1. Details of Module and its structure

Module Detail	
Subject Name	Biology
Course Name	Biology 03 (Class XII, Semester - 1)
Module Name/Title	Sexual Reproduction – Part 2
Module Id	lebo_10102
Pre-requisites	Knowledge about how organisms reproduce?
Objectives	After going through this lesson, the learners will be able to understand the following: 1. Cyclic changes during reproduction a) Oestrous Cycle b) Menstrual cycle 2. Pre-fertilisation Events a) Gametogenesis b) Gamete Transfer 3. Advantages and Disadvantages of sexual reproduction
Keywords	Sexual reproduction, Juvenile phase, Vegetative phase, Oestrous cycle, Menstrual Cycle, Gametogenesis, Pre fertilization phase

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1. Introduction

Sexual reproduction is a form of reproduction where two morphologically distinct types of specialized reproductive cells called gametes fuse together. Each gamete contains half the number of chromosomes of normal cells.

Sexual reproduction involves formation of the male and female gametes, either by the same individual or by different individuals of the opposite sex. These gametes fuse to form the zygote which develops to form the new organism. It is an elaborate, complex and slow process as compared to asexual reproduction. Because of the fusion of male and female gametes, sexual reproduction results in offspring that are not identical to the parents or amongst themselves.

A study of diverse organisms–plants, animals or fungi–show that though they differ so greatly in external morphology, internal structure and physiology, when it comes to sexual mode of reproduction, surprisingly, they share a similar pattern. Let us first discuss what features are common to these diverse organisms.

All organisms have to reach a certain stage of growth and maturity in their life, before they can reproduce sexually. That period of growth is called the **juvenile phase**. It is known as **vegetative phase** in plants. This phase is of variable durations in different organisms.

The end of juvenile/vegetative phase which marks the beginning of the reproductive phase can be seen easily in the higher plants when they come to flower.

How long does it take for marigold/rice/wheat/coconut/mango plants to come to flower? In some plants, where flowering occurs more than once, what would you call the inter-flowering period – juvenile or mature?

Observe a few trees in your area. Do they flower during the same month year after year? Why do you think the availability of fruits like mango, apple, jackfruit, etc., is seasonal? Are there some plants that flower throughout the year and some others that show seasonal flowering?

Plants–the annual and biennial types, show clear cut vegetative, reproductive and senescent phases, but in the perennial species it is very difficult to clearly define these phases. A few plants exhibit unusual flowering phenomenon; some of them such as bamboo species which flower only once in their life time, generally after 50-100 years, produce large number of fruits and die. Another plant, *Strobilanthus kunthiana* (neelakuranji), flowers once in 12 years. You know in September-October 2006, this plant flowered in huge number. Its mass flowering transformed large tracks of hilly areas in Kerala, Karnataka and Tamil Nadu into blue stretches and attracted a large number of tourists. In animals, the juvenile phase is followed by morphological and physiological changes prior to active reproductive behaviour. The reproductive phase is also of variable duration in different organisms.

Can you list the changes seen in human beings that are indicative of reproductive maturity?

Among animals, for example birds, do they lay eggs all through the year? Or is it a seasonal phenomenon? What about other animals like frogs and lizards? You will notice that, birds living in nature lay eggs only seasonally. However, birds in captivity (as in poultry farms) can be made to lay eggs throughout the year. In this case, laying eggs is not related to reproduction but is a commercial exploitation for human welfare.

2. Cyclic changes during reproduction

The females of placental mammals exhibit cyclical changes in the activities of ovaries and accessory ducts as well as hormones during the reproductive phase. In non-primate mammals like cows, sheep, rats, deer, dogs, tiger, etc., such cyclical changes during reproduction are called **oestrus cycle** where as in primates (monkeys, apes, and humans) it is called **menstrual cycle**.

A) Oestrus cycle

The estrous cycle (oestrous) is the main reproductive cycle of other species females of non-primate vertebrates, for example rats, mice, horses, pig have this form of reproductive cycle. The cycle of reproductive activity shown by most sexually mature nonpregnant female mammals except most primates.

There are four phases: *pro-oestrus*, *oestrus*, *metoestrus*, *dioestrus.*

(1) *pro-oestrus* (*follicular phase*) – Graafian follicles develop in the ovary and secrete oestrogens. One or several follicles of the ovary start to grow and their number is species

specific. Typically this phase can last as little as one day or as long as three weeks, depending on the species. Under the influence of estrogen the lining in the uterus (endometrium) starts to develop. Some animals may experience vaginal secretions that could be bloody. The female is not yet sexually receptive; the old corpus luteum gets degenerated; the uterus and the vagina get distended and filled with fluid, become contractile and secrete a sanguinous fluid; the vaginal epithelium proliferates and the vaginal smear shows a large number of non-cornified nucleated epithelial cells.

(2) *oestrus* (*heat*) – ovulation normally occurs, the female is ready to mate and becomes sexually attractive to the male. **Estrus** refers to the phase when the female is sexually receptive ("in heat"). Under regulation by gonadotropic hormones, ovarian follicles mature and estrogen secretions exert their biggest influence. The female then exhibits sexually receptive behavior, a situation that may be signaled by visible physiologic changes. A signal trait of estrus is the ***lordosis reflex***, in which the animal spontaneously elevates her hindquarters. Estrus is commonly seen in the mammalian species, including primates. It is thought that this increased sexual receptivity is a functional design in order for the female to obtain mates with superior genetic quality. In some species, the labia are reddened. Ovulation may occur spontaneously in some species.

(3) *metoestrus* (*luteal phase*) – corpus luteum develops from ruptured follicle.

(4) *dioestrus* – progesterone secreted by corpus luteum prepares uterus for implantation. This phase is characterized by the activity of the corpus luteum, which produces progesterone. The signs of estrogen stimulation subside and the corpus luteum starts to form. The uterine lining begins to appear. In the absence of pregnancy the dioestrus phase (also termed pseudo-pregnancy) terminates with the regression of the corpus luteum. The lining in the uterus is not shed, but is reorganized for the next cycle.

The length of the cycle depends on the species: larger mammals typically have a single annual cycle with a well-defined breeding season (they are described as *monoestrous*). The males have a similar cycle of sexual activity. Other species may have many cycles per year (i.e. they are*polyoestrous*) and the male may be sexually active all the time.

B) Menstrual cycle

The **menstrual cycle** is the regular natural change that occurs in the female reproductive system like the uterus and ovaries that make pregnancy possible. The cycle is required for the production of oocytes, and for the preparation of the uterus for pregnancy.

The menstrual cycle can be described by the ovarian or uterine cycle. The ovarian cycle describes changes that occur in the follicles of the ovary whereas the uterine cycle describes changes in the endometrial lining of the uterus.

The day count for menstrual cycle begins on the first day of menstruation when blood starts to come out of the vagina. In this section, the length of menstrual cycle has been assumed to be 28 days (which is the average among women). The entire duration of a Menstrual cycle can be divided into four main phases:

1. Menstrual phase (From day 1 to 5)
2. Follicular phase (From day 1 to 13)
3. Ovulation phase (Day 14)
4. Luteal phase (From day 15 to 28)

Menstrual phase (day 1-5)

Menstrual phase begins on the first day of menstruation and lasts till the 5th day of the menstrual cycle. The following events occur during this phase:

- The uterus sheds its inner lining of soft tissue and blood vessels which exits the body from the vagina in the form of menstrual fluid.
- Blood loss of 10 ml to 80 ml is considered normal.
- You may experience abdominal cramps. These cramps are caused by the contraction of the uterine and the abdominal muscles to expel the menstrual fluid.

Follicular phase (day 1-13)

This phase also begins on the first day of menstruation, but it lasts till the 13th day of the menstrual cycle. The following events occur during this phase:

- The pituitary gland secretes a hormone that stimulates the egg cells in the ovaries to grow.
- One of these egg cells begins to mature in a sac-like-structure called follicle. It takes 13 days for the egg cell to reach maturity. This follicle matures to Grafian follicle.
- While the egg cell matures, its follicle secretes a hormone that stimulates the uterus to develop a lining of blood vessels and soft tissue called endometrium.

Ovulation phase (day 14)

On the 14th day of the cycle, the hormones secreted by the pituitary gland reachs peak level and this causes the the ovary to release the matured egg cell. The released egg cell is swept into the fallopian tube by the cilia of the fimbriae. Fimbriae are finger like projections located at the end of the fallopian tube close to the ovaries and cilia are slender hair like projections on each Fimbria.

Luteal phase (day 15-28)

This phase begins on the 15th day and lasts till the end of the cycle. The following events occur during this phase:

- The egg cell released during the ovulation phase stays in the fallopian tube for 24 hours.
- If a sperm cell does not impregnate the egg cell within that time, the egg cell disintegrates.
- The hormone that causes the uterus to retain its endometrium gets used up by the end of the menstrual cycle. This causes the menstrual phase of the next cycle to begin.

Many mammals, especially those living in natural, wild conditions exhibit such cycles only during favourable seasons in their reproductive phase and are therefore called seasonal breeders. Many other mammals are reproductively active throughout their reproductive phase and hence are called continuous breeders.

The end of reproductive phase can be considered as one of the parameters of senescence or old age. There are concomitant changes in the body (like slowing of metabolism, etc.) during this last phase of life span. Old age ultimately leads to death.

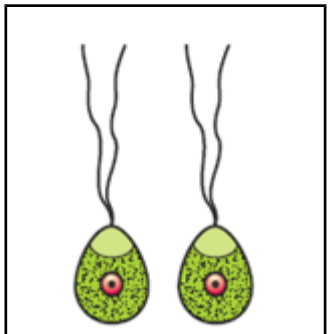
In both plants and animals, hormones are responsible for the transitions between the three phases. Interaction between hormones and certain environmental factors regulate the reproductive processes and the associated behavioural expressions of organisms.

Events in sexual reproduction: After attainment of maturity, all sexually reproducing organisms exhibit events and processes that have remarkable fundamental similarity, even though the structures associated with sexual reproduction are indeed very different. The events of sexual reproduction though elaborate and complex, follow a regular sequence. Sexual reproduction is characterised by the fusion (or fertilisation) of the male and female gametes, the formation of zygote and embryogenesis. For convenience these sequential events may be grouped into three distinct stages namely, the **pre-fertilisation, fertilisation** and the **post-fertilisation events.**

3. Pre-fertilisation Events

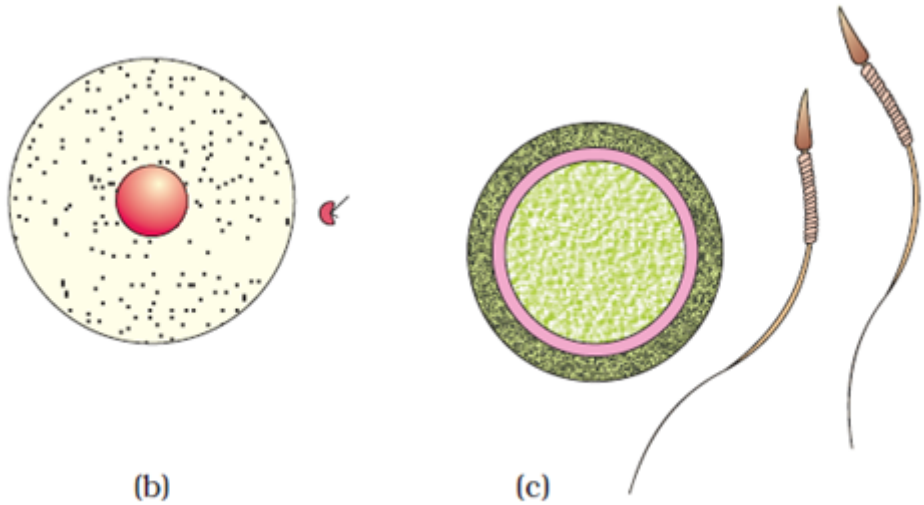
These include all the events of sexual reproduction prior to the fusion of gametes. The two main pre-fertilisation events are **gametogenesis** and **gamete transfer.**

A) *Gametogenesis*



Isogametes of *Cladophora*

G**ametogenesis** refers to the process of formation of the two types of gametes – male and female. Gametes are haploid cells. In some algae the two gametes are so similar in appearance that it is not possible to categorise them into male and female gametes. They are hence called **homogametes** (**isogametes)**. However, in a majority of sexually reproducing organisms the gametes produced are of two morphologically distinct types (**heterogametes).** In such organisms the male gamete is called the **antherozoid** or **sperm** and the female gamete is called the **egg** or **ovum.**



(b) Heterogametes of *Fucus* (an alga); (c) Heterogametes of *Homo sapiens* (Human beings)

Sexual reproduction in organisms generally involves the fusion of gametes from two different individuals. But this is not always true.

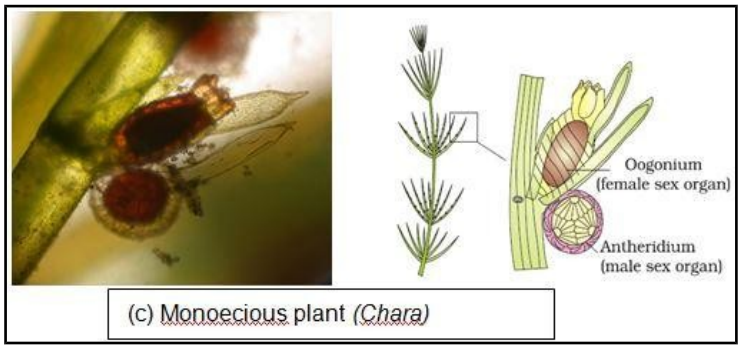
From your recollection of examples studied in Class XI, can you identify cases where self-fertilisation is observed?

Self-fertilization, also known as autogamy, occurs in hermaphroditic organisms where the two gametes fused in fertilization come from the same individual, e.g., some foraminiferans and some ciliates. The term "autogamy" is sometimes substituted for autogamous pollination (not necessarily leading to successful fertilization) and describes self-pollination within the same flower, distinguished from geitonogamous pollination, transfer of pollen to a different flower on the same flowering plant, or within a single monoecious Gymnosperm plant. *Helonias bullata* suffer from low genetic diversity due to self-fertilization.

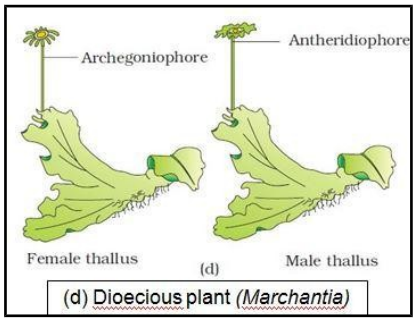
Of course, citing such examples in plants is easy**.** Plants may have both male and female reproductive structures in the same plant (bisexual) (Figure 1.6 c, e) or on different plants (unisexual) (Figure 1.6d).

In several fungi and plants, terms such as **homothallic and monoecious** are used to denote the bisexual condition and **heterothallic** and **dioecious** are the terms used to describe

unisexual condition. In flowering plants, the unisexual male flower is **staminate**, i.e., bearing stamens, while the female is **pistillate** or bearing pistils. In some flowering plants, both male and female flowers may be present on the same individual (monoecious) or on separate individuals (dioecious).



(c) Monoecious plant *(Chara)*



(d) Dioecious plant *(Marchantia)*

Some examples of monoecious plants are cucurbits and coconuts and of dioecious plants are papaya and date palm.

But, what about animals? Are individuals of all species either male or female (**unisexual**)? Or are there species which possess both the reproductive organs (**bisexual**)?

You probably can make a list of several unisexual animal species.

Earthworms, (Figure 1.6a) sponge, tapeworm and leech, typical examples of bisexual animals that possess both male and female reproductive organs, are **hermaphrodites**. Cockroach (Figure 1.6b) is an example of a unisexual species.

Gametes in all heterogametic species are of two types namely, **male** and **female**. Gametes are **haploid** though the parent plant body from which they arise may be either haploid or diploid. A haploid parent produces gametes by mitotic division.

Does this mean that meiosis never occurs in organisms that are haploid?

Several organisms belonging to monera, fungi, algae and bryophytes have **haploid** plant body, but organisms belonging to pteridophytes, gymnosperms, angiosperms and most of the animals including human beings, the parental body is **diploid.** It is obvious that meiosis, the reduction division, has to occur if a diploid body has to produce haploid gametes.

Table 1.1: Chromosome Numbers in Meiocytes (diploid, 2n) and Gametes (haploid, n) of Some Organisms. Fill in the Blank Spaces.

Name of organism	Chromosome number in meiocyte (2n)	Chromosome number in gamete (n)
Human beings	46	23
House fly	12	—
Rat	—	21
Dog	78	—
Cat	—	19
Fruit fly	8	—
Ophioglossum (a fern)	—	630
Apple	34	—
Rice	—	12
Maize	20	—
Potato	—	24
Butterfly	380	—
Onion	—	8

In diploid organisms, specialised cells called **meiocytes** (gamete mother cell) undergo meiosis**.** At the end of meiosis, only one set of chromosomes gets incorporated into each **gamete**. Carefully study this table and fill in the diploid and haploid chromosome numbers of organisms.

Is there any relationship in the number of chromosomes of meiocytes and gametes?

b) Gamete Transfer

After their formation, male and female gametes must be physically brought together to facilitate fusion (fertilisation). *Have you ever wondered how the gametes meet?* In a majority of organisms, male gamete is motile and the female gamete is stationary. Exceptions are a few fungi and algae in which both types of gametes are motile (Figure1.7a). There is a need for a medium through which the male gametes move. In several simple plants like algae, bryophytes and pteridophytes, water is the medium through which this gamete transfer takes place. A large number of the male gametes, however, fail to reach the female gametes. To compensate this loss of male gametes during transport, the number of male gametes produced is several thousand times the number of female gametes produced.

In seed plants, pollen grains are the carriers of male gametes and ovule has the egg. Pollen grains produced in anthers therefore, have to be transferred to the stigma before it can lead to fertilisation (Figure 1.7b). In bisexual, self-fertilising plants, e.g., peas, transfer of pollen grains to the stigma is relatively easy as anthers and stigma are located close to each other; pollen grains soon after they are shed, come in contact with the stigma. But in cross pollinating plants (including dioecious plants), a specialised event called **pollination** facilitates transfer of pollen grains to the stigma. Pollen grains germinate on the stigma and the pollen tubes carrying the male gametes reach the ovule and discharge male gametes near the egg. In dioecious animals, since male and female gametes are formed in different individuals, the organism must evolve a special mechanism for gamete transfer. Successful transfer and coming together of gametes is essential for the most critical event in sexual reproduction, the fertilisation.

4. Advantages and Disadvantages of sexual reproduction

Advantages

1. Sexual reproduction permits variation, which is evolution's fundamental element. It creates species, which can adapt to harsh environmental changes, and cannot be wiped out by a single disease or any other catastrophe.
2. Sexual reproduction helps natural selection remove harmful mutations from the population.
3. Offspring are much different than parents.

   In species that produce asexually, offspring are the exact replica of their parents. Essentially, they just spread and multiply. But sexual reproduction is so much more different given that two beings are needed to form one offspring.

4. The offspring's genetics are unique as they are formed from crossing over. It is favourable when the environment is not favourable or stable for the species. This is a slower rate of reproduction, but has faster evolution.

Disadvantages

1. Sexual reproduction requires two parents. The parents must expend energy in order to find; court or identify, and copulate with their mate. If conditions are stable, the genetic recombination may be counter-reproductive. Also, sexual reproduction is less efficient at passing in genes. The favorable genes combination may be broken.
2. Sexual reproduction also requires more time to produce offspring. Animals may take months before they can produce offspring. In plants, it may take years before they bear fruits, which is why asexual reproduction is most preferred by breeders.
3. Reproduction is not always guaranteed

   Lots of factors go into the successful creation of offspring. Meaning, not every act of sexual reproduction is guaranteed to produce an offspring. Some may try for years before anything fruitful comes out of the process.
4. **Gene Roulette.**

   Combining two vastly different sets of genes together can be risky, and mutations are the result. Diseases, illnesses, deformities, and birth defects can all result from two sets of genes not mixing well together. This is a pure guessing game for parents. These mutations of the genes are described as undesirable traits and are a result of sexual reproduction.

5. **Summary**

Individual organisms come and go, but, to a certain extent, organisms transcend time through producing offspring. Sexual reproduction is the formation of a new individual following the union of two **gametes**. Sexual reproduction involves the formation and fusion of gametes. It is a complex and slower process as compared to asexual reproduction. Most of the higher animals reproduce almost entirely by sexual method. Events of sexual reproduction may be categorised into pre-fertilisation, fertilisation and post-fertilisation events. Pre-fertilisation events include gametogenesis and gamete transfer while post-fertilisation events include the formation of zygote and embryogenesis.