Telematic Schools Project

2022 SUBJECT WORKBOOK
Grade 12

LIFE SCIENCES

A joint initiative between the Western Cape Education Department and Stellenbosch University.

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BROADCAST SESSIONS

GRADE 12 **LIFE SCIENCES**

Session	Date	Time	Topic
12	21/02/2022	15h00-16h00	DNA, RNA and protein synthesis
12	12/04/2022	16h00-17h00	Meiosis
12	19/07/2022	16h00-17h00	Theories of evolution

WHAT YOU SHOULD KNOW

Revise the cell structure covered in Grade 10 with emphasis on the ribosome, cytoplasm and parts of the nucleus.

Revise nucleic acids that were covered in Grade 10

Revise the process of mitosis in grade 10.

Two types of nucleic acids are found in a cell, namely DNA and RNA. Nucleic acids consist of nucleotides.

DNA

Location of DNA:

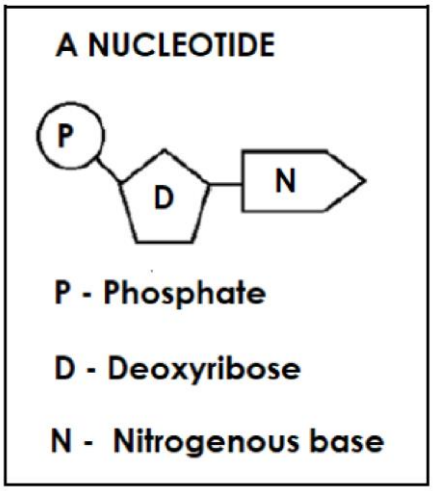
- DNA is mainly located in the **nucleus** where it forms part of the chromatin network.
- Chromosomes are thread-like structures in the nucleus and composed of DNA that is wrapped around proteins, called **histones**.
- A small amount of DNA occurs outside the nucleus, in the **mitochondria** of plant and animal cells as well as **chloroplasts** of plant cells.
- A short segment of a DNA molecule coding for a specific inherited characteristic is known as a **gene**.

Brief history of the discovery of DNA:

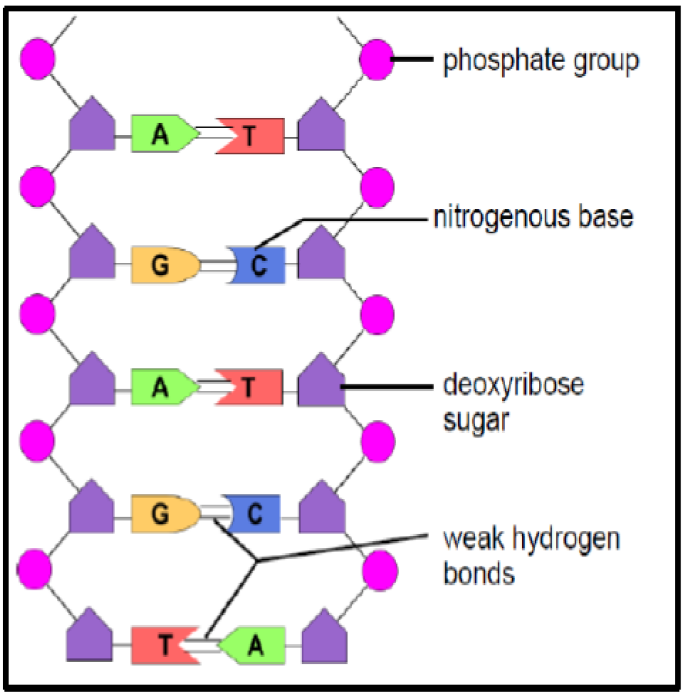
- 1952 – Rosalind Franklin and her assistant Maurice Wilkins researched the structure of DNA using X-ray diffraction images.
- Watson and Crick did independent research on DNA.
- Watson and Crick proposed a 3-D double helix model for DNA in 1953.
- 1962 – Watson and Crick received the Nobel Prize for the discovery of the structure of DNA, and Wilkins received an award for his X-ray photography.

Structure of DNA:

- DNA is a polymer and consists of two strands that are twisted to form a **double helix**.
- Each strand of the helix is made up of a sequence of DNA **nucleotides**.
- Each nucleotide consists of a **sugar** molecule (deoxyribose), a **phosphate** group and a **nitrogenous base.**



- Deoxyribose combines with the phosphate group
- One nitrogenous base combines with deoxyribose
- The sides of the DNA ladder consist of alternating deoxyribose molecules and phosphate groups
- There are four types of nitrogenous bases in DNA i.e. **Adenine (A), Guanine (G), Cytosine (C)** and **Thymine (T)**
- **Adenine** always combines to **Thymine**
- **Guanine** always combine to **Cytosine**
- There are equal numbers of adenine and thymine bases as well as equal numbers of guanine and cytosine bases in a DNA molecule. (A = T and G = C)
- Nitrogenous bases are joined by **weak hydrogen bonds** which are easily broken by enzyme action.
- One DNA strand is the complement of the other strand.

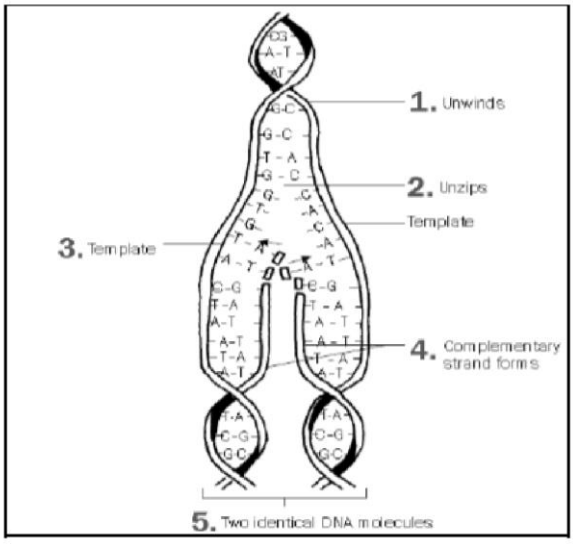


Functions of DNA:

- DNA makes up genes which carry hereditary information.
- DNA contains coded information for protein synthesis.

DNA replication:

- DNA replication is the process during which a DNA molecule makes an exact copy (replica) of itself.
- DNA replication takes place during **interphase** of the cell cycle.



How DNA replication takes place (names of enzymes are not required):

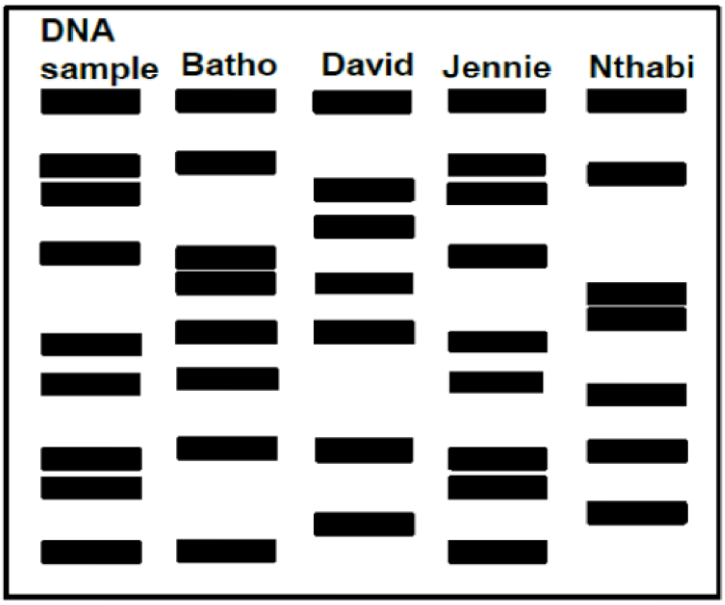
1. The DNA double helix unwinds
2. Weak hydrogen bonds between nitrogenous bases break and the two DNA strands unzip
3. Both DNA strands serves as templates
4. Free nucleotides in the nucleoplasm are used to build a complementary DNA strand onto each of the original DNA strands (A to T and G to C)
5. This results in two identical DNA molecules. Each molecule consists of one original and one new strand.

Significance of DNA replication:

- Doubles the genetic material so that each cell receives the same amount of DNA during cell division
- Results in the formation of identical daughter cells during mitosis

DNA profiling

- A DNA profile is a pattern of black bars that represents the DNA fragments of a person.
- Every person except identical twins has her/his own unique DNA profile.



DNA profiling can be used for the following:

- As proof of paternity
- To trace missing persons
- To identify genetic disorders
- To establish family relations
- To match tissues for organ transplants
- To identify dead persons/animals
- To identify crime suspects in forensic investigations.

Use of DNA profile	What to look for
Forensics (Identification of a criminal, family member or a deceased person)	All the bands of the DNA sample must match exactly with that of the individual in question.
Paternity testing	Each band of the child must match either that of the mother or of the potential father. If the child has a band that does not match that of either parent, then that excludes that male as the father

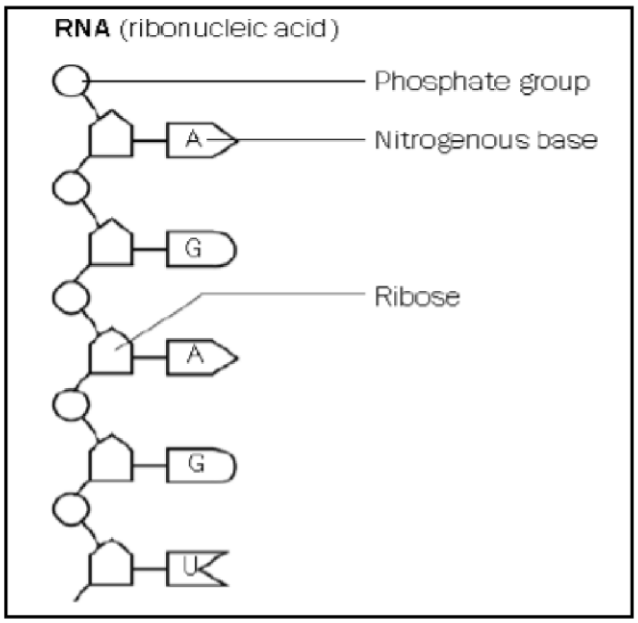
RNA: Location, structure and function

Location of RNA:

- mRNA is formed in the **nucleus** and functions on the ribosome
- tRNA is located in the **cytoplasm**

Structure of RNA:

- RNA is **single stranded** and is made up of **nucleotides**
- Each nucleotide consists of a sugar molecule called **ribose,** a **phosphate group** and a **nitrogenous base.**
- The four types of nitrogenous bases in RNA are **adenine (A), uracil (U), guanine(G) and cytosine(C)**
- The phosphate group is attached to the ribose sugar and the nitrogenous base is attached to the ribose sugar
- Nitrogenous bases on RNA are arranged in triplets i.e. **codons** on mRNA and **anticodons** on tRNA
- tRNA has a clover-leaf/hairpin structure
- tRNA has a place of attachment for an amino acid.

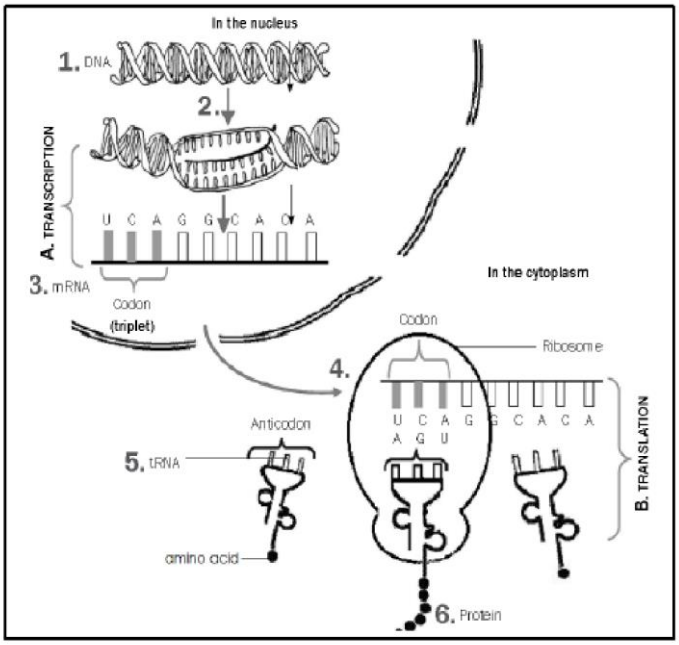


Function of RNA

- RNA plays a role in protein synthesis

Protein synthesis:

- The involvement of DNA and RNA in protein synthesis:



The process of protein synthesis occurs in two main steps i.e. transcription and translation

Transcription:

- The double helix DNA unwinds.
- The double-stranded DNA unzips/weak hydrogen bonds break
- Two separate strands are formed.
- One strand is used as a template to form mRNA
- Free RNA nucleotides from the nucleoplasm are used.
- The mRNA is complementary to the DNA.
- mRNA now has the coded message for protein synthesis.
- mRNA moves from the nucleus to the cytoplasm and attaches to the ribosome.

Translation:

- Each tRNA carries a specific amino acid.
- The anticodon on the tRNA matches the codon on the mRNA
- tRNA brings the required amino acid to the ribosome. (Note: Names of specific codons, anticodons and their amino acids are not to be memorised.)
- Amino acids become attached by **peptide bonds** to form the required **protein**.

The table below outlines differences in the processes of DNA replication and transcription.

DNA replication	Transcription
Both strands act as templates	Only one strand acts as a template
Free DNA nucleotides from the nucleoplasm attach to each strand	Free RNA nucleotides from the nucleoplasm attach to the template strand
Complementary base pairing occurs (A-T) and (G-C)	Complementary base pairing occurs (A-U) and (G-C)
Two Identical DNA molecules are formed	An mRNA molecule is formed

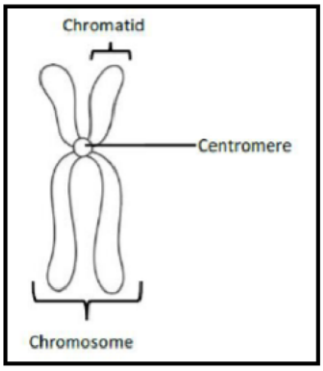
Meiosis:

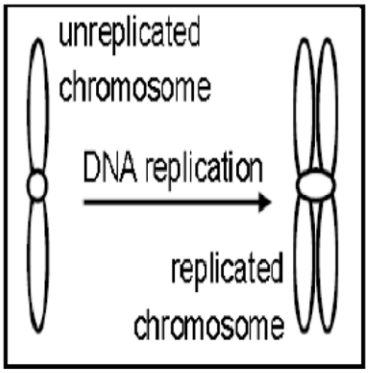
- Meiosis is a type of cell division whereby a diploid cell (somatic cell) undergoes two cell divisions and divides to form four haploid cells (gamete or sex cells).
- Meiosis takes place in the **testes** and **ovaries** of animals and in the **anthers** and **ovules** of plants

Note: Meiosis is a continuous process, but the events are divided into different phases for convenience.

Structure of chromosomes:

- Chromosomes consist of DNA (which makes up genes) and protein.
- The number of chromosomes in a cell is a characteristic of an organism (e.g. humans have 46 chromosomes)
- Diploid cells have two sets of chromosomes, where each chromosome has a homologous partner.
- Haploid cells only have one set of chromosomes.
- Chromosomes in haploid cells have no homologous partners.
- Before meiosis begins (during interphase), DNA replication takes place.
- Chromosomes which are single threads become double (two **chromatids** joined by a **centromere**) as a result of DNA replication.





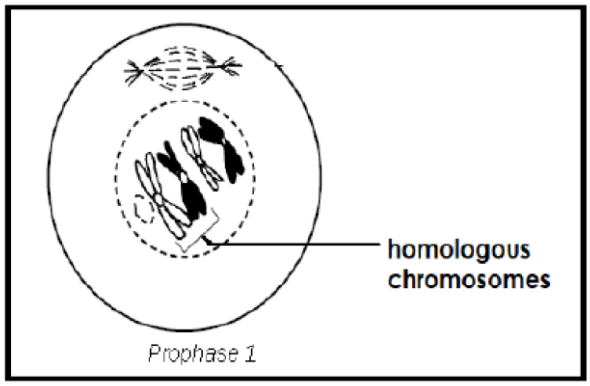
Term	Description
Chromosome	The DNA-containing structure that is made up of genes (found in cells that are undergoing cell division)
Centrosome	Structure that is responsible for the formation of spindle fibres during cell division in animal cells and is made up of two centrioles
Centromere	Structure that holds two chromatids together in a replicated chromosome and which also attaches the chromosome to the spindle fibres during cell division
Centriole	Two structures arranged at right angles to each other and together make up the centrosome.
Chromatin	The DNA-containing network found in cells in interphase (non-dividing)
Chromatid	A chromosome is made up of two chromatids held together by a centromere

Events of interphase:

- DNA replication takes place
- Each chromosome will now consist of two chromatids joined by a centromere
- DNA replication helps to double the genetic material so that it can be shared by the new cells arising from cell division.

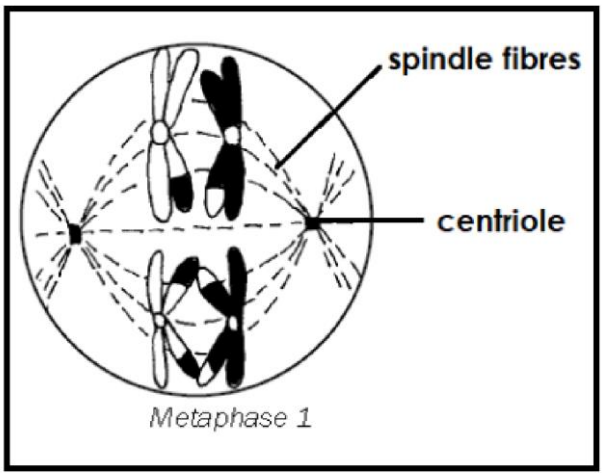
First meiotic division (Meiosis I):

Prophase 1:



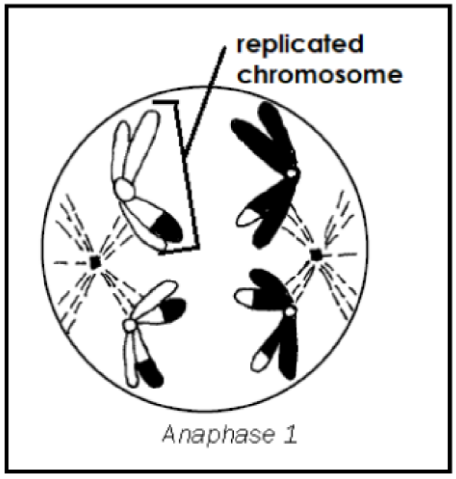
- During **Prophase I** the nuclear membrane and nucleolus start to disappear.
- Spindle fibres develop between the centrioles
- Chromatin network condenses into individual chromosomes
- Adjacent chromatids of homologous chromosomes overlap and touch each other at a point called the **chiasma** (plural: chiasmata) in a process called **crossing over**
- Chromatid segments break off and are exchanged, resulting in the exchange of genetic material.
- This process is called crossing over and it brings about **variation**.

Metaphase 1:



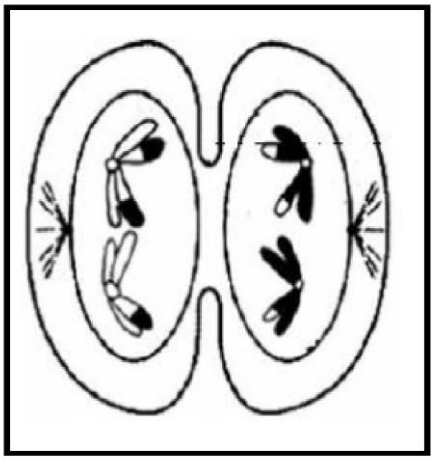
- During **Metaphase I** the homologous chromosome pairs are arranged at the equator of the cell in a **random** way with the chromosome attached to the spindle fibre
- Which chromosome lies on which side of the equator is totally up to chance.
- This is called **random arrangement** and brings about further variation.

Anaphase I:



- During **Anaphase I** the chromosome pairs separate and chromosomes move to opposite poles – one to each pole

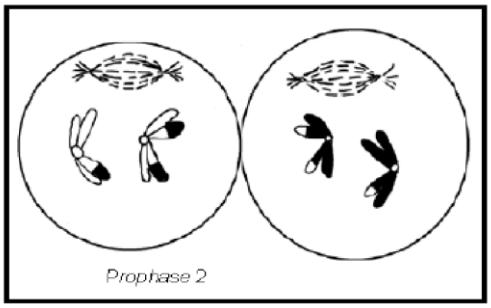
Telophase I:



- During **Telophase I** the chromosomes reach the poles of the cell
- Each pole has half the number of chromosomes present in the original cell.
- The cell membrane constricts and divides the cytoplasm in half to form two cells.

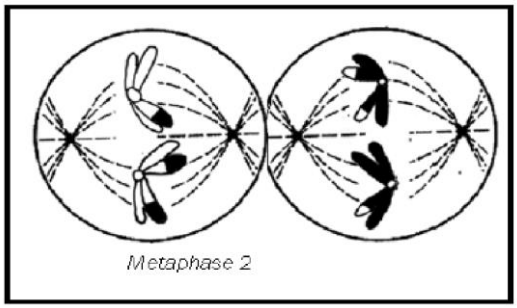
Second meiotic division (Meiosis II):

Prophase II:



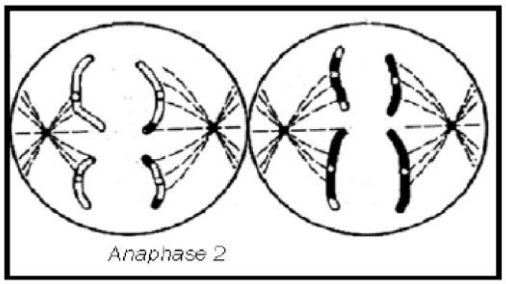
- During **Prophase II** the chromosomes are not in pairs
- Nucleolus and nuclear membrane disappear
- A spindle forms.

Metaphase II:



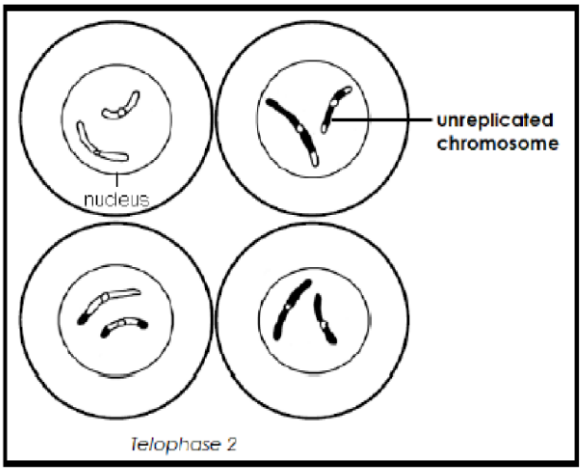
- During **Metaphase II** the individual chromosomes line up at the equator of each cell, with the centromeres attached to the spindle fibres

Anaphase II:



- During **Anaphase II** the spindle fibres contract
- The centromere of each chromosome splits into two
- Two chromatids of each chromosome separate and move to opposite poles

Telophase II:



- A new nuclear membrane forms around the unreplicated chromosomes at each pole
- Cytokinesis splits the cells into two new cells
- Four cells, each with a haploid number of chromosomes, have been formed.

The importance of meiosis:

- Production of haploid gametes.
- The halving effect of meiosis (from the diploid to the haploid number) overcomes the doubling effect of fertilisation, thus maintaining a constant chromosome number from one generation to the next.
- Meiosis introduces **genetic variation** through crossing over and the random arrangement of chromosomes at the equator.

Abnormal meiosis:

- Sometimes mistakes occur during the process of meiosis.
- This can happen in **Anaphase I** where there may be **non-disjunction** of homologous chromosomes into separate chromosomes. (Non- disjunction refers to the failure of chromosome pairs to separate during meiosis)
- It can also happen in **Anaphase II** when there may be **non-disjunction** of chromosomes into single-stranded chromosomes (chromatids).
- If there is **non-disjunction of chromosome pair 21 during Anaphase I** in humans, it leads to the formation of an abnormal gamete with an extra copy of chromosome 21.
- If there is fusion between a normal gamete (with 23 chromosomes) and an abnormal gamete (with an extra copy of chromosome 21) it leads to **Down Syndrome** (47 chromosomes in the zygote instead of 46 chromosomes).
- A person with Down syndrome will have three chromosomes at chromosome pair 21 in every somatic cell.

Similarities between mitosis and meiosis:

- Both processes are cell division processes.
- Both require DNA replication to occur during interphase before the division phases begin.
- Both show the following phases i.e. prophase, metaphase, anaphase and telophase

Differences between mitosis and meiosis:

Mitosis	Meiosis
Occurs in body cells	Occurs in reproductive organs
Chromosome number remains constant	Chromosome number is halved
Two cells form	Four cells are formed
Cells formed at the end are genetically identical to one another and to the parent cell	Cells formed at the end are genetically different from each other and from the parent cell
Crossing over does not occur	Crossing over occurs
Only one division takes place	Two divisions take place
No pairing of homologous chromosomes	Homologous chromosomes arrange in pairs during prophase I

Lamarck explained evolution using the following two 'laws':

- **The inheritance of acquired characteristics**: Characteristics developed during the life of an individual (acquired characteristics) can be passed on to their offspring.

- **The law of use and disuse:** As an organism uses a structure or organ more regularly, it becomes better developed or enlarged. If an organism does not use a structure or organ frequently, it becomes less developed or reduced in size and may disappear altogether.

Darwin's theory of evolution by natural selection:

- There is a great deal of **variation** amongst the offspring.
- Some have favourable characteristics, and some do not.
- When there is a change in the environmental conditions or if there is competition,
- then organisms with characteristics, which make them more suited, survive
- whilst organisms with unfavourable characteristics, which make them less suited, die.
- The organisms that survive, reproduce and thus pass on the **allele** for the favourable characteristic to their offspring.
- The next generation will therefore have a higher proportion of individuals with the favourable characteristic.

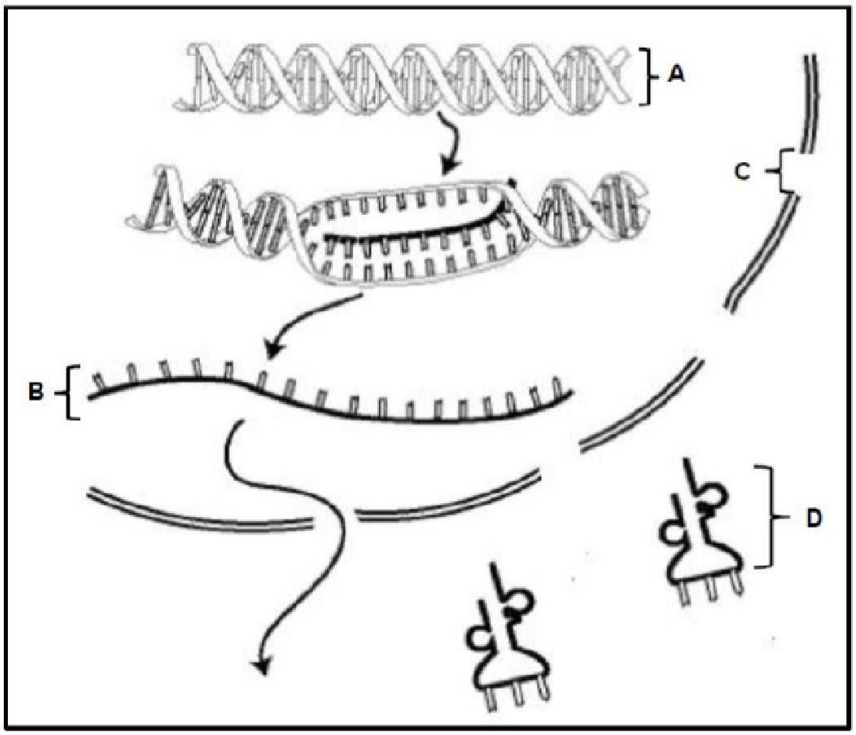
Punctuated equilibrium:

- Evolution involves long periods of time where species do not change or change gradually through natural selection (known as equilibrium).
- This alternates with (is punctuated by) short periods of time where rapid changes occur through natural selection
- during which new species may form in a short period of time.

Speciation through geographic isolation:

- If a **POPULATION** of a single species
- becomes separated by a geographical barrier (sea, river, mountain, lake)
- then the population splits into two.
- There is now no gene flow between the two populations.
- Since each population may be exposed to different environmental conditions/the selection pressure may be different
- natural selection occurs independently in each of the two populations
- such that the individuals of the two populations become very different from each other
- genotypically and phenotypically.
- Even if the two populations were to mix again
- they will not be able to interbreed.
- The two populations are now different species.

1.1 Study the diagram below of protein synthesis.



1.1.1 Identify:

(a) Molecule **A**
(1)

(b) Molecule **B**
(1)

(c) Structure **C**
(1)

(d) Molecule **D**
(1)

1.1.2 Tabulate TWO differences between the monomers of molecules **A** and **B**.
(5)

1.1.3 Describe the process of translation during protein synthesis.
(6)

Answers:

1.1.1 (a) DNA✓

(b) mRNA✓

(c) Nuclear pore✓

(d) tRNA✓

1.1.2

DNA	mRNA
Deoxyribose as a sugar	Ribose as a sugar
Thymine as nitrogenous base	Uracil as nitrogenous base

1.1.3 Each tRNA carries an amino acid✓
When the anticodon on the tRNA✓
matches the codon on the mRNA✓
tRNA brings the required amino acid to the ribosome✓
Amino acids become attached by peptide bonds✓
To form the required protein✓

1.2 A section of a DNA molecule has the following base sequence:

CTT ACA

1.2.1 The percentage of guanine in this DNA molecule is 30%. Give the percentage of thymine in the same molecule.

(1)

1.2.2 Give the mRNA sequence, from left to right, for this segment of DNA.
(2)

1.2.3 The table below shows the DNA triplets that code for some amino acids. Give the

DNA TRIPLET	AMINO ACID
ACA	Cysteine
CTT	Glutamic acid
TGT	Threonine
TTA	Asparagine
GAA	Leucine
TAC	Methionine

1.2.4 Give the anticodon for the amino acid methionine.

(1)

1.2.5 Name and describe the process occurring in the nucleus which results in the formation of an mRNA molecule.

(6)

Answers:

1.2.1 20✓%

1.2.2 GAA✓ UGU ✓

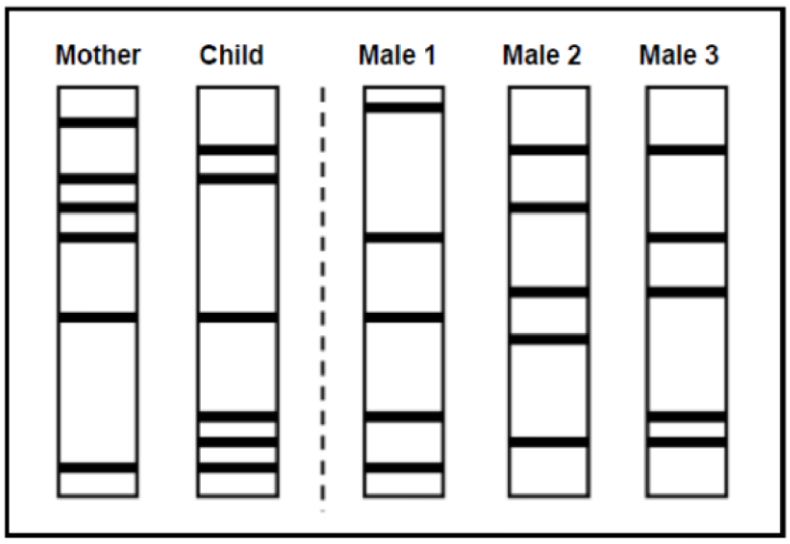
1.2.3 Glutamic acid ✓– Cysteine✓

1.2.4 UAC✓

1.2.5 The process is **transcription✓* Compulsory mark**
The double helix DNA molecule unwinds✓/the weak hydrogen bonds break to form two separate strands✓
One strand is used as the template ✓
to form mRNA ✓
using free RNA nucleotides from the nucleoplasm ✓
The mRNA is complementary to DNA✓/A-U, C-G
mRNA now has the coded message for protein synthesis✓

1.2.6 Gene mutation✓

1.3 The diagram below shows a technique used in paternity testing.



1.3.1 Identify the technique shown above.
(1)

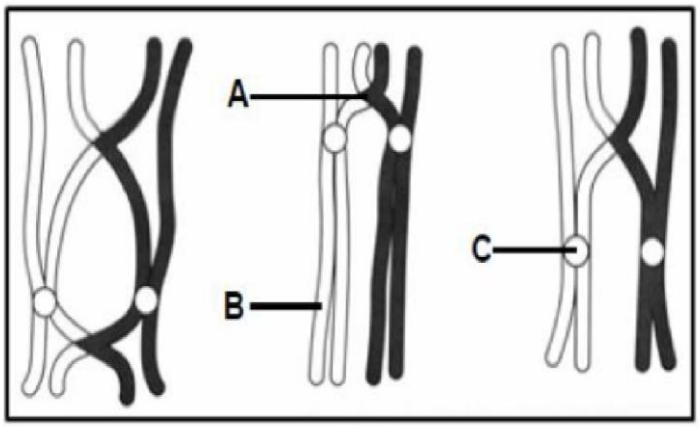
1.3.2 Which male is the biological father of the child?
(1)

1.3.3 Explain your answer to QUESTION 1.3.2.
(2)

Answers:

1.3.1 DNA profiling✓
1.3.2 Male 3✓
1.3.3 Three bands of the child are identical to that of the mother✓
The remaining three bands correspond with that of male 3✓

1.4 The diagram below represents ALL the chromosomes in a cell that is undergoing normal cell division.



1.4.1 Name the:

(a) Type of cell division that is occurring in the cell in the diagram

(1)

(b) Phase of cell division during which the chromosomes behave as shown in the diagram

(1)

1.4.2 Where in the human female body would the type of cell division named in QUESTION 1.4.1 (a) take place?

(1)

1.4.3 Give the LETTER and NAME of the structure that attaches to the spindle fibres.

(2)

1.4.4 How many chromosomes will be found in each daughter cell at the end of this cell division?

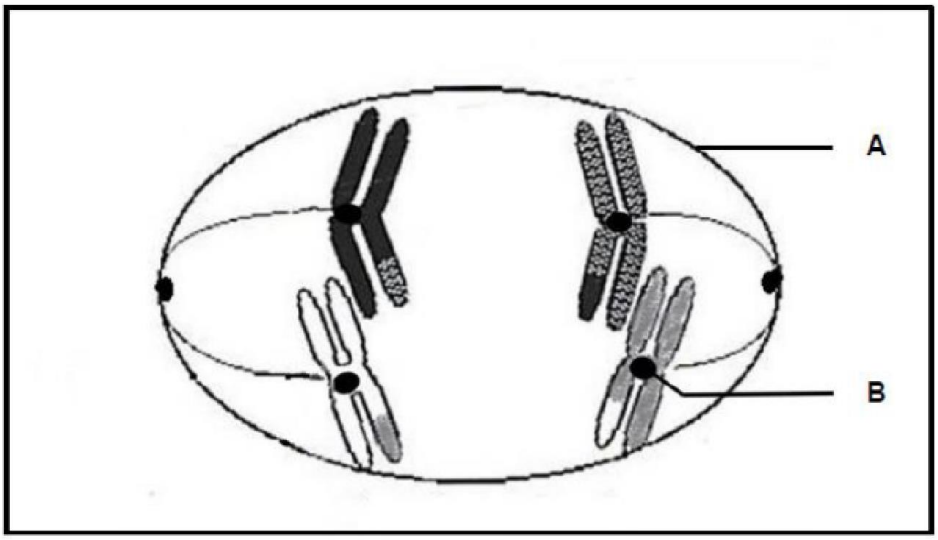
(1)

Answers:

1.4.1 (a) Meiosis✓/Meiosis 1
(b) Prophase 1✓
1.4.2 Ovary✓
1.4.3 C✓ – centromere✓
1.4.4 3✓

QUESTIONS AND ANSWERS (MEIOSIS)

1.5 The diagram below represents a phase of meiosis.



1.5.1 Identify the phase represented in the diagram.
(1)

1.5.2 Give TWO visible reasons for your answer to QUESTION 1.5.1.
(2)

1.5.3 Identify the part labelled:

(a) A

(1)

(b) B

(1)

1.5.4 State the number of chromosomes that would be present in each daughter cell at the end of meiosis 2 of this cell.
(1)

1.5.5 Draw a labelled diagram of the phase before the one mentioned in QUESTION 1.5.1.
(4)

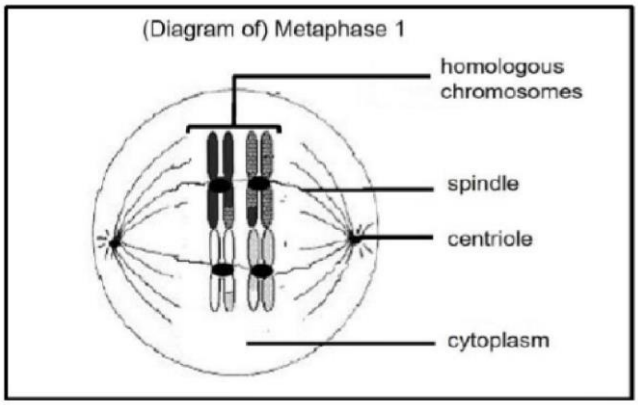
Answers

1.5.1 Anaphase 1✓

1.5.2 Chromosomes✓ are pulled from the equator to the poles✓

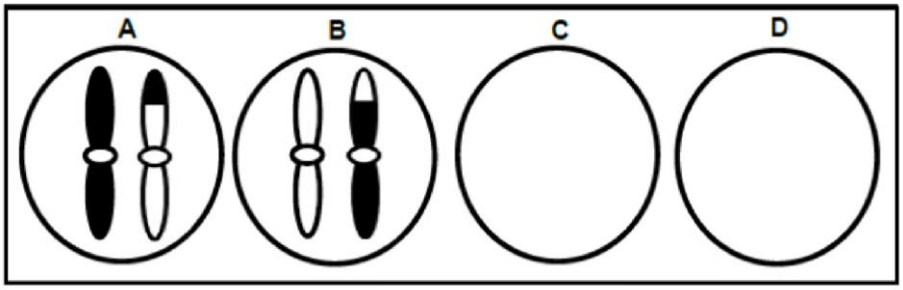
1.5.3 (a) Cell membrane✓
(b) Centromere✓

1.5.5



Correct caption	(C)	1
Diagram drawn correctly showing TWO homologous pairs at the equator	(D)	1
Any TWO correct labels	(L)	2

1.6 The diagrams below represent the distribution of chromosome pair 21 as it appears in gametes at the end of meiosis **II** in a human male.



1.6.1 Explain why the gametes represented by diagrams **C** and **D** do not have any chromosomes.

(3)

1.6.2 If gamete **A** is involved in fertilisation, describe how this may result in Down syndrome.

(1)

1.6.3 Due to the process of crossing over, the chromosomes in diagrams **A** and **B** appear different to each other.

(a) Identify the phase of meiosis during which crossing over occurs.
(1)

(b) Describe the events during crossing over.
(3)

(c) Explain the significance of crossing over in natural selection.
(3)

QUESTIONS AND ANSWERS (MEIOSIS)

Answers:

1.6.1 Due to non-disjunction✓**/** Non-separation of a chromosome pair during Anaphase **I**✓
Two chromosomes moved to the one pole✓ and
none moved to the other pole✓

1.6.2 Gamete **A** will have 24 chromosomes✓/an extra chromosome
and when it fertilises a normal ovum✓/gamete with 23 chromosomes
the zygote will have 3 chromosomes at position 21✓/ 47 chromosomes

1.6.3 (a) Prophase 1✓

(b) Adjacent chromatids of homologous chromosomes crossP at a point called the chiasma✓
There is an exchange of DNA segments✓/genetic material

(c) Crossing over introduces genetic variation✓ in gametes
Genetic variation may result in favourable characteristics✓
that ensure a better chance of survival✓
when environmental conditions change✓

1.7 Read the extract below.

> In Brazil there are different lizard species that feed on termites. Termites are small ant-like insects. They vary in size. Lizard species with bigger body size have larger heads and can eat larger termites. In 1996 a dam in Brazil flooded creating several islands. These islands each had a variety of different species of lizards.
>
> The lizard species with bigger body size died out on the islands, because there was not enough food for them to survive. But a very small lizard species, *Gymnodactylus amarali,* was able to survive. There were plenty of termites for them to eat.
>
> But there was a problem: *Gymnodactylus amarali* lizards had small heads and some of the termites were nearly the same size as them. However, some of the *Gymnodactylus amarali* lizards had slightly larger heads and were able to eat these termites.
>
> When scientists visited these islands 15 years later they found that the *Gymnodactylus amarali* lizards on the islands had heads that were four percent larger than those found on the mainland.

1.7.1 Use Darwin's theory of natural selection to explain why the population of the *Gymnodactylus amarali* lizards on the islands have larger heads. (5)

1.7.2 Describe how it can be proven that the species of lizard on the different islands are the same species as that on the mainland. (2)

Answers:

1.7.1 On the island there was variation in the size of *Gymnodactylus amarali* ✓ /lizards
Some lizards had smaller heads while others had larger heads ✓
When there were more larger termites on the islands ✓
Those with smaller heads died out ✓ since they could only eat the smaller termites
Those with larger heads survived ✓ could eat large termites
they reproduced and passed on their characteristic of larger heads to their offspring ✓
Eventually over time there was a greater proportion of lizards with larger heads ✓

1.7.2 If the island species can interbreed with the mainland species ✓ and produce fertile offspring they are the same species ✓ /if they do not produce fertile offspring, they are not the same species.

Read the extract below.

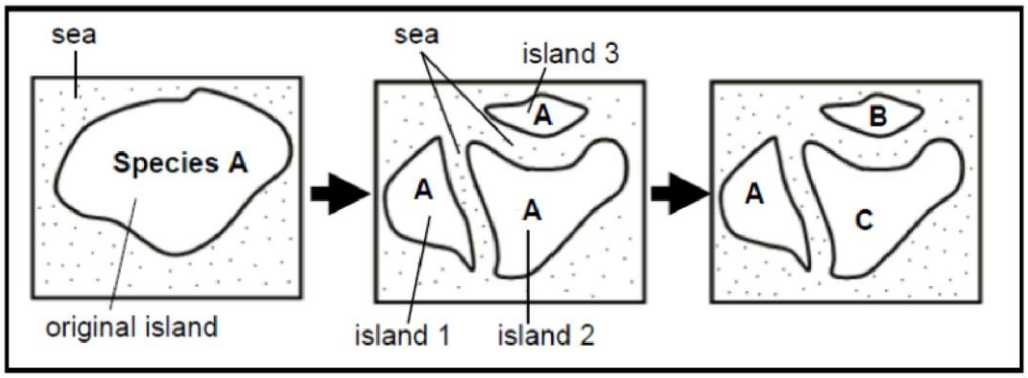
> Modern spider monkeys live high up in trees. They have very long tails which they use to hold on to branches. This reduces their risk of falling to the ground where they could be attacked by predators. The ancestor of spider monkeys had a much shorter tail.

1.8.1 Use Lamarck's theory to explain why all spider monkeys have long tails.
(6)

Answers:

1.8.1 According to **Lamarck's theory / laws of use and disuse***✓
And law of **inheritance of acquired characteristics***✓
the ancestors of spider monkeys had short tails✓
The ancestors stretched✓/used their tails
To be able to hold onto branches✓
Their tails became longer✓
and this characteristic was passed on to the next generation✓.

1.9 The diagrams below represent the process of speciation in tortoises.
Over a period of time species **B** and **C** evolved from species **A**.



1.9.1 Explain why species **A** continued to exist on island **1**.
(2)

1.9.2 Describe how species **B** and **C** evolved from species **A**.
(6)

Answers:

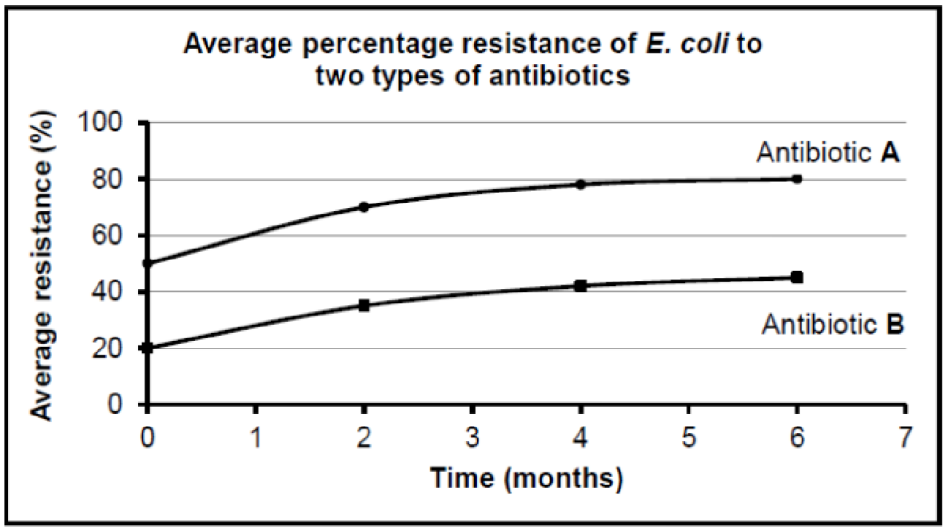
1.9.1 Conditions/example on the island probably remained the same ✓
so they experienced the same selection pressure ✓
species A was already suited to those conditions ✓

1.9.2 The original species was separated ✓ into three/different populations
by the sea ✓ *
There was no gene flow ✓ between the populations
Each population was exposed to different environmental conditions ✓
Natural selection occurred independently ✓ in each population
and the individuals of each population became different ✓ from each other over time
genotypically ✓ /phenotypically
Even if the three populations were to mix again ✓
they would not be able to reproduce with each other ✓ /interbreed

1.10 Certain The *E. coli* bacterium lives in the intestines of pigs where they reproduce rapidly.

strains of *E. coli* cause diarrhoea in young pigs (piglets).
Scientists carried out an investigation using 100 piglets to determine the resistance of *E. coli* to two antibiotics, **A** and **B**.

The results are shown in the graph below.



1.10.1 Identify the independent variable in this investigation.
(1)

1.10.2 Explain the results that are shown in the graph for antibiotic **A** in terms of natural selection.
(5)

Answers:

10.1 Type of antibiotic ✓

10.2 There was variation in the population of *E. coli* bacteria ✓
Some were resistant to antibiotic **A** ✓
others were not resistant ✓
Those *E. coli* bacteria which were not resistant to antibiotic **A** were killed ✓
Those which were resistant to antibiotic **A** survived and reproduced ✓
passing on the alleles for resistance to their offspring ✓
Over many years the percentage of *E. coli* bacteria dying decreases ✓ /the resistance increases.

TOPIC	LINK	QR CODE
DNA, RNA and protein synthesis	https://bit.ly/2lkL83C	
Meiosis	https://youtu.be/NRJcjjREcwc	
Theories of evolution	https://youtu.be/Y_AqhhRFjlk	