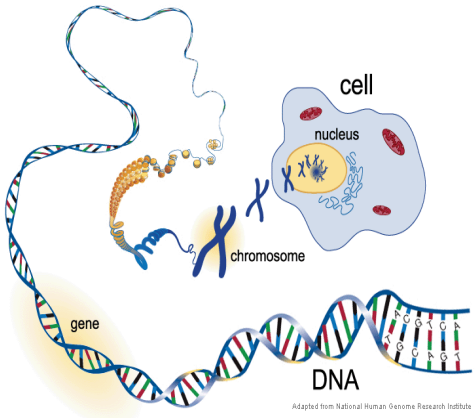
3.1 Genes

a.Gene
b.Genome
c.Chromosome
d. Allele
e.HGP
f.Locus
g.Sickle Cell Anemia
h.Base Substitution Mutation



a) Heritable factors that consist of a length of DNA and influences a specific characteristic
b) An organism's complete set of DNAs, including all of its genes.
c) A structure within the cell that bears the genetic material as a strand of DNA bonded to various proteins in the nucleus of eukaryotic cells, or as a circular strand of DNA in the cytoplasm of prokaryotes and in the mitochondrion and chloroplast of certain eukaryotes
d) Different forms of genes
e) An international research effort to determine the DNA sequence of the entire human genome.
f) A fixed position on a chromosome, like the position of a gene or a marker (genetic marker).
g) A genetic blood **disease** due to the presence of an abnormal form of hemoglobin
h) Mutation characterized by a substitution of one or few nucleotides of a gene

General Overview:

- DNA is the genetic blueprint which codes for, and determines, the characteristics (physical, behavioural and physiological) of an organism
- The position of a gene on a particular chromosome is called the locus (plural = loci)
- A gene is a sequence of DNA that encodes for a specific trait
- DNA is packaged and organised into discrete structures called chromosomes
- Alleles are alternative forms of a gene that code for the different variations of a specific trait As alleles are alternative forms of the one gene, they possess very similar gene sequences (Alleles only differ from each other by one or a few bases
- A gene mutation is a change in the nucleotide sequence of a section of DNA coding for a specific trait New alleles are formed by mutation

3.1:Genes

Gene: A heritable factor that consists of a length of DNA and influences a specific characteristic.

- location of genes: each gene occupies a specific position on one type of chromosome where it is located, it is called the locus of the gene.

Alleles: the various specific forms of a gene

- there can be more than two alleles of a gene ex: ABO blood groups
- they occupy the same position on one type of chromosome- they have the same locus.
- only one allele can occupy the locus of a gene on a chromosome.
- as alleles are alternative forms of the one genee, they possess very similar gene sequences, they differ from each other by one or a few bases only.
- new alleles are formed by mutation.

Mutations

- a gene mutation is a change in the nucleotide sequence of a section of DNA coding for a specific trait
- new alleles are formed by mutation
- random changes- there is no mechanism for a particular mutation being carried out
- most significant type of mutation: BASE SUBSTITUTION
- mutations in cells that develop into gametes can be passed onto the offspring and cause genetic disease

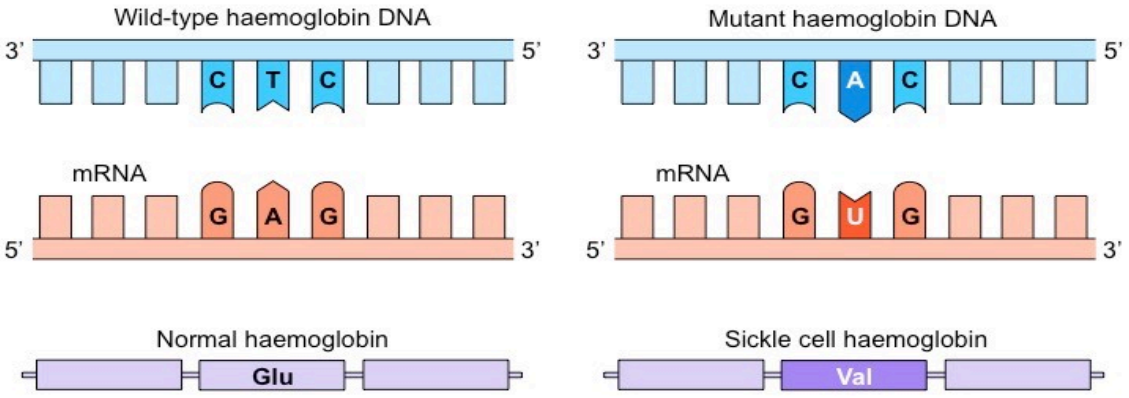
Example of a disorder caused by a gene mutation:

Sickle cell anemia (most common genetic disease in the world)

Cause:

- mutation of a gene that codes for the alpha-globin polypeptide in hemoglobin (Hb)
- happens in the sixth codon

➔ Most humans have Hb^a allele.
➔ Base substitution mutation converts the 6th codon of a gene from GAG to GTG. Therefore, a new allele is formed Hb^s.
➔ When Hb^s allele is transcribed, mRNA produced has GUG instead of GAG.
➔ When this mRNA is translated, the sixth amino acid is valine instead of glutamic acid.
➔ **DNA:** The DNA sequence changes from GAG to GTG on the non-transcribed strand (CTC to CAC on the template strand)
➔ **mRNA:** The mRNA sequence changes from GAG to GUG at the 6th codon position
➔ **Polypeptide:** The sixth amino acid for the beta chain of haemoglobin is changed from glutamic acid to valine (Glu to Val)



Consequences:

The amino acid change (Glu → Val) alters the structure of haemoglobin, causing it to form *insoluble fibrous strands*

- The insoluble haemoglobin cannot carry oxygen as effectively, causing the individual to feel constantly tired

The formation of fibrous haemoglobin strands changes the shape of the red blood cell to a *sickle shape*

- The sickle cells may form clots within the capillaries, blocking blood supply to vital organs, reducing blood flow and causing myriad health issues.
- The sickle cells are also destroyed more rapidly than normal cells, leading to a low red blood cell count (anemia)

Homozygous state (HbS HbS): Causes severe anemia, death at low O2 concentrations

Heterozygous state (HbA HbS): Has less anemia, minor effects, it provides protection against malaria

Genome: whole genetic information of an organism

- this includes all genes as well as non-coding DNA sequences

The Human Genome Project

- ➔ the entire base sequence of human genes was sequenced.
- ➔ HPG showed that humans share the majority of their sequence, with short nucleotide polymorphisms (snips) contributing diversity.
- ➔ the completion of the HGP lead to **many outcomes:**
  - ◆ **mapping:** number, location, size and sequence of human genes is now established, mapping all human genes

- **screening:** this has allowed for the production of specific gene probes to detect sufferers and carriers of genetic diseases, screen for diseases
- **medicine:** the discovery of new proteins have lead to improved treatments, developing new drugs based on base sequences
- **ancestry:** comparisons with other genomes have provided insight into the origins, evolution and migratory patterns of man, find evidence for evolutionary relationships/ancestry

Techniques used for genome sequencing:

Key advances in technology:

- Biotechnology techniques such as PCR are used to prepare samples: the DNA needs to be copied to prepare a sufficiently large pure samples to sequence
- Computers automate the sequencing process
- Fluorescent labelling techniques enable all four nucleotides to be analysed together
- Lasers are used to fluoresce the dye markers.
- Digital camera technology reads the dye markers
- Computers are used to assemble the base sequence.

Gene comparisons:

- the number of genes present in an organism will differ between species and is not a valid indicator of biological complexity
- the number of genes in a genome is usually predicted by identifying sequences common to genes
- As scientists may use different approaches to predicting gene numbers, final estimations can vary significantly.

3.2: Chromosomes

Bacterial Chromosomes

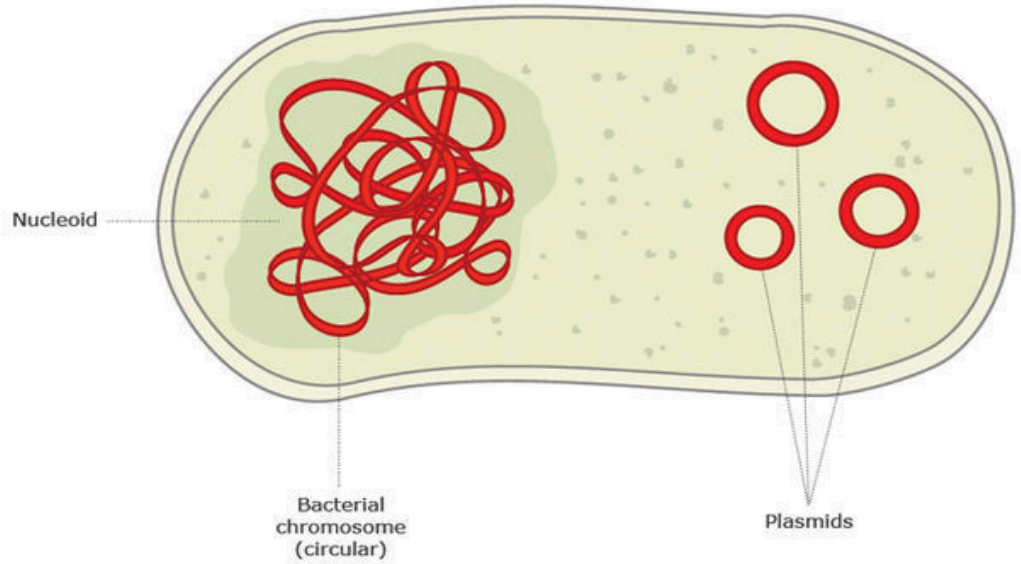
Genome: the entire sum of an organism's genetic information.

- Prokaryotes **do not possess a nucleus**-instead genetic material is found free in the cytoplasm in a region called the **nucleoid.**
- In most prokaryotes, there is one chromosome (because there is only one copy of each gene/simple metabolism requires less genes), consisting of a circular DNA molecule that contains the entire genome, including all the genes necessary to carry out the functions of life.
- DNA in bacteria is not associated with proteins, so is sometimes described as naked.
- There is usually one copy of each gene.
- Two identical copies are present after replication but they are moved to opposite poles and then the cell splits into two.

Plasmids: small extra DNA molecules that are commonly found in prokaryotes but very unusual in eukaryotes.

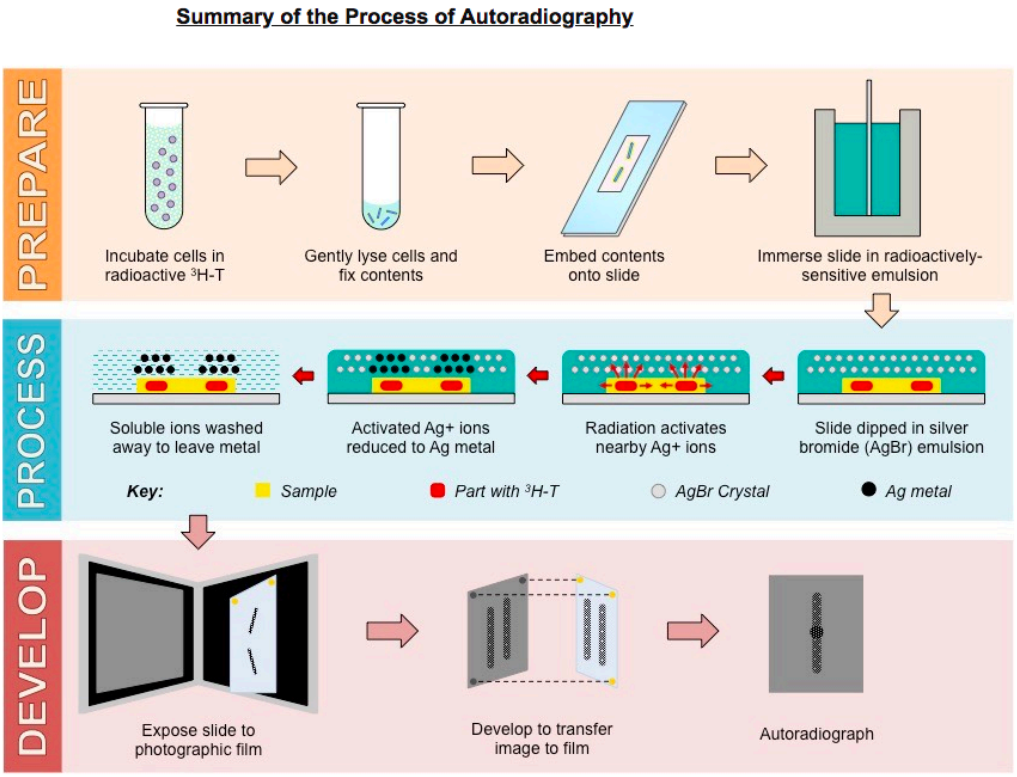
- they are small, naked and circular
- contains a few genes that may be useful for basic life processes (ex: genes for antibiotic resistance)
- can be multiple copies of plasmids in a cell.
- may not be passed to both cells formed by cell division, capable of self-replication

Bacterial DNA	Plasmids
Naked DNA	Naked DNA
Free, single, circular DNA	Additional small rings of DNA
Responsible for all life processes	Contain genes for survival characteristics such as antibiotic resistance
Cannot be passed between bacteria	**Can be passed** between bacteria (conjugation)



Autoradiography (radioactive isotopes) to measure the length of DNA molecules-John Cairns:

1. Cells were grown in a culture medium containing tritiated thymidine that contains radioactive hydrogen.
2. Digestion of cell walls of bacteria by lysozyme. DNA is released, placed on a dialysis membrane.
3. DNA is mixed with photographic emulsion for 2 months in a dark environment. Thymidine starts to emit high energy electrons which react with film.
4. The film is examined under a microscope and position/length of DNA is identified.



Eukaryote chromosomes

Eukaryote chromosomes are linear DNA molecules associated with histone proteins.

- are composed of DNA and protein
- DNA is a single immensely long linear DNA molecule associated with histone proteins
- Histones are globular in shape and are wider than the DNA
- Many histones in a chromosome, with DNA wrapped around them, allows for more efficient storage

Eukaryote chromosomes	Prokaryote chromosomes
DNA with histones	Naked DNA (no histones)
Many chromosomes	Single chromosome

Linear DNA	Circular DNA
Found in nucleus	Found in nucleoid region or cytoplasm
DNA replication in interphase-mitosis	DNA replication-immediately in binary fission

Differences between chromosomes

In a eukaryote species there are different chromosomes that carry different genes.

Three ways in which chromosomes can vary:

1. Length (number of base pairs)
2. Locus of genes
3. Position of centromere

If chromosomes vary, how are individuals of a species similar in terms of their DNA?

- same chromosomes, same genes with the same gene loci but different alleles

Homologous chromosomes

Homologous chromosomes carry the same sequence of genes but not necessarily the same alleles of those genes.

➔ Sexually reproducing organisms inherit their genetic sequences from both parents.
➔ This means that these organisms will possess two copies of each chromosome (one from each parent).
➔ These maternal and paternal chromosome pairs are called homologous chromosomes.

If two chromosomes have the same sequence of genes they are homologous.

Chromosome pairs share:

- same structural features (same size, same banding patterns, same centromere position)
- same genes at the same loci positions (while the genes are the same, alleles may be different)

Homologous chromosome: Chromosome pair from each parent that have similar length, gene position and centromere position.

- Homologous chromosomes must be separated in gametes (via meiosis) prior to reproduction, in order to prevent chromosome numbers continually doubling with each generation.
- If eukaryotes are members of the same species, we can expect each of the chromosomes in one of them to be homologous with at least one chromosome in the other. This allows members of a species to **interbreed**.

Diploid vs. Haploid

As sexually reproducing organisms receive genetic material from **both** parents, they have two sets of chromosomes (*diploid*)

To reproduce in turn, these organisms must create sex cells (gametes) with half the number of chromosomes (*haploid*)

Haploid nuclei

Haploid nuclei have one chromosome of each pair. (n)

- Haploid: a cell that contains a single set of chromosomes
- ex: gametes such as sperm or ovum (n=23)
- These nuclei will possess a single gene copy for each trait

Diploid nuclei

Diploid nuclei have pairs of homologous chromosomes. (2n)

- Diploid: a cell that contains 2 sets of chromosomes
- ex. somatic cells (kidney, skin, testes, ovary cells) (2n=46)
- These nuclei will possess two gene copies (alleles) for each trait

Cells that are neither haploid nor diploid: Red blood cells, Skeletal muscle cells

Chromosome numbers

The number of chromosomes is a characteristic feature of members of species.

- Organisms with different diploid numbers are unlikely to be able to interbreed (cannot form homologous pairs in zygotes)
- In cases where different species do interbreed, offspring is usually infertile (cannot form functional gametes.)

Sex determination

Sex is determined by sex chromosomes and autosomes are chromosomes that do not determine sex.

- There are 2 chromosomes in humans that determine sex: X and Y
- **Females** posses 2 copies of a large X chromosome (**XX**)
- **Males** possess one copy of an X chromosome and one copy of a much shorter Y chromosome (**XY**)
- The **presence of SRY Gene** causes the **development of male characteristics** and the absence of SRY Gene causes the development of female characteristics.

X chromosome:

- relatively large and has its centromere near the middle
- has many genes essential in both males and females.
- all humans have at least one X chromosome.

Y chromosome:

- contains the genes for developing male sex characteristics (SRY gene)
- only has a small number of genes

Why are X and Y chromosomes not homologous?

➔ X chromosome is longer than Y chromosome, carrying a non-homologous section with additional genes.

Karyograms

A karyogram shows the chromosomes of an organism in homologous pairs of decreasing length.

The chromosomes are stained and photographed to generate a visual profile that is known as a **karyogram**

- The chromosomes of an organism are arranged into homologous pairs according to size (with sex chromosomes shown last)

➔ A karyogram can be used to deduce the sex of an individual, to find missing or extra chromosomes, and to detect other chromosomal mutations. It is not able to detect differences in alleles or mutations that affect a single gene.

Karyotypes and down syndrome

➔ Karyogram: Graphical representation of chromosomes

➔ Karyotype: Observed characteristics of chromosomes (number, shape, size, centromere location)

Karyotypes are the number and types of chromosomes in a eukaryotic cell – they are determined via a process that involves:

- Harvesting cells (usually from a foetus or white blood cells of adults)
- Chemically inducing cell division, then arresting mitosis while the chromosomes are condensed
- The stage during which mitosis is halted will determine whether chromosomes appear with sister chromatids or not

Visual aspects of homologous chromosomes which can be used to identify them for the purpose of a karyotype:

1. Banding patterns
2. Size
3. Centromere Position

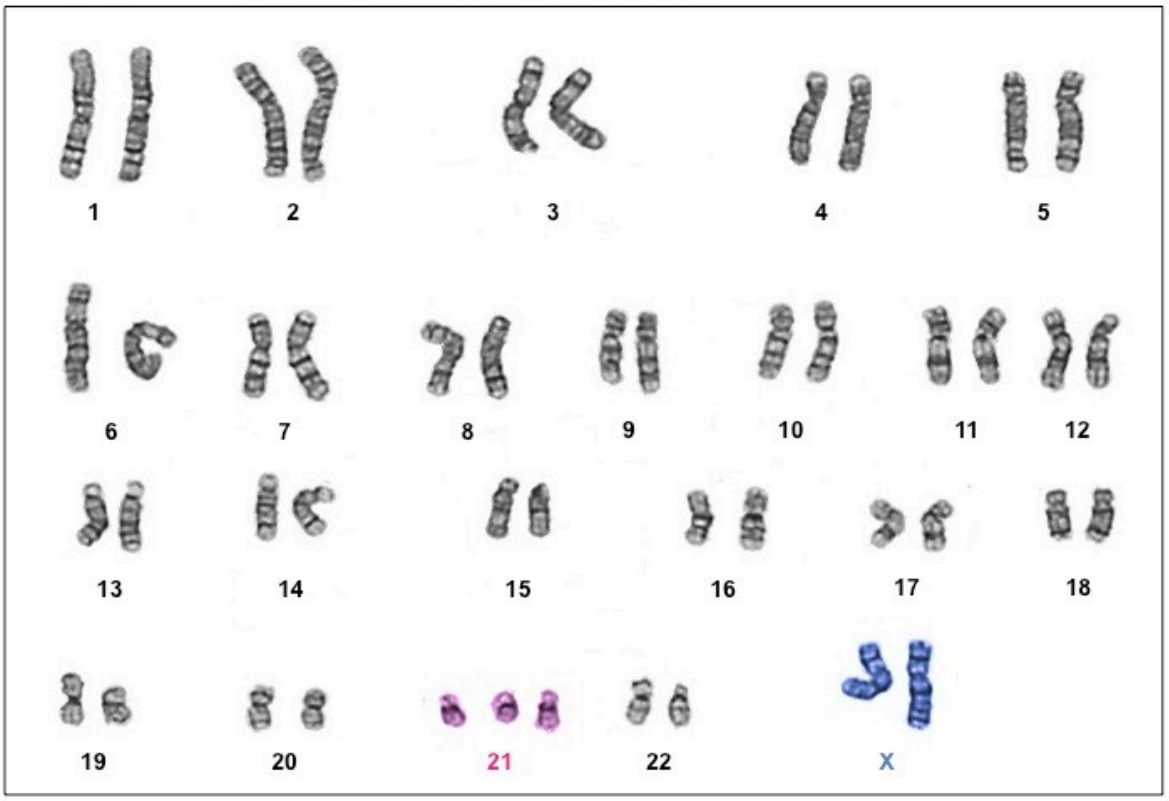
Down Syndrome

➔ During meiosis, when the gametes are formed, the resulting ova or sperm cells can sometimes contain an extra or missing copy of a chromosome. This is caused by the failure of a pair of homologous chromosomes or sister chromatids to separate and is known as non-disjunction.

➔ Zygotes formed when one gamete has an extra chromosome give rise to individuals with three copies of one particular chromosome, a condition called **trisomy**.

➔ With most autosomes, trisomy is fatal. However, **where there are three copies of chromosome 21 present (trisomy 21), Down syndrome occurs.** This syndrome causes hearing loss, heart and vision problems, intellectual disability and slower growth leading to smaller stature.

Karyogram #2: Female with Trisomy 21 (47, XX)



Genome Size

Genome size can vary greatly between organisms and is not a valid indicator of genetic complexity.

Genome size: total number of DNA base pairs/total length of DNA in an organism

As a general rule:

- Viruses and bacteria tend to have very small genomes
- Prokaryotes typically have smaller genomes than eukaryotes
- Sizes of plant genomes can vary dramatically due to the capacity for plant species to self-fertilise and become polyploid

3.3 Meiosis

Meiosis: the process by which sex cells (gametes) are made in the reproductive organsi

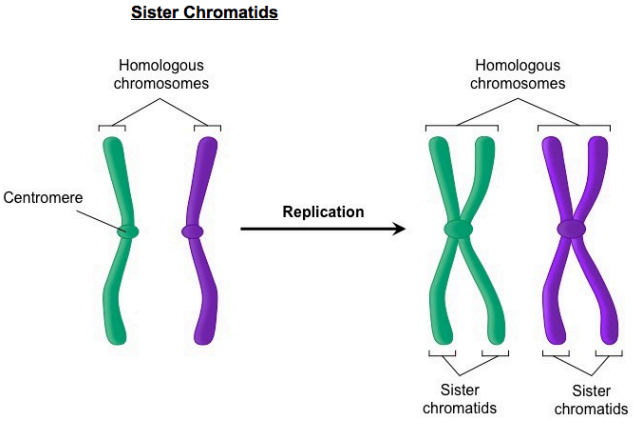
- It is the nuclear division that produces four genetically distinct haploid nuclei from one diploid nucleus.

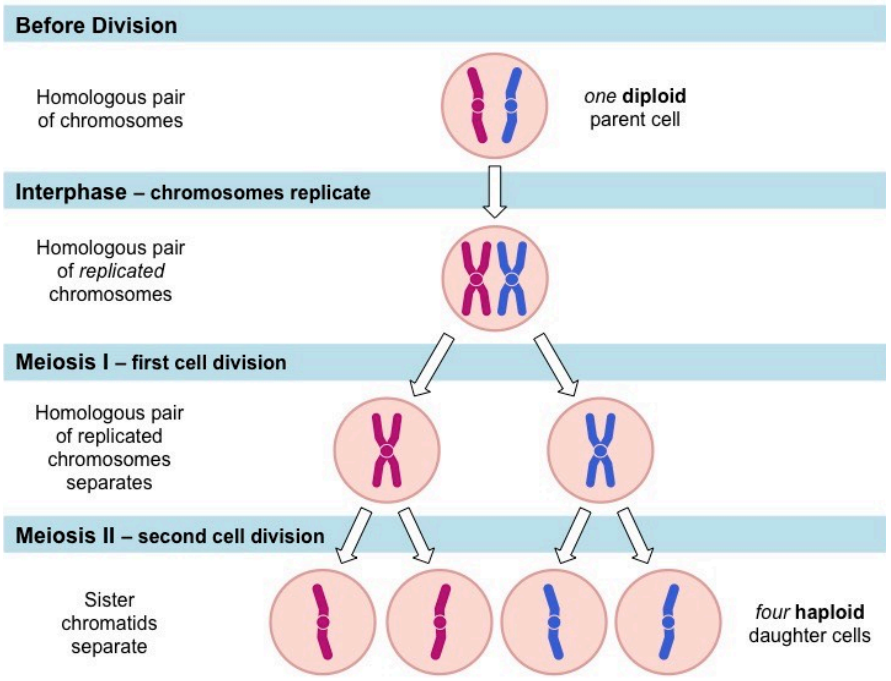
The process of meiosis consists of two cellular divisions:

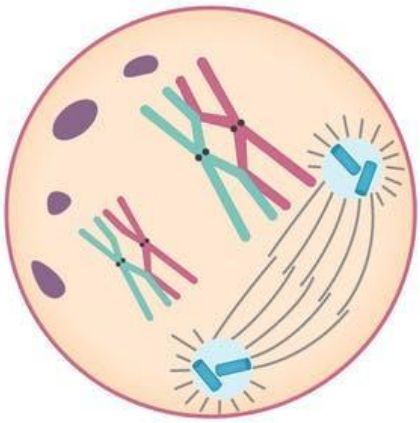
- The first meiotic division separates pairs of homologous chromosomes to halve the chromosome number (diploid → haploid)

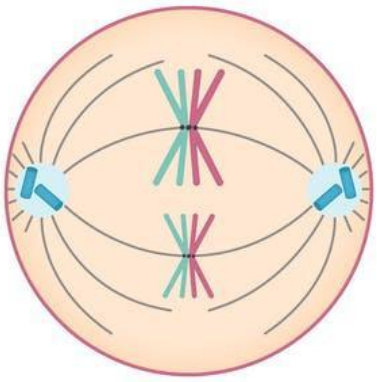
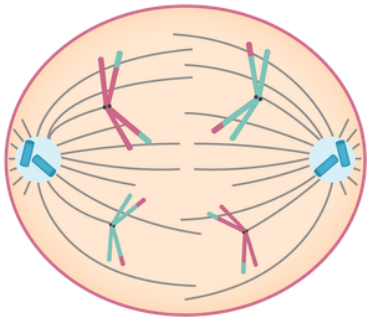
Meiosis is preceded by interphase, during which DNA is replicated (in the S phase) to produce two genetically identical copies

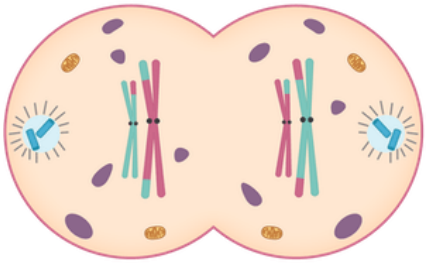
- The two identical DNA molecules are identified as *sister chromatids*, and are held together by a single centromere
- The sister chromatids are separated during meiosis II, following the separation of homologous chromosomes in meiosis I
- The second meiotic division separates sister chromatids (created by the replication of DNA during interphase)

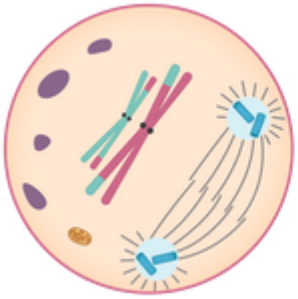


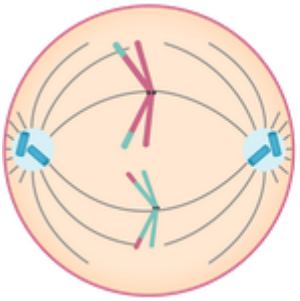
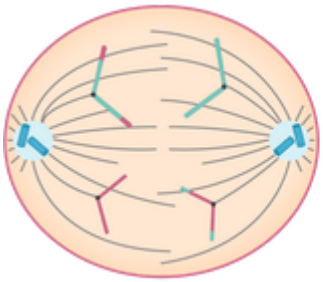
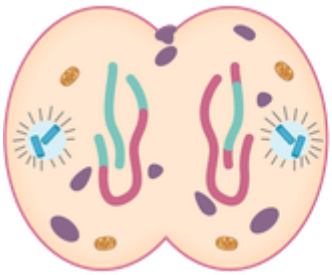


Phase	Description of events	
MEIOSIS I: **Reduction division –** Cells begin with two copies of each chromosome and end with only one; Diploid (2n) → Haploid (n)		
Prophase I		Chromosomes become visible due to supercoiling. The replicated chromosomes form closely-linked homologous pairs (called tetrads or bivalents), which have two chromosomes and four total chromatids. At this stage, non-sister chromatids may **cross over** at points called chiasmata and exchange equivalent segments of DNA. Centrioles, if present, migrate to opposite poles and spindle fibres start to form. The nucleolus and nuclear membrane disintegrate.

Metaphase I		Homologous pairs move together along the metaphase plate, which lies halfway between the two poles. Maternal and paternal homologues show **random orientation** towards the poles. The spindle fibres attach to the centromeres of each chromosome and gently pull to align them along the equatorial metaphase plate. Spindle fibres connect each centromere to one pole only.
Anaphase I		Spindle microtubules shorten, pulling homologous chromosomes apart towards opposite poles. Unlike mitosis, sister chromatids remain connected at the centromere and move to the same pole.

Telophase I		The first meiotic division effectively ends when the chromosomes arrive at the poles. Note that each chromosome still consists of a pair of chromatids. The chromatids partially uncoil and a nuclear membrane then reforms around each nucleus formed. Although technically not part of meiosis, cytokinesis usually occurs during telophase I. Cytokinesis results in two daughter cells with haploid nuclei from meiosis.

MEIOSIS II: Separation of chromatids in haploid cells (n → n)		
Prophase II		Chromosomes condense again. Centrioles, if present, migrate to opposite poles and spindle fibres start to form. The nucleolus and nuclear membrane disintegrate.

Metaphase II		The spindle fibres attach to the centromere and connect each centromere to both poles. They exert a gentle pull to align the sister chromatids at the equator.
Anaphase II		Centromeres divide and chromatids are moved to opposite poles by spindle fibres. *Once sister chromatids are separated, they are called chromosomes.*
Telophase II		Chromosomes reach opposite poles and uncoil. This is followed by nuclear envelope formation and cytokinesis. Meiosis is now complete, resulting in four haploid daughter cells. Note that each of the four cells are genetically distinct.

Prophase I and Crossing Over:

In **prophase I**, homologous chromosomes undergo a process called *synapsis*, whereby they pair up to form a *bivalent* (or tetrad)

- The homologous chromosomes are held together at points called <u>chiasmata</u> (singular: chiasma)

Crossing over of genetic material between non-sister chromatids can occur at these chiasmata when equivalent portions of the non-sister chromatids are exchanged.

- As a result of this exchange of genetic material, new gene combinations are formed on chromatids (recombination)

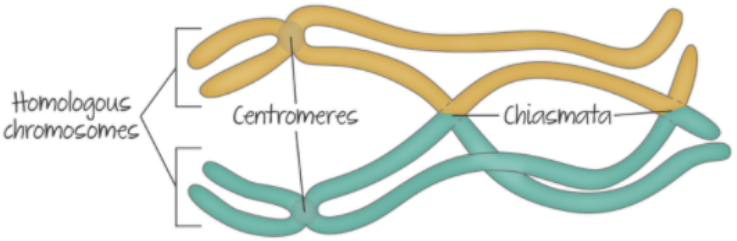
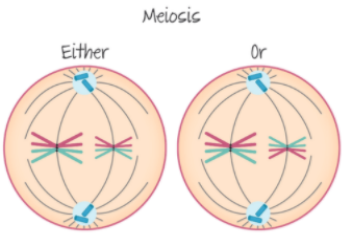


Figure 3. Crossing over during prophase I.

- Further, crossing over can occur almost anywhere along the chromosome (though some areas are more frequent). There is a near-infinite number of possible crossing-over combinations in the 23 pairs of human chromosomes, ensuring that every gamete produced is genetically unique.

<u>Note:</u> Synapsis is the pairing of homologous chromosomes **during** the prophase 1 of the meiosis 1 whereas **crossing over** is the exchange of the genetic material **during synapsis**.

Metaphase I and Random Orientation:



- ➔ During metaphase I, the pairs of homologous chromosomes (also called bivalents or tetrads) that cross over in prophase I align along the equatorial plate of the cell.
- ➔ When homologous chromosomes line up in metaphase I, their **orientation** towards the opposing poles is **random**. The **orientation** of each bivalent occurs independently, **meaning** different combinations of maternal / paternal chromosomes can be inherited when bivalents separate in anaphase I.

Genetic Variation

The advantage of meiotic division and sexual reproduction is that it promotes genetic variation in offspring

The three main sources of genetic variation arising from sexual reproduction are:

1. **Crossing over (in prophase I):** Homologous chromosomes come together and sections are exchanged between non-sister chromatids. This allows the

mixing of alleles from the two parental chromosomes to form new, nearly limitless combinations in gametes. This occurs during gamete formation in both parents.

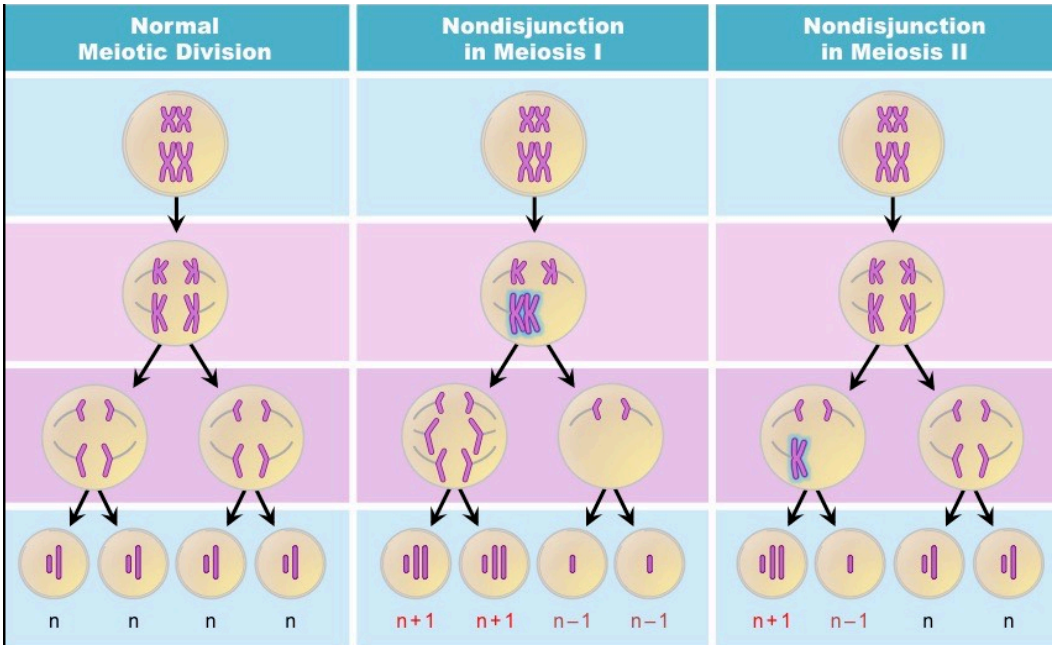
2. **Random assortment of chromosomes (in metaphase I):** The orientation of homologous chromosomes at the equatorial plate during metaphase I determines which pole each pair of sister chromatids will move toward during anaphase I. The orientation of each pair of chromosomes is independent of other such pairs. Thus, the allele inherited for one gene will not affect the allele inherited for another
3. **Random fusion of gametes from different parents:** The fusion of male and female gametes (sperm and egg) from different parents combines alleles from two different sources in the diploid zygote. The sperm may carry alleles that have never before combined with alleles found in the egg. Since the genetic information is coming from two different sources, this creates a much broader range of possibilities. Further, which sperm and egg are involved in fertilisation is random.

- The number of possible chromosome combinations in the gametes can be calculated using **2n** (where n is the haploid number of chromosomes).

Non-disjunction: the chromosomes failing to separate correctly, resulting in gametes with one extra, or one missing, chromosome.

The failure of chromosomes to separate may occur via:

- Failure of homologous to separate in Anaphase I (resulting in four affected daughter cells)
- Failure of sister chromatids to separate in Anaphase II (resulting in only two daughter cells being affected)



Chromosomal Abnormalities

- ➔ **Down Syndrome:** Individuals with Down syndrome have three copies of chromosome 21 (trisomy 21)
- One of the parental gametes had two copies of chromosome 21 as a result of non-disjunction
- The other parental gamete was normal and had a single copy of chromosome 21
- When the two gametes fuse during fertilisation, the resulting zygote had three copies of chromosome 21
- **Effects on the individual:** developmental delays, health issues (respiratory problem, hearing difficulties…), physical features (low muscle tone, a flat bridge…)

Karyotyping

- Is an image of a cell's homologous chromosome pairs ordered by decreasing size.
- Karyotyping is used to check the number and type of chromosomes and is typically used to determine the gender of an unborn child and test for chromosomal abnormalities.

- Cells are harvested from the foetus before being chemically induced to undertake cell division (so chromosomes are visible)
- The stage during which mitosis is arrested will determine whether chromosomes appear with sister chromatids
- Finally, chromosomes are stained and photographed, before being organised according to structure

1. **Amniocentesis:**
   - ➔ Amniocentesis involves the extraction of a small amount of amniotic fluid (contains fetal cells) with a needle.
   - ➔ Usually performed between weeks 14 and 20 of pregnancy
   - ➔ A doctor uses ultrasound imagery to guide a syringe needle through the abdomen and uterine wall without piercing the fetus. The needle is then used to withdraw a small amount of amniotic fluid. Fetal cells floating in the fluid are cultured and karyotyped.
2. **Chorionic villus sampling (CVS):**
   - ➔ Involves removing a sample of the chorionic villus (placental tissue) via a tube inserted through the cervix.
   - ➔ It can be done at ~11 weeks of pregnancy with a slight risk of inducing miscarriage (~1%)

3.4 Inheritance

Mendel and the principles of inheritance

While there are caveats to Mendel's conclusions, certain rules can be established:

1. **Law of Segregation:** When gametes form, alleles are separated so that each gamete carries only one allele for each gene
2. **Law of Independent Assortment:** The segregation of alleles for one gene occurs independently to that of any other gene*
3. **Principle of Dominance:** Recessive alleles will be masked by dominant alleles†

* The law of independent assortment does not hold true for genes located on the same chromosome (i.e. *linked genes*)

† Not all genes show a complete dominance hierarchy – some genes show *codominance* or *incomplete dominance*

Advantages of using pea plants:

1. Characteristics are seen easily over generations
2. Reproduction cycle is short
3. They have unlinked genes
4. Easy to cross-fertilize

	Flower Colour	Plant Height	Seed Color	Seed Shape	Pod Colour	Pod Shape	Flower Position
Dominant Trait	 Purple	 Tall	 Yellow	 Round	 Green	 Inflated (full)	 Axial
Recessive Trait	 White	 Short	 Green	 Wrinkled	 Yellow	 Constricted (flat)	 Terminal

Gametes and Segregation of alleles

- Gametes are haploid sex cells formed by the process of meiosis – males produce sperm and females produce ova.
- Gametes are haploid so contain one allele of each gene.
- During meiosis I, homologous chromosomes are separated into different nuclei prior to cell division.

- As homologous chromosomes carry the same genes, segregation of the chromosomes also separates the allele pairs
- Consequently, as gametes contain only one copy of each chromosome they therefore carry only one allele of each gene.

Zygotes

- Fusion of gametes results in diploid zygotes with 2 alleles of each gene that may be the same allele or different alleles.
- Ex. if the alleles were A and a, possible combinations would be AA, Aa, aa.

Dominant, recessive and codominant alleles

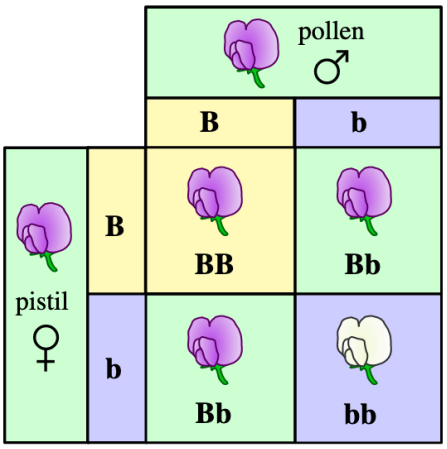
- The gene composition (i.e. allele combination) for a specific trait is referred to as the **genotype**.
- The observable characteristics of a specific trait (i.e. the physical expression) is referred to as the **phenotype.**
- The dominant allele will mask the recessive allele when in a heterozygous state.
- Homozygous dominant and heterozygous forms will be phenotypically indistinguishable.
- The recessive allele will only be expressed in the phenotype when in a homozygous state.
- Codominance occurs when pairs of alleles are *both expressed equally* in the phenotype of a heterozygous individual.
- Heterozygotes therefore have an altered phenotype as the alleles are having a joint effect.

Punnett grids

A monohybrid cross determines the allele combinations for potential offspring for **one** gene only

Monohybrid crosses can be calculated according to the following steps:

- **Step 1:** Designate letters to represent alleles (*dominant* = capital letter ; *recessive* = lower case ; *co-dominant* = superscript)
- **Step 2:** Write down the genotype and phenotype of the prospective parents (this is the P generation)
- **Step 3:** Write down the genotype of the parental gametes (these will be haploid and thus consist of a single allele each)
- **Step 4:** Draw a grid with maternal gametes along the top and paternal gametes along the left (this is a Punnett grid)
- **Step 5:** Complete the Punnett grid to determine potential genotypes and phenotypes of offspring (this is the F_1 generation)



ABO blood groups

- Human ABO blood types follow a codominant inheritance pattern. Also the ABO blood groups are controlled by a single gene with multiple alleles (A, B, O).
- A and B alleles are codominant whereas the O allele is recessive.
- The genotypes for blood groups:

Phenotype	Genotype
Blood Type A	I^AI^A or I^Ai
Blood Type B	I^BI^B or I^Bi
Blood Type AB	I^AI^B
Blood Type O	ii

Genetic diseases due to recessive alleles

- Occurs only if both alleles are recessive (faulty)/both parents are carriers
- If a person has a dominant allele and a recessive allele, then they are **carriers**.

Ex. Cystic fibrosis

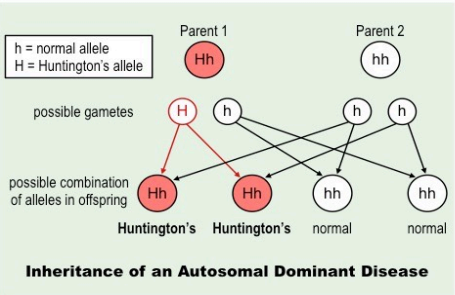
Genotype	CC	Cc	cc
Description	No CF	Normal	Has CF
Phenotype	unaffected	carrier	affected

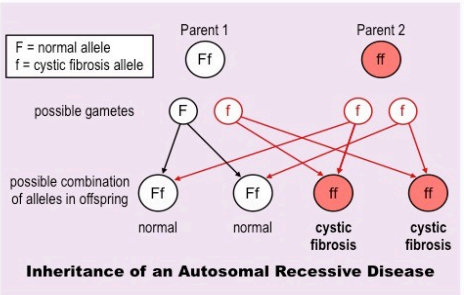
Genetic diseases due to dominant alleles

- Occurs if they have one dominant allele (faulty allele).
- Both homozygous and heterozygous will develop the full range of symptoms.

Ex. Huntington's disease

Genotype	HH	Hh	hh
Description	Has Huntington's	Has Huntington's	Normal
Phenotype	affected	affected	unaffected





Genetic diseases due to codominant alleles

- Only requires one copy of the faulty allele to occur

Ex. Sickle cell anemia

- ➔ Hb^s= faulty allele
- ➔ Hb^A= normal allele

Genotype	Hb^AHb^A	Hb^AHb^s	Hb^sHb^s
Description	Not anemic Normal red blood cell shape	Mild anemia Normal red blood cell shape	Anemic Sickle-cell shape
Phenotype	unaffected	carrier	affected
Malaria protection?	no	yes	yes

Genetic diseases in humans

- Many genetic diseases have been identified in humans but most are very rare.
- This is due to most genetic diseases being caused by very rare recessive alleles.
- An individual can only produce a child with a genetic disease due to one of these alleles if the other parent of the child has the same recessive allele.

Sex-linked genes

- The pattern of inheritance is different with sex-linked genes due to their location on sex chromosomes.
- Sex linkage: A gene located on a sex chromosome

- ❖ Sex linked inheritance: A pattern of inheritance in which genes are found on the X or Y chromosome.
- ❖ Sex linked conditions are usually X-linked.

For X-linked conditions:

- ■ Only females can be carriers (a heterozygote for a recessive disease condition), males cannot be heterozygous carriers.
- ■ Males will <u>always</u> inherit an X-linked trait from their mother (they inherit a Y chromosome from their father).
- ■ Females cannot inherit an X-linked recessive condition from an unaffected father (must receive his dominant allele).

Ex. Red-green color-blindness

- Allele for color blindness is recessive (n) to the allele for normal vision (N).

	Female	Male
Normal	X^NX^N	X^NY
Affected	X^nX^n	X^NY
Carrier	X^NX^n	Not possible!

Ex.Hemophilia

- Allele for hemophilia is recessive (h) to the allele for normal vision (H).

	Female	Male
Normal	X^HX^H	X^HY
Affected	X^hX^h	X^nY
Carrier	X^HX^h	Not possible!

Pedigree Charts

- ❖ A pedigree is a chart of the genetic history of a family over several generations
- ■ Males are represented as squares, while females are represented as circles
- ■ Shaded symbols mean an individual is affected by a condition, while an unshaded symbol means they are unaffected
- ■ A horizontal line between man and woman represents mating and resulting children are shown as offshoots to this line
- ■ Generations are labeled with roman numerals and individuals are numbered according to age (oldest on the left)

Determining Autosomal Inheritance
Autosomal Dominant

- If *both parents are affected and an offspring is unaffected*, the trait **must** be dominant (parents are both heterozygous)
- All affected individuals **must** have at least one affected parent
- If both parents are unaffected, all offspring **must** be unaffected (homozygous recessive)

Autosomal Recessive

- If *both parents are unaffected and an offspring is affected*, the trait **must** be recessive (parents are heterozygous carriers)
- If both parents show a trait, all offspring **must** also exhibit the trait (homozygous recessive)

Determining X-Linked Inheritance
It is **not** possible to confirm sex linkage from pedigree charts, as autosomal traits could potentially generate the same results

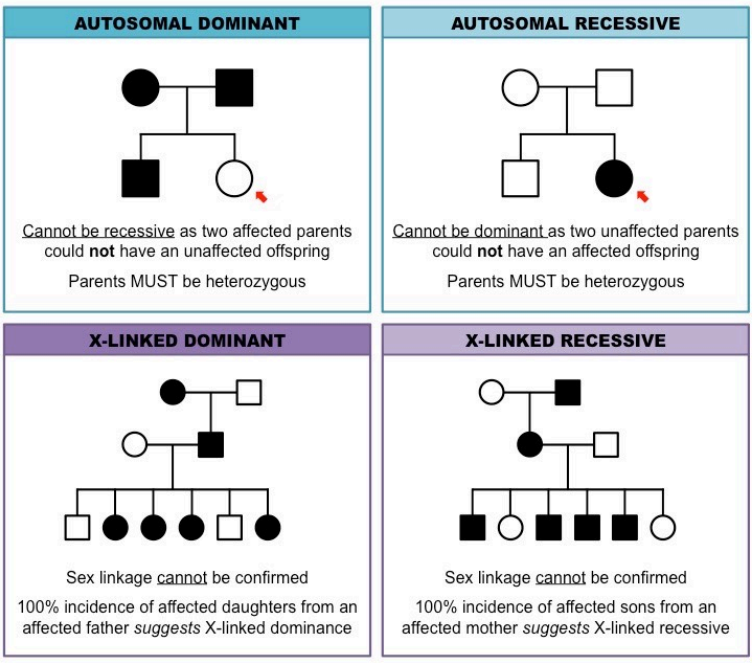
- However certain trends can be used to confirm that a trait is **not** X-linked dominant or recessive

X-linked Dominant

- If a male shows a trait, so too **must** all daughters as well as his mother
- An unaffected mother **cannot** have affected sons (or an affected father)
- X-linked dominant traits *tend* to be more common in females (this is not sufficient evidence though)

X-linked Recessive

- If a female shows a trait, so too **must** all sons as well as her father
- An unaffected mother *can* have affected sons *if* she is a carrier (heterozygous)
- X-linked recessive traits *tend* to be more common in males (this is not sufficient evidence though)



Causes of mutation

- **Mutation:** Random change to the base sequence of a gene.
- Two factors can increase the mutation rate:
    1) Radiation
    2) Chemical substances
- Mutations of the genes that control cell division can cause a cell to divide endlessly and develop into a tumour. Mutations are therefore a cause of cancer.
- Mutations in cells that develop into gametes can be passed onto offspring. This is the origin of genetic diseases.

Consequences of nuclear bombing and accident at nuclear power stations

- The nuclear bombing of Hiroshima and an accident at Chernobyl are two examples of a catastrophic release of radioactive material.
- Radioactive isotopes were released into the environment and as a result people were exposed to potentially dangerous levels of radiation.
- Effects of nuclear fallout:
    - Miles of forest land killed, including animals and plants.
    - Bioaccumulation caused high levels of radioactive isotopes in fish as far as Germany and Scandinavia.
    - More than 6000 cases of thyroid cancer.

3.5 Genetic Modification and Biotechnology

Gel electrophoresis
DNA amplification by PCR
DNA profiling
Paternity and forensic investigations
Analysis of DNA profiles
Genetic modification
Techniques for gene transfer to bacteria
Assessing the risks of genetic modification
Risks and benefits of GM crops
Analysing risks to monarch butterflies of Bt corn
Clones
Natural methods of cloning
Factors affecting the rooting of stem cutting
Cloning animal embryos
Cloning adult animals using differentiated cells
Methods used to produce Dolly