Sex-linked inheritance refers to a unique pattern of genetic inheritance where traits are controlled by genes located on the sex chromosomes (X and Y). Unlike Mendelian inheritance, where traits are inherited independently of sex, sex-linked inheritance is influenced by the sex chromosomes, leading to different inheritance patterns between males and females.

In humans and many other organisms, the **XY system** determines biological sex:

- **Males** are XY, with one X and one Y chromosome.
- **Females** are XX, with two X chromosomes.

The **X chromosome** is significantly larger than the **Y chromosome**, containing more than 1,000 genes, many of which are unrelated to sex determination. The Y chromosome, in contrast, contains fewer genes, many of which are responsible for male-specific functions like sperm production and male development. As a result, traits associated with the X chromosome often follow a specific inheritance pattern called **X-linkage**, while traits associated with the Y chromosome follow **Y-linkage**.

Understanding X-Linked Inheritance

Most sex-linked traits are associated with the **X chromosome**, and they follow a distinctive pattern of inheritance because males and females inherit X chromosomes differently.

X-Linked Inheritance:

1. **Males are Hemizygous for X-linked Traits**:
   Males have one X chromosome, meaning they are **hemizygous** for X-linked traits. If they inherit a recessive allele on the X chromosome, they will express the trait because they do not have a second X chromosome to mask it.
2. **Females are Homozygous or Heterozygous**:
   Females, with two X chromosomes, can be either **homozygous** (two identical alleles) or **heterozygous** (two different alleles) for a particular gene. In cases of X-linked recessive inheritance, a female must inherit two copies of the recessive allele (one from each parent) to express the trait. If she inherits one normal and one mutant allele, she becomes a **carrier** and does not show symptoms but can pass the trait to her offspring

X-linked recessive inheritance

1- The incidence of disease is very much higher in males than females.

2- The mutant allele is passed from an affected man to all of his daughters, but they do not express it.

3- A heterozygous 'carrier' woman passes the allele to half of her sons, who express it, and half of her daughters who do not.

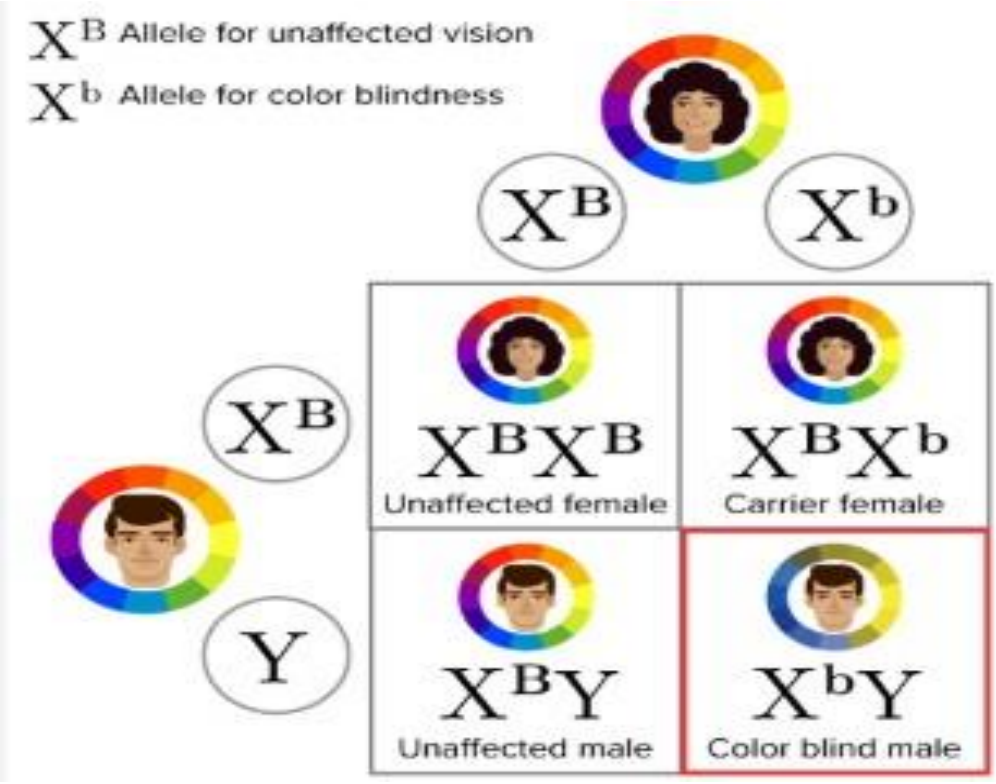
4- The mutant allele is never passed from father to son. Example: Haemophili

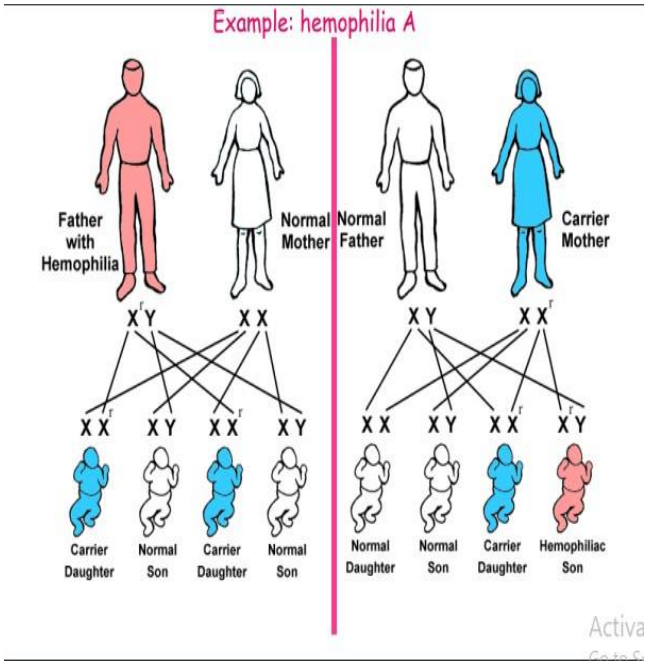
X LINKED RECESSIVE INHERITANCE: LIKE hemophilia , G6PD AND Red-Green Colorblindness

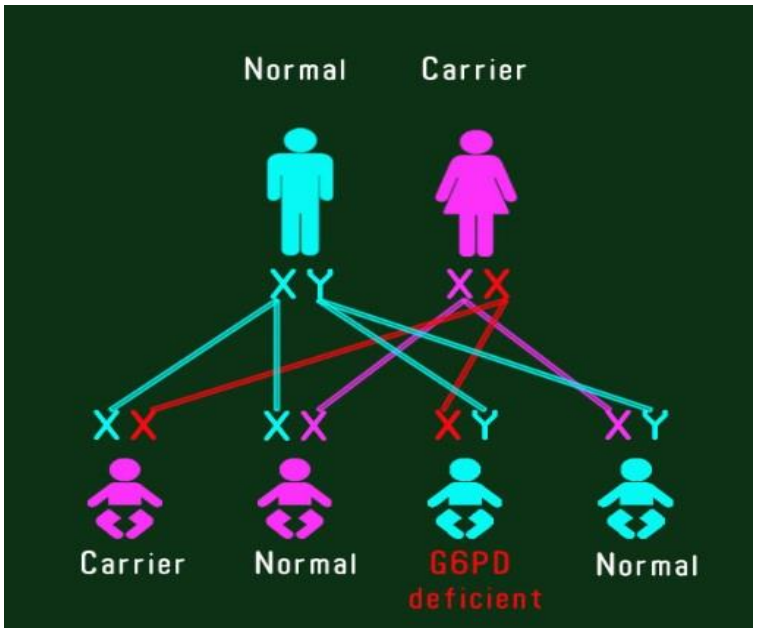
Red-Green Colorblindness

One of the most well-known X-linked recessive traits is **red-green colorblindness**, a condition that affects the ability to distinguish between red and green hues.

- **Males** are more likely to be colorblind than females because they only have one X chromosome. If this X chromosome carries the colorblindness allele, they will express the condition.
- **Females** with one normal and one colorblind allele on their X chromosomes will not show symptoms of colorblindness because the normal allele on the second X chromosome masks the effect. These females are called **carriers** and can pass the
- colorblindness allele to their children.





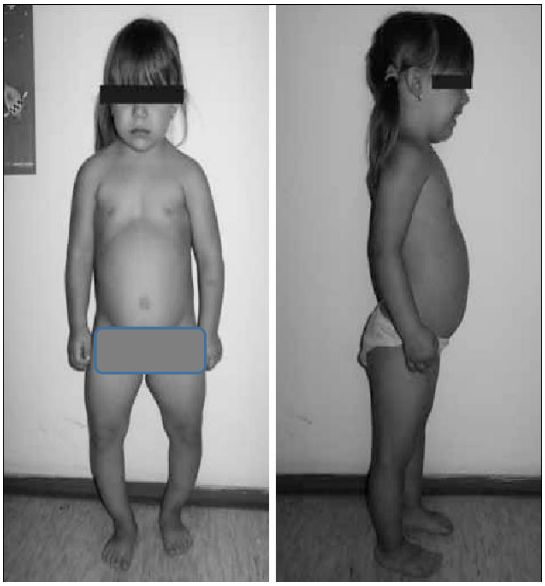


X-Linked Dominant Traits

While most sex-linked traits are recessive, **X-linked dominant inheritance** is also possible. In this case, only one copy of the dominant allele on the X chromosome is needed for a female to express the trait, and males who inherit the dominant allele will also express it.

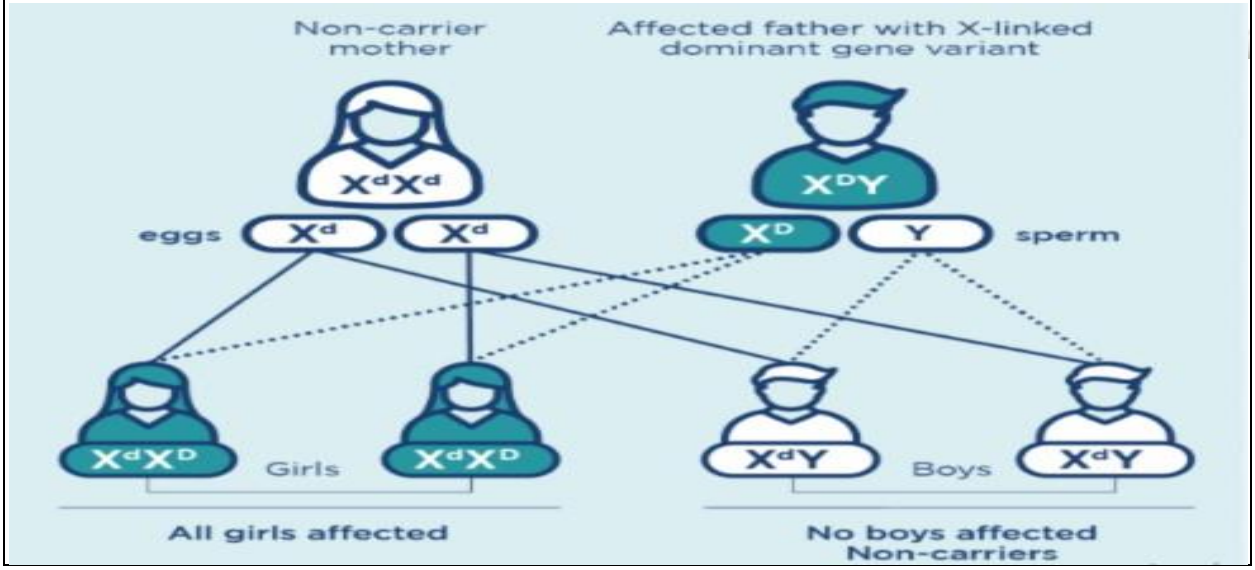
Examples of X-linked Dominant Traits: Alport Syndrome , Rett Syndrome AND **Hypophosphatemic Rickets**

Hypophosphatemic Rickets:
A form of rickets caused by a defect in phosphate metabolism that leads to weakened bones. It is an X-linked dominant condition that affects both males and females, but females typically show milder symptoms due to having two X chromosomes.



X-linked dominant disorders:

- X-linked dominant disorders are all rare.
- Rules: 1- The condition is expressed and transmitted by both sexes.
- 2- The condition occurs twice as frequently in females as in males.
- 3- An affected man passes the condition to every daughter, but never to a son. 4 An affected woman passes the condition to every son and half her daughters.
- **Example: Hypophosphataemia or vitamin o-resistant rickets.**



Y-Linked Inheritance

While most sex-linked traits are X-linked, there are a few traits located on the **Y chromosome**. These traits are only passed from father to son and are present only in males. Y-linked traits include genes responsible for **spermatogenesis** and the **SRY gene**, which determines maleness.

Features of Y-Linked Inheritance:

Only Males are Affected: Y-linked traits are inherited exclusively through the paternal line and affect only males. All male offspring of an affected male will inherit the Y-linked trait.
Example: SRY gene (Sex-determining Region Y) is responsible for triggering male development in embryos. Mutations in this gene can result in male infertility or disorders of sexual development.

mitochondrial inheritance

- Humans have **46 chromosomes**, which are found in the **nucleus** of the cell.
- **Mitochondria**, located outside the nucleus in the **cytoplasm**, also contain their own genetic material.

- **Mitochondrial DNA**:

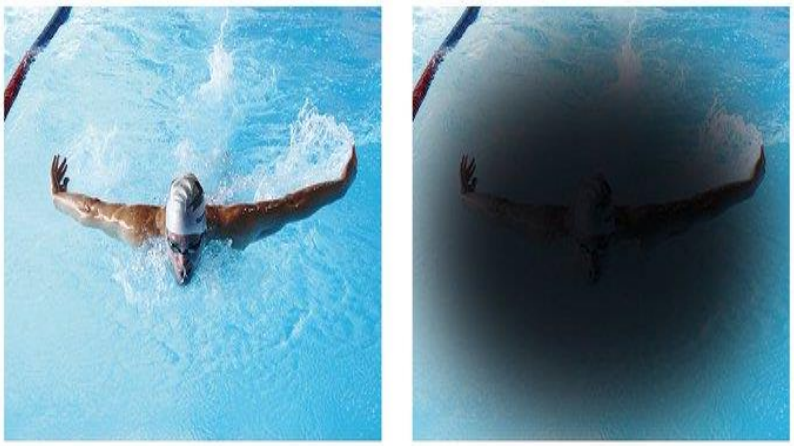
  - Mitochondrial genes are distinct from nuclear genes.
  - Unlike nuclear genes, which are inherited from **both parents**, mitochondrial genes are inherited **only from the mother**.

- Inheritance **Pattern of Mitochondrial DNA**:

  - Mitochondrial mutations are passed from **mother to all of her children** (both sons and daughters).
  - **Sons** with a mitochondrial mutation will not pass it on to their children, while **daughters** with the mutation will pass it on to all their offspring.

- Liber's **Hereditary Optic Neuropathy (LHON)**:

  - The first human disease associated with mitochondrial DNA mutations a condition that leads to loss of vision.



Normal vision LHON vision

LECTURE 9 : HUMAN GENETIC

MULTIPLE CHOSE QUESTION (MCQ)

1. Which of the following is true about sex-linked inheritance?

A) Sex-linked traits are controlled by genes on the X or Y chromosomes.
B) Males inherit X-linked traits from both parents.
C) Females inherit X-linked traits only from their mothers.
D) Sex-linked inheritance shows different patterns of inheritance in males and females.

2. What is the main reason males are more likely to inherit X-linked recessive traits like red-green colorblindness?

A) Males have two X chromosomes.
B) Males have only one X chromosome, which cannot be masked by another X chromosome.
C) Males inherit X chromosomes from their mothers and fathers.
D) Females inherit two X chromosomes, which mask the effect of recessive genes.

3. Which of the following is an example of an X-linked recessive inheritance?

A) Hypophosphatemic Rickets
B) Rett Syndrome
C) Hemophilia
D) Alport Syndrome

4. In X-linked recessive inheritance, what is FALSE for females who are carriers?

A) They will always express the trait.
B) They inherit two copies of the recessive allele.
C) They carry one normal allele and one mutant allele but do not express the trait.
D) They pass the trait to all their male children.

5. Which of the following X-linked dominant traits is most likely to affect females more severely than males?

A) Hypophosphatemic Rickets
B) Rett Syndrome
C) Duchenne Muscular Dystrophy
D) Red-Green Colorblindness

6. What is the characteristic inheritance pattern of Y-linked traits?

A) Y-linked traits are inherited through both the maternal and paternal lines.
B) Only males can inherit and express Y-linked traits.
C) Y-linked traits are passed on from fathers to daughters.
D) Y-linked traits affect females and males equally.

7. Which of the following is an example of a Y-linked inheritance?

A) Hemophilia
B) SRY gene
C) Duchenne Muscular Dystrophy
D) Rett Syndrome

8. Which statement about mitochondrial inheritance is false?

A) Mitochondrial DNA is inherited from the mother only.
B) Mitochondrial mutations can be passed from father to son.
C) Sons with mitochondrial mutations do not pass the mutation to their children.
D) Daughters with mitochondrial mutations will pass them on to their offspring

9. What condition is associated with a mutation in mitochondrial DNA?

A) Red-Green Colorblindness
B) Duchenne Muscular Dystrophy
C) Leber's Hereditary Optic Neuropathy (LHON)
D) Haemophilia

10. Which of the following is true about the inheritance of mitochondrial DNA?

A) Mitochondrial DNA is inherited from both parents.
B) Mitochondrial DNA is inherited only from the father.
C) Mitochondrial mutations can be passed down through both males and females.
D) Mitochondrial mutations are passed from mother to all of her children.