Oestrous Cycles

Mature female mammals characteristically have oestrous cycles during which they become fertile, can conceive and become pregnant. Though humans have oestrous (menstrual) cycles which follow one another every month from the time of puberty to the menopause, other mammals have oestrous cycles which may only number one or two at a time and only occur during certain seasons. Outside the time of an oestrous cycle the female mammal is infertile and incapable of becoming pregnant.

Definitions relevant to human reproduction

Puberty is the time when the child becomes sexually mature and capable of reproducing. It usually occurs when the child is 11 to 13 years old. The menopause is when women stop having menstrual cycles and stop ovulating, thus they are not fertile after the menopause. It usually occurs when the woman is 45 to 50 years old.

Oogenesis is the method by which female mammals produce gametes. The female gamete of a mammal is called a secondary oocyte. Ovulation is the release of a primary oocyte (potential female gamete) from the ovary into the ovarian funnel. At this time the primary oocyte becomes a secondary oocyte.

The anatomy of the human female reproductive system

This is illustrated in Figs. 1 and 2.

Fig 1. Ventral view of female reproductive system

The ovary produces potential female gametes and also secretes the sex hormones oestrogen and progesterone. The ovarian funnel receives any secondary oocytes released by the ovary at ovulation and passes them to the oviduct which carries them to the uterus. If fertilisation occurs the sperm from the male fuses with the oocyte in the oviduct. The uterus houses the developing baby and its life support system (the placenta) throughout pregnancy. The cervix allows the entry of sperm during mating, or the exit of the baby during birth. The vulva is the external female genital opening and the vagina is the passage which receives the penis during mating.

Fig 2. Median (mid-line) section of female reproductive system (showing its relationship to the urinary system).

Oogenesis – gamete production in the human female

When studying this section the student should refer to figures 3 and 4. This process occurs in the ovaries and oviducts. It has three phases:

1. The phase of multiplication occurs in the fetal ovary before birth. The gamete stem cells, which lie in the cuboidal epithelium lining the ovary divide many times by mitosis to produce several thousand diploid oogonia. These lie dormant until puberty in small primary follicles embedded in the connective tissue of the ovary.

2. The phase of growth occurs during the first phase of the menstrual cycle. Two or three primary follicles develop into mature ovarian follicles in which the oogonia grow into primary oocytes. Eventually a follicle ovulates or ruptures releasing the oocyte into the ovarian funnel. The other developing follicles then degenerate.

3. The phase of maturation then occurs and involves the process of meiosis. Meiosis I occurs due to the stimulus of ovulation and results in the primary oocyte becoming a secondary oocyte. This has to be penetrated by a sperm (fertilisation) before meiosis II can occur to produce a haploid egg cell. (Thus, in mammals, by the time the egg cell is formed it is already fertilised).
Fig 3. The process of oogenesis

The histological appearance of the ovary varies over the monthly menstrual cycle. In the pre-ovulatory phase it will show primary follicles developing into mature ovarian follicles. At ovulation it will show a mature ovarian follicle bursting on the ovary surface to release the oocyte. In the post-ovulatory phase it will show the remains of the burst follicle in the ovary, developing into a corpus luteum (yellow body). At the end of the menstrual cycle, if implantation of a developing embryo has not occurred the corpus luteum degenerates into a corpus albicans (white body). If implantation has occurred then the corpus luteum persists.

Exam hint – questions on oogenesis usually focus on its differences to spermatogenesis or on how it relates to the menstrual cycle.

Remember – the term ‘Graafian’ follicle is now discontinued. Use the term ‘ovarian’ follicle.

The cells in the walls of the primary, developing and mature ovarian follicles secrete the female sex hormone, oestrogen. The cells of the corpus luteum secrete both oestrogen and progesterone.

Monthly changes in uterine histology

The uterus consists of an inner lining called the endometrium to the outside of which is a thick layer of smooth muscle called the myometrium. The endometrium alters in thickness during the course of the monthly menstrual cycle. This is shown in Fig 5.

Fig 5. The monthly histology of the endometrium (vertical section)

Menstruation is the breakdown of the endometrium from its thickened state at the end of a menstrual cycle into its thin state ready to commence another cycle. It is marked by a flow of cells and blood from the shedding endometrial surface to the exterior. It is triggered by a fall in progesterone and oestrogen concentrations due to the breakdown of the corpus luteum to the corpus albicans. Then, under the influence of increasing oestrogen concentrations from the developing ovarian follicles the glands and blood vessels in the endometrium multiply and grow, thus preparing the endometrium for a possible embryo implantation and pregnancy. After ovulation, the endometrial growth continues and is maintained by oestrogen and progesterone from the corpus luteum.

Exam hint – Questions are frequently asked about the structural changes in the ovary and uterus and hormonal changes that occur during the menstrual cycle.

Remember – The uterine glands will secrete a nutritive fluid for the implanted embryo, to maintain it until the placenta is fully established, by the 8th week of pregnancy.
The hormonal control of the menstrual cycle

The changes in hormone concentrations during the menstrual cycle are shown in Fig 6.

Fig 6. Changes in hormone concentrations during the menstrual cycle

![Graph showing changes in hormone concentrations during the menstrual cycle](image)

A is the menstrual phase., B is the pre-ovulatory or proliferative phase, C is the post-ovulatory or secretory phase.

**FSH** is Follicle Stimulating Hormone
**LH** is Luteinising Hormone

The menstrual cycle is regulated by the secretion of a hormone called gonadotropin releasing factor (GnRF) from the hypothalamus in the midbrain. This hormone passes in the blood to the anterior pituitary body where it triggers secretion of FSH. FSH stimulates the development of primary ovarian follicles into mature ovarian follicles, and the secretion of increasing quantities of oestrogen by the follicles. The oestrogen stimulates the growth of the glandular tissue and blood vessels of the endometrium. A high level of oestrogen in the blood around the time of ovulation has two effects:

- It inhibits the release of GnRF, and hence of FSH (by negative feedback).
- It stimulates the anterior pituitary to release increasing quantities of LH (by positive feedback).

The increase in LH concentration stimulates three things:

- ovulation to occur.
- the remains of the ovarian follicle in the ovary to develop into the corpus luteum.
- the secretion of increasing quantities of oestrogen and progesterone by the corpus luteum.

The oestrogen and progesterone together maintain and cause further growth of the endometrium.

If fertilisation and implantation does not occur, the increasing concentrations of these hormones inhibit the further secretion of GnRF and LH. Thus the corpus luteum is allowed to degenerate into a corpus albicans and the secretion of oestrogen and progesterone is reduced. Thus their maintaining effect on the endometrium is lost so that it breaks down, resulting in the menstrual flow of blood and cells through the vagina.

If implantation occurs then the corpus luteum persists, and produces even larger quantities of oestrogen and progesterone, to maintain the pregnancy. In this case the corpus luteum will only degenerate at about 10 weeks into the pregnancy, when the placenta itself takes over the secretion of the hormones.

Fig 7. shows the roles of negative feedback inhibition in the control of the menstrual cycle

**Fig 7. Negative feedback inhibition**

![Diagram showing negative feedback inhibition](image)

Exam Hint - A very common spelling error is to refer to FSH and LH as gonadothropins. They are gonadotropins. 'Trophos' is Greek for 'feeding' and so has a different biological meaning to 'tropos' which is Greek for 'growth' or 'change'. In examinations it is important to spell biological terms correctly.

Oestrous cycles in the cow and sheep

Cattle usually become sexually mature between 9 and 12 months old. They are polyoestrous (have oestrous cycles throughout the year). An oestrous cycle averages 21 days in length, with the actual time of oestrous (heat) occurring towards the end of the cycle. The duration of oestrous averages 18 hours. Ovulation occurs about 10 hours after the end of oestrous.

**Remember – in humans there is no particular time of oestrous in the menstrual cycle and humans will mate during the pre-ovulatory, ovulatory and post-ovulatory phases of the cycle. In other mammals there is a particular time of oestrous, or heat, which is the only time the female will mate with the male. The time of oestrous coincides with, or is close to, the time of ovulation.**

Oestrous cycles in cattle are suppressed during lactation. When the farmer wishes to breed from the cow again, the milking regime of the cow will be reduced until the cow no longer produces milk (is ‘dried off’). The cow will then start having oestrous cycles again. Since cows are usually fertilised by artificial insemination, the farmer must be able to recognise the time of oestrous so that insemination can be timed to coincide with ovulation. Oestrous in cows is marked by a flow of mucus and cells out of the vagina, but is more easily recognised by the cow showing ‘bulling behaviour’. This is when the cow attempts to mount on the back of other cows. The length of pregnancy in cows averages 280 days.

Sheep usually become sexually mature between 5 and 10 months old. Ewes (mature female sheep) are seasonally polyoestrous (have several oestrous cycles at a particular season of the year). Oestrous cycles tend to be triggered by shorter days, particularly if a ram (mature male sheep) is present. Oestrous cycles tend to average 17 days in length with the time of oestrous lasting for 1 to 2 days. The time of oestrous within the cycle is variable, but it can be recognised by a flow of mucus and cornified cells through the vagina, also by the ewe’s willingness to mate with the ram. Ovulation occurs near the end of oestrous.

**Thus in Britain lambs tend to be conceived in the Autumn. Since the length of pregnancy averages 150 days, the lambs tend to be born in the Spring.**

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*Oestrous Cycles*
**Practice Questions**

1. Read through the following account of the roles played by hormones in controlling the menstrual cycle, and then fill in the spaces using the most appropriate word or words.

The development of an ovarian follicle in the ................. phase of the menstrual cycle is controlled by the hormone ................. secreted by the ......................... gland. As the ovarian follicle matures it releases increasing quantities of ...................... which stimulate the repair of the endometrium following ......................... . It also starts to inhibit the secretion of ......................... and promotes the secretion of ......................... . This hormone has two main effects, at this time, one is the stimulation of ......................... and the other is the stimulation of the conversion of the ruptured follicle into a ......................... . This structure then secretes ......................... which promotes further development of the endometrium. If ......................... does not occur, the secretion of this hormone ceases and following ......................... a new cycle commences.

(12 marks)

2. The table below refers to hormones involved in the menstrual cycle. If a statement is correct place a tick (✓ ✓✓ ✓✓) in the appropriate box and if it is incorrect place a cross (✗ ✗✗ ✗✗) in the appropriate box.

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Secreted by</th>
<th>Secreted by</th>
<th>Reaches highest level in blood before ovulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oestrogen</td>
<td>anterior</td>
<td>corpus</td>
<td></td>
</tr>
<tr>
<td>Luteinising hormone</td>
<td>pituitary</td>
<td>luteum</td>
<td></td>
</tr>
<tr>
<td>Progesterone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follicle stimulating hormone</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. The diagram below shows a section of a human ovary containing structures that may appear during a normal menstrual cycle.

(a) (i) Name structures A to H. (8 marks)

(ii) Which of the following illustrates the correct sequence of developments of the ovarian structures?

BDACEGF

FBDAEGC

EFGABCD

ABCDEF

(1 mark)

(b) (i) Name the hormones secreted by structures A and E. 2

(ii) State one function in the menstrual cycle for each of the hormones you have named. 2

4. Artificial insemination has been used for many years in cattle breeding.

(a) Explain what is meant by the term ‘artificial insemination’. 3

(b) Suggest two advantages of artificial insemination of cows. 2

(c) Suggest one disadvantage of artificial insemination of cows. 1

5. When managing flocks of breeding ewes the ram is usually only allowed to join the flock during the autumn months. Suggest and explain two reasons for this. 4

6. Suggest answers to the following questions about the human female reproductive system:

(a) what is the purpose of menstruation? (not all mammals menstruate). 3

(b) what are the functions of the developing ovarian follicles as they form primary oocytes? 3

(c) why do polar bodies from in the process of oogenesis? 3

Total 9

**Bio Factsheet**

(a) (i) Name structures A to H. (8 marks)

(ii) Which of the following illustrates the correct sequence of developments of the ovarian structures?

BDACEGF

FBDAEGC

EFGABCD

ABCDEF

(1 mark)
### Answers

Marking points are shown by semicolons

1. pre-ovulatory/proliferative; FSH/follicle stimulating hormone; anterior pituitary; oestrogen; menstruation; FSH/follicle stimulating hormone; LH/luteinising hormone; ovulation; corpus luteum; progesterone; implantation;

<table>
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</tr>
<tr>
<td>Follicle stimulating hormone</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
</tbody>
</table>

menstruation;

2. 1 mark per correct horizontal line

3. (a) (i) A = mature ovarian follicle; B = primary follicle; C = secondary oocyte; D = developing ovarian follicle; E = corpus luteum; F = ovarian/cuboidal epithelium; G = corpus albicans; H = stroma/connective tissue;

   (ii) FBDACEG

   (b) (i) A - oestrogen; E - oestrogen and progesterone;

   (ii) oestrogen:
       stimulates repair of endometrium after menstruation;
       progesterone:
       maintains thickness of endometrium in a state suitable to support pregnancy;

4. (a) sperm is collected from (good quality) bulls and can be stored;
   is passed into the uterus of the cow via a tube/syringe;
   inserted via the vagina and cervix by the operator/inseminator/veterinary surgeon.

   (b) can be timed to coincide with oestrous/ovulation (so that the cow is more likely to conceive than if left to the bull);
   sperm can be used which comes from a bull having the genetic qualities the farmer wants in the herd;

   (c) farmer has to maintain a careful/continual watch over his herd to determine which cows are in oestrous/when cows are in oestrous;

5. the ewes only become fertile/have oestrous cycles in Autumn/when days shorten;
   thus will only mate with the ram at this time/ram is fertile all year and in other seasons would harass the ewes for mating;
   presence of a ram in the herd stimulates the ewes to start oestrous cycles;
   thus makes successful mating take place earlier in season/gives an early yield of lambs in Spring;
   unlike cattle, farmer cannot check easily when individual ewes come into oestrous;
   thus, this has to be left to the ram;

6. (a) to remove the unwanted tissue/endometrial tissue that was built up during the menstrual cycle;
   to remove the unfertilised primary oocyte;
   to reduce the changes of infection/remove any infected material;

   (b) protect the developing primary oocytes;
   secrete oestrogen;
   in increasing amounts to stimulate endometrial growth;

   (c) to enable bulk of cytoplasm to remain with egg;
   enabling mitochondrial DNA/ribosomes to stay with egg;
   allows removal of unwanted nuclear material;

### Acknowledgements;

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