Unit
2B

Chapter 11
Reproductive cycles and fertilisation

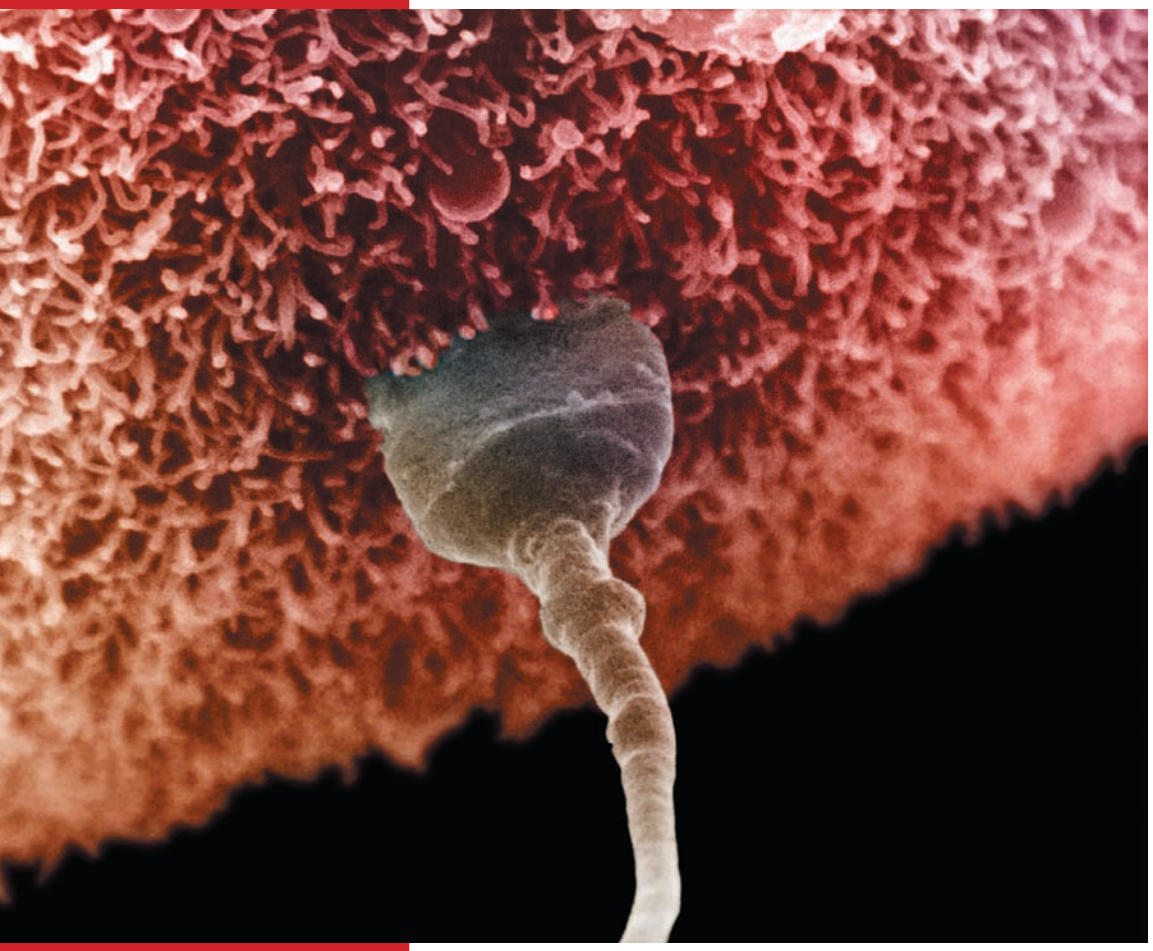

Figure 11.1 A human sperm fertilising an egg

Unit content

Body systems
Reproductive systems are specialised for gamete production and fertilisation. Reproduction is controlled by hormones.

Reproductive systems:

- structure and function of male and female reproductive systems
- hormonal control of menstrual and ovarian cycles and spermatogenesis.

The ovarian cycle

The **ovarian cycle** is a series of events that take place within the ovaries. It includes the maturation of an egg and its release into a uterine tube. Associated with these events are the development of follicles in the ovary and the formation of a structure called the corpus luteum. The length of the ovarian cycle is highly variable, depending on the individual and her circumstances. It may range from 20 to 40 days, with an average of about 28 days. For this reason, the ovarian cycle is commonly considered to be a 28-day cycle, even though only about 30% of women have a cycle that is 27 or 28 days in length.

At birth, the ovaries of a human female contain about 400 000 immature eggs. The formation of these eggs began before birth, during foetal development. Cells in the ovary undergo a number of divisions but stop dividing before any eggs are actually formed. The immature eggs then remain in a resting phase for many years. Other cells within the ovary surround each immature egg to produce a sphere composed of a single layer of cells. This is called a **primary follicle** (Fig. 11.2).

When a female matures sexually—a period referred to as **puberty**—some of the primary follicles undergo further development. Cells forming the wall of the primary follicle begin to enlarge and divide, creating a layer of cells around the developing egg. Secretions of these cells create a fluid-filled space that gradually forces the egg to the edge of the follicle. It is now referred to as a **secondary follicle**. Several secondary follicles may commence development in each ovarian cycle but usually only one completes development. The others normally break down to be reabsorbed into the ovary. As more fluid accumulates within the follicle, it continues to enlarge and gradually moves towards the surface of the ovary. On reaching the surface it produces a bulge, which looks like a swollen blister on the surface of the ovary. At this stage it is referred to as a **mature follicle** (once known as a Graafian follicle) (Fig. 11.2). It usually takes between 10 and 14 days for a primary follicle to develop into a mature follicle.

When the mature follicle bursts it expels the egg, a process called **ovulation** (Fig. 11.2). The open end of the uterine tube is like a funnel over the ovary. Beating cilia within the funnel create a current that sweeps the egg into the uterine tube. Usually only one follicle matures at a time, so only one egg is released. However, very occasionally, two or more follicles may burst at the same time, releasing more than one egg. The egg is gradually swept down the uterine tube towards the uterus by the beating of cilia lining the inside of the tube.

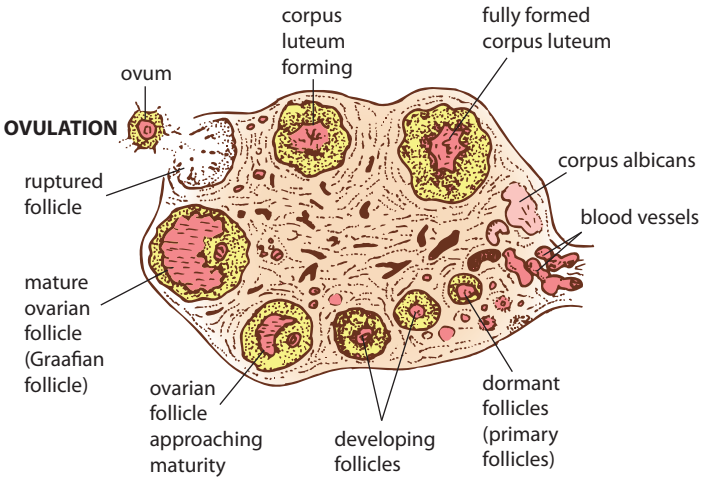

Figure 11.2 The sequence of events in the ovarian cycle, including ovulation

Following ovulation, the ruptured follicle collapses and the blood within forms a clot. The clot is gradually absorbed by the remaining follicle cells, which enlarge and change colour to form a cream coloured body, the **corpus luteum** (which is Latin for 'yellow body'). Hormones that influence the development of the lining of the uterus are secreted by the corpus luteum. If fertilisation has not occurred, the corpus luteum reaches its maximum development about eight to 10 days after ovulation. It then begins to degenerate into a fibrous mass of scar tissue, the **corpus albicans** (Latin for 'white body'), which eventually disappears (Fig. 11.2). Another ovarian cycle then begins. It seems to be a matter of chance whether it occurs in the same ovary or in the opposite ovary.

If fertilisation of an egg does take place and pregnancy follows, the corpus luteum continues to develop and the ovarian cycles cease. The corpus luteum reaches the peak of its development in about the third month of pregnancy. After this it begins to degenerate, although degeneration is slow and it is still present in the ovary at childbirth. Ovarian cycles usually resume only after breastfeeding of the baby has ceased.

The menstrual cycle

While the cycle of changes is going on in the ovaries, another cycle of changes occurs in the uterus and, to a lesser extent, the vagina. This is the **menstrual cycle**—a cycle where changes in the lining of the uterus are closely associated with stages in the ovarian cycle. The changes in the uterine lining, the **endometrium**, are in preparation for a developing embryo in case the egg released at ovulation is fertilised. When the embryo reaches the uterus it has to implant itself in the endometrium.

In the first stage of the ovarian cycle—the period during which the follicle is maturing—the endometrium of the uterus becomes thicker and softer. There is an increase in the number of blood vessels and mucus-secreting glands (Fig. 11.3). After ovulation the endometrium continues to thicken and glands within it begin to secrete a watery mucus rich in glycogen.

If the egg is not fertilised by a sperm the corpus luteum degenerates, reducing the amount of hormone influencing the build-up of the endometrium, which results in its breakdown. About 14 days after ovulation, blood from broken-down capillaries, mucous secretions and cell debris from the uterine lining are lost through the vagina.

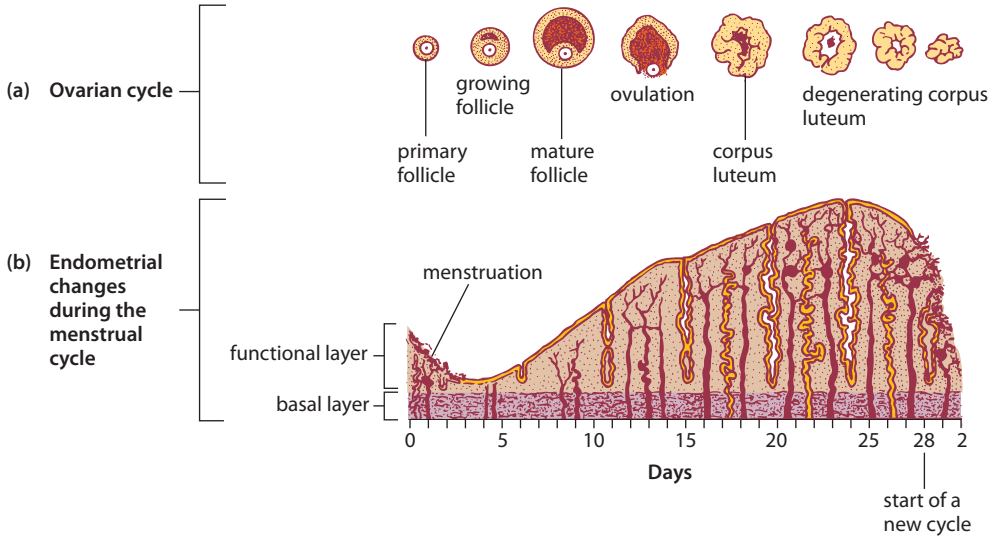

Figure 11.3 Correlation of the menstrual and ovarian cycles: **(a)** the changes taking place in the ovary; **(b)** the changes in the endometrium of the uterus

This is **menstruation**. Menstruation takes place over several days and is commonly referred to as the **menstrual period** (or, often, just 'period'). As this event is the most recognisable point in the menstrual cycle, the onset of menstruation is taken to be day 1 of the cycle (Fig. 11.3). A summary of the major stages of the menstrual cycle is given in Table 11.1.

Table 11.1 Major stages of the menstrual cycle

Stage	Time span (days)	Events
Menstruation	1–4	Uterine bleeding, accompanied by shedding of the endometrium
Preovulation	5–12	Endometrial repair begins; development of ovarian follicle; uterine lining gradually thickens
Ovulation	13–15	Rupture of mature follicle, releasing egg
Secretion	16–20	Secretion of watery mucus by glands of endometrium, cervix and uterine tubes; movement and breakdown of unfertilised egg; development of corpus luteum
Premenstruation	21–28	Degeneration of corpus luteum; deterioration of endometrium

When menstruation first begins in a female it is called **menarche**. This marks the commencement of puberty. From that time on a female will have a menstrual cycle about once a month unless it is interrupted by pregnancy. The cycles last until the **menopause**, the time when the processes that occurred at puberty are reversed. These changes usually begin between the ages of 45 and 55. They take place over a period of years, during which time the menstrual cycle becomes irregular until it eventually ceases. Typically, a woman has a potential of about 35 child-bearing years, and in most women only about 400 of the initial 400 000 potential eggs reach maturity.

EXTENSION

Endometriosis is a condition where the endometrium, the tissue that lines the uterus, grows outside the uterus in other parts of the body. Most growths occur on organs in the abdominal cavity such as the ovaries, uterine tubes, and the outside of the uterus, bladder and intestines. The growths detach and bleed at menstruation, but the blood and tissue cannot be passed to the outside. It is estimated that at least 10% of women suffer from endometriosis during their reproductive years. About 30 to 40% of those sufferers are infertile—it is one of the main causes of infertility.

Find out:

- the symptoms of endometriosis
- possible causes of endometriosis
- how diagnosis is made
- the treatment.

Hormonal regulation

The menstrual and ovarian cycles, and other features of human reproductive systems, depend on the **endocrine** glands for their regulation and control. These glands empty their secretions, called **hormones**, into the extracellular fluid that surrounds the cells making up the gland. The secretion then usually passes into the capillaries, to be transported by the blood. Hormones play an important role in the development and maintenance of body structures, processes and behaviours, including those associated with reproduction.

One of the important endocrine glands associated with the reproductive system is the pituitary gland. The **pituitary** is a small organ lying in a pit in the bone below the brain and above the roof of the mouth (Fig. 11.4). The hormones it secretes include some which stimulate parts of the reproductive system. When a hormone enters the blood, it circulates round the body until it reaches the organ on which it will have an effect—this is referred to as the **target organ** (see Table 11.2). The main target organs for hormones involved in reproductive processes are the testes of the male and the ovaries of the female.

There are two hormones secreted by the pituitary that affect the gonads and are thus called **gonadotropic hormones**, or **gonadotropins** (Fig. 11.5). One is **follicle-stimulating hormone (FSH)**, which, in the

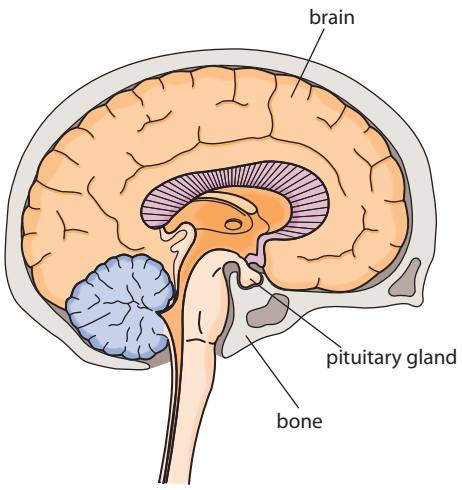

Figure 11.4 Location of the pituitary gland

Table 11.2 Reproductive hormones

Hormone	Target organ	Effect of hormone
Follicle-stimulating hormone (FSH) from pituitary gland	Seminiferous tubules of testes	Production of sperm
	Follicles of ovaries	Maturation of ovarian follicles
Human chorionic gonadotropin (HCG) from placenta	Corpus luteum	Maintenance of corpus luteum during early stages of pregnancy
Lactogenic hormone (prolactin) from pituitary gland	Breasts	Production of milk in activated glands
Luteinising hormone (LH) from pituitary gland	Interstitial cells of testes	Stimulates secretion of testosterone
	Cells of the ovaries	Stimulates secretion of oestrogens and progesterone
Oestrogens from ovarian follicle and corpus luteum	Various	Development of female reproductive system
		Development of secondary sexual characteristics
Oxytocin from pituitary gland	Uterus	Stimulates contraction of smooth muscle
	Breasts	Promotes contraction of muscle cells surrounding breast lobules
Progesterone from corpus luteum	Uterus	Maintenance of endometrium
	Placenta	Development and maintenance of placenta
	Breasts	Development of milk-secreting glands
Testosterone from cells in testis	Various	Development of male reproductive system
		Development of secondary sexual characteristics

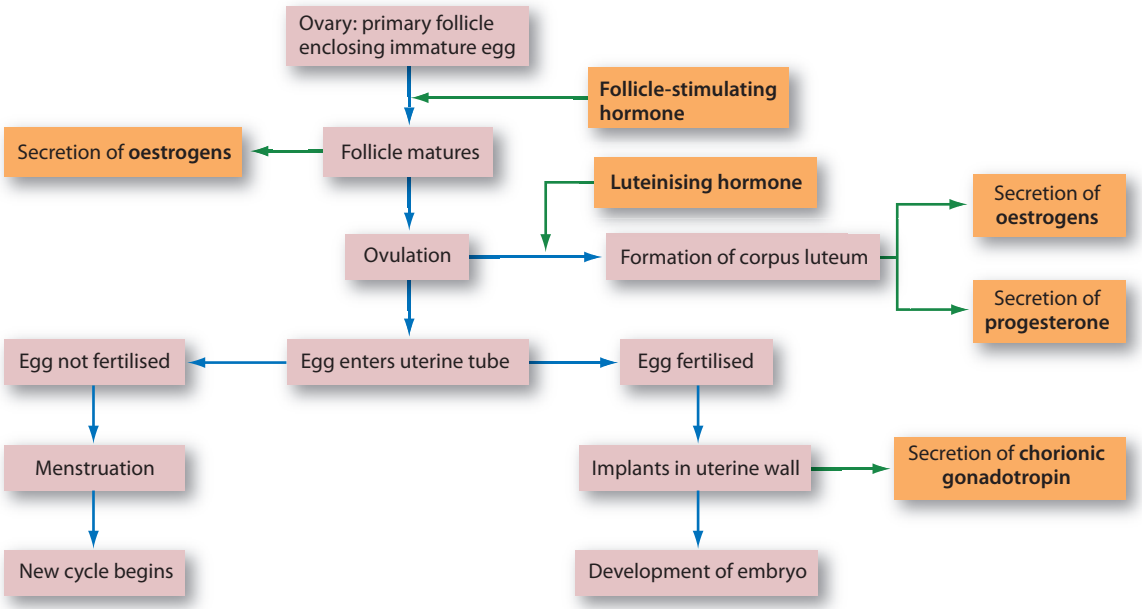

Figure 11.5 A summary of the relationship between the ovarian cycle and the reproductive hormones

female, stimulates the development and maturation of the ovarian follicle. During its development the ovarian follicle secretes its own hormone, **oestrogen**. Secretion of the follicle-stimulating hormone is reduced as the level of oestrogen increases in the blood. The second pituitary hormone is **luteinising hormone (LH)**, which promotes final maturation of the ovarian follicle, ovulation, and the formation of the corpus luteum. The corpus luteum secretes another ovarian hormone—known as **progesterone**—as well as oestrogens. There is a gradual reduction in the production of luteinising hormone as the level of progesterone in the blood increases. The corpus luteum is maintained by **human chorionic gonadotropin (HCG)**, a hormone produced by the developing placenta in a pregnant woman. Once the placenta is itself able to secrete oestrogens and progesterone, the corpus luteum begins to degenerate. (The role of the placenta is discussed in more detail in Chapter 12.)

In males, follicle-stimulating hormone stimulates the epithelial tissue of the seminiferous tubules in the testes to produce sperm. Luteinising hormone stimulates cells in the testes to secrete the hormone testosterone. **Testosterone** is important for sperm production.

In addition to the gonadotropic hormones, the pituitary gland secretes **lactogenic hormone**, or **prolactin**. This hormone has a direct effect on the breasts of the woman, and together with other hormones is important in the preparation and maintenance of milk production. (This is discussed in greater detail in Chapter 13.)

At puberty the secretion of gonadotropic hormones stimulates a number of changes, both physical and psychological and in both males and females. In males, the production of testosterone influences the development of the body to sexual maturity. In females, the same sexual maturation is brought about by oestrogens.

Puberty and development of secondary sexual characteristics

The secretion of sex hormones at puberty brings about the development of **secondary sexual characteristics**—those characteristics associated with a person's sex but not

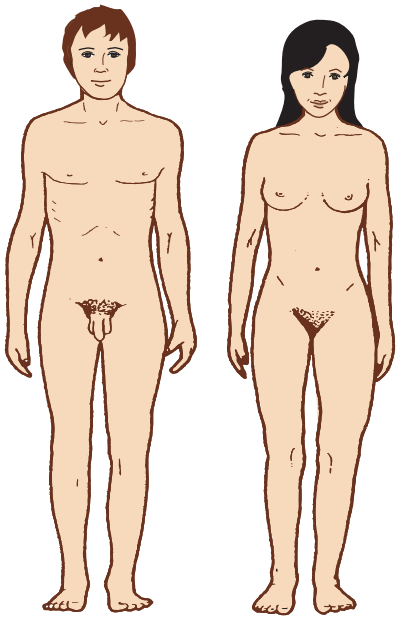

Figure 11.6 Changes at puberty: secondary sexual characteristics in the male and female

directly involved in sexual reproduction (Fig. 11.6). In females the development of secondary sexual characteristics begins with enlarging of the breasts. At the same time there is a broadening of the hips. The growth of the pelvic bones and the deposition of fat contribute both to this and to the more rounded contours of the female body compared with those of the male.

The distribution of added hair and change in voice properties are also secondary sexual characteristics. Pubic hair begins to grow early in puberty in both males and females. As puberty progresses it changes from straight and fairly light in colour to a thicker, curlier and darker covering. Shortly afterwards, hair grows in the armpits of both sexes. Later still in males, it grows on the face, chest and possibly the back. Males also have an increase in the size of the larynx, with an associated lengthening of the vocal cords. This results in a gradual deepening of the voice even though it may appear to 'break' suddenly. In females the voice deepens to some extent but seldom does it reach the deeper tones of the male.

Sexual intercourse

For fertilisation to occur, male sperm need to be brought into contact with an egg produced by the female. The usual method by which this is brought about is **sexual intercourse**. For sexual intercourse to take place, and for sperm to be deposited in the vagina, the penis must become enlarged and firm, a condition referred to as an **erection**. An erection results from blood rushing into the spaces of the erectile tissue of the penis. Sexual excitation initiates this blood flow.

When sexual stimulation of the penis within the vagina becomes sufficiently intense, rhythmic contractions of the epididymis, the vas deferens, the seminal vesicles and the prostate gland occur. The contractions propel the contents of the ducts and glands into the urethra and then out of the body. This process is called **ejaculation**. The ejaculated material consists of fluid, or **semen**, which contains **sperm**. Accompanying ejaculation is a rapid heartbeat, an increase in blood pressure and breathing rate, and intensely pleasurable sensations. These reactions constitute an **orgasm**.

An ejaculation normally expels about 3 mL of semen (about one teaspoonful), containing between 250 and 300 million sperm. Besides the sperm, semen contains the secretions of the seminal vesicles, bulbourethral glands and prostate gland. The greatest contribution comes from the seminal vesicles, which produce a thick fluid containing nourishment for the sperm. Besides nourishment, semen provides the sperm with a fluid in which to swim and it also neutralises the acid nature of the male urethra and female vagina. In addition, it contains enzymes that activate the sperm once ejaculation has taken place.

When the female is sexually stimulated, erectile tissue in the region of the vaginal opening fills with blood. This reduces the size of the vaginal opening and tends to increase the stimulation of the penis during sexual intercourse. Arousal also results in copious secretions of mucus by glands located around the cervix and in the region of the vaginal opening. These secretions lubricate the epithelial lining of the vagina, allowing for easy entry of the penis.

As sexual intercourse progresses the external genitalia are rhythmically stimulated and, when sexual arousal reaches sufficient intensity, the female undergoes an orgasm, or **climax**. Female orgasm is somewhat like that of the male, with the exception that there is no ejaculation in the female. However, there may be an increase in the secretion of cervical mucus. A female does not need to reach an orgasm for fertilisation to occur, and it is still not known whether female orgasm helps fertilisation in any way.

EXTENSION

One way of checking a male's fertility is to do a sperm count.
Find out:

- what is meant by sperm count and what is considered to be a normal sperm count
- whether there is anything a male can do to increase his sperm count
- whether it is possible for a male with a low sperm count to father children.

Fertilisation

When the male ejaculates, the sperm are in the vagina at the entrance to the uterus, a process called **insemination**. Once within the vagina, the sperm travel through the cervix and the body of the uterus into the uterine tubes. They reach the upper portions of the uterine tubes quickly—often within a few minutes. This rate is too fast to be due solely to the swimming motion of the sperm. It is thought that muscular contractions of the uterus and uterine tubes help to transport sperm through the female reproductive tract (Fig. 11.7).

Of the hundreds of millions of sperm deposited into the vagina during sexual intercourse, only a few thousand reach the uterine tubes. The death rate of sperm, called **sperm mortality**, is high, and is one reason why large numbers of sperm are required if fertilisation is to occur. Fertilisation normally occurs in the uterine tubes when the egg is about one-third of the way down the tube. After ovulation, muscular contractions of the uterine tube, together with the beating action of cilia, have been transporting the egg towards the uterus (Fig. 11.7).

The mature egg is surrounded by a layer of follicle cells known as the **corona radiata** (Figs 11.1 and 11.8). An acid holds these cells together. The tips of the sperm

Find out more about how fertilisation takes place by going to http://health.howstuffworks.com/adam-200048.htm

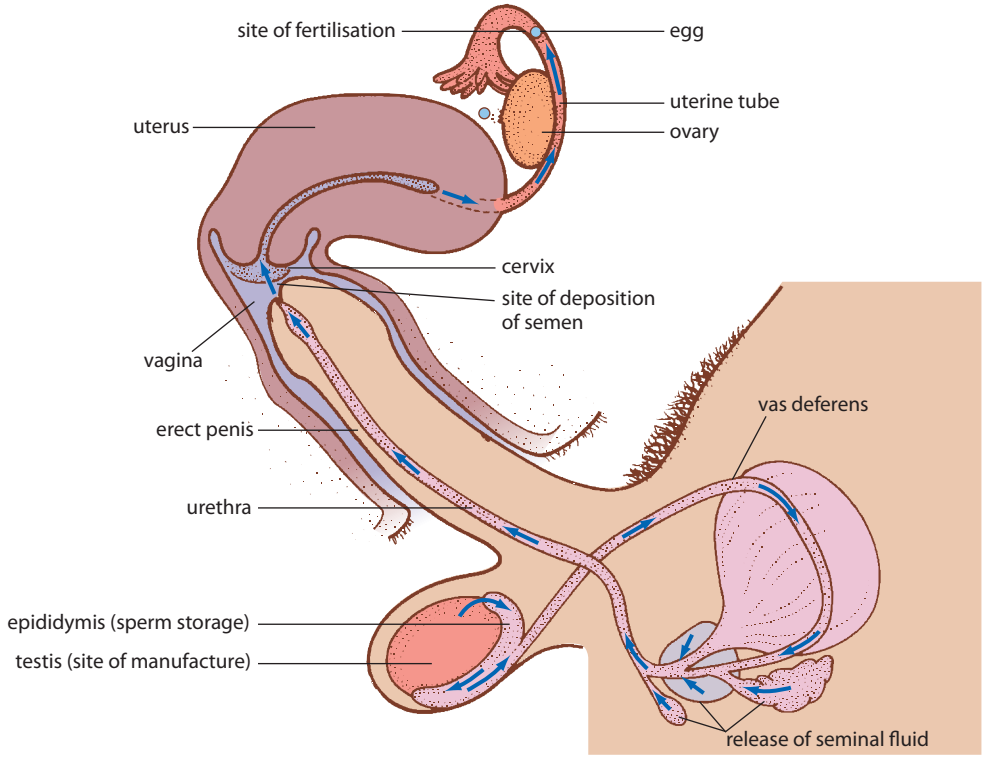

Figure 11.7 The pathway taken by the sperm during sexual intercourse

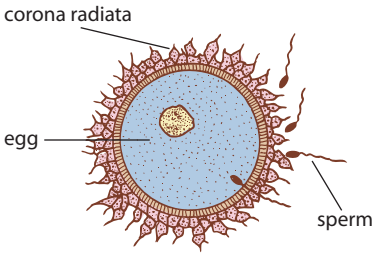

Figure 11.8 Fertilisation

contain an enzyme capable of breaking down the acid holding the cells of the corona radiata together. However, the amount of enzyme contained in a single sperm is extremely small and ineffective. When several thousand sperm surround the egg there is enough enzyme to loosen the cells of the corona, allowing one sperm into the egg to accomplish fertilisation. This is another reason why large numbers of sperm are required if fertilisation is to occur. The entrance of one sperm into the egg stimulates the formation of a fertilisation membrane around the egg, which prevents the entrance of any more sperm.

Once the sperm has entered the egg, the tail is absorbed and the head begins to move through the cytoplasm of the egg in the form of a **male pronucleus**. The entrance of the sperm stimulates the egg (strictly speaking, the secondary oocyte) to complete the second meiotic division. The nucleus of the egg develops into a **female pronucleus**, which fuses with the male pronucleus to form a single nucleus that now has the diploid number of chromosomes. Fertilisation is complete, and the fertilised egg is called a **zygote**.

Working scientifically

Activity 11.1 The ovary

This activity allows you to examine the various stages of the ovarian cycle. Your teacher may have set up a demonstration slide for you to view.

You will need (if doing this activity yourself)

A microscope; microscope lamp; prepared microscope slides of a transverse section of a mammalian ovary

What to do

1. Set up the microscope and place a prepared slide on the stage. Examine the cross-section of an ovary.
2. Identify the various stages of development of the follicles using Figure 11.2.

Studying your observations

1. Draw a diagram of your observations, labelling all visible structures.
2. Compare your drawing with Figure 11.2. Were there any structures you were unable to see on the microscope slide? If so, you may wish to annotate your diagram using information from Figure 11.2.

REVIEW QUESTIONS

1. **(a)** List the stages of the ovarian cycle, using a diagram to illustrate your answer.
   (b) What is ovulation?
   (c) Describe the changes undergone by the corpus luteum during a normal ovarian cycle. How do these changes differ if pregnancy occurs?
2. Outline the major events of the menstrual cycle, and relate these to the stages of the ovarian cycle.

3. **(a)** Explain what is meant by a target organ.
   (b) What are the target organs for testosterone and follicle stimulating hormone?
4. Explain the role of hormones in regulating the ovarian and menstrual cycles.
5. What do the terms 'menarche' and 'menopause' refer to?
6. **(a)** Define fertilisation.
   (b) Describe the events that take place in humans so that fertilisation can be achieved.
   (c) Where does fertilisation normally occur?
   (d) What is a zygote?
7. Describe the pathway of sperm from the seminiferous tubules to the time fertilisation takes place.
8. **(a)** Explain the need for the production of very large numbers of sperm in order for fertilisation to take place.
   (b) Besides sperm, what other components make up the semen?
9. **(a)** What are 'secondary sexual characteristics'?
   (b) Briefly describe the development of secondary sexual characteristics in both males and females.

APPLY YOUR KNOWLEDGE

1. Could a woman become pregnant the first time she has sexual intercourse? Explain.
2. Explain how the human male and female reproductive organs are arranged so that sperm can be transferred from the body of the male to the female for fertilisation to occur.
3. Animals that breed in water, such as crayfish, fish and frogs, have no penis or vagina. Explain the advantages of these organs to a mammal, such as a human.
4. Draw a diagram of the female reproductive system and mark in the:
   (a) place where sperm are deposited
   (b) site where fertilisation takes place
   (c) path taken by the sperm to unite with the egg
   (d) path the egg follows to unite with the sperm.
5. Although most books refer to a 28-day menstrual cycle, only about 30% of women have a cycle of this length and for many the cycle is irregular. What factors could affect the length of the menstrual cycle? List as many reasons as possible to support your answer.
6. List the following events in the order in which they would occur in the female body: ovulation; the endometrium begins to thicken; formation of the corpus luteum; a follicle begins to develop; uterine bleeding; egg travels down the uterine tube; follicle approaches maturity; degeneration of the corpus luteum; breakdown of unfertilised egg; the development of the mature follicle; deterioration of the endometrium.