Course: Genetics
Lecture: five

Sex determination

Members of almost all species are often divided into two sections according to the kind of gamete or sex cell produced by them, male sex and female sex. The word **sex** has been derived from Latin word sexus meaning section or separation. However, some of the lowest forms of plant and animal are found to have several sexes. For example, in one variety of the ciliated protozoan *Paramecium bursaria* there are eight sexes or "mating types" all morphologically identical. Each mating type is physiologically incapable of conjugating with its own type, but may exchange genetic material with any of the seven other types within the same variety.

Further, in organisms in which the number of sex reduced to just two, sexes may reside in different individuals or within the same individual. An animal possessing both male and female reproductive organs is usually referred to as a **hermaphrodite**. In plants where **staminate** (male) and pistillate (female) flowers occur on the same plant, the term of preference is **monoecious**. Most of our flowering plants have both male and female parts within the same flower **(called perfect flower).**

The organisms in which both male and female gametes are produced by different individuals are called **dioecious**.

The sex cells and reproductive organs form the primary sexual characters of male and female sexes. Besides these primary sexual characters, the male and female sexes differ from each other in many somatic characters known **as secondary sexual characters.** The phenomenon of molecular, morphological, physiological or behavioral differentiation between male and female sexes is called **sexual dimorphism.**

Modern geneticists have reported many different mechanisms of determination of sex in living organisms. Some important and common mechanisms of sex determination are following:

Genetically Controlled Sex Determining Mechanisms:

Most of the mechanisms of the determination of the sex are under genetic control and they may be classified into following categories:

1. Sex chromosome mechanism or Heterogamesis.

2. Genic balance mechanism.

3. Male haploidy mechanism.

4. Single gene Control of Sex**.**

- **Sex chromosome mechanism:**

In dioecious diploidic organisms following two systems of sex chromosomal determination of sex have been recognized:

(a) Heterogametic males

(b) Heterogametic females

Heterogametic Males

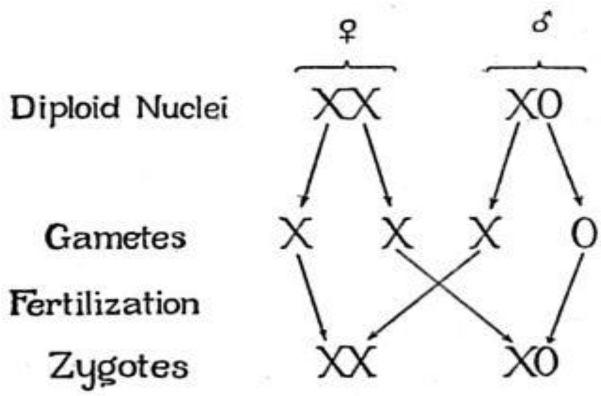
In this type of sex chromosomal determination of sex, the female sex has two X chromosomes, while the male sex has only one X chromosome. Because, male lacks a X chromosome, therefore, during gametogenesis gametes, 50 per cent gametes carry the X chromosomes, while the rest 50 per cent gametes lack in X chromosomes. Such a sex which produces two different type of gametes in terms of sex chromosomes is called **heterogametic sex. The female sex, because, produces similar type of**

gametes, is called, **homogametic sex.** The heterogametic males may be of following two types:-

(a) XX-XO type. In certain *Dioscorea sinuata,* etc.,) and insects specially those of the orders Hemiptera (true bugs) and Orthoptera (grasshoppers and roaches), the female having two X chromosomes (hence, referred to as XX) and are, thus, homogametic, while the male having only one X chromosome (hence, referred to as XO). The presence of an unpaired X chromosome determines the masculine sex.

The male lacking in one X chromosome produces two types of sperms: half with X chromosome and half without X chromosome. The sex of the offspring depends upon the sperm that fertilizes the egg

(each of which carries a single X chromosome**).**



Heredity of sex chromosomes in XO sex determination

(b) XX-XY type. In man, other mammals, certain insects including Drosophila and *Lygaeus turicicus* and in certain angiospermic plants such as *Melandrium album* (Lychis), *Humulus lupulus*, *Coccinia indica*, the female possesses two homomorphic X chromosomes in their body cells

Hence, referred to as XX) and they being homogametic, produce one kind of eggs, each with one kind of eggs, each with one X chromosome. The males of these organisms possess one X chromosome and one Y chromosome (hence, referred to as XY). The males having two heteromorphic sex chromosomes produce two kinds of sperms:

half with X chromosome and half with Y chromosome. The sex of embryo depends on the kind of sperm. An egg fertilized by a X-bearing sperm, produces a female, but, if fertilized by a Y-bearing sperm, a male is produced.

Heterogametic Females

In this type of sex chromosomal determination of sex, the male sex possesses two homomorphic X chromosomes, therefore, is homogametic and produces single type of gametes, each carries a single X chromosome. The female sex either consists of single X chromosome or one X chromosome and one Y chromosome. The female sex is, thus, heterogametic and produces two types of eggs, half with X chromosome and half without X chromosome (with or without a Y chromosome). To avoid confusion with that of XX-XO and XXXY types of sex determining mechanisms, instead of the X and Y alphabets, Z and W alphabets are generally used respectively.

The heterogametic females may be of following two types:

(a) ZO-ZZ system. This system of sex determination is found in certain moths and butterflies. In this case, the female possesses single Z chromosome in its body cells (hence, is referred to as ZO) and is heterogametic, producing two kinds of eggs, half with a Z chromosome and half without any Z chromosome. The male possesses two Z chromosomes (hence, referred to as ZZ) and is homogametic producing single type of sperms, each of which carries a single Z chromosome.

The sex of the offspring depends on the kind of egg as shown below:

Parent:	**Female**	**X**	**Male**
	2A+ZO		**2A+ZZ**
Gametes:	**(A+Z) (A+O)**		**(A+Z) (A+Z)**
	Ova		**Sperms**
F1 :	**2A+ZZ ,**		**2A+ZO**
	Male,		**Female**

(b) ZW-ZZ system. This system of sex determination occurs in certain insects (*gypsy moth*) and vertebrates such as fishes, reptiles and birds and plants such as *Fragaris elatior*. Here the female sex has one Z chromosome and one W chromosome. It is heterogametic and produces two types of ova, 50 per cent ova carry the Z chromosomes, while rest 50 per cent ova carry W chromosomes. The male sex has two homomorphic Z chromosomes and is homogametic producing single type of sperms, each carries a Z chromosome. The sex of the offspring depends on the kind of egg, the Z bearing eggs produces males but the W bearing eggs produce females.

Parent:	**Female**	**X**	**Male**
	2A+Zw		**2A+ZZ**
Gametes:	**(A+Z) (A+w)**		**(A+Z) (A+Z)**
	Ova		**Sperms**
F1:	**2A+ZZ,**		**2A+Zw**
	Male,		**Female**

- **Genic Balance Mechanism**

By studying sex chromosomal mechanism of sex determination, it may appear at first glance that some genes carried by the sex chromosomes (X and Y) were entirely responsible for sex.

Sex determination in Drosophila.

In Drosophila, the presence of Y chromosome has been found essential for the fertility of male sex but that has nothing to do with the determination of male sex. In this fly, the sex is determined polygenically. The sex determining genes were so distributed that the net effect the effect results in the autosomes determining genes were so distributed that the net effect results in the autosomes maleness and the X chromosomes femaleness. The sex of an individual then depends upon the ratio of X chromosomes to autosomes. If each haploid set of autosomes carries factors with a male-determining value equal to one (1), then each X chromosome carries factors with a female determining value of one and half (1½).

Let a represent a haploid set of autosomes. In a normal male (AAXY) the male and female determinants are in the ratio of 2: 1½ and, therefore, the genic balance is in the favour of maleness. A normal female (AAXX) has a male and female ratio of 2:3 and, therefore, the balance is in the favour of femaleness.

Diploid (male)

Triploid (female) **2A+ XY**

3A+XXX

A+X A+Y

2A+XX

A+X

2A+x

A+XX

Triploid female **3A+XXX**	**Triploid intersex** **3A+XXY**
Diploid female **2A+XX**	**Diploid male** **2A+XY**
Triploid intersex **3A+XX**	**Super male** **3A+XY**
Super female **2A+XXX**	**Diploid female** **2A+XXY**

Fig: Results obtained from a Bridge's classical cross of a triploid (3A+XXX) Female fly and a diploid (2A+XY) male fly (Drosophila).

- **Male Haploidy Mechanism**

Male haploidy or haplodiploidy or arrhenotokous parthenogenesis is particularly common in the hymenopterous insects such as ants, bees, sawflies and wasps (e.g., *Bracon hebetor*). In these insects, since, fertilized eggs develop into diploid females and unfertilized ones into haploid males; so arrhenotoky is both a form of reproduction and a means of sex determination. Meiosis is normal in females, but crossing over and reduction in chromosome number fail to occur during spermatogenesis in males due to their haploidy.

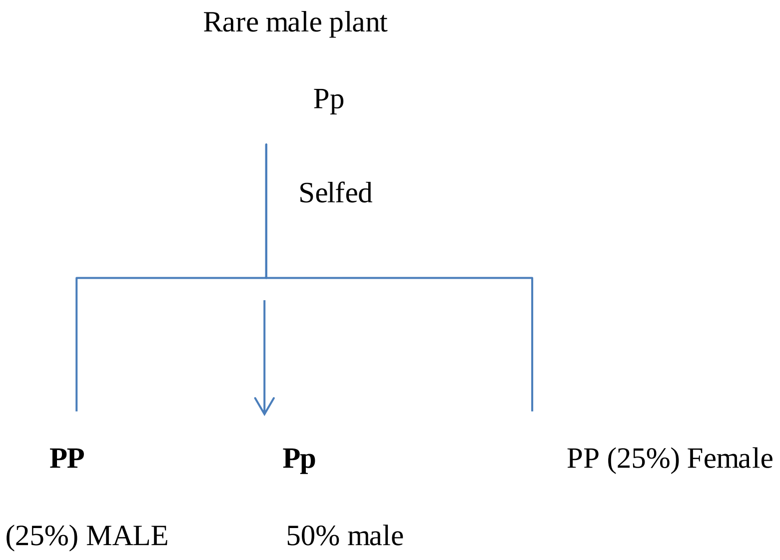
For example, a honeybee queen (whose diploid number is32) can lay two types of eggs. By controlling the sphincter of her sperm receptacle (which holds sperms previously obtained in mating with males during nuptial flight), she produces a fertilized egg (a diploid zygote having 32 chromosomes and developing into a female) or an unfertilized egg (a haploid zygote having 16 chromosomes and developing into a male).

The diploid female zygotes can differentiate into either workers (sterile) or queens (fertile) depending on the diet they consume during their development.

- **Single Gene Control of Sex**

In certain organisms, for example *Chlamydomonas, Neurospora,* yeast, Asparagus, maize, Drosophila, etc., individual single genes are found to be responsible for the determination or expression of sex, following cases exemplified the single gene control of sex:

(a) Sex-determination in Asparagus. Asparagus is a dioecious plant, however, sometimes the female flowers bear rudimentary anthers and the male flowers bear rudimentary pistils. Thus, sometime when the seeds of such a rare male flower were raised into plants, then, the male and female plants were found to be present in 3: 1 ratio. When the male plants raised thus were used to pollinate the female flowers on female plants, only two third of them showed segregation indicating that the sex is controlled by a single gene.



Segregation for sex in seed obtained from a rare bisexual flower in Asparagus showing monogenic control.