SEX DETERMINATION :

- Sex determination is always a point of interest to the scientific community.
- The early scientist conceived the ideas, which were unscientific about the sex. Only in the recent years this problem had been solved with the knowledge of genetics.
- In higher animals, male and female gonads are present in separate individuals. So these are called **dioecious** or **unisexual.**
- Most of them are also **sexually dimorphic.** Gonads produce the gametes. Male gonads, testes produce sperms and female gonads, ovaries produce ova.
- Generally two parental gametes that unite during fertilization are physically distinct from each other (i.e., **sperm** and **ovum).**
- Most of the plants and a few lower animals are **bisexual or monoecious,** male and female reproductive organs are present in the same individual.

SEX CHROMOSOMES:

- In most of the animals a pair of chromosomes is responsible for the determination of sex. This pair of chromosomes is called **sex chromosomes** or **allosomes**.
- The chromosomes other than the sex chromosomes are called autosomes. If the two sex chromosomes are similar the individual is described as **homogametic,** if the two sex chromosomes are different or it contains one sex chromosome, individual is described as **heterogametic.**
- The reproductive organs that produce gametes form the **primary sexual characters.**
- **The development of gonads in the body is the main character for sex determination.** Other somatic differences of the male and female animals are called the **secondary** sexual **characters.**
- The development of secondary sexual characters is called **sexual differentiation**. Sex determination is by *sex chromosomes* and sexual differentiation is by *hormones.*
- **H. Henking** discovered the X body. In the later investigations this X body is designated as X chromosome.
- **Stevens** and **Wilson** 1907 observed the spermatogenesis in a bug *Protenor.* Diploid males have 13 chromosomes and diploid females have 14 chromosomes.
- Therefore in pairing there will be one extra chromosome in the male. This extra chromosome in males is known as the **X-chromosome.**
- While working with *Lygaeus turcicus* they found both males and females are diploid having 14 chromosomes.
- In male all the chromosomes are paired, but the chromosome homologous to X chromosome is distinctly small.
- This smaller chromosome is called the **Y- chromosome.**
- The various explanations given for sex determination are : 1. chromosomal theory of sex determination, 2. genic balance theory of sex determination, 3. hormonal sex determination, and 4. environmental sex determination.

HETEROGAMETIC SEX DETERMINATION :

- It is proposed by **Correns.** It is based on number of chromosomes and nature of allosomes.

i. Sex determination based on number of sex cbromosomes

- In this method of sex determination chromosomal number differs in male and female.

a. XX-XO method of sex determination

- In the insects of Hemiptera (bugs) and Orthoptera (grasshoppers and cockroaches) females have two X chromosomes and males have one X chromosome in their karyotypes.
- The unpaired X chromosome determines the male sex.
- **C.E. McClung** observed this in grasshoppers. Karyotype of female is AAXX and male is AAXO. All the ova formed from the oogonial cells contain 'AX' complement of chromosomes.
- The sperms formed from the spermatogonial cells are of two types. Half of them have 'AX' and the other half have A complement of chromosomes.
- So females are homogametic and males are heterogametic. The sex of the offspring depends on the fertilizing sperm**.**

b. ZO-ZZ method of sex determination

- In *Fumea* (moth) the female is heterogametic with one Z chromosome (ZO) and male is homogametic with two Z chromosomes (ZZ).
- In this **"ZO" method of sex determination**, the unpaired Z chromosome in the female determines the sex.
- All the sperms are similar in their karyotype but ova differ in their karyotype. The sex of the offspring depends on the fertilizing ovum.

ii. Sex determination based on differences in sex chromosomes

- In this type of sex determination, both males and females have the same number of chromosomes.

a. XX-XY method of sex determination

- In humanbeings and insects like *Drosophila* both females and males have the same number of chromosomes. Females are homoeametic with XX chromosomes producing similar ova having X chromosome.
- Males are heterogametic with X and Y chromosomes producing two kinds of sperms, half of them with X-chromosome and the other half with Y chromosome.
- On fertilization the zygotes may have either the XX or XY. The zygote with XX becomes the female and the zygote with XY becomes the male.
- In humanbeings females are heterogametic with 44 autosomes and XX allosomes. Males are heterogametic with-44 autosomes and XY allosomes.
- All the eggs are similar in their karyotype having 23 chromosomes, (22+X). Sperms also have 23 chromosomes but are of two types.
- Half of them are with allosome X (22+X) and the other half with allosome Y(22+Y). The sex of the offspring depends on the fertilizing sperm.

b. ZW-ZZ method of sex determination

- In birds, reptiles, some fishes, butterflies etc., females are heterogametic with ZW chromosomes and males are homogametic with ZZ chromosomes.
- All sperms are similar with allosome 'Z', but ova are of two different kinds. Half of the ova are with allosome 'Z^1 and other half with allosome 'W. The sex of the offspring depends on the fertilizing egg.

SEX DETERMINATION IN *DROSOPHILA* (GENIC BALANCE THEORY)

- The sex determination in *Drosophila* is XY method. The allosomes are X and Y chromosomes. Males and females have the same number of chromosomes i.e. 8.
- Of these, six are autosomes and two are allosomes. Female is homogametic AAXX and male is heterogametic AA XY, where A is the single set of autosomes.
- **Calvin Bridges,** 1916 showed that Y chromosome has no role in the determination of sex in *Drosophila.* He proposed that both the X chromosomes and autosomes together play a critical role in the determination of sex in *Drosophila.*
- He studied the offspring resulting from the nondisjunction of X chromosomes during meiosis in females.
- **Nondisjunction** is the failure of the paired chromosomes to segregate or separate during the anaphase stage of the first or second meiotic divisions of gametogenesis.
- The result is the production of abnormal gametes. One of which contains one extra chromosome (AXX) and other contains one chromosome less
  (A). Fertilization of such gametes with normal gametes produces **aneuploid zygotes** (2n+1 or 2n–1).
- Bridges crossed a triploid female (AAAXXX) to a normal male and observed many combinations of autosomes and sex chromosomes in the offspring.
- Triploid female produces gametes like 'AAXX', 'AX', 'AAX', and 'AXX'. These gametes fertilize with normal sperms of the male producing different karyotypes.
- From these karyotypes, Bridges found that the XXY flies were normal females, and the XO flies were sterile males.
- The presence of Y chromosome in the XXY flies did not cause maleness, and its absence in the XO flies did not produce femaleness.
- He concluded that Y chromosome in *Drosophila* lacks male-determining factors, but contains gametic information essential to male fertility as the XO males were sterile.
- He realised that the factor in determining the sex in *Drosophila* is the ratio of X chromosomes to the number of haploid sets of autosomes.
- Normal females have a ratio equal to 1.0. If the ratio is >1.0, females are **metafemales,** which are infertile.
- Normal males have a ratio equal to 0.5. When the ratio decreases the males are **metamales,** which are infertile.
- If the ratio is between 0.5 and 1.0, the flies are **intersexes,** which are larger, with morphological abnormalities and rudimentary bisexual gonads.
- This mode of sex determination is explained as the **genic balance theory** of Bridges.
- This theory explains that genes for maleness are located on autosomes and for femaleness on X-chromosomes in Drosophila.

SEX DETERMINATION AND SEXUAL DIFFERENTIATION IN HUMANBEINGS :

Sex determination

- Sex determination in humanbeings is also by XY method, where allosomes are X and Y chromosomes.
- The number of chromosomes in humanbeing is 46. Females are homogametic, AA XX and males are heterogametic, AA XY. Unlike in *Drosophila,* the Y-chromosome determines maleness in humanbeings.
- The following syndromes are produced due to **nondisjunction of allosomes** in humanbeings.
- These syndromes explain the importance of Y chromosome in the determination of male sex in humanbeings.

1. Turner syndrome:

- In Turner syndrome the affected individual has female external genitalia and internal genital ducts, but the ovaries are rudimentary.
- Other abnormalities are short stature, webbed neck and a broad, shield-like chest.
- Karyotype is 45, 44X. It is due to the monosomy of 23rd pair. Turner female is *negative* for Barr body.

2. Klinefelter syndrome:

- These individuals have male genitalia and internal genital ducts, but their testes are underdeveloped. Feminine sexual development is not completely suppressed. Karyotype is 47, 44XXY.
- It is due to the trisomy of 23rd pair. Klinefelter male is *positive* for Barr body.

ii. Sexual differentiation

- Genetic information on the sex chromosomes is responsible for the primary sex determination.
- The early differentiation occurs under the influence of male or female sex hormones.
- These hormones support, if not determine, the expression of secondary sexual characters in the development.

iii. Barr bodies

- **Murray L. Barr** and **others** in cats, **Keith Moore** and **Barr** in humanbeing studied the genetic dosage difference.
- Barr and Bertram observed darkly staining body in the interphase nerve cell of female cats, but absent in male cats.
- These bodies are also observed in the buccal mucosa and fibroblasts of female humanbeings but are absent in males.
- This highly condensed structure is called **sex chromatin** body or **Barr body. Mary Lyon** suggested that this Barr body represents an inactive X chromosome.
- Barr body is a tightly coiled heterochromatin. Lyon proposed that inactivation occurs randomly in somatic cells at a point early in embryonic development.
- Once inactivation occurs, all the progeny cells have the same inactivated X chromosome.
- Number of Barr bodies = number of X chromosomes – 1.
- The Barr body in some neutrophils of woman is present as **drumstick body.** (A small body attached to one of the nuclear lobes of neutrophill it is more like a drumstick).

HAPLO-DIPLOIDY IN HONEYBEES :

- In insects belonging to the order Hymenoptera (honeybees), sex is determined by the number of sets of chromosomes (haploid or diploid) a bee receives.
- The eggs fertilized are diploid and the unfertilized eggs are haploid *(Apis mellifica* has 16 chromosomes in haploid state and 32 chromosomes in diploid state). Diploid zygotes develop into diploid females.
- Female that feeds on royal jelly becomes the fertile female called **queen** and others feed on honey become the sterile females called **workers**.
- The unfertilized eggs undergo **parthenogenesis**, which is an asexual process of embryonic development, to produce haploid fertile males called **drones**.
- This parthenogenetic development of haploid males from the unfertilized eggs is called **arrhenotoky**. Males produce sperms by mitosis rather than meiosis.

EFFECT OF ENVIRONMENT ON SEX DETERMINATION:

- In *Bonelia virids,* a marine worm, all the larvae are genetically and cytologically similar. If a particular larva settles near the proboscis of an adult female, it becomes a male individual.
- On the other hand, if it develops free in water, it becomes a female. The secretions of proboscis in the female influence the young worms to develop in to males.

HORMONAL CONTROL OF SEX :

- **Crew** had reported a case of complete **sex reversal** in fowls. A fertile hen may change to fertile cock due to the damage to the ovary or after the natural cessation of egg-laying.
- The ovary in the reproductive female secretes a male suppressing hormone. Hence male development is suppressed as long as ovary is active.
- Testis may develop in the absence of the ovary or in the natural cessation of ovary.
- In cattle when **fraternal twins**, or **dizygotic twins** (one male and the other female) are produced the female becomes sterile and the male becomes normal. This sterile female co-twin is called **freemartin**.
- Male hormones are produced earlier. These male hormones circulate to the female foetus during the development suppressing the development of ovary in the female. So, the female co-twin becomes sterile.