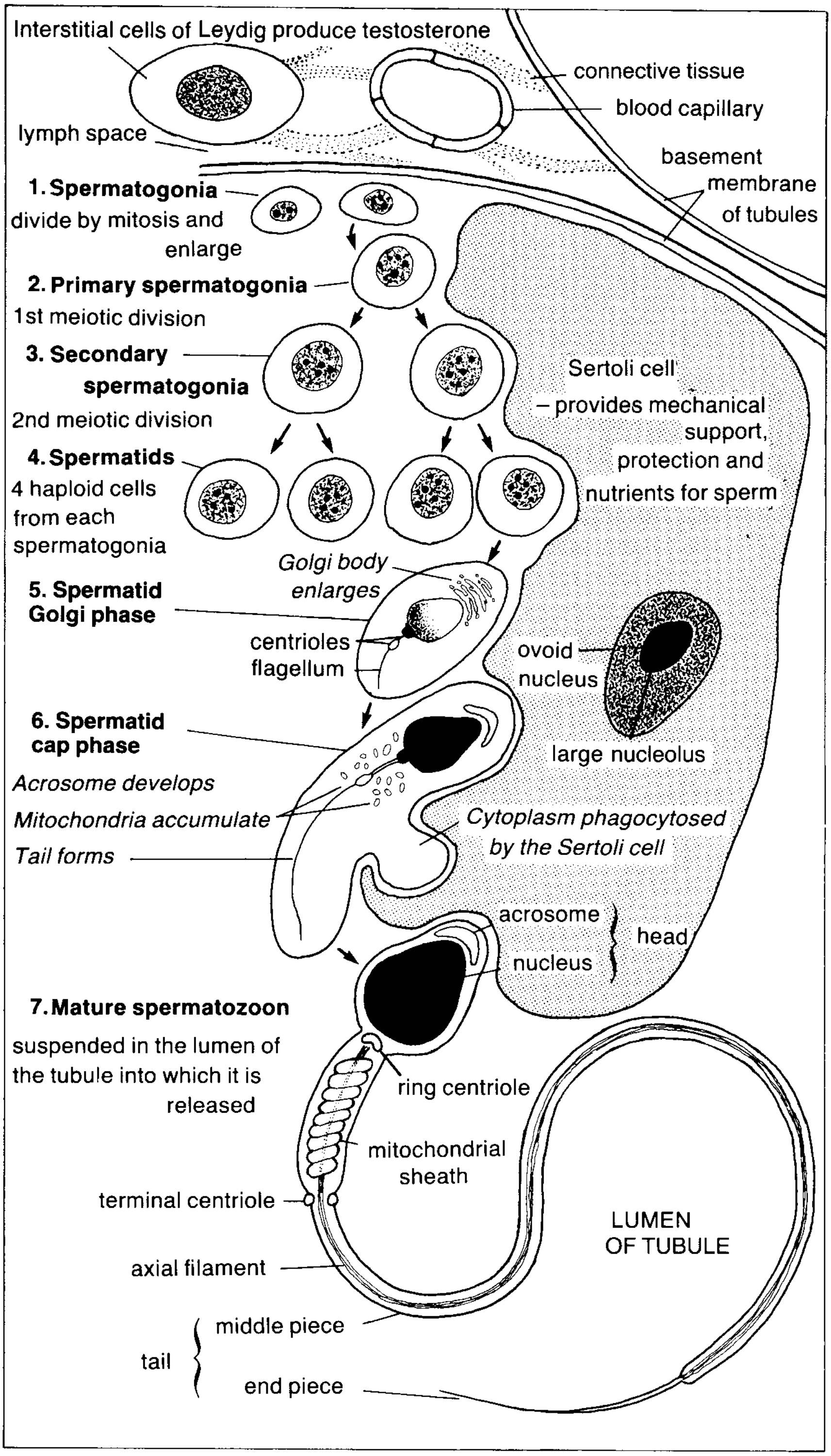

Figure 1.2 A small segment of a testis tubule and associated connective tissue showing spermatozoa formation

II. This random fusion of gametes, crossing over and chromosome segregation, all contribute to the genetic uniqueness of the individual. Identical twins, which arise from a single zygote, have the same genetic make up. The fact that they also differ from each other to a greater or lesser extent is largely attributable to differences in the environment (see Section 6.4). Hence there is a fourth cause of variation.

The **spermatids** now undergo spermiogenesis to become mature spermatozoa. First the cell elongates, and the enlarged Golgi body becomes active, manufacturing granules for the acrosome. One of the centrioles forms the basal body giving rise to the flagellum, which grows out through the cytoplasm. The other centriole becomes located near the nucleus and mitochondria move to associate in the neck of the developing sperm. The nucleus enlarges, the acrosome shapes around it and the tail elongates to produce a mature spermatozoon as shown in Figure 1.2.

Also found on the tubule basement membrane are the **Sertoli cells**. These long triangular shaped cells between the germ cells provide mechanical support and protection. Sertoli cells are also thought to provide nutrients for the developing germ cells and to phagocytose cytoplasm extruded from the developing spermatids.

The semiferous tubules are surrounded by connective tissue which contains blood capillaries and interstitial cells called the **cells of Leydig**. These cells secrete steroid hormones under the influence of **interstitial cell stimulating hormone**, (ICSH) which is secreted by the lobe of the pituitary gland. ICSH induces the interstitial cells of Leydig to produce androgen hormones, notably testosterone and androstenedione. These androgen hormones pass into the nearby blood capillaries and circulate around the body to influence the development of the **secondary sexual characteristics** at puberty. They induce beard growth, deep voice, growth of the sex organs, muscular development and other male characteristics. These hormones also influence sexual and agressive behaviour.

The hormones from the cells of Leydig also pass through lymph spaces into the seminferous tubules where they help to control the process of spermatogenesis. Also controlling this process is another pituitary hormone called **follicle stimulating hormone** (FSH) which acts directly to produce the spermatozoa. There is a negative feedback process by which testosterone secretion reduces the secretion of FSH from the pituitary, so maintaining fine control over the developing spermatozoa. Castration, which involves the removal of the testes, stops testosterone secretion, cutting out the negative feedback so that much FSH is excreted in the urine. Hence castration prior to puberty stops the development of the male characteristics and produces eunuchs. (See Figure 7.1.)

Spermatogenesis takes about two days, but a further twelve days is required before the mature spermatozoa can pass out of the male tract. **Mature spermatozoa** are about 50 μm long. The majority of the head is filled by the nucleus, the anterior portion of which is covered by the acrosome. The **acrosome** is similar to a modified lysosome, containing enzymes capable of dissolving the egg membrane to facilitate fertilisation.

The middle piece of the spermatozoa contains a sheath of mitochondria, which contain the oxidative enzymes necessary to provide the energy for locomotion. These mitochondria surround an axial filament having the typical 9+2 arrangement of micro-tubules as in flagella. The lashing of the tail provides the movement of the spermatozoon.

Further reading

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More information

2 The female reproductive system

2.1 Structure and function of the female reproductive system

The female gametes or **ova** are produced in the **ovaries**, located one at each side of the abdominal cavity. The almond shaped ovaries are held in position near the back wall of the pelvis by the ovarian and broad ligaments. Closely applied to the ovary is the **fimbriated funnel** of the oviduct, which serves to collect the ripe ova when they are released from the ovary. The **oviduct** (fallopian tube) is approximately 10 cm long, lined with cilia which help transport the ova to the uterus.

The **uterus** is a pear-shaped structure with the widest part or fundus at the top. The oviducts enter on either side of this wide part of the uterus. The uterine wall has an outer serous coat, a thick layer of smooth muscle called the **myometrium** (important in childbirth), and the endometrium, a vascular layer

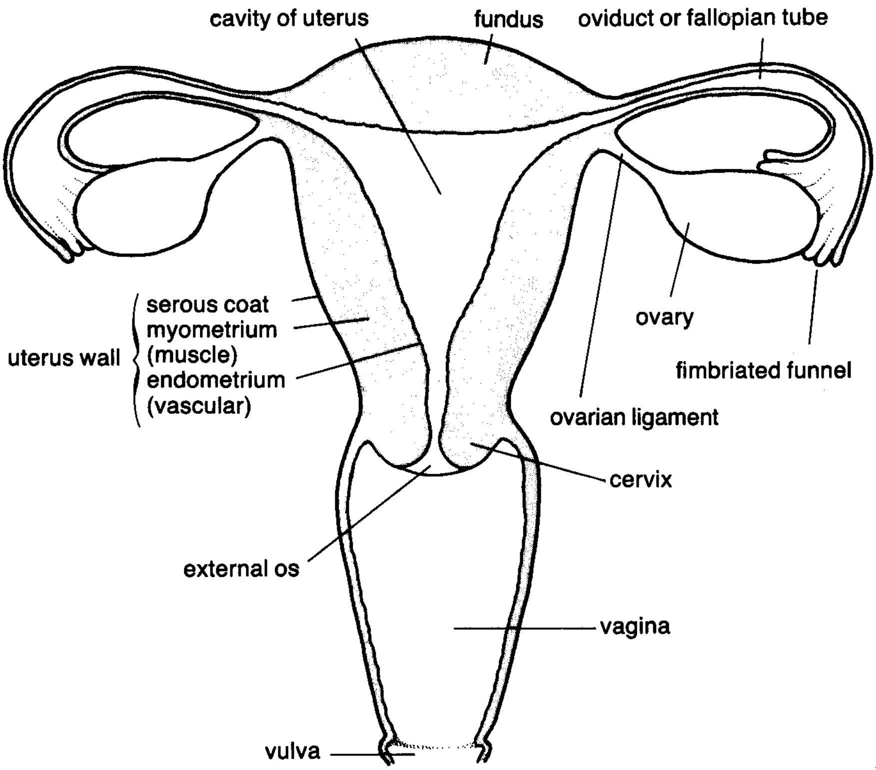

Figure 2.1 Front sectional view of the female reproductive system

which is largely shed at menstruation. The lower end of the uterus, called the **cervix**, consists of a ring of muscle capable of closing the uterus at the **external os**, where it enters the vagina.

The **vagina** is a fibrous, muscular tube about 8 cm long, lined by epithelial cells which are thrown into folds. Bacteria found in these folds ferment glycogen in the epithelium, producing lactic acid which creates an acidic condition in the vagina. Breakdown of the epithelium produces a normal vaginal discharge. Vaginal smears of this fluid are used to diagnose uterine cancer and this technique has proved to be a very successful form of preventative medicine. The **urethra** from the bladder enters the vagina just before it opens to the exterior, at the vulva.

The **vulva** or external genitalia is largely covered by skin folds called labia. Between these is a cleft (vestibule) in which the vaginal orifice may be seen partly covered by a thin membrane called the **hymen**. This membrane can be broken at first coitus and the blood shed was often taken to indicate a first loss of virginity. However, such indications are false because frequently the hymen may still be present in certain women who have had sexual intercourse and it can be absent in those who have not. Rupture of the hymen may also occur due to exercise or by using tampons during menstruation.

The anterior part of the vulva contains the clitoris, a homologue of the penis which is very sensitive and is important in sexual stimulation during intercourse.

2.2 The ovaries and oogenesis

The ovaries are concerned with the production of eggs and sex hormones. Blood vessels, nerves and lymphatics supplying the 2 cm × 1 cm ovary pass in through the hilum (see Figure 2.2).

Histologically, each ovary has an outer layer of cuboidal epithelial cells called the **germinal epithelium.** Unlike the testis this does not produce the germ cells, but, together with an underlying thin layer of the **tunica albuginea**, it serves simply as a supporting envelope. The rest of the ovary is composed of a **stroma** of connective tissue, in which the outer region called the **cortex** contains follicles in various stages of development. The inner region of the stroma is called the **medulla.**

Oogenesis is the name given to the formation, development and maturation of the female gametes. Initially primordial ovarian follicles arise early in the human life cycle when the foetus is only four to five months old. Some seven million oogonia arise by rapid mitotic division, so it is not surprising that after this stage further oocytes are not produced. Instead, many oocytes degenerate and are absorbed in a process called **atresia**. At birth only about two million oocytes remain and eventually only 500 at the most will reach ovulation. This figure is calculated on the assumption that the period from puberty to menopause may last as long as 40 years and one egg is released monthly throughout this time in a childless woman.

The primordial follicles have a small primary oocyte surrounded by a single layer of stroma cells. Under the influence of FSH from the pituitary, enlargement occurs to form **primary follicles**. The oocyte enlarges and rapid

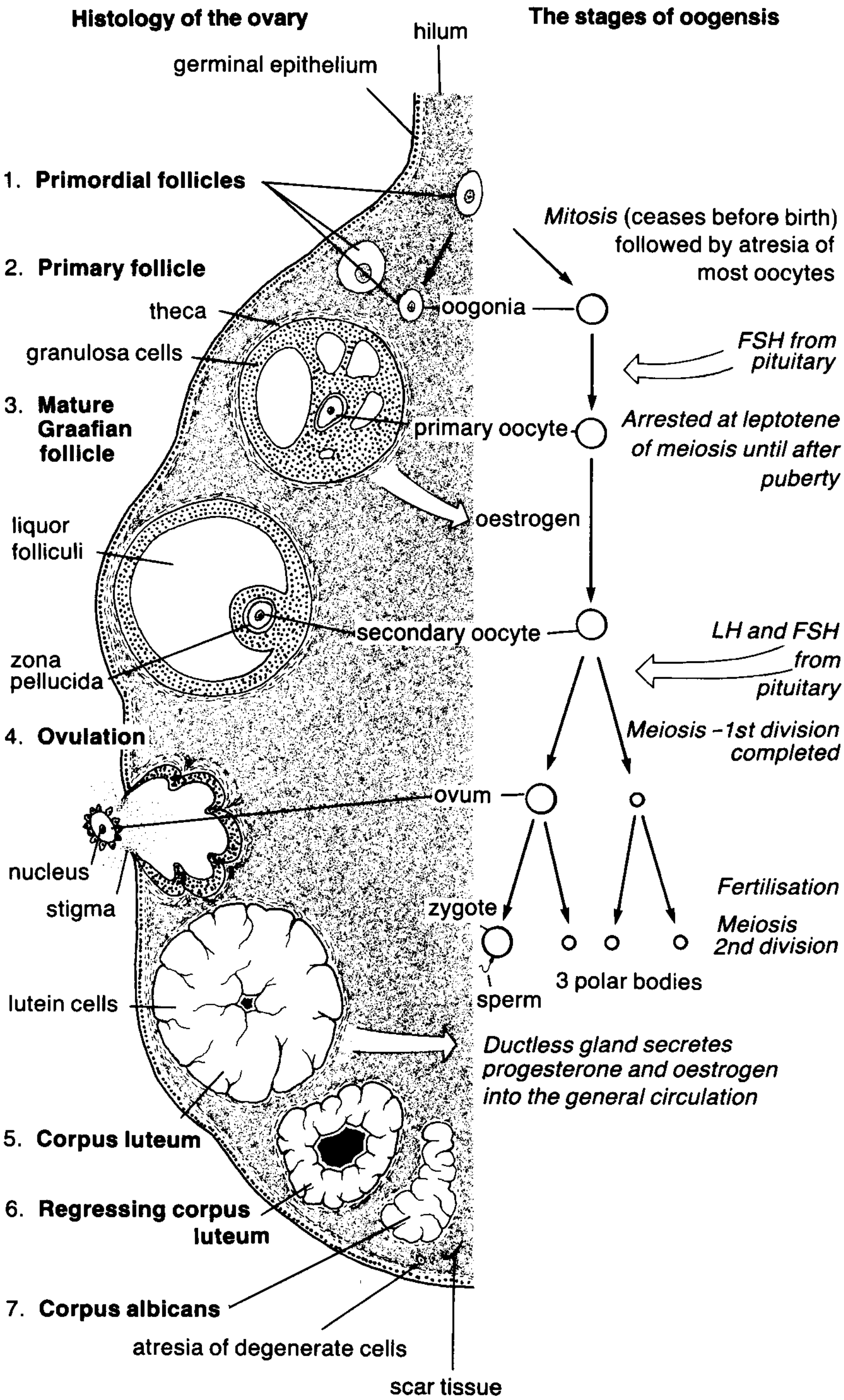

Figure 2.2 Histology of the ovary with developmental stages idealised

division of the surrounding **granulosa cells** occurs. Blood capillaries form a vascular layer called the **theca** supplying nutrient to the oocyte. A fluid called **liquor folliculi** fills cavities arising between the granulosa cells, so that the whole structure enlarges to form a **Graafian follicle** containing a secondary oocyte.

Meiosis starts in the **primary oocytes** and the chromosomes remain at the diplotene stage of prophase I for many years until stimulated by FSH. Only then (14 to 15 years later) is the first meiotic division completed to form the haploid **secondary oocyte**. The second meiotic division starts, but is completed only after ovulation when the oocyte is fertilised. Unlike the case in spermatogenesis (see Section 1.2) each primary oocyte can only produce one mature ovum. Unequal division of the cytoplasm produces one **polar body** at the first meiotic division and three polar bodies at the second (see Figure 2.2). These three polar bodies degenerate. Meiosis ensures reduction to the haploid number of chromosomes and the reshuffling of the genes to produce variation.

The oocyte becomes suspended to one side of the Graafian follicle surrounded by two or three layers of granulosa cells. A **zona pellucida** between the granulosa cells and the oocyte allows the exchange of materials. A surge of **luteinising hormone** (LH) from the pituitary causes further division of the granulosa cells which, with increased liquor folliculi secretion, enlarges the Graafian follicle to a diameter of 10 to 15 mm. This mature Graafian follicle produces a bump on the surface of the ovary. Prior to ovulation the oocyte may break to allow the fluid to ooze out with the ovum at ovulation. Hence the ovum passes into the body cavity and then into the fallopian tube.

After ovulation the Graafian follicle collapses and the granulosa cells further multiply to form **lutein cells** which secrete a yellow pigment. The collapsed Graafian follicle is now known as the **corpus luteum** (yellow body) which serves as a ductless gland, secreting mainly the steroid hormone **progesterone**. Progesterone controls pregnancy if fertilisation occurs. It prepares the wall of the uterus for the zygote, stops further ovulation and finally helps stimulate milk production. If fertilisation does not occur, the corpus luteum regresses to leave remains called a **corpus albicans**, which finally only exists as fine scar tissue in the ovary.

The maturing follicles under the influence of FSH from the pituitary secrete **oestrogens** (mainly oestradiol) which control the development of the female secondary sexual characteristics at puberty. The mammary glands enlarge, the pelvic girdle widens, the uterus and vulva enlarge, pubic hair grows and ovulation and menstruation begin. The hormone also causes an increase in sexual desire.

2.3 The menstrual cycle

The menstrual cycle is the cycle of events in the reproductive processes of the female which are controlled by hormones. These hormones are secreted from both the pituitary and ovary. The average length of the cycle is 28 days but there is considerable variation. For descriptive purposes we will start with the most noticeable feature of the cycle, the monthly period or menstruation. See Figure 2.3 as you read this description of the sequence of events.

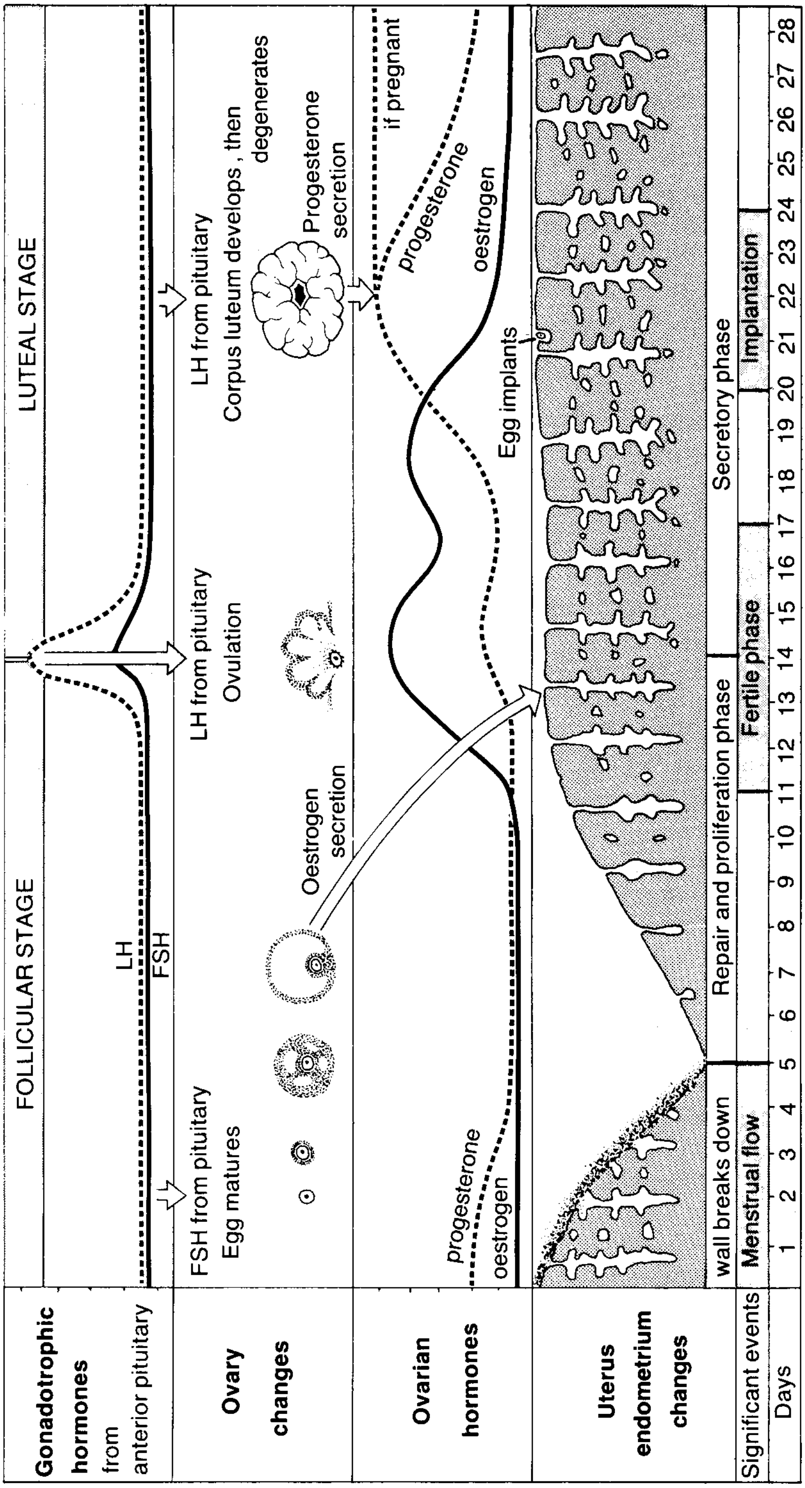

Figure 2.3 Sequence of events in a 28-day menstrual cycle