# BASIC CONCEPTS OF GENETICS

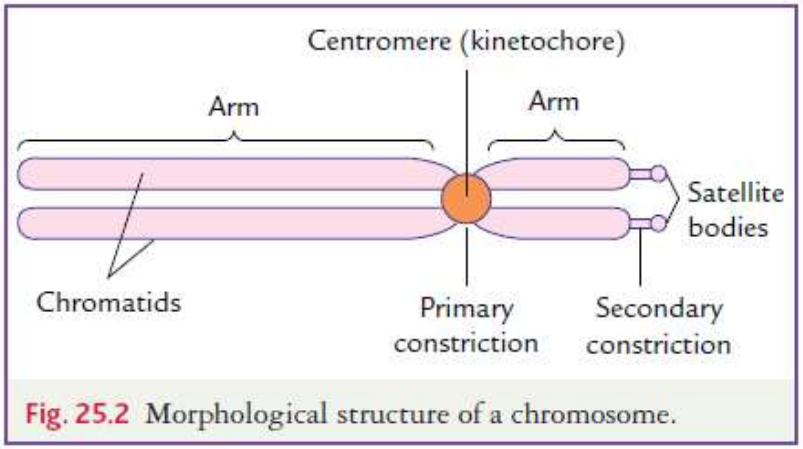


Fig. 25.2 Morphological structure of a chromosome.

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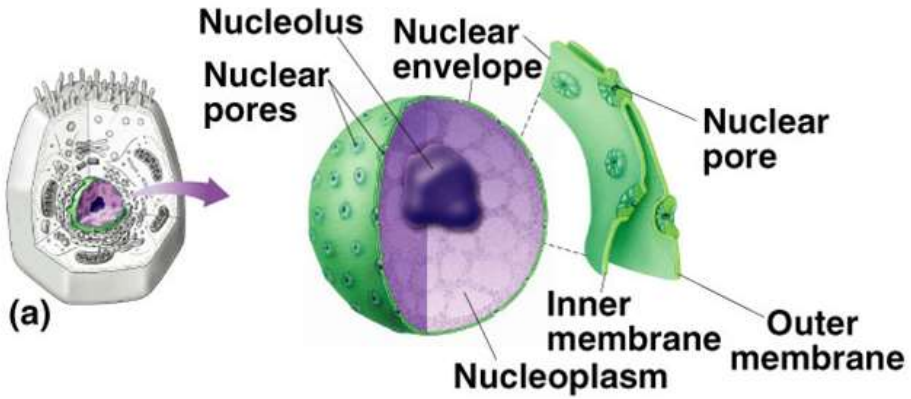


# Gene & Chromosome

- Gene is the hereditary unit formed by the segments of DNA.
- There are about 80,000 genes in a human cells.
- It is composed of Deoxyribose sugar, nitrogen bass & phosphates.

- Chromosome - a thread-like structure of nucleic acids and protein found in the nucleus of most living cells,
- Function is to carrying genetic information in the form of genes.
- It is made up of two identical parallel filaments called chromatids held together by a narrow constriction called centromeres.
- Male – XY
- Female – XX

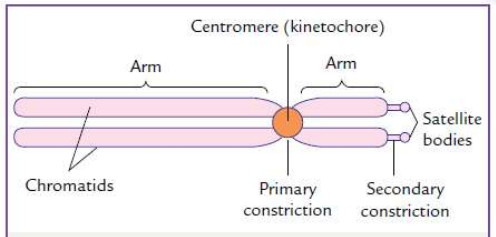


Fig. 25.2 Morphological structure of a chromosome.

- Karyotyping – mapping of chromosomes depending upon the length & position of centromere is called Karyotyping.
- It helps to identify abnormal chromosomes & determination of sex.

- Father of Genetics - Gregor Johann Mendel (discovered fundamental laws of inheritance in 1865)
- Correct structure of DNA was first deduced by - James Watson and Francis Crick (1953)
- The term ‘gene’ was first coined by - Johannsen (1909)
- Structural unit of DNA - Gene
- Unit of inheritance - Gene
- Number of genes in human genome - 50,000 to 100,000
- Most important intermediary molecule for gene expression - RNA

# Medical Genetics

- Genetics is the study of heredity—a process by which children inherit certain characteristics (traits) from their parents.
- These are called **inherited traits that include physical,** mental, normal, as well as abnormal characteristics in an individual.
- The characteristics (traits) pass from parents to children through the inheritable material (**genetic code) present in the** nucleus of the cell. The genetic code is carried by the deoxyribonucleic acid (DNA) molecules.
- The functional unit of DNA is called **gene.**
- The DNA molecules are arranged in linear sequences in chromosomes inside the nucleus of the cell.
- The total genetic information present in a cell is called **genome.**
- **The human** genome comprises about 50,000–100,000 genes.
- The gene expression occurs by formation of different types of proteins.
- The protein is synthesized by transcription of genetic code into the ribonucleic acid (RNA), by DNA replication.
- The RNA forms protein by translation using genetic code. Thus RNA is an intermediary molecule to execute gene expression.

# Deoxyribonucleic Acid

- The deoxyribonucleic acid (DNA) is a double-stranded molecule, made up of two chains of nucleotides, coiled around each other, forming what is commonly described as a **double helix. The double helix model of DNA was** first introduced by James Watson and Francis Crick in 1953.
- The nucleotides are the basic structural units of the DNA.
- Each nucleotide consists of three subunits:
- 1. A sugar
- 2. A phosphate group
- 3. A nitrogenous base.

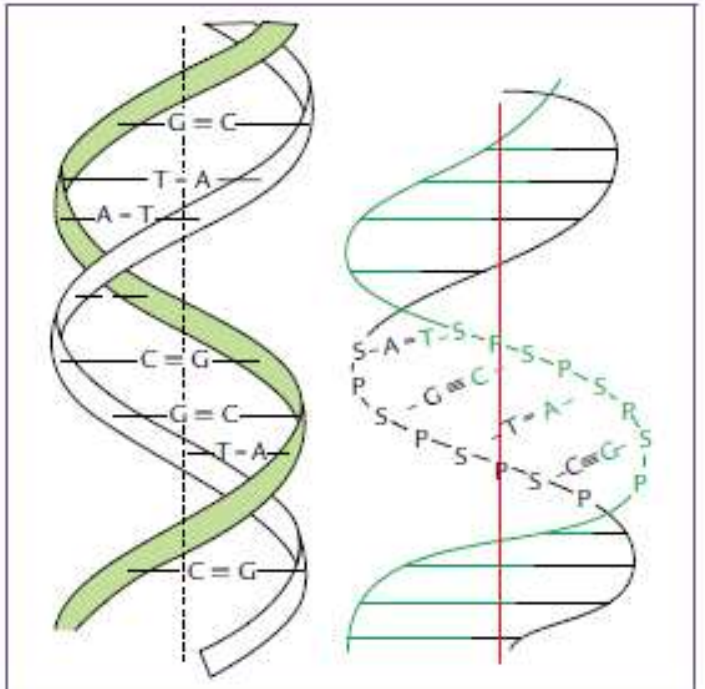



Fig. 25.1 Double helical model of DNA.

- The functions of DNA molecule are as follows:

- 1. **Self-replication: During nuclear division the two** strands of DNA separate and each strand acts as a template to form a new complementary strand.

- 2. **Synthesis of RNA and proteins: Certain regions** of DNA serve as a template for the synthesis of RNA, which in turn synthesizes proteins.

- 3. **Recombination: During crossing over in meiosis,** there is an exchange of genetic material between homologous chromosomes, which leads to shuffling of genes, and the process is called **recombination.**

- 4. **Mutation: It is the major source of genetic variation.** Change of base sequence in a gene or gene sequence in the DNA molecule is called **gene mutation. The** mutation may be spontaneous or induced. The inducing agents include chemicals, radiation, etc.

# Ribonucleic Acid (RNA)

- The RNA is synthesized in the nucleus by the transcription of one strand of DNA.
- RNA is structurally related to DNA.
- Its structure is similar to a single strand of DNA with the difference that the sugar molecule in RNA is ribose sugar and uracil substitutes for thymine. The uracil can bind only to adenine.
- The DNA molecule acts as a template for the synthesis of RNA.
- The flow of information from DNA to protein occurs in 2 steps.
- DNA ⟹ RNA (by transcription)
- RNA ⟹ protein (by translation)

# Branches of Genetics

- 1. **Cytogenetics: It deals with the study of chromosomes** and genes.
- 2. **Molecular genetics: It deals with the study of** chemical structure of genes at molecular level.
- 3. **Developmental genetics: It is the study of genetic** control of embryonic development.
- 4. **Immunogenetics: It deals with the genetics of** production of various types of antibodies.
- 5. **Behavioral genetics: It deals with influence of** genes on the behavior of individual.
- 6. **Population genetics: It deals with the laws of** genetics applicable on human population.
- 7. **Biochemical genetics: It deals with the inborn** errors of metabolism.

# Applications of Genetics in Medicine

- To study various diseases that have a genetic background.
- To study factors that control embryonic development.
- To study immunological status of an individual.
- To study the inborn errors of metabolism.
- To make prenatal diagnosis and treatment.
- To do genetic counseling for helping in planning pregnancies.
- To do gene therapy in patients who have a genomic defect.

# Genes

- Gene, the functional unit of DNA, is the unit of inheritance.
- The term ‘gene’ was coined by Johannsen (1909).
- The properties of gene include:

1. To determine traits, e.g., color of skin, intelligence, height, etc.
2. To undergo replication
3. To undergo mutation.

- About 50,000–100,000 genes are present in the human genome; out of these, about 450 genes are linked to human diseases.

- **Functions of Genes**

1. Maintain the genetic specificity of an individual.
2. Play key role in transmission of traits from parents to offspring.
3. Synthesize various proteins and enzymes of cell.

- The genes are classified into various types.
- 1. **Structural genes:** These are those DNA segments that code for specific amino acid sequences in a protein.

- 2. **Regulatory genes:** These are those DNA segments that control structural genes being transcribed for synthesis of a protein.

# Location of Genes

- Each gene occupies a specific **locus on a chromosome.**
- Both chromosomes of a given pair contain similar genes. The two chromosomes of a pair are homologous and genes occupying the same locus on homologous chromosomes are called **alleles.**
- **If two allelic genes are** identical, the person is **homozygous** for the trait specified by that gene locus.
- If the two alleles are different, the person is **heterozygous for that trait.**

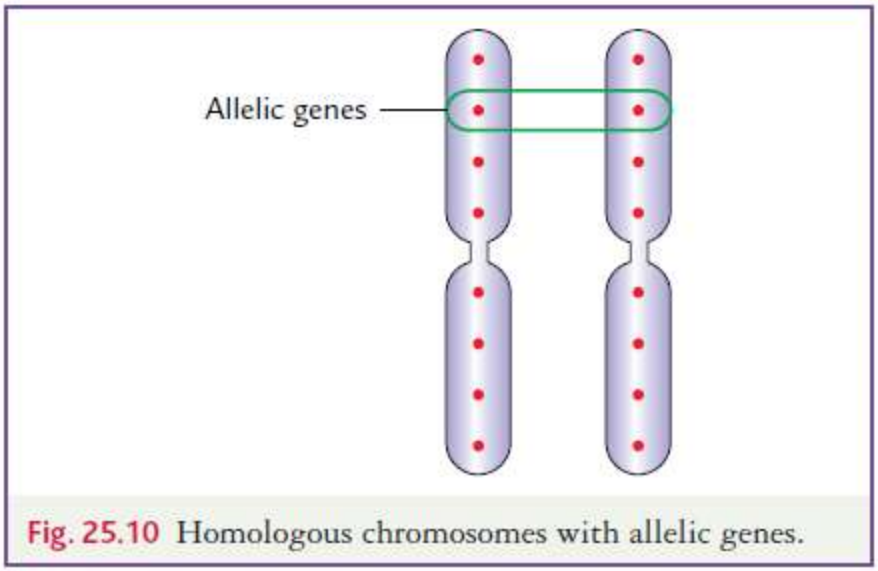
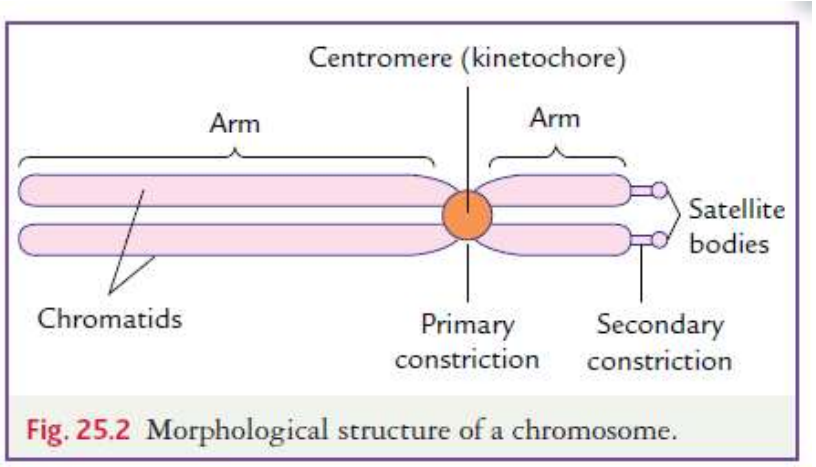


Fig. 25.10 Homologous chromosomes with allelic genes.

- Chromosome - a thread-like structure of nucleic acids and protein found in the nucleus of most living cells,
- Function is to  carrying genetic information in the form of genes.
- It is made up of two identical parallel filaments called chromatids held together by a narrow constriction called centromeres.

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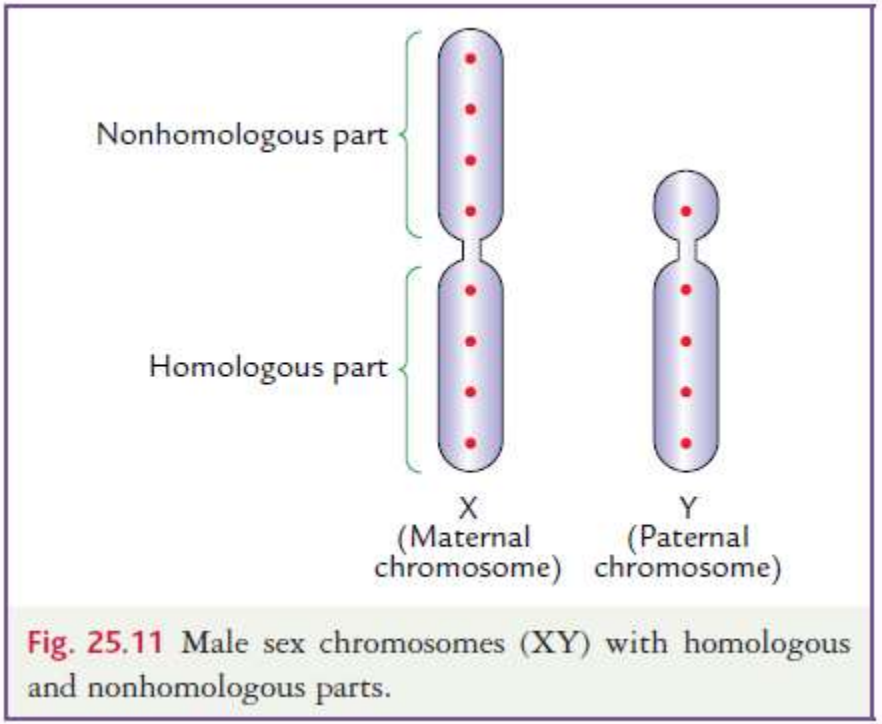



Fig. 25.11 Male sex chromosomes (XY) with homologous and nonhomologous parts.

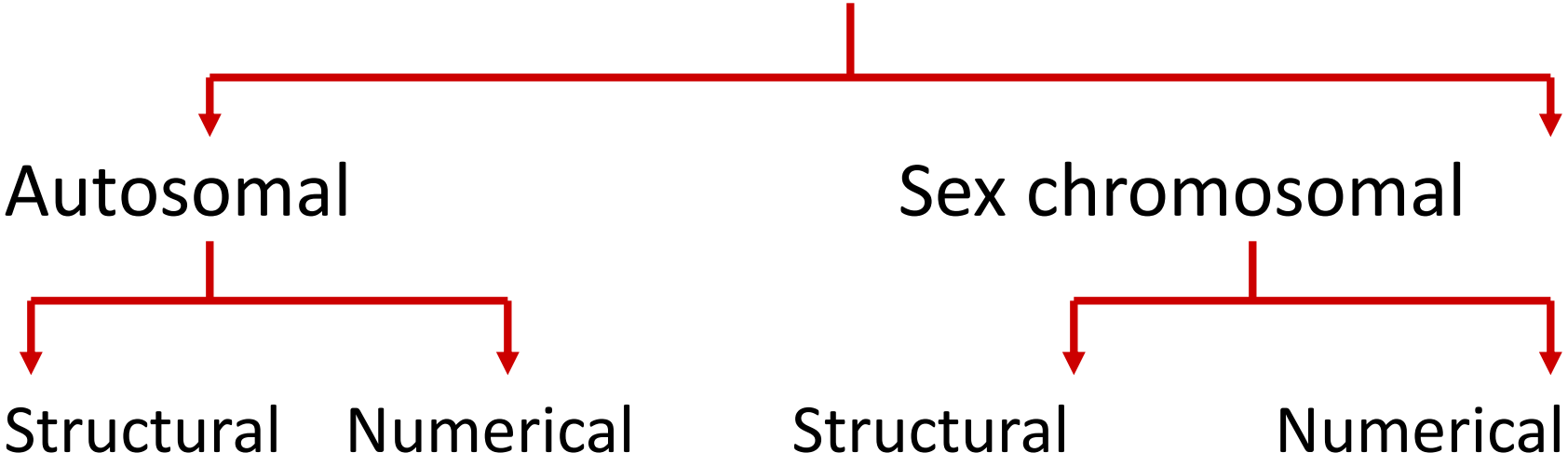
# Inheritance

- Inheritance is the process of transmission of characters/ traits from generation to generation.
- The inheritance of traits from parents to offspring takes place through genes which carry all information about all types of traits.
- The genes are located in both autosomes and sex chromosomes.
  - **Types of inheritance: There are three types of** inheritance as follows:

1. Autosomal inheritance
2. Sex-linked inheritance
3. Multifactorial inheritance.

  - The inheritance occurring through genes of autosomes is called **autosomal inheritance,**
  - The inheritance occurring through genes of sex chromosomes is called **sex-linked inheritance.**
  - The inheritance which occurs due to interaction of gene and environmental factors, viz., infectious agents, drugs, or ionizing radiation is called **multifactorial inheritance.**

# Abnormalities of the Chromosomes




**Structural:** Deletion, Invertion, Ring chromosome, Translocation and Isochromosome

**Numerical:** Polyploidy, Aneuploidy

## Structural abnormalities are..

## Deletion:

**Deletion means loss of segment of chromosome.**

- **It is caused due to a chromosomal break and subsequent loss of segment.**

## Inversion:

- **A part of chromosome result from two breaks, unites with same chromosome in inverted position.**
- **Genes are not lost but placed in altered position.**

## Ring chromosome:

**Ring chromosome results in deletion in both ends, and join together in the form of ring.**

**Translocation:**

**Exchange of a portion of segment between non homologous chromosomes is known as translocation.**

- **Translocations may not always abnormal phenotypes.**
- **But it can lead to the formation of abnormal gametes and carries high risk of infertility and abortion.**

**<u>Isochromosomes:</u>**

- **The Centromere in abnormal anaphase (Mitosis or Meiosis) splits transversely instead of longitudinal.**
- **Results in the formation of two new chromosomes from short and long arm.**

## Numerical abnormalities are..

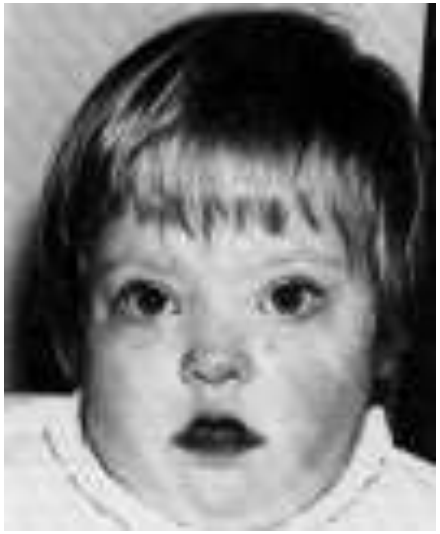
- **Aneuploidy** is the presence of an abnormal number of chromosomes in a cell, for example a human cell having 45 or 47 chromosomes instead of the usual 46.

- **Polyploidy** is a condition in which the cells of an organism have more than one pair of (homologous) chromosomes.

## SOME IMORTANT SYNDROMES

- Down Syndrome
- Klinefelter's syndrome
- Turner's syndrome
- Patau's syndrome
- Edward's syndrome
- Cri du chat syndrome

# Down syndrome



**Incidence:** 1 in 700 live births.

**Cause:** Trisomy of chromosome 21

**Genotype:** 47XX +21, 47XY +21.

**Symptoms:**

Round face

Incomplete ossification of skull

Widely separated sutures

Maxilla is small

Short nose and flat bridge of nose

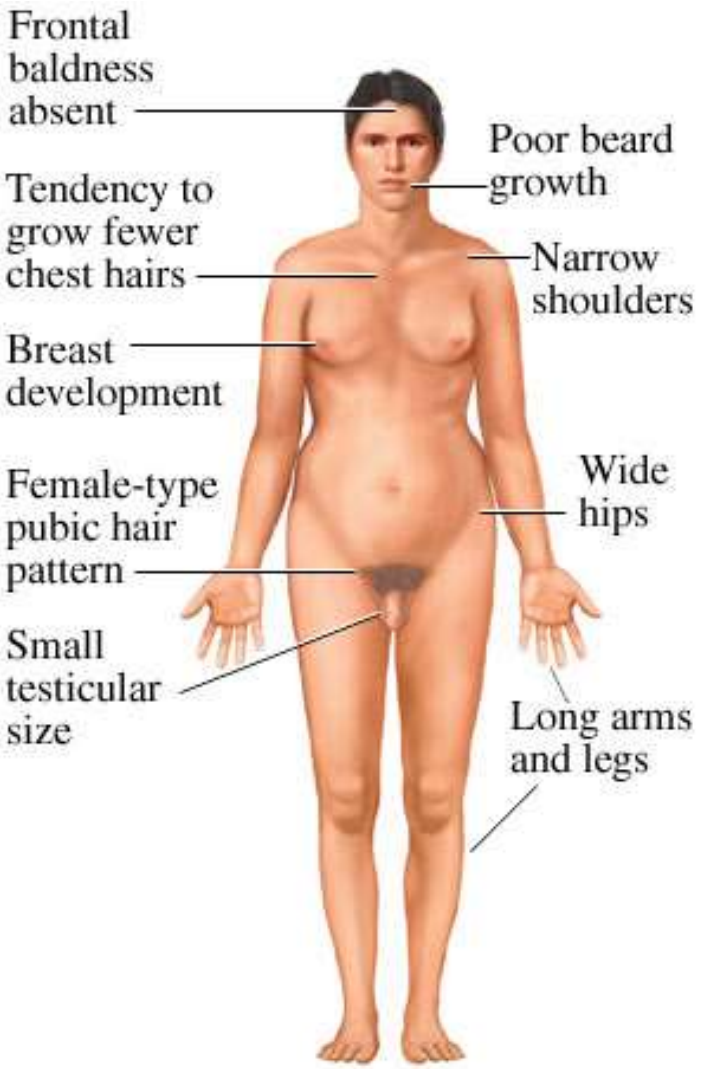
Small mouth and protruding tongue.

- Mental retardation
- Generalized muscular weakness
- Congenital heart defects

# Klienfelter' syndrome

- Incidence: 1 in 1000 births
- Cause: Trisomy of X chromosome
- Genotype: 47 XXY.
- Phenotype: in Male Barr body is present

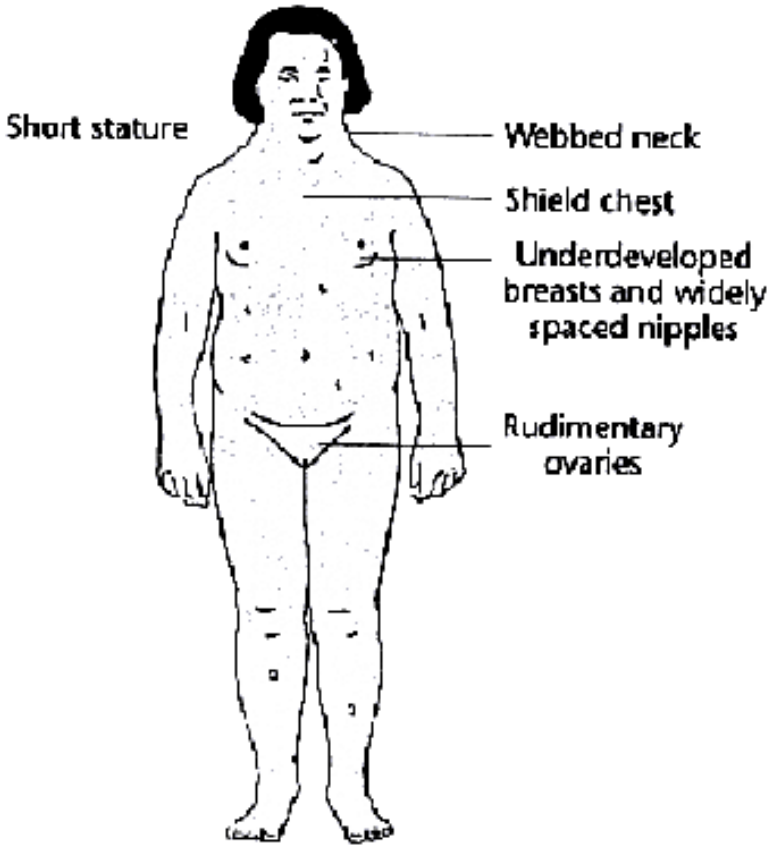
- Tall individuals
- Body hair very less
- Mild obesity
- Small testis with infertile
- Gyanacomastia



# Turner's syndrome

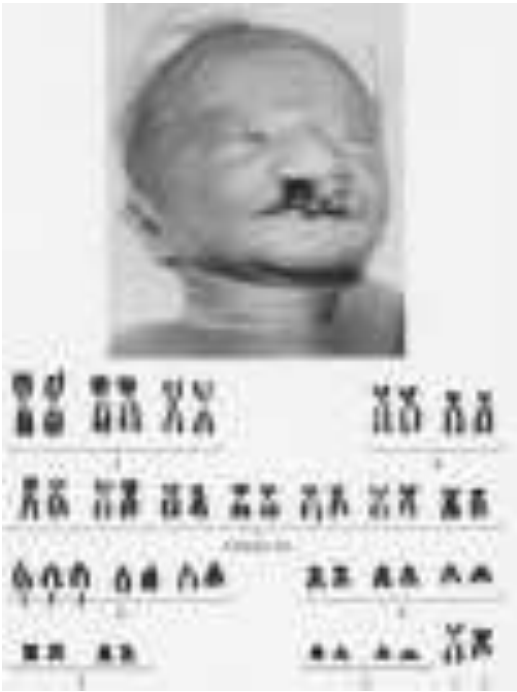
- Incidence: 1 in 5000 births
- Cause: Monosomy of X
- Genotype: 45 X.
- Phenotype: in female Barr body is absent

- Stature- small
- Mouth shark like
- Abnormal teeth
- Chest shield like
- Small genitalia
- Webbing of neck



# Patau's syndrome

- Incidence: 1 in 5000 births.
- Cause: Trisomy 13.
- Genotype: 47,XY,+13.

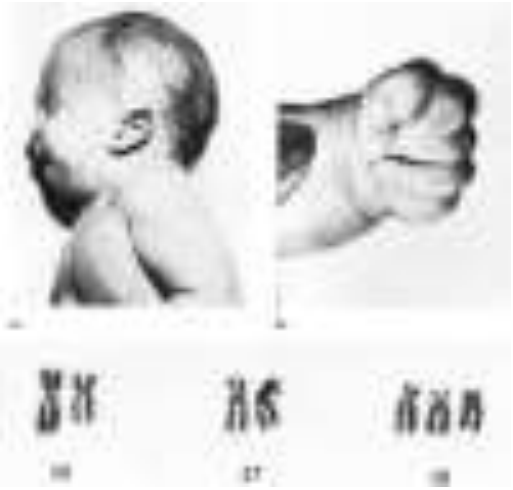


**Symptoms:**

- Malformation of brain
- Microopthalmia.
- Hare lip or Cleft palate.
- CHD
- Survival not more than few week

# Edward's syndrome

- Incidence: 1 in 5000 births.
- Cause: Trisomy 18.
- Genotype: 47,XY,+18.

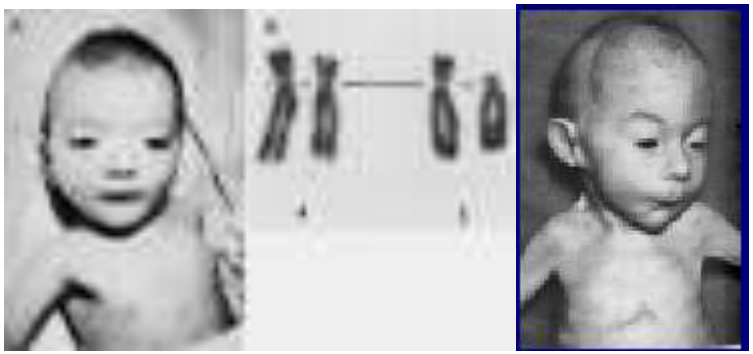


**Symptoms:**

- Elongated head
- Broad and flat nose
- Low set ears
- Clenched of Fingers
- CHD
- Child dies with in few weeks

# Cri du chat syndrome

**Incidence: 1 in 50,000 births.**
**Cause: Terminal Deletion of 5p.**
**Genotype: 5 p-**



**Symptoms:**

- **Round face**
- **Saddle nose**
- **Mental Retardation**
- **Cries like a cat**

# Non disjunction

- In some conditions, due to the abnormalities in Mitotic spindle or in the formation of separate nuclear membrane.
- Chromosomes may not be equally distributed in to 2 daughter cells. Resulting abnormal number of chromosomes in daughter cells.
- This phenomenon is called as *Non disjunction*.

- It may involve sex chromosomes as well as autosomes.
- Autosomal non disjunction is comparatively less than the sex chromosomal non disjunction.

## *1) Aneuploidy:*

This is a condition where chromosomal number is increased or decreased by one or more number, but not with the multiplies of haploids.

**Types of aneuploidy;**

Trisomy: Presence of an extra chromosome is called Trisomy.

E.g.: Trisomy 13,18, 21& X chromosomes.

***Monosomy:***

The absence of a single chromosome is called as Monosomy.

E.g.: Monosomy of X chromosome (Turner syndrome).

Mosaicism:

If the non disjunction take place in first cleavage division of Zygote, all the cells will be Aneuploid, i.e. half of the total cells will be Trisomic and another half will be Monosomic.

## 2) Polyploidy:

It is a condition where the number of chromosomes increased by multiplies of Haploid (23).

- If the number is increased by 3 times of haploid is called as Triploid (69).
- If the number is increased by 4 times of haploid is called as Quadriploid or Tetraploid(92).

- Causes:

1) Fertilization of one ovum with two spermatozoa. (Polyspermy)

2) In abnormal conditions nuclear membrane fails to form separately and encloses all chromosomes, which has double number of chromosomes.

- Polyploidy is normally identified in liver cells and mucous membrane of urinary bladder and oral cavity.
- Most polyploidy conceptions are spontaneously aborted or will have short time survival.

## Symbols used in genetics:

p------ Short arm of chromosome.

q------ Long arm of chromosome.

t------ Translocation.

Inv--- Inversion.

i------ Isochromosome.

r------ Ring chromosome.

+ or – sign , when used before an appropriate symbol, it means addition or missing of whole chromosome.

When + or – signs are placed after a symbol, indicates increase or decrease in length of chromosome.

# 3 laws of Mendel

- The Mendel's laws of inheritance include
- **law of dominance,**
- **law of segregation and**
- **law of independent assortment**.

1. Law of dominance states that in a heterozygote, one trait will conceal the presence of another trait for the same characteristic.

2. Law of Segregation- which states that sexually reproducing organisms possess genes that occur in pairs and that only one member of this pair is transmitted to the offspring.

3. The law of independent assortment indicates that the transmission of a specific allele at one locus (“rounded” or “wrinkled”) has no effect on which allele is transmitted at the other locus (“tall” or “short”).

THANK YOU