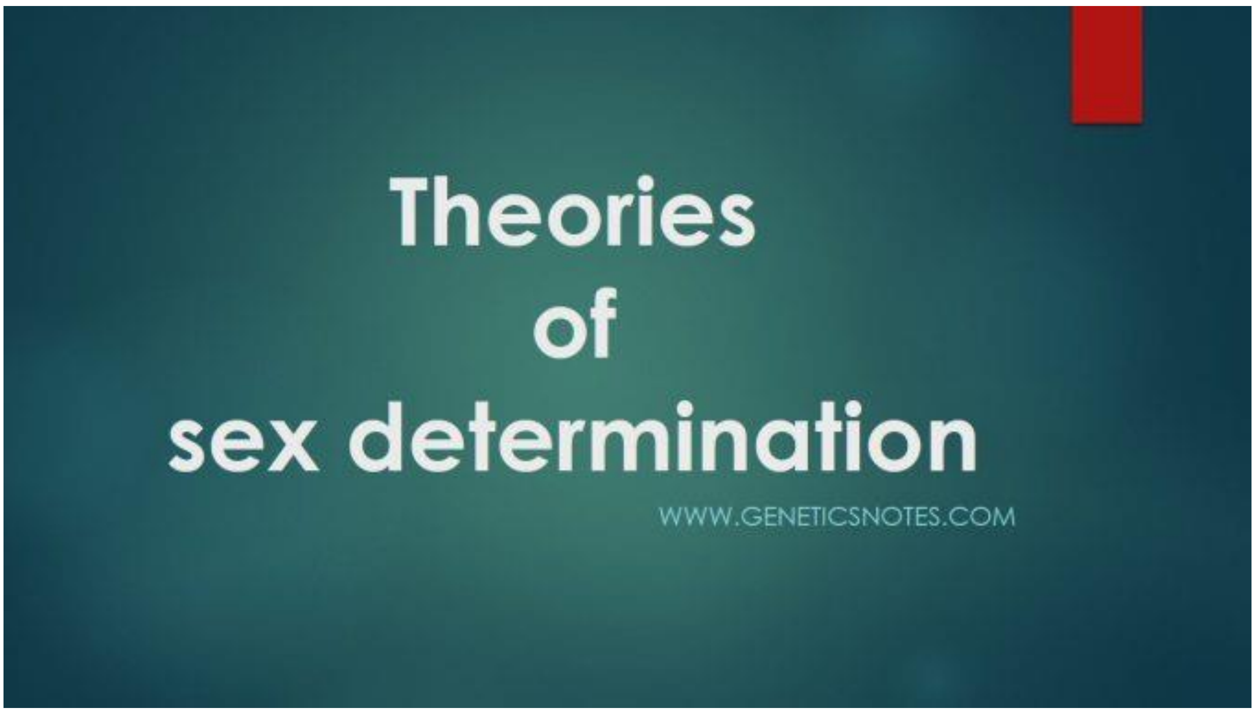
Theories of sex determination in organisms



Theories of sex determination in organisms

- The mechanism of sex determination are similar in both plants and animals.

I. Classical Theories of sex determination:

1. Metabolic theory of sex determination:

- This theory was developed by Riddle
- According to metabolic theory, sex is conditioned by metabolism of cells.

- The high rate of oxidation, large quantity of water content and less protein leads to maleness while reverse in there metabolic activity leads to femaleness.

2. Quantitative theory of sex determination:

- This theory is developed by Goldschmidt
- According to quantitative theory, the enzyme **andrase** is responsible for maleness and **gynase** for femaleness.
- The balance between these two enzymes produces different sexes and intersexes in varying degree.

II. Modern theories of sex determination:

1. Chromosomal theory of sex determination:

- In sexual reproduction in higher organism, male and female gametes are produced and fuse together to form zygote. These gametes are specialized cell with haploid number of chromosome. The chromosomes are of two types- autosomes and sex chromosomes.
    - Autosomes: it determines the phenotypic body chcaracters. These chromosomes (22 pairs) in diploid organism do not differs among male and female. Their number and morphology are conserved in male and female.
    - Sex chromosome: it determines sex.
- Herman Henking (1891) observed darkly stained chromatin element and named it as X body which was later found to be sex chromosome and named as X-chromosome.
- Miss Stevens (1905) observed *Drosophila melanogaster* and found four pair of chromosomes. In male flies, one pair of chromosome was peculiar, one of them resembles with the X-chromosome of female while other is unequal in size. Later Wilson (1909) term this unusual chromosome as Y-chromosome. So, Drosophila could be described as XX female and XY male.
- McClung (1902) suggests the chromosome was responsible for sex determination
- In human, there are 23 pairs of chromosomes
    - Female= (22 pairs of AA chromosomes + XX)
    - Male = (22 pairs of AA chromosome + XY)
- X and Y chromosomes differ from each other. In human Y chromosome is shorter than X- chromosome while In *Drosophila* Y chromosome is larger than X-chromosome.

2. Genic balance theory of sex determination:

- B Bridge (1925) put forward the genic balance theory of sex determination in which he stated that the sex of an individual is determined by a balance between the genes for maleness and those for femaleness present in an individual.
- While studying *Drosophila,* it was found that Y chromosome is mostly heterochromatin and play no significant role in sex determination, the gene for maleness is present in autosomes while the gene for femaleness is present in X-chromosome.
- Therefore all the individuals carry the gene for both sex-male and female. But it is actually the ratio between X-chromosome and the autosomes which governs the development of male or female sex. The ratio is known as sex index ratio.
- Sex index ratio (X/A) = (X chromosome number/ Number of autosome sets)
    - If the sex index ratio (X/A) is 0.5 or less, it gives male sex
    - If the sex index ratio (X/A) is 1 or more than 1 then it gives female sex
    - If the sex index ration (X/A) is between 0.5 and 1 then it gives intersex

Ploidy condition in *Drosophila*	No. of X chromosome	No. of autosomal set (A)	Sex index ratio (X/A)	Phenotype character
2n (XXX)	3	2	1.5	Super female (XXX)
3n	3	3	1	Female
4n	4	4	1	Female
2n	2	3	0.67	intersex
2n	1	2	0.5	Male
3n	1	3	0.33	Super male
2n	2	4	0.5	Male

- This table shows sex expression in *Drosophila* according to sex index ratio.
- Genic balance theory explain the sex determination in *Drosophila* on the basis of sex index ratio, where Y-chromosome does not play role in sex determination.
- However this genic balance theory of sex determination does not hold true for human or mammals and also in those individuals where Y chromosomes plays certain role in sex determination.

3. Haplo-diplo mechanism of sex determination:

- In haplo-diplo mechanism of sex determination, females developed from fertilized egg and are diploid whereas male developed from unfertilized egg by the process called parthenogenesis and are haploid.

- This method of sex determination is very common in Insects species such as bees, ants, wasps.
- In a study conducted by Whitings (1945) on wasp species (*Habrobracon*), it was found that all females were diploid whereas most of the males were haploid and developed from unfertilized egg and very few males were diploid.
- Diploid male were poorly viable.
- Similar type of result can be observed in honey bees, where male drone developed by parthenogenesis process.

4. Single gene sex determination:

- In microorganisms such as *Chlamydomonas, Neurospora* and *Saccharomyces* species, the sex is determined by a single gene. These microorganism have two separate mating type (+/-strains) which are determined by a pair of allele (gene). Sexual reproduction takes place when gametes from two opposite strain fused together. Gametes from same strain do not fuse in such organisms.
- Similarly in some plants and animals, sex is determined by a single gene. For examples, Male and female mosquito differ from each other in a single gene.
- An example of single gene sex determination is observed in maize. Maize is a monoecious plant with both male and female sex organs in same plant. If gene for both bassen cob and gene for tassel ear are in recessive form, then the monoecious plant is converted into dioecious plant (female).

5. Cytoplasmic theory of sex determination:

- In bacteria eg *E. coli,* extra chromosomal DNA called sex factor (F-plasmid) is responsible for sexuality.
- The bacteria containing F-plasmid is known as donor (male) and denoted as F+ cell while the bacteria lacking F-plasmid is known as recipient (female) and denoted as F-cell.
- During bacteria conjugation, donor cell transfer its F-factor into recipient cell and finally F- cell also become F+ cell.
- F- factor may integrate with DNA of donor cell and become Hfr cell (high frequency recombination) and can transfer its genetic material to recipient cell
- However, cytoplasmic factor is also responsible for sexuality is some microorganisms is postulated by this theory.

6. Nutritional theory of sex determination:

- It was proposed by Sharp (1934)
- According to this theory, sex determination is not only genetic but also depends upon the nourishment of gametes.

- For examples; In *Equisetum* (puzzlegrass), when its spore is grown under good growth condition, it develops into female whereas when grown under unfavorable condition, it develops into male.
- Similarly, in a marine worm (Dinophilus), size of egg determines the nature of sex. The small egg develops into male whereas large egg develops into female.

7. Environmental theory of sex determination:

- According to this theory, environmental factor plays direct or indirect role in determining sex of an organism.
- Every zygote contains all the responsible gene required for development of sex and expression of particular sex (male or female) is determined by internal or external environmental condition.
- In certain environmental condition, particular sex gene might get inhibited such that other sex gene get activated giving one type of sex and similarly in other environmental condition the process might get revered giving other type of sex.
- For example, in reptile like turtles, high temperature (30-35) induce the expression of female and low temperature (23-28) induce male sex.
- Also in plants like *Equisetum* (puzzlegrass), spore grown under optimum condition develops into female gametophyte and when grown under unfavorable condition develops into male.
- Other examples: In cucumber and melon, day lights length, temperature etc also differentiate sex.

8. Hormonal control theory of sex determination:

- In certain animals, hormone plays an important role in sex determination (differentiation).
- For examples- A marine worm
- The worm Bonellia is morphologically distinct. Male worm is sessile, lives inside uterus of female worm and smaller in size than female worm which is about 2 inch long.
- After fertilization of egg, larvae are releases in water. All larvae are cytogenetically identical.
- Those larvae, which comes in contact with mature female get attached to their proboscis and develop into male. These male then migrate to female reproductive organs and live a parasite. But those larvae which do not comes in contact with mature female develops into female worm.
- It has been found that the proboscis of mature female worm secrete hormone like substance which inhibits the larval gene determining female sex and allowing male gene to express.
- Other example; freemartin or hormonal intersex cattle

- If a cattle develops dizygotic twins of opposite sex, there is more chance of development of sterile female calf (freemartin) and a normal male calf.
- Freemartin develops only when foetal membrane of two embryos fused together such that cross circulation between two embryos occurs.
- It was found that during cross circulation, some of the hormone released by male embryo cross the placenta of female embryo and it inhibits the secondary sexual characters in female embryo and at the same time induce male characters. Such that the female embryo after birth become more like male but it is sexually female.