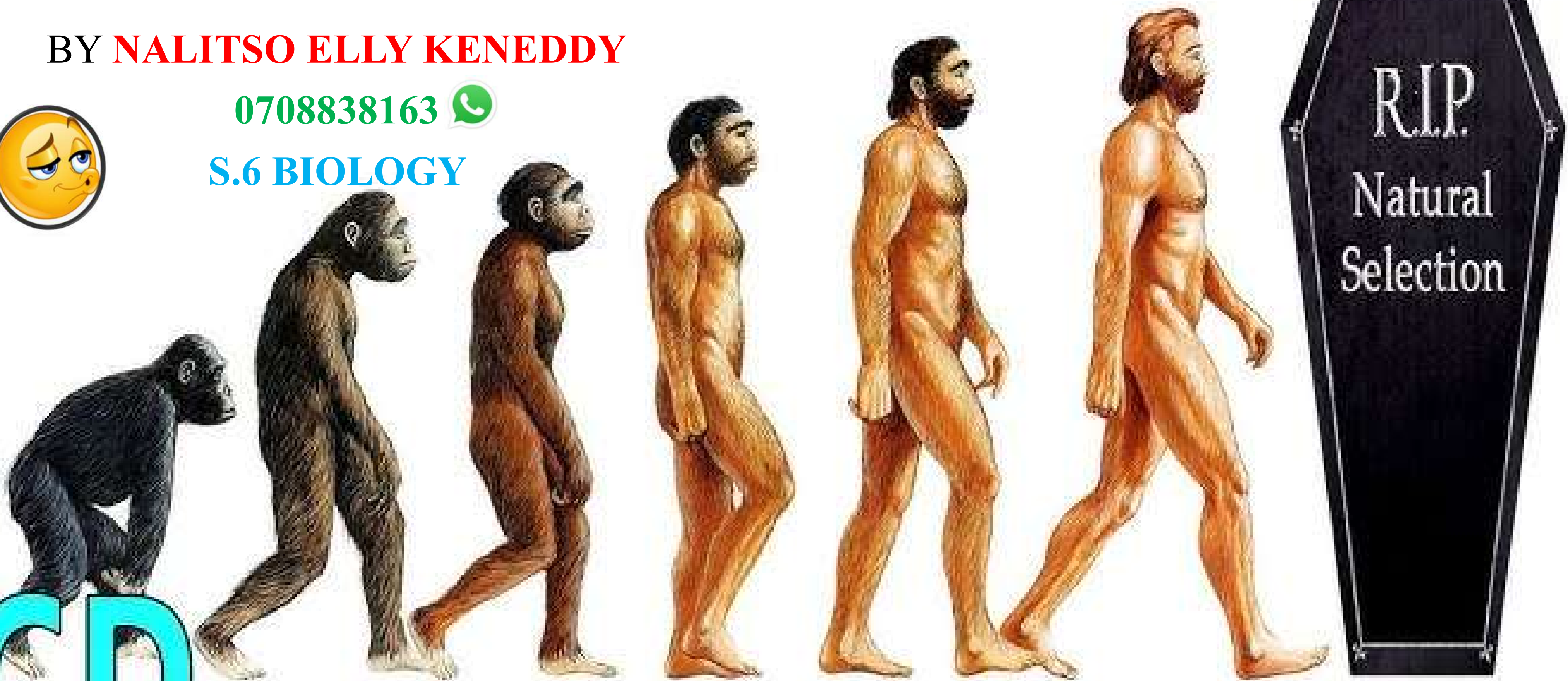
INHERITANCE & EVOLUTION

BY **NALITSO ELLY KENEDDY**

0708838163

S.6 BIOLOGY

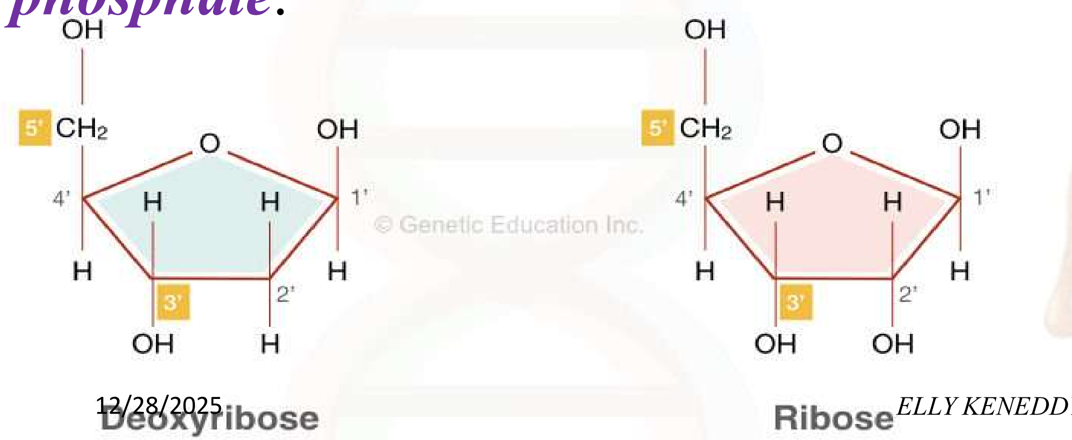


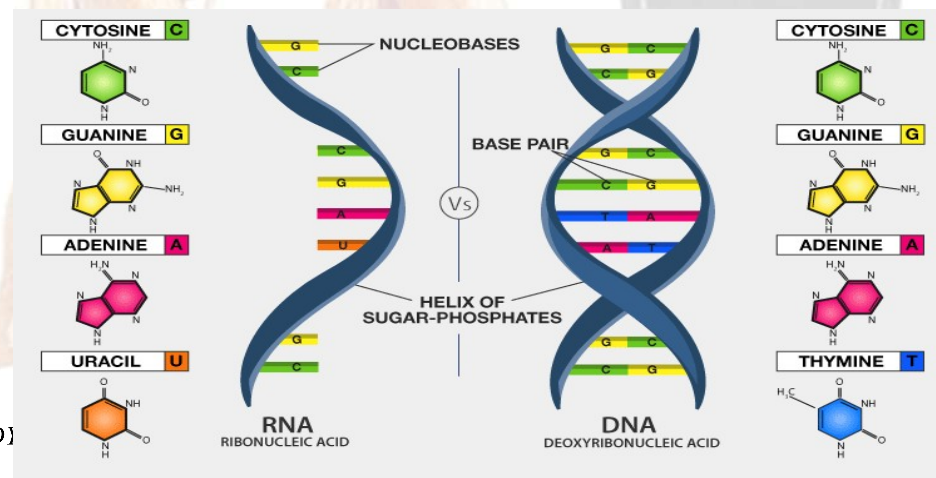
LEARNING OUTCOMES.

- Analyze the structural and functional significance of nucleic acids in meiosis and mitosis, their role in cellular functions, and how mutations in nucleotide sequences can contribute to disease (cancer). (u, s, gs, v/a)
- Assess gene technology techniques, their applications in various fields, and the associated ethical implications. (u, s, gs, v/a)
- Apply Mendelian principles to predict inheritance patterns and utilize mathematical models to analyze allele frequencies and genotype distributions within populations. (u, s)
- Examine different forms of allele interactions (autosomal linkage, multiple alleles, codominance and incomplete dominance), including their examples and influence on phenotypic expression. (u, s, gs)

NUCLEIC ACIDS.

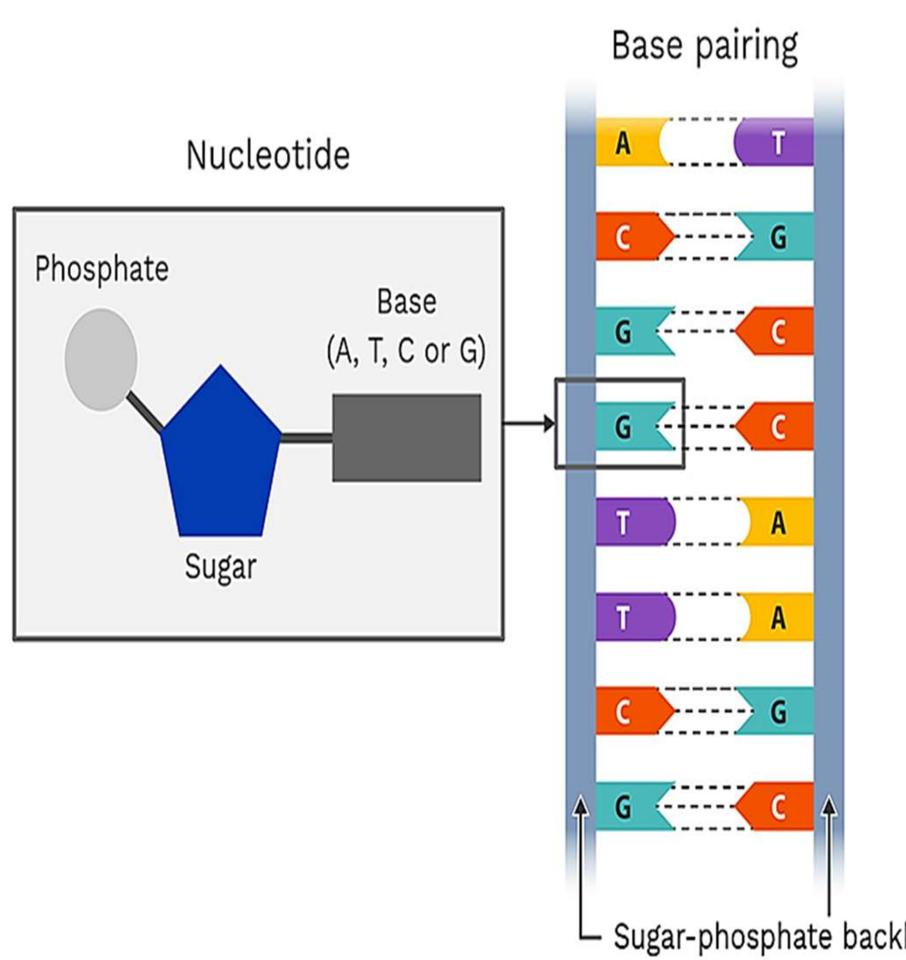
- Nucleic acids are long chain molecules i.e. ***DNA*** and ***RNA***. ***Deoxyribonucleic acid*** (DNA) and ***Ribonucleic acid*** (RNA) are the two main kinds of nucleic acid.
- DNA is ***found mainly in the nuclei of cells***, small amounts in ***mitochondria*** and ***chloroplasts***. RNA occurs ***mainly in the cytoplasm***, particularly at the ***ribosomes***. Both DNA and RNA are polymers, and their building blocks are called ***nucleotides*** hence the nucleic acids are described as ***polynucleotides***. A nucleotide is made up of three parts, a ***pentose sugar***, a ***nitrogenous base*** and ***phosphate***.



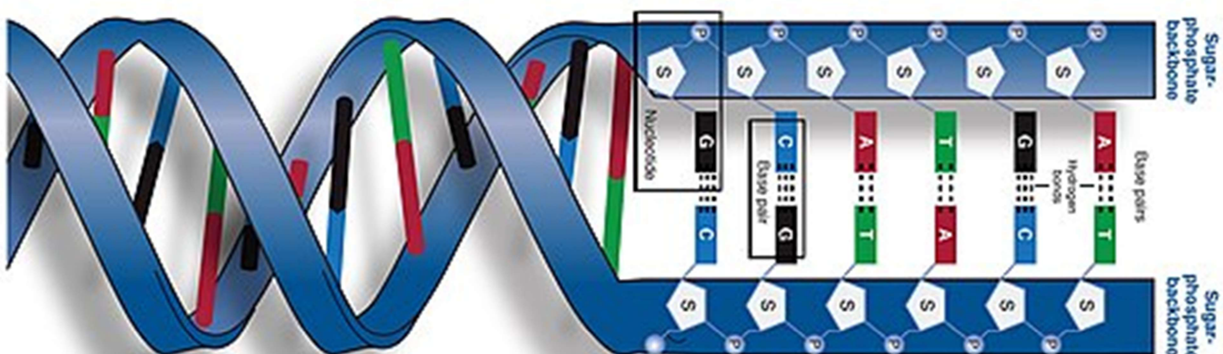


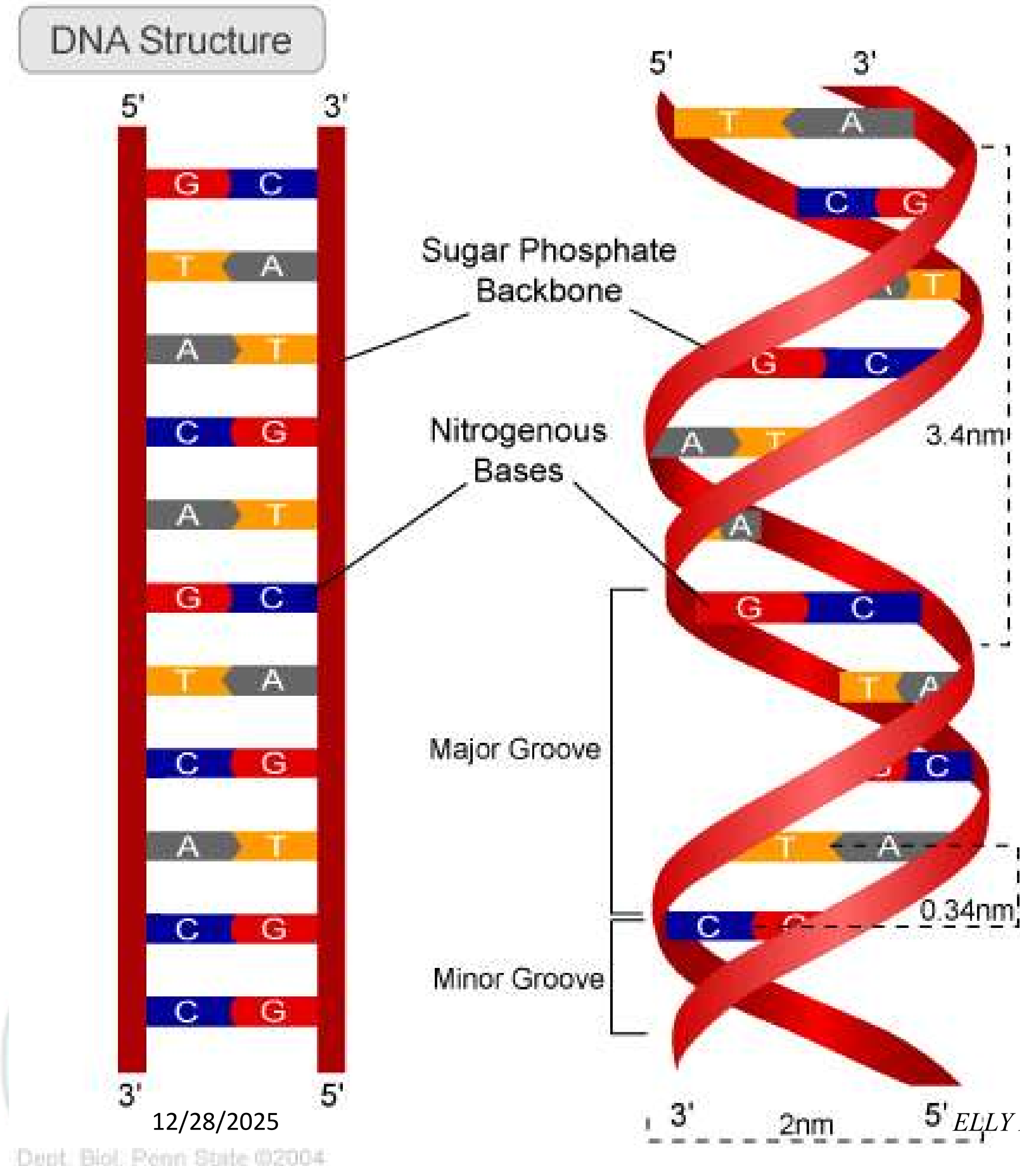
STRUCTURE OF DNA.

- In DNA the ***pentose sugar*** is ***deoxyribose*** . Four different ***nitrogenous bases*** occur in DNA .
- ***Adenine*** (A) and ***guanine*** (G) belong to a group of compounds called ***purines***.
- ***Cytosine*** (C) and ***thymine*** (T) are ***pyrimidines***.
- The sugar, nitrogenous base and ***phosphate*** are bonded to form a nucleotide.
- In a DNA molecule the ***phosphate groups join nucleotides together*** by their sugar molecules hence forming a polynucleotide.

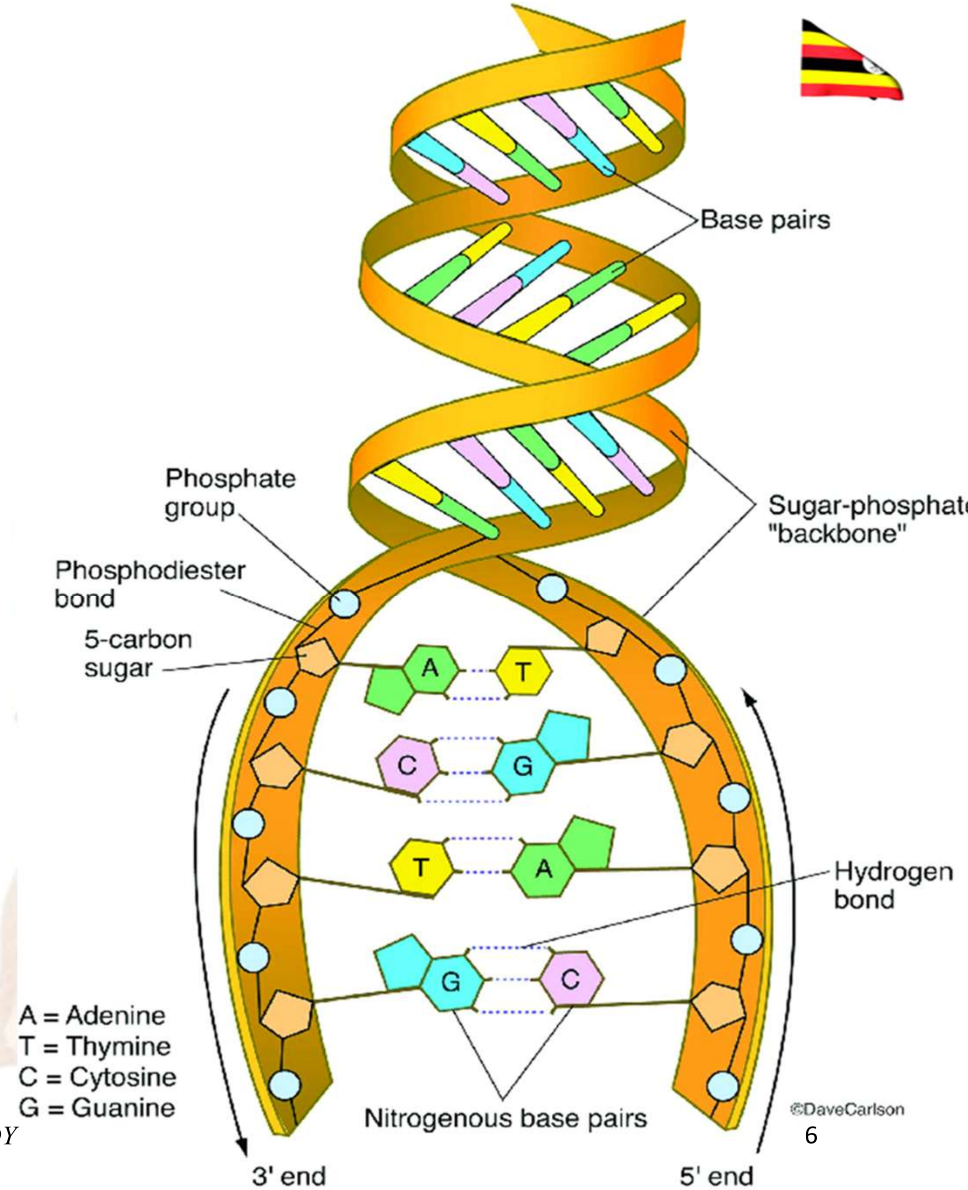


- DNA molecule consists of ***two polynucleotide strands*** each ***coiled in a right-handed spiral helix***. The polynucleotide ***strands run anti parallel to each other***.
- The two strands ***coil around each other to form a double helix*** are ***held together by hydrogen bonding*** found ***between the nitrogenous bases of adjacent nucleotides***. ***Adenine pairs with thymine***, and ***guanine with cytosine***; the adenine-thymine pair has ***two hydrogen bonds*** while the guanine-cytosine pair has ***3 hydrogen bonds***.
- Along the axis of the molecule the base pairs are 0.34nm apart. For each complete twist of the double helix there are 10 pairs of nucleotides





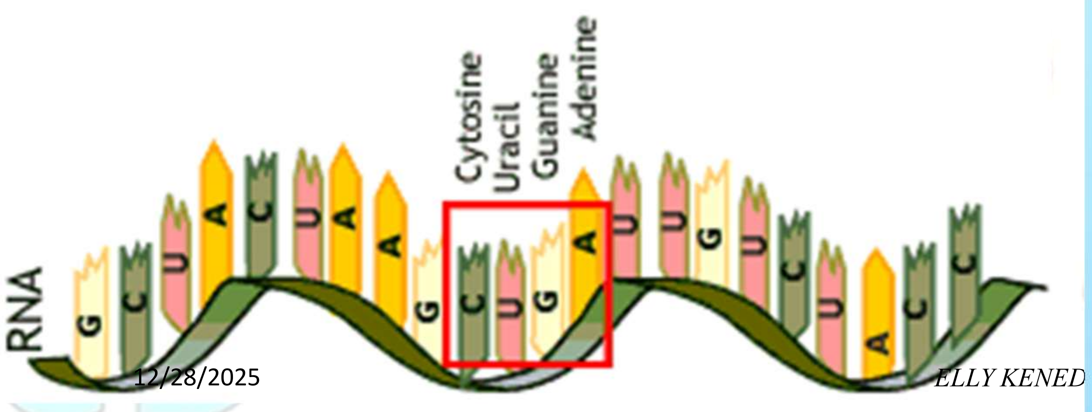
DNA Structure
5'
3'
Sugar Phosphate Backbone
Nitrogenous Bases
Major Groove
Minor Groove
3.4nm
0.34nm
2nm
Dept. Biol. Penn State ©2004

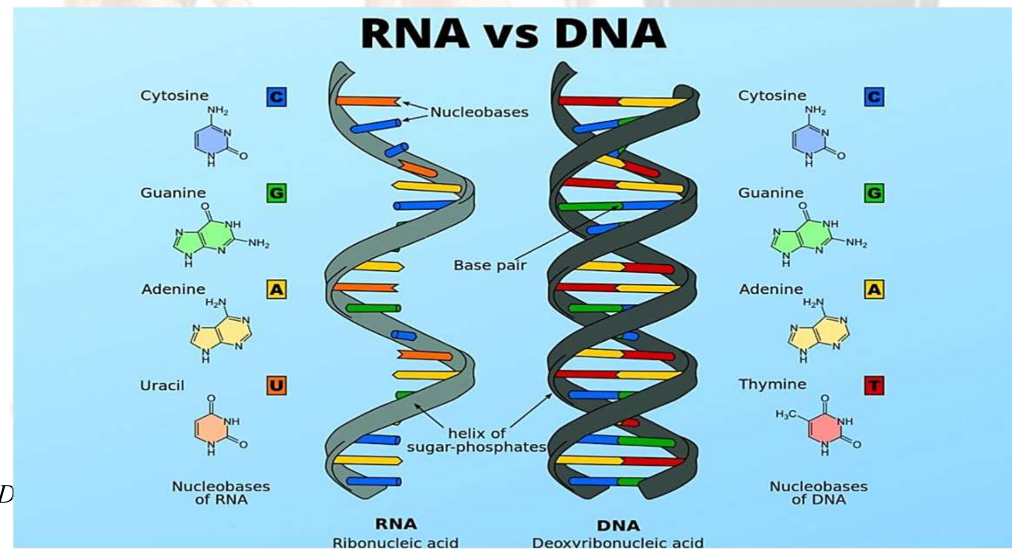


Base pairs
Phosphate group
Phosphodiester bond
5-carbon sugar
Sugar-phosphate "backbone"
Hydrogen bond
A = Adenine
T = Thymine
C = Cytosine
G = Guanine
Nitrogenous base pairs
3' end
5' end
©DaveCarlson

STRUCTURE OF RNA.

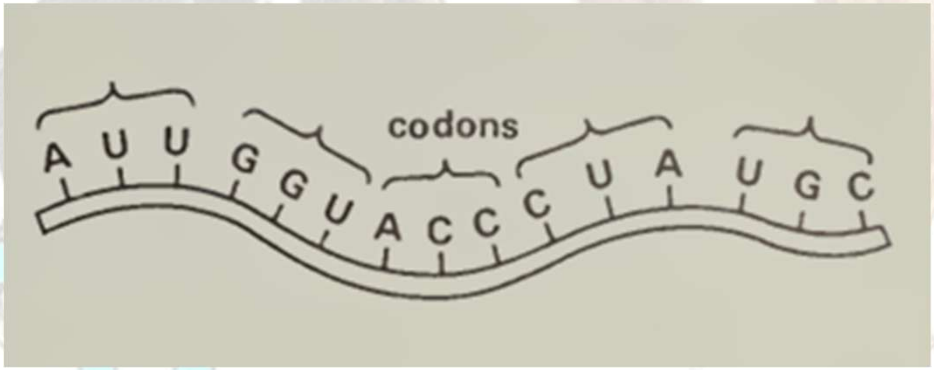
- There are three different kinds of ribonucleic acid i.e. ***messenger RNA*** (mRNA), ***transfer RNA*** (tRNA) and ***ribosomal RNA*** (rRNA).
- The nucleotides of RNA are made contain the pentose sugar ***ribose***, not deoxyribose as in DNA.
- Another difference is that ***thymine is not found in RNA*** which is ***replaced by the nitrogenous base uracil (U)*** instead.





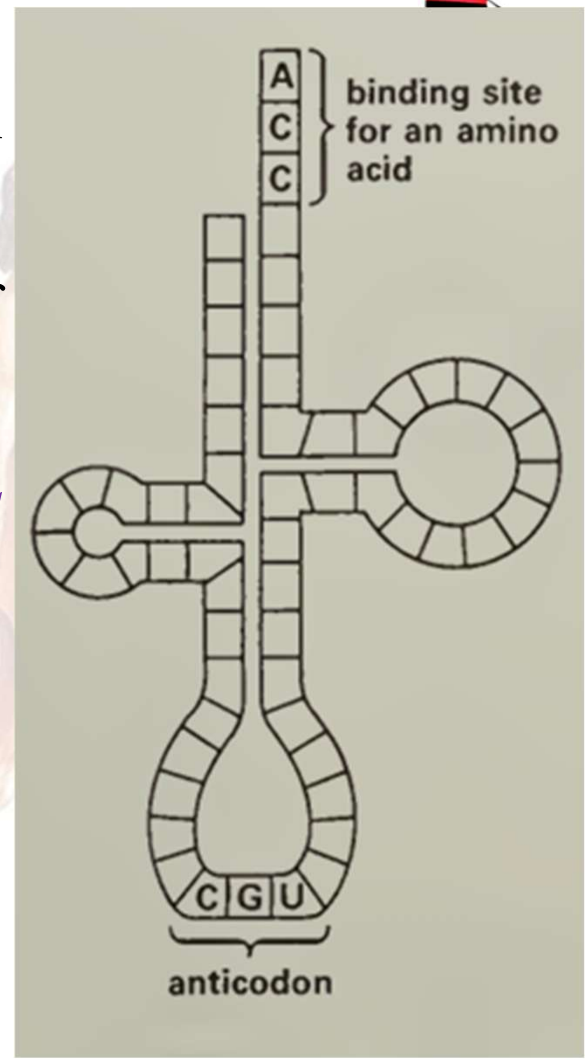
MESSENGER RNA

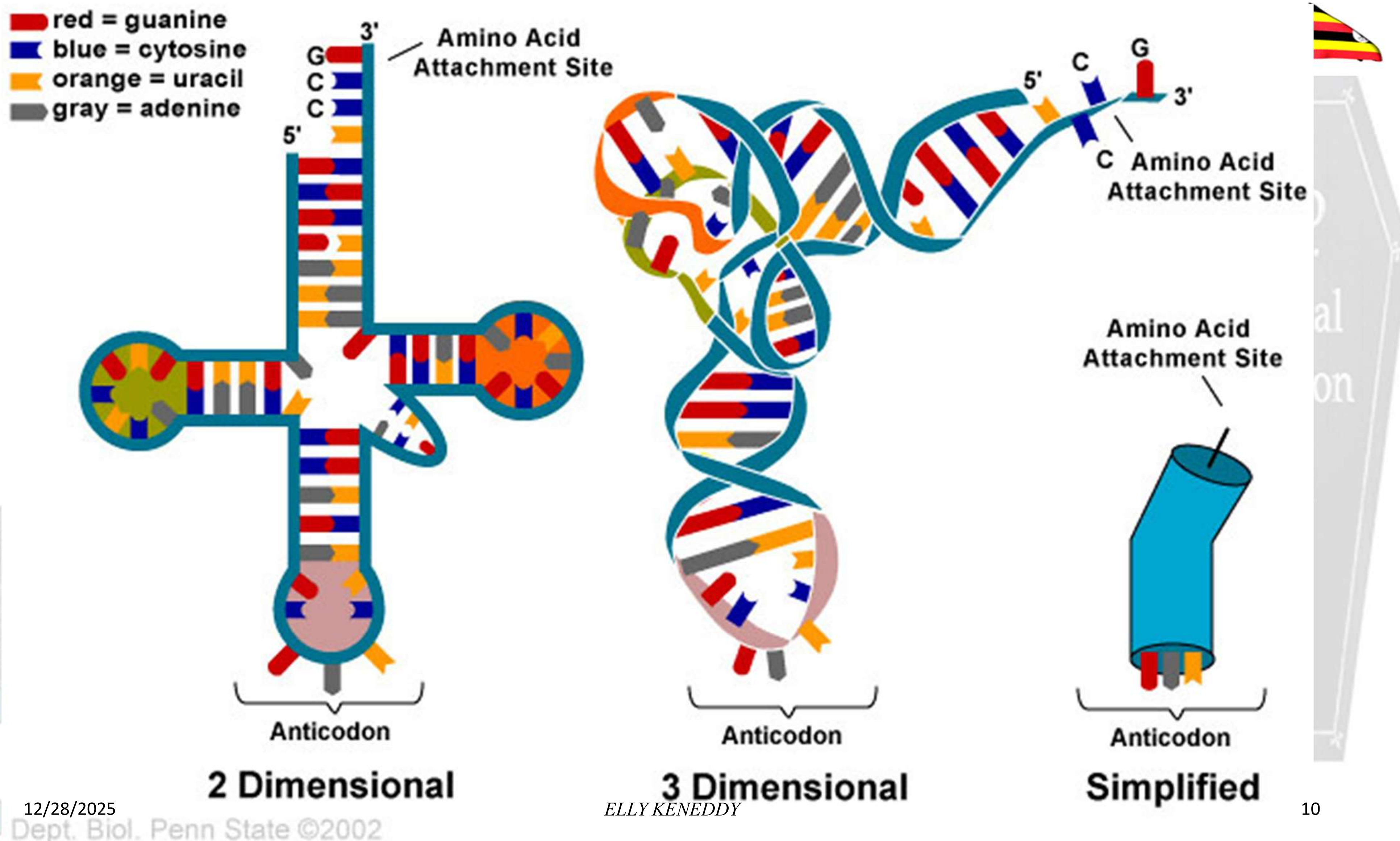
- Between 3 and 5 % of the RNA in a cell is mRNA. The molecules of mRNA are ***single***, ***helical strands*** made of up to ***several thousand nucleotides***. Messenger RNA is ***made in the nucleus from a single strand of DNA*** by a process known as ***transcription***. In the formation of mRNA only ***one strand of the DNA molecule is copied.***
- From there it passes through ***the nuclear membrane pores*** to the ribosomes where ***triplets of bases in the mRNA act as codons*** in the synthesis of proteins. Most mRNA exists within the cell for a short time.



TRANSFER RNA

- Transfer RNA makes up between **10** and **15** % of a cell's RNA content. The ***single strand of 75-90 nucleotides*** which make up a tRNA molecule is ***wound into a double helix*** which usually has ***three prominent bulges*** to form a clover-leaf arrangement.
- ***One of the free ends*** of every tRNA molecule ends with nucleotides containing the following ***order of bases ACC where the amino acid binds***.
- There are at least twenty different kinds of tRNA and ***differ in the sequence of base triplets*** making up the ***anticodons by which tRNA binds to the codons of mRNA*** during the synthesis of proteins
- Base pairing occurs in certain regions of the molecule. The 3 unpaired bases at the bottom loop (anti codon) pair with m RNA

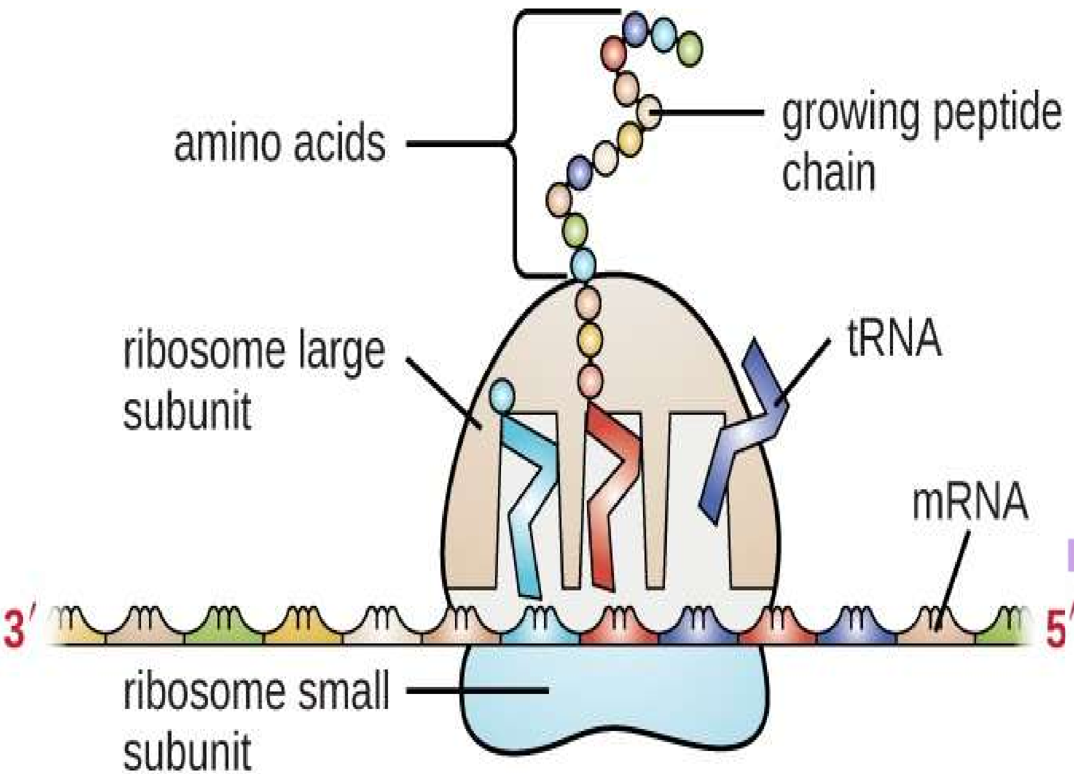


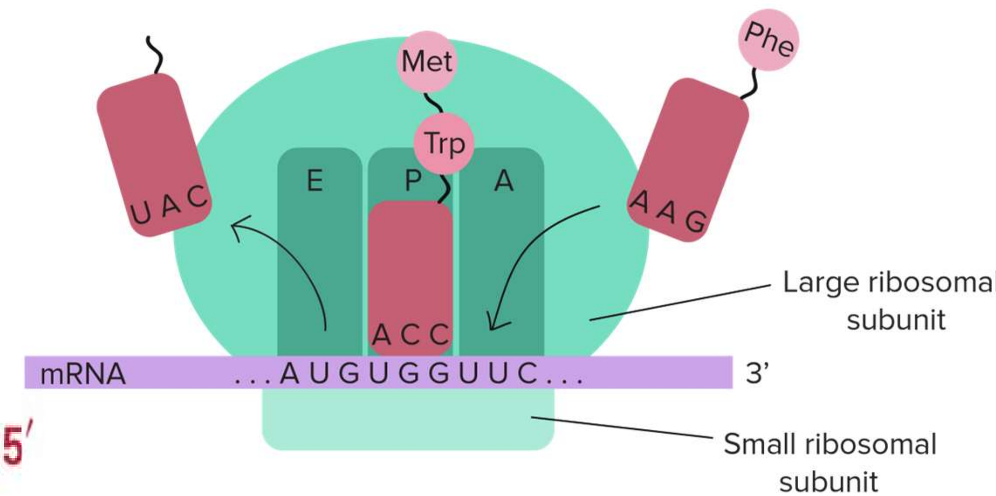

red = guanine
blue = cytosine
orange = uracil
gray = adenine
3'
G
C
C
5'
Amino Acid
Attachment Site
Anticodon
2 Dimensional
5'
C
G
3'
C
Amino Acid
Attachment Site
Anticodon
3 Dimensional
Amino Acid
Attachment Site
Anticodon
Simplified
Dept. Biol. Penn State ©2002

RIBOSOMAL RNA

- The many ***thousands of nucleotides which make up a molecule*** of rRNA are wound into a complex structure consisting ***partly of single*** and ***partly of double helices.***
- Ribosomal RNA is ***made in the nucleus under the control of the nucleoli***. It ***enters the cytoplasm and binds with protein molecules*** to become ribosomes.
- Over half the mass of a ribosome consists of rRNA and it ***makes up more than 80 % of the total RNA*** in a cell. Even so, the precise function of rRNA is still not known.
- It is synthesized by genes present on the DNA of several chromosomes found within a region of the nucleolus known as the nucleolar organizer.
- It is ***found in the cytoplasm*** where it is associated with protein molecules

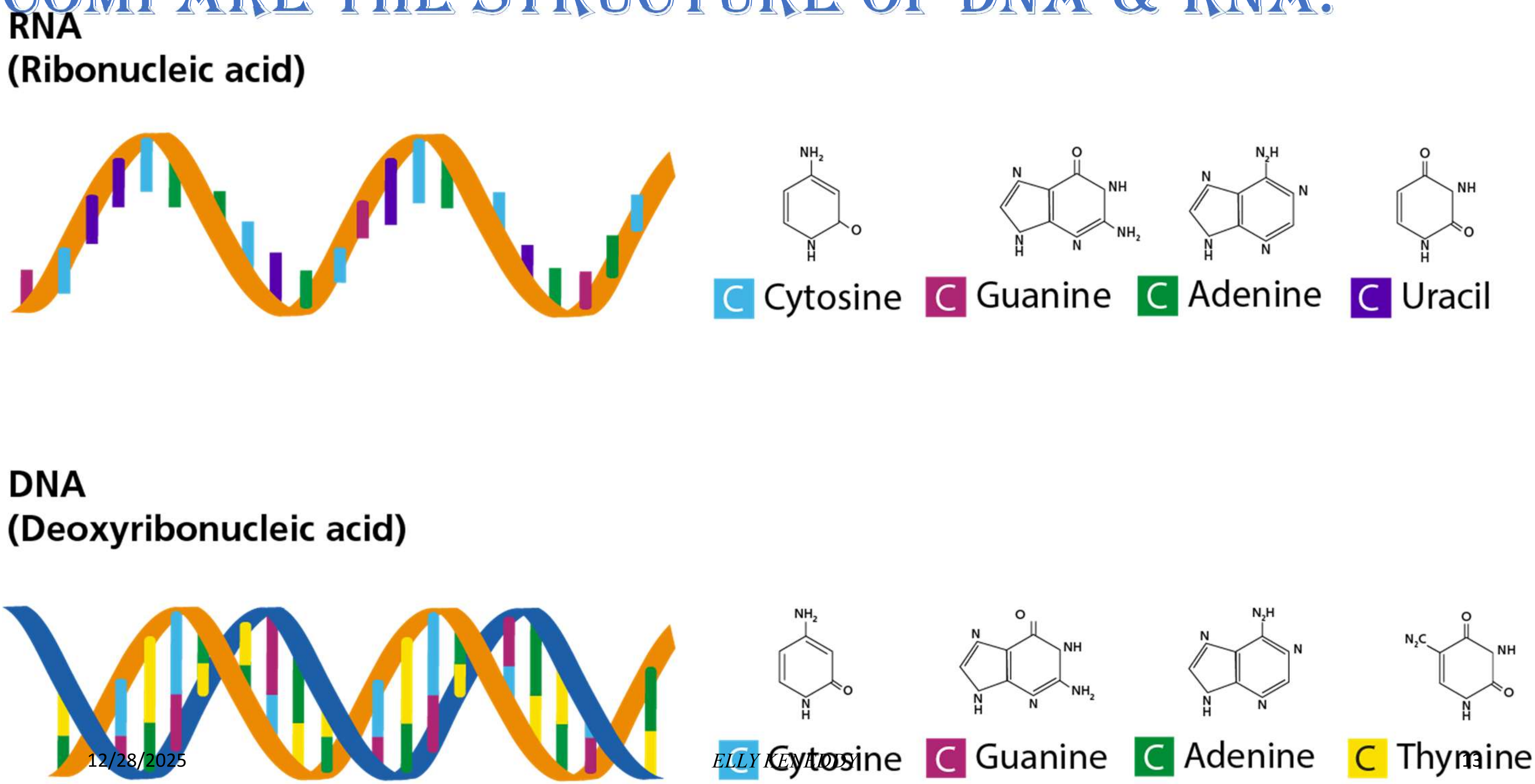
RIBOSOMAL RNA.





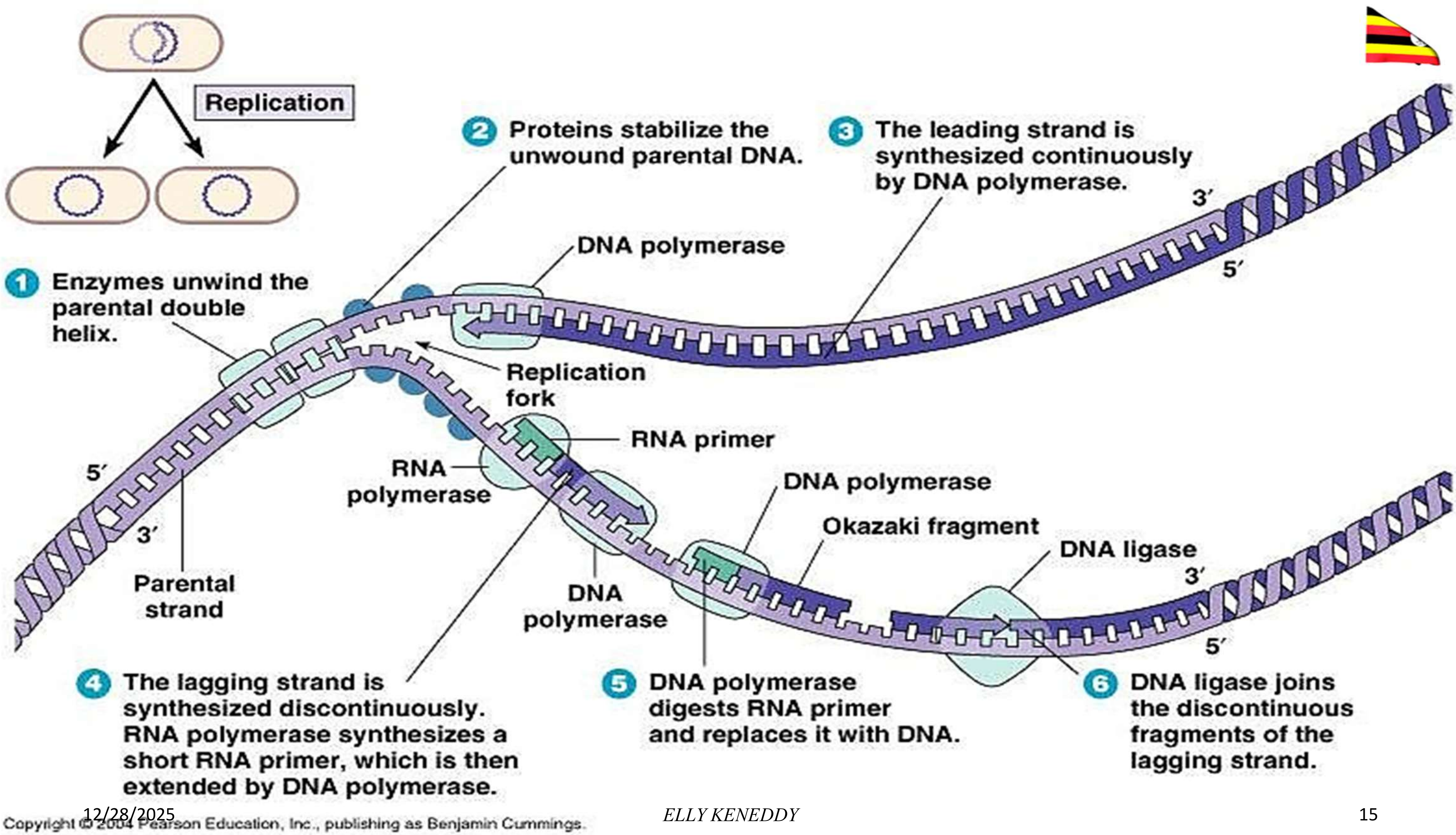
ASSIGNMENT.

COMPARE THE STRUCTURE OF DNA & RNA.



DNA REPLICATION.

- The process of replication ***starts with the unwinding*** of the DNA double helix. This ***controlled by the enzyme DNA helicase*** which ***breaks hydrogen bonds between complementary bases***. Bonding proteins ***keep the un-winded strands apart*** and expose the bases.
- Free Nucleotides with ***complementary bases are attracted***. ***DNA polymerase then binds to the single strand of DNA*** that results and ***starts to move along the strand.***
- Each time it meets the next base on the DNA, ***free nucleotides approach the DNA strand,*** and the ***one with the correct complementary base*** to the base in the DNA ***forms hydrogen-bonds with it***.
- The ***free nucleotide is then held in place by the enzyme*** until it ***binds to the preceding nucleotide***, thus ***extending the new strand of DNA***. The ***enzyme continues to move along one base at a time*** with the new DNA strand growing as it does so.



Replication
1 Enzymes unwind the parental double helix.
2 Proteins stabilize the unwound parental DNA.
3 The leading strand is synthesized continuously by DNA polymerase.
DNA polymerase
3′
5′
Replication fork
5′
3′
Parental strand
RNA primer
RNA polymerase
DNA polymerase
Okazaki fragment
DNA ligase
DNA polymerase
3′
5′
4 The lagging strand is synthesized discontinuously. RNA polymerase synthesizes a short RNA primer, which is then extended by DNA polymerase.
5 DNA polymerase digests RNA primer and replaces it with DNA.
6 DNA ligase joins the discontinuous fragments of the lagging strand.
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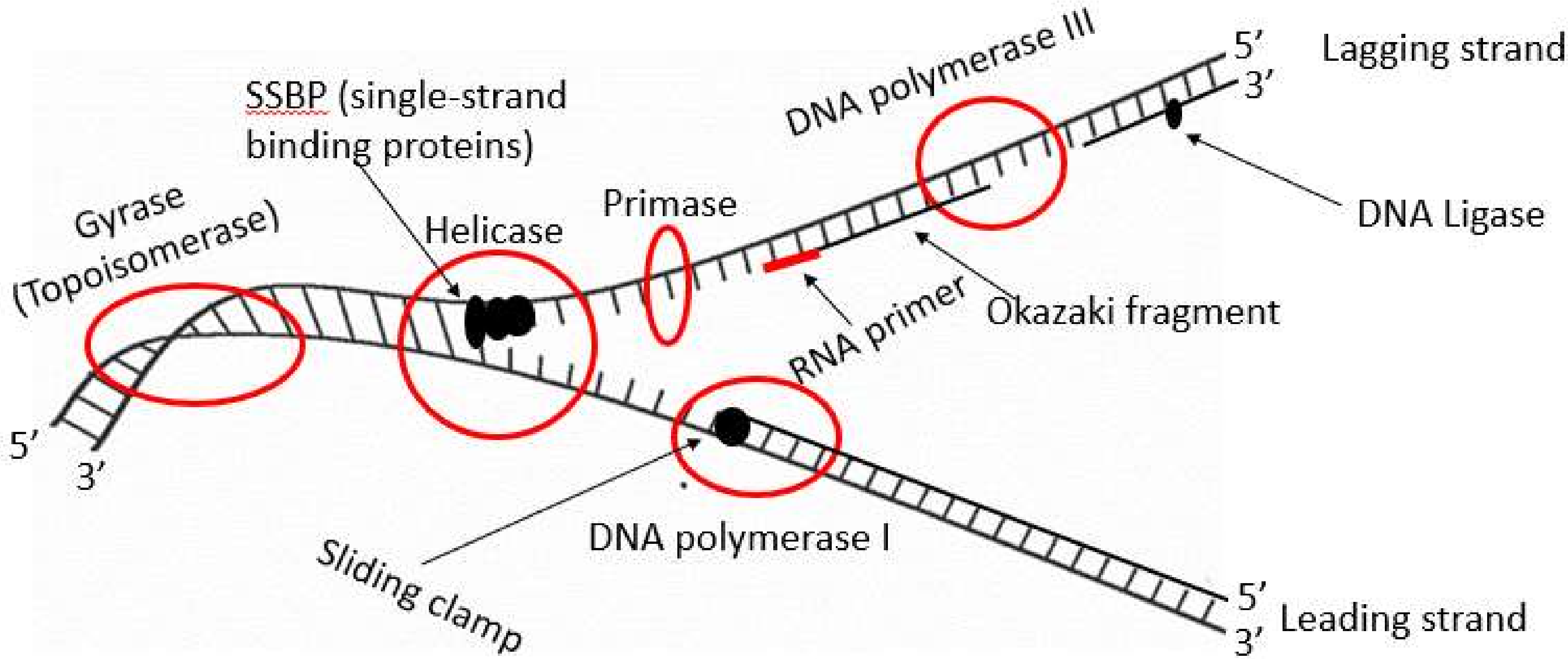
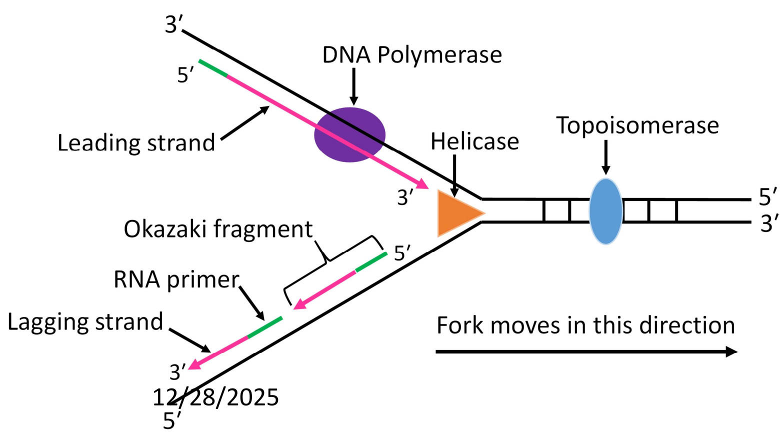
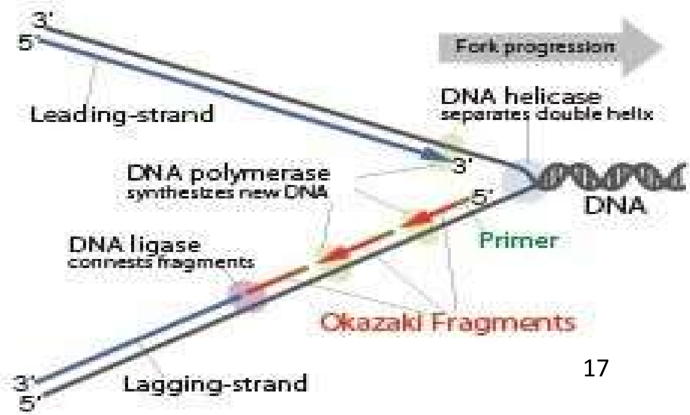
- This movement ***can only happen in the 5’- 3' direction*** (leading strand). The leading strand ***can be copied continuously by DNA polymerase*** because the ***Polymerase enzyme is moving in the same direction*** as the unwinding enzyme. This is called ***continuous replication***.
- The copying of the other strand (lagging strand) has to ***keep being started again***, because the ***DNA polymerase has to move away from the unwinding enzyme*** in the 5’-3' direction.
- This ***results in small gaps being left*** because the ***DNA polymerase cannot join the 3' end of one newly synthesized piece*** of DNA to the 5' end of the next.
- Another enzyme, ***DNA ligase, is needed to close the gaps*** between the formed poly nucleotides. This is called ***discontinuous replication***.



Lagging strand
5′
3′
DNA polymerase III
SSBP (single-strand binding proteins)
Gyrase (Topoisomerase)
Helicase
Primase
DNA Ligase
Okazaki fragment
RNA primer
5′
3′
Sliding clamp
DNA polymerase I
5′
3′
Leading strand



3′
5′
DNA Polymerase
Leading strand
Helicase
Topoisomerase
3′
5′
3′
Okazaki fragment
5′
RNA primer
Lagging strand
Fork moves in this direction
3′
5′



3′
5′
Fork progression
Leading-strand
DNA helicase
separates double helix
DNA polymerase
synthesizes new DNA
3′
5′
DNA
DNA ligase
connects fragments
Primer
Okazaki Fragments
3′
5′
Lagging-strand

CONSERVATIVE AND SEMI-CONSERVATIVE HYPOTHESIS

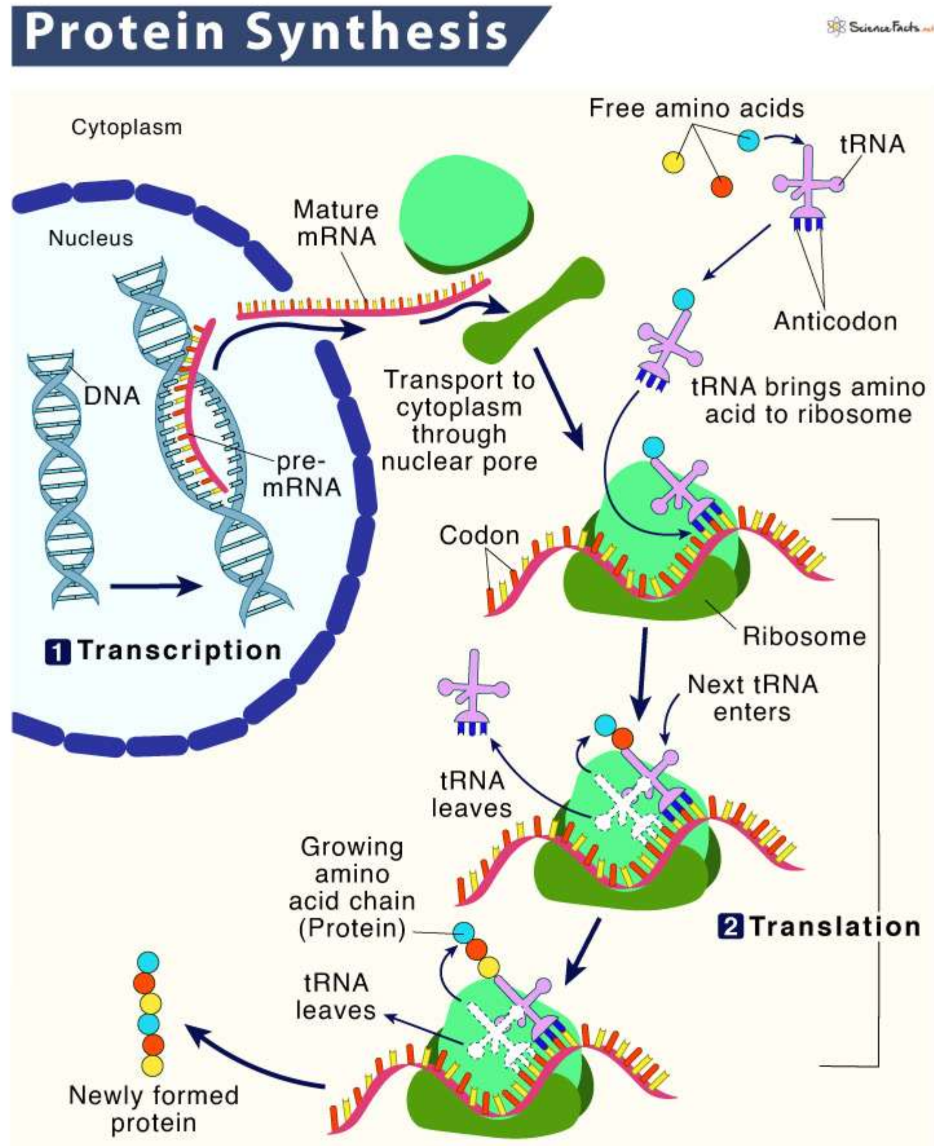
- There are two theories of DNA replication i.e. the ***conservative*** and ***semi conservative hypothesis***.
- In the semi conservative hypothesis, ***two strands unzip and the new nucleotides come into position in relation to each of the strands*** forming ***new daughter strands*** which ***wind together after to form a double helix***. The new DNA molecule is composed of ***one old strand*** and ***one new strand***.
- The result is that daughter DNA Molecules ***never contain precisely the same nucleotides as the parent molecule***.
- In conservative replication the ***DNA strand unzips using helicase enzyme and forms two new DNA strands*** which ***zip together to become a DNA double helix*** made of ***new strands only***. The old strands also zip together again after replication so that they form another DNA molecule made of old strands only.

PROTEIN SYNTHESIS.

- This is the ***process by which the coded information*** is ***transferred from DNA on chromosomes*** in the nucleus to the ribosomes in the cytoplasm to ***make the proteins.***

There are three main stages in the formation of a protein namely;

- **Transcription**
- **Amino acid activation**
- **Translation**

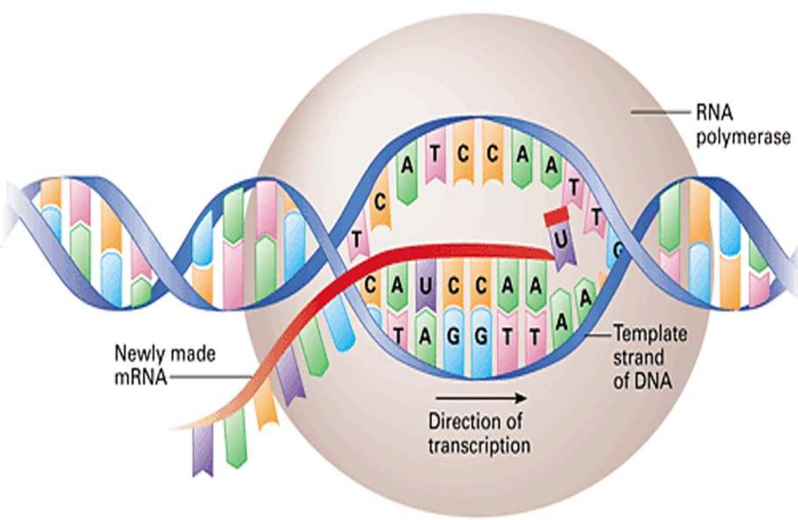


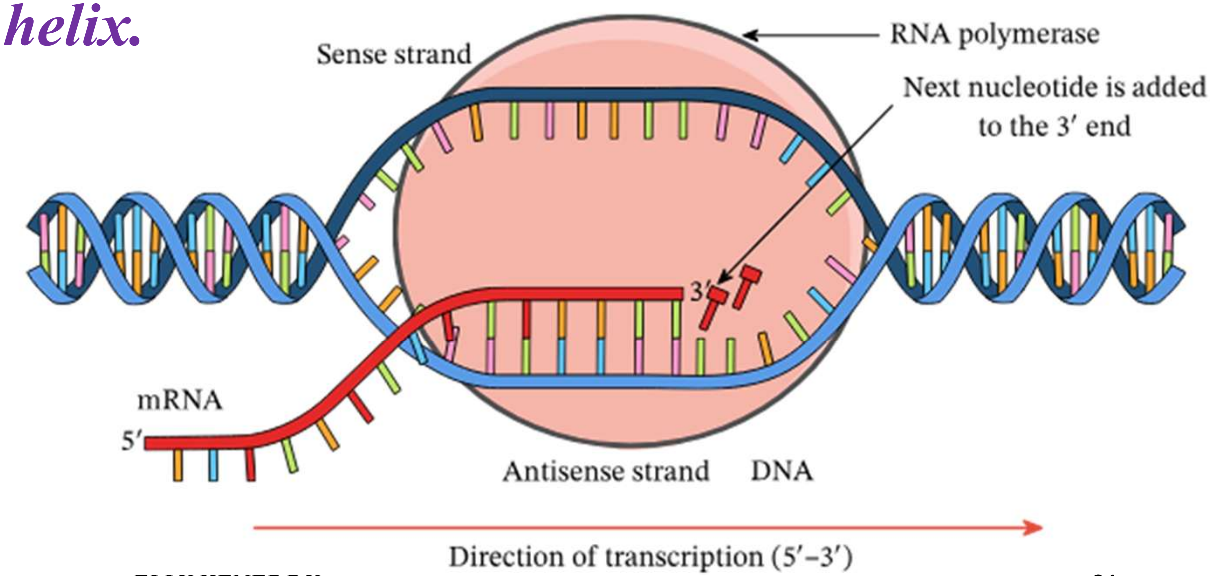
TRANSCRIPTION.

- Transcription is the ***mechanism by which the base sequence of a section of DNA*** representing a gene ***is converted into the complementary base sequence of mRNA.***
- ***RNA polymerase first recognizes the start sequence in the DNA*** coding strand and becomes attached to the DNA at this point.
- The ***DNA double helix unwinds*** by ***breakage of the relatively weak hydrogen bonds*** between the bases of the two strands, ***exposing bases on single strands of DNA.***
- ***Only one of these strands can selected*** as a template for the formation of a complementary single strand of mRNA.
- A large enzyme called ***polymerase attaches to the strand at a particular base sequence, the promoter site***, initiating transcription.
- mRNA molecule is ***formed by the linking of free nucleotides*** under the ***influence of RNA polymerase*** and according to the rules of base pairing between DNA and RNA however thymine is replaced by uracil.

CONT…………

- At the ***end of transcription RNA polymerase recognizes the stop sequence*** on the cistron and ***becomes detached from the cistron at this point***.
- When the mRNA molecules have been synthesized, they ***leave nucleus via the nuclear pores*** and ***carry the genetic code to the ribosomes***.
- When sufficient numbers of mRNA molecules have been formed from the gene the RNA polymerase molecule leaves the DNA and the ***two strands 'zip up' again, re-forming the double helix.***





PROCESSING MRNA

- In eukaryotic cells, mRNA has to be processed to ***remove the introns*** before it leaves the nucleus.
- Introns are sequences of nucleotides that lie between the ***cistrons that code for polypeptides.*** (They are called 'introns' because they 'intrude' into the cistron but are not expressed in the final protein.)
- After the introns have been cut out and removed, the remaining sections of RNA (called exons because they are expressed) are spliced together to form the final strand of mRNA.

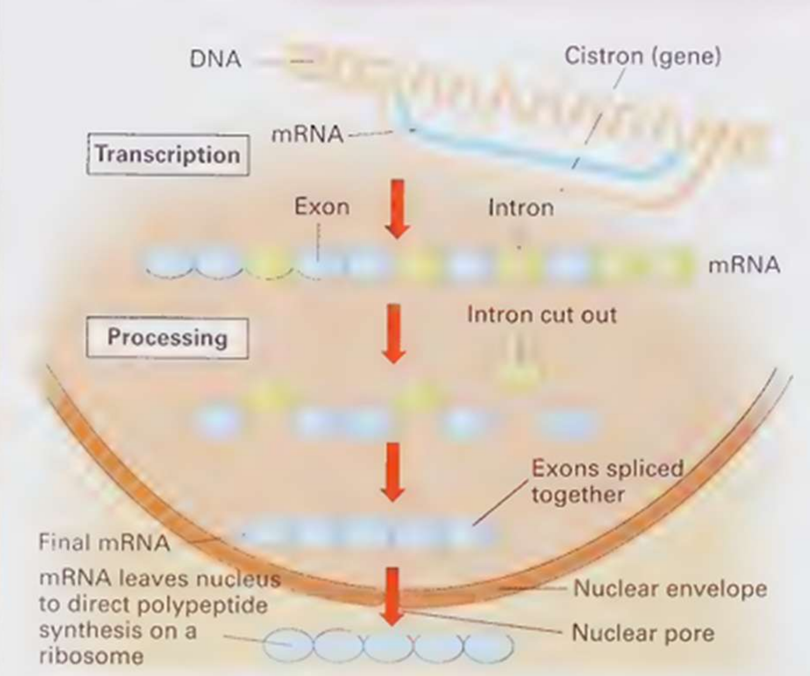
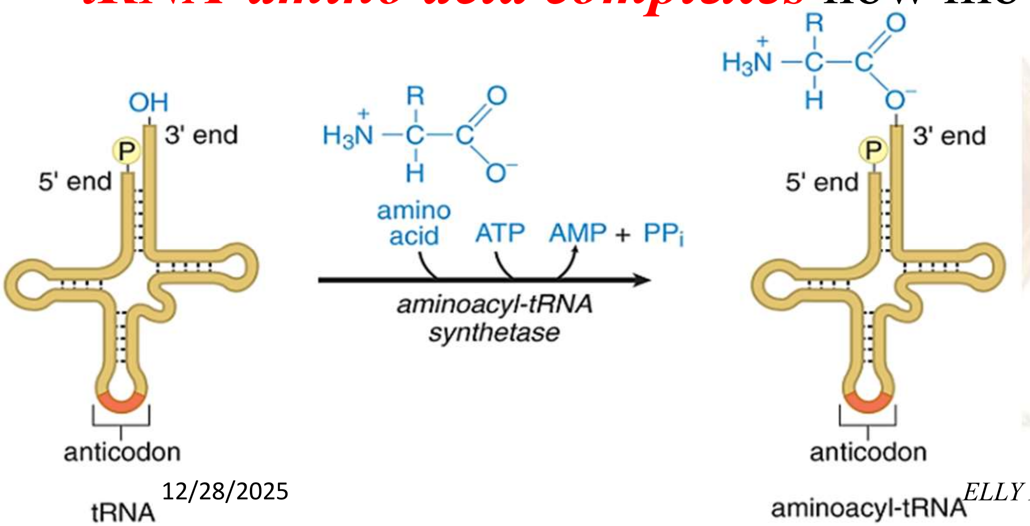
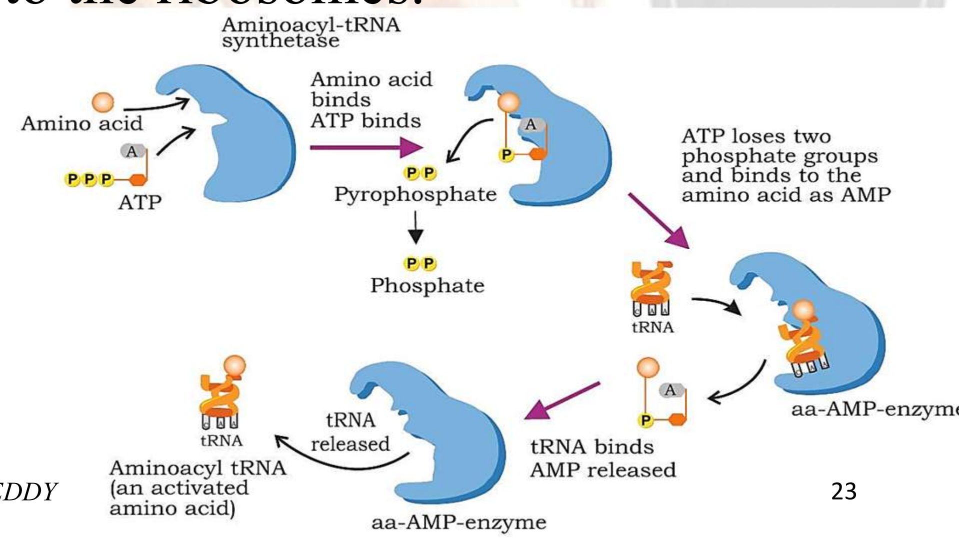


Figure 3 *Transcription and processing in a typical eukaryotic cell. Prokaryotes and some eukaryotes (such as single-celled organisms) have no introns so their mRNA does not need to be processed. After transcription, prokaryotic mRNA goes directly to the ribosomes to be translated.*

Amino acid activation.

- During activation, energy from *ATP is used to combine* ***tRNA molecules with amino acid molecules.***
- There are at least *twenty different kinds of tRNA*, the important difference between them being the sequence of nitrogenous bases in their anticodons.
- *Each type of tRNA binds with a specific amino acid*. The amino acid molecules *join to the free ends of the tRNA molecules* where *bases ACC are found*. The *tRNA-amino acid complexes* now move to the ribosomes.

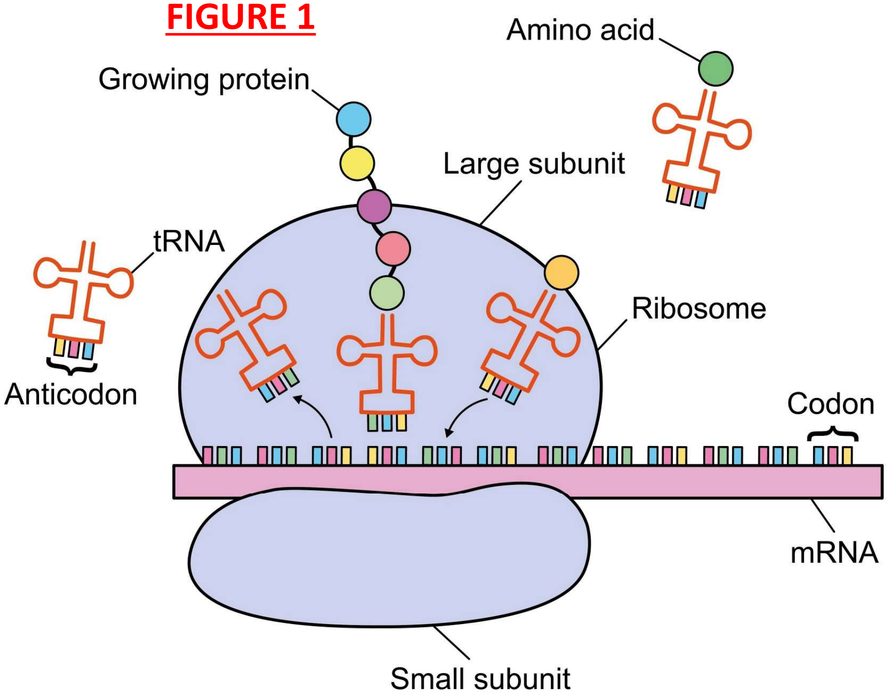




TRANSLATION.

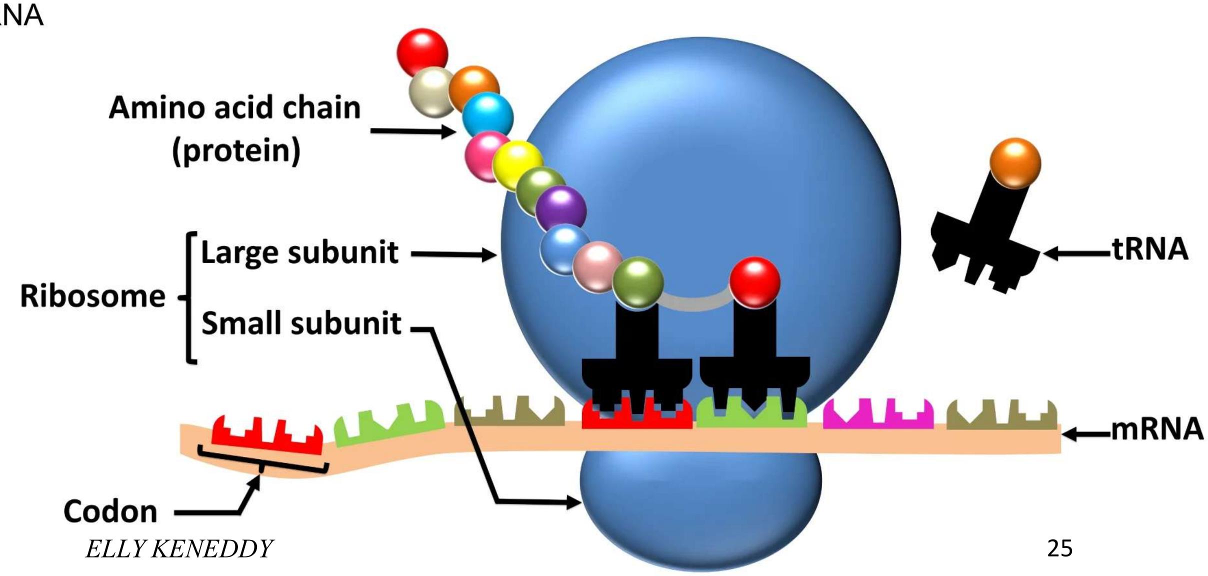
- This is the ***mechanism by which the codons of mRNA*** are ***converted into a specific sequence of amino acids*** in a polypeptide chain ***on the ribosomes***.
- During this process mRNA attaches itself on a group of ribosomes (like beads on a string) to form a structure called polysome.
- Within the ribosomes there are two tRNA sites where the ***mRNA codon can become attached*** by ***complementary base pairing*** to a molecule of tRNA bearing the anti codon.
- The complementary anti-codon of the tRNA-amino acid complex is ***attracted to the first codon on the mRNA strand*** enclosed by the ribosomes.
- The second mRNA codon likewise attracts its complementary anti-codon of the second tRNA amino acid complex.
- The ribosome ***holds the mRNA and the tRNA amino acid complexes together*** until the ***two amino acids form a peptide bond*** by a condensation reaction there by forming a dipeptide catalyzed by ***peptidyl transferase enzyme***.

FIGURE 1



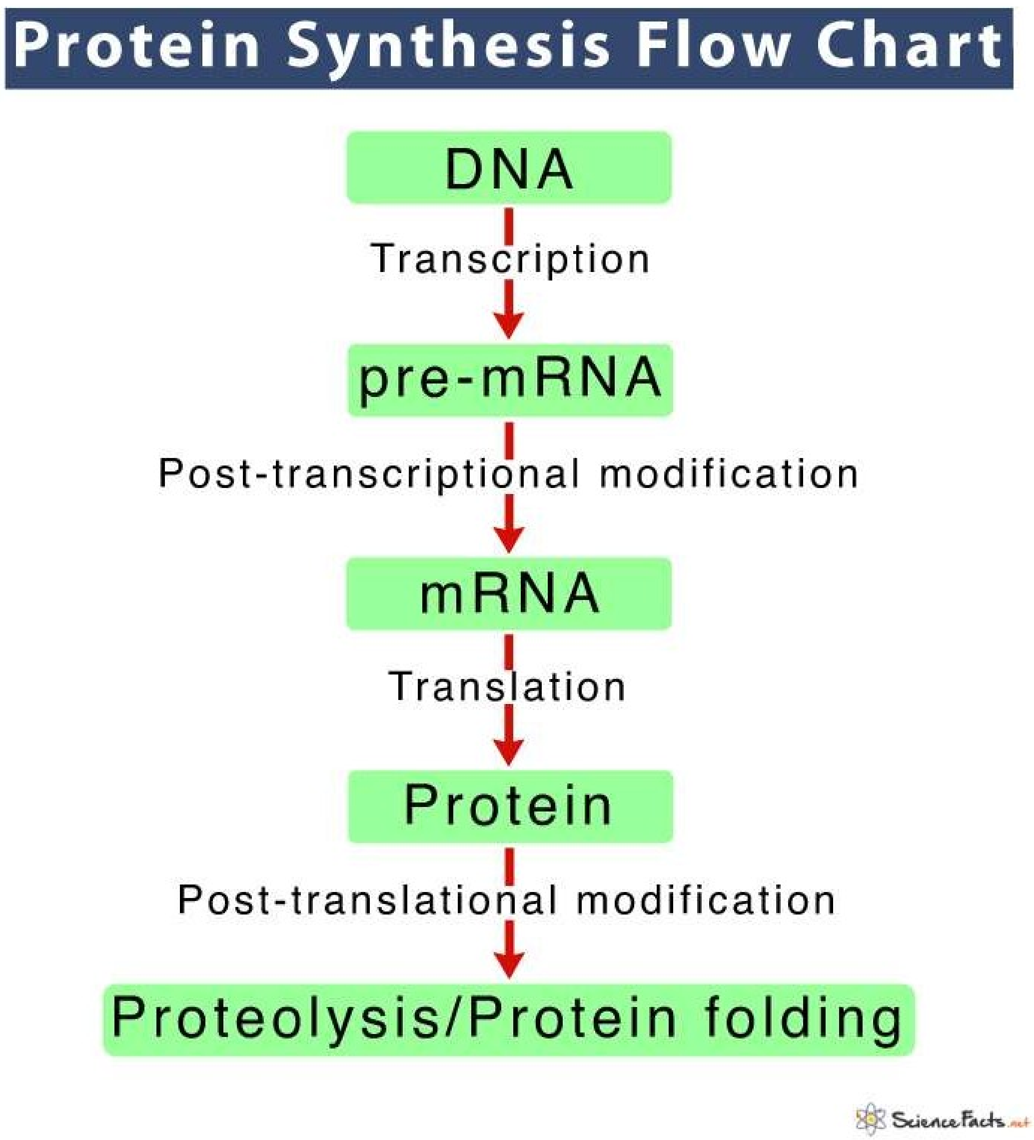
- The ***small subunit*** has a ***binding site for mRNA.***
- The ***large subunit*** has ***binding sites for transfer RNA (tRNA).***

FIGURE 2

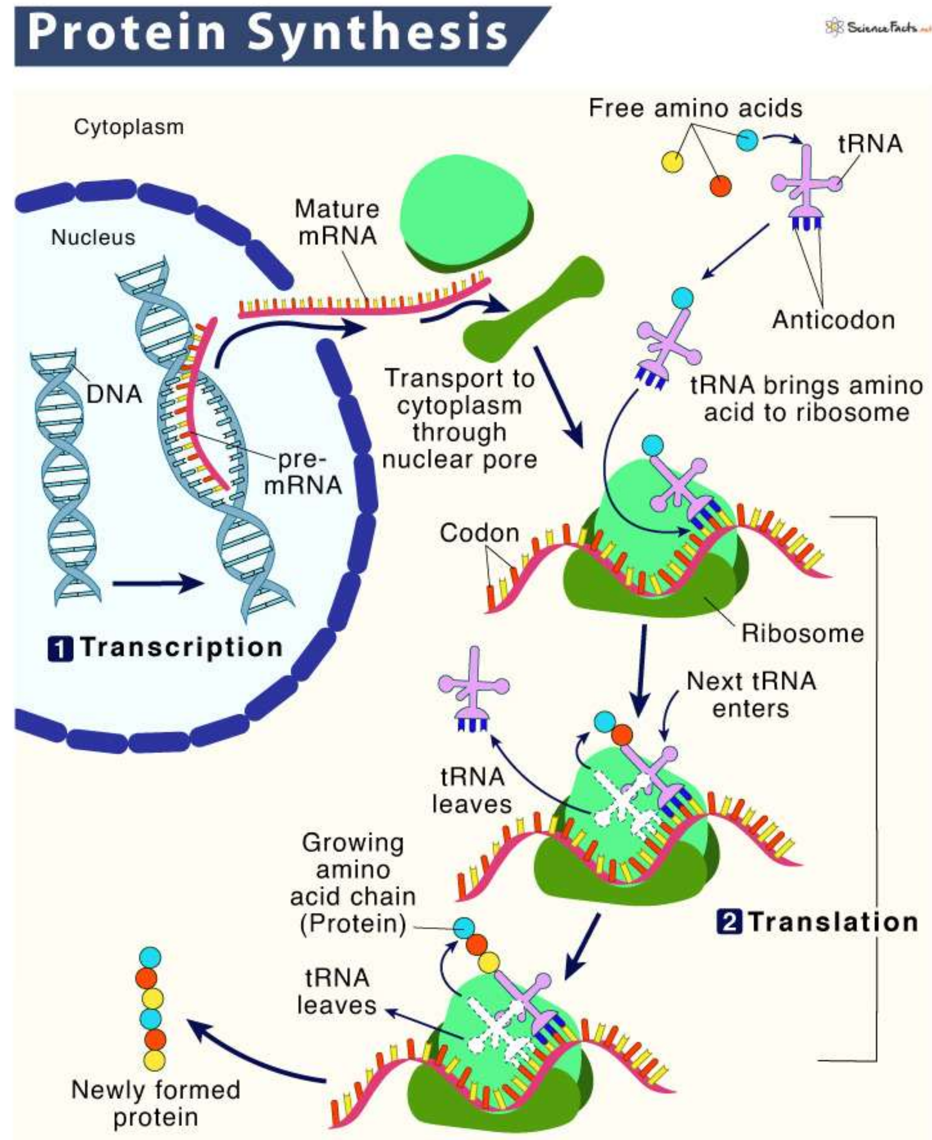


CONT……………….

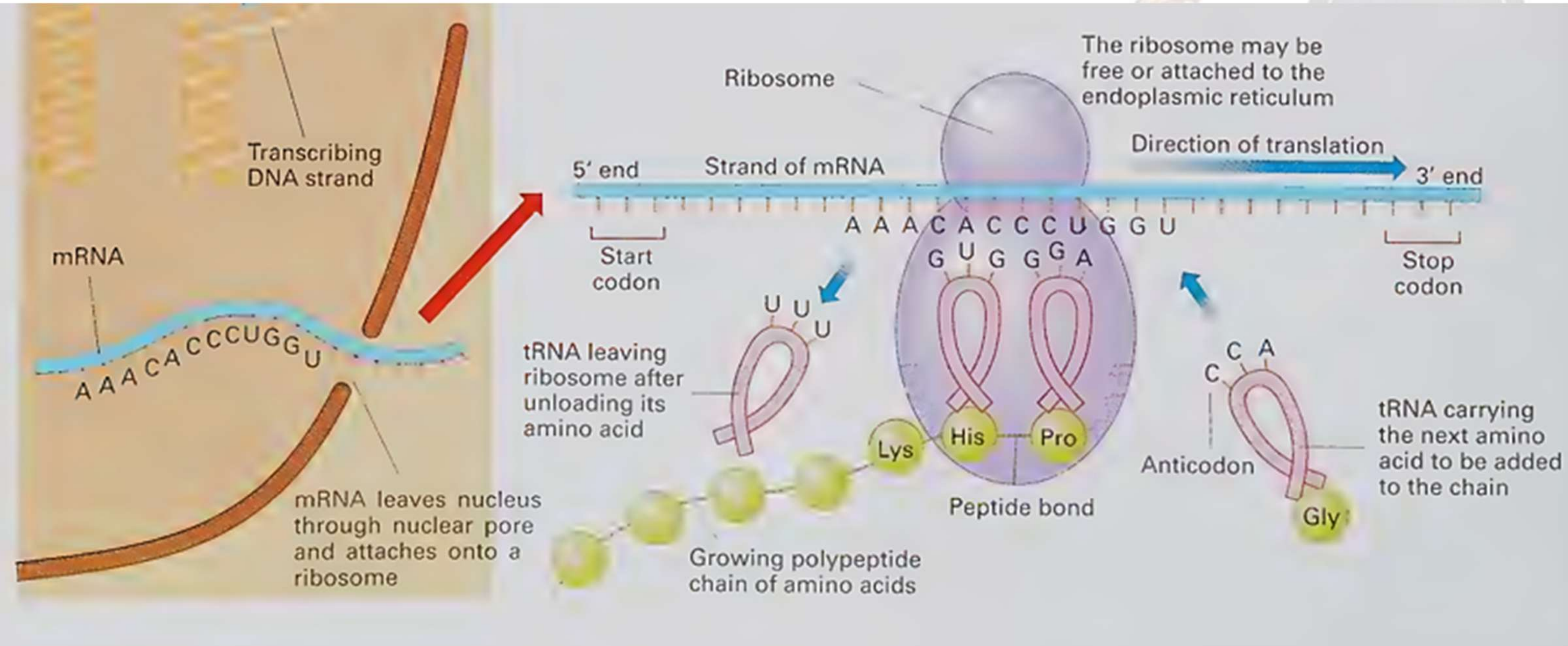
- Once the two amino acids have combined into a dipeptide, the ***first tRNA is disconnected from its amino acid*** and therefore leaves the ribosome which ***moves one step along the mRNA strand*** so as ***to hold the next codon-anti codon complex*** together until the third amino acid is linked condensation reaction.
- In this way, a ***polypeptide chain is assembled by the addition of one amino acid at a time*** along the polysome (group of many ribosomes).
- Once each amino acid is linked to the growing polypeptide chain, the ***tRNA which carried it to the mRNA codon is released*** back into the cytoplasm.
- This tRNA is again free to combine with its specific amino acid in the cytoplasm.
- This sequence of the ribosome, steadily reading the mRNA code and translating it, continues until the ribosome comes into contact with the stop codon


Protein Synthesis Flow Chart
DNA
Transcription
pre-mRNA
Post-transcriptional modification
mRNA
Translation
Protein
Post-translational modification
Proteolysis/Protein folding

DY


Protein Synthesis
Cytoplasm
Nucleus
DNA
pre-mRNA
Mature mRNA
Transport to cytoplasm through nuclear pore
1 Transcription
Free amino acids
tRNA
Anticodon
tRNA brings amino acid to ribosome
Codon
Ribosome
Next tRNA enters
tRNA leaves
Growing amino acid chain (Protein)
tRNA leaves
Newly formed protein
2 Translation

PROTEIN SYNTHESIS ILLUSTRATED..



FEATURES OF A GENETIC CODE.

- ✓It is a triplet code
- ✓The triplet code is also called a degenerate code i.e. a given amino acid may be coded for by more than one code
- ✓It is punctuated i.e. it has a start codon usually AUG and three stop codons namely UAA, UAG and UGA.
- ✓The genetic code is also described as universal because the same triplet of bases code for the same amino acid in all organisms.
- ✓The genetic code is non-over lapping e.g. each triplet of bases is read separately UACACCAUGGGC is read as UAC-ACC-AUG-GGC.

THE CELL CYCLE AND CELL DIVISION.

- Cells undergo a ***series of changes in their life time during which they produce new daughter cells***.
- New cells are ***formed from an already existing cell by cell division***. Cell division ensures continuity of life through giving rise to new individuals in unicellular organisms.
- There are two forms of cell division namely **mitosis** and **meiosis**. **Mitosis** promotes the ***multiplication of cells*** to bring about growth whereas ***meiosis*** promotes breeding by promoting ***gamete formation in sexual reproduction.***
- Cell division occurs due to the presence of chromosomes in the nucleus of the cell. Chromosomes are ***thread-like structures in the nucleus*** of the cell made of ***DNA molecules*** and ***histone proteins***.
- A chromosome contains a pair of elongated structures called ***chromatids*** which are joined together by the ***centromere***. Chromosomes carry genes.

THE CELL CYCLE

- The ***sequence of events which occurs between one cell division and the next*** is called the ***cell cycle***. It has three main stages.

1. **Interphase**. This is a period of ***synthesis of molecules*** and ***growth***. The cell produces many materials required for its own growth and for carrying out all its functions. DNA replication also occurs during interphase.
2. **Mitosis**. This is the process of ***nuclear division*** (formation of 2 separate nuclei).
3. **Cytokinesis**. This is the process of ***division of the cytoplasm*** into two daughter cells.

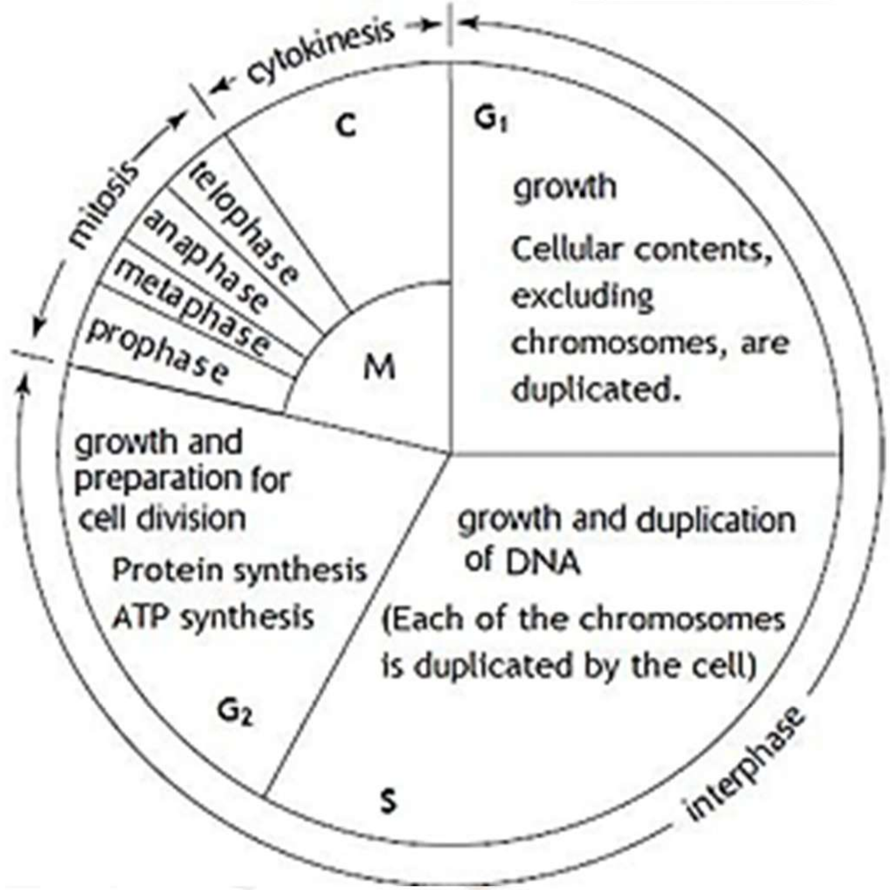
- The length of the cycle depends on the type of cell and external factors such as temperature, food and oxygen supplies e.g. Bacteria may divide every 20 minutes, epithelial cells of the intestine wall every 8-10 hours.

INTERPHASE.

- This is the period in which the cell ***prepares for the next cell division***.(involves cell growth) Interphase occupies by far the ***longest part*** of the cell cycle and can be divided into the following stages:
- ***The G_1 stage***, in which ***synthesis of RNA*** and ***proteins occurs***. Synthesis of ***ATP/ energy stores*** and ***centriole replication*** begins. It takes about 8 hours to complete.
- ***The S stage***, in which ***replication of DNA is completed*** and ***duplication of histone proteins occurs***. Chromatids are formed from chromosomes. It lasts about 6 hours.
- ***The G_2 stage***, in which synthesis and ***replication of organelles*** such as mitochondria, new ribosomes, E.R occurs. ***Spindle fibres begin to form*** and ***replication of centrioles becomes complete***. About 4 hours are normally required for this stage to be completed.

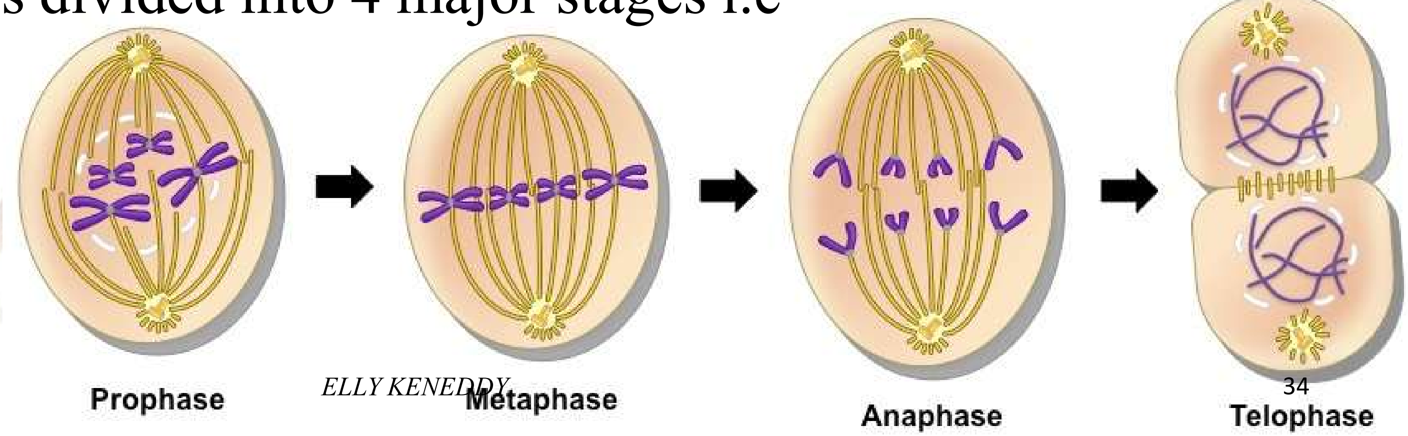
MAJOR EVENTS OCCURRING DURING INTERPHASE.

- Replication of DNA and chromosomes so as to double their amounts
- Replication of the centrioles occurs in animal cells.
- There is synthesis of a lot of ATP for cell division.
- There is replication of cell organelles like mitochondria, endoplasmic reticulum, and Golgi body etc..
- There is synthesis of histone proteins, RNA and other types of proteins occurs.
- Spindle fibre formation begins.
- Synthesis of proteins which later make up the microtubules of the spindle



MITOSIS.

- This is a type of cell division in which the ***mother cell divides into two identical daughter cells*** which are similar to the mother cell with ***the same number of chromosomes as the mother cells.***
- Mitosis ***maintains the chromosome number*** and produces daughter cells which are identical (clones) to the parent cell.
- Mitosis ***occurs in somatic cells*** and also can occur in haploid, diploid and polyploidy cells.
- The nuclear division is divided into 4 major stages i.e
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase



PROPHASE.

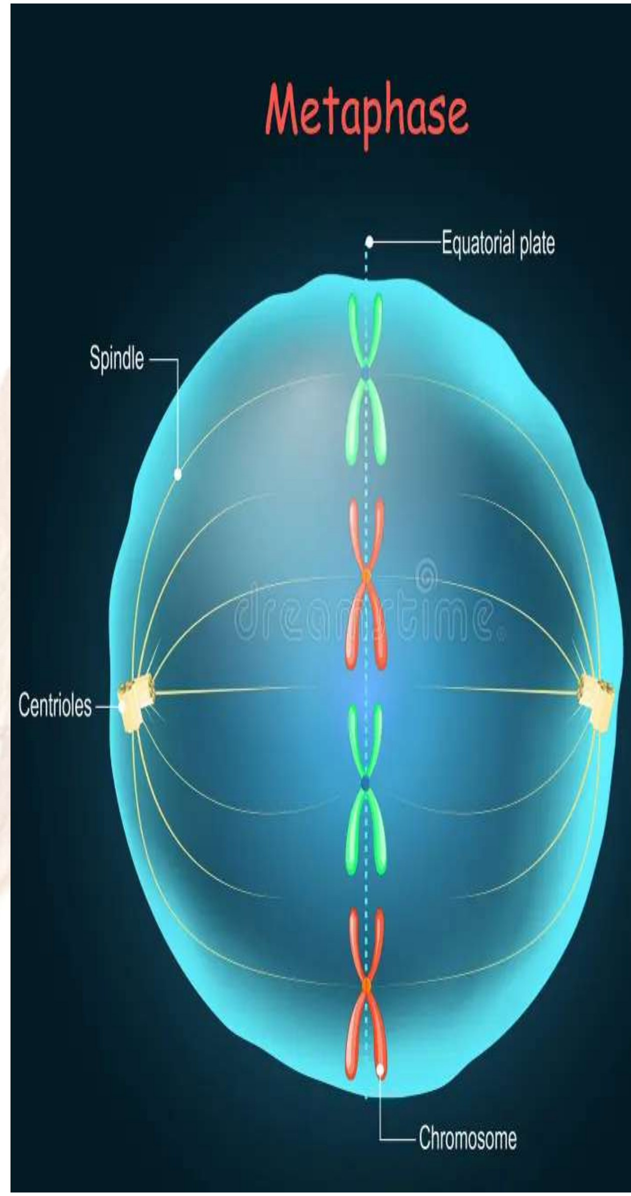
- At the start of prophase, ***chromosomes become visible inside the nuclear membrane.*** At first, they are ***long***, ***thin***, entangled threads. As time goes on the threads become ***shorter*** and ***thicker***.
- As the chromosomes become visible the ***nucleoli gradually disappear***.
- The ***centrioles*** which duplicated at interphase begin to ***migrate to opposite ends (poles) of the cell.***
- As they move apart the ***centrioles lay down microtubules which extend from one pole of the cell to the other***.
- The microtubules are the spindle, a fibrous structure which is widest at the centre (equator) of the cell.
- The ***nuclear membrane disintegrates*** and nucleus shrinks.

METAPHASE.

- This is the second stage of mitosis also having early metaphase and late metaphase.
- During this stage the ***chromosomes line up at the equator of the spindle fibres independently*** ***attached by their centromere to the spindle fibers*** i.e. homologous chromosomes do not associate together.
- At late metaphase the ***sister chromatids slightly repel each other at the centromere*** due the contraction of the spindle fibres, thereby orienting the chromatids towards opposite poles.

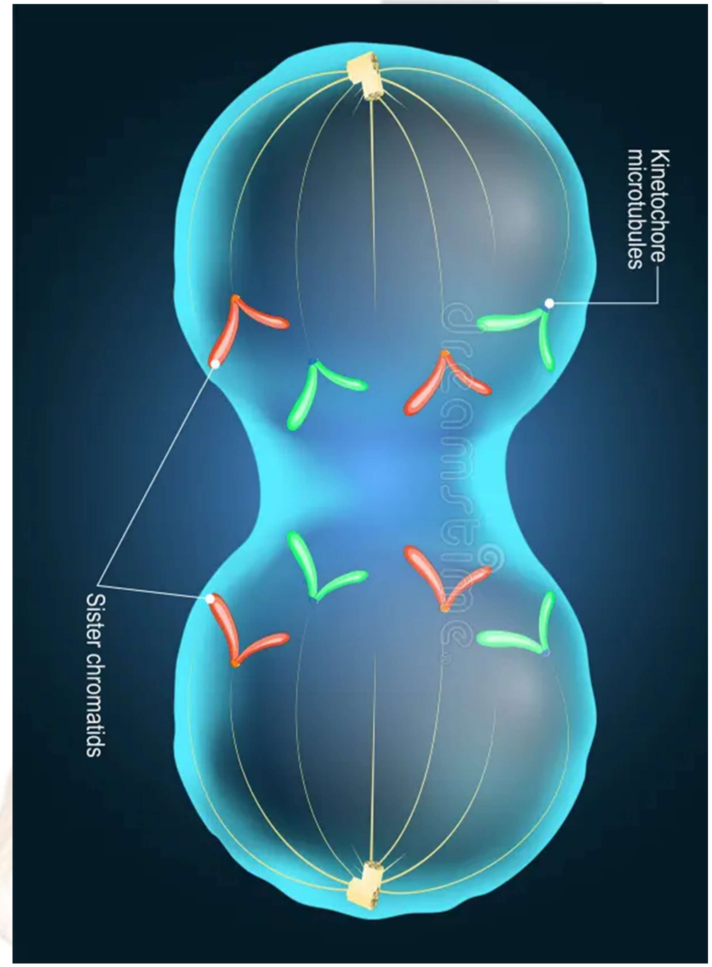
Note

- Mitochondria often gather near the nuclear membrane at metaphase. They may provide energy for some of the spindle microtubules to pull the nuclear membrane apart.



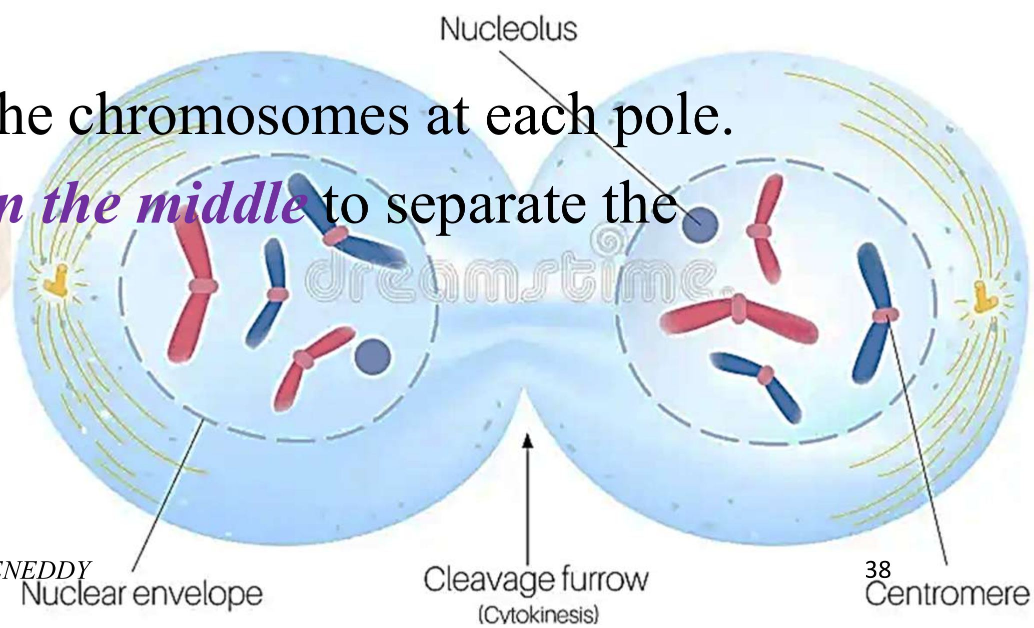
ANAPHASE

- This is the third and shortest stage of mitosis. It is divided into early anaphase and late anaphase.
- During early anaphase, ***the centromere split*** and the ***spindle fibers contract and start pulling the daughter chromosomes*** formed together with the sister chromatids attached to opposite poles of the cell.
- The fibres ***continue coiling thereby becoming shorter*** and this process uses a lot of energy in form of ATP.
- By late anaphase the chromatids will have reached the poles of the cell.



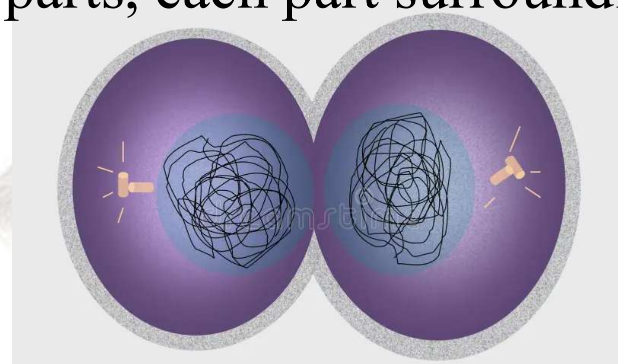
TELOPHASE

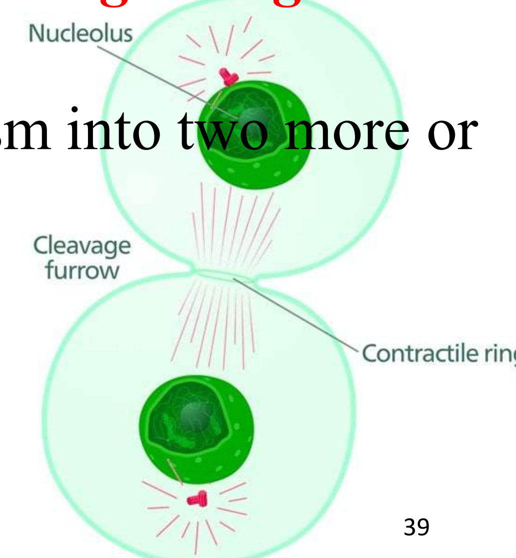
- This is the last stage of mitosis and it involves the following changes;
- The *chromatids at the pole uncoil* and ***lengthen to form chromatin and become invisible*** again i.e. the chromatids become chromosomes which uncoil and gain their thread like nature
- The ***nucleolus*** and ***nuclear membrane reappears***.
- The ***spindle fibers breakdown***
- A ***nuclear membrane reforms*** around the chromosomes at each pole.
- The ***cell membrane starts to constrict in the middle*** to separate the cytoplasm



CYTOKINESIS.

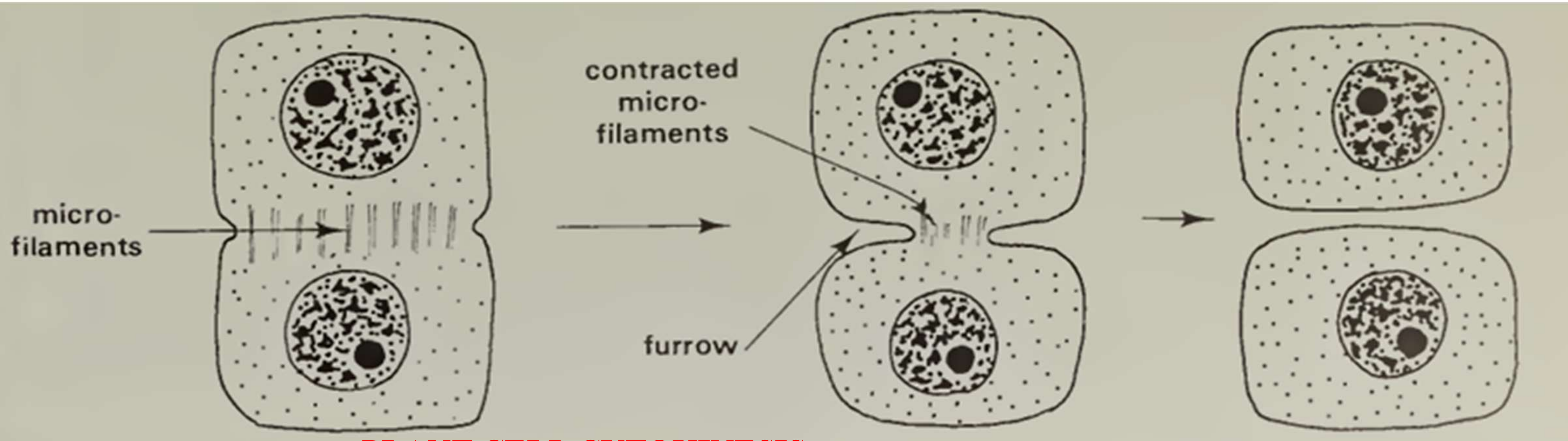
- Cytokinesis refers to ***separation of the mother cell into two daughter cells through division of the cytoplasm*** .
- Cytokinesis in animal cells ***is brought about by the alignment of the micro filament in the middle of the cell***.
- When the ***microfilament contract, an invagination/ furrow is formed from either side of the cell*** and when these ***invaginations become big enough and meet***, the mother cell divides into two daughter cells.
- Shortening of the filaments ultimately pinches the cytoplasm into two more or less equal parts, each part surrounding a nucleus.



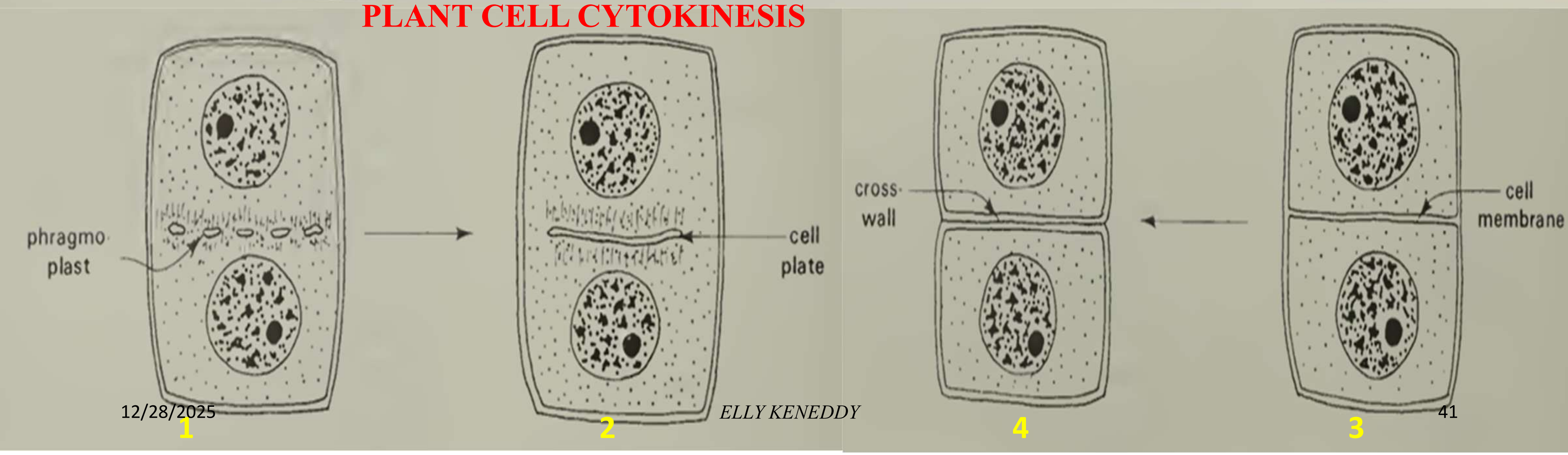


CYTOKINESIS IN PLANT CELLS.

- Plants ***do not have centrioles*** and ***their spindle fibers are produced by the Golgi body***
- Cytokinesis in plants ***involves formation of a primary cell wall in the middle of the mother cell*** to separate it into two daughter cells.
- The development of the primary cell wall ***begins with small vesicles derived from the Golgi apparatus moving along microtubules*** to the ***middle*** of the cell where they line up across the mother cell which ***eventually fuse together to form a*** **cell plate**.
- The cell wall materials carried in the vesicles collect in the ***cell plate as it grows, it later becomes the primary cell wall***



PLANT CELL CYTOKINESIS

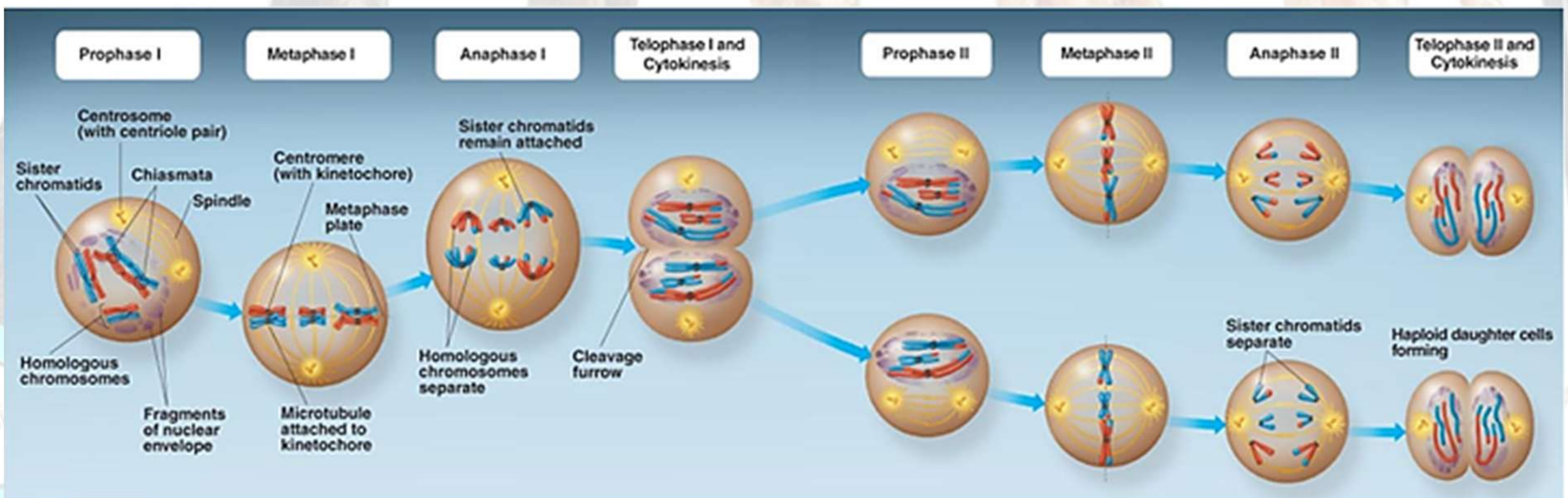


SIGNIFICANCE OF MITOSIS

- It maintains the chromosome number of the daughter cells similar to that of the parent cell hence ***creates genetic stability*** since ***daughter cells genetically identical to the parent cell*** and ***no variation in genetic information is introduced***.
- It ***promotes growth of the body*** as it ***increases the number of cells within an organism*** to cause increase in size and height.
- Cells in the body are constantly dying and being replaced by mitosis to form new tissues ***repairing damaged tissues***.
- It is a ***basis for asexual reproduction***.
- Promotes *formation of gametes* in organisms that reproduce by ***parthenogenesis*** (in animals) e.g. male bees called drones, aphids
- Mitosis enables regeneration to occur. During regeneration, some animals are able to regenerate (redevelop) whole parts of their bodies such as legs in crustacean and arms in starfish.

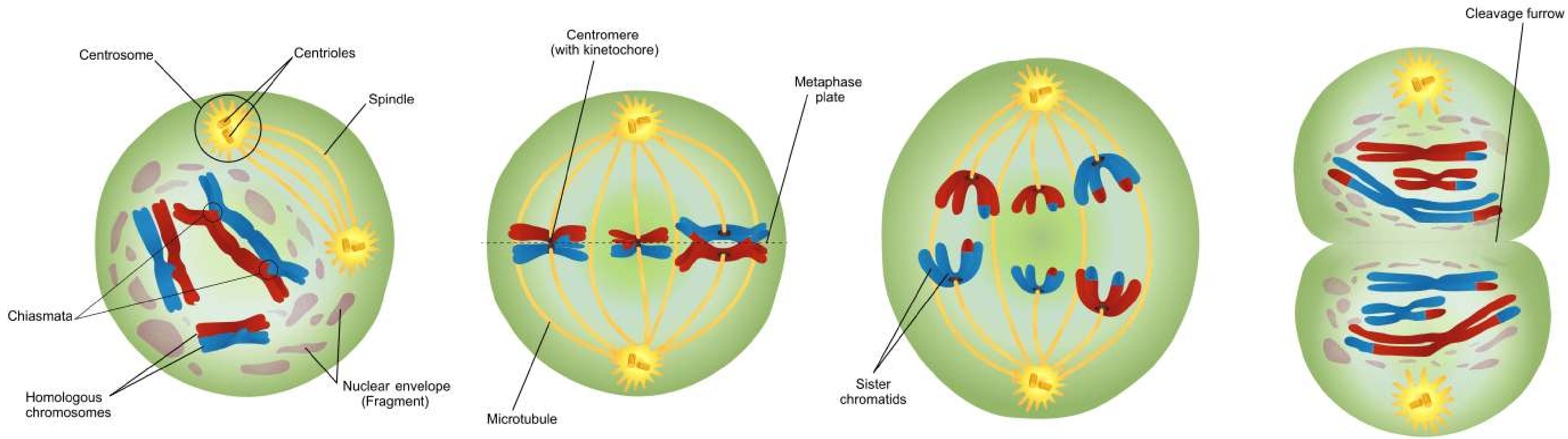
MEIOSIS

- Meiosis occurs in the ***formation of gametes in organisms*** which reproduce ***sexually***.
- In meiosis, nuclear division is ***followed by cytoplasmic cleavage***, but in contrast with mitosis there are ***two nuclear divisions*** not ***one***.
- Thus, ***four nuclei are formed from a cell*** which undergoes meiosis, not two as in mitosis. However, there are other differences which are just as important. The interphase stage of meiosis is the same as in mitosis.



THE FIRST MEIOTIC DIVISION

- In meiosis, division of the nucleus is separated into two i.e. ***first meiotic division*** and ***second meiotic division***.
- Meiosis ***involves one division of the chromosomes*** followed by ***two divisions of the nucleus and cell***.
- The result is that the number of chromosomes in each cell is reduced by half. The diploid (2n) parent cell gives rise to four haploid (n) daughter cells.
- Meiosis occurs in the formation of gametes, sperm and ova, in animals, and in the production of spores in most plants.
- In each division, all the 4 stages of nuclear division occur i.e prophase, metaphase, anaphase and telophase.



Prophase I

The chromosomes condense, and the nuclear envelope breaks down. Crossing-over occurs.

Metaphase I

Pairs of homologous chromosomes move to the equator of the cell.

Anaphase I

Homologous chromosomes move to the opposite poles of the cell.

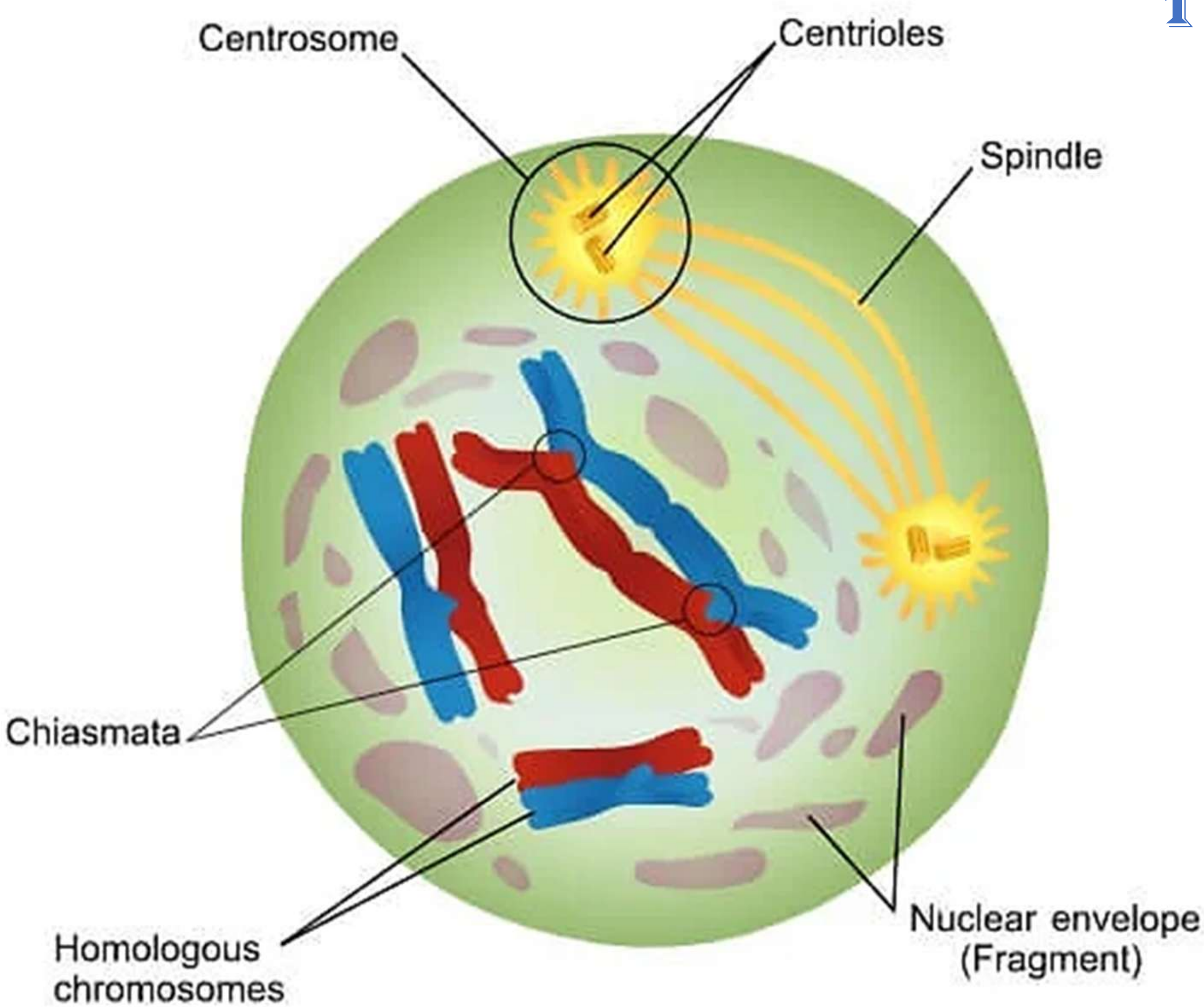
Telophase I & cytokinesis

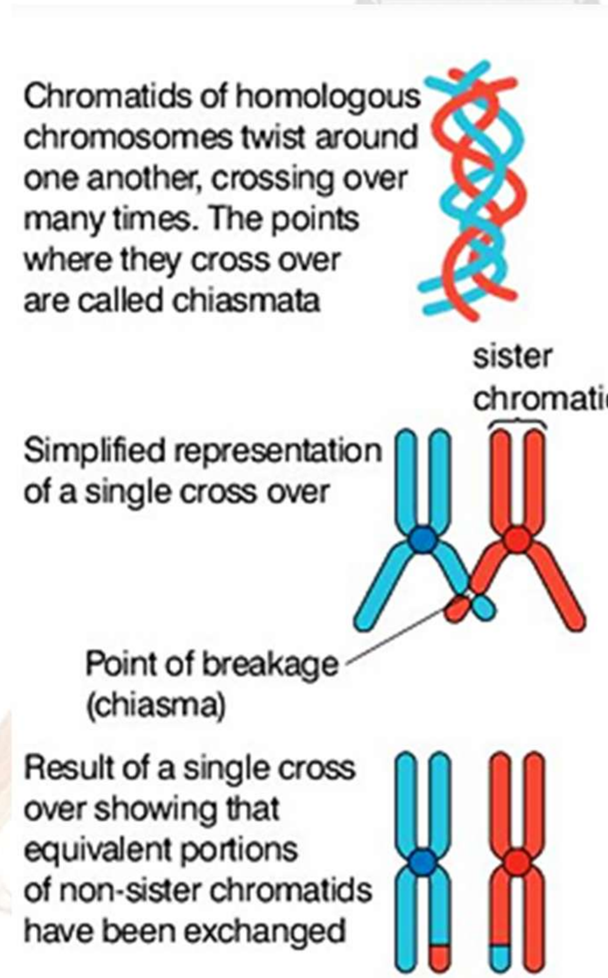
Chromosomes gather at the poles of the cells. The cytoplasm divides.

PROPHASE I.

- It is the longest stage of meiosis. Prophase I of meiosis is similar to prophase in mitosis. In this stage, the ***chromosomes become visible***, ***shorten*** and ***thicken***, ***Establishment of the poles of the cell***, The ***centrioles migrate to opposite poles of the cell***, The centrioles ***begin to synthesize spindle fibres***, The ***nucleolus*** and the ***nuclear membrane*** begin to ***break down and eventually they disappear*** completely. Chromosomes ***come together by a process*** termed **synapsis** and each pair is called a **bivalent**.
- Each chromosome of the pair is seen to comprise two chromatids. ***These chromatids wrap around each other***. The chromatids of the ***pair partially repel one another although they remain joined at certain points*** called **chiasmata** (singular-chiasma).
- It is at these points that chromatids may ***break and recombine with a different chromatid.*** This swapping of portions of chromatids is termed ***crossing over***.

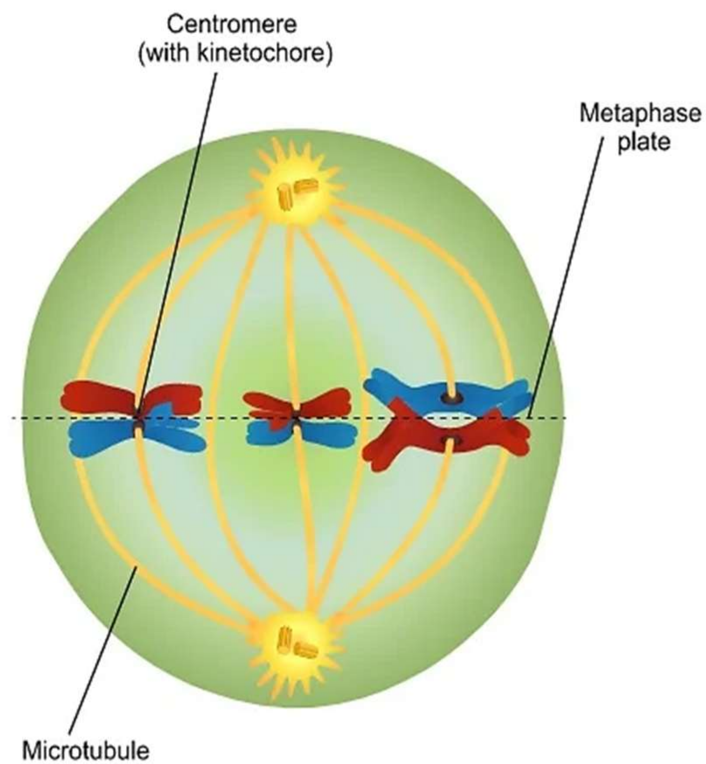
PROPHASE 1


Centrosome
Centrioles
Spindle
Chiasmata
Homologous chromosomes
Nuclear envelope (Fragment)


Chromatids of homologous chromosomes twist around one another, crossing over many times. The points where they cross over are called chiasmata
sister chromatic
Simplified representation of a single cross over
Point of breakage (chiasma)
Result of a single cross over showing that equivalent portions of non-sister chromatids have been exchanged

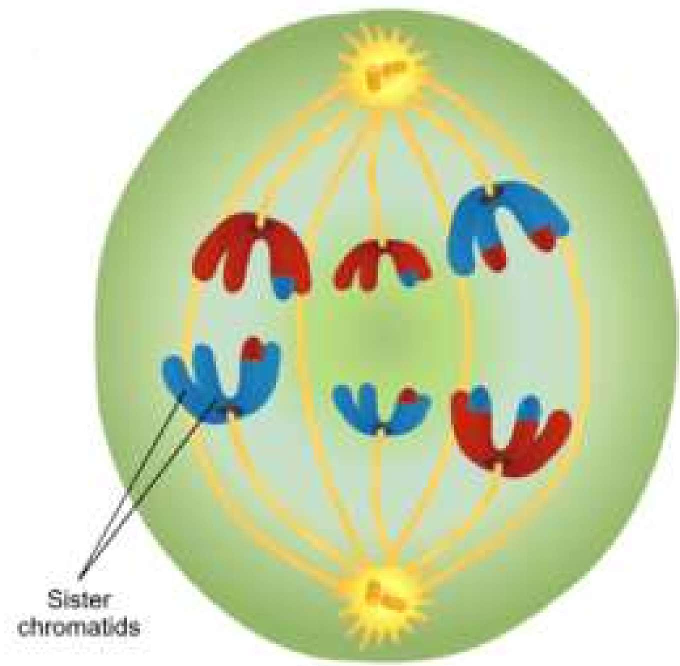
METAPHASE I

- During this stage, the homologous chromosomes ***line up together*** at the ***equator of the spindle inform*** of ***bivalents***.
- The bivalents arrange themselves on the equator with ***each of a pair of orientated to opposite poles***.
- Chromosomes distributed randomly at the equator of the cell ***segregate (separate) independently which leads to the mixing of genes*** in the daughter cells formed at the end of meiosis. This results into genetic variation.



ANAPHASE I

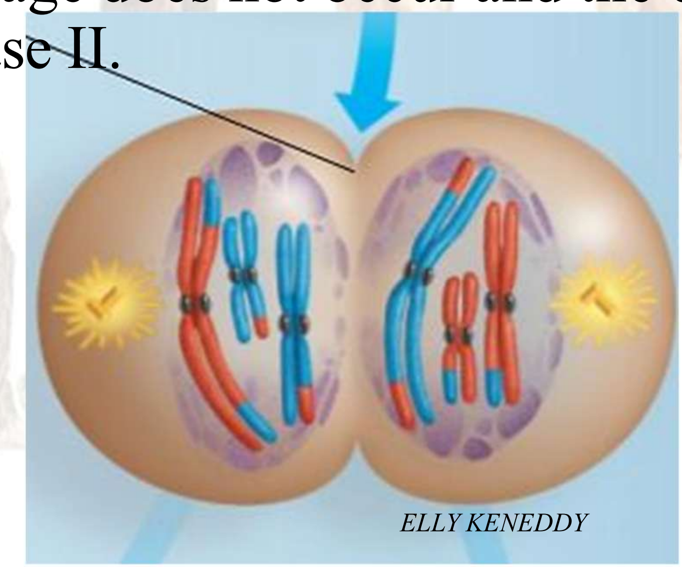
- The spindle fibers, which are attached to the centromeres, ***contract and pull the homologous chromosomes apart.***
- One of each pair is pulled to one pole, its sister chromosome to the opposite one.
- This is ***through spiral coiling*** due to ***contraction of the proteins*** that make up these fibers hence separating the chromosomes.

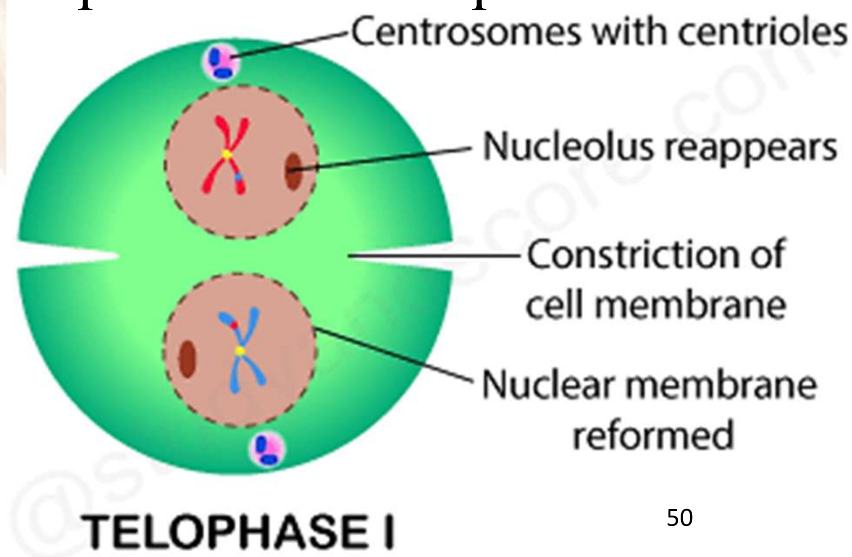


Homologous chromosomes move to the opposite poles of the cell.

TELOPHASE I

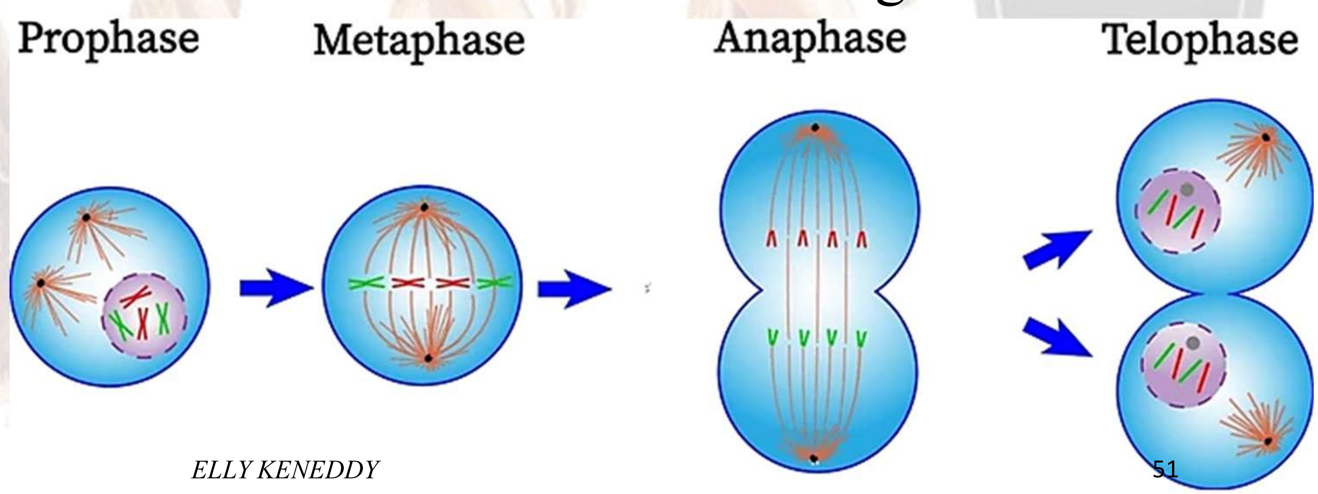
- The chromosomes ***reach their opposite poles*** and a ***nuclear envelope forms around*** each group. In most cells the ***spindle fibers disappear*** and the ***chromatids uncoil***.
- Cell division, or cleavage, may follow. The nucleus may enter ***interphase*** although ***no replication of the DNA takes place***.
- In some cells this stage does not occur and the cell passes from anaphase I directly into prophase II.





MEIOSIS II

- After meiosis I, each of the daughter cells formed ***enters a short interphase period.***
- During this period, the ***cells synthesize more ATP*** and ***replication of cell organelles such centrioles occur.*** However, during this interphase period replication of ***DNA chromosomes does not occur***.
- Meiosis II is also sub divided into four stages namely; prophase II, metaphase II, anaphase II, and telophase II. The events which occur during ***meiosis II are similar to those of mitosis***

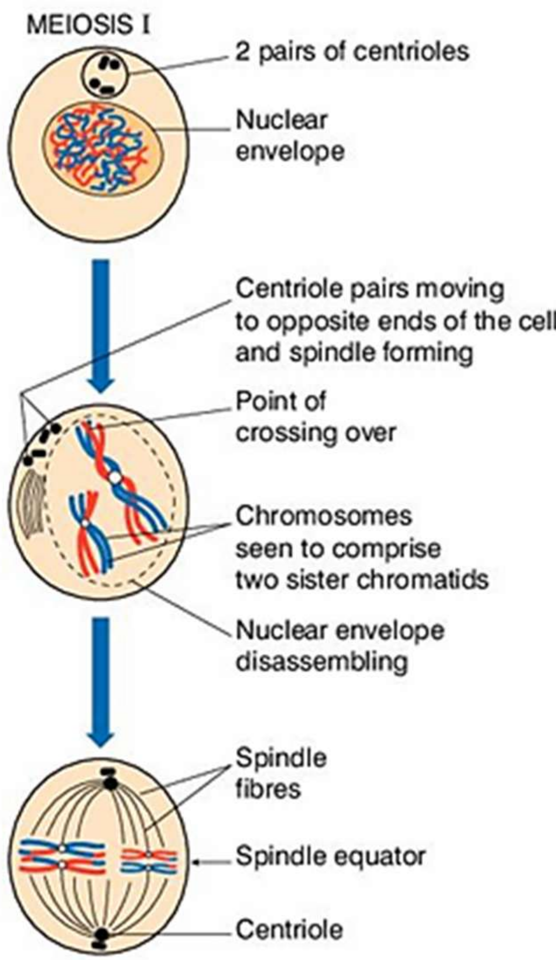


SUMMARY OF MEIOSIS 1

Interphase
In late interphase (S phase), before meiosis, DNA replicates so that the cell now contains four, rather than the original two, copies of each chromosome. In animal cells the pair of centrioles replicates.

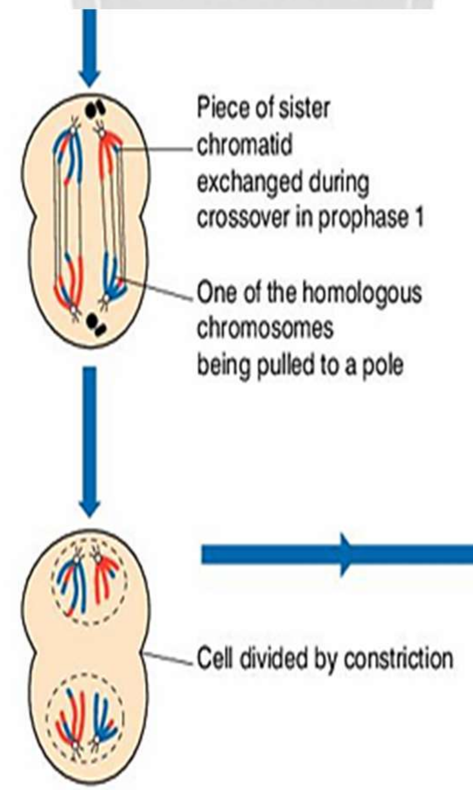
Prophase I
The chromosomes shorten and fatten (condensation) and come together in their homologous pairs to form a bivalent. The chromatids wrap around one another and non-sister chromatids of homologous chromosomes attach at points called chiasmata. The chromatids may break at these points and swap similar sections of chromatids with one another in a process called crossing over. Finally the nucleolus disappears and the nuclear envelope disassembles. The centromeres are attached to spindle fibres.

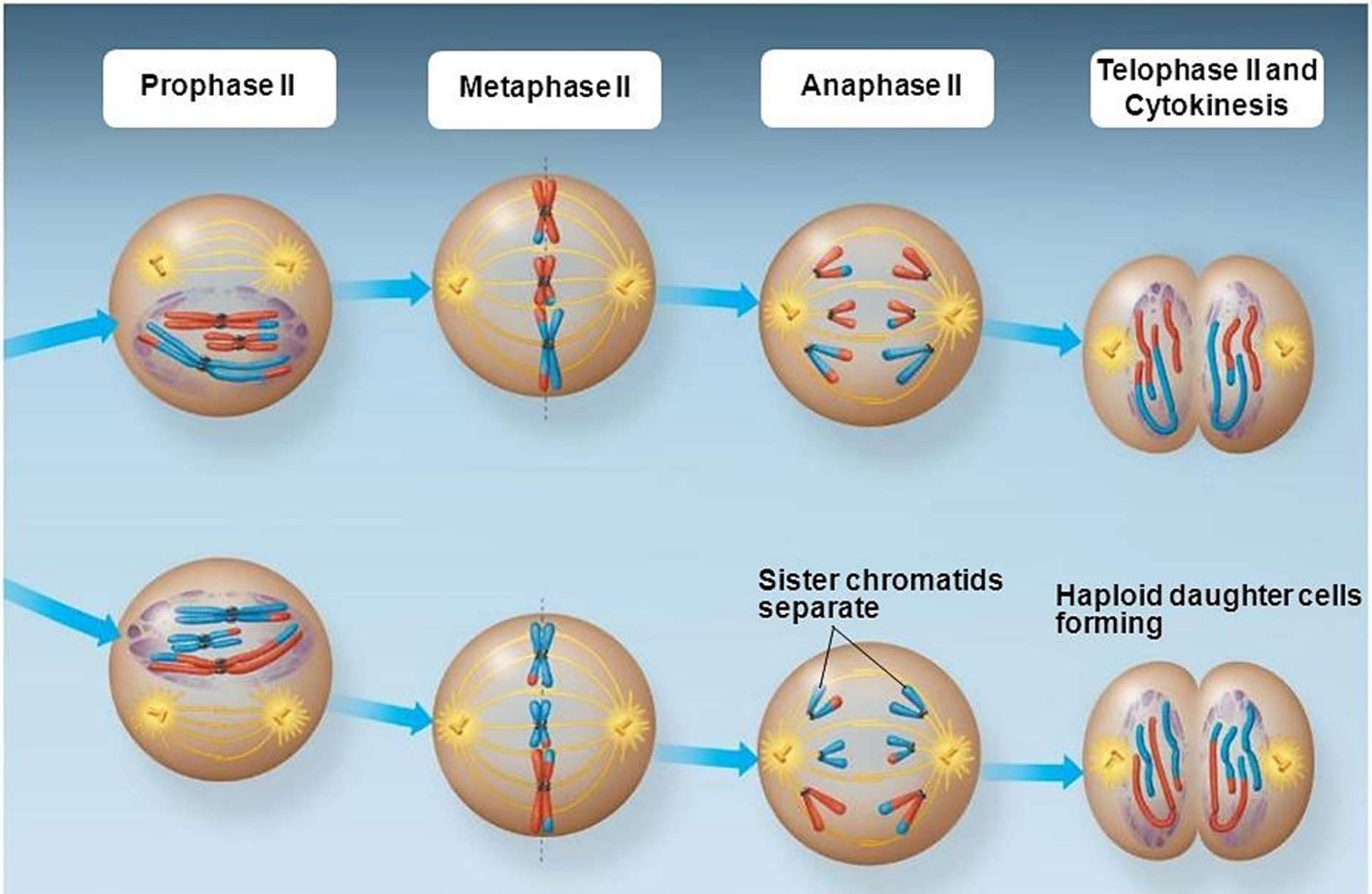
Metaphase I
With centromeres attached to the spindle, the bivalents arrange themselves randomly on the equator of the cell with each of a pair of homologous chromosomes facing opposite poles.



Anaphase I
One of each pair of homologous chromosomes is pulled by spindle fibres to opposite poles.

Telophase I and cytokinesis
Microtubules pull two sides of the cell surface membrane together so that the cell becomes narrower towards its centre until the opposite parts of the membrane fuse to give two separate cells. In most animal cells a nuclear envelope re-forms around the chromosomes at each pole, but in most plant cells there is no telophase I and the cell goes directly into metaphase II.




Prophase II
Metaphase II
Anaphase II
Telophase II and Cytokinesis
Sister chromatids separate
Haploid daughter cells forming

Metaphase II

- The chromosomes ***line up individually on the equator of the spindle*** as in meiosis. At late metaphase the ***sister chromatids slightly repel*** each other at the centromere due the contraction of the spindle fibers, thereby orienting the chromatids towards opposite poles.

Anaphase II

- The ***centromeres split*** and ***chromatids of the two chromosomes in each cell separate*** and ***move to opposite poles due to spiral coiling of spindle fibers***. By late anaphase the chromatids will have reached the poles of the cell.

Telophase II

- Each cell divides by ***constricting across in the middle***. The ***chromatids unwind and become indistinct*** so as to become chromosomes. Four ***new cells are formed each having half the number of chromosomes*** compared to the original parent cell.
- The spindle fibers disappear and the nucleus, nucleolus as well as the nuclear membrane reform such that the cells enter interphase.

HOW GENETIC VARIATIONS ARISE DURING MEIOSIS.

- Meiosis brings about genetic variation i.e. During ***crossing over*** between homologous chromosomes involves ***breaking*** and ***exchange of sections of chromosomes*** leads to ***mixing*** and ***rearrangement of genes*** which were ***originally located on the same chromosome***. This leads to a variety of ***new gene recombination's on the chromosome*** in the daughter cells which leads to genetic variation which occurs during prophase 1.
- During metaphase I, homologous chromosomes are ***distributed randomly at the equator of the cell*** and ***segregate independently*** leading to formation of gametes with ***different alleles*** which are ***none identical to each other***.
- Meiosis results into formation of new gametes which are a basis of sexual reproduction.

COMPARE MEIOSIS AND MITOSIS.

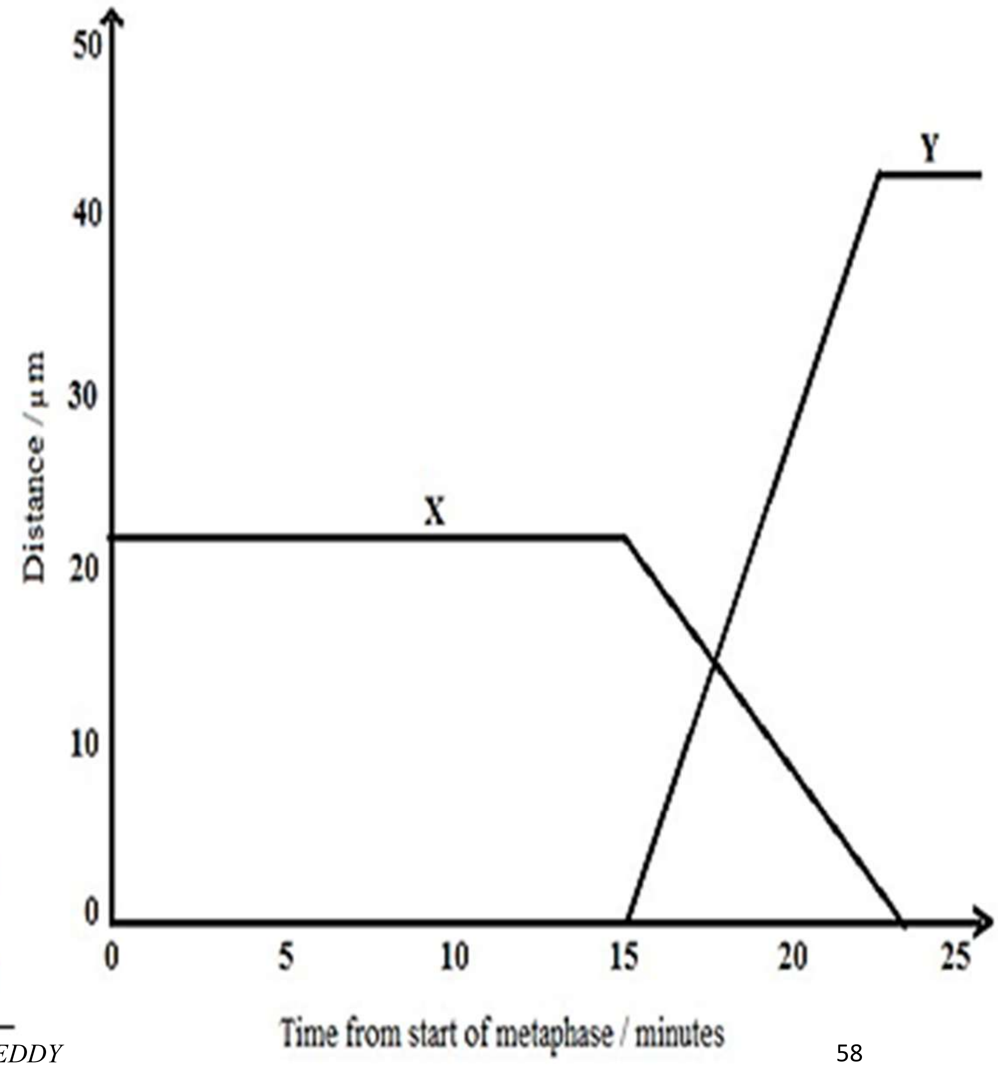
- Both involve four stages of cell division namely; prophase, metaphase, anaphase and telophase.
- Both require the interphase period before they occur.
- Both are energy consuming processes i.e. they require ATP.
- Both can lead to the formation of gametes.
- Both involve condensation of the chromosomes.
- Both involve nuclear division and cytokinesis.

DIFFERENCES.

MITOSIS	MEOSIS
Results into formation of 2 daughter cells	Results into formation of 4 daughter cells
Daughter cells are identical to the mother cell	Daughter cells are different from the mother cell
It occurs in somatic cells	It occurs during formation of gametes
No crossing over occurs	Crossing over occurs
Chiasmata are not formed	Chiasmata are formed
Homologous chromosomes do not associate	Homologous chromosomes associate
There is no formation of bivalents	Bivalents are formed during prophase 1
It involves only one nuclear division	It involves 2 nuclear divisions
Maintains the chromosome number constant	It halves the number of chromosomes
It takes a shorter time	It takes a longer time.

BRAIN CHECK.

- The graph below shows how the position of centromeres change during mitosis. Line X is the distance between the centromeres and the ends of the spindle. Line Y is the distance between the centromeres of pairs of chromatids. Measurements started at the beginning of metaphase.



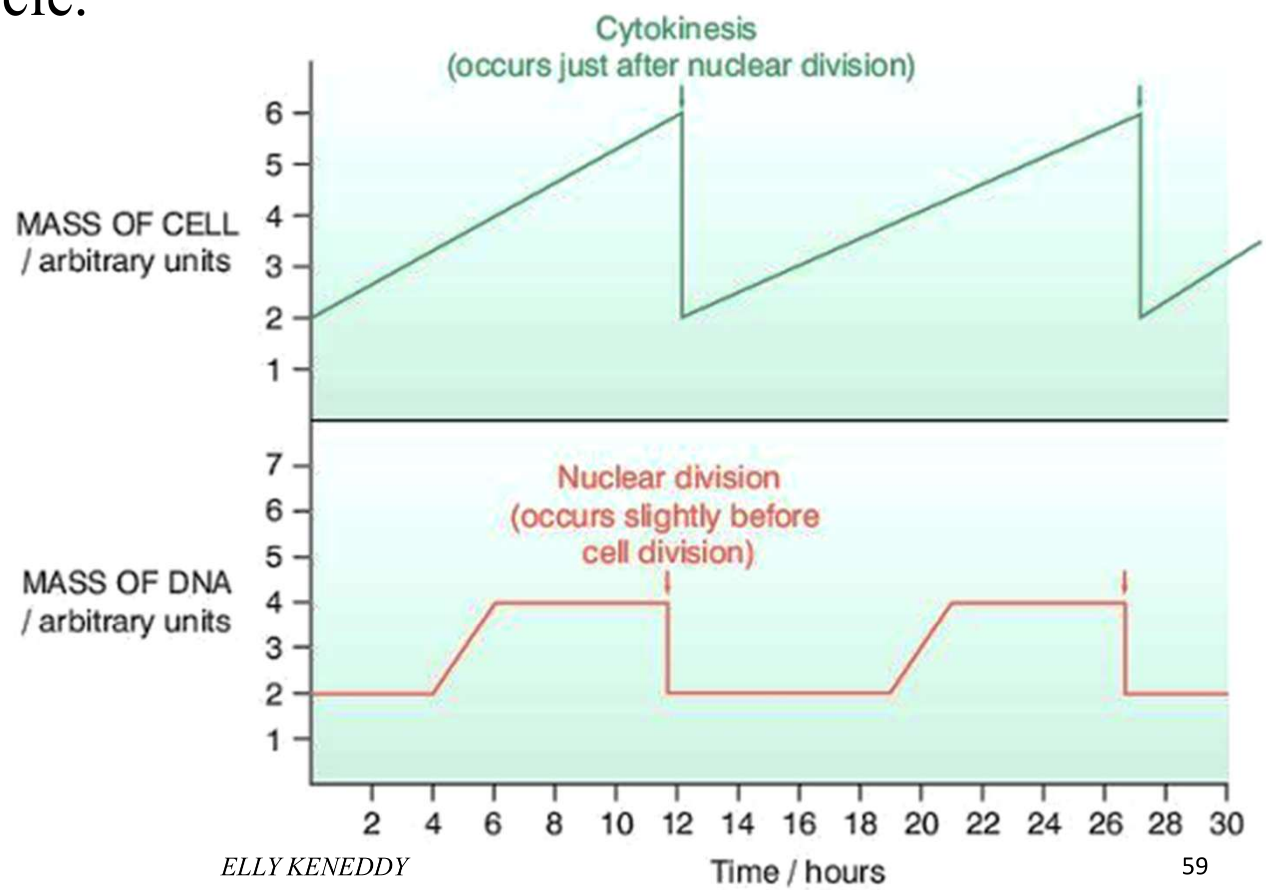
- Explain the trend in distance represented by

1) Curve **X**
2) Curve **Y**

BRAIN CHECK.

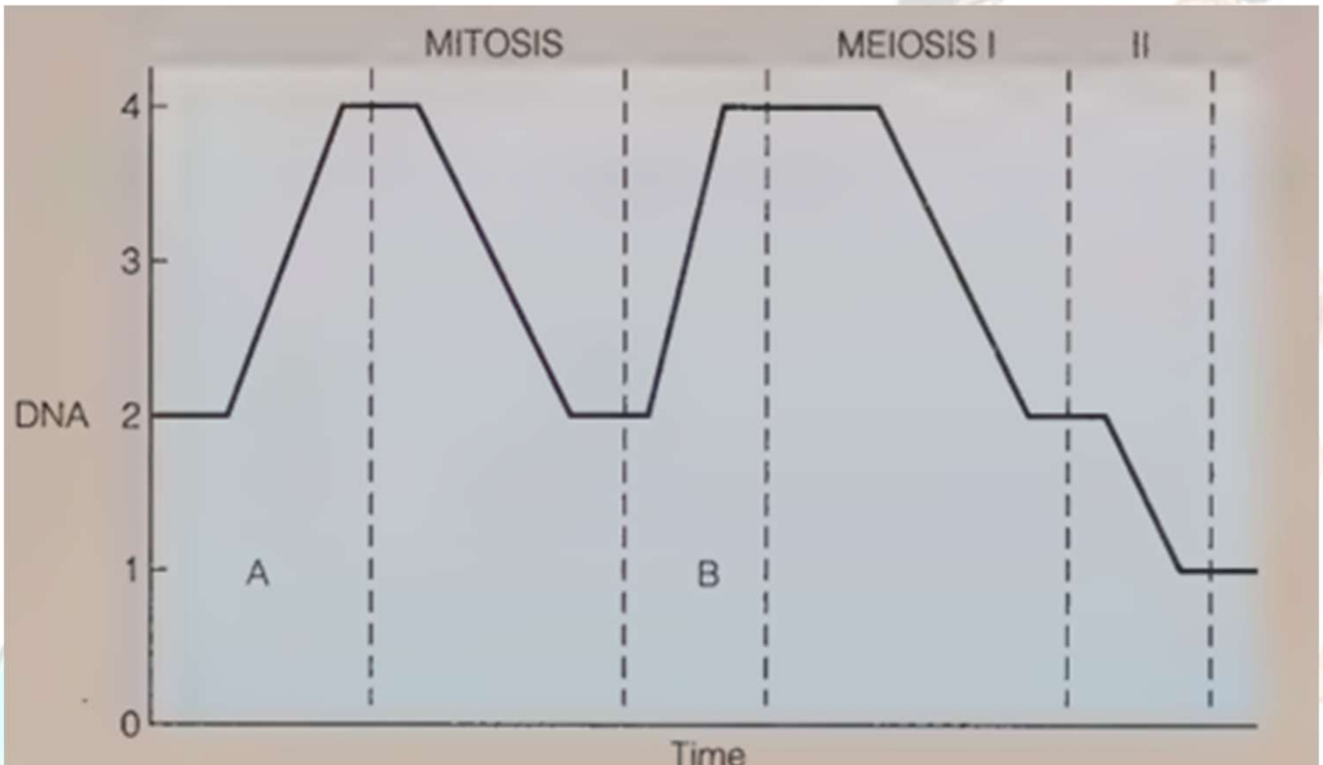
- The graph below shows the changes in the mass of a diploid cell and DNA within it during the cell cycle.

a. Account for the observed changes in the mass



BRAIN CHECK.

The following diagram shows the changes in the amount of DNA (arbitrary values) in the spermatogonia of a diploid organism as the spermatogonia undergo mitotic nuclear division, and then the amount of DNA in the primary and secondary spermatocytes as they undergo meiosis.



(a) Explain what process accounts for the change in DNA quantity during periods A and B in the diagram.

(b) Notice that the amount of DNA doubles before mitosis and meiosis. Does the number of chromosomes double? Explain your answer.

(c) If the diploid chromosome number in this organism is 8 and the haploid number is 4, what is the chromosome number of cells:

(i) at the end of mitotic division?

(ii) at the end of meiotic division?

MUTATIONS AND THEIR EFFECTS.

- This refers to the ***sudden or spontaneous changes*** which ***occur in the genetic constitution of an organism***. These changes are brought about by substances called ***mutagens*** which include ***chemicals*** and ***high energy radiations***.
- Mutations change the genotype of an organism with respect to a given characteristic because it ***produces new alleles in the population***. Mutations cause ***permanent genetic variations***.
- During mutation, some genetic material may be ***lost***, ***doubled***, ***inverted***, ***translocated*** (moved), ***substituted*** and ***inserted***, resulting into unique genetic constitution different from the non-mutants.
- Individuals or cells resulting from mutations are known as mutants. There are two types of mutations namely; ***Chromosomal*** and ***Gene (point)*** mutations

Chromosomal mutations

- This refers to the ***changes that occur in the chromosome number*** or ***chromosome structure*** which occur mainly during ***crossing over in prophase I*** or ***anaphase I.***

Gene mutations (point mutation)

- This is a ***sudden change in the sequence of nuclear nucleotides*** or ***bases of DNA.***

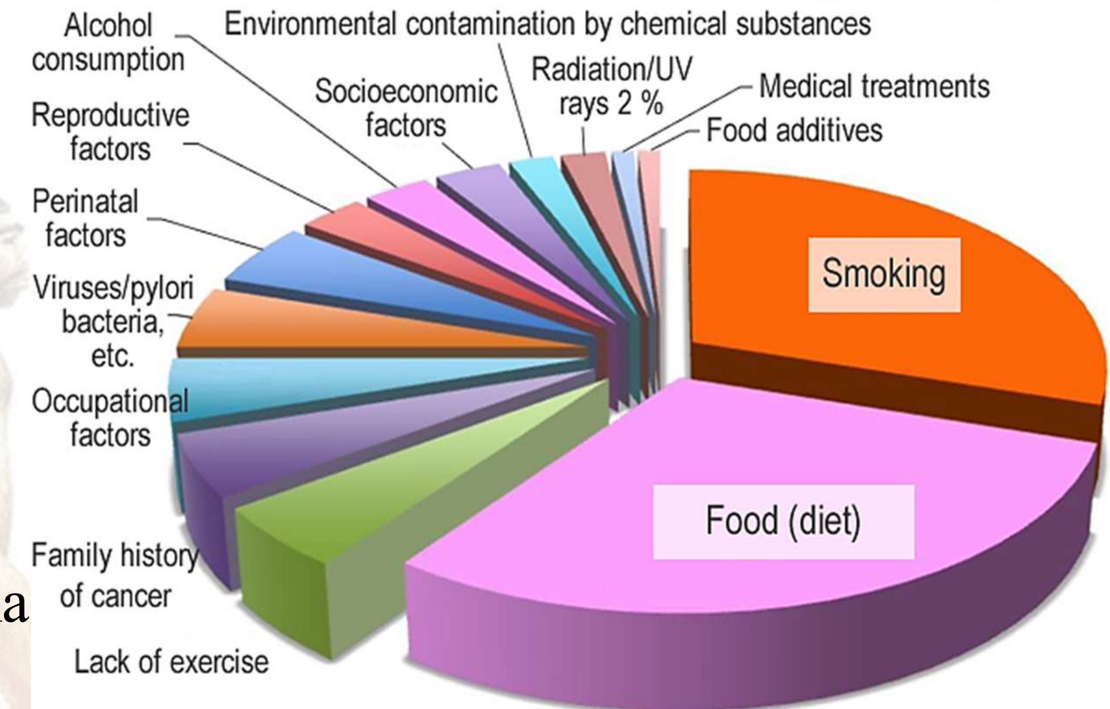
Cancer and how it arises.

Cancer is fundamentally a genetic disease caused by an accumulation of mutations, in a cell's DNA. These mutations alter the instructions (genes) that control critical cell functions, particularly those related to growth, division, and repair.

This leads to the characteristics of cancer, such as uncontrolled proliferation, cause the cell to ignore signals that tell it to stop dividing or to die when it becomes damaged and gives cells the ability to invade other tissues which leads to development of tumors.

Cancer cause risks.

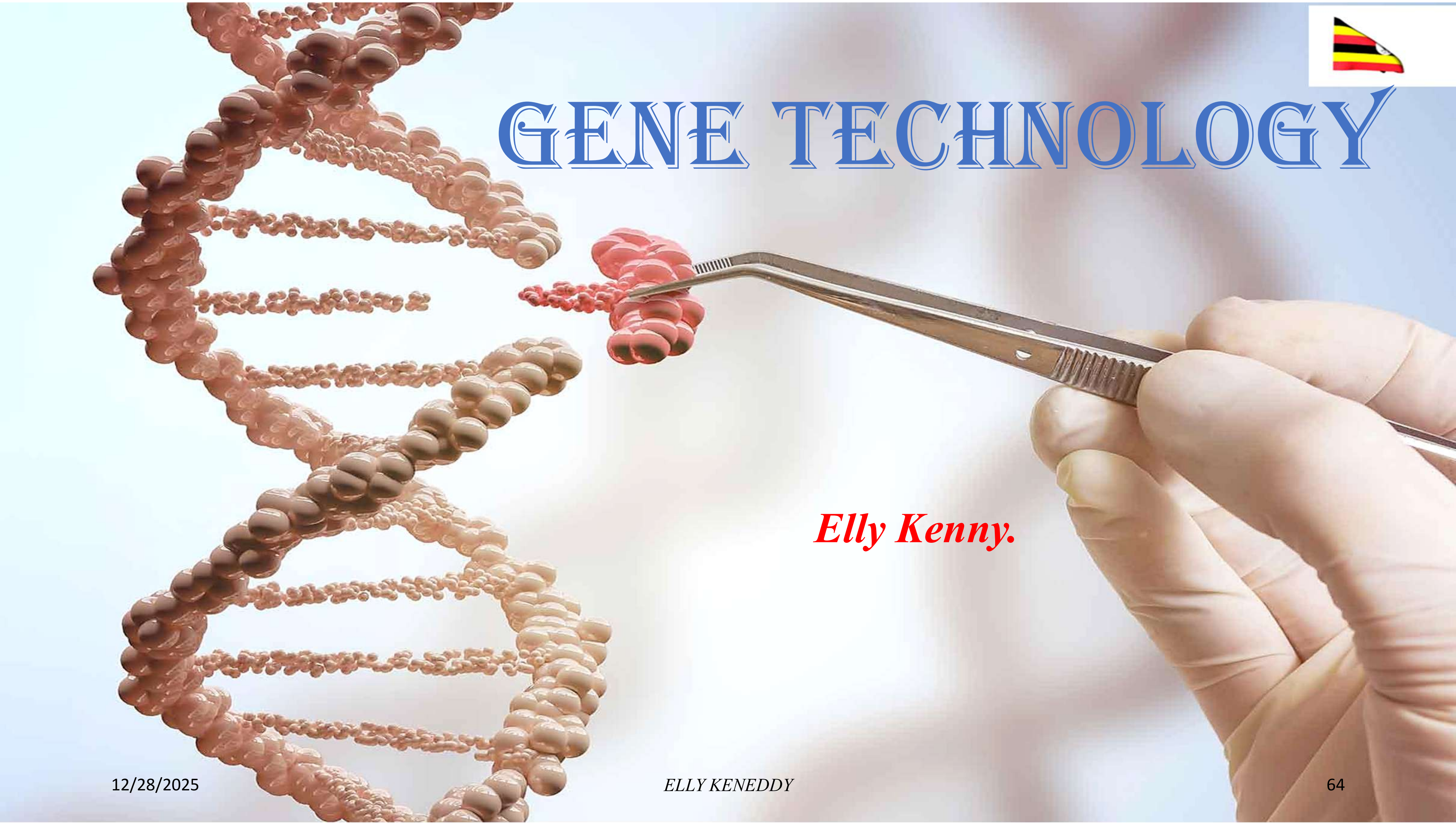
- Gamma rays
- Alpha and beta particles
- X-rays
- Cosmic rays
- Ultra violet rays
- Excessive heat
- Chemicals such as caffeine, Marijuana
- Aging



Causes of Cancer :
Richard Doll (Epidemiologist), WHO/IARC,National Cancer Center Japan, Harvard University, etc.

Assignment.

- ***Describe the management and prevsntion measures of cancer.***



GENE TECHNOLOGY

Elly Kenny.

- Gene technology enables scientists to manipulate DNA in many ways. An individual gene can be ***isolated***, ***removed*** and ***cloned***. The ***DNA of one organism can be combined with the DNA of another***. Genes can also be made from the RNA of an organism.
- There are already many commercial applications of genetic engineering, and future developments may well provide the means to alleviate suffering and cure disease. However, there are many reservations about the long-term effects of a genetically-modified world.
- The basic principles of genetic engineering
- ***Restriction endonucleases*** are *enzymes that cut DNA into small fragments*. This allows individual genes to be isolated.
- A gene from one organism can be inserted into the DNA of another. The gene that has been isolated for insertion is called ***donor DNA***. The donor DNA is inserted into the host DNA of another organism. DNA that contains genetic material from ***two*** different organisms is called ***recombinant DNA***.

- ***Restriction endonucleases*** are used to cut the donor DNA and the host DNA into smaller pieces.
- The enzymes make staggered cuts, called ‘sticky ends’, which allow the donor DNA to be spliced into the host DNA. Another group of enzymes, called ***DNA ligases***, are used to *join the sticky ends of the donor DNA and the host DNA together*.
- The sticky ends are complementary. For instance, an ATG end will ‘stick’ to a TAC end.
- Host cells with recombinant DNA can be used to clone genes or to produce important substances such as antibiotics, hormones and enzymes.
- An enzyme called ***reverse transcriptase*** can be used to make ***a gene from RNA***. First, the RNA is extracted, which is a mirror image copy of the desired gene. Then reverse transcriptase is used to make a single strand of copy DNA from the isolated RNA.
- The single strand of DNA can be used as a template to make the second strand, so forming the double-stranded DNA helix of the gene.

RECOMBINANT DNA TECHNOLOGY.

- Recombinant DNA technology is ***the laboratory process of joining together DNA molecules from different species and inserting the resulting "recombinant" DNA into a host organism***.
- This allows scientists to ***produce new genetic combinations*** that are valuable for ***science***, ***medicine***, ***agriculture***, and ***industry***. When DNA is formed by joining together DNA from two different sources, the resultant is known as ***recombinant DNA.***
- An organism containing recombinant DNA is known as a ***Genetically modified organism(GMO)***. Where the DNA has been transformed into another organism for a protein product to be synthesized and harvested, the organism is called ***a recombinant host.***
- Techniques have been developed to produce large quantities of pure proteins by *isolating genes*, *cloning them* and *transferring them into microorganisms*. The microorganisms are then grown to provide a factory for continuous production of the desired protein.

STEPS INVOLVED IN GENETIC ENGINEERING.

- ***Isolation and extraction*** : The target DNA (gene of interest) and the vector DNA are *extracted and purified from their respective cells*/ *synthesis of a gene for a desired protein.*
- ***Cutting (Digestion):*** Both the target DNA and the vector are *treated with the same restriction enzyme*. This ensures *they have complementary "sticky ends*."
- ***Joining (Ligation):*** The gene of interest and the vector are mixed together. *DNA ligase is added to bond them*, forming a *recombinant plasmid in the vector.*
- ***Transformation***: The recombinant DNA is *introduced into a host cell (e.g., bacteria)*. This is often done using heat shock or electricity (electroporation).
- ***Selection & Screening***: Since not all host cells will take up the DNA, scientists use "marker genes" *to identify and grow only the successfully transformed cells*.
- ***Product Expression***: The transformed host cells are *grown in large bioreactors to produce the protein* encoded by the foreign gene.

GENE CLONING.

- Sometimes large quantities of a particular gene are required. A possible treatment for cystic fibrosis (CF) requires many copies of the appropriate healthy human gene. Techniques in ***gene cloning allow this to be achieved***.
- The DNA fragment containing the wanted gene is ***inserted into the DNA of a host cell.*** The host cell is known as a ***vector***.
- The ***recombinant DNA*** acts as a ***carrier molecule for the gene that is to be copied***. As the host cell reproduces and replicates its DNA, ***clones of the required gene are made at the same time.***
- ***Bacteria***, ***viruses*** and ***even some eukaryotic cell***s have all been used as *vectors*. Bacteriophages can be used as vectors since they are able to inject the recombinant DNA into bacterial cells such as ***Escherichia coli***.
- The ***host cell then replicates the virus*** many times, making multiple copies of the recombinant DNA.

- The most ***commonly-used vector*** is a ***bacterial plasmid***. In addition to their single loop of DNA, bacterial cells also ***contain small circles of DNA*** called ***plasmids***.
- Plasmids are easy to work with since they ***can replicate very quickly***, producing many copies of the original gene.
- Plasmids can be ***isolated*** and ***cut open*** by restriction ***endonucleases***. A human gene that has been cut out of a human chromosome by restriction endonuclease can ***be spliced into the plasmid*** using ***DNA ligase***. The ***recombinant plasmid is then inserted into the host bacterium***.
- The ***bacterial cells are grown in nutrient medium*** in industrial fermenters.
- In these conditions, the bacteria ***multiply rapidly***, ***making many copies of the human gene***.
- The ***human DNA is transcribed*** and ***translated by the bacterial cells***, so producing the human protein. The protein is then separated and purified. Eukaryotic cells have also been used as vectors to clone recombinant DNA.

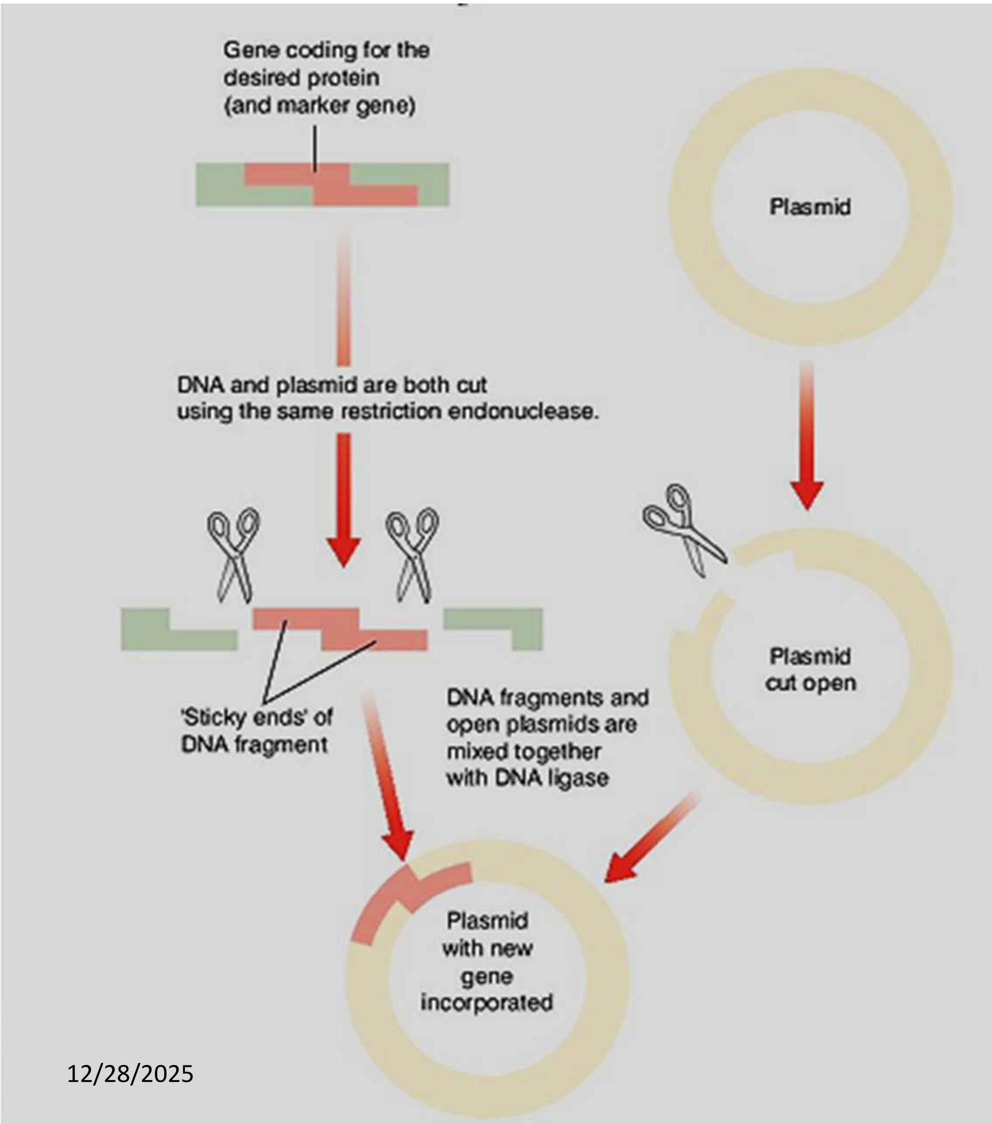
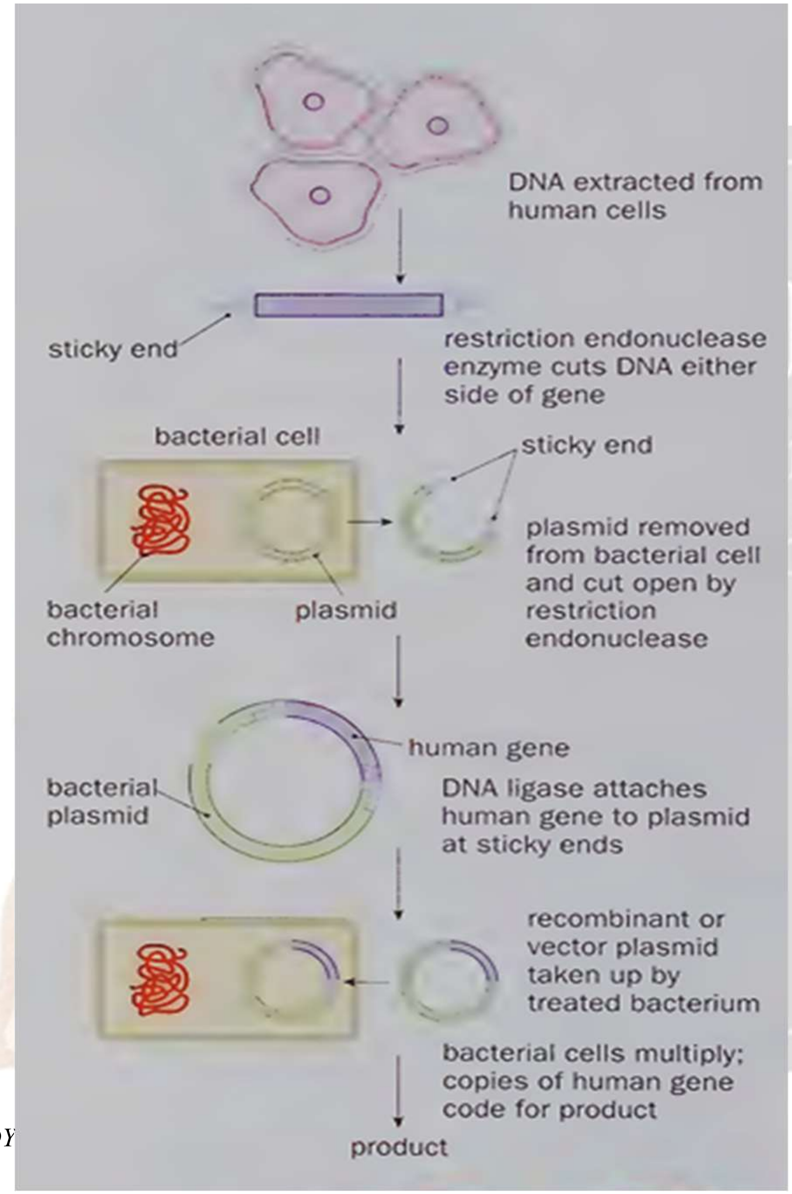


Figure 2 *Inserting a gene into a plasmid vector*



- Yeast cells often have naturally-occurring plasmids in them. They can be used to make yeast artificial chromosomes (YACs). These are used for cloning larger DNA fragments.
- Sometimes ***marker genes are used to indicate that new genes have been incorporated*** into host cells.
- Marker genes are linked to the desired gene, so they ***give clear evidence*** that the ***desired gene has been carried to the host cell***.
- Some of them ***may be radioactive so that the position of the labelled gene can be easily located***. Bacterial cells containing genetically engineered plasmids can also be identified by the use of marker genes that confer antibiotic resistance.
- So, the cells into which the gene has been inserted can be identified by the fact that the host cell is now resistant to a certain antibiotic.

POLYMERASE CHAIN REACTION.

- The polymerase chain reaction ie ***an automated process***, making it both rapid and efficient. The polymerase chain reaction (PCR) ***allows gene cloning to take place in a test-tube.***
- The reaction ***enables many identical copies of double-stranded DNA to be made without the use of bacteria***.
- Each strand is copied, producing two new strands, then each of these is copied and so on, doubling the amount of DNA at each cycle. This is ***semi-conservative replication of DNA*** in a test-tube. The raw materials are:

✓ ***The original sample of DNA*** is dissolved in a buffer solution and mixed with the following:

✓ ***DNA polymerase*** (this is a ***heat-stable form of the enzyme extracted*** from the thermophilic bacterium *Thermus aquaticus*).

- This bacteria *lives in hot springs* and remarkable of ***Taq- polymerase*** which is *tolerant to high temperatures/ thermostable*.(not denatured at high temperature).
- DNA polymerase is capable of joining ten thousands of nucleotides in a minute.

✓ ***The four different types of nucleotide*** containing the bases adenine, guanine, cytosine and thymine,

✓ ***Short pieces of DNA*** called ***primers***, which act as signals to the DNA polymerase enzyme to start copying.

✓ ***Thermocycler***: a computer-controlled machine that varies temperature precisely over a period of time.

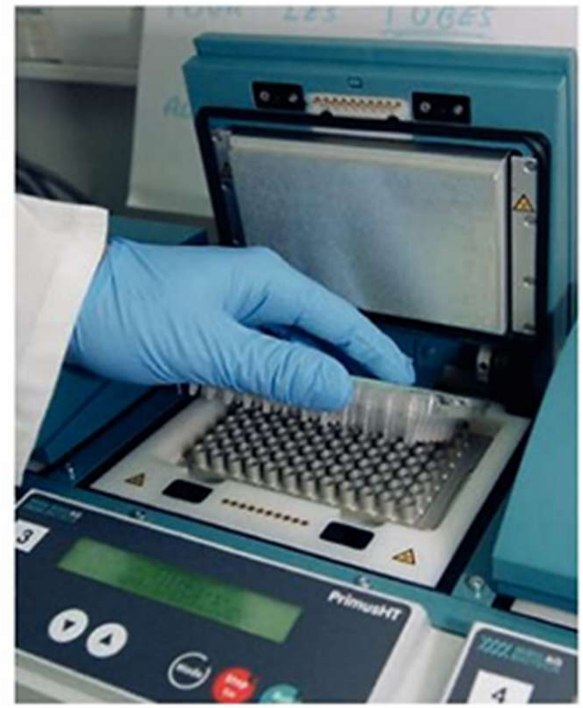


Figure 1 *Thermocycler – a machine that carries out the polymerase chain reaction (PCR)*

STAGES OF THE PCR CYCLE

- ***Strand separation of original DNA double helix***: the mixture containing *DNA fragments*, *primers*, *nucleotides* and *Taq polymerase* is placed in a vessel in the thermocycler, *heated to 95°C for 5 minutes* and *denatured*. ***DNA separates out into two single strands*** by ***breaking hydrogen bonds***.
- ***Primer binding***: the solution is ***rapidly cooled to 55°C to enable the primers to bind*** to the complementary base sequences on each of the single strands of DNA. This provides a ***starting point for the DNA replication***.
- ***Strand synthesis***: the solution is ***heated to 70°C***. The thermostable DNA polymerase enzyme ***catalyzes the synthesis of a complementary strand*** for DNA i.e. single strands of DNA using the supply of nucleotides.
- The DNA polymerase produces two identical double strands of DNA. The *process is then repeated by changing the temperature of the solution to 95°C, then 55°C and then 70°C*, so doubling the amount of DNA produced each time.

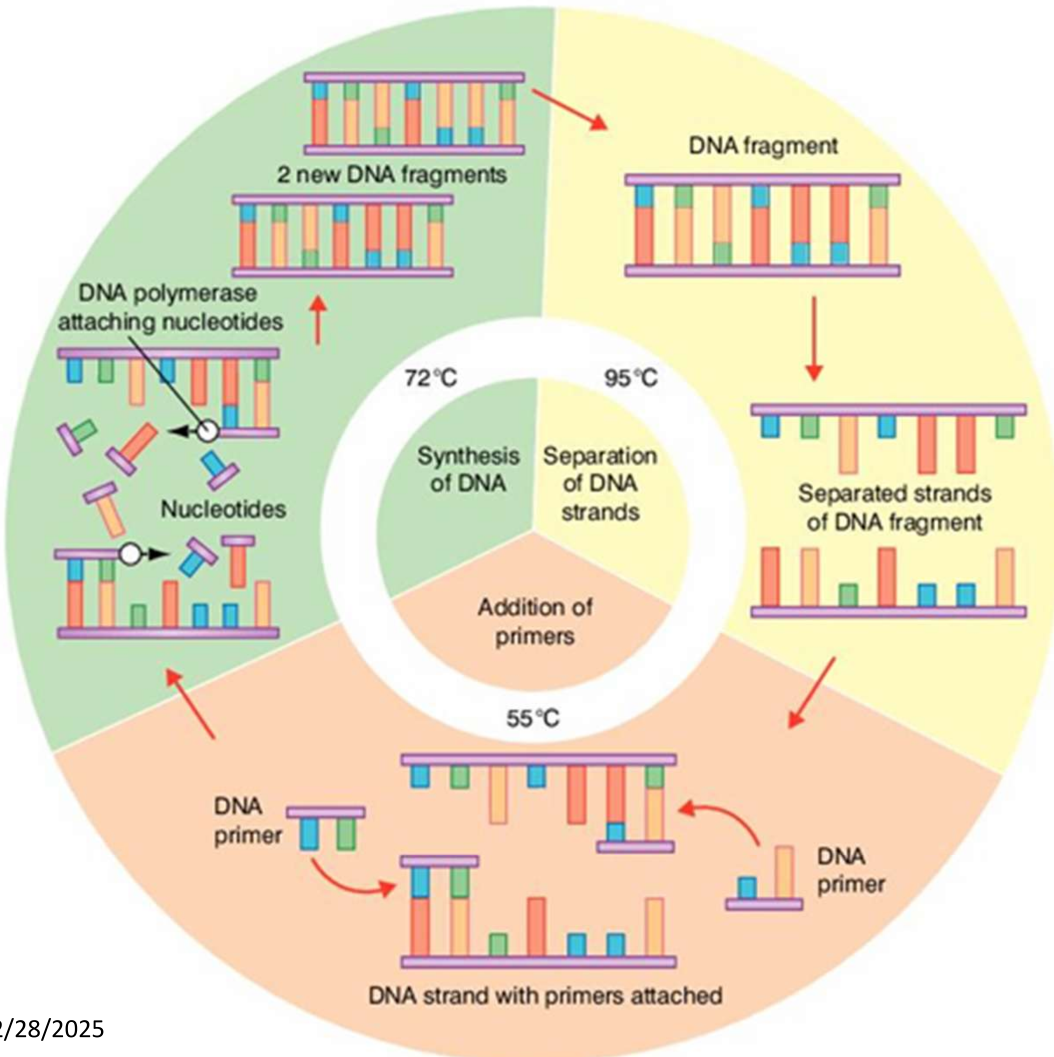
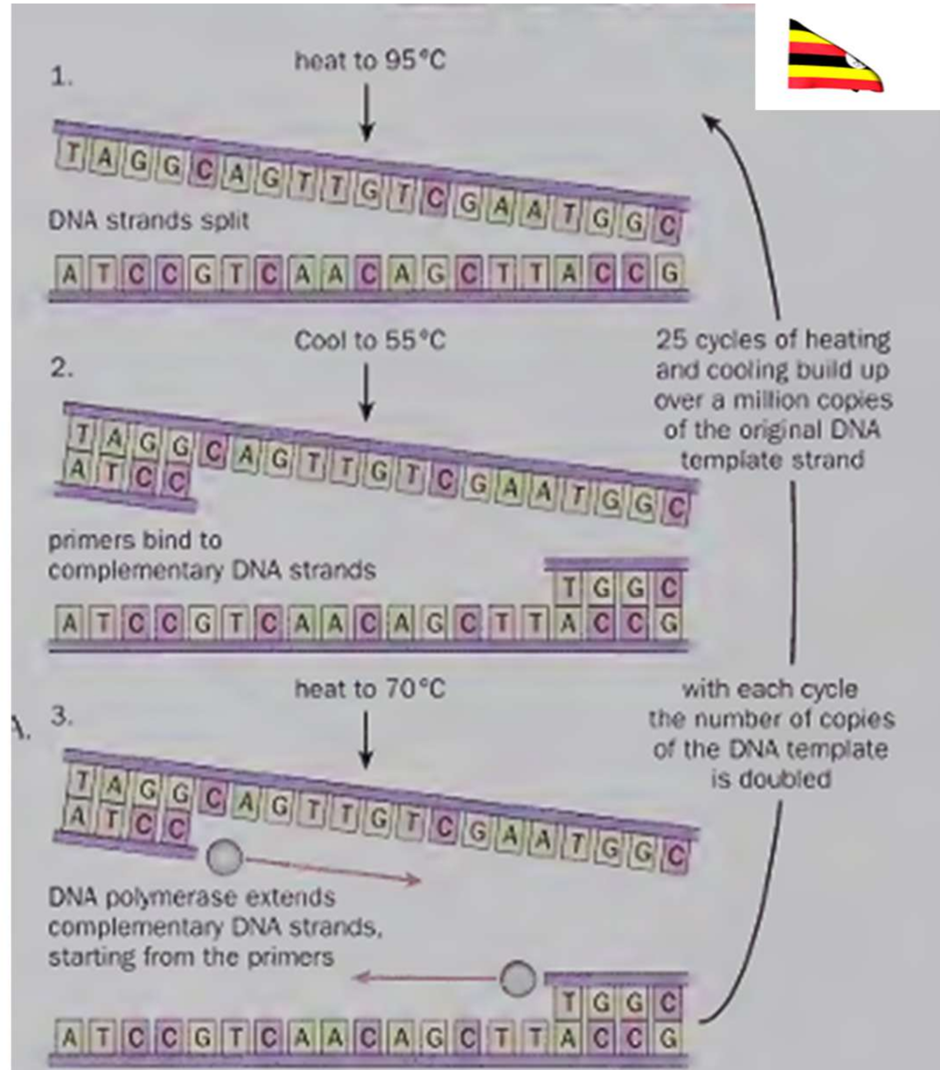


Figure 2 *The polymerase chain reaction showing a single cycle*



Stages of the PCR cycle

- Once the two strands are completed, the process is repeated by carrying out the temperature cycle again. This gives four molecules and so on until million copies are formed and this is known as DNA amplification.
- Many processes in DNA technology require large amounts of DNA, for example DNA sequencing and DNA fingerprinting.
- Often only small samples are available, so ***PCR can be used to create vast quantities.*** It can be ***used to increase the tiny amount of DNA sample in a speck of blood.*** This gives ***forensic scientists enough material to use for genetic fingerprinting***, which may lead to the identification of a criminal.
- Apart from its use as a forensic tool, genetic fingerprinting has also been used to detect inherited diseases, to monitor bone marrow transplants, and to confirm animal pedigrees.

APPLICATIONS OF GENETIC ENGINEERING IN INSULIN PRODUCTION.

- Some human diseases are caused by the ***inability of a person to produce certain chemicals***.
- For instance, diabetics are unable to make their own ***insulin*** and ***haemophiliacs are unable to produce factor VIII.***
- Many of these chemicals are proteins coded for by DNA. In the past, some of these diseases ***have been treated using chemicals extracted from animals***.
- Sometimes this ***resulted in side-effects produced by the patient's immune system.***

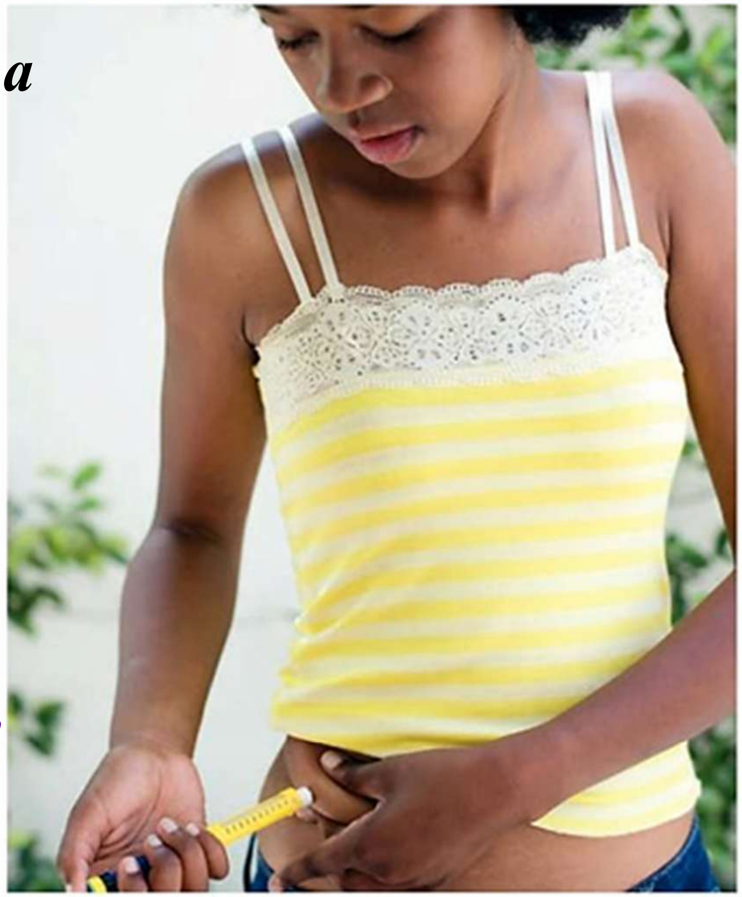
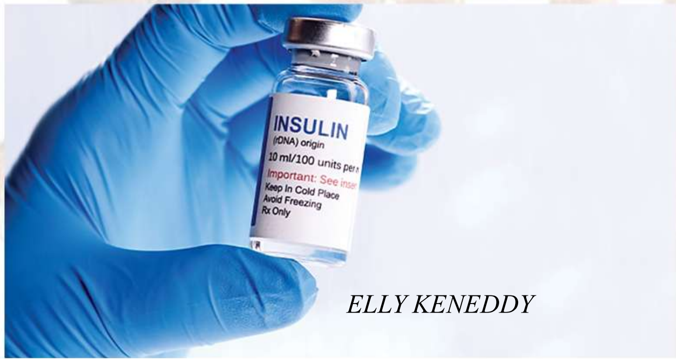


Figure 1 A person with diabetes injecting insulin

- Genetic engineering has now ***made it possible to use bacteria to mass-produce human insulin.*** First, the ***gene that codes for insulin is identified*** and ***isolated from a healthy human cell.***
- Then the ***donor DNA is spliced into the host bacterial DNA***. The bacterial cells are ***grown in a nutrient medium in a large industrial fermenter***, which provides ideal conditions for growth.
- The bacterial cells ***multiply rapidly and soon there are millions of cells*** all carrying the insulin-producing gene. The gene is ***transcribed and translated and the insulin produced.***
- This type of insulin does not have the side-effects associated with animal insulin.



APPLICATIONS OF GENETIC ENGINEERING IN DRUG PRODUCTION.

- Genetic engineering has revolutionized the pharmaceutical industry by moving away from traditional chemical synthesis toward biopharmaceuticals. These are drugs produced using living systems. The primary method used is ***Recombinant DNA Technology***. This involves

Synthesis of vaccines

- Traditional vaccines used weakened or killed viruses. Genetic engineering ***allows synthesis of subunit vaccines*** E.g. For the Hepatitis B vaccine, ***only the "surface protein" of the virus is produced in yeast cells***. Because the ***actual virus is never present***, there is ***zero risk of the patient catching the disease*** from the vaccine.

Synthesis of monoclonal Antibodies

- These are proteins engineered to track down and bind to specific targets in the body, such as cancer cells or inflammatory markers. Drugs like ***Herceptin target specific proteins on breast cancer*** cells to ***stop them from growing.***

DISCOVER (AN ANTIBIOTIC)

- An antibiotic is a ***substance produced by one microorganism*** that is ***capable of destroying or inhibiting the growth of another microorganism***.
- Antibiotics are regarded as secondary metabolites because they are ***not essential for the growth or reproduction of the organism that produces them***. Their formation is thought to give a selective advantage to the microorganism ***(antibiotics produced by Penicillium might, for example, act as growth inhibitors to competing microorganisms***).
- Antibiotics that destroy ***(kill) microorganisms*** are described as ***biocidal***; those that ***inhibit the growth and reproduction*** of microorganisms are ***biostatic***.
- Antibiotics are not effective against viruses. Only microorganisms (mainly bacteria and a few fungi) produce antibiotics, so substances produced by plants and animals or synthesized by humans are not strictly antibiotics. However, the term is generally used more loosely to include a wide range of chemicals which damage pathogens.
- Thus, antibiotics generally include chemicals produced naturally by microorganisms, animals and plants; chemicals such as penicillin which are produced naturally but altered chemically to make them more effective.

MECHANISM OF ACTION.

- Penicillin, vancomycin, and cephalosporins all ***weaken bacterial cell walls***. These walls are made up of long chains of peptidoglycan molecules. The antibiotics ***inhibit the synthesis of peptide links which bind the molecules together***. The ***cell wall becomes so weak that the bacterium bursts (lysis***). Unfortunately, the antibiotics only work on bacteria that are growing; hence have no effect on dormant bacteria in the body.
- Streptomycin, erythromycin, tetracyclines, and chloramphenicol either ***inhibit protein synthesis*** or ***promote the synthesis of abnormal proteins in bacterial cells***. The antibiotics ***bind to bacterial ribosomes*** but do not affect eukaryotic ribosomes (including those of humans), which are larger.
- Anthracyclines and rifampicin ***disrupt the synthesis of nucleic acids***. Anthracyclines do this by ***inhibiting DNA replication***, whereas rifampicin ***prevents transcription***
- Some antibiotics kill or destroy pathogens by ***disrupting cell membranes***. For example, fungal cell surface membranes are normally stabilized by ***ergosterol***, which has the same function as cholesterol in animals. The antibiotic amphotericin B binds to ergosterols, distorting the lipid bilayer. It is thought that this allows the contents of the cell to leak out, with fatal consequences for the pathogen.

IMPLICATIONS OF GENE TECHNOLOGY.

- **Environmental safety** : there are worries that *new GM food plants will become successful weeds*, that *they will transfer their new genes to wild relatives or similar crops nearby*, and that those with insect-resistant genes will lead to the establishment of resistant populations of pests.
- **Food safety** : concern focuses on the *inclusion of marker genes for antibiotics and herbicides*. In particular, the proteins these genes can produce, *what levels should be acceptable* and whether the *genes are transferable to other organisms such as microbes in the intestine of the consumer*. There is no recorded evidence currently of such transfer occurring between plants and microbes or humans.
- **Changes in farming structure**: may occur which *amplify the existing trends towards larger farms and more capital-intensive systems* favouring only wealthy farmers in the northern hemisphere.

CONT……………….

- ***Biodiversity*** :fewer companies will ***increasingly control plant breeding***, *reducing the number of plant varieties available to farmers* and *leading to a reduction in the use of the old varieties* and wild relatives. This could make plants more susceptible to attack by pests and diseases.
- ***Animal health*** : developments in livestock production that affect animal welfare are increasingly unlikely to be accepted by regulatory authorities or the public. There are currently no products of animal biotechnology in food shops. In the future, such research could, however, benefit disease resistance in cattle in developing countries.

POSITIVE IMPLICATIONS.

- ***Solving global hunger*** :genetic modification could feed the world through the *development of crops that will tolerate drought*, ***saline soils*** or *frost*, and thus *increase food production in some areas*.
- ***Environmentally friendly*** :genetic modification can *confer resistance to insects, weeds* and *pathogens*. Together with genes that improve nitrogen uptake, these improvements should lead to a decrease in the use of chemicals.
- ***Consumer benefits*** :genetically modified food plants have already been produced which can *provide food with an improved flavour* and *better keeping qualities*, which are easier to produce, and which require fewer additives.
- ***Production of drugs***: genetic modification has been *used in production of synthetic drugs*, ***insulin***, *Clotting factor VIII* which are *used in management of diseases* and *healthy challenges* e.g. diabetes mellitus and haemophilia.

POPULATION GENETICS

***Terms used in population genetics*.**

- **A population** is a group of ***organisms of the same species living together in a given habitat*** at a ***given time***.
- **A species** refers to a group of organisms with ***similar features and characteristics*** which can ***interbreed successfully to produce fertile offsprings***.
- **Gene pool**; Refers to the ***total variety of genes*** and ***alleles*** present in a ***sexually reproducing population***. In any given population the composition of the gene pool may be constantly changing from generation to generation.
- New combinations of genes produce unique genotypes which, when expressed in physical terms as phenotypes, undergo environmental selection pressures
- A population whose gene pool shows consistent change from generation to generation is said to be undergoing ***evolutionary change***.

- **<u>Allele frequency</u>** refers to the ***total number of copies of a given allele*** expressed as a ***percentage of the total number of alleles*** for ***that gene*** in a population. (the percentage of organisms in a population carrying a particular allele).
- For example, in humans the frequency of the ***dominant allele for the production*** of pigment in the **skin**, **hair** and **eyes** is ***99%***.
- The ***recessive allele, which is responsible for the lack of pigment***, a condition known as ***albinism***, has a frequency of ***1%***.
- This means that of the total number of alleles controlling production of the pigment, 1% result into lack of pigment and 99% result in its presence.
- However, frequencies in population genetics are usually represented as decimals rather than percentages or fractions,

$$0.99 + 0.01 = 1.00.$$

- Mathematically; if we let p and q to represent the dominant and recessive allele frequencies respectively,

- Then p + q = 1…………………………………………………………………… (I)
- Using the equation (i) above; if the allele frequency of either allele is known, the allele frequency of the other can be determined.
- E.g. If the allele frequency of the recessive allele is 25%,

Then q = 0.25.

Using : P + q = 1

P = 1 - 0.25

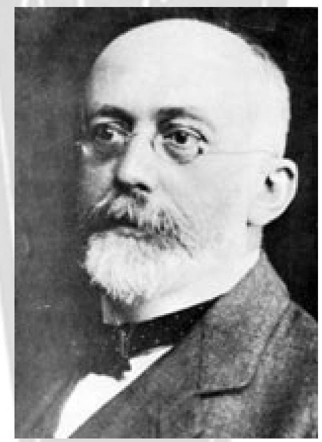
P = 0.75.

- ***Genotype frequency*** refers to the ***total number of individuals carrying a particular genotype*** expressed as a ***percentage of the total population***. (genotype can be ***homozygous recessive***, ***homozygous dominant*** or ***heterozygous***)
- In populations, it's only possible to estimate the frequency of two alleles in a homozygous state as this is the only genotype which can be directly observed phenotypically (***heterozygous cant be observed***). E.g. 1 person in 10000 is albino.

HARDY-WEINBERG'S PRINCIPLE

- The mathematical ***relationship between*** the frequencies of ***alleles*** and genotypes in populations was developed in 1908 by an English mathematician G. H. Hardy and a German physician W. Weinberg.
- The relationship, known as the ***Hardy-Weinberg equilibrium***, is based upon a principle which states that '*the frequency of dominant and recessive alleles of a large sexually reproducing population will remain constant from generation to generation provided disruptive factors like selection and mutation do not exist*.'

These ***conditions must be fulfilled*** for the principle to hold



✓The population is large

✓Mating is random

✓No mutations occur

✓Generations do not overlap;

✓There is no immigration into or emigration from the population

✓All genotypes are equally fertile so that no natural selection is taking place.

THE HARDY-WEINBERG EQUATION

- Hardy and Weinberg devised an equation to calculate allele and genotype frequencies. The equation is based on the fact that the total frequency of alleles of a gene must equal 100% (this is usually expressed as a decimal, where 1.0 represents 100%).
- They considered a population with a gene that has two alleles, **A** which is *dominant* and **a** which is *recessive*. **P** was used to represent the *frequency of the dominant allele* (A) and **q** to represent the *frequency of the recessive allele* (a) in the population. The total allele frequency must equal 100%

$$P + q = 1.0$$

- The equation above is used to calculate the allele frequencies. However, in diploid organisms, ***alleles occur in pairs***. In order to calculate genotype frequencies, a second equation is used, derived from the first:

$$p^2 + 2pq + q^2 = 1.0$$

- Where: p^2 represents the frequency of the **AA** genotype

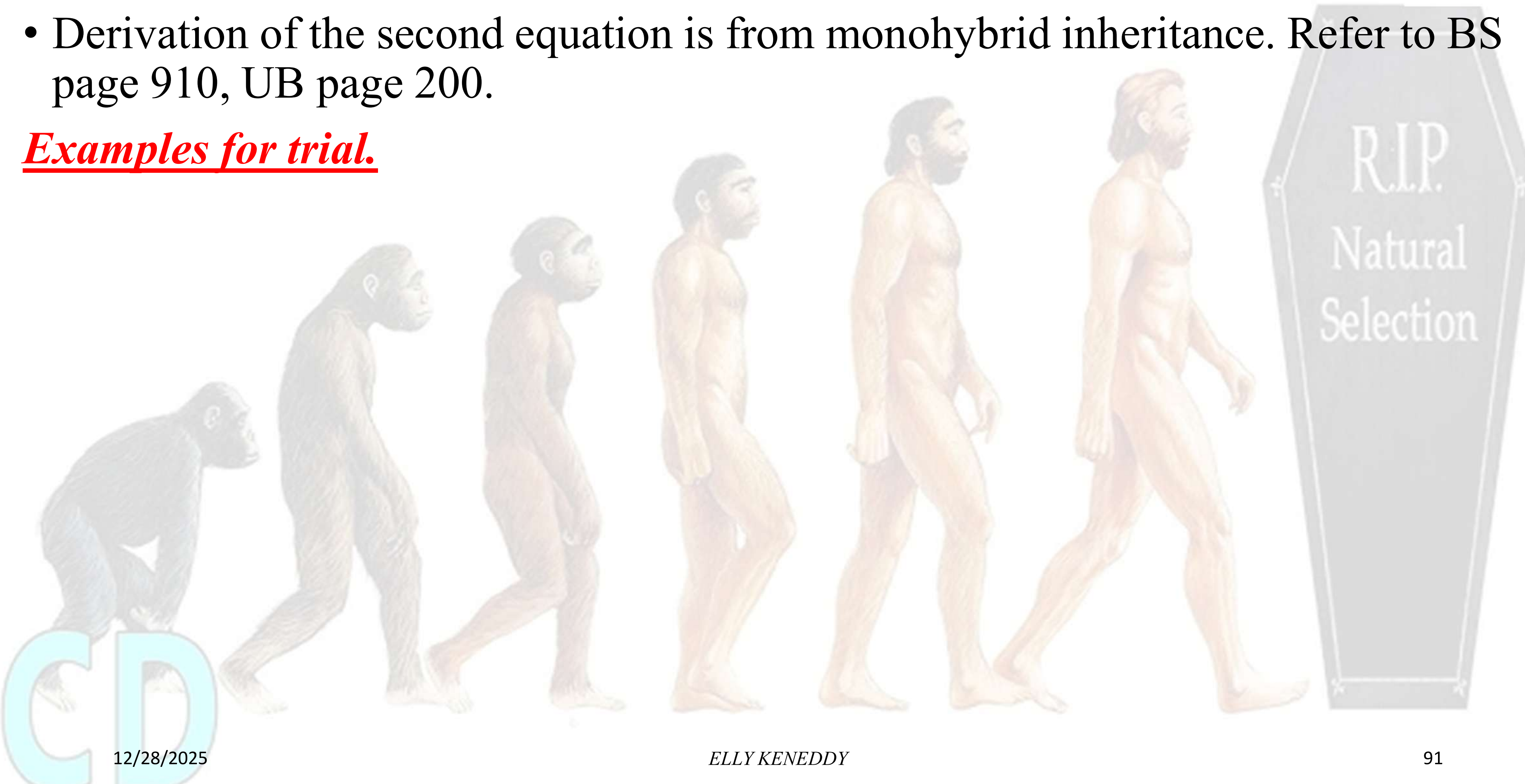
  2pq represents the frequency of the **Aa** genotype

  q^2 represents the frequency of the **aa** genotype.

NOTE.

- Derivation of the second equation is from monohybrid inheritance. Refer to BS page 910, UB page 200.

<u>Examples for trial.</u>



FACTORS LEADING TO CHANGE IN ALLELE AND GENE FREQUENCY.

Natural selection.

- This favours alleles and genotypes that produce ***environmentally adapted phenotypes*** which ***interbreed successfully***, leading to ***increase in their frequencies*** while those that are ***less adapted to the environment are eliminated*** hence their ***frequencies decline***.

Gene flow.

- It refers to the ***movement/continual interchange of alleles*** from one population to another ***as a result of interbreeding*** among the members of the two populations. This results into ***introduction of new alleles from other populations*** leading to ***change in the allele frequencies*** of the population.
- However, gene flow is conservative to evolutionary change in the long run because it ensures uniform distribution of alleles in all populations which reduces genetic variation and increases uniformity among organisms as all populations sharing a common gene pool, this limits the action of natural selection.

Mutations:

- Mutation is the ***sudden change in the genetic composition*** of an organism that ***occurs by chance***. Mutations ***lead to introduction of new genes and alleles*** thus greatly increase genetic diversity. Mutations producing advantageous traits are favoured and increase in frequency over successive breeding generations while those producing disadvantageous traits are eliminated by natural selection.

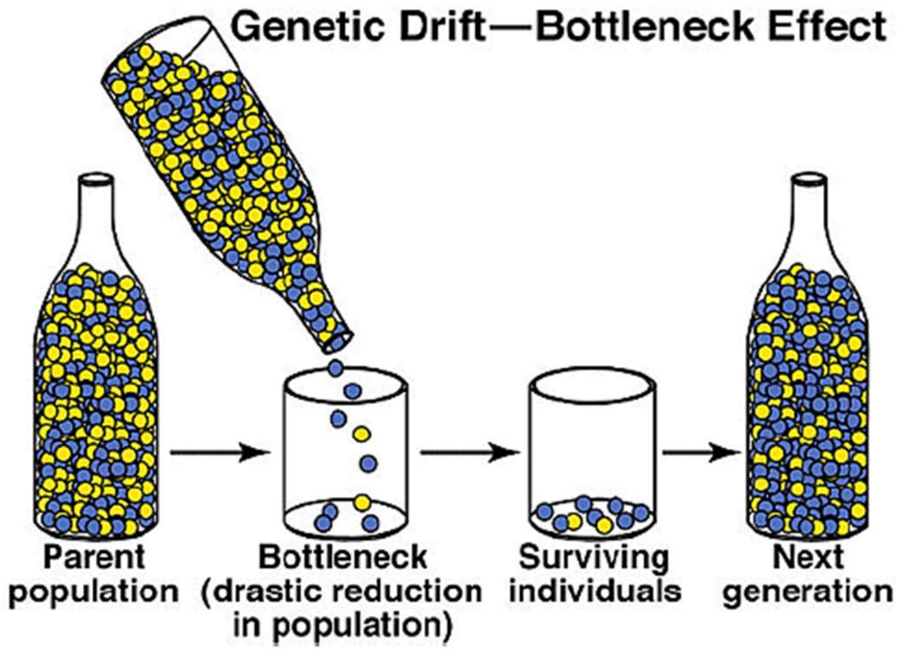
Non-Random Mating:

- This occurs when there is ***sexual selection*** (mechanisms which increase success of mating among particular individuals of a population). It occurs when there is presence of inherited characteristics which increase the likelihood of successful fertilization e.g colour patterns in insects and birds, petal size and colour in flowers). In such cases, only organisms having ***desired characteristics*** will ***have high chances of breeding*** hence passing on their genes to next generations, while those ***without such features*** will have ***reduced reproductive potentials***. Only some alleles will be passed to next generation leading to change in their frequencies

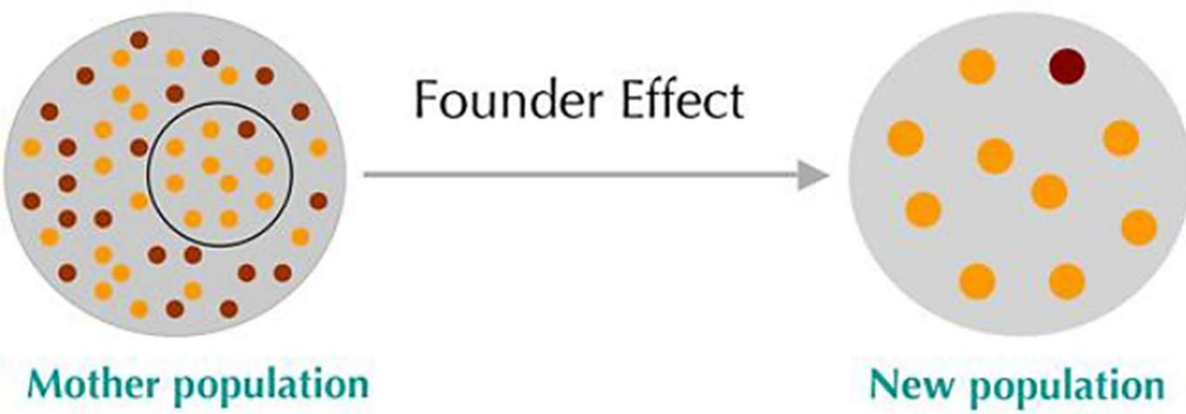
GENETIC DRIFT.

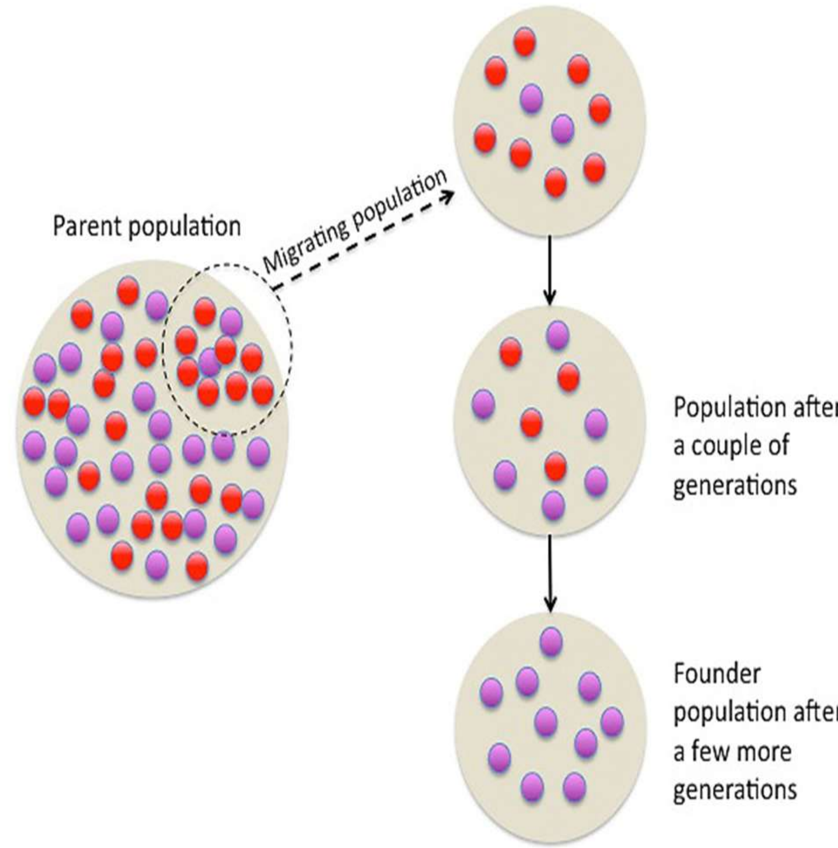
This refers to the ***change in the gene frequencies*** within a ***small population*** as a ***result of chance rather than by natural selection***.

- Although chance events occur in populations of all sizes, they alter allele frequencies substantially only in small populations.
- A small population may ***become isolated from a large population by geographical barriers*** and it ***may not be truly representative of the original population*** in terms of allele and genotype frequencies. Some alleles ***may be absent*** while others ***may be disproportionally/ over represented.*** while others ***may be under represented.***
- Continuous breeding within the pioneer population will ***produce a gene pool with allele frequencies different from that of the original parent population***; this is known as the ***Founder effect*** (as it occurs in the founder population).



Founder effect





- In the same way, a ***sudden change in the environment***, (such as a fire or flood) ***may drastically cause death of individuals reducing the size of a population***, just by chance.
- ***Among the few survivors***, certain alleles ***may be overrepresented***, others ***may be underrepresented***, and some ***may be absent altogether***.
- ***Continuous breeding within the survivor population*** will produce a gene pool with ***allele frequencies different from that of the original parent population***. This is referred to as the ***bottleneck effect***.

Genetic load

- This is the existence within the population of ***disadvantageous alleles in heterozygous genotypes.*** Very many disadvantageous alleles are able to exist in populations in heterozygous forms as in this form they ***are rarely expressed phenotypically for possible elimination by environmental selection***, for example albinism, colour blindness, sickle-cell anemia, etc.

GENETICS.

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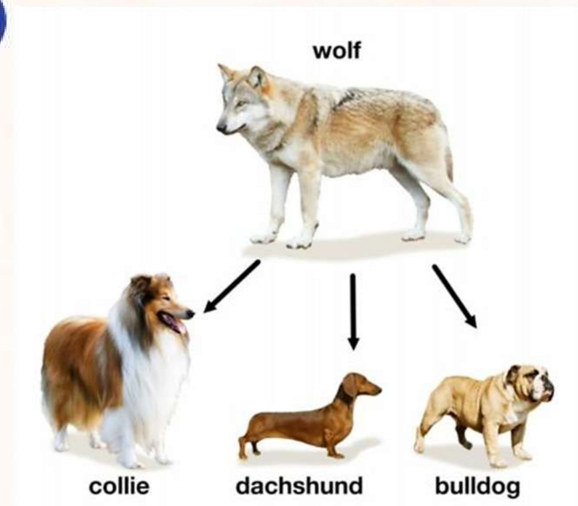


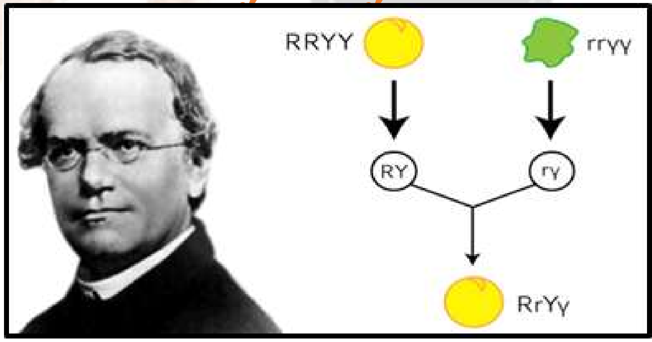
INTRODUCTION.

- Genetics is the ***science of inheritance***, the ***way in which characteristics are passed from parent to offspring.***
- All organisms ***closely resemble their parents***. Offsprings created asexually are ***likely to resemble their parents more closely*** than those arrived at by sexual reproduction.
- This happens because ***mitotic nuclear division, which gives rise to progeny asexually***, reproduces the genetic material with ***little or no variation***.
- Meiotic nuclear division is an integral part of the life cycle of every creature which reproduces sexually and ***allows scope for genetic variation***.
- It is desirable to be acquainted with some commonly used genetic terms before studying the inheritance of characteristics. i.e.
- ***Gene***: The basic unit of inheritance for a given characteristic

- ***Allele*** : One of a number of alternative forms of the same gene responsible for determining contrasting characteristics
- ***Locus*** : Position of an allele within a DNA molecule or chromosome.
- ***Homozygous*** : The diploid condition in which the alleles at a given locus are identical
- ***Heterozygous***: The diploid condition in which the alleles at a given locus are different
- ***Phenotype*** :The observable characteristics of an individual usually resulting from the interaction between the genotype and the environment.
- ***Genotype***:The genetic constitution of an organism with respect to the alleles under consideration
- ***Dominant allele***: The allele which influences the appearance of the phenotype even in the presence of an alternative allele
- ***Recessive allele***: The allele which influences the appearance of the phenotype only in the presence of another identical allele

MENDELIAN PRINCIPALS OF INHERITANCE

- The earliest humans noticed the remarkable similarities that often occur between parents and their offspring. They must also have noticed that offspring differ from each other and from their parents in many aspects.
- They probably realized that ***some characteristics are passed on to the next generation*** while ***others appear to be lost***.
- However, it was not accounted for until the 1850s that genetics really began. Starting in about 1856, ***Gregor Mendel*** carried out a ***large number of experiments which laid the foundation for genetics***.
- Even though Mendel had no knowledge of genes or chromosomes, ***his work showed that inheritance is particulate***: it ***depends on the transfer of discrete (separate) factors*** from parents to offspring.



MENDEL'S EXPERIMENTS

- Mendel was an Austrian monk who studied the inheritance of characteristics in garden peas (*Pisum sativum*), which he grew them in the vegetable garden of his monastery.
- He chose peas because they were ***easy to grow***, they ***had a short life cycle***, ***their pollination could be controlled***, and they had ***easily observable contrasting characteristics.*** He studied seven characteristics, each of which has two contrasting alternatives.
- Mendel first established ***pure-breeding plants*** **(***plants which when self fertilized produce identical offspring generation after generation***)**.
- Mendel then selected for his experiments two pure-breeding plants with alternative expressions of a particular characteristic (for example, a tall plant and a dwarf plant). He ***crossed the plants by transferring pollen from one plant*** (the 'male' parent) to the stigma of a second plant (the 'female' parent).

- Mendel made sure that the 'female' plant could not be pollinated either by its own pollen or by any other by ***removing its anthers*** and ***covering its flowers with fine muslin bags.***
- Mendel collected the seeds produced by the 'female' parent and grew them the ***next year to give the first-generation offspring*** (the offspring of pure-breeding parents are often called the first filial generation or F_1).
- He carefully recorded the characteristics of these plants and then ***crossed two plants from this generation***. This type of cross involving plants of the same generation is called a ***self-cross***.
- Again, the seeds produced were collected and grown the following year to give the second-generation offspring (the offspring produced by a cross between F_1, parents is often called the second filial generation or F_2).
- The characteristics of each plant were again recorded.

MONOHYBRID INHERITANCE

- Mendel's first experiments were designed to follow the ***inheritance of one well-defined characteristic***. In his procedure, ***he cross-pollinated pure-breeding varieties of the garden pea***, collect the seeds and sow them the following year. The plants which grew were then ***allowed to self-pollinate***, and the seeds they produced were again collected.
- The phenotypes of the plants which grew from the seeds were carefully noted. One of the traits Mendel worked with was the ***height of the plants***.
- During his investigation he crossed a pure-breeding tall plant with a pure-breeding dwarf plant. All the were F_1 offsprings were tall
- When he self-pollinated the F_1 offsprings, F_2 plants were a mixture of tall and dwarf in which there was a ratio of ***3 tall: 1 dwarf***. This is known as a ***Monohybrid ratio***. The tall characteristic, which the F_1 plants showed, Mendel termed it as dominant. Its contrasting trait, dwarfness, was termed recessive.

- Let : ***T*** represent the allele for ***tall pea plant*** (dominant)

  t represent the allele for ***dwarf pea pant***(recessive)

Parental phenotypes: Pure breeding tall pant X Pure breeding short plant

Parental genotypes: **T T** X **t t**

Meiosis

Gametes: All **T** All **t**

Note.
The gametes must be enclosed by circles.

Random fertilization

F_1 genotypes : all Tt

F_1 phenotype : all heterozygous tall pea plants.

Selfing the F_1 offsprings

F_1 phenotypes : Tall pea plant X Tall pea plant

F_1 genotypes : Tt X Tt

Meiosis

Gametes : T t T t

Random fertilization

F_2, genotypes TT Tt Tt tt

F_2 phenotype : 3 tall pea plants : 1 dwarf pea plant

MENDEL'S FIRST LAW, OR THE PRINCIPLE OF SEGREGATION

- In interpreting his results, Mendel concluded that the ***features were passed on from one generation to the next via the gametes***.
- The parents, ***must possess two pieces of information about each character***. However, only one of these pieces of information was found in an individual gamete.
- On the basis of this he formulated his first law, the Law of Segregation, which states: **"***the characteristics of an organism are determined by internal factors which occur in pairs*. *Only one of a pair of such factors can be represented in a single gamete***"**.
- This law is ***explained by meiosis*** which ***halves the chromosome number***. When homologous chromosomes ***segregate and move towards opposite pole of the cell during anaphase I of meiosis***. This results into each ***gamete carrying one allele of the gene pair*** due to the separation of a pair of chromatids during anaphase I.

MENDEL'S FIRST LAW ILLUSTRATED

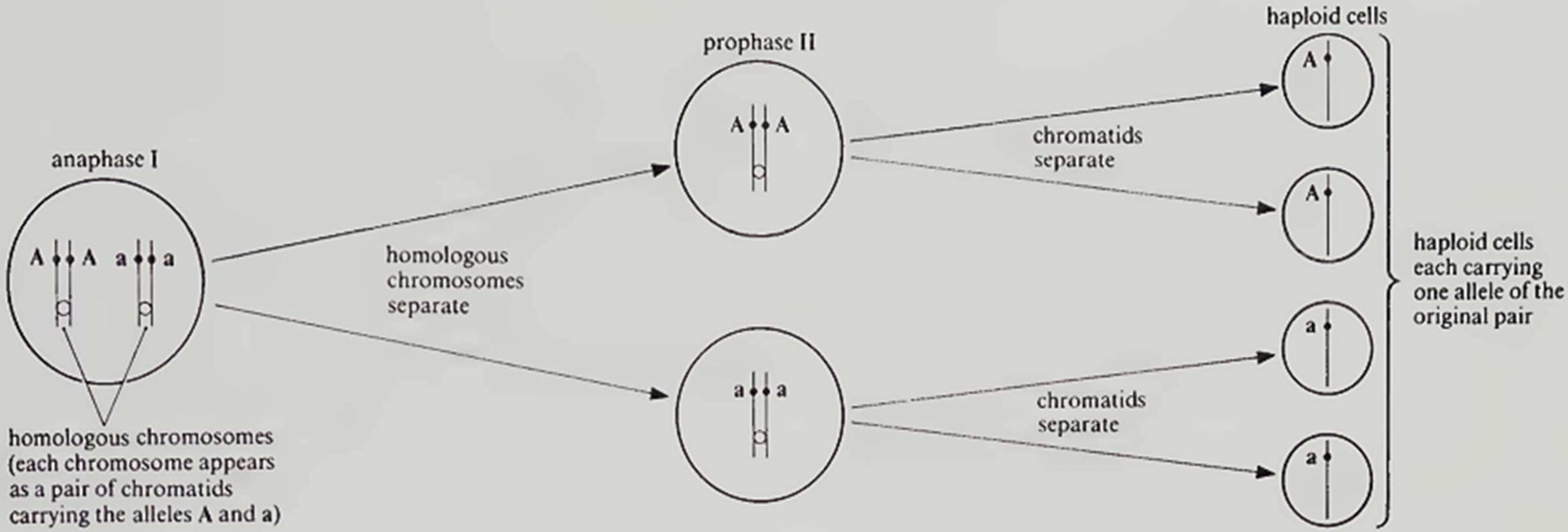


Fig 24.6 *Mendel's principle of segregation of factors (alleles)* **A** *and* **a** *described in terms of the separation of homologous chromosomes which occurs during meiosis.*

EXAMPLES.

- Suppose a man who is a tongue roller marries a woman who is a non-tongue roller and all the children obtained in F_1 are tongue rollers.

(a) Represent the above information as a genetic cross

(b) One of the children married a non-tongue roller. And they had three children. What is the probability that their 4th born is a tongue roller?

- If a pure strain of mice with brown- coloured fur are allowed to breed with a pure strain of with grey-coloured fur they produce offspring having brown-coloured fur. If the F_1 mice are allowed to interbreed they produce an F_2 generation with fur colour in the proportion of three brown-coloured to one grey.

(a) Explain these results fully.

(b) What would be the result of mating a brown- coloured heterozygote from the F_2 generation with the original grey-coloured parent?

DIHYBRID INHERITANCE AND THE PRINCIPLE OF INDEPENDENT ASSORTMENT

- Having established that it was possible to predict the outcome of breeding crosses involving a single pair contrasted characteristics, Mendel ***turned his attention to inheritance of two pairs of contrasted characteristics***.
- Since two pairs of alleles are found in the heterozygotes, this condition is known as ***dihybrid inheritance***. Dihybrid inheritance is the inheritance of two characteristics, each controlled by a different gene at a different locus found on different chromosomes.
- In one of the experiments, Mendel used ***pea seed shape*** and ***pea seed cotyledon colour*** as the characteristics. Using the same techniques, he crossed pure- breeding (homozygous) plants having round and yellow peas with pure-breeding plants having wrinkled and green peas.
- The F_1 generation seeds were ***round and yellow***. Mendel knew that these ***characteristics were dominant*** from earlier monohybrid breeding experiments but it was the nature and number of organisms of the F_2 generation produced from the self-pollination of the F_1 plants that now interested him.

- He collected a total of 556 F_2 seeds from the F_1 generation which showed the following characteristics: ***315 round and yellow***, ***101 wrinkled and yellow***, ***108 round and green***, ***32 wrinkled and green***.
- The proportions of each phenotype approximated to a ratio of **9:3:3:1**. This is known as the ***dihybrid ratio***. Mendel made two deductions from these observations.
- ***Two new combinations of characteristics had appeared*** in the F_2 generation: wrinkled and yellow, and round and green.
- The ratios of each pair of allelomorphic characteristics (phenotypes determined by different alleles) appeared in the monohybrid ratio of 3:1, that is 423 round to 133 wrinkled, and 416 yellow to 140 green.
- On the basis of these results, Mendel was able to state that the two pairs of characteristics (seed shape and colour) while combining in the F_2 generation, ***separate and behave independently from one another*** in subsequent generations. This forms the basis of ***Mendel's second law or the principle of independent assortment*** which states that: *any one of a pair of characteristics may combine with either one of another pair.*

MENDEL'S SECOND LAW ILLUSTRATED.

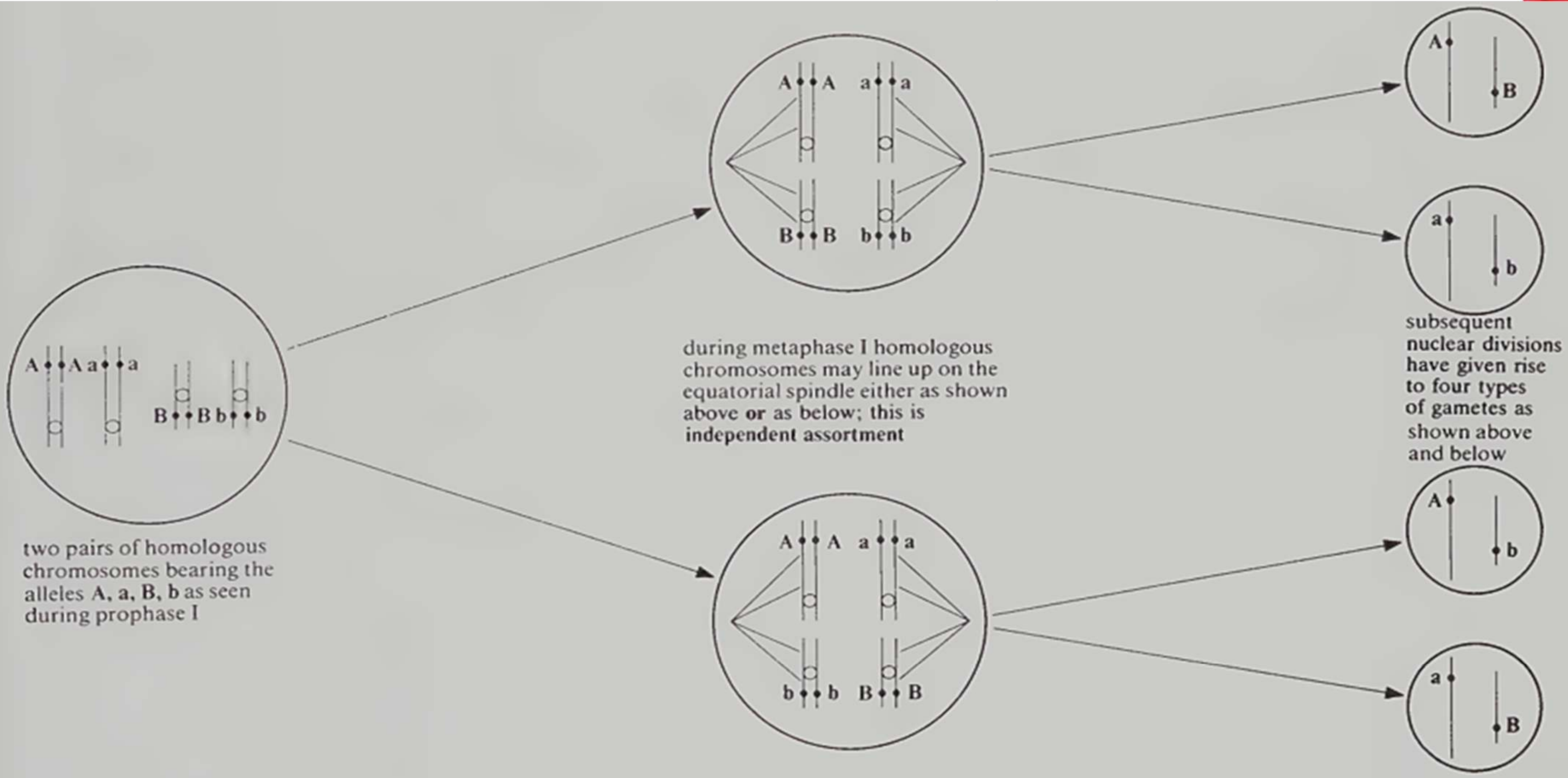


Fig 24.7 *Mendel's principle of independent assortment of factors (alleles)* **A**, **a**, **B**, **b**, *described in terms of the separation of homologous chromosomes which occurs during meiosis (compare fig 23.16).*

In **arrangement 1**, the two pairs of homologous chromosomes orientate themselves on the equator in such a way that the chromosome carrying the allele for tall stems and the one carrying the allele for terminal flowers migrate to the same pole. The alleles for short stems and axial flowers migrate to the opposite pole. Cell ❶ therefore carries the alleles for tall stems and terminal flowers while cell ❷ carries the ones for short stems and axial flowers.

In **arrangement 2**, the left-hand homologous pair of chromosomes is shown orientated the opposite way around. As this orientation is random, this arrangement is equally as likely as the first one. The result of this different arrangement is that cell ❸ carries the alleles for short stems and terminal flowers, whereas cell ❹ carries ones for tall stems and axial flowers.

All four resultant cells are different from one another. With more homologous pairs the number of possible combinations becomes enormous. In pea plants with 7 pairs, this is 2^7 combinations; a human, with 23 such pairs, has the potential for $2^{23} = 8\ 388\ 608$ combinations.

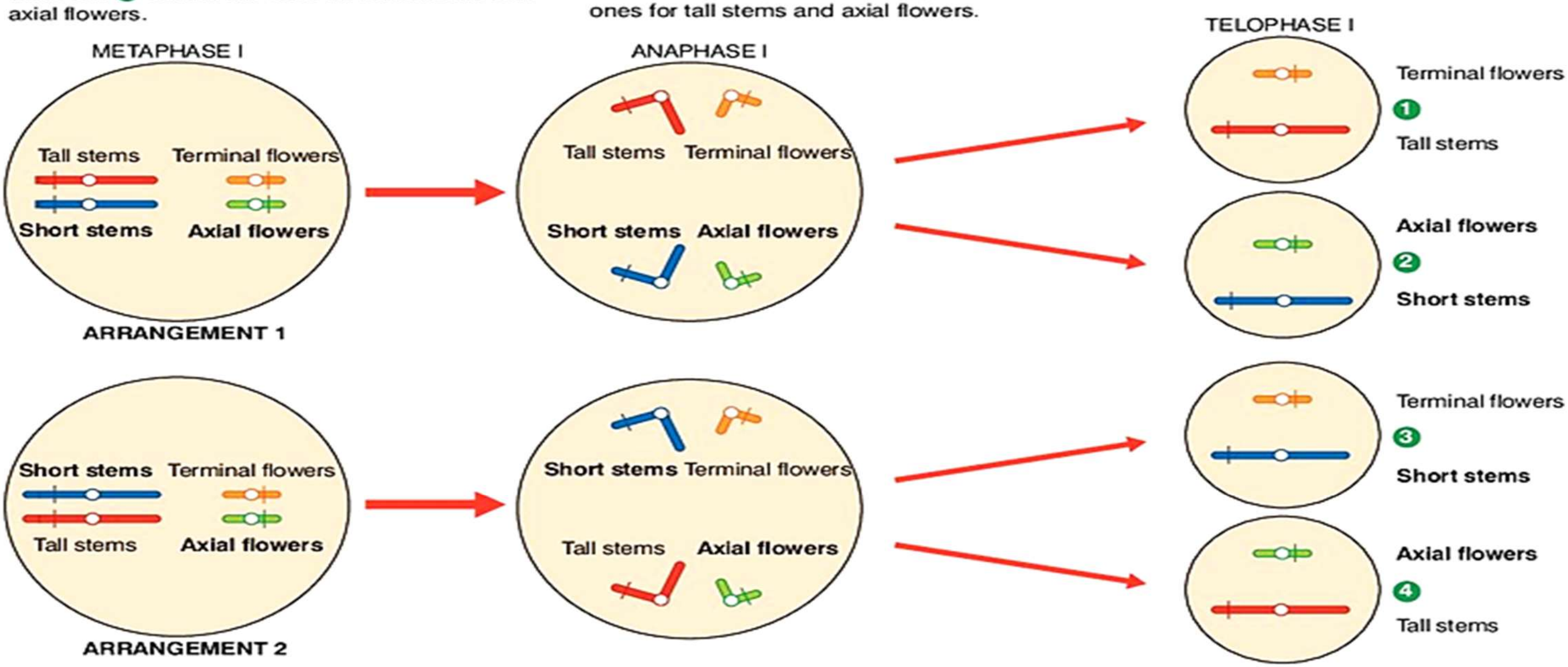


Figure 3 How random assortment of chromosomes during metaphase I contributes to genetic variation in gametes and hence the offspring

Let: **R** be the allele for *round seed* and ***r*** be the allele for *wrinkled seed*.

Let **Y** be the allele for *yellow seed* and **y** be the allele *for green seed colour*.

Parental phenotypes: Round and yellow seeded plant (*homozygous*) X Green and wrinkled seeded plant (*homozygous*)

Parental genotype : RRYY X rryy

Meiosis

Gametes : All **RY** All **ry**

Random fertilization

F_1 genotype : All **RrYy.**

All heterozygotes with round and yellow seeds

Selfing F_1 offsprings.

Parental phenotypes: Round and yellow seeded plant (*heterozygous*) X Round and wrinkled seeded plant (*heterozygous*)

Parental genotype : RrYy X RrYy

Meiosis

Gametes : **RY** **Ry** **rY** **ry**   **RY** **Ry** **rY** **ry**

Random fertilization (*Punnett square*)

F_2 genotype

	RY	**Ry**	**rY**	**ry**
RY	RRYY	RRYy	RrYy	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Phenotype: ***9*** *round yellow:* ***3*** *round green:* ***3*** *wrinkled yellow:* ***1*** *wrinkled green.*

The mechanism of dihybrid inheritance quoted above and dihybrid ratio of 9:3:3:1 ***apply to characteristics controlled by genes on different chromosomes only***. Genes ***situated on the same chromosome may not show independent assortment***.

From Mendel's experiments, the following conclusions were made.

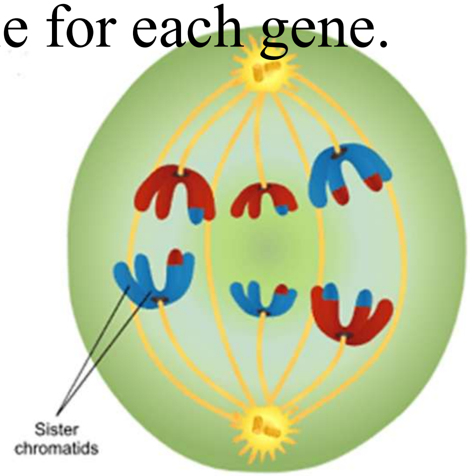
- ✓Each characteristic of an organism is controlled by a pair of alleles.
- ✓If an organism has two unlike alleles for a given characteristic, one may be expressed (the dominant allele) to the total exclusion of the other (the recessive allele).
- ✓During meiosis each pair of alleles separates (segregates) and each gamete receives one of each pair of alleles (the principle of segregation).
- ✓During gamete formation in each sex, either one of a pair alleles may enter the same gamete cell of (combine randomly) with either one of another pair (the principle of independent assortment).
- ✓Each allele is transmitted from generation to generation as a discrete unchanging unit.
- ✓Each organism inherits one allele from each parent.

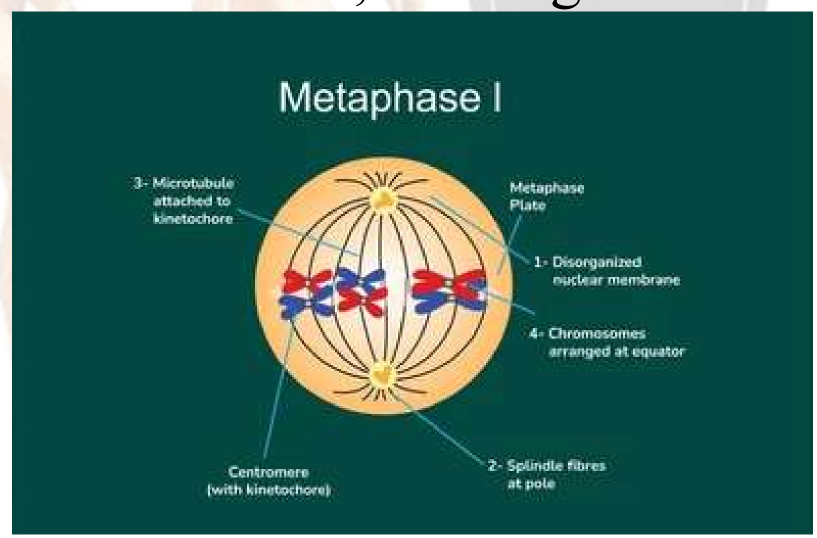
EXAMPLES.

- In the garden pea plant, the gene controlling flower color is located on different chromosome to that controlling height. Suppose a pure bleeding tall red flowered plant is crossed with a white short flowered plant, the F1 offsprings obtained are tall red flowered plants. If the F1 offsprings are selfed.
  a) What would be the phenotypic ratio in the F2 generation
  b) If 700 pea plants are formed in F2 generation, what would be number of pea plants in each phenotypic class
  c) How would you experimentally determine the genotypes of the F1 plants
- In Drosophila melanogaster flies, the gene determining the size of the abdomen occurs on the same chromosome with that determining the length of the wings. When a pure breeding broad and long winged female fly was crossed with a narrow and vestigial winged male fly all the F1 offsprings obtained head broad abdomen and long wings. If the F1 offsprings were selfed to obtain F2.
  a) Using suitable genetic symbols work out the phenotypes and genotypes that were obtained in F2 generation.
  b) Suppose 480 flies were obtained in F2 work out the numbers of the flies for each phenotype class.

NOTE.

- This law is also explained by meiosis as follows. During gamete formation by meiosis, the distribution of each allele from a pair of homologous chromosome is entirely independent of the distribution of alleles of other pairs.
- During metaphase I of meiosis ***homologous chromosomes lineup on the equator of the spindle randomly*** and subsequently separate (*segregate*) independently to ***opposite poles independently during*** ***anaphase I*** which ***leads to a variety of allele recombination*** in the gametes formed, as long as each gamete has one allele for each gene.



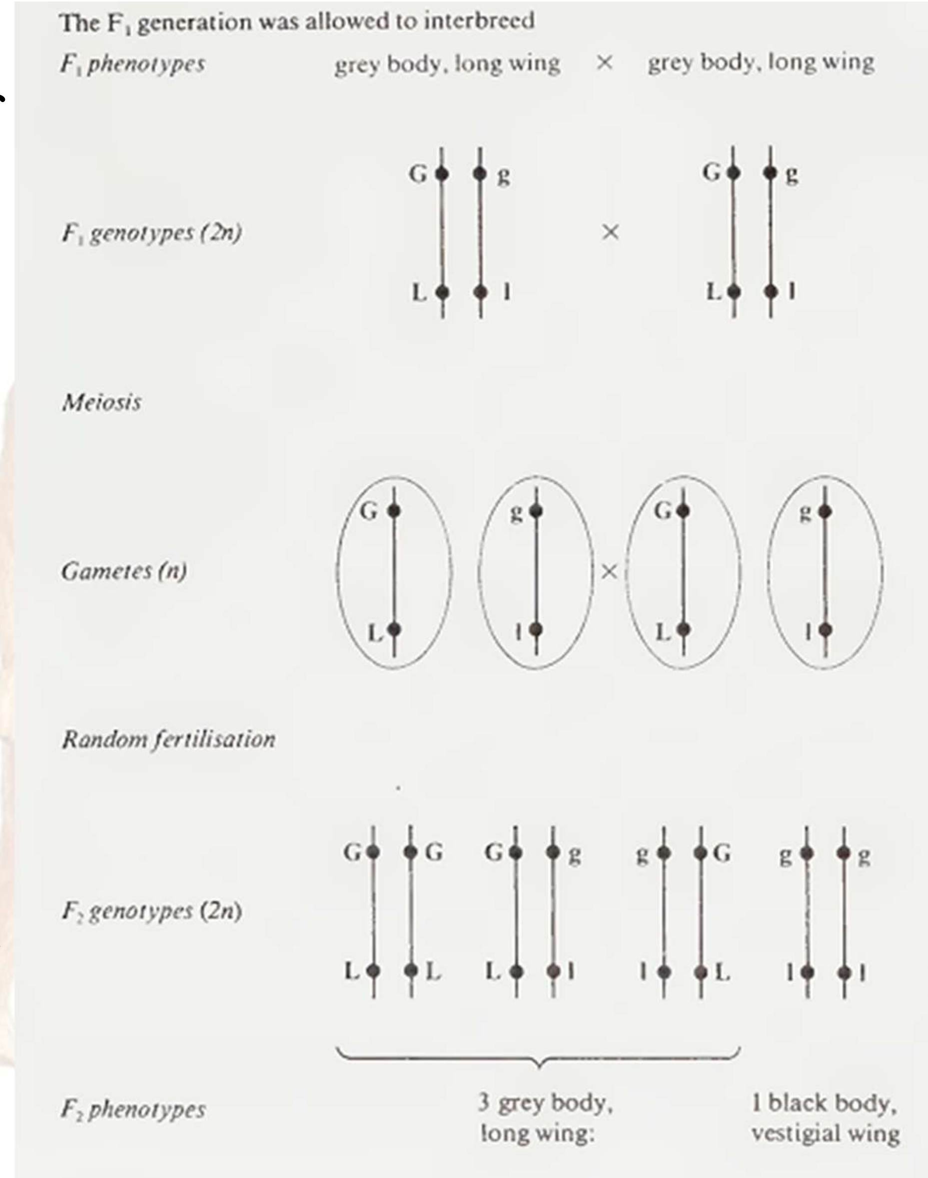


GENE LINKAGE.

- All the situations above deal with the inheritance of genes situated on different chromosomes.
- Humans possess 46 chromosomes in all the somatic (body) cells. Since humans ***possess thousands of characteristics*** such as blood group, eye colour, skin colour, the ability to secrete insulin, etc., it follows that ***each chromosome must carry a large number of genes***.
- ***Genes situated on the same chromosome*** are said to be ***linked***. All ***genes on a single chromosome form a linkage group*** and are ***usually passed into the same gamete*** during meiosis and are ***inherited together***.
- Although these genes occur on the same chromosome, each one controls the specific characteristic irrespective of the other.
- There are two types of linkage; ***autosomal gene linkage***, when the *genes are on the same autosome*, and ***sex-linkage***, when the *genes are located on the sex chromosomes, mainly the X chromosome*.

- Genes belonging to the same linkage group usually ***do not show independent assortment***. There fore, these genes do not conform to Mendel's principle of independent assortment they ***fail to produce the expected 9:3:3:1*** ratio in dihybrid inheritance.
- In these situations, ***a variety of ratios are produced*** which ***may be explained using understanding of the mechanisms of inheritance*** and ***knowledge of cell division*** and ***gene technology***.
- In Drosophila the genes for body colour and wing length have the following phenotypic characteristics determined by different alleles: grey and black body, and long and vestigial (short) wings. Grey body and long wing are dominant.
- If pure-breeding grey-bodied long-winged Drosophila are crossed with black-bodied vestigial-winged Drosophila, the expected F_2 phenotypic ratio would be 9:3:3:1. This would indicate a normal case of Mendelian dihybrid with random assortment resulting from the genes for body colour and wing length being situated on non-homologous chromosomes

- However, this result is not obtained. Instead, the ***show an approximately 3:1 ratio*** of parental phenotypes.
- This may be explained by assuming that the ***genes for body colour and wing length are found on the same chromosome***, that is they are linked.
- In practice, though, this 3:1 ratio is never achieved and four phenotypes are invariably produced. This is because ***total linkage is rare***.
- Most breeding experiments involving linkage ***produce approximately equal the parental phenotypes*** and a significantly ***smaller number of phenotypes showing new combinations of characteristics***. These phenotypes are described as **<u>Recombinants</u>**.



RECOMBINANTS AND CROSSING OVER

- The ***occurrence of recombinants*** shows that ***linkage was not complete***. These recombinants can be accounted for by the crossing over that can occur during prophase I of meiosis.
- The genetic significance of this process was clarified by Morgan who proposed that ***crossing-over of alleles occurred*** as a result of ***the breakage and recombination of homologous chromosomes*** at ***chiasmata***.
- The ***alleles of parental linkage groups separate*** and ***new associations of alleles are formed in the gamete cells***, a process known as ***genetic recombination***. Offspring formed from these gametes showing 'new' combinations of characteristics are known as recombinants.
- Thus ***crossing- over a major source of observable genetic variation*** within populations. The further apart the genes are, the more likely it is that crossing over will result in the formation of recombinants.

CROSS OVER VALUES.

- The proportion of recombinants resulting from a dihybrid test cross is used to calculate the cross over value (COV), a measure of linkage, and if linkage occurs, the distance between genes.

$$\text{COV} = \frac{\textit{total number of recombinants}}{\textit{total number of offspring}} \times 100\%$$

If the ***genes are not linked,*** the expected phenotype ratio of such a cross is **1:1:1:1** and, as there is a 50 per cent chance that alleles on separate chromosomes will be inherited together, ***the expected COV is 50 per cent***.

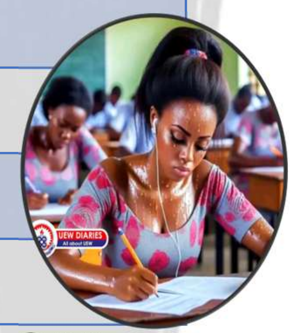
Linkage results in the COV being significantly less than 50 per cent; ***the lower the value, the closer the genes***. Thus, the COV can be used to locate the relative positions of genes on chromosomes, a process called chromosome mapping or genetic mapping.

Try any one example to demonstrate.

EXAMPLE.

- In Drosophila flies the genes controlling body color and eye color occur on the same chromosome and are linked together. In an experiment, a heterozygous female fly for grey body and normal eyes was crossed with a black body and purple eyed fly. In these flies, grey body is dominant over black while normal eyes are dominant over purple flies. If 1000 offsprings were obtained from this cross as below

Expected number	Phenotype	Genotype	Number obtained
250	Grey, normal eyes	GgNn	480
250	Grey, purple eyes	Ggnn	18
250	Black, normal eyes	ggNN	17
250	Black, purple eyes	Ggnn	485



Qn. Show how the above phenotypes were obtained and calculate the COV

MULTIPLE ALLELES.

- Each characteristic has is controlled by a gene which may ***appear in one of two forms or alleles.***
- However, there are several conditions where a single characteristic ***may appear in several different forms controlled by three or more alleles***, of which any two may occupy the same gene loci on homologous chromosomes at any one time.
- This is known as the ***multiple allele (multiple allelomorph)*** condition and it ***controls such characteristics*** as coat colour in mice, eye colour in mice and blood group in humans.
- Blood group is controlled by an autosomal gene. The gene locus is represented by the symbol **I** (which stands for *isohaemagglutinogen*) and there are three alleles represented by the symbols ***A, B*** and ***0***.

- *Allele A causes production of antigen A on red blood cells*. *Allele B causes production of antigen B on red blood cells.*
- *Allele O causes no production of antigens on red blood cells.* The alleles A and B are equally dominant and o is recessive to both.
- The presence of a single dominant allele results in the blood producing a substance called agglutinin which acts as an antibody.

Example.

A cross between certain individuals of blood group A and certain individuals of blood group B may produce offspring with any one of the four blood groups.

✓Let: I^A be the allele for blood group A.

✓Let I^B be the allele for blood group B.

✓Let: I^O be the allele for blood group O.

GENOTYPE	PHENOTYPE
I^AI^A (AA)	Blood group A (homozygous)
I^AI^O (AO)	Blood group A (heterozygous)
I^BI^B (BB)	Blood group B
I^BI^O (BO)	Blood group B
I^AI^B (AB)	Blood group AB (co-dominant)
I^OI^O (OO)	Blood group O

Parental phenotypes: Man with blood group A X Woman with blood group B

Parental genotypes: $I^A\ I^O$ X $I^B\ I^O$

Meiosis

Gametes: $\mathbf{I^A}$ $\mathbf{I^O}$ $\mathbf{I^B}$ $\mathbf{I^O}$

Random fertilization

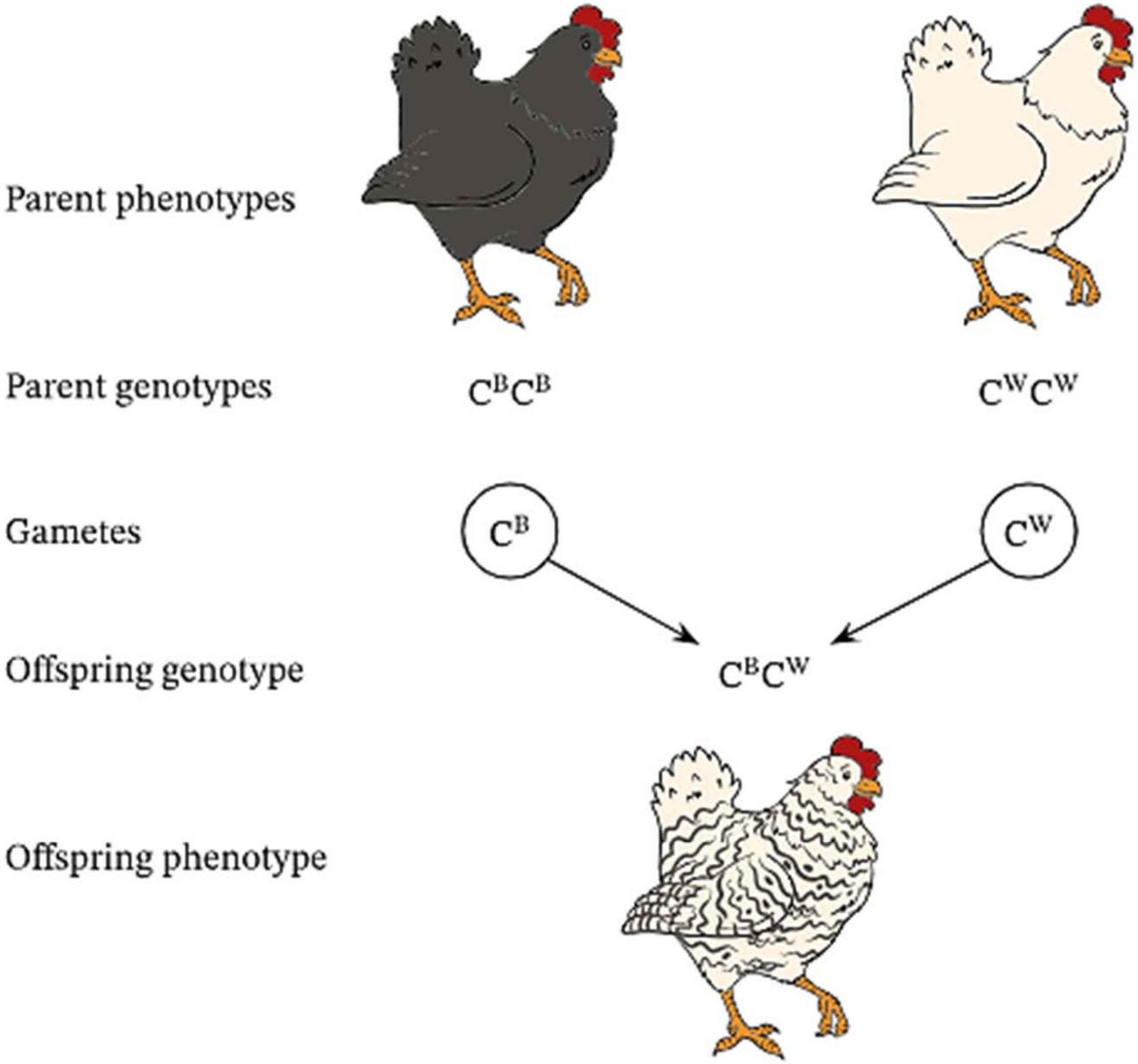
F_1 genotypes : $\boldsymbol{I^A\ I^B}$ $\boldsymbol{I^A\ I^O}$ $\boldsymbol{I^B\ I^O}$ $\boldsymbol{I^O\ I^O}$

F_1 phenotype : AB A B O

Blood groups

CO-DOMINANCE.

- There are not several conditions where two or more alleles do not show complete dominance or recessiveness due to the failure of any allele to be dominant in the heterozygous condition. This state of ***codominance*** is an exception to the situation described by Mendel in his monohybrid breeding experiments.
- Codominance is found in both plants and animals. In most cases the ***heterozygote has a phenotype which is intermediate*** between the homozygous dominant and recessive conditions.
- An example is the production of ***blue Andalusian fowls*** by crossing ***pure-breeding black*** and ***splashed white parental stocks***. The presence of ***black plumage*** is the result of the ***possession of an allele for the production of the black pigment melanin***, the ***splashed white stock lack this allele***.
- The heterozygotes show ***a partial development of melanin which produces a blue sheen in the plumage***. As there are no accepted genotypic symbols for alleles showing codominance, the importance of specifying symbols in genetic explanations is apparent.


Parent phenotypes
Parent genotypes
C^BC^B
C^WC^W
Gametes
C^B
C^W
Offspring genotype
C^BC^W
Offspring phenotype

CODOMINANCE

- A typical example is seen in people who have the sickle cell trait. The condition is caused by an allele which codes the production of haemoglobin S. Individuals who are heterozygous produce equal amounts of haemoglobin S and normal haemoglobin A. They have a relatively mild form of anaemia.
- Homozygotes produce only haemoglobin S and have a severe form of anaemia. It is therefore apparent that the allele for producing normal haemoglobin A does not completely suppress the allele which regulates production of haemoglobin S.
- Another example of incomplete dominance is seen in people who suffer from thalassaemia (Mediterranean anaemia). The condition is caused by an allele HbB which is only partly dominated by the allele HbA which controls production of normal haemoglobin A.
- It means that people who are heterozygous for the condition HbAHbB have a mild form of anaemia (thalassaemia minor). Homozygotes HbBHbB suffer from very severe anaemia (thalassaemia major) and usually die in childhood.

Example.

Remember that we cannot use upper- and lower-case letters for the alleles, as this would imply that one (the upper case) was dominant over to the other (the lower case).

We therefore use different letters R for red and W for white and use these as superscripts on a letter that represents the gene, in this case C for colour i.e. $\boldsymbol{C^R}$ and $\boldsymbol{C^W}$

Consider a cross between a red bull and a white cow, whose F1 (spotted) offsprings are selfed. Workout the genotypes and phenotypes in F1 and F2 generation stating in each case the ratios

Let $\boldsymbol{C^R}$ represents the allele for red colour production in cattle

Let $\boldsymbol{C^W}$ represent the allele for no colour production in cattle

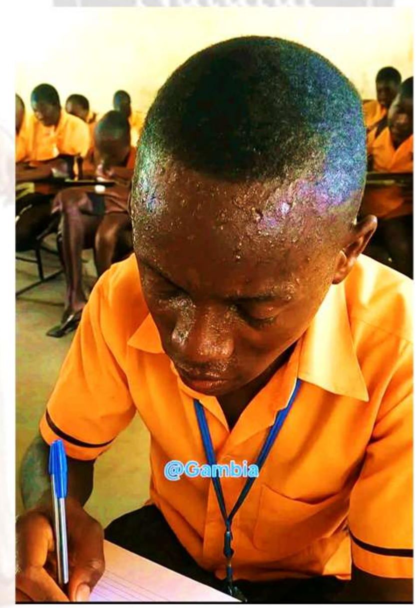
MAKE A CROSS TO IILUSTRATE.

ACTIVITY.

In cats, the genes controlling the coat colour are carried on the X chromosomes and are codominant.

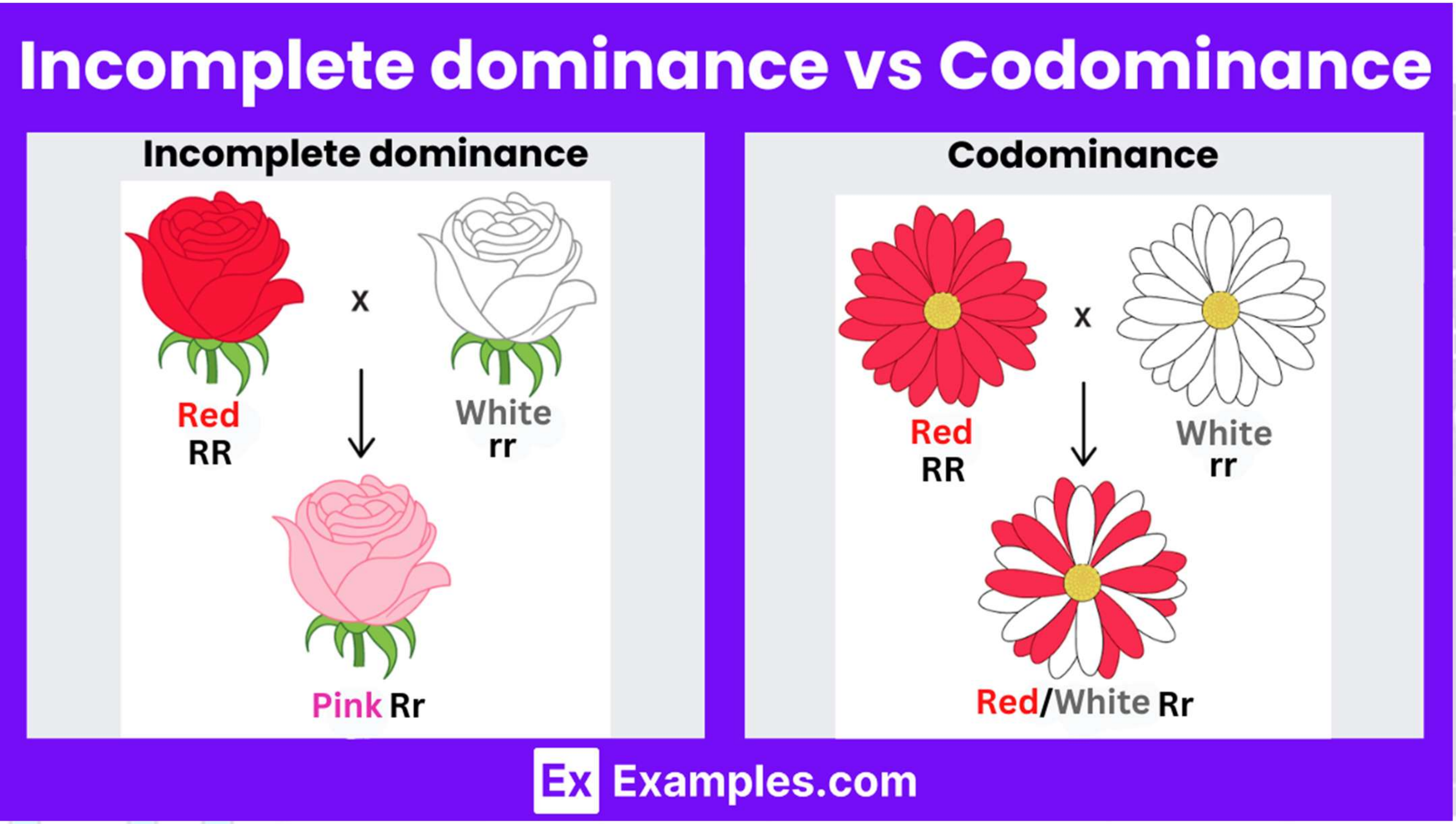
A black-coat female mated with a ginger-coat male produced a litter consisting of black male and tortoiseshell female kittens. What is the expected F, phenotypic ratio?

Explain the results.



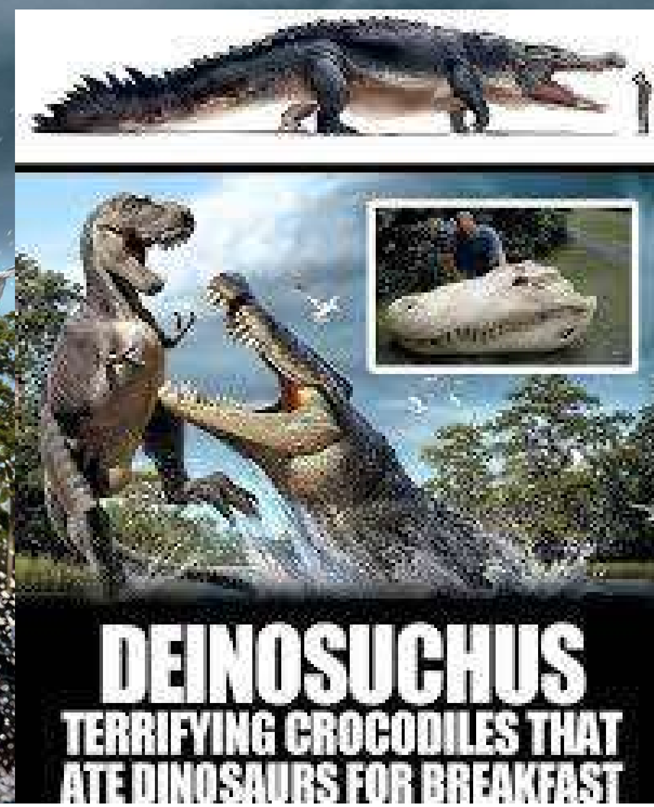
INCOMPLETE DOMINANCE.

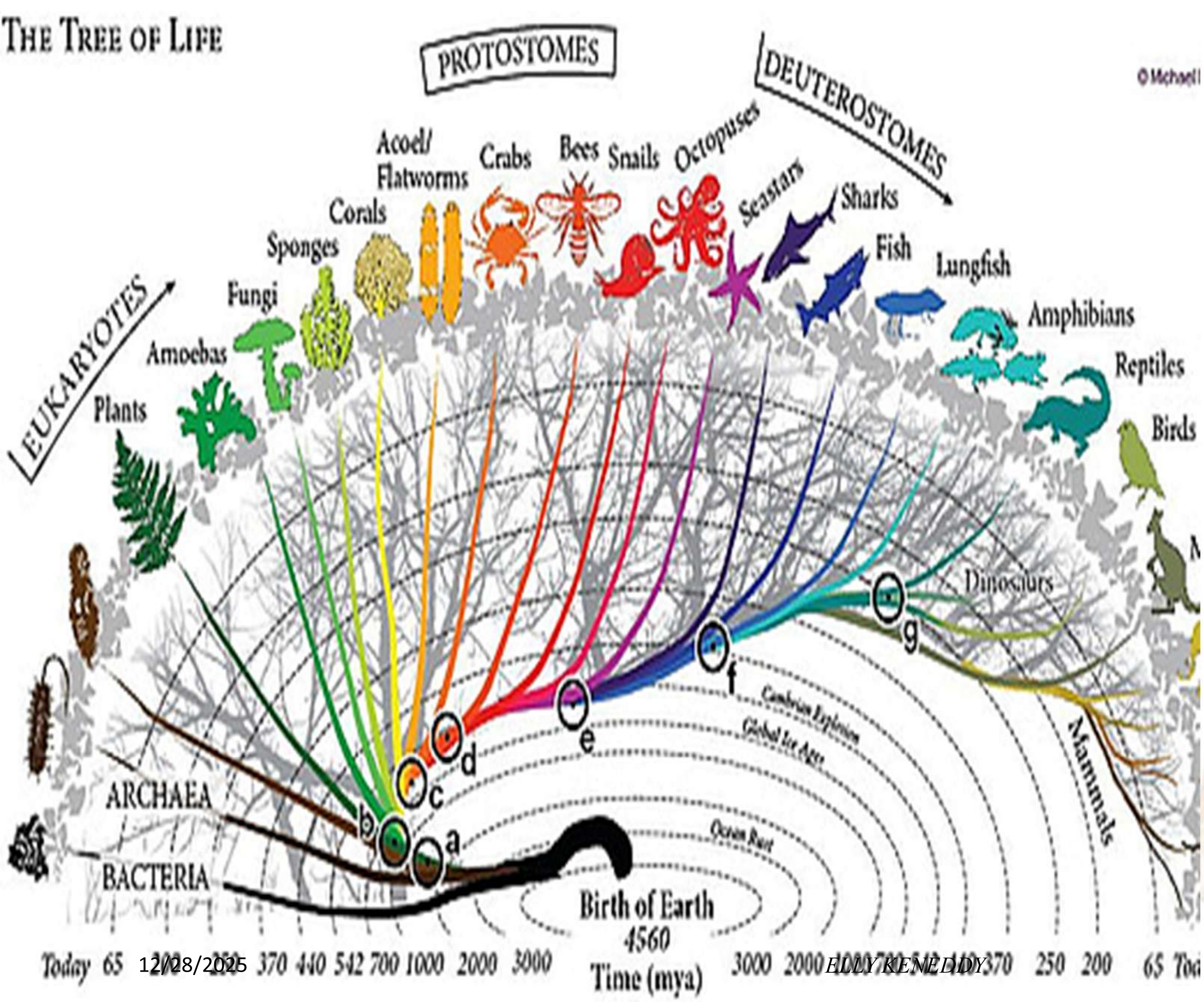
- Incomplete dominance is shown by some alleles such that the heterozygous condition ***produces a different phenotype*** from the homozygous state of either allele.
- For example, in Antirrhinum (snapdragon), two alleles for flower colour are codominant. Homozygous individuals may be either red or white, whereas ***heterozygous individuals are pink***. This is because in the heterozygous individual, ***neither alleles of the pair is expressed fully in the phenotype***.
- The heterozygous Antirrhinum is ***part-way between the phenotypes of the two types of homozygous individuals***, and this is often the case with incomplete dominance alleles.
- N.B. Where codominance and incomplete dominance is involved, it is normal to use different letters to represent each allele, e.g. R to represent red flowers and W to represent white flowers.

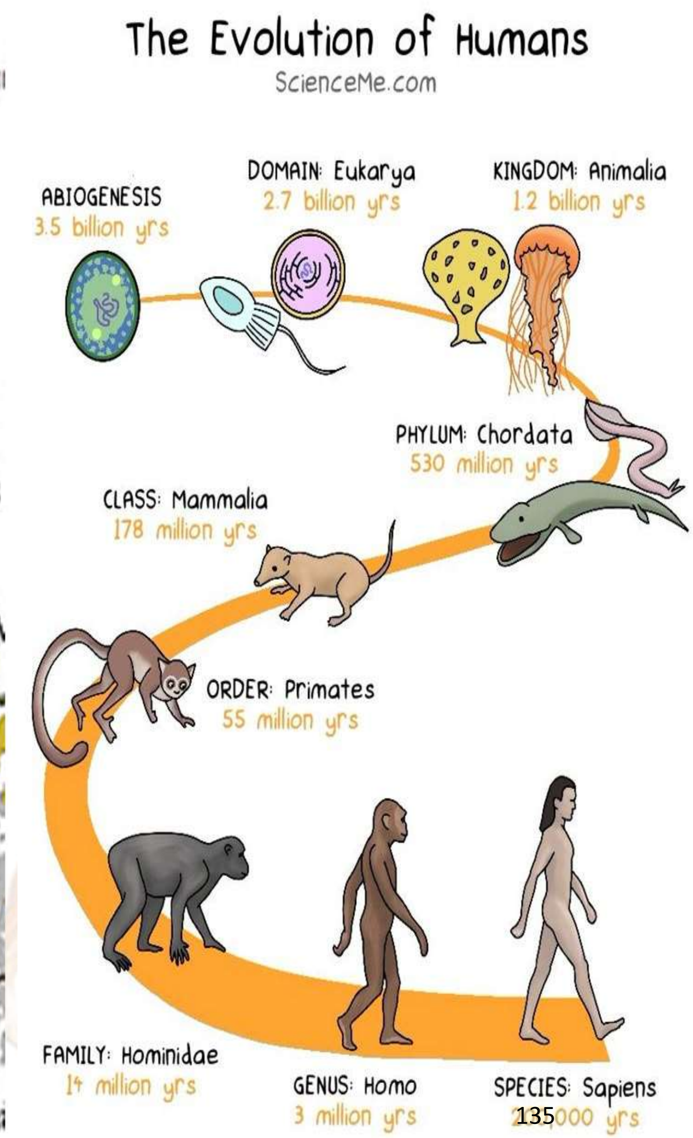

Incomplete dominance vs Codominance
Incomplete dominance
Red
RR
x
White
rr
Pink Rr
Codominance
Red
RR
x
White
rr
Red/White Rr
Examples.com

EVOLUTION.

@Elly kenny.




THE TREE OF LIFE
PROTOSTOMES
DEUTEROSTOMES
EUKARYOTES
Plants
Amoebas
Fungi
Sponges
Corals
Acoel/ Flatworms
Crabs
Bees
Snails
Octopuses
Seastars
Sharks
Fish
Lungfish
Amphibians
Reptiles
Birds
Dinosaurs
Mammals
ARCHAEA
BACTERIA
Cambrian Explosion
Global Ice Ages
Ocean Rust
Birth of Earth
4560
Time (mya)
Today 65 200 250 370 440 542 700 1000 2000 3000
3000 2000 1000 700 440 370 250 200 65


The Evolution of Humans
ScienceMe.com
ABIOGENESIS
3.5 billion yrs
DOMAIN: Eukarya
2.7 billion yrs
KINGDOM: Animalia
1.2 billion yrs
PHYLUM: Chordata
530 million yrs
CLASS: Mammalia
178 million yrs
ORDER: Primates
55 million yrs
FAMILY: Hominidae
14 million yrs
GENUS: Homo
3 million yrs
SPECIES: Sapiens

SPECIATION

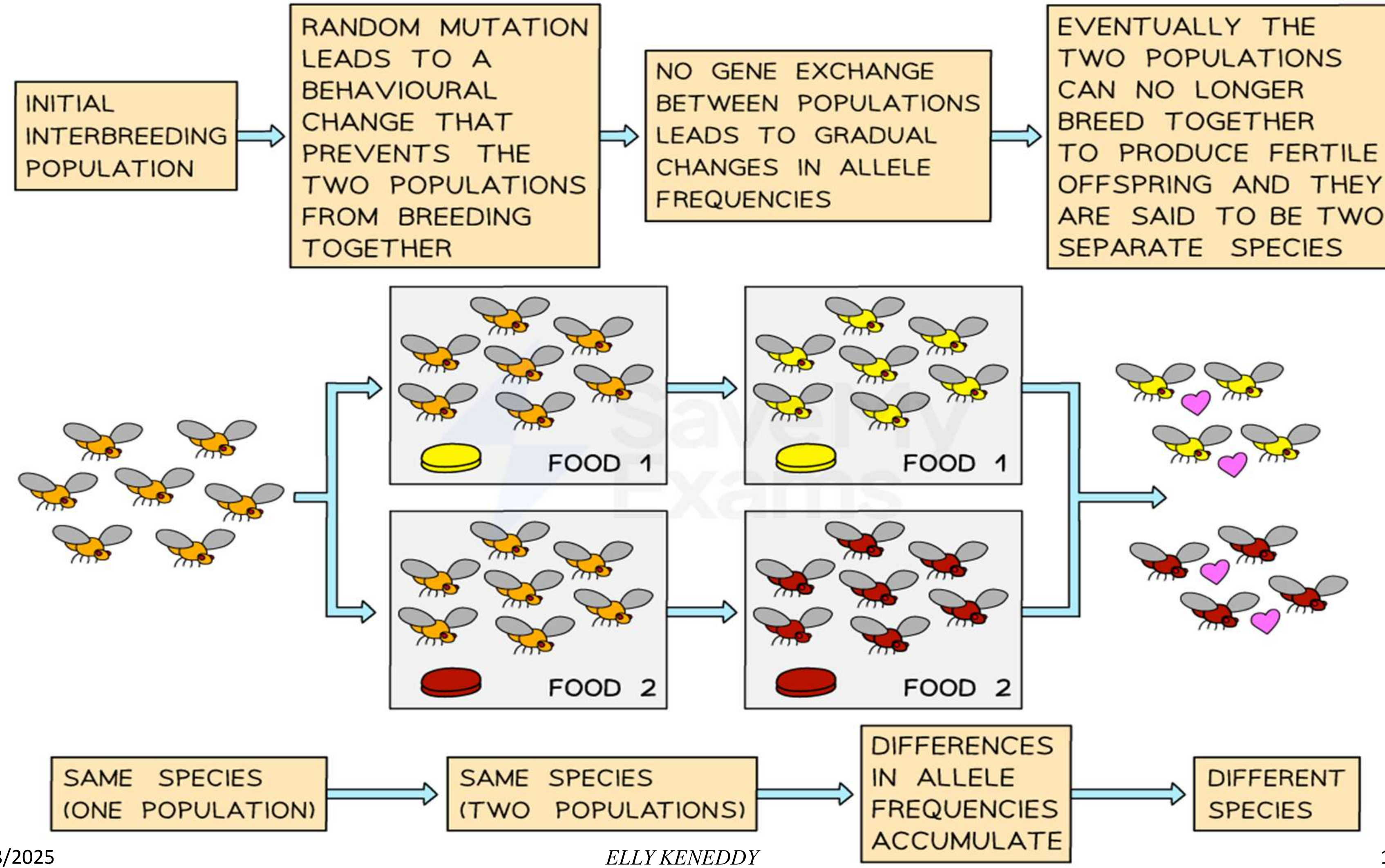
SPECIATION.

- This is the ***process by which new species may arise from pre-existing species***.
- ***A species*** can be defined as: *a group of organisms with similar features which can interbreed to produce fertile offspring*, and *which are reproductively isolated from other species.*
- There are 2 types of speciation i.e.
- ***Intraspecific speciation*** is when a ***single species gives rise to new species***. If this occurs when the ***whole population is occupying the same geographical area***, it's referred to as ***sympatric speciation***

whilst

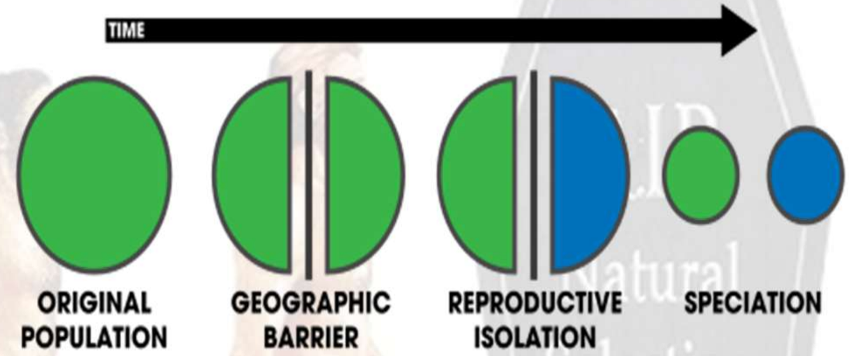
- ***Allopatric speciation*** occurs when the ***populations are occupying geographical isolated habitats***.
- In some cases, commonly in flowering plants, two species may give rise to a new species; this is known as ***interspecific hybridization***.

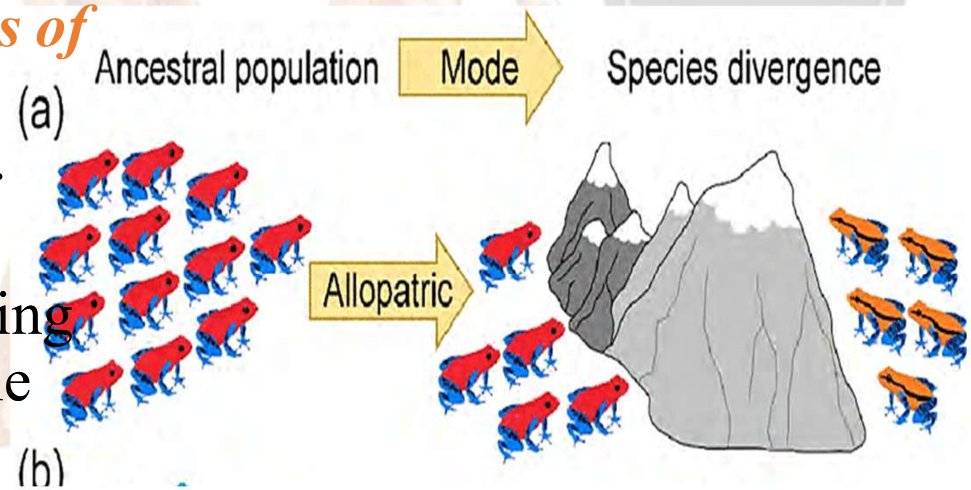
SUMMARY OF HOW SPECIATION OOCCURS.

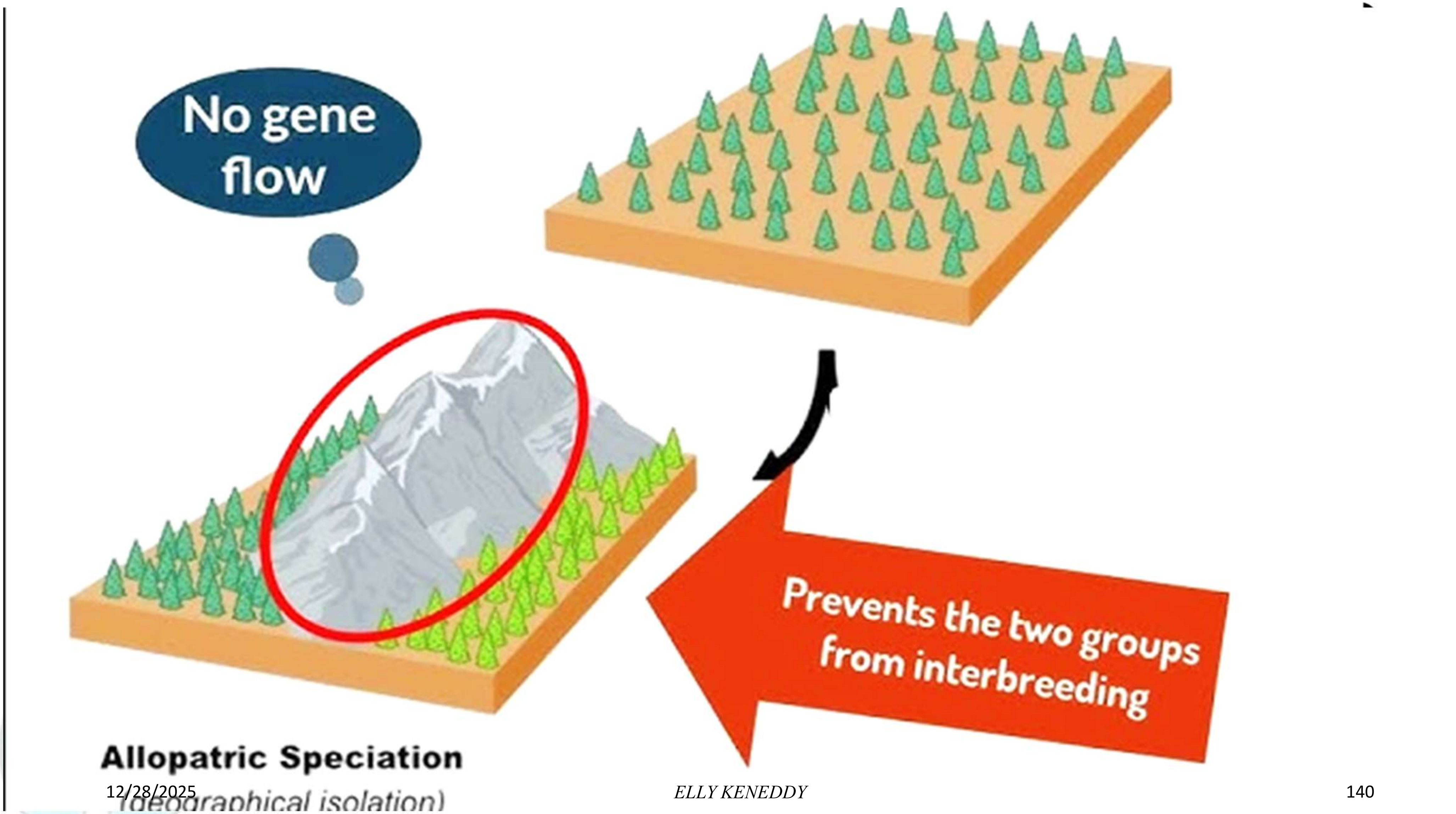


ALLOPATRIC SPECIATION

- (*Allopatric means literally 'different countries*) This is the type of intraspecific speciation which occurs ***as a result of spatial separation of a population into two subpopulations***, usually due to ***geographical barriers*** like **mountains**, **seas**, **rivers** or differences in habitat preferences.
- Any physical barrier ***that prevents members of different populations from meeting*** must inevitably prevent them from interbreeding.
- This ***prevents interbreeding among the individuals of the two subpopulations*** leading to ***reproductive isolation*** and interrupts gene flow.

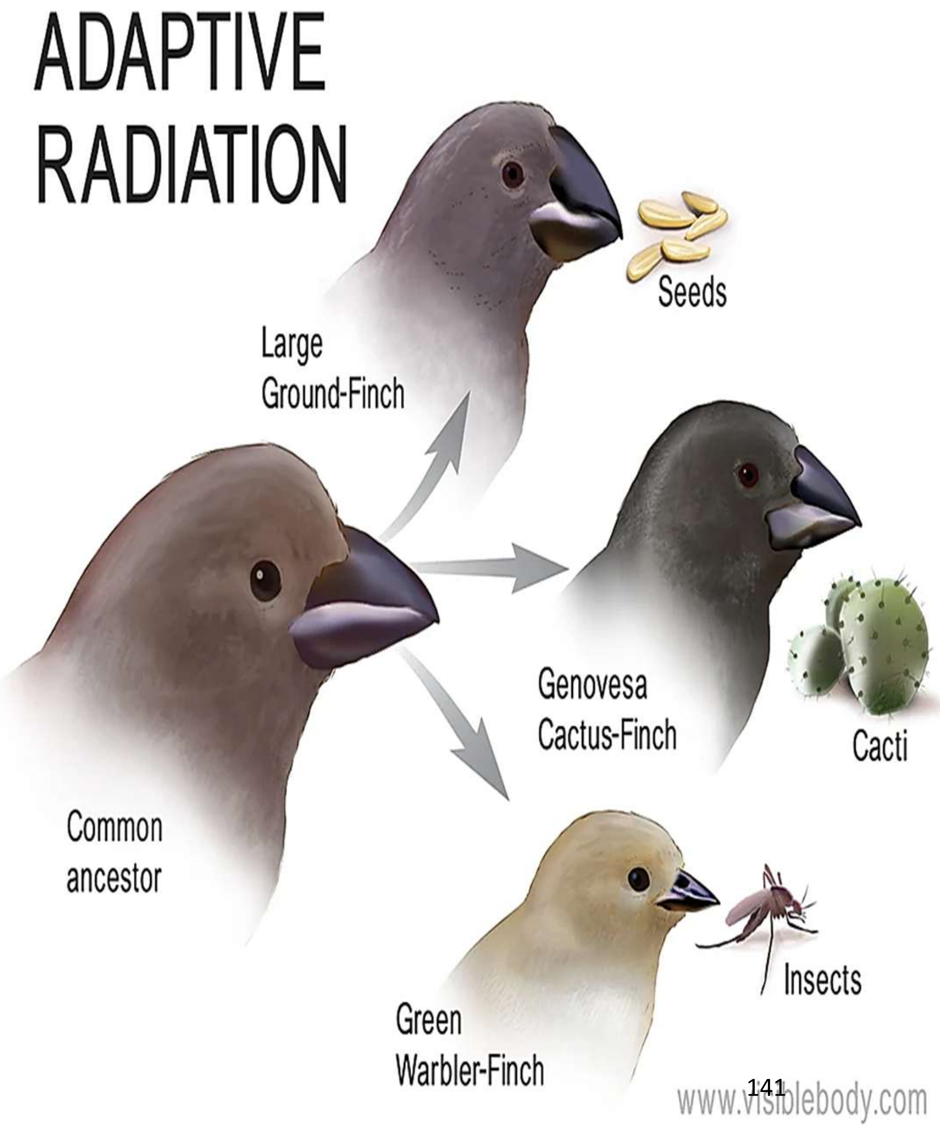




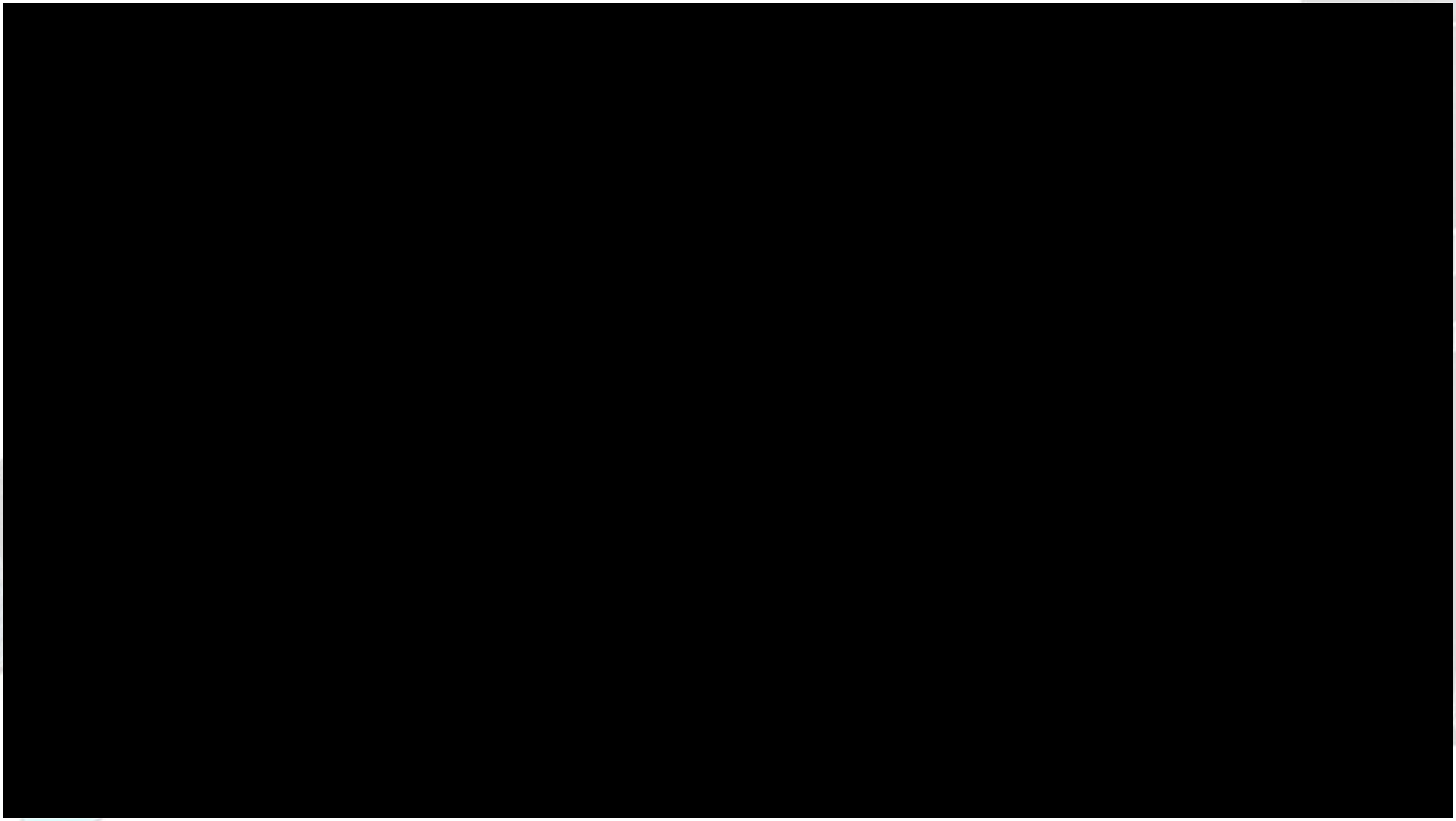

No gene flow
Prevents the two groups from interbreeding
Allopatric Speciation
(geographical isolation)

- Due ***to continuous mutations*** and **random genetic drift** result into changes in the allele and genotype frequencies of the two populations, ***making their gene pools to diverge*** more from that of the original population.

- Prolonged separation results into the populations becoming ***genetically isolated such that the individuals can no longer interbreed*** successfully, the two are now different species and speciation is said to have occurred

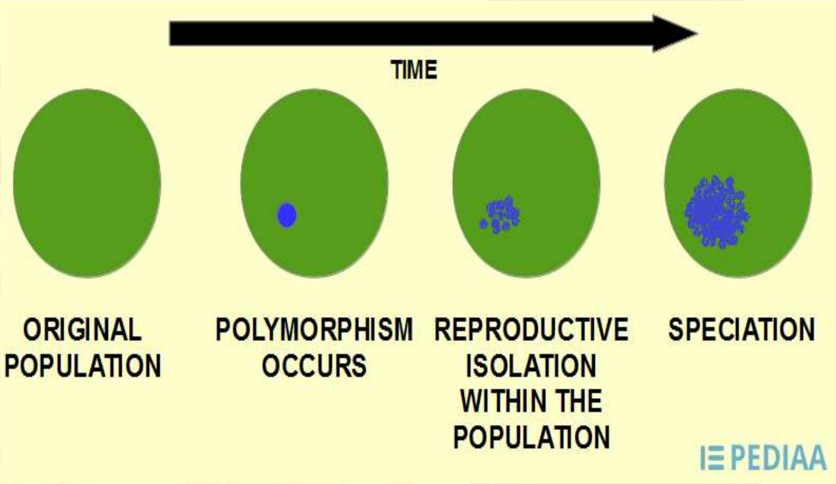


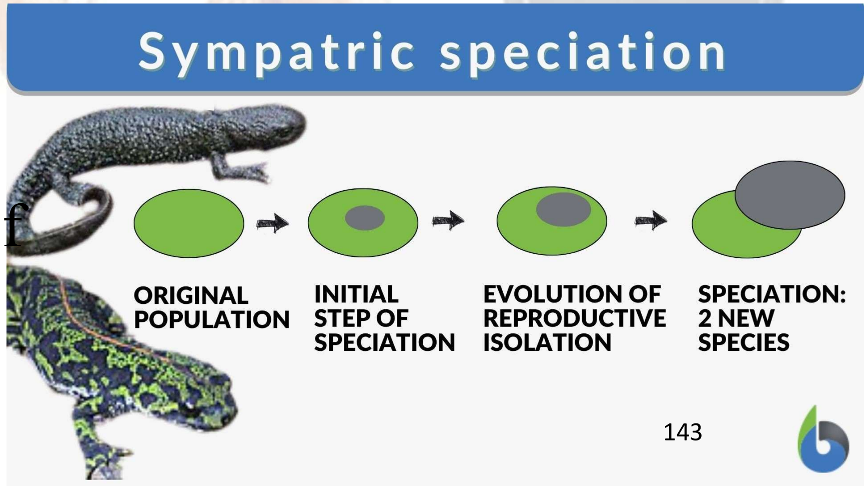
TYPES OF SPECIATION & ISOLATION MECHANISMS

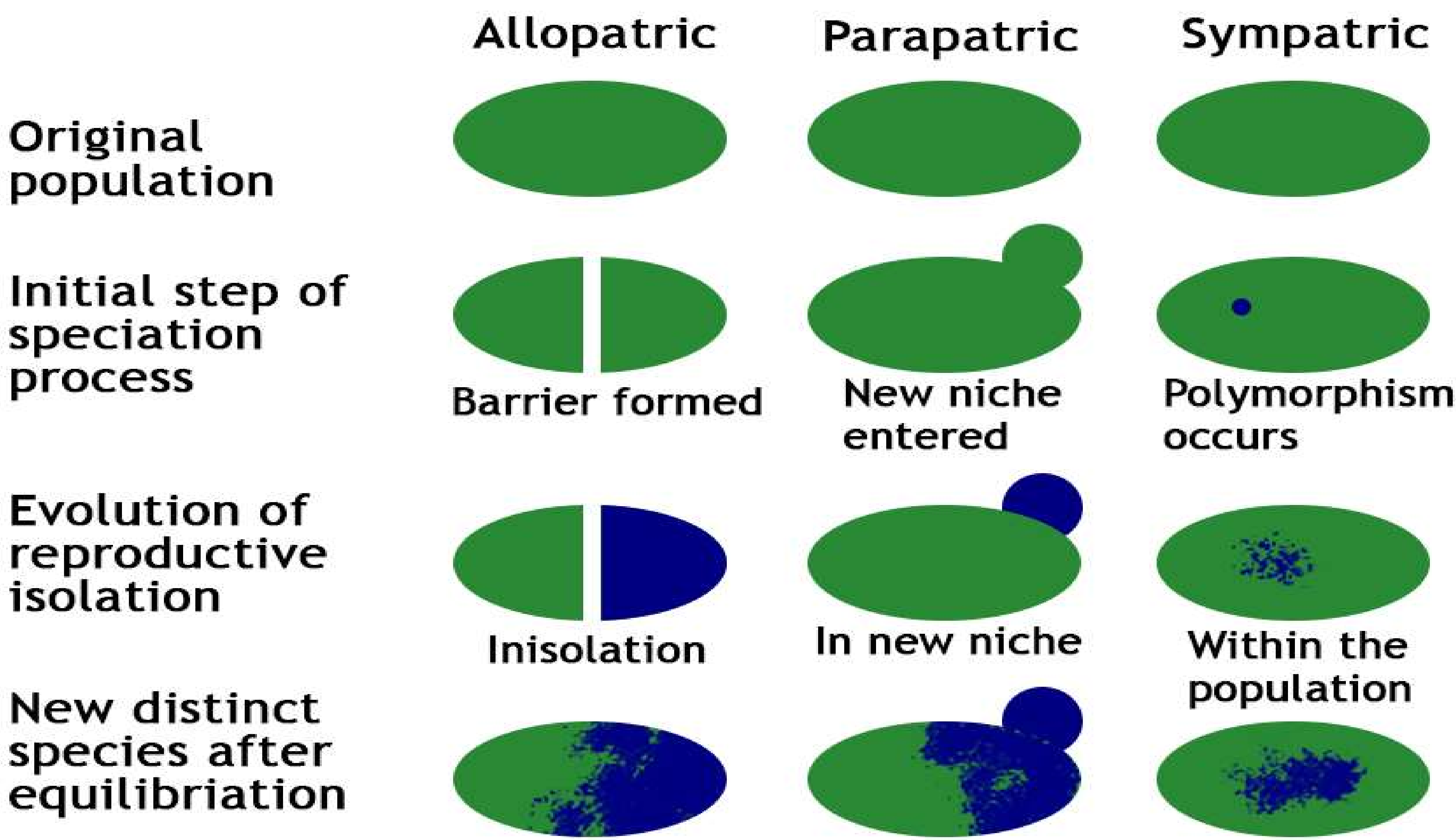


SYMPATRIC SPECIATION

- This occurs when organisms ***inhabiting the same area become reproductively isolated*** into two groups for reasons ***other than geographical barriers***.
- This ***interrupts gene flow leading to genetic isolation of the two groups coexisting in the same area***.
- The overall result is independent change in the allele and genotype frequencies of the two subpopulations ***leading to formation of subspecies.***
- If genetic isolation persists over a long period of time; these may gradually evolve into different species.





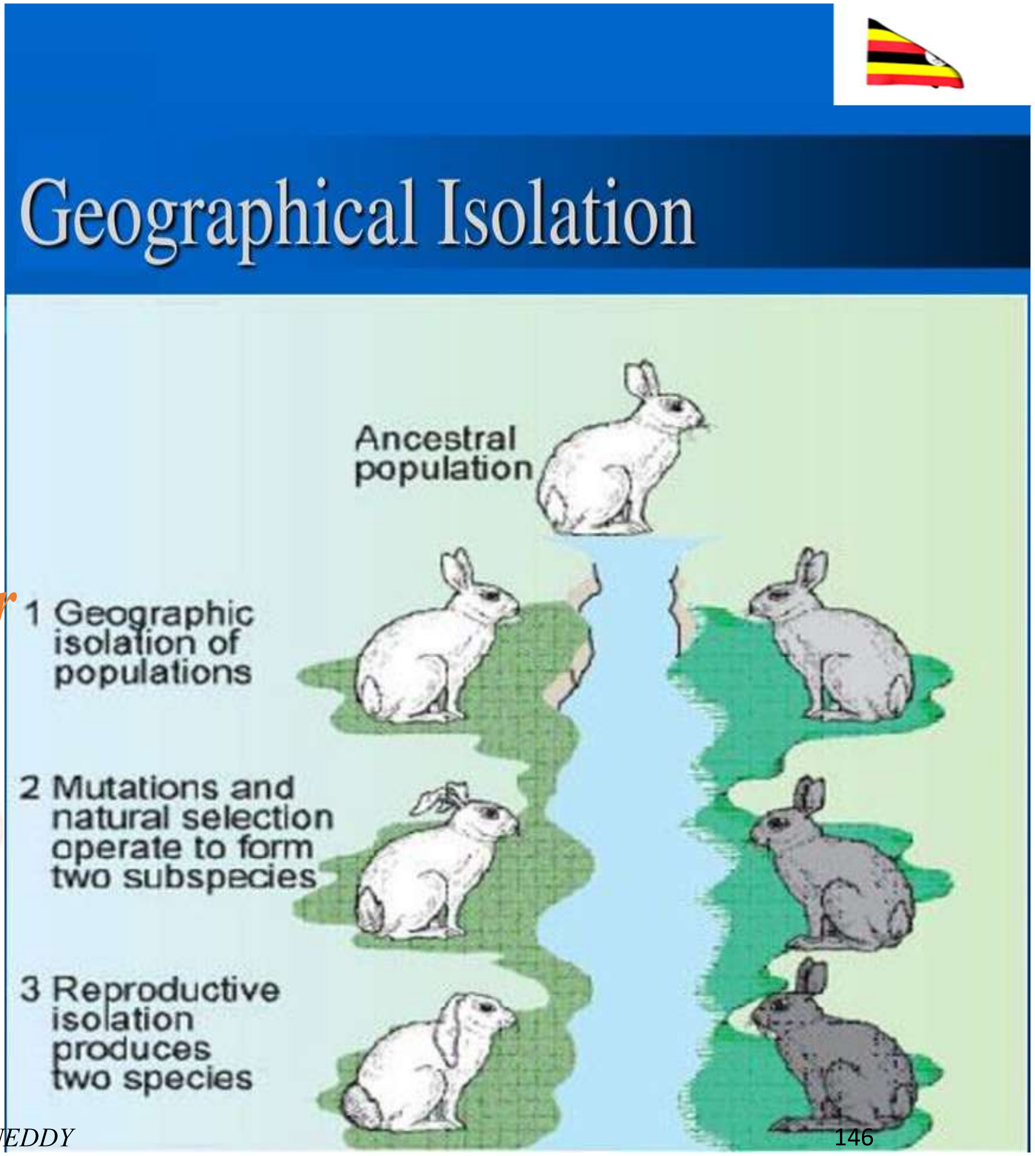

Allopatric
Parapatric
Sympatric
Original population
Initial step of speciation process
Barrier formed
New niche entered
Polymorphism occurs
Evolution of reproductive isolation
Inisolation
In new niche
Within the population
New distinct species after equilibriation

ISOLATING MECHANISMS

- An isolating mechanism is a means of ***preventing organisms of a given species from interbreeding within a population*** which can ***eventually lead to speciation***. These are often called reproductive isolation mechanisms
- ***Reproductive isolation*** refers to the existence of biological barriers that restrict members of the same or different species from interbreeding successfully
- Within a population of one species, there are ***groups of individuals which breed with one another***. These breeding sub units is called a **deme**.
- It is still possible for them to breed with other individuals from other demes. Therefore it remains a single gene pool but ***if demes become separated in any way***, ***the flow of genes between them may cease***.
- Each deme may then develop a long a separate line. The two demes may become so different that even if reunited, they will be incapable of successful breeding thus become separate species each with its gene pools.

Geographical isolation

- Due to ***physical barriers which prevent two groups of the same species from mating or*** **interbreeding**.
- Such barriers include **mountains**, **deserts**, **rivers**, **oceans**, etc.
- The ***environmental conditions on either side of the barrier frequently differ***.
- This leads to ***a group on either side adapting to suit its own environments***.
- The process is known as **adaptive radiation**.



Ecological isolation

- Occur when two species inhabit similar regions but ***have different habitat preferences within that same area***.
- Such species can meet only very rarely if at all.

Behavioral mechanism

- This occurs where animals exhibit courtship patterns.
- Mating only results if the ***courtship behavior displayed by one sex is accepted or interpreted by another***. E.g. Colour and marking on members of the opposite sex. The song of a bird or the call of a frog must be exact if it is to elicit the appropriate breeding response from the opposite sex.

Seasonal isolation

- ✓The timing of courtship behaviour and gamete production is also important.
- ✓If the breeding season of two groups (demes) does not coincide, they cannot breed.
- ✓Different flowering times in plants may mean that cross-pollination is impossible.

Physiological/reproductive isolation forms

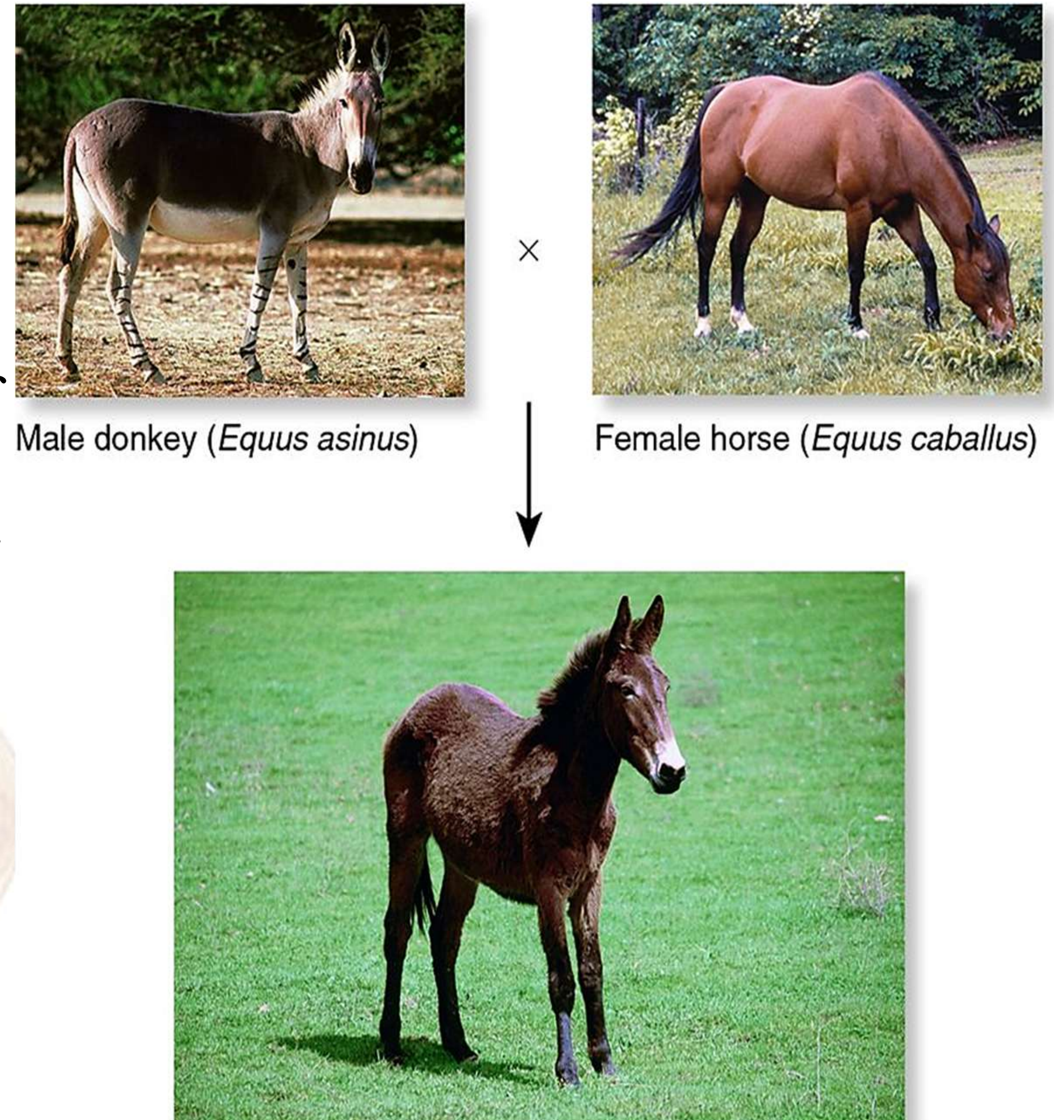
- ✓The genetalia of the groups may be ***incompatible*** (***mechanical isolation***). i.e. impossible for the penis of the male to enter a female's vagina.
- ✓The gametes may be prevented from meeting e.g. in animals, the ***sperms may not survive in the female reproductive parts*** or in plants, ***the pollen tube may fail to grow.***
- ✓Fusion of gametes may not take place despite the sperm reaching the ovum thus in this case, the ***gametes are incompatible*** so do not fuse. (***gametic isolation***)
- ✓Development of the embryo may not occur despite fertilization taking place or fetal abnormalities may arise during early growth causing death. (***hybrid isolation***)
- ✓The hybrid may be sterile (hybrid sterility). E.g. a mule. (hybrid isolation)

- Isolating mechanisms are classified as **prezygotic mechanisms** (***barriers that prevent formation of the zygote***) or **post zygotic mechanisms** (***barriers that prevent hybrids from reproducing***) or (development of embryo may not occur after fertilization)

✓ ***Hybrid inviability***; this is when the produced hybrids are unable to survive to reproductive maturity. The genes may interact in ways that impair the hybrid's development.

✓ ***Hybrid breakdown***: The F1 hybrids are fertile but the F2 hybrids and their back crosses are infertile

- ✓***Hybrid sterility*****(Polyploidy)** : This is when hybrids are viable but fail to produce functional gametes and are therefore infertile.
- ✓This is because the chromosomes of the two parent species differ in number or structure, that they cannot allow for complete pairing of chromosomes during meiosis e.g. the mule (2n =63) results from a horse 2n=60 and donkey (2n=66)



Mule

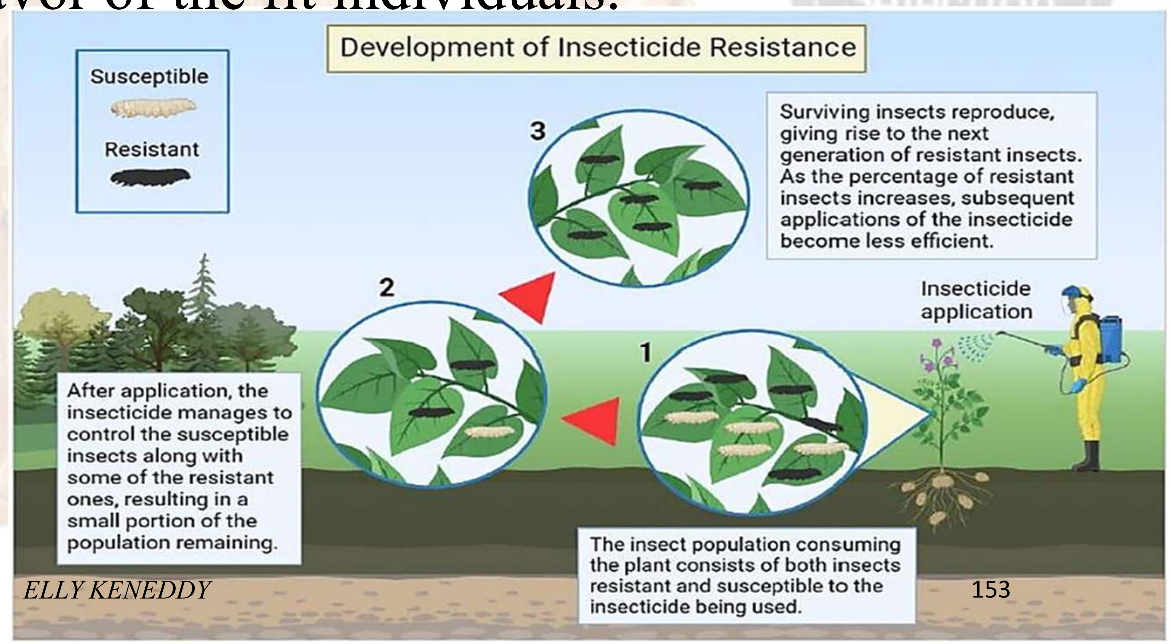
NATURAL SELECTION AND RESISTANCE

- This is the process by which ***organisms that are better adapted to their environment survive to breed*** while those ***less adapted fail to do so and die in the process***.
- The better ***adapted ones are likely to pass their characteristics to the succeeding generations***.
- Therefore, selection determines the spread of any allele within a gene pool.

<u>How natural selection occurs</u>

- During periods of population increase, ***some resources become limited*** and ***competition sets*** in for such resources.
- This ***creates a struggle for existence in which individuals that are physically, physiologically or behaviorally better adapted*** to the environment (have a selective advantage) and are selected for by the environment.
- These ***reproduce and pass their traits to the next generations***, and their numbers increase over time.

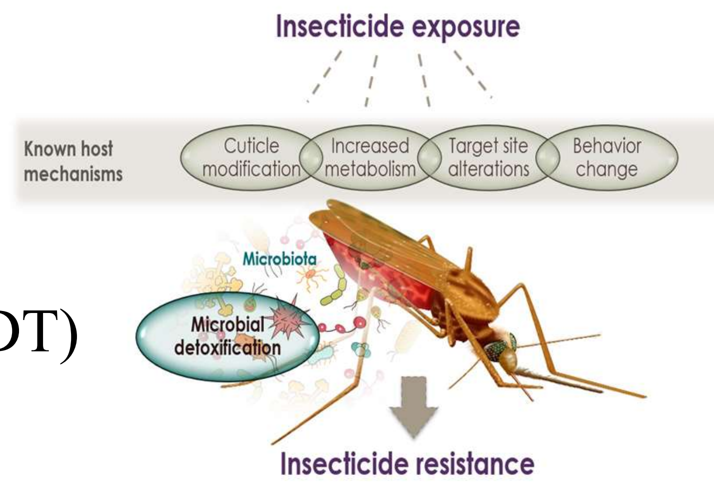
- Those that are ***less adapted are said to have a selective disadvantage*** and are selected against, ***fail to reproduce or survive and their numbers decline significantly.***
- Gradual accumulation of the favorable traits in one direction over a long period of time may result into the two groups evolving into different species.
- Selection acts by weeding out those individuals, whose characteristics confer a selective disadvantage (unfit) in favor of the fit individuals.



NATURAL SELECTION IN ACTION

This refers to the ***day-to-day observations of natural selection*** or examples of natural selection. Examples include the following.

- Insect resistance to insecticides, like flies and mosquitoes to Dichlorodiphenyltrichloroethane (DDT)
- Pesticide resistance in pests
- Heavy metal tolerance in grass and other plants
- Antibiotic resistance by pathogens e.g. bacteria to penicillin and methycilin
- Resistance to antimalarial drugs by plasmodium parasites.



HEAVY METAL TOLERANCE.

- Another example of natural selection ***occurs on spoil heaps***, which ***contain the waste material from mining activities***. Spoil heaps ***contain high concentrations of certain heavy metals***, e.g. *tin*, *lead*, *copper* and *nickel*. In such high concentrations, ***these metals are toxic to most plants***. Some varieties of grasses, e.g. *Festuca ovina* and *Agrostis tenuis*, have become genetically adapted to survive high levels of these metals.
- These plants are ***less competitive where the concentration of these metals is low*** and so ***do not always survive***. The tolerant plants may be ***able to trap heavy metals on organic molecules in the cellulose cell wall***, ***confine the metals to the vacuoles***, or ***excrete the metals back into the environment***. In all cases, ***tolerance to heavy metals is inherited*** and appears to have evolved by ***directional selection***.
- Heavy-metal tolerant plants are less competitive (have a selective disadvantage) in unpolluted areas and rarely survive there.
- However, tolerant individuals ***flourish in polluted areas as the heavy metals kill their rivals***, and they pass on their tolerance to their offspring.

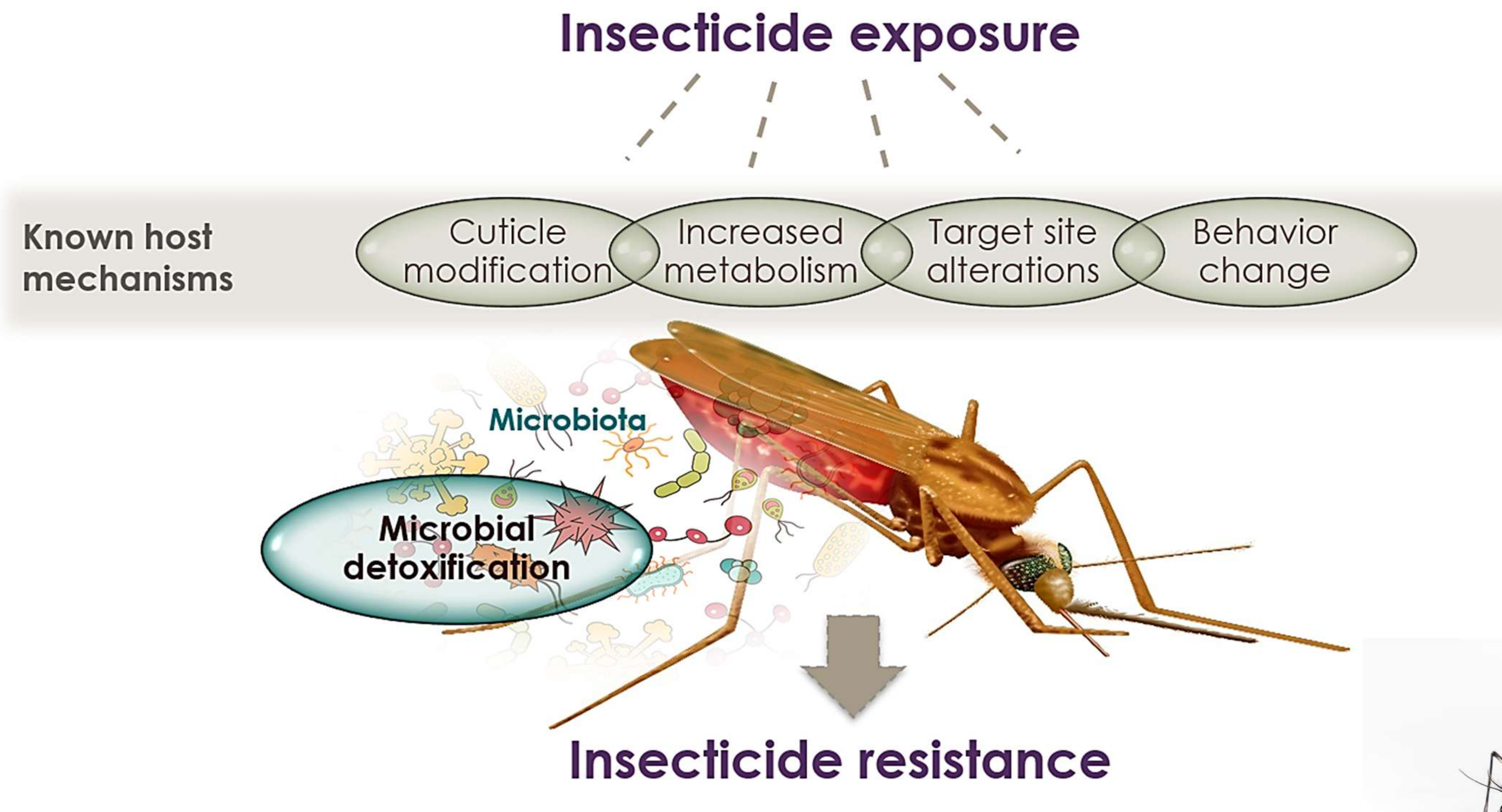
ANTI-BIOTIC RESISTANCE.

- Following the production of antibiotics in the 1940s, it was ***noticed that certain bacterial cells developed resistance to these drugs***, i.e. the ***antibiotics failed to kill them in the normal way***. This has made the usefulness of many antibiotics destroyed by bacterial resistance to them.
- By 1950, majority of ***staphylococci*** were already resistant to antibiotics such as ***penicillin*** and ***methycillin*** (strains resistant to methycillin are described as MRSA: methycillin-resistant *Staphylococcus aureus usually harmless when inhabiting the skin, but potentially lethal if it enters the bloodstream*). The problem has been made more acute by the ***recent discovery that resistance can be transmitted between species***. This means that ***disease-causing bacteria can become resistant to a given antibiotic even before the antibiotic is used against them***.

- Experiments showed that this was not a cumulative tolerance to the drug. Anti-biotic resistance in bacteria and pathogens ***arises as a result of random mutations*** by chance some of them will be resistant to a particular antibiotic .
- When bacteria are ***exposed to chemicals present in drugs, they undergo mutations*** giving rise to ***some genes that code for synthesis of enzymes which are break down drugs*** into less harmful substance. (*As bacteria have only one strand of DNA and one copy of each gene, the mutant allele is expressed immediately and is not masked by a dominant allele.*)
- In the body, ***antibiotics act as a selection pressure***, therefore the ***bacteria which are resistant to drug effects have a selective advantage***, they therefore ***multiply rapidly by mitosis/binary fission passing on their resistant genes*** hence increase in number forming the resistant strains while those which are ***non resistant are killed by the antibiotics*** hence fail to reproduce and become extinct.

PESTICIDE RESISTANCE.

- Resistance to insecticides has come about in a similar way. Within two years of using DDT, many ***insects had developed resistance to it***, often independently in different parts of the world. Most common insect pests are now resistant to most insecticides. This is due to ***random mutations*** caused by ***chemicals in the pesticide***
- In many cases the ***presence of the insecticide switches on the gene present in the mutant varieties***. This ***gene initiates the synthesis of enzymes*** which ***break down the insecticide into non toxic chemicals*** ***preventing it from penetrating into specific tissues***. In environments where DDT is continuously applied, it ***acts as a selection pressure.*** The ***non-resistant pests are killed by the pesticide*** hence *fail to survive* while the ***resistant pests are not killed*** hence, they are ***selected for***, ***breed and pass their resistant traits to next generations*** increasing in number.
- Apart from directly harmful insects, ***insect vectors have also acquired resistance***. Examples include mosquitoes of the genus Aedes, which carry yellow fever, and of the genus Anopheles which carry malaria.


Insecticide exposure
Known host mechanisms
Cuticle modification
Increased metabolism
Target site alterations
Behavior change
Microbiota
Microbial detoxification
Insecticide resistance

Elly Kenny.

EXTINCTION

INTRODUCTION.

- ***Extinction*** refers to ***the permanent disappearance of a species from earth*** occurring ***when the last member of the species dies*** hence ***can no longer reproduce.*** There are ***2 major types of extinction*** which are caused by different factors.
- ***Background Extinction***: This is the ***constant, low-level rate of species loss occurring over millions of years***. On average, a species survives for about *1 to 5 million years before going extinct*.
- ***Mass Extinction***: These are ***rare events*** where at ***least 75% of all species vanish in a geologically short period*** (*usually less than 2 million years*). However isolated extinctions of species and clades are quite common and are natural part of evolutionary process. There have been at least 5 mass extinctions in the history of life on earth which are explained below.

ORDOVICIAN-SILURIAN EXTINCTION (450-440 MILLION YEARS AGO)

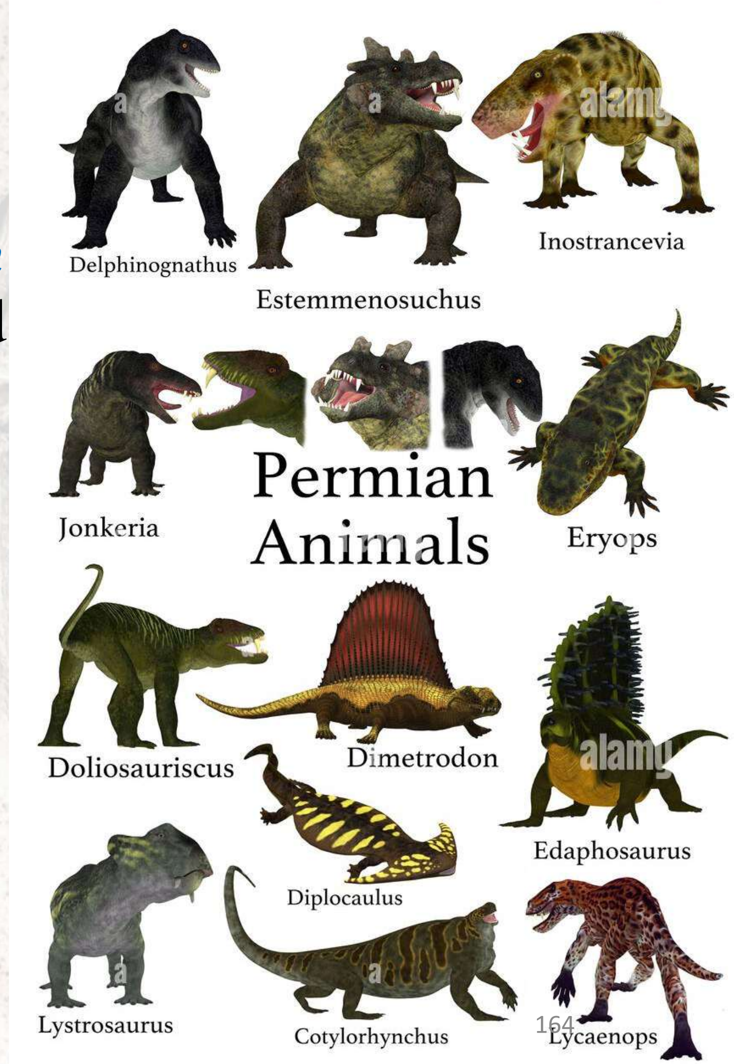
- It is the *first of the five major extinction* events. It occurred ***445 million years*** ago and considered to be the *second largest extinction event*. It led to ***disappearance*** of ***brachiopod*** and ***bryozoan** families*. Despite , it never produced major changes in the ecosystem structure and morphological innovations. It is majorly attributed to ***glaciation which shifted the earth*** from ***green house*** to ***ice house***, ***sea-level drop***, and ***cooling led to habitat loss*** leading to a significant loss of marine life. About 85% of species went extinct, including many ***trilobites*** and ***brachiopods***.

Late Devonian Extinction (375 Million Years ago)

- This occurred around ***372 million years ago*** at the boundary between ***Frasnian*** and ***Famennian*** ages with around ***40% marine species going extinct***. A series of extinctions likely caused by ***climate change***, ***changes in sea level,*** ***ocean anoxia*** *(low oxygen),* and ***possibly asteroid impacts***. About 75% of species went extinct, including many ***fish*** and ***coral species***. The extinction was ***accompanied by wide spread of oceanic anoxia allowing fossilization.*** By the end of late Devonian extinction, the land had been colonized by plants and insect. Major hit to marine ecosystems including many ***trilobites*** and ***brachiopods*** and *affecting reef-builders.*

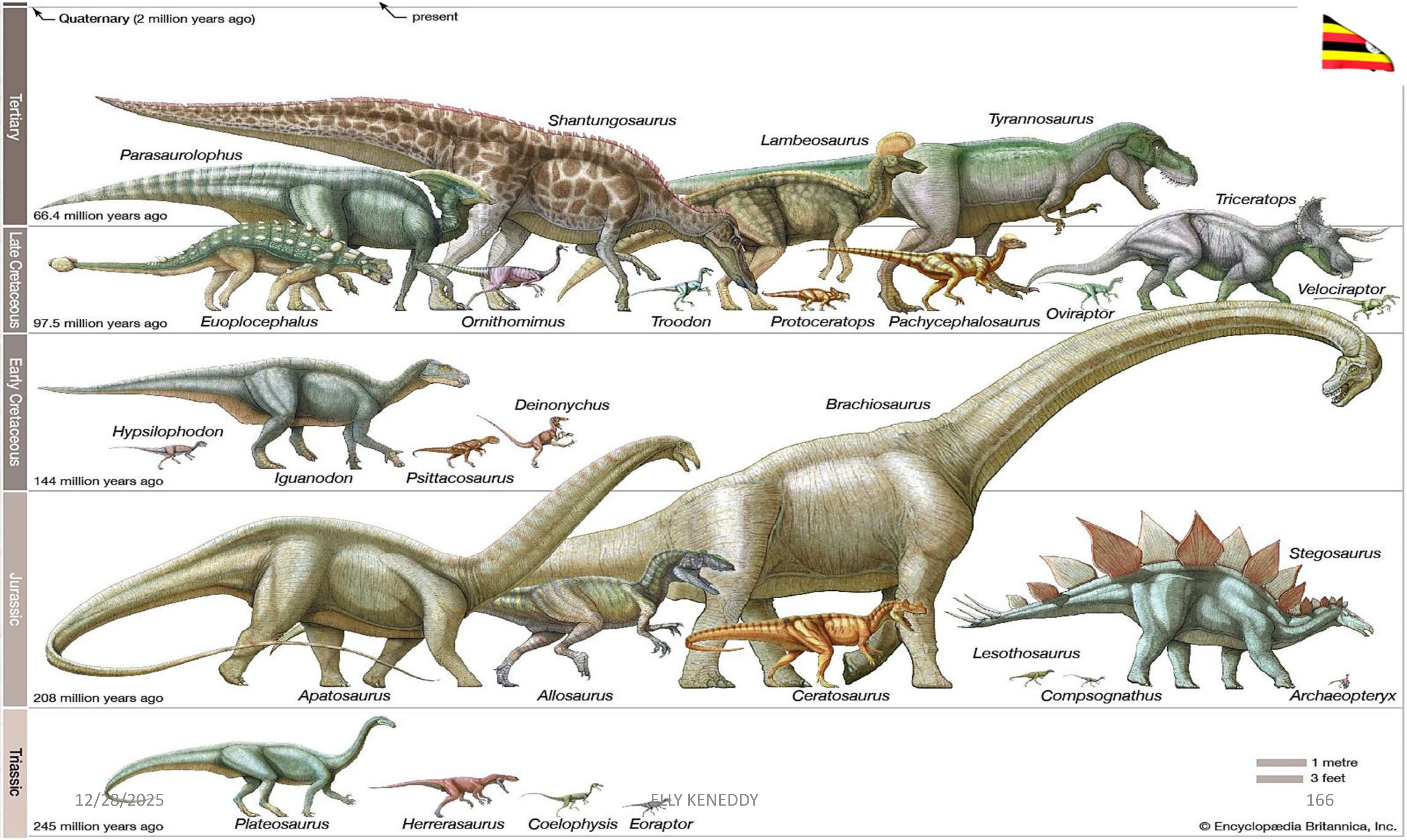
PERMIAN-TRIASSIC EXTINCTION (252 MILLION YEARS AGO)

- This is also known as the ***great dying***. It is the earths most severe extinction event. It ***occurred about 252 million years ago*** at the boundary between, ***Permian*** and ***Triassic*** *geologic periods* with the *Paleozoic* and *Mesozoic errors.*
- ***Massive volcanic eruptions*** (*Siberian Traps*) which ***released Sulphur dioxide*** and ***carbon dioxide led to extreme climate change***, ***ocean acidification, and anoxia***. Up to 96% of marine species and 70% of vertebrae terrestrial species went extinct.
- It is also the greatest known mass extinction of insects. Most devastating extinction, reshaping life on Earth.



Triassic-Jurassic Extinction (200 million years ago)

- This marks the boundary between ***Triassic*** and ***Jurassic*** periods which ***occurred 201 million years ago***. It was caused by ***massive volcanic activity*** (*Central Atlantic Magmatic Province*) which ***released large amounts of carbon dioxide*** causing *global warming*, *ocean acidification*, *climate change*, and ***discharged immense quantities of toxic mercury*** into the environment. Older hypotheses have proposed ***asteroid strikes***. About 23-34% of marine genera went extinct, including ***corals***, ***bivalves***, ***branchiopods*** & ***radiolarians***. On land many large ***amphibians and reptiles went extinct*** excluding dinosaurs, pterosaurs and crocodylomorphs. This Paved the way for dinosaurs to dominate. Mammals survived



Quaternary (2 million years ago)
present
Tertiary
Late Cretaceous
Early Cretaceous
Jurassic
Triassic
Shantungosaurus
Tyrannosaurus
Lambeosaurus
Parasaurolophus
Triceratops
66.4 million years ago
Euoplocephalus
Ornithomimus
Troodon
Protoceratops
Pachycephalosaurus
Oviraptor
Velociraptor
97.5 million years ago
Deinonychus
Brachiosaurus
Hypsilophodon
Iguanodon
Psittacosaurus
144 million years ago
Stegosaurus
Lesothosaurus
208 million years ago
Apatosaurus
Allosaurus
Ceratosaurus
Compsognathus
Archaeopteryx
1 metre
3 feet
245 million years ago
Plateosaurus
Herrerasaurus
Coelophysis
Eoraptor
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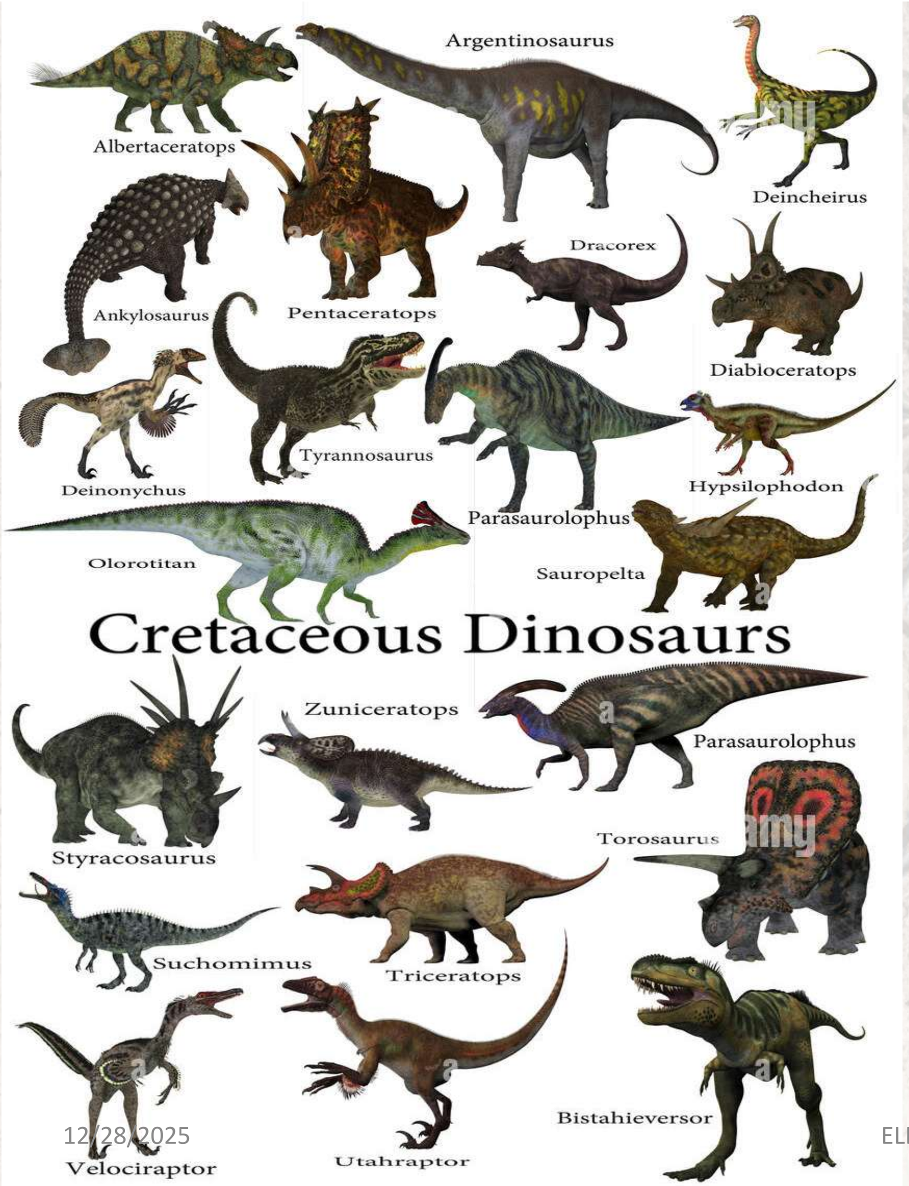
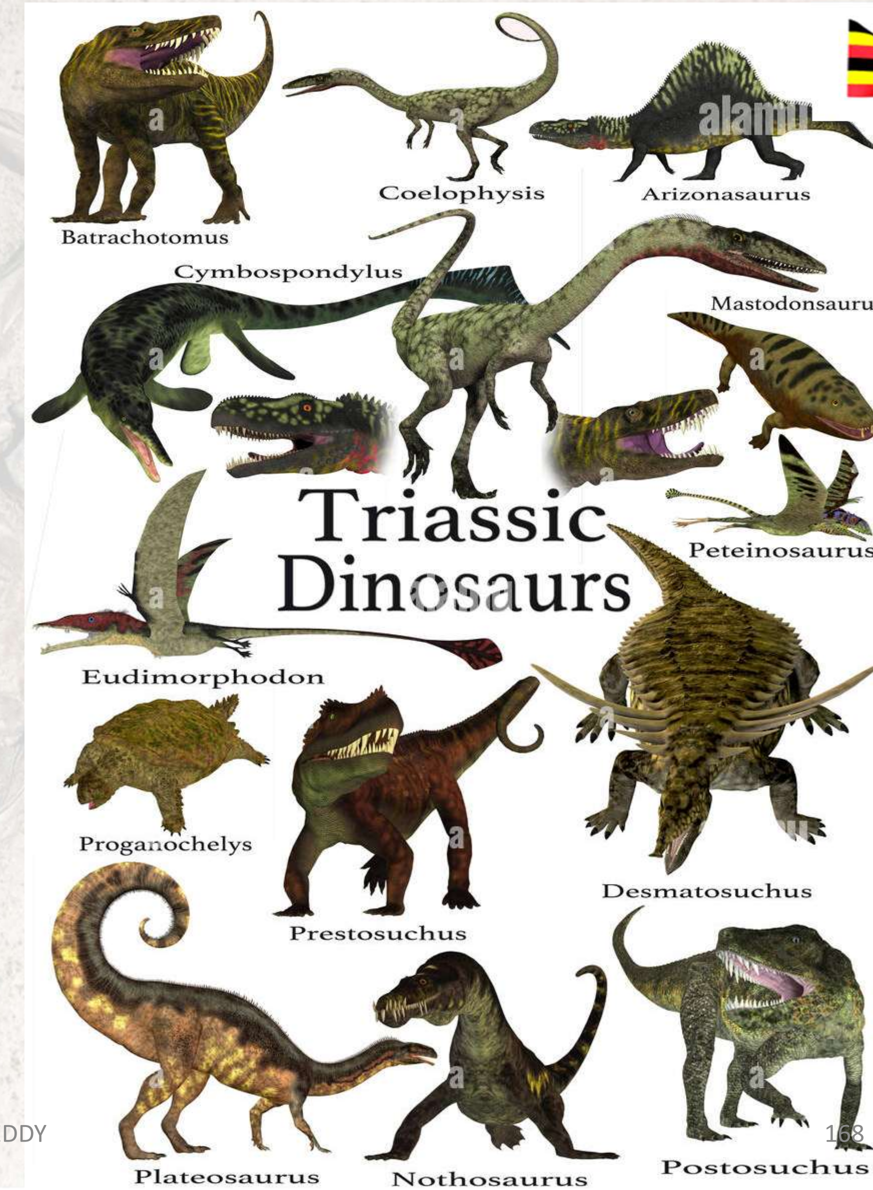
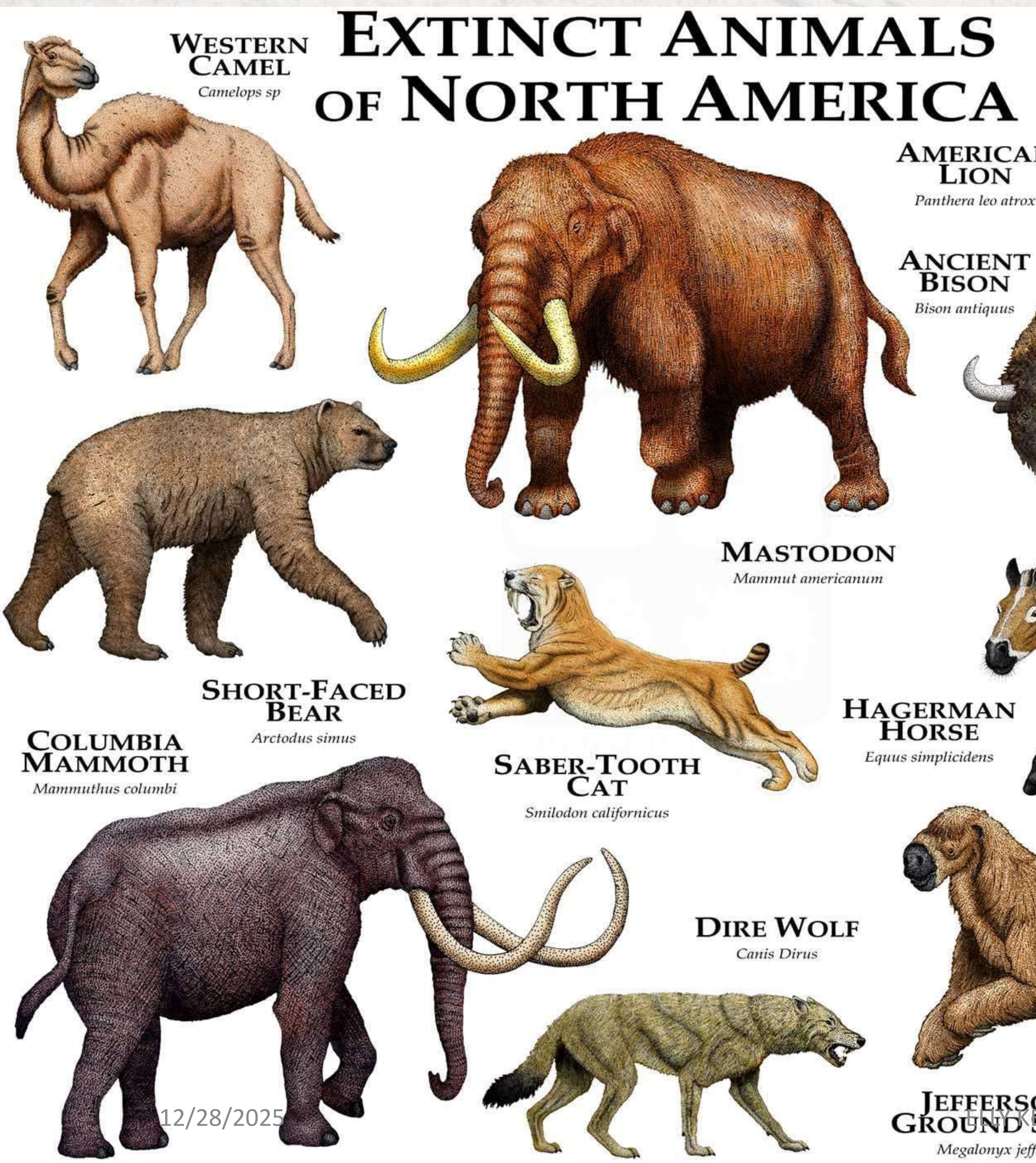
CRETACEOUS-PALEOGENE EXTINCTION (65 MILLION YEARS AGO)

- ***A massive asteroid impact*** (*Chicxulub*) ***combined with volcanic activity*** led to a "***nuclear winter***", which ***halted photosynthesis in plants and planktons*** wiping out about 75% of species, including ***non-avian dinosaurs***, many ***mammals***, ***insects***, ***lizards***, ***plants***.
- Most tetraploids weighing more than 25kg became extinct ***except exothermic species*** like ***sea turtles*** and ***crocodiles***. This ***ended the dinosaur era***, ***allowing mammals to rise.*** It *marked the end of the cretaceous* and *Mesozoic era* while marking the beginning of the ***current Cenozoic era***. *Mammals in particular diversified evolving to new forms* i.e. *horses*, *whales*, *bats* and *primates*. The *surviving group of dinosaurs were avians* which radiated into ***modern birds***.


Argentinosaurus
Albertaceratops
Deincheirus
Ankylosaurus
Pentaceratops
Dracorex
Diabloceratops
Deinonychus
Tyrannosaurus
Parasaurolophus
Hypsilophodon
Olorotitan
Sauropelta
Cretaceous Dinosaurs
Zuniceratops
Parasaurolophus
Styracosaurus
Torosaurus
Suchomimus
Triceratops
Bistahieversor
Velociraptor
Utahraptor


Batrachotomus
Coelophysis
Arizonasaurus
Cymbospondylus
Mastodonsaurus
Triassic Dinosaurs
Peteinosaurus
Eudimorphodon
Proganochelys
Prestosuchus
Desmatosuchus
Plateosaurus
Nothosaurus
Postosuchus

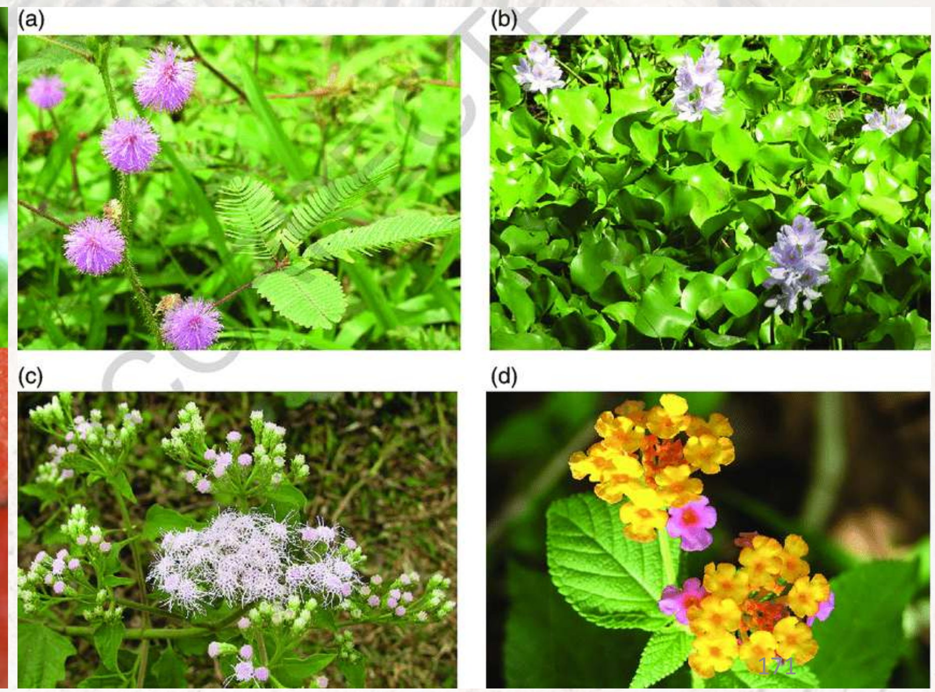

EXTINCT ANIMALS OF NORTH AMERICA
WESTERN CAMEL
Camelops sp
AMERICAN LION
Panthera leo atrox
ANCIENT BISON
Bison antiquus
MASTODON
Mammut americanum
SHORT-FACED BEAR
Arctodus simus
HAGERMAN HORSE
Equus simplicidens
COLUMBIA MAMMOTH
Mammuthus columbi
SABER-TOOTH CAT
Smilodon californicus
DIRE WOLF
Canis Dirus
JEFFERSO
GROUND S
Megalonyx jeffe


Extinct Animals
Saber-Toothed Cat
Dodo
Dinosaur
Golden Toad
Tasmanian tiger
Woolly Mammoth
Passenger Pigeon
Ground Sloth
EXTINCTANIMALS

HUMAN FACTORS LEADING TO EXTINCTION

- ***Habitat Destruction***: This is the leading cause of extinction today. As humans *convert forests, wetlands, and grasslands* into ***farms***, ***cities*** , ***roads*** and ***settlement land*** which has caused pollution and climate change. ***Species lose the food and shelter they need to survive*** hence they are ***forced to migrate or exposed to predators leading to their death***.
- ***Population Growth (Human):*** The exponential growth of the human population ***increases the demand for land, water, and energy***, resulting into displacement of other species out of their natural niches.

- ***Invasive Species***: When non-native species are introduced to a new environment either by accident (stowaways on ships) or on purpose they can outcompete , prey upon, or bring new diseases to native species that have no natural defenses.
- These cause decline in the population of native species making them prone to extinction.



- ***Pollution***: Chemical runoff from agriculture, plastic waste in oceans, and pollution, ***poison animals and plants in the ecosystem leading to death***, ***degrade habitats causing migration and death***. *For example, acid rain can change the pH of lakes, making them uninhabitable for certain fish and amphibians*, *disrupt food chains through bioaccumulation and bio magnification* causing reproductive failure
- ***Overexploitation***: This includes ***overhunting***, ***overfishing***, and the ***illegal wildlife trade***. When a ***species is harvested faster than it can reproduce*** (like the Passenger Pigeon or certain shark species), its population eventually

NATURAL AND ENVIRONMENTAL FACTORS LEADING TO EXTINCTION.

Throughout Earth's history, species have gone extinct due to large-scale natural changes:

- ***Climate Change***: causes extinction by *altering habitats through global warming* causing ***drought*** and ***changes in sea level***. This forces species to ***adapt*** or ***die when their physiological toleration limits are exceeded***. Sudden shifts in temperature (Ice Ages or global warming) can ***happen faster than species can evolve or migrate.*** This ***alters food chains and destroys specialized habitats*** like coral reefs causing death of organisms inhabiting them.
- ***Genetic Factors***: Small isolated populations often ***suffer from inbreeding depression***, ***leading to a lack of genetic diversity*** and ***variations*** making the group ***more vulnerable to diseases*** and ***less able to adapt to environmental changes.***

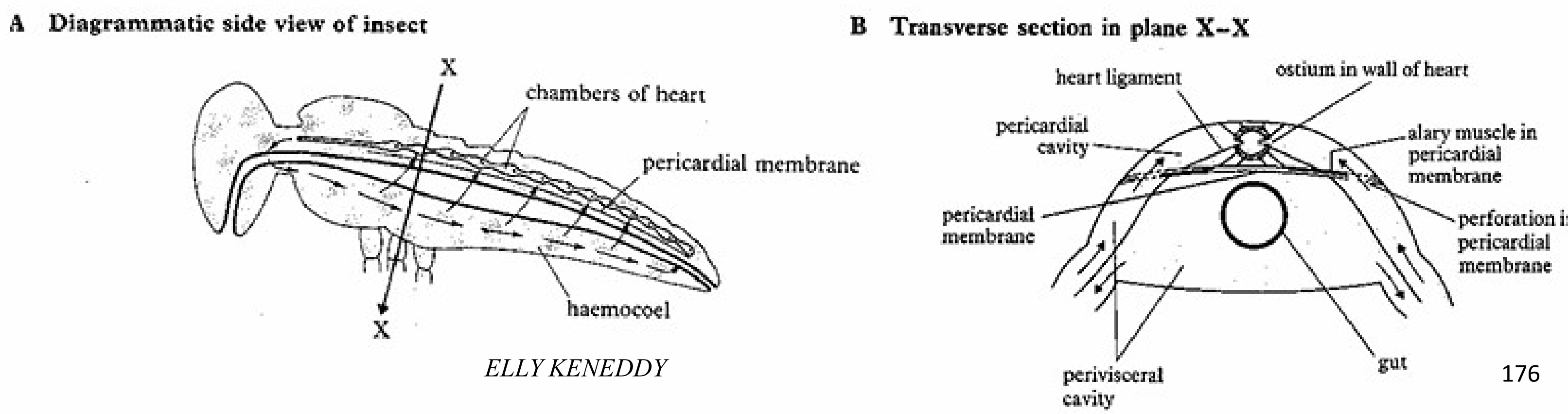
- ***Catastrophic Events***: cause extinction by inducing ***rapid and severe changes in the earths eco-system.*** Rare but devastating events like ***massive volcanic eruptions*** or ***asteroid impacts***, ***hurricanes***, ***tsunamis*** can *cause immediate death* or *migration of organisms of a population*. These events also *destroy habitats, food sources* and *fundamental ecological interractions*. The most famous example is the asteroid that triggered the extinction of non-avian dinosaurs.
- ***Co-extinction***: The ***loss of one species can lead to the loss of another that depends on it***. For example, if a specific pollinator goes extinct, the plants that rely solely on it for reproduction may soon follow.

HOW EXTINCTION CONTRIBUTES TO EVOLUTION.

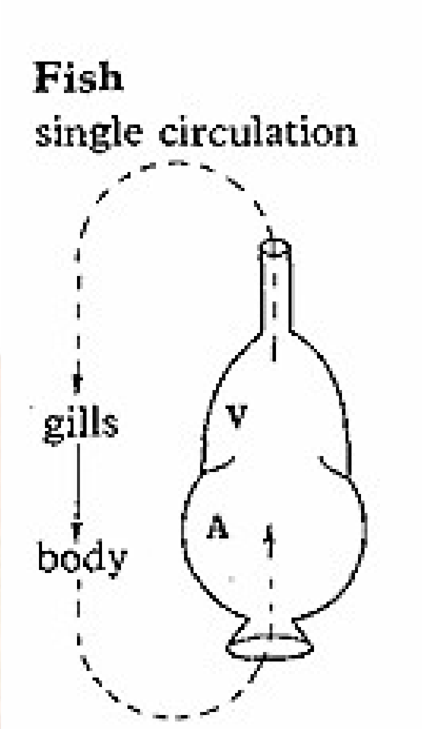
- Extinction drives evolution by ***creating vacant ecological niches*** allowing *the few survivors to diversify* and *undergo adaptive radiation to occupy the niches*, ***eliminates intraspecific and interspecific competition*** *through wiping out the dominant species allowing other species to dominate* e.g. extinction of dinosaurs gave way for dominance of mammals, ***eliminates the less fit species*** *availing resources for other species to utilize and evolve*.

EVOLUTIONARY ADVANCEMENT IN CIRCULATION.

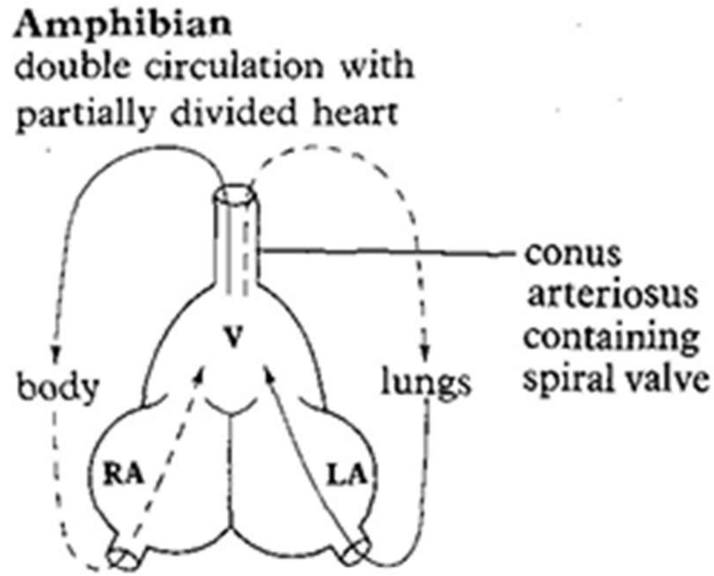
- ***The primitive organisms were unicellular*** i.e. bacteria, amoeba, hence had a ***large surface area to volume ratio***. These ***exchanged and circulated materials in their body by simple diffusion***. As organisms evolved and became advanced, ***they became multicellular*** and ***larger in size*** hence *diffusion became insufficient to meet the metabolic demand* and these *developed a simple circulatory system* i.e. an ***open circulatory system*** present in ***insects*** and ***crustaceans***. This consists of *blood called* ***haemocoel*** which ***flows in open spaces in the insect's body*** ***pumped by the dorsal heart***. This is efficient for small organisms with relatively high metabolic demands.



- As organisms evolved, they gave rise to ***vertebrates which were bigger in size*** and had ***higher metabolic demands.***
- These required faster supply of metabolic substrates hence evolved a ***single closed circulatory system*** where *blood is enclosed in blood vessels and never comes into contact with tissues*.
- The primitive form consisted of a heart with ***2 chambers*** (*1 atrium and 1 ventricle*) and ***blood flows through it once*** i.e. from the body to heart and pumped to gills.
- This is a characteristic of fish which is well suited for aquatic life.

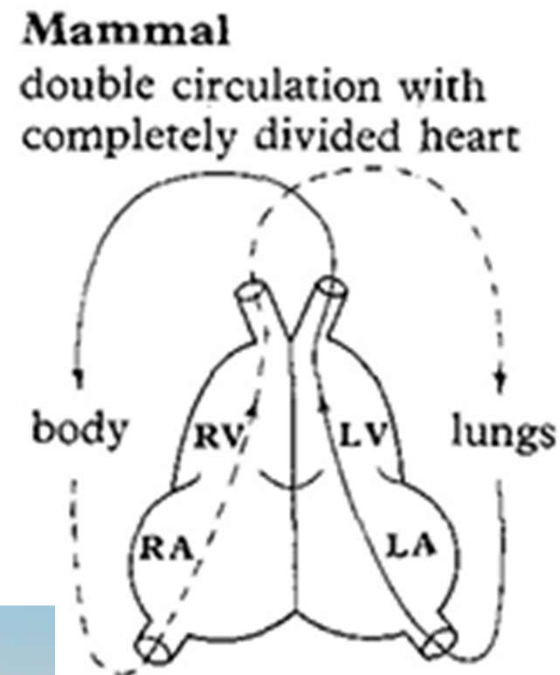


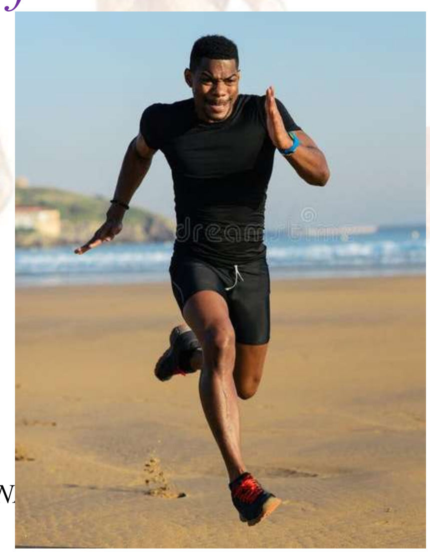
- Fish later evolved to give rise amphibians and reptiles which evolved an i***incomplete double circulatory system*** with ***3 chambered*** (*2 atrium and 1 ventricle*).
- This ensured more efficient delivery of oxygen and other materials to the body to meet metabolic demands of these animals.
- The ***ventricle is undivided*** hence *oxygenated and deoxygenated blood mixes* however the ***ventricle contraction provides sufficient pressure*** for fast flow of blood to lungs and the body.




Toad

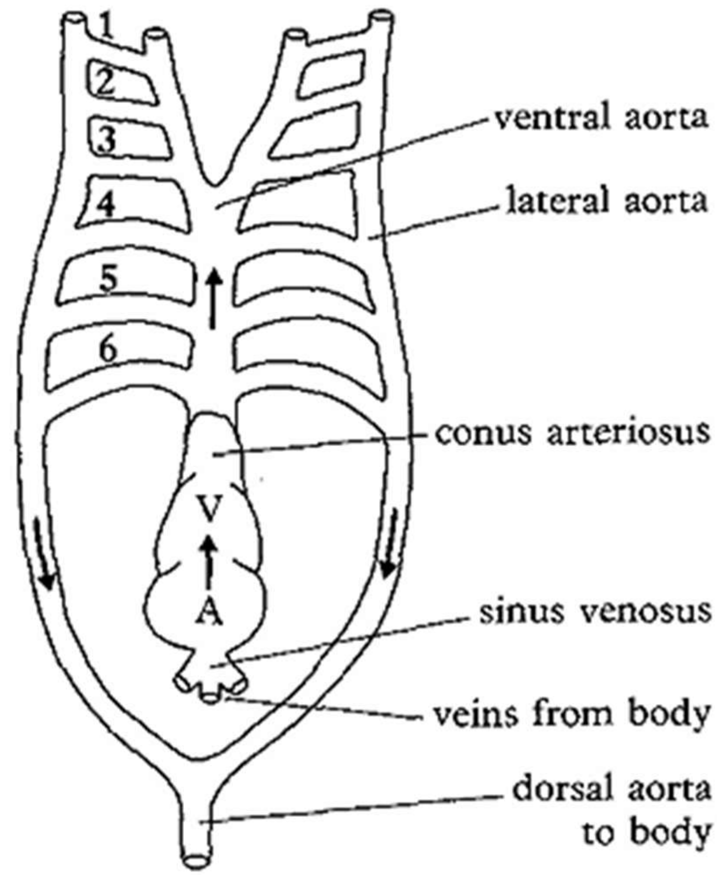
- Reptiles evolved to give rise to ***mammals*** and ***birds*** which are warm blooded.
- Due to their ***high activity*** and ***endothermic nature***, they ***have high metabolic demands necessitating for efficient*** and ***fast supply of materials*** around the body thus evolved ***a complete double circulatory system*** with 4 chambers ensuring ***separation of oxygenated*** and ***deoxygenated blood in ventricles*** hence *efficient oxygen supply and blood flow at a greater speed to supply materials*.





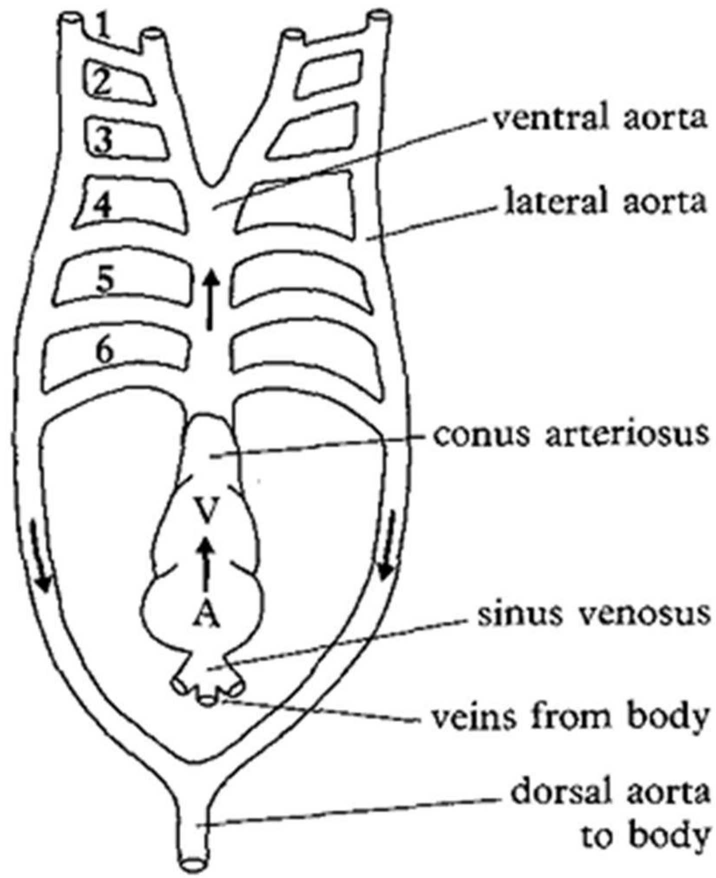
EVOLUTIONARY ADVANCEMENT IN CIRCULATORY SYSTEM.

- The basic plan of the heart and the pattern of arteries leading from it is ***seen in vertebrae embryos.***
- The heart consists of ***a single atrium***, ***ventricle*** and ***conus arteriosus*** which ***leads into the ventral aorta.***
- Embryology studies show that in all vertebrates, ***six arterial arches link the ventral aorta*** with a ***pair of lateral dorsal aortae on each side*** of the body.
- These ***unite posteriorly*** to form a ***single dorsal aorta*** which takes blood to the body

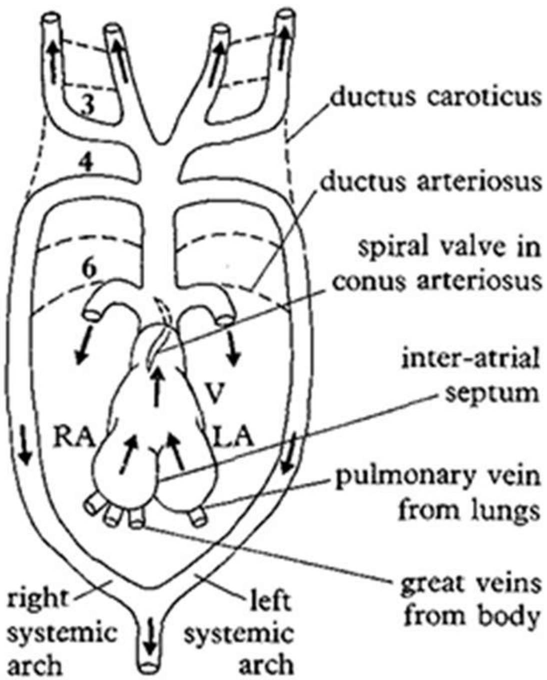


CONT…………..

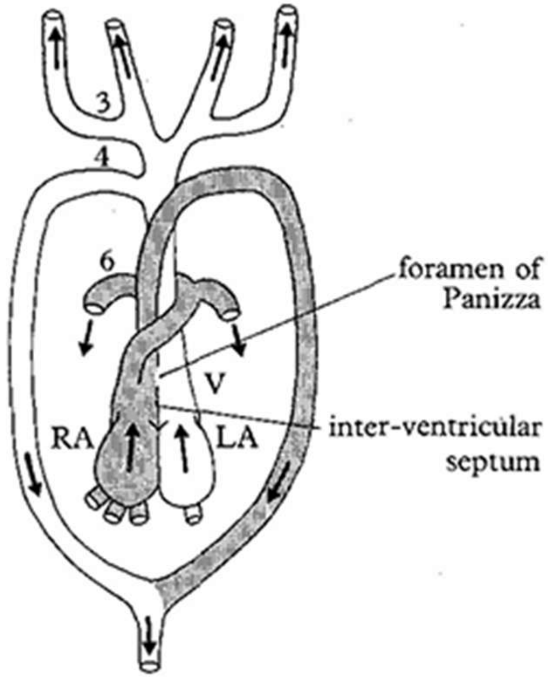
- Although this embryonic pattern is shown in development of most vertebrates, ***only fish show this primitive arrangement in the adult stage*** which show a single circulatory system ***however it is modified to some extent*** i.e.
- In fish, the ***first one or two arterial arches disappea***r and the ***remaining serve the gills***. Fish have a single circulation.
- In amphibians, certain ***fundamental changes have taken place*** which can be best understood using a tadpole.(*serves as a link between fish and amphibians*)



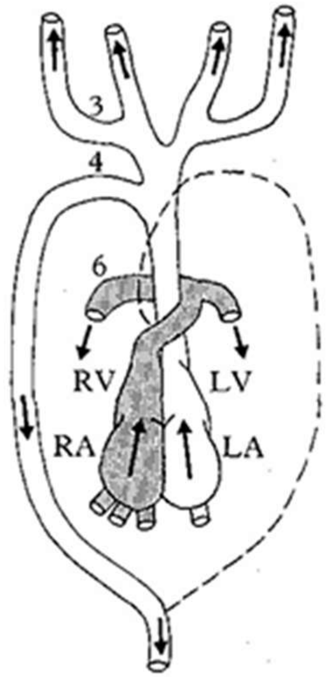
- The tadpole has a single circulatory system; the ***first two arterial arches disappear*** during early development but the ***remainder serve as gills as in fish.***
- At metamorphosis, when the ***tadpole forsakes its aquatic existence for dry land***, drastic changes occur . ***Part of the lateral dorsal aorta*** between ***the third*** and ***fourth arterial arches constricts*** to become the ***ductus coroticus***, the ***fifth arterial arch disappears altogether*** and the ***other outer portion of the sixth constricts*** to become the ***ductus arteriosus***.
- This leaves arterial arches 3,4 and 6. The ***third becomes*** the ***carotid arch***, the ***fourth becomes*** the ***systemic arc*** and the ***sixth becomes*** the ***pulmonary arch*** conveying blood to newly developed lungs.
- The atrium becomes divided into the left and right as the ventricle remains undivided.



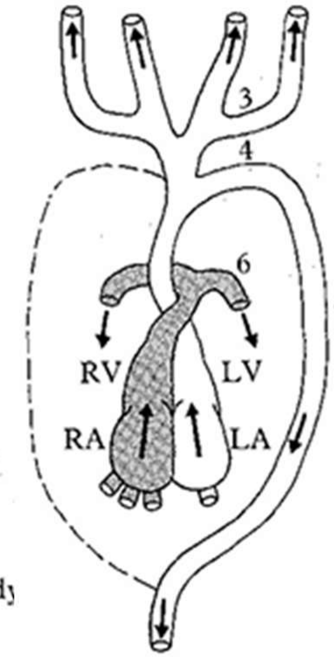
C Adult amphibian
Lateral aorta between arches 3 and 4 constricts to become the ductus caroticus. Arch 5 disappears. Distal portions of arch 6 constrict to become the ductus arteriosus. This leaves:
Arch 3 → carotid arch (serving head)
Arch 4 → systemic arch (serving body)
Arch 6 → pulmonary arch (serving lungs)
Atrium becomes divided into left and right atria by inter-atrial septum.



D Crocodile
Inter-ventricular septum divides ventricle into right and left halves. Conus arteriosus of amphibian replaced by separate vessels arising direct from ventricle. But note that left systemic arch carries deoxygenated blood.



E Bird
Left systemic arch disappears.
Right systemic takes blood to body



F Mammal
Right systemic arch disappears.
Left systemic takes blood to body.

ADVANCEMENT IN RESPIRATORY SYSTEMS.

- In the earliest life forms, gas exchange occurred by ***simple diffusion across the body surface***. This was due to the ***small size of the organisms which provided a large surface to volume ratio.***
- As organisms grew larger, the ***surface area to volume ratio greatly reduced*** and hence the ***diffusion across the body surface became insufficient,*** leading to the evolution of specialized respiratory surfaces which include.
- ***Skin (Cutaneous Respiration):*** Many small or primitive aquatic animals still use their skin. Even some amphibians today use moist skin for a significant portion of their gas exchange.
- ***Gills***: Gills are outgrowths of the body surface used for gaseous exchange in aquatic organisms. They utilize a counter-current exchange mechanism, where blood flows in the opposite direction of water. This maintains a steep concentration gradient, allowing fish to extract up to 80-90% of the dissolved oxygen from water.

Lungs.

- Reptiles moved away from skin-breathing (to prevent dehydration) and developed tougher, more compartmentalized lungs. Their lungs ***have internal ridges*** (***septa***) *to increase the surface area for gas exchange.* They also ***developed Negative Pressure Breathing***. Instead of "swallowing" air, reptiles ***use thoracic muscles to expand the chest cavity***, creating a vacuum that pulls air in
- Mammals evolved a ***highly branched system of airways ending in alveoli***. The ***numerous alveoli provide a large surface area for gas exchange surface***. Evolution of the diaphragm allowed for ***more powerful and controlled negative pressure breathing***, supporting a high-energy demand and endothermic lifestyle.
- Birds possess the ***most efficient respiratory system of all vertebrates*** to support the extreme metabolic cost of flight. They have a series of ***posterior and anterior air sacs***. Unlike the mammalian "tidal" system (where air goes in and out the same way), air in a bird's lung (parabronchi) ***flows in one direction during both inhalation and exhalation***. This ensures that the ***lungs are always exposed to fresh, oxygen-rich air.***

Evolution of Lungs

- About 380–400 million years ago, ***as water levels fluctuated and oxygen levels in stagnant pools dropped***. The first "proto-lungs" *appeared during the Devonian Period* . Early bony fish often lived in warm, shallow, or stagnant fresh water where oxygen levels were low.
- As water levels fluctuated and oxygen levels in stagnant pools dropped, ***certain fish (**like the Sarcopterygians** or *lobe-finned fish*) evolved out pocketings of the foregut***. To survive, these fish would swim to the surface and gulp air.
- Small out pocketings developed in the esophagus or pharynx to hold this air were called ***Pharyngeal Pouch***.
- Over time, these pouches ***became vascularized (filled with blood vessels), allowing oxygen to diffuse directly into the bloodstream***. These became the *ancestors of all land vertebrates* (*tetrapods*).

- Ray-finned fish (Actinopterygii), which make up most modern fish for example goldfish, ***had their lungs evolve into swim bladders*** (*gas-filled sacs used for buoyancy rather than breathing*). As the ancestors of amphibians began to spend more time near the water's edge, ***their lungs became more complex***.
- ***To support larger bodies*** and ***higher activity levels***, the simple sacs developed ***internal folds (septa)*** to increase the surface area for oxygen exchange. Once on land, ***lungs evolved into the diverse forms we see today.***

Other advancements to be continued.

ALWAYS AIM FOR EXCELLENCE

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S.6 BIOLOGY