SEX DETERMINATION

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SEX DETERMINATION

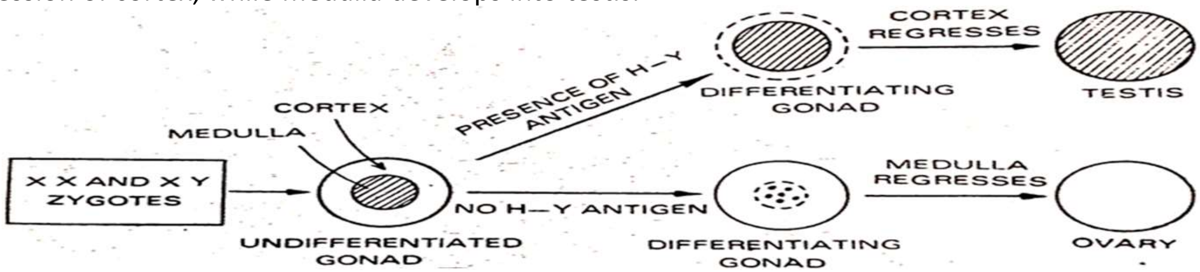
- In plants, specialized haploid cell produced through gametogenesis during meiosis which participates in fertilization, called gametes.
- In animals, gametes are produced in specialized reproductive organs, called gonads.

SEX CHARACTERS:

- In plants, male and female flower can not be differentiated from each other. There are different types of flowers such as bisexual or hermaphrodite, monoecious plants (maize, castor, coconut, etc.), dioecious plants (papaya, asparagus, etc.)
- In animals, male and female individuals differentiated in many characteristic features such as primary and secondary sex characters.
- Primary sex characters are related to gonads which producing organs in male and female individuals. The development of primary sex characters depends on the genes present in the zygotes. But these are not clearly understood.
- Secondary sex characters such as genital ducts, genitalia, facial hairs, mammary gland development, pitch of voice, degree of muscle development and subcutaneous fat deposition, etc which are developed in humans.
- The development of these characters is induced by the hormones produced by gonads.
- Interphase nuclei of females have a dark staining which is regular mass of chromatin and is known as sex chromatin or barr body, while it is absent in males.
- The presence of barr body is universally accepted as an unambiguous indication of femaleness of a human individual and is the basis of sex test in case of controversy.
- The barr body is produced due to the heterochromatinization of one of the two X-chromosomes found in human females.

GONAD DIFFERENTIATION IN ANIMALS

- After fertilization, a zygote is determined genetically to develop either as a male or a female.
- Gonads in the early stage of embryo development are undifferentiated which are neither male nor female due to two main regions: (i) central medulla, and (ii) peripheral cortex.
- During the later stages of embryonic development of XX zygotes, there is general regression of medulla accompanied with the development of cortex and gonad differentiate into ovary, while in XY zygotes, there is regression of cortex, while medulla develops into testis.



- In this mechanism, H-Y (Histocompatibity Y-chromosome-linked) antigen play the key role in gonad differentiation.
- Heterogametic sex (XY) is the dominant sex, while the homogametic sex (XX) is the neutral sex.
- The presence of H-Y antigen on the surface of embryonic gonad cells leads to the development of gonads of heterogametic sex. For example, in mammalian males and avian (bird) females.
- Once testis and ovaries are differentiated, their somatic cells produces males and females hormones which are develops of male and female reproductive organs and other sex characters
- In birds, when the production of female hormones by the ovaries is stopped due to a disease or some other reason, the developed medulla present in the ovaries may develop and change them into testis. Such bird develops a male phenotype and may function as a normal male, this phenomenon is called sex reversal, e.g., in poultry and other birds.

MECHANISMS OF SEX DETERMINATION

The various mechanisms of sex determination in plants and animals may be classified into three main groups: A. Environmental, B. Chromosomal, and C. Genic sex determination.

A. ENVIRONMENTAL SEX DETERMINATION

Zygotes do not differ genetically for sex differentiation. Sexual differentiation is determined by environmental factors.

IN ANIMALS: Example- In sea fishes.

- Labroides sea fishes which lives in a colony and their sex is determined by its colony member.
- A colony has a single male member, while the remaining members of the colony are females
- The male of a colony is the largest in body size, while the body size of the females of colony are according to their status in the colony.
- Therefore, the most dominant female is the largest among the females, if it is the last in social order.
- The smallest individual in the colony which has the gonad of a female fish, also contain the elements of female gonad in the rudimentary state.
- When male of a colony dies, the largest female of the colony begins to differentiate into male. This transition may take 14-18 days.
- Tus females of colony are infect hermaphrodite anatomically, but are functionally female.
- However, they are convert to maleness once, they are elevated to the number one position in the colony.

IN PLANTS

- Equiseptum plant grown under optimum conditions develops as females, but those grown under adverse condition become male.
- Melons, cucumber, cannabis, etc., the sex of flowers is affected by many environmental factors such as temperature, day length, ethylene, gibberellic acid, Ca and Mg ions, etc. A treatment with these hormones promote the production of female flower in otherwise male plants.

B. CHROMOSOMAL SEX DETERMINATION

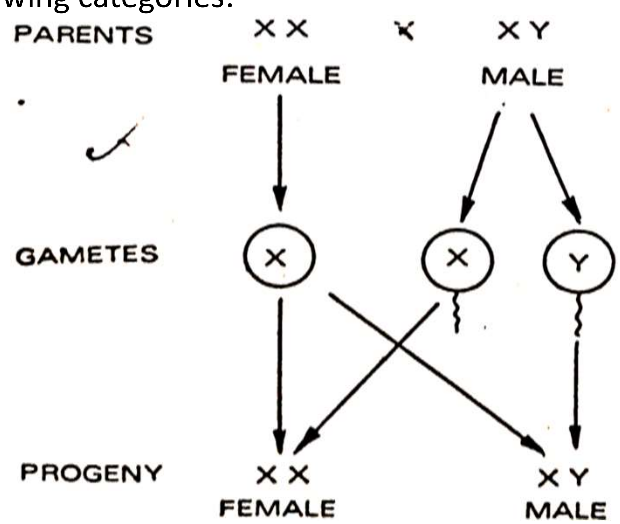
- It was bieved that sex determination is due to sex chromosome only, and that autosomes do not play any role in it. However, this may be true only in case of mammals and some plants, but not in many animals, e.g., Drosophila, bird and many plants.
- There are two types of sex chromosomes such as X and Y. The X-chromosome is found in both males and females, although, one sex has only one, while other sex has two X-chromosome.
- In contrast, the Y-chromosome ordinarily occurs only in one of the two sexes of species, e.g., male mice, male Drosophila, man, etc.; female bird, female reptiles, etc.
- Y-chromosome contains mostly heterochromatin and only few genes are located in it. In human, only one gene H-Y is present in the Y-chromosome.
- On the other hand, the X-chromosome is composed of euchromatin and the many genes located in it which show a peculiar pattern of inheritance, called sex linkage.

Chromosomal sex determination may be grouped into the following categories:

1. XX female and XY male

In this system, it is most common in plants and animals. In plants- Melondrium, Rumex acetosella, Humulus lupulus,Salix, Brayonia, etc.

Female have XX chromosome while male plants have one X and one Y chromosome, hence half of the pollen have one X chromosome and the remaining half of the pollen have a Y chromosome, but femal produce only one gamete. Rendom union between male and female gametes produces two types of zygotes: 50% of the zygotes are XX and give rise to female plants, while remaining 50% zygotes are XY and produce male plants.



In melondrium:

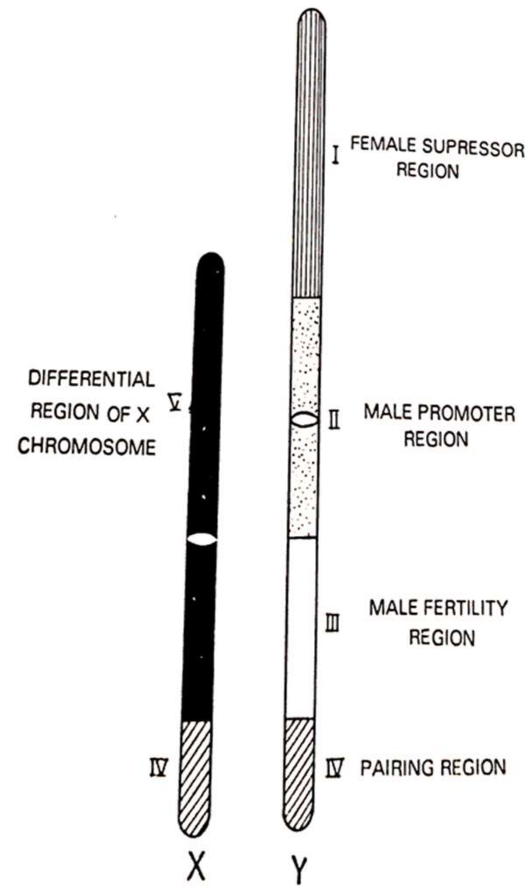
Y chromosome is the largest chromosome it has following four functionally distinct segments:

(I) The segment contain female suppressor region. A deletion for this segment produce hermaphrodite flowers on XY plants.

(II) This segment has male promoter gene. It initiate the development of anther. A deletion for this region give rise to female flower on XY plants.

(III) This segment contain gene governing male fertility and anther maturation. A deletion for this region produces male sterile plants. This segment is homologous of X chromosome. At this point, X and Y chromosome are paired during prophase-I of meiosis.

(IV) A large segment of X chromosome is non-homologous to the Y chromosome. It has genes for governing the development of female reproductive region.



In Rumex acetosella:

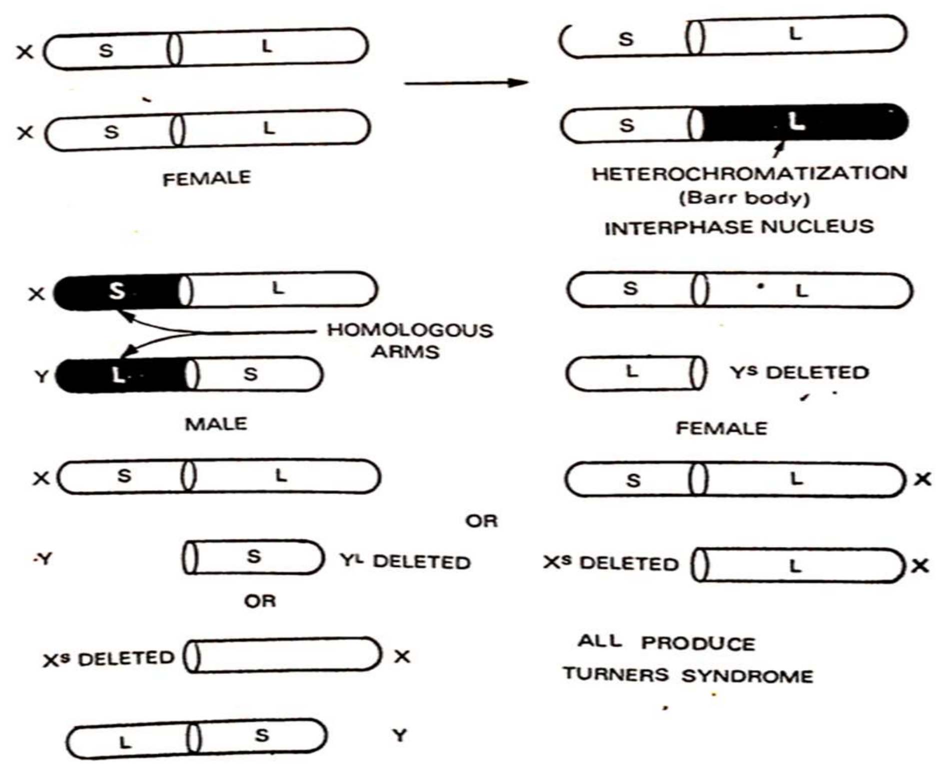
Ploidy level	Female	Male
2X (diploid)	XX	XY
4X (tetraploid)	XXXX	XXXY
6X (hexaploidy)	XXXXXX	XXXXXY
8X (octaploid)	XXXXXXXX	XXXXXXXY

IN ANIMALS

It is found in human, mice, mammals Hemiptera, Coleoptera, Diptera (Drosophila and fly), Some fishes, Some amphibia, etc. In these species, females are homogametic sex and have two X chromosome, while males are heterogametic sex and have one X and one Y chromosome. The Y chromosome is generally smaller than X chromosome.

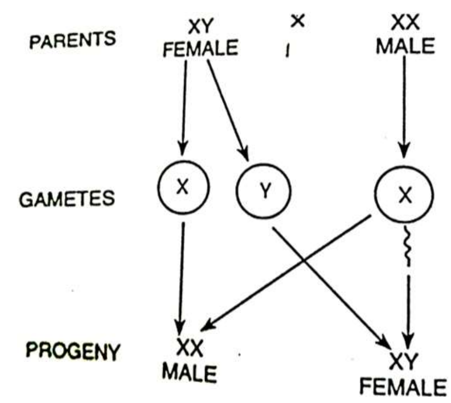
In Human

- The short arm of X chromosome (x^S) is believed to be homologous with the large arm of Y chromosome (Y^L).
- There is normal pairing and crossing over between x^S and Y^L. So that the genes located on x^S show normal disomic inheritance.
- Thus human males have two copies (one x^s and one Y^L). Which is essential for their normal development.
- The loss of one x^S of females and of the Y^L of males produces Turner's syndrome.
- The XO condition produces Turner's syndrome, while XXY, etc. lead to the development of Klinefelter syndrome. Such individuals show female and male phenotypes, respectively.
- Barr body is produced due to the inactivation of one x^Larm in females (XX).



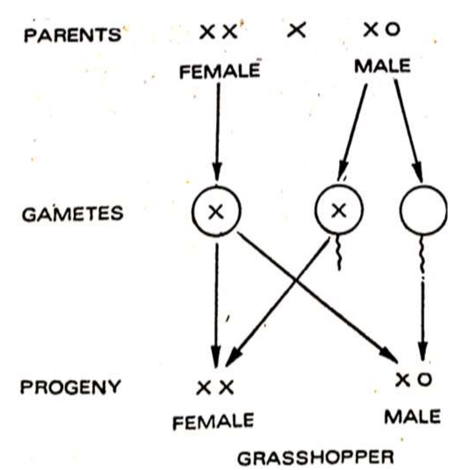
2. XY female and XX male

This system of sex determination operates in plants of Fragraris.
Female plants are XY and produces two types of egg cells: half of the egg cells have an X chromosome, while the remaining half have a Y chromosome. The male plants have XX chromosome and produces only one type of pollen (Y). A random union between male and female gametes produces 50% male zygote and 50% female zygote.
In Animal: Birds,Reptile, Some insects- silk worm, snakes, etc.
In these species, males are homogametic sex and have two X chromosome, while females are heterogametic sex and have one X and one Y chromosome.

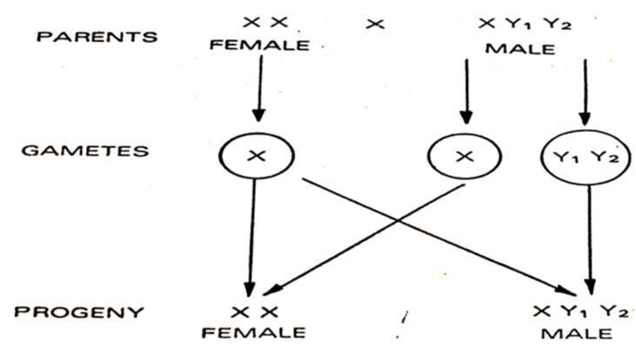


3. XX female and XO male:

This system of sex determination operates in plants of Dioscorea sinauta, Vellisneria spiralis, etc.
All the egg cells produced by female plants have one X gamete, while male produces half of the pollen grain with X chromosome and half of the pollen grain with O chromosome. A random union between male and female gametes produces 50% XX zygotes and 50% XO zygotes.
In Animal: Grasshopper, Protener, and Orthoptera insect, etc.
Female are known as homogametic sex which has XX chromosome. In male, single X chromosome remains unpaired during prophase-I and metaphase-I. Generally, it passes to one pole of the two poles at anaphase-I. As a result, two of the four sperms produced by one meiotic event receive one X chromosome, while the remaining two sperms do not receive any X chromosome. Thus half of the sperms in males have X chromosome, while the other half have none. Therefore, males are known as heterogametic sex.



4. XX female and XY_1Y_2



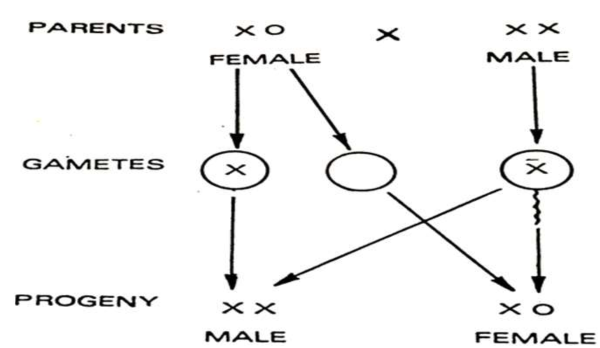
This system is found in plants like Rumex acetosa, Humulus joponicus, etc.

Female have XX chromosome, hence all their egg cells have one X chromosome, while male have XY_1Y_2 which produce half of the pollen with one X chromosome and half of the pollen with Y_1Y_2 chromosome. A random union between male and female gametes, produces XX female zygote and X Y_1Y_2 male zygote.

In Animal: Drosophila.

The sex of an individual is determined by a balance between the genes for maleness present in the autosome and those for femaleness located in the X chromosome. The Y chromosome (Y_1Y_2) do not play any role in sex determination.

5. XO female and XX male



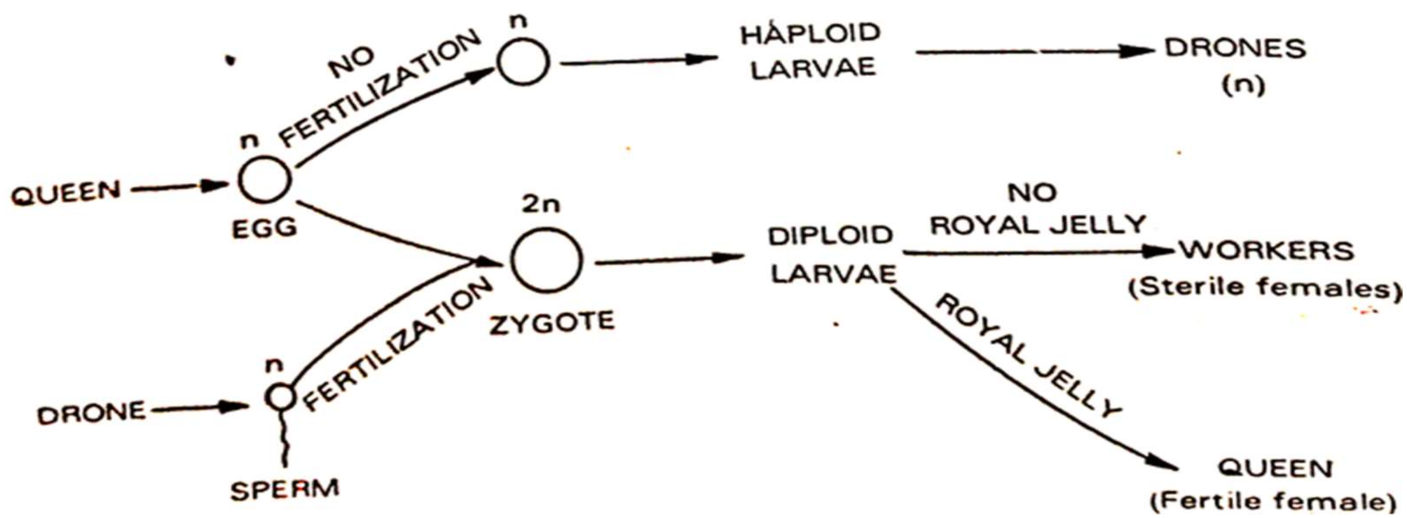
This system is known only in animal like Fumea insect. This system is not found in plant.

Female have only X chromosome which produce half egg cells (X chromosome) and half no X chromosome and they are heterogametic sex, while males have wo X chromosome which have all the sperm one X chromosome and they are homogametic sex. The union between male and female produce XX male zygote and XO female zygote.

6. Diploid (2n) female and haploid (n) male

In animal, this system is found mainly in Hemineptera (e.g., Honey bee, Ants,Termides).

Female is diploid (2n), while male is haploid (n). This fact is demonstrated by **Dzierzon** (1850). During spermatogenesis, all the n chromosome of male regularly pass to a single pole at anaphase-I. So that opposite pole have no chromosome at all. Thus all the sperms are regularly haploid which is union to eggs produce diploid larvae. Generally, such larvae give rise to **workers** which are sterile females. But diploid larvae fed on royal jelly develop into fertile female, called **queen**. Royal jelly contain honey, pollen and some substances (hormones) secreted by workers. Unfertilized eggs developed parthenogenetically to produce haploid larvae and ultimately fully fertile haploid males, called **drone**.



GENIC SEX DETERMINATION

This system is found in some plants such as papaya, spinach, Vitis cineria, asparagus, etc.

IN PAPAYA

- A single gene with three alleles (m, M1 and M2) is to be control the sex determination.
- Female plants are homozygous for mm, while male plants are heterozygous for M1m. The genotypes M1M1, M1M2 and M2M2 inviable, that is M1 and M2 alleles are recessive lethal.

I. Mating between female (mm) and male (M1m) produce 50% M1m male and 50% mm female progeny.

II. Similarly mating between female (mm) and a hermaphrodite (M2m) plants produce 50% hermaphrodite (M2m) and 50% female (mm).

III. When hermaphrodite plants are selfing, and it produces 2/3 hermaphrodite (M2m) and 1/3 female (mm) plants, and about ¼ zygotes are M2M2 and do not survive.

IN MAIZE

Plants are monoecious.

- A single recessive gene, ba (barren cab), and dominant gene Ba is responsible for development of cab (female inflorescence) when it is in homozygous state.
- The cabs remain undeveloped in ba ba plant, making these plants functionally male. (male plant in place of monoecuous)
- Dominant gene Ts is responsible for development of pollen (male inflorescence) when it is in homozygous state.
- Recessive gene (ts) convert the male flowers in tassels of ts ts plants into female flower. (female plant in place of monoecuous)
- As a result, the tassels of ts ts plants do not produce pollen, but they set seed. This is known as tassel seed which are functionally female.
- If plants are homozygous for both ba and ts ,i.e., baba tsts. The cabs are undeveloped (rudimentary) and barren, but many seeds are produced in the tassel which are functionally female.
- Clearly, two recessive genes (baba tsts) have converted monoecious maize plants into a dioecious plants.

genotypes	Survival	Individuals
mm	Vital	Female
M1m	Vital	Male
M2m	Vital	Hermaphrodite
M1M1, M1M2 and M2M2	Lethal (all die)	-

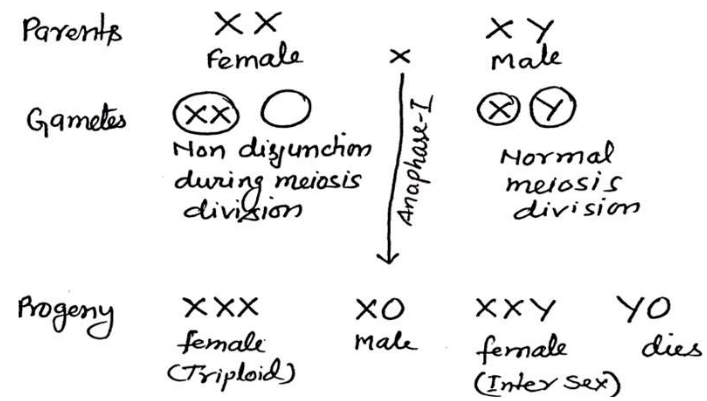
Monogenic sex determination in papaya

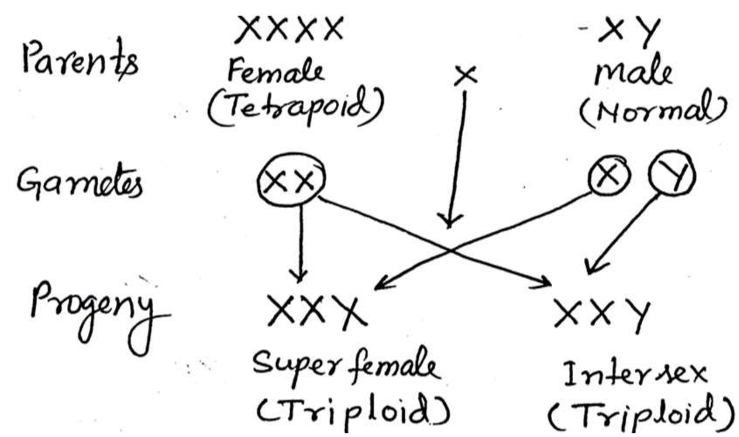
Genotypes	Female flowers (Cab)	Male flower (Tassel)	Sex expression
BaBa TsTs	Normal	Normal	Monoecious
baba TsTs	Rudimentory	Normal	Male
BaBa tsts	Normal	Develop into female flower	Female
baba tsts	Rudimentory	Develop into female flower	Female

Sex determination in maize

SEX DETERMINATION BY GENIC BALANCE (Genic balance theory)

- Mostly animals and plants, XX zygotes produce femaleness and XY zygotes produce maleness.
- The specific (X and Y) chromosome themselves determine the sex of zygotes. Some specific genes located in these chromosomes should be involved in sex determination, called autosome.
- Chromosomes other than sex chromosomes; their kind and number is the same in males and females of a species, it is known as autosome.
- A condition to that effect was reached by Bridge (1921), how finally proposed his well recognized genic balance theory of sex determination in Drosophila.
- Bridge (1916) discovered XXY female and Xo male, while studying the inheritance of vermillion eye gene located in the X chromosome, which showed that XX and XY chromosomes were not essential for femaleness and maleness and that Y chromosome did not play a role in sex determination.
- Bridge (1925) obtained tetraploid females when tetraploid females mated with normal diploid males produce a number of aneuploid situations. The progeny from such a cross showed five different sex expression such as super female, female, intersex, male and super male.
- Bridge developed the genic balance theory of sex determination on the basis of correlating the sex of an individual with its chromosome constitution.
- Sex expression in Drosophila as a function of the ratio of the number of X chromosomes and the number of autosomal sets present in an individual (sex ratio= X/A)





SEX INDEX

- The genic balance theory state that the sex of an individual is determined by a balance between X chromosome and an autosome sex.
- In Drosophila, genes for maleness are present in autosomes, while genes of femaleness are located in the X chromosome.
- A single X chromosome are stronger than one set of autosomes, when the number of X chromosome and that autosome set is equal in an individual, it produce into female. When the number of X chromosome is exactly half of the number of its autosome set, produce into a male. This ratio is known as sex index.

$$\text{Sex index} = \frac{\text{Number of } X \text{ chromosomes } (= X)}{\text{Number of autosomal sets } (= A)} = X/A$$

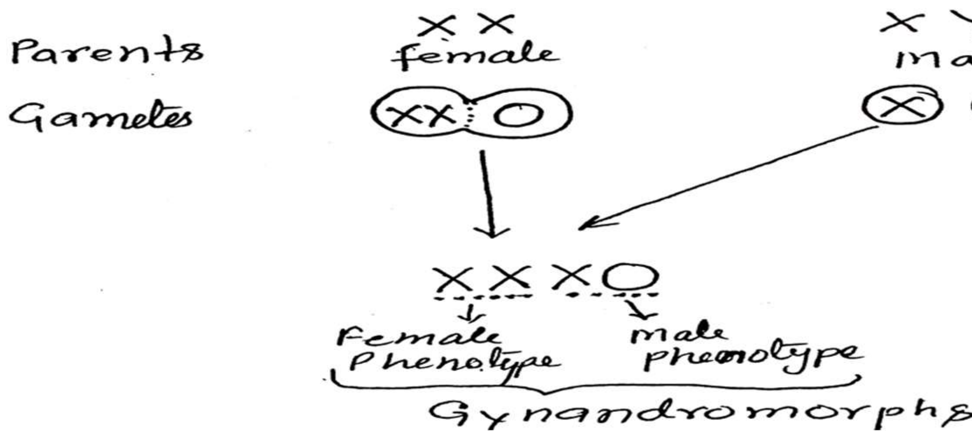
Individuals with the sex index of 1.0 are normal female, and they are XX, XXX, or XXXX.

- Similarly, flies having the sex index of 0.5 are normal male, and they are XO, XXOO, XXYY.
- Those flies that have a sex index between 1.0 and 0.5 developed into inter sex, inter sex are neither male nor female and are completely sterile.
- Some aneuploid flies have the sex index in excess of 1.0, these individual have a more pronounced female characteristic than normal female, and are called super female which are generally weak and sterile and often inviable.
- Super male flies have a sex index of less than 1.0, are weak, sterile and often inviable.

Si. No.	Polyploid	No. of X chromosome (=X)	No. of Autosome set (=A)	Sex index (X/A)	Sex expression
1	2n (XXO)	3 (XXX)	2 (AA)	3/2=1.5	Super female
2	3n (XXXO)	4 (XXXX)	3 (AAA)	4/3=1.33	Super female
3	4n (XXXX)	4 (XXXX)	4 (AAAA)	4/4=1.0	Female (tetraploid)
4	3n (XXX)	3 (XXX)	3 (AAA)	3/3=1.0	Female (triploid)
5	2n (XX)	2 (XX)	2 (AA)	2/2=1.0	Female (diploid)
6	4n (XXXY)	3 (XXX)	4 (AAAA)	¾=0.75	Inter sex
7	3n (XXY)	2 (XX)	3 (AAA)	2/3=0.67	Inter sex
8	2n (XY)	1 (X)	2 (AA)	½=0.5	Male (diploid)
9	4n (XXYY)	2 (XX)	4 (AAAA)	2/4=0.5	Male (tetraploid)
10	3n (XYY)	1 (X)	3 (AAA)	1/3=0.33	Super male

GYNANDROMORPHS

- In Drosophila, some individual show male characteristic in a part of their body, while their remaining parts show the female phenotype. Such individuals are known as gynandromorphs.
- The male phenotype in gynandromorphs; on one extreme; may extend to about one half of the body.
- In some flies, male and female parts run longitudinally, while in some others they run transversely.
- Gynandromorphs are always mosaic for the X chromosome, the parts with male phenotype are always XO, while those with the female phenotype are XX.
- It has been suggested that gynandromorphs arise from XX zygotes. During embryonic development in one or more cells, one of the two X chromosomes does not pass to any pole at anaphase-I, and as a result, is last, Consequently, one or more daughter cells having a single X chromosome are produced; those cells divide and give rise to the male parts of gynandromorphs.



SEX-INFLUENCE CHARACTERS

- Generally, the same dominant allele of a gene is present in both the males and females of a species, and dominant relationship at a locus is not affected by sex.
- But in some cases, dominance relationship of their alleles is affected by sex of individuals in which they are present.
- As a result, one allele is dominant in males, while the other is dominant in females of a species, it is referred to as sex-influence characters.
- Examples: Horns in sheep, red and mahogany coat colour in cattle, crown boldness (b) in human harelip, gout and white forelock in human, etc.
- For horns characters in sheep, both males and females of the Dorset breed have horns, while those of Suffolk are hornless, both are crossed together.
- In F1 progeny, males have horned, while all the females are hornless. In F2 generation, 3 horned : 1 hornless ratio is obtained in males, while females show the ratio 3 hornless : 1 horned.
- These finding are summarised: (i) the allele producing horns (H) is dominant over that producing hornless (h) in males. (ii) the heterozygous (Hh) males will produce horns, while Hh females will remain hornless.

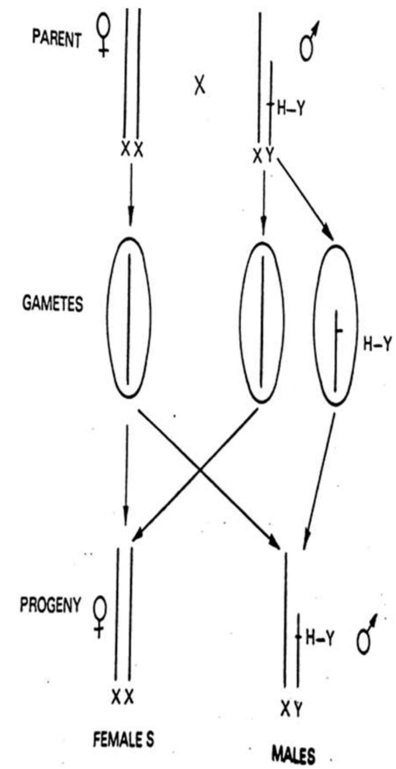
Population	Genotype	Frequency	Phenotype	
			Males	Females
Dorset	HH	All	Horned	Horned
Suffolk	Hh	All	Hornless	Hornless
F1	Hh	All	Horned	Hornless
F2	HH	¼	Horned	Horned
	Hh	2/4	Horned	Hornless
	hh	1/4	Hornless	Hornless

- In crown baldness in human, this character is produced by gene b, because b is dominant in male, but recessive in female. So, B gene produced normal phenotype.
- Heterozygous (Bb) male produced baldness, while Bb female are normal phenotype.
- A female will developed crown baldness only when it is homozygous bb.
- Therefore, sex-influence characters are markedly more common in one sex than in the other.

SEX-LIMITED CHARACTERS

- Generally, genes express themselves in both the sexes, although the dominance alleles of some genes may be modified by sex.
- But some genes express themselves in only one of the to sexes, although they are present in the appropriate genotype in the individuals of both the sexes.
- "Those characters whose development is limited to only one sex are known as sex-limited characters".

- In Drosophila, maleness is produced by genes present in the autosomes, while gene governing femaleness are located in X-chromosome. But both males and females have autosomes as well as X-chromosomes.
- As a result, they both have genes for maleness and femaleness, but only one or other is expressed making them either male and female.
- For milk production in cattle, gene governing milk production in cattle, these genes are present in both males and females, but they are expressed only in females.
- For egg production in poultry, gene controlling egg production in poultry are contributed by both male and female parents, but they are expressed only in female.
- Holandric characters or male limited in human beings, the Y-chromosome is transmitted from father to son only.
- Consequently, traits produced by the genes located in the Y-chromosome are also passed from father to son only, and they never appear in females.
- Therefore, such characters are referred to as male limited or holandric characters.
- Holandric genes are controlling male fertility in man and Drosophila.
- The H-Y gene governing histocompatibility in man and possibly the gene governing the presence of hairs on human ears.
- H-Y gene is responsible for hairs appear on human ears.



SEX LINKAGE

- Sex linkage is the consequence of a gene being located in the X or sex chromosome, which occurs in different numbers in the two sex(XX in one sex and only X in the other).
- The phenomenon of sex linkage was presented by Morgan (1910) for white eye gene (w) in Drosophila.

- The location of w gene in the X-chromosome is indicated by writing it as a superscript of X.
- All the eggs of the red-eyed female will be XW, while half the sperms of the white eyed male will be Xw and the other half will be Y.
- A random union between male and female gametes will produces red eyed female and red eyed male flies, respectively.
- Segregation in the F1 families XW Xw will produce two types of eggs, XW and Xw in equal frequency.
- Similarly, the F1 males (XW Y) will also produce two types of sperms, XW and Y in equal frequency.
- A random union between male and female gametes will produce the following four types: XW XW and XW Xw (females), and XW Y and Xw Y (males). The first two of these would produce red eyed females, third a red eyed male and the fourth a white eyed male.
- In reciprocal cross, a white eyed female Xw Xw was mated with a red eyed male XW Y. All the eggs of female will be Xw, while the male will produce XW and Y sperms in equal frequency.
- In the F1, two types of zygotes will be produced: XW Xw (red eyed females) and Xw Y (white eyed males).
- The F1 females XW Xw will produce XW and Xw eggs, while F1 males Xw Y will produce Xw and Y sperms.
- A random union between eggs and sperms will produce four types of zygotes: XW Xw and Xw Xw (females), and XW Y and Xw Y (males)
- The first zygotic combination will give rise to a red eyed female, the second Xw Xw to a white eyed female, the third XW Y to a red eyed male and fourth Xw Y to a white eyed male.
- Thus the hypothesis that w gene is located in the X-chromosome and that it has no allele in the Y-chromosome is adequate to explain the peculiar inheritance pattern of the white eye trail in Drosophila.