Sex-linked, sex-limited and sex-influenced inheritances

Contents: Definition- Sex-linked inheritance; Discovery; Characteristics; Examples in man; Examples in *Drosophila*; Sex-limited and sex-influenced traits and their inheritance; Suggested reading.

Definition

The inheritance of certain traits that are controlled by genes located on the sex chromosomes of an organism is referred to as sex-linked inheritance

Discovery

Sex-linked inheritance was first described in *Drosophila melanogaster* by T. H. Morgan (1910), who discovered the white eye mutant in the fly.

Fig. 6.1 Thomas Hunt Morgan (1866-1945), who was awarded Nobel Prize in 1933

Characteristics of sex-linked inheritance

1. Sex-linked recessive genes are transmitted from the affected male parent to grandsons through his daughters. This is known as 'criss-cross' inheritance or 'skip generation';
2. The female parent is often the carrier of such recessive genes, and frequency of the affected females is much less than that of the affected males;
3. An X-linked trait is never transmitted directly from fathers to their sons;
4. Whereas the Y-linked traits are transmitted directly from fathers to their sons.

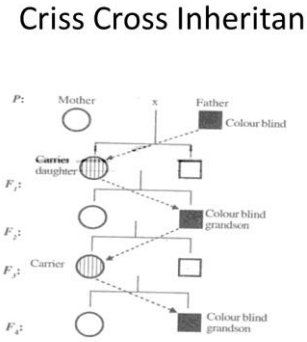


Fig. 6.2 An example of criss-cross transmission for colour blindness in man

Examples of sex-linked inheritance in man

X-linked recessive traits:

- Colour blindness (Colour vision deficiency)
- Haemophilia
- Duchene muscular dystrophy
- Lesch-Nyhan syndrome etc

X-linked dominant traits:

- Retinitis pigmentosa
- Ret syndrome
- Hunter's syndrome
- Vitamin D resistant rickets etc.

Y-linked traits:

- Hairy pinnae (hypertrichosis of ears)
- Testis determining factor
- Male fertility etc.

Colour blindness in man

It was discovered in 1911. This is due to a recessive gene on the X chromosome that affects the functioning of the colour sensitive cones of the retina. Colour blindness in man is mainly of three following types:

1. Deuteran or 'green blind', most common, ~8% males and 0.5% females are affected, controlled by *OPN1LW* gene
2. Protan or 'red blind', less common, males and females are equally affected, 1 in 10,000 people, controlled by *OPN1MW* gene
3. Tritan or 'total blind', least common, 1 in 100,000 people, males are more affected than females, controlled by *OPN1SW* gene

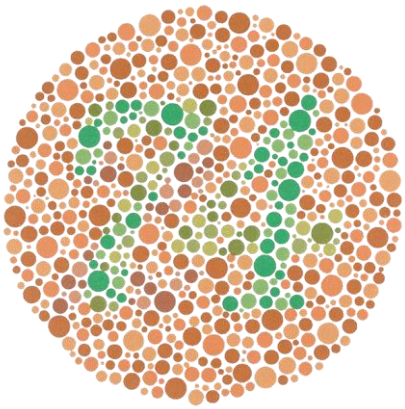


Fig. 6.3 Colour blindness in man could be diagnosed by Ishihara colour test shown above. Normal persons can read the number 8 in the diagram, whereas a colourblind person cannot read the number

Inheritance of colour blindness in man

The possible genotypes of mothers could be normal (X^+/X^+), carrier (X^c/X^+) or colourblind (X^c/X^c); that of the males could be normal (X^+/Y) or colourblind (X^c/Y). The possible genotypes of the offspring are shown in the following checkerboard.

♂/♀	Normal mother	Carrier mother	Colourblind mother
Normal father	All normal sons and daughters	50% normal daughters 50% carrier daughters 50% normal sons 50% colourblind sons	All carrier daughters All colourblind sons
Colourblind father	All carrier daughters All normal sons	50% normal daughters 50% colourblind daughters 50% normal sons 50% colourblind sons	All colourblind sons and daughters

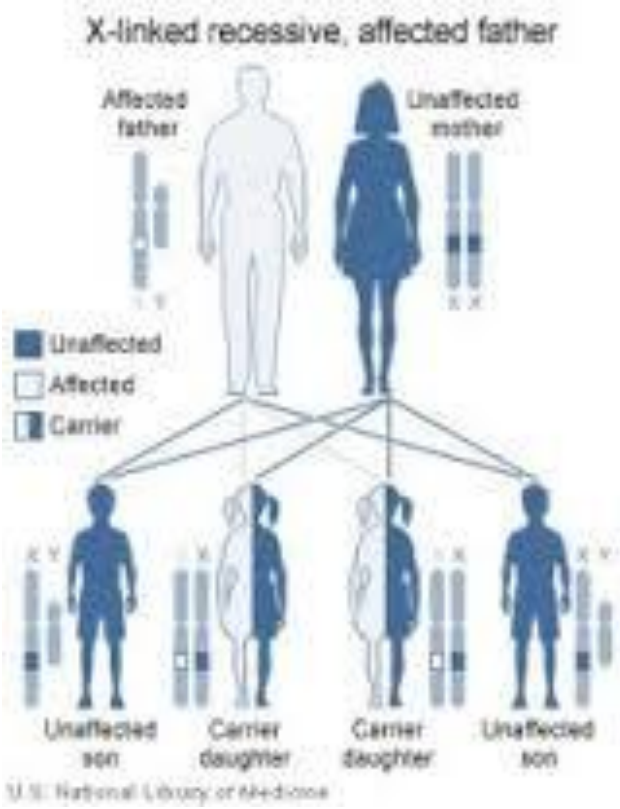


Fig. 6.4 The pattern of inheritance for a sex-linked recessive trait like colour blindness in man. All the sons of an affected father are unaffected, but all the daughters are carrier.

Inheritance of haemophilia or bleeder's disease in man

- First detected in the Queen Victoria (1837-1901) and her descendants, especially the Royal families of Europe
- This is due to a recessive gene on the X chromosome that affects blood clotting time, leading even to death
- Normal coagulating time: 2-8 min; haemophilics: 30 min-24h

Mainly of two types:

1. Haemophilia A: Due to the lack of blood factor VIII (Anti-haemophilic globulin, AHG), ~80% haemophilics; controlled by *F8* gene
2. Haemophilia B (Christmas disease): Due to the lack of blood factor IX (Plasmathromboplastin component, PTC), ~20% haemophilics, controlled by *F9* gene

The frequency of haemophilia A is about 1 in 10,000 males and 1 in 100,000,000 females

Fig. 6.5 Queen Victoria of England (1837-1901), who was a carrier for colour blindness

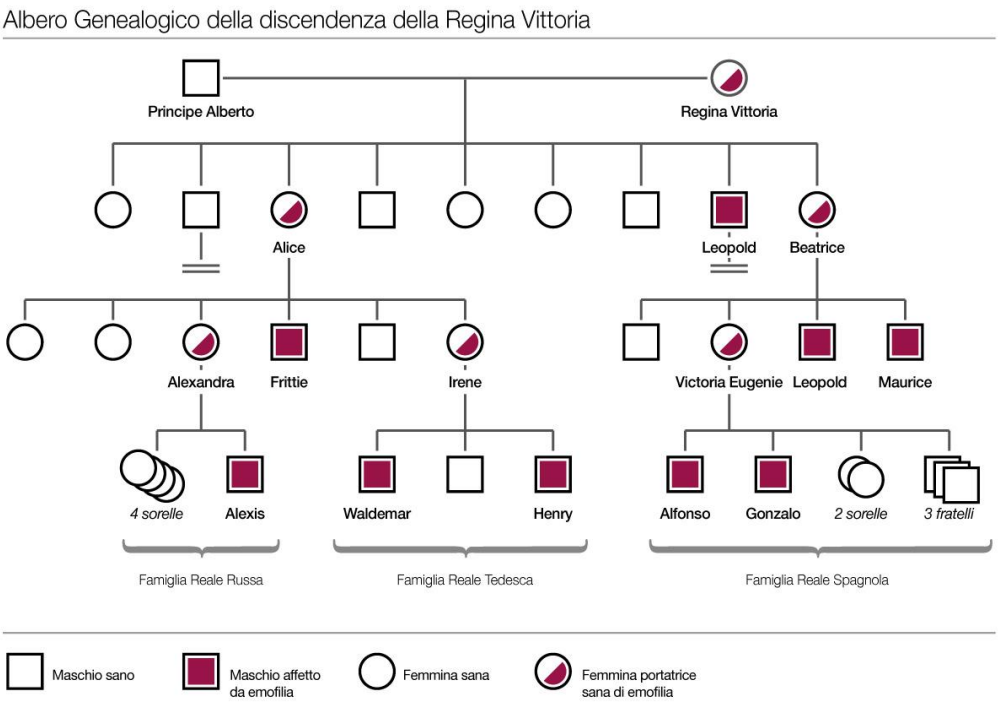


Fig. 6.6 Inheritance of haemophilia in Queen Victoria and her descendants

The pattern of inheritance for haemophilia is shown in the table below:

Father/Mother	Normal Mother	Carrier Mother	Haemophilic Mother
Normal father	All normal ♂ and ♀	50% normal ♀ 50% carrier ♀ 50% normal♂ 50% haemophilic ♂	×
Haemophilic father	×	×	×

Note: Haemophilic fathers and mothers are unable to reproduce

Examples of sex-linked inheritance in *Drosophila*

1. X-linked recessive trait: white eye (w), recessive mutant, 1.5 locus on the X chromosome
2. X-linked dominant trait: Bar eye (B), dominant mutant, 57.0 locus on the X chromosome

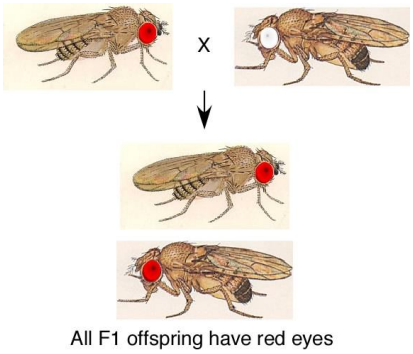
Fig. 6.7 White-eyed (left) and bar-eyed (right) *Drosophila*

Examples of a sex-linked recessive trait (white-eyed mutant) in *Drosophila*

1. P: Red-eyed ♀♀ × white-eyed ♂♂

F_1: All red-eyed offspring (see the diagram below)

F_2: 3 red-eyed: 1 white-eyed offspring (Fig. 6.8 left)



2. P: White-eyed ♀♀ × Red-eyed ♂♂
F_1: Females red-eyed; males white-eyed
F_2: 1 red-eyed: 1 white-eyed offspring (Fig. 6.8 right)

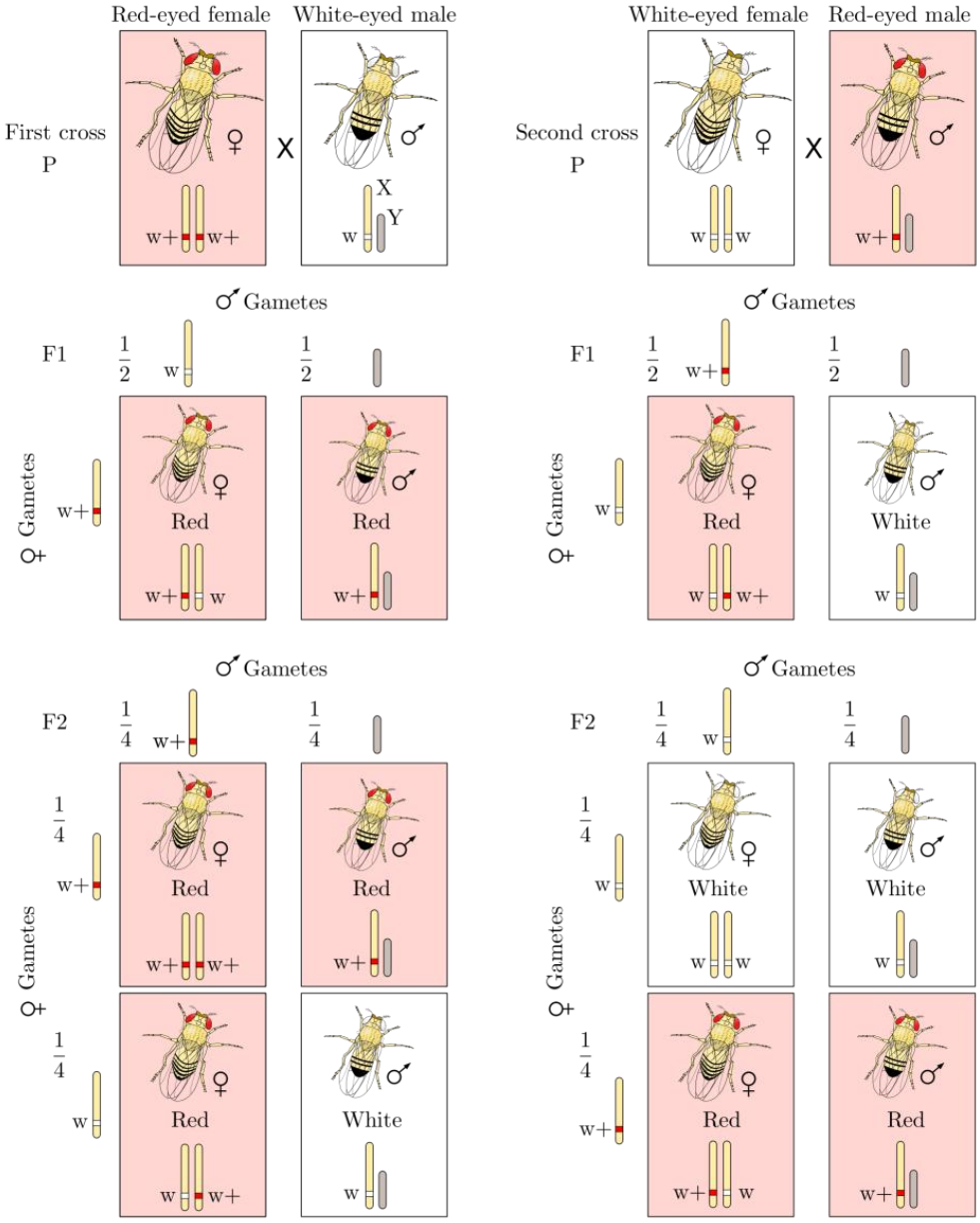


Fig. 6.8 Inheritance of white-eyed mutant (reciprocal crosses) *Drosophila* in

Examples of a sex-linked dominant trait (Bar-eyed mutant) in *Drosophila*

1. P: Bar-eyed ♀♀ × normal-eyed ♂♂
   F_1: All bar-eyed offspring
   F_2: 3 bar-eyed: 1 normal-eyed offspring

2. P: Normal-eyed ♀♀ × Bar-eyed ♂♂
   F_1: Females bar-eyed; males normal-eyed
   F_2: 1 Bar-eyed: 1 normal-eyed offspring

Sex-limited traits and their inheritance

- Such traits are controlled by autosomal genes;
- Traits are related to sex hormones; and
- Expression of such traits is limited to one sex or the other *i.e.* limited to any one sex (male or female) of the animal.

Examples include:

(i) Genes for beard and mustache are present in both males and females, but they are expressed only in males;

(ii) Broad jawbones and hairlines are limited to boys, whereas breasts and broad pelvis are present in girls;

(iii) In chickens, females have hen feathers, and males have cock feathers;

(iv) In cattle, milk producing genes are present in both cows and oxen, but they are expressed only in cows

Examples of sex-limited traits in man

Fig. 6.9 Beard and mustache (left), hairline (middle) and broad jaw bones (right) are sex-limited traits of males

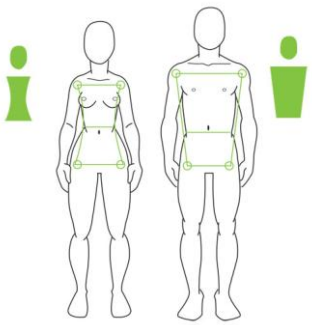


Fig. 6.10 Breasts and broad pelvis are sex-limited traits of females

Examples of sex-limited traits in other animals

Fig. 6.11 Hen (left) and cock (middle) feathers in chickens; udder (right) in cow are examples of sex-limited traits

Sex-influenced traits and their inheritance

- Such traits are also controlled by autosomal genes; and
- Dominance of such traits is influenced by the sex/gender of their bearers.

Common examples include:

1. Pattern baldness in man;
2. Length of index finger in man

Fig. 6.12 Types of hair loss due to pattern baldness in man (above) and women (below)

Characteristics of pattern baldness in man

- In males, both homozygous (BB) and heterozygous (Bb) conditions result in baldness
- In females, only homozygous dominant condition (BB) gives rise to baldness

Genotypes	Phenotypes	
	Males	Females
BB	Bald	Bald
Bb	Bald	Nonbald
bb	Nonbald	Nonbald

Length of index finger in man

- In males, the dominant condition is: shorter index finger than the ring finger
- In females, the dominant condition is: longer index finger than the ring finger

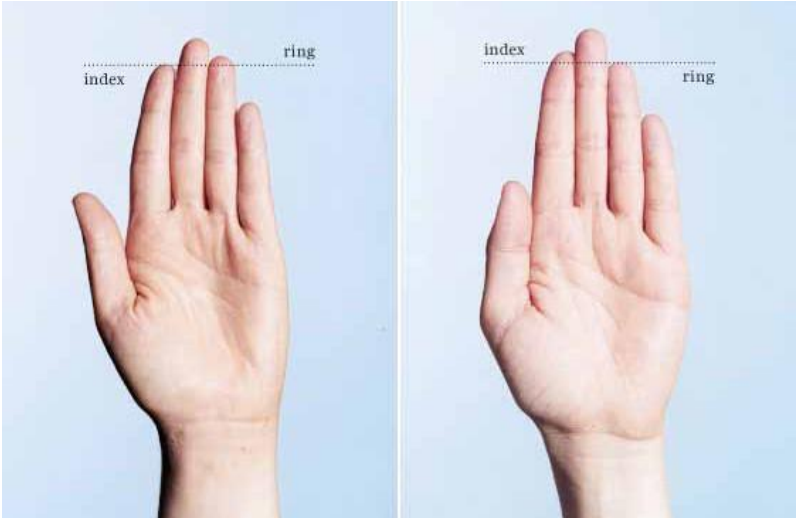


Fig. 6.13 Shorter index finger in a male (left) and longer in a female (right) are dominat conditions in man

Suggested reading:

Burns, GW. 1980. *The Science of Genetics* (4th edn)
Gardner *et al*. 1991. *Principles of Genetics* (8th edn)
Islam, MS. 2018. *Selected Lectures on Genetics*. LAP Lambert Academic Publishing, Germany.
Sinnott *et al.* 1973. *Principles of Genetics* (5th edn)
Stansfield, WD. 1991. *Theory and Problems of Genetics* (3rd edn)
Winchester, AM. 1966. *Genetics* (3rd edn)
Wikipedia: www.wikipedia.com
ইসলাম, ম.সা., খান, হা.সা. ও রানা, ম.হা.তা. ২০১৭। *জেনেটিক্স: মিল ও অমিলের বিজ্ঞান*। অন্যপ্রকাশ, ঢাকা।