Sex linked inheritance

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College of Science/ Department of Biology
Course: Genetics
Lecture: 4

- **SEX LINKED GENES**
- **SEX-LIMITED GENES**
- **SEX-INFLUENCED GENES**
- Characters for which genes are located on sex on X chromosomes are known as sex linked traits.
- Genes controlling these traits are called sex linked genes.

- The genes which occur exclusively on the X chromosome (mammals, Drosophila, Melandrium, etc.) or on the analogous Z chromosome (in birds and other species with ZO or ZW mechanism of sex determination) are called

  X- or Z -linked genes.
- Most genes for sex link traits are present only on the X chromosome. The Y-chromosome is smaller (Very few genes are located on Y chromosome).
- Because of their location in the sex chromosomes, they are said to be *"sex* linked *traits"*
- The genes which exclusively occur in Y chromosome are called **holandric genes**.
- The inheritance of X- or Z-linked and holandric genes is called **sex-linked inheritance**

sex-linked genes can be classified into following three types

- **X-linked**. is performed by those genes which are localized in the nonhomologous sections of X-chromosome, and that have no corresponding allele in Y chromosome. The X-linked genes are commonly known as sex-linked genes.
- **Y-linked**. is performed by those genes which are localized in the non-homologous section of Y chromosome, and that have no alleles in X-chromosome. (**Holandric genes**)
- **XY-linked**. is performed by those genes which are localized in homologous sections of X and Y chromosomes

Characteristics of Sex-linked Inheritance

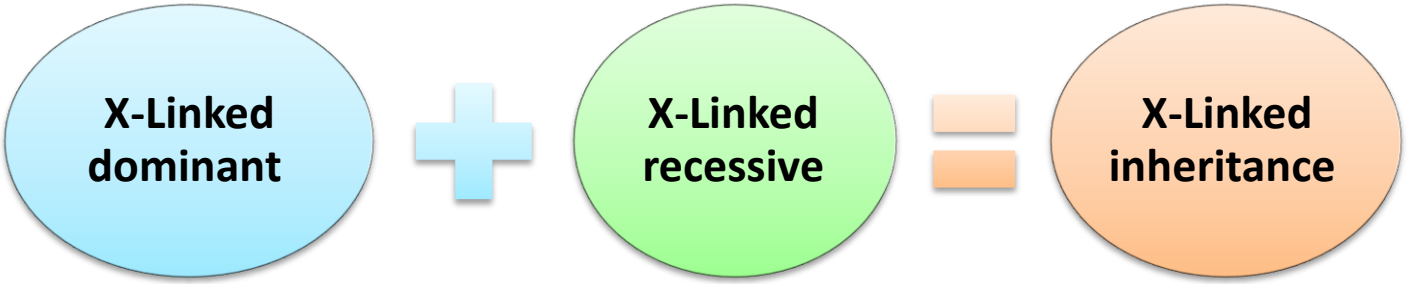
a. The pattern of inheritance of sex linked trait is criss-cross. It is the transmission of a gene from mother to son or father to daughter. Those patterns of inheritance are called crisscross inheritance or skip generation inheritance, in which a character is inherited to the second generation through the carrier of first generation. The father cannot pass a sex linked allele to a son directly.

b. The mother can pass the allele of a trait to both daughter and son.

c. Only homozygous females can express a recessive trait, while heterozygous female are carriers and do not express the trait.

d. Males express the trait immediately because of the absence of a corresponding allele. This is the reason why males suffer from sex linked disorders more than females.

e. Most of the sex linked traits are recessive. Some examples of sex linked traits include Haemophilia or Bleeder's disease, Daltinism or Colour blindness



Sex linked genes show the dominance recessive relationship only in **homogametic sex** (e.g. female in humans) because it can carry two alleles at the sex linked locus. So, female can be homozygous or heterozygous.

- In the **heterogametic sex** (males in humans and females in birds) do not show dominance recessive relationship because the existence of only a single X or Z chromosome.
- The term **hemizygous** is used for X linked gene in males as they carry only one allele with regard to sex linked trait (In birds the female is hemizygous).

Dominant X-linked genes

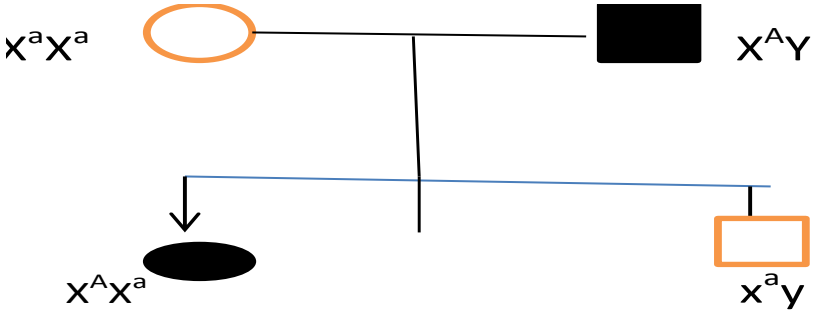
can be detected in human pedigrees (also in Drosophila) through the following clues :

❖It is more frequently found in the female than in the male of the species.

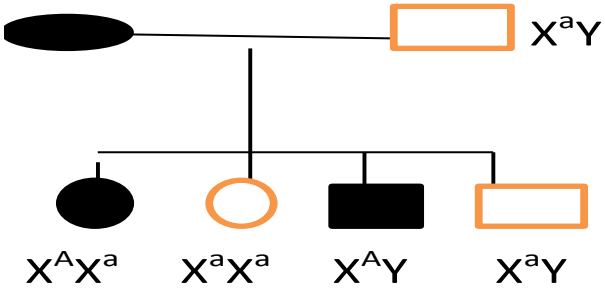
❖ The affected males pass the condition on to all of their daughters but to none of their sons

❖Females usually pass the condition (defective phenotype) on to one-half of their sons and daughters

❖ X-linked dominant gene fails to be transmitted to any son from a mother which did not exhibit the trait itself.

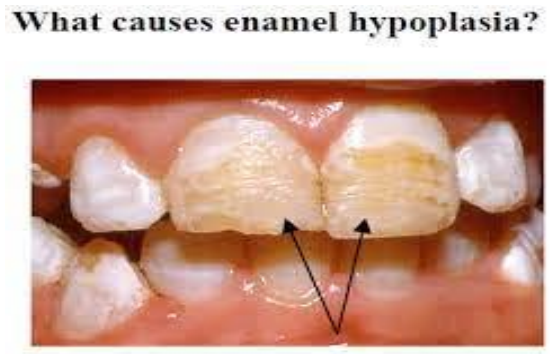


- Pedigree chart showing how X-linked dominants are expressed in all the daughters of affected males



Pedigree chart showing that females effected by an X-Linked dominant condition usually heterozygous and pass the condition to one- half of their progeny

- In humans, X-linked dominant conditions are relatively rare. example is
- hypophosphatemia **(XLH)** - vitamin D-resistant rickets).
- hereditary enamel hypoplasia (hypoplastic amelogenesis imperfecta), in which tooth enamel is abnormally thin so that teeth appear small and wear rapidly down to the gums



The X-linked recessive genes

- it show the following two more peculiar features :criss-cross pattern of inheritance (i.e., in criss-cross inheritance, a X-linked recessive gene is transmitted from P1male parent (father) to F2 male progeny (grandsons) through its F1 heterozygous females (daughters), which are called carriers) and different F1 and F2 results (ratios) in the reciprocal crosses.
- The X-linked recessives can be detected in human pedigrees (also in Drosophila) through the following:-

i) The X-linked recessive phenotype is usually found more frequently in the male than in the female.??This is because an affected female can result only when both mother and father bear the X-linked recessive allele ($X^AX^a \times X^aY$), whereas an affected male can result when only the mother carries the gene. Further, if the recessive X-linked gene is very rare, almost all observed cases will occur in males.

(ii) Usually none of the offspring of an affected male will be affected, but all his daughters will carry the gene in masked heterozygous condition, so one half of their sons (i.e., grandsons of F1 father) will be affected

(iii) None of the sons of an affected male will inherit the X-linked recessive gene, so not only will they be free of the defective phenotype; but they will not pass the gene along to their offspring

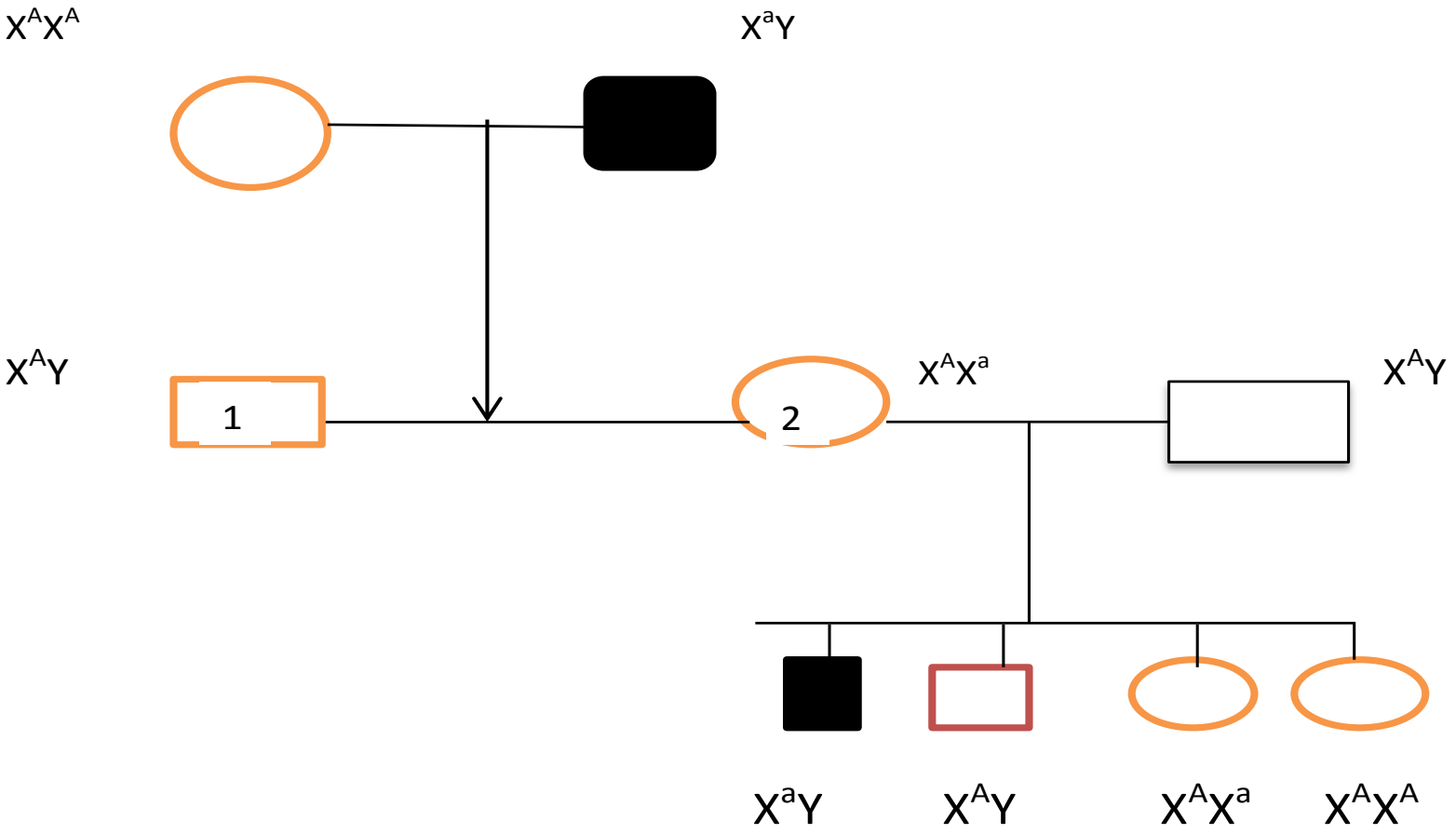


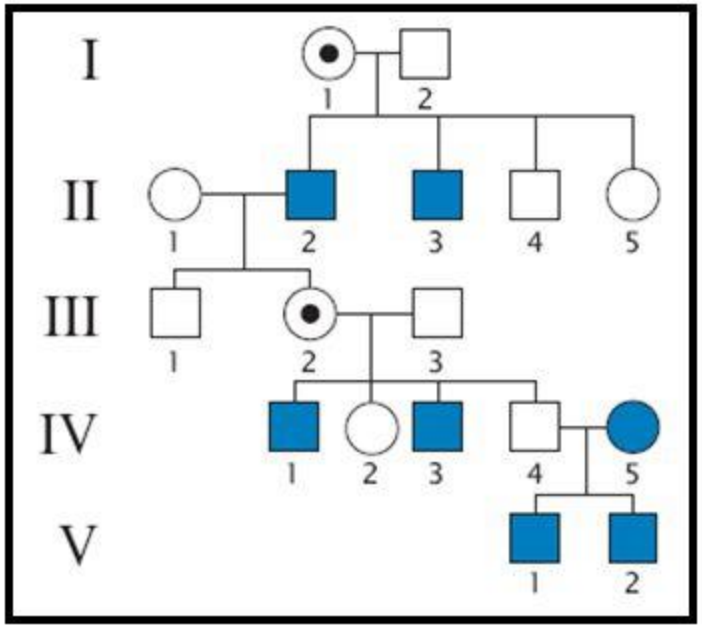
Fig. Pedigree showing how X-linked recessive genes are expressed in males, then carried unexpressed by females in the next generation, to be expressed in their sons. II.3 and III.4 heterozygous or carrier females are not distinguished phenotypically

X linked Recessive Pattern

- An idealised pattern of inheritance of an X-linked recessive trait includes the following features:
  - all the sons of a female with the trait are affected
  - all the daughters of a male with the trait will be carriers of the trait and will not show the trait; the trait can appear in their sons
  - none of the sons of a male with the trait and an unaffected female will show the trait, unless the mother is a carrier
  - all children of two individuals with the trait will also show the trait
  - in a large sample, more males than females show the trait.

Examples include:

- Ichthyosis, an inherited skin disorder
- One form of red–green colour-blindness
- One form of severe combined immunodeficiency disease
- Haemophilia
- Fragile X syndrome
- Duchenne muscular dystrophy



Example of Inheritance of X-Linked Recessive Genes

The crisscross inheritance of recessive X- linked genes can be well understood by following classical examples in Drosophila, man, moth and chikens etc.:

1. Inheritance of X-Linked Gene for Eye Colour in Drosophila

In Drosophila, the gene for white eye color is X-linked and recessive to another X-linked ,dominant gene for red-eye color. It is discovered by Morgan in 1910.

Following crosses between white eyed and red eyed Drosophila will make clear the characteristic criss-cross inheritance of gene for white eyed color in it :

(a) Red eyed female × White eyed male If a wild red eyed female Drosophila is crossed with a mutant white eyed male Drosophila, all the F1 individuals irrespective of their sex have red eyes

P X^RX^R *X* X^rY

F1 X^RX^r , X^RY

Red eyed female , Red eyed male

- When the red eyed male and red eyed female individuals of F1 are intercrossed,

X^RX^r X X^RY

X^RX^R, X^RY , X^RX^r , X^rY

Red eyed female, red eyed male, Red eyed female, white eyed male

3 red : 1white eyed

- the F2 progeny is found to include an exclusively red eyed female population and a male population with 50 per cent red eyed individuals and 50 per cent white eyed individuals. Thus, F2 generation includes red eyed and white eyed individuals in the ratio of 3: 1.

(b) **White eyed female × Red eyed male**. When a white eyed female Drosophila is crossed with a red eyed male Drosophila, all the female individuals in the F1 generation are red eyed

X^rX^r x X^RY

X^RX^r , X^rY

Red eyed female , white eyed male

•When these red eyed female individuals and white eyed male individuals of F1 are intercrossed,

X^RX^r x X^rY

X^RX^r , X^RY, X^rX^r, X^rY

Red eyed female , Red eyed male , white eyed female , white eyed male

•the female population of F2 generation is found to include 50 per cent red eyed and 50 per cent white eyed flies. Similarly, the male population of F2 includes 50 per cent, red eyed and 50 per cent white eyed flies.

The results of these experiments, thus, are clearly indicating that the trait located on a sex chromosome alternates the sex from one generation to the next generation, i.e, the trait of white eyes transfers from P1 father to F1 daughter and from F1 daughter to F2 son.

Inheritance of X-Linked Recessive Genes in Humans

In human beings more than 150 confirmed or highly probable X-linked traits are known; most of these are recessives. Certain well known examples

- red- green colour blindness or daltonism,
- haemophilia
- Duchenne's muscular dystrophy.
- G6PD deficiency - deficiency of enzyme glucose-6 phosphate dehydrogenase ,in erythrocytes causing haemolytic anaemia during allergy reaction of persons for the drugs such as sulphonamides or for the broad bean (Vicia faba), called favism;
- night blindness
- white frontal patch of hair.

Colour blindness

a dominant X- linked gene is necessary for the formation of the colour sensitive cells, the cones, in the retina of eye. According to trichromatic theory of colour vision, there are three different types of cones, each with its characteristic pigment that react most strongly to red, green and violet light. The recessive form of this gene (i.e., presence of recessive X-linked allele for colour blindness) is incapable of producing the colour sensitive cones and the homozygous recessive females **(X^c X^c)** and hemizygous recessive males **(X^c Y)** are unable to distinguish between these two colours.

- **The frequency of colour blind women is much less than colour blind man?**

(i) Marriage between colour-blind man and normal vision woman.

When colour-blind man marries with a normal vision woman, then they will produce normal vision male and female individuals in F1. The marriage between a F1 normal vision woman and normal vision male will produce in F2 two normal vision female, one normal vision male and one colour-blind male

Normal female Colour-blind male

Parent : $X^+ X^+$ X $X^c Y$

Gametes : (X^+) (X^c) (Y)

F1: ½ X^+X^c : ½ X^+Y

(ii) Marriage between a carrier female and a normal male produces the

carrier female x Normal male

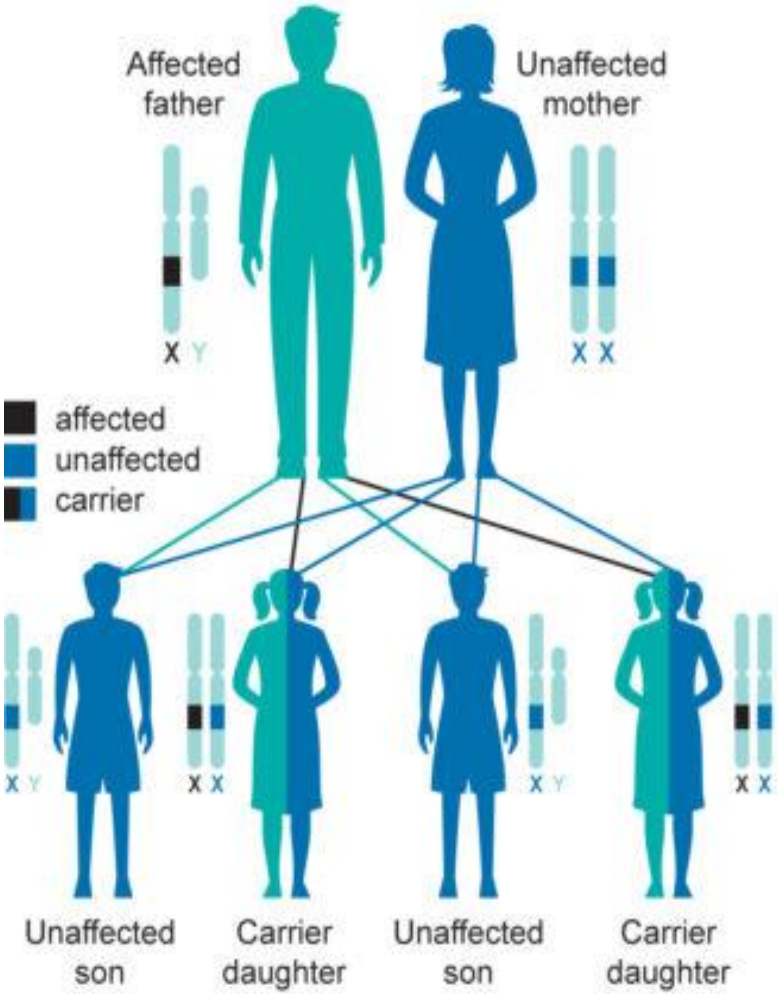
P2 X^+X^c X^+Y

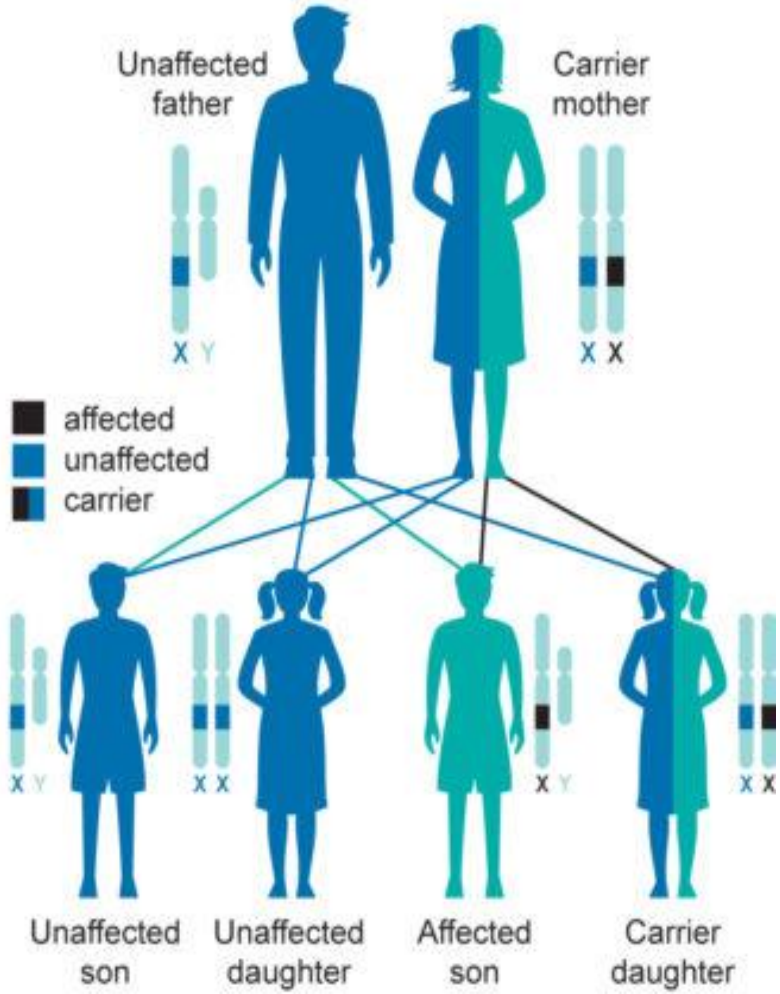
G2 X^+, X^C X^+, Y

F2 X^+X^+, X^+Y, X^+X^C, X^CY

Normal female Normal male carrier female Colour-blind male

X-Linked Recessive Inheritance





Hemophilia

is the most serious and notorious disease which is more common in men than women. This is also known as bleeder's disease. The person which contains the recessive gene for hemophilia lacks in normal clotting substance (thromboplastin) in blood so minor injuries cause continuous bleeding and ultimate death of the person due to hemorrhages. This hereditary disease was reported by John Cotto of Philadelphia in 1803 in man.

(a) Hemophilia A. It is characterized by lack of anti hemophilic globulin (Factor VIII). About four fifths of the cases of hemophilic are of this type.

(b) Hemophilia B. It is also called **"christmas disease"** after the family in which it was first described in detail. Hemophilia B results from a defect in plasma thromboplastic component (factor IX). This is milder form of hemophilia.

Parents : X^+X^h × X^+Y

Normal mother(carrier) Normal father

Gametes: (X^+) (X^h) (X^+) (Y)

Progeny : X^+X^+ , X^+X^h , X^+Y , X^hY

Normal daughter, Normal (carrier), Normal , Hemophilic

B. INHERITANCE OF Y-LINKED GENES

Genes in the non-homologous region of the Y chromosome pass directly from male to male.

❖In man, the Y-linked or holandric genes are transmitted directly from father to son Having hairy ears was once thought to be a Y-linked trait in humans, but that hypothesis has been discredited.

❖It has often been said that little is known about genes that may be Y-linked. This is no longer true. As of the year 2012, about three dozen genes were known to be Y-linked including:

❖ASMTY (which stands for acetyl serotonin methyltransferase)

❖TSPY (testis-specific protein)

❖Y-Chromosome deletions are a frequent genetic cause of male infertility. In some males a small deletion in the DAZ gene (deleted in azoosprmia) on the Y chromosome cause **azoospermia**

•SEX-INFLUENCED GENES

are **autosomal genes** those whose dominance is influenced by the sex of the bearer. Thus, male and female individuals may be similar for a particular trait but give different phenotypic expressions of the same trait..

Example :

1- In man the baldness may occur due to disease, radiation or thyroid defects but in some families balldness is found to be inherited trait. In such inherited baldness the hairs gradually become thin on head top, leaving ultimately a fringe of hair low on the head and commonly known as pattern baldness. The gene B for baldness is found to be dominant in males and recessive in females. In heterozygous condition it expresses itself only in the presence of male hormones (in male sex):

Genotype	**Phenotypes**	
	Men	women
BB	Bald	Bald
Bb	Bald	Non-bald
bb	Non-bald	Non-bald

2- In sheep, the genes for the development of horns is dominant in males and recessive in female.

SEX-LIMITED GENES

Sex-limited genes are **autosomal genes** whose phenotypic expression is determined by the presence or absence of one of the sex hormones. Their phenotypic effect is limited to one sex or other. In other words, the penetrance of a sex-limited gene in one sex remain zero.

Sex-limited genes are responsible for sexual dimorphism, which is a phenotypic (directly observable) difference between males and females of the same species. These differences can be reflected in size, color, behavior ,Example

1. The bulls have genes for milk production which they transmit to their daughters, but they or their sons are unable to express this trait. The production of milk is, therefore, limited to variable expression only in the female sex.
2. Beard development in human beings is a sex limited trait as men normally have beards, whereas women normally do not. Likewise, the genes for male voice, body hair and physique are autosomal in human beings, but they are expressed only in the presence of androgens which are absent in females.
3. In chicken the recessive gene (h) for cock feathering is male sex-limited (i.e., it is penetrant only in male environment)

Genotype	**Phenotypes**	
	male	female
HH	Hen feathering	Hen-feathering
Hh	Hen feathering	Hen-feathering
hh	Cock feathering	Hen-feathering