MONASH University

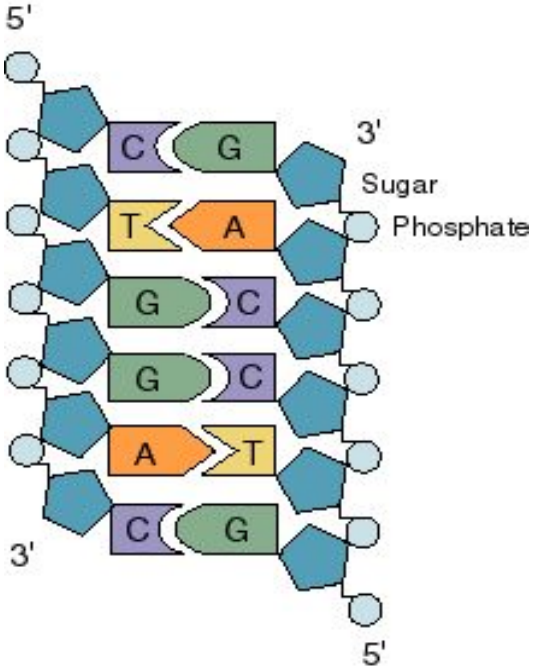
Biology Unit 3&4 Review

Presenter: Craig Major

GROUP OF EIGHT AUSTRALIA

Nucleic acids

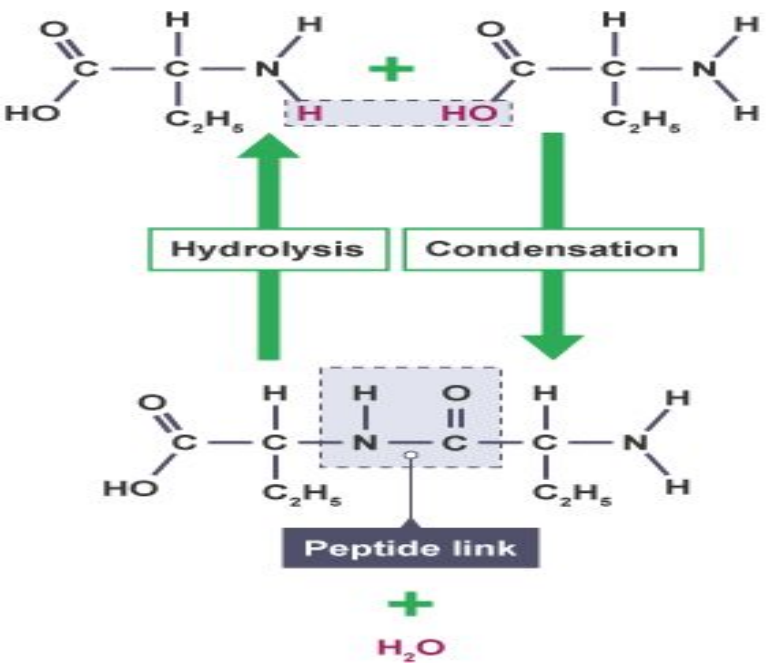
- Nucleic acids are composed of **Carbon, Hydrogen, Oxygen, Nitrogen** and **Phosphorus** in a ring like structure.
- There are only two types of nucleic acids, **DNA (deoxyribonucleic acid) and RNA (ribonucleic acid)**. Both are made of long chains of subunits called nucleotides.
- **DNA** carries the instructions that are required in order to construct proteins. Double stranded molecule. **ACTG**
- **RNA** (Ribosomes) is involved in the manufacture of the proteins and is a single stranded molecule. **AUCG**

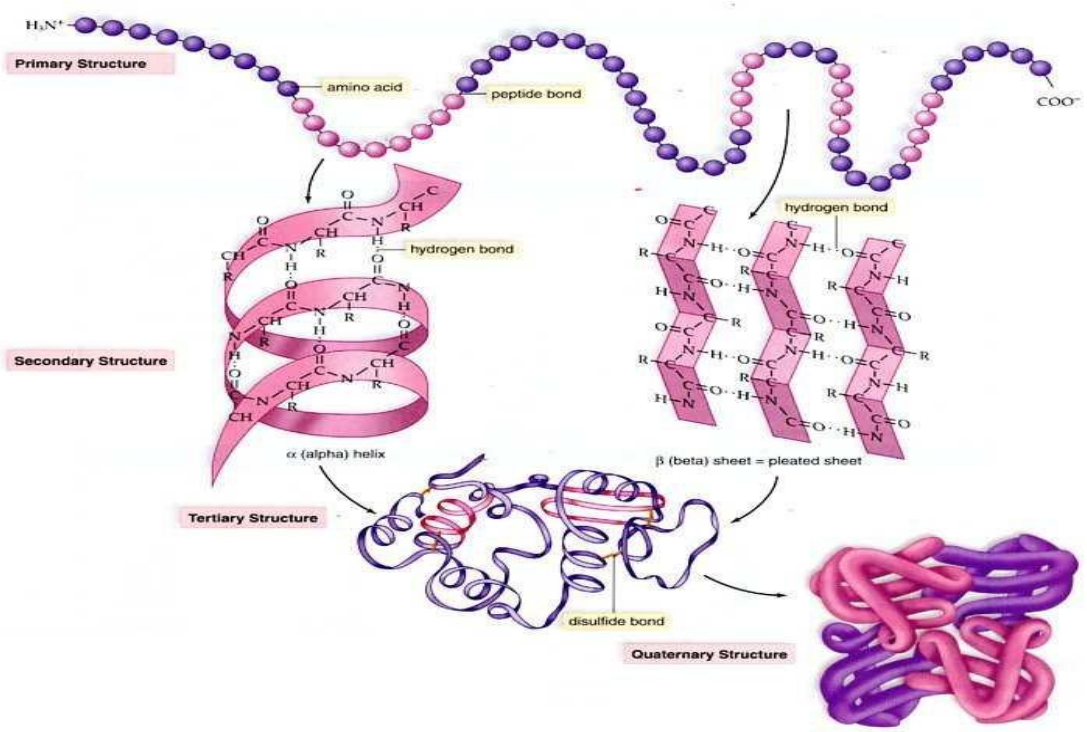


DNA	RNA
Codes for protein	Reads the code and produces protein
Composed of ATCG	Composed of AUCG
Double stranded	Single stranded
Deoxyribose sugar	Ribose sugar

Proteins

- All proteins contain **carbon, hydrogen, oxygen, nitrogen and sulphur.**
- Proteins are composed of chains of smaller sub-units called **amino acids**. Amino acids are joined together via **peptide bonds**, and form a **polypeptide chain**.
- Proteins need to be folded into a specific 3D shape in order to give them specificity. This involves alpha helix and beta pleated sheet folding.
- Proteome

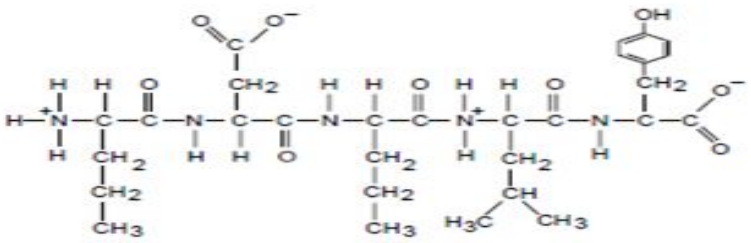




Question 1

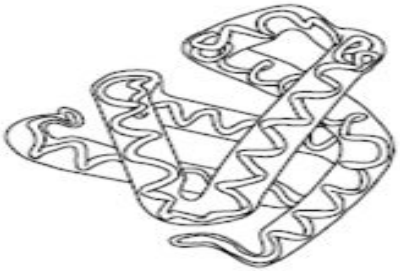
The secondary structure of a protein is represented by

A.

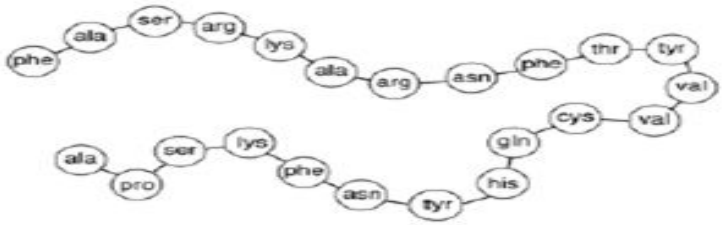


B.

C.



D.



Question 2

The proteome is

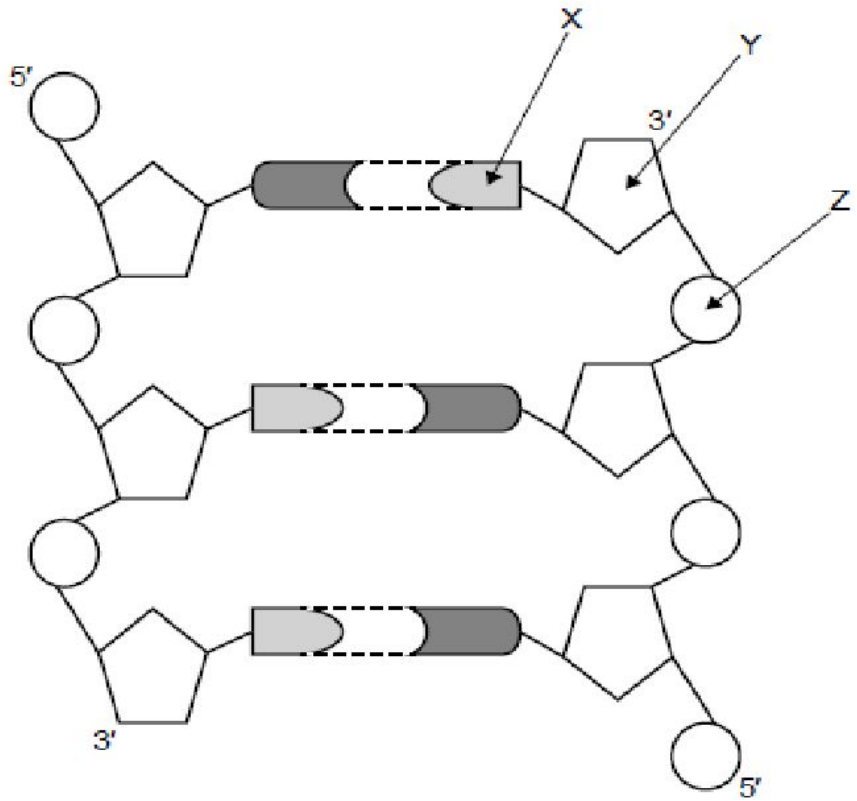
A. the total DNA content that is present within one cell of an organism.

B. a complete set of chromosomes found inside a cell of an organism.

C. the entire set of proteins expressed by an organism at a given time.

D. the four hierarchical levels of protein structure.

Question 3



A single DNA nucleotide is shown by sub-unit(s)

A. X alone.

B. X and Y together.

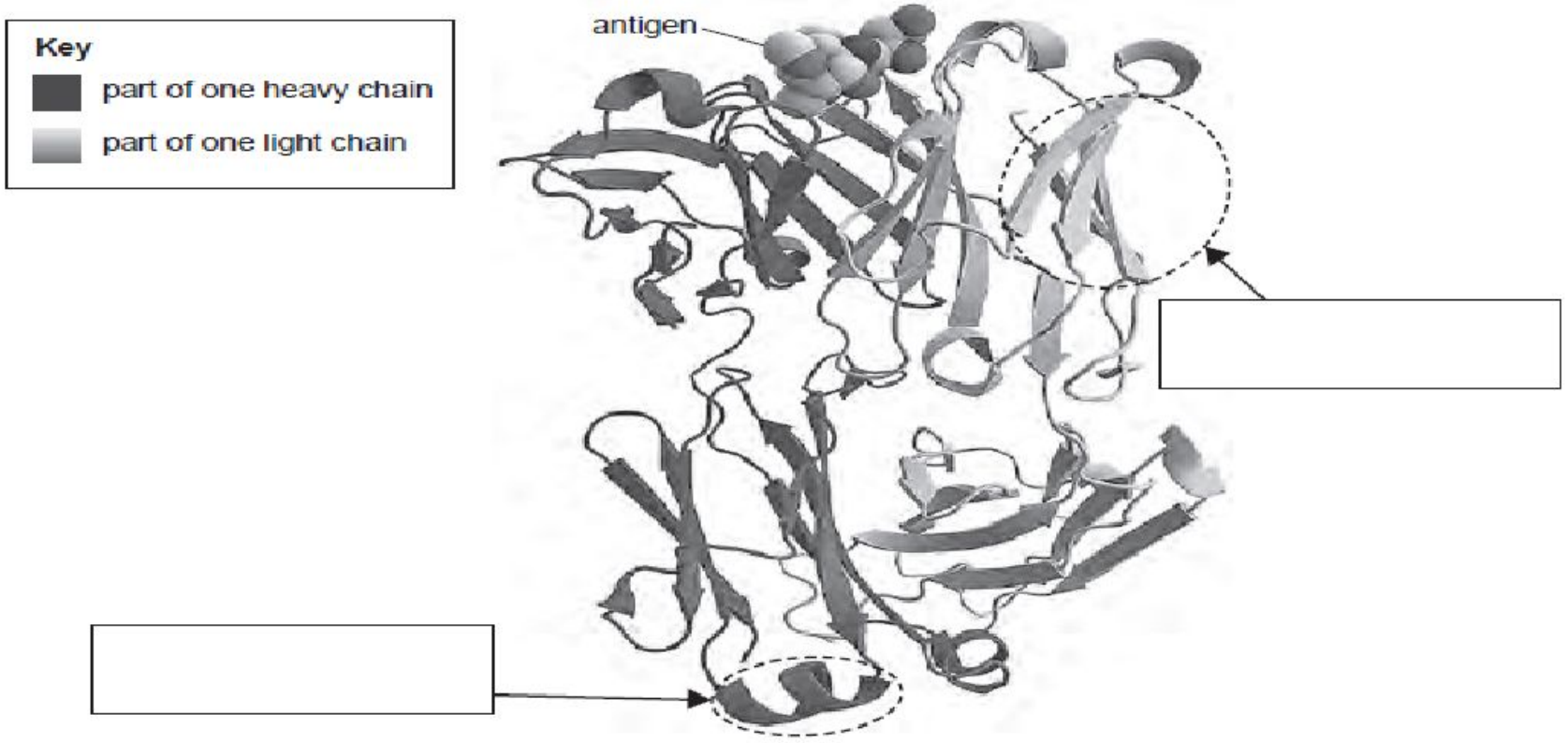
C. Y and Z together.

D. X, Y and Z together.

Question 4

Part of a mouse immunoglobulin molecule bound to an antigen is shown in the diagram below.
Two arrows point to two different types of secondary structures of the immunoglobulin molecule.

Give the name of each structure in the boxes provided. 2 marks



Source: Thomas Splettstoesser (www.scistyle.com)

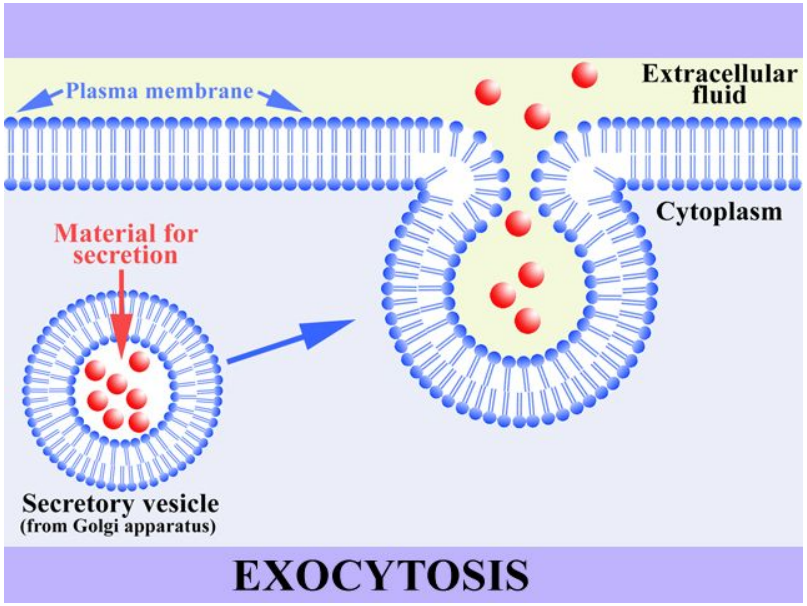
Immunoglobulin molecules also display a tertiary structure and a quaternary structure.

Referring to the diagram, explain what 'quaternary' means. 2 marks

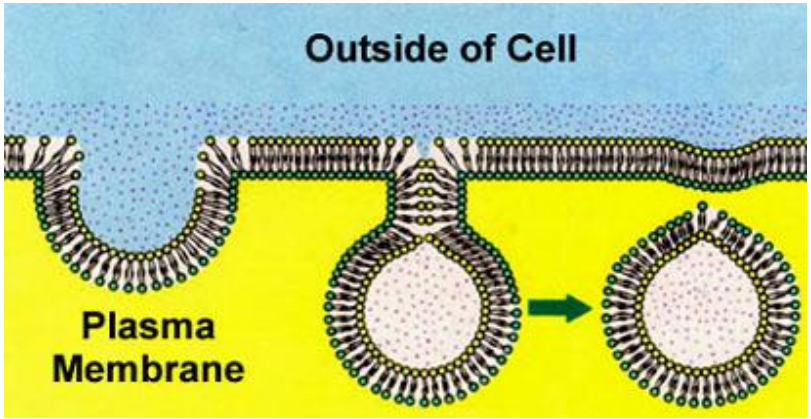
_____

_____

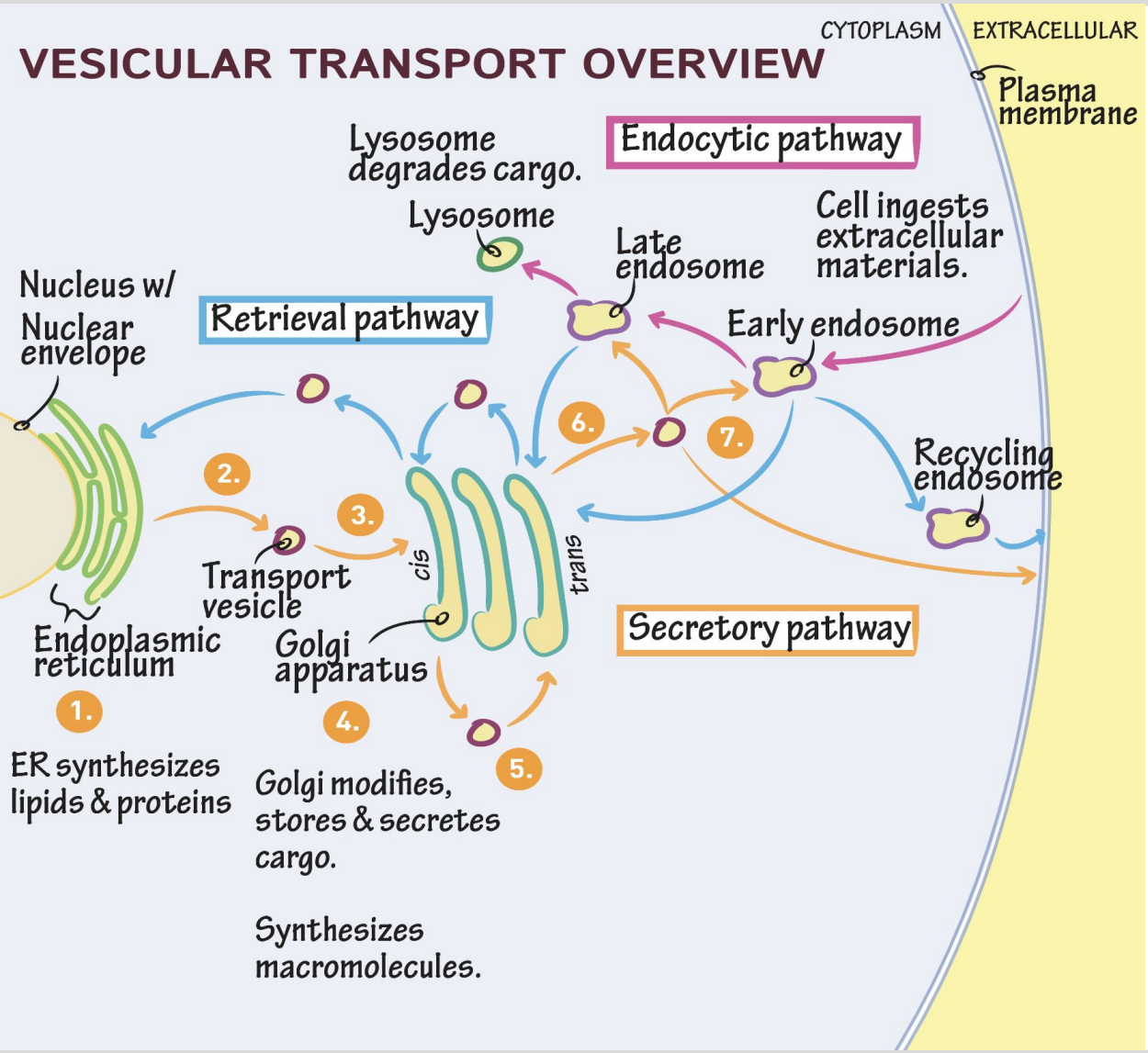
_____



Exocytosis:
Cellular products that have been created via the ribosomes and the smooth or rough endoplasmic reticulum move to the Golgi body to be packaged within a lipid based vesicle.
The lipid based secretory vesicle is necessary in order for successful exocytosis as the cellular membrane needs to interact with the vesicle. Upon exocytosis the cellular membrane gets slightly larger.

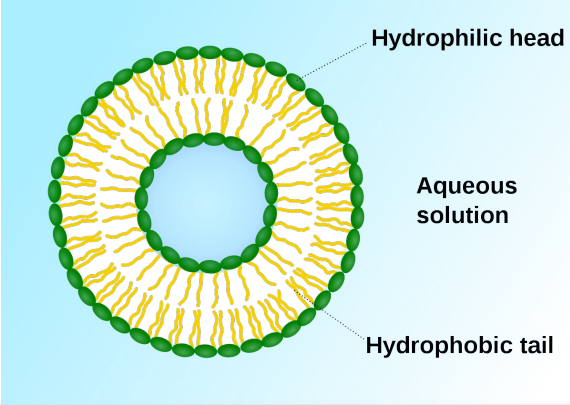


Endocytosis:
Products produced from other cells or molecules that are necessary for effective cellular communication need to enter the cell. To do this a small portion of the cellular membrane is pinched off. The vesicle is then broken down by a lysosome to free the cellular product.



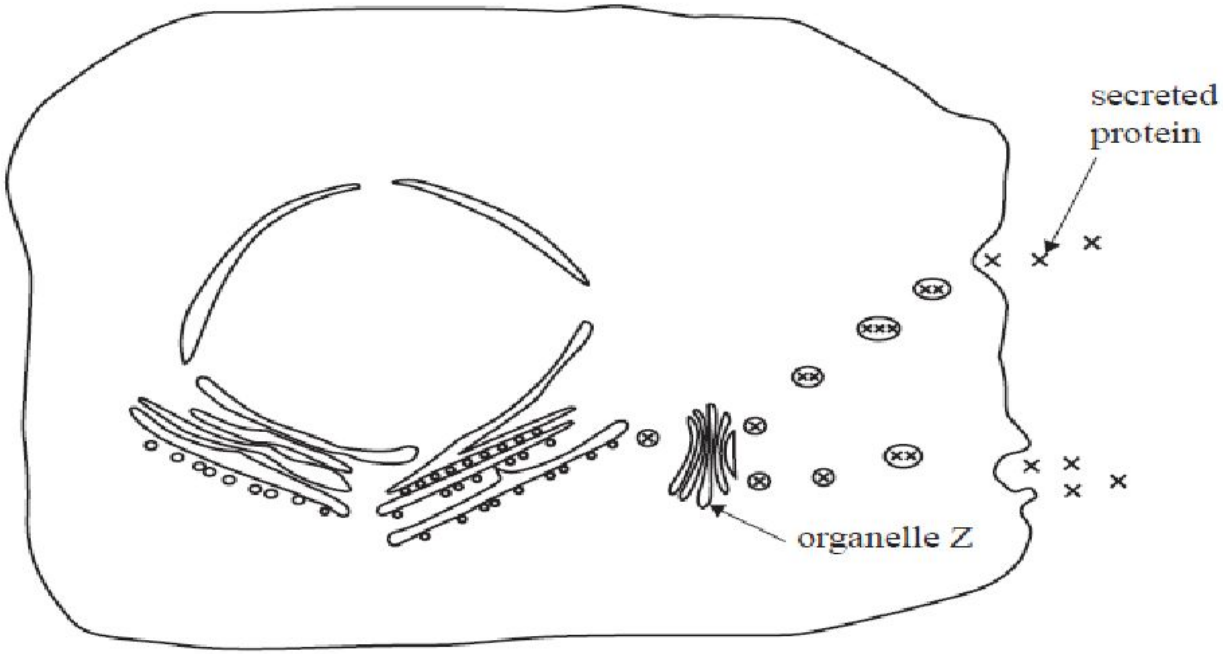
Vesicle transport.

- All internal transport within the cell requires vesicles.
- All vesicles are composed of phospholipids.
- All vesicles are composed of a double layer of phospholipids.
- The double layer allows for the creation of an internal aqueous environments.



Question 5

The diagram below represents a human cell secreting protein molecules.



The role of organelle Z is to

A. produce energy for protein production.

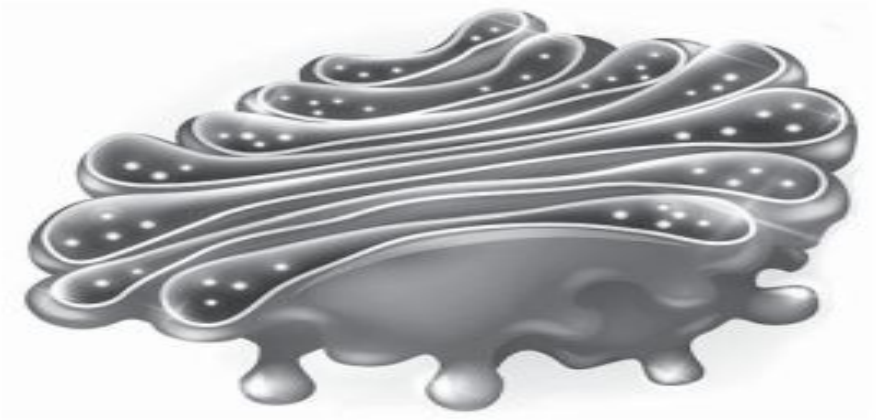
B. transport protein through the cytosol.

C. synthesise protein for secretion.

D. package protein into vesicles.

Question 6

The diagram below shows the structure of an organelle in a cell.



Source: Tefi/Shutterstock.com

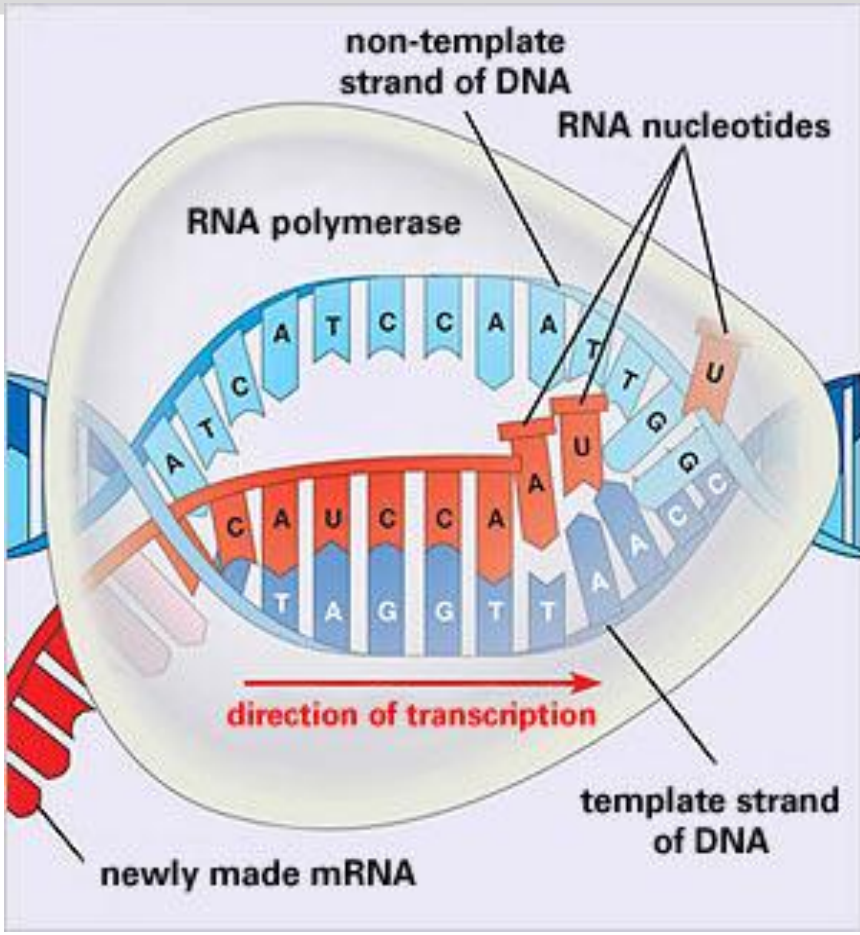
The organelle would

A. synthesise most of the ATP molecules required by a cell.
B. modify and package proteins into secretory vesicles.
C. transport proteins throughout the cytosol of a cell.
D. assemble amino acids into proteins.

Protein creation

Transcription:

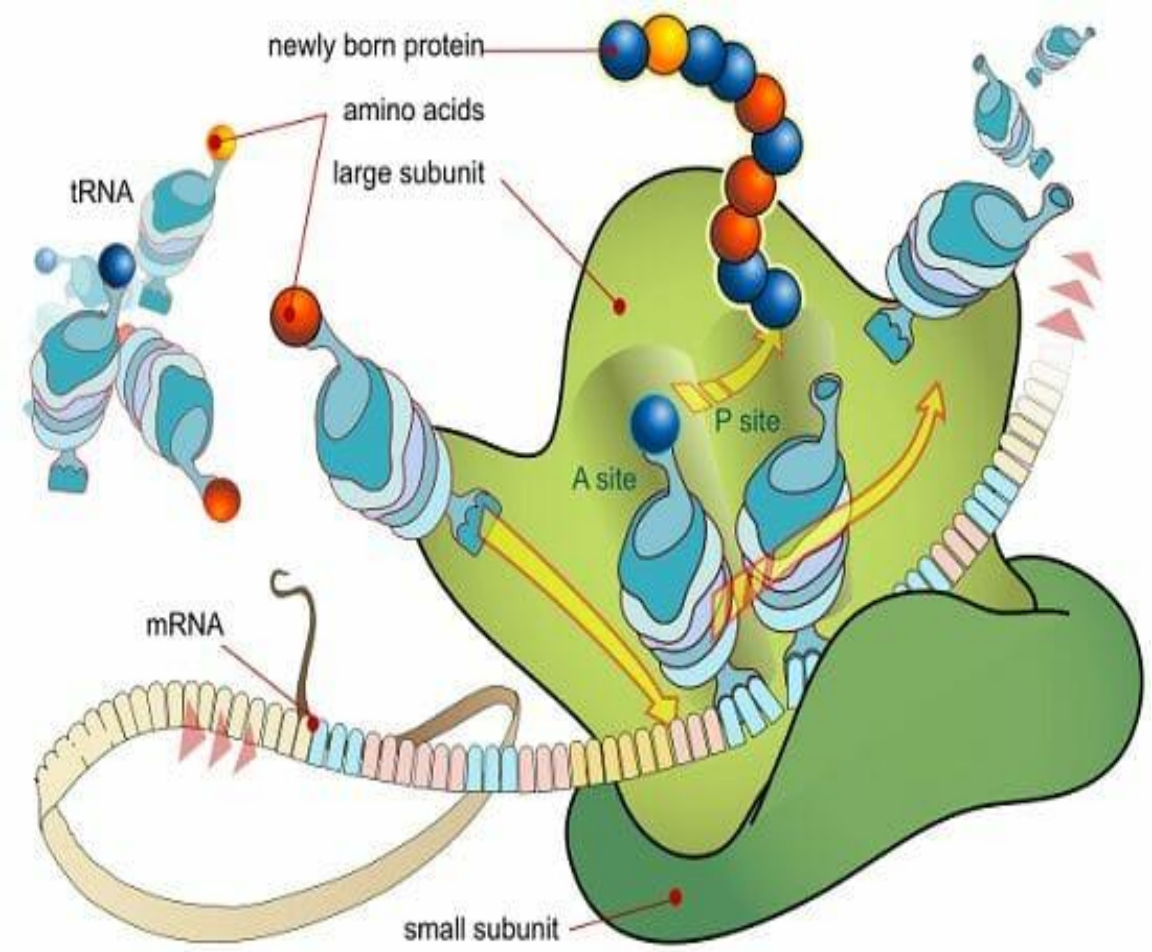
- Occurs within the nucleus of a cell
- An enzyme known as RNA polymerase unzips the DNA and copies one strand.
- The single stranded complementary copy that is made is called mRNA. The nucleic acid Uracil now replaces Thymine.
- Pre-mRNA is created.
- ***POST TRANSCRIPT MODIFICATION (RNA processing)***
- Introns are removed, exons are stuck together to create mRNA.
- Post transcription modification involves attaching a poly A tail (3') and a methyl cap (5') to make the mRNA stable.



DNA: A C T T T A G A G T
mRNA: U G A A A U C U C A

Translation:

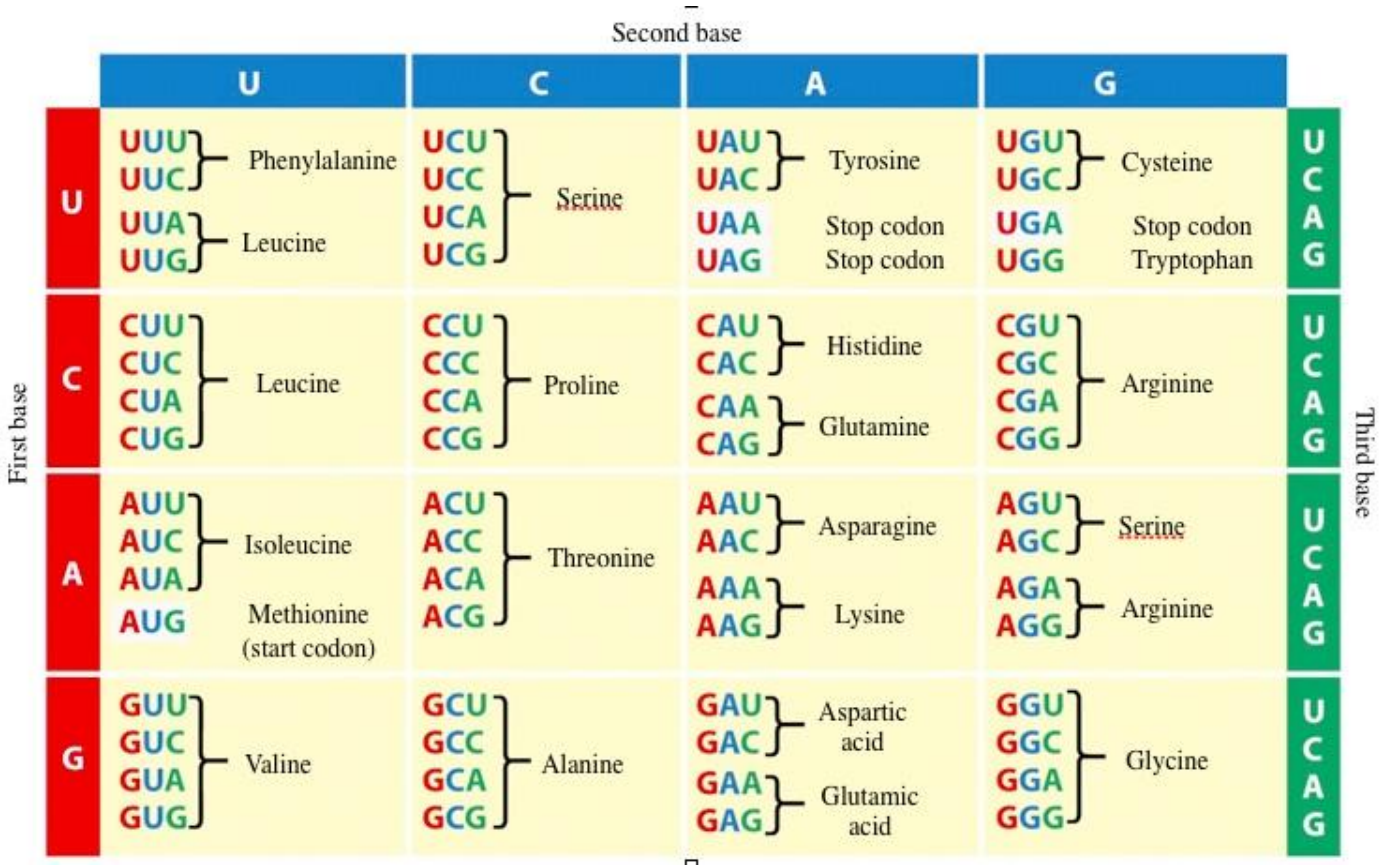
- Occurs within the cytoplasm.
- mRNA from the nucleus moves out into the cytoplasm and interacts with ribosomes (rRNA).
- rRNA subunits attaches to the mRNA and provides the mechanism for the construction of a polypeptide chain.
- Eukaryotic subunits are 60s and 40s.
- Prokaryotic subunits are 70s and 30s.
- X3 mRNA bases equals 1 amino acid.
- tRNA brings the appropriate amino acid that corresponds to the mRNA triplet via a codon anticodon relationship.



Post translational modification

Amino acid tables.

DNA – ATG GTA TTA TTT AAA GGT GCT
mRNA- UAC CAU AAU AAA UUU CCA CGA
tRNA- AUG GUA UUA UUU AAA GGU GCU



The DNA code is considered to be degenerative or redundant. Ie more than one DNA triplet/RNA codon can code for a specific amino acid.
This provides an element safety to ensure that not all mutations result in abnormal proteins being created.

DNA vs RNA

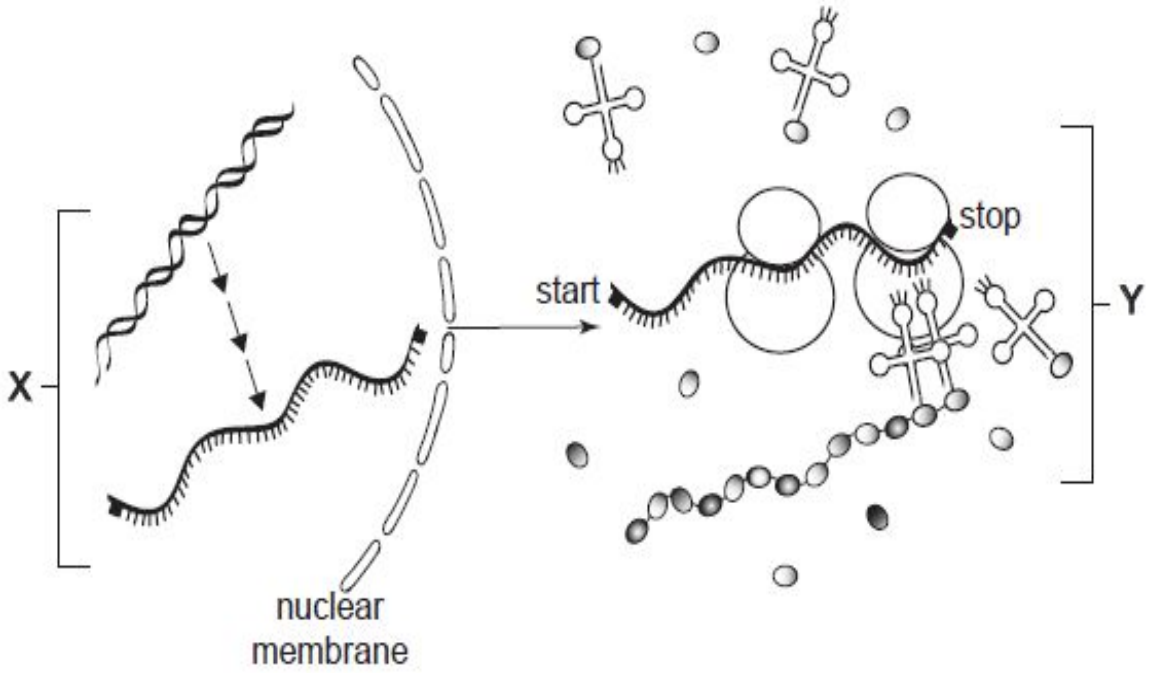
DNA	RNA
Codes for protein	Reads the code and produces protein
Composed of ATCG	Composed of AUCG
Double stranded	Single stranded
Deoxyribose sugar	Ribose sugar

RNA comparison

RNA type	Function
mRNA	Single stranded copy of DNA template strand. (Uracil replaces Thymine). Pre-mRNA vs mRNA
tRNA	Single stranded, transports amino acids to mRNA via corresponding base sequences.
rRNA	Subunits that allow for the interaction of mRNA and tRNA. Allows for the growing peptide chain to be created.

Question 7

The following diagram outlines processes that occur in living cells.



a. **i.** Name the process represented at **X**.

_____

ii. Describe the sequence of events that occur during the process at **X**.

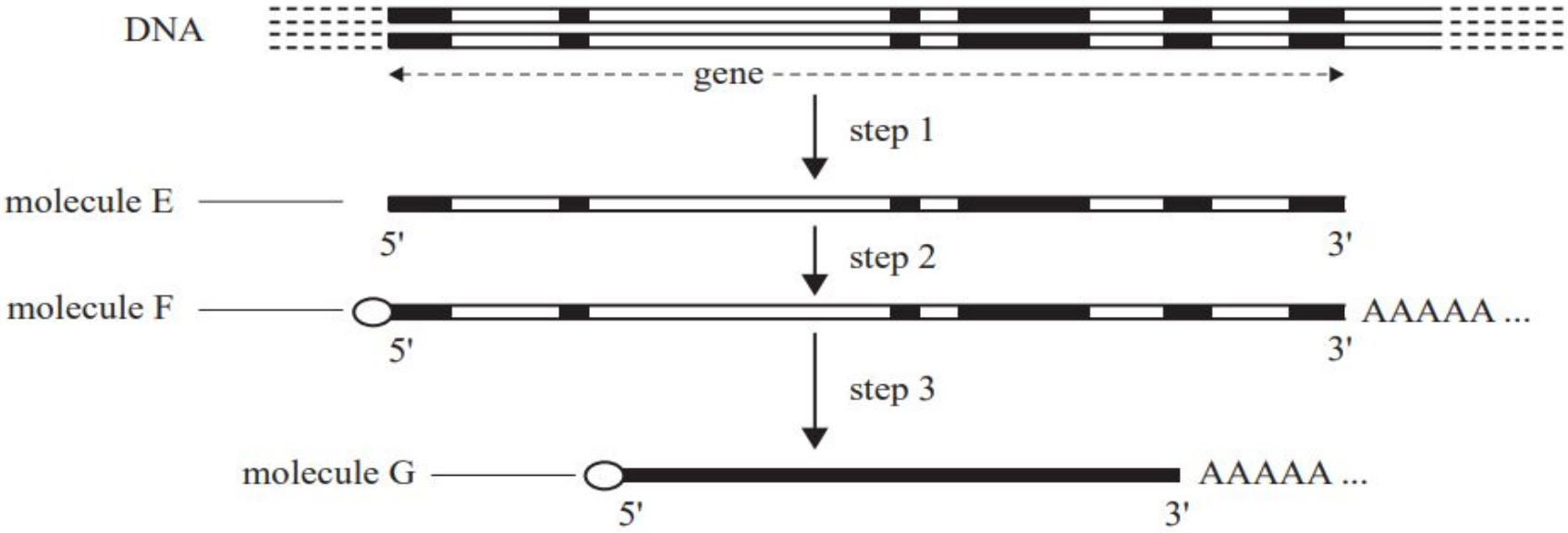
_____

_____

_____

Question 8

The following diagram shows some of the steps in the production of a protein within a cell.



Which one of the following is a correct statement?

A. Step 1 represents translation.

B. There are six introns in the gene.

C. RNA polymerase is required for Step 3.

D. The circle on molecule F represents a modified guanine molecule.

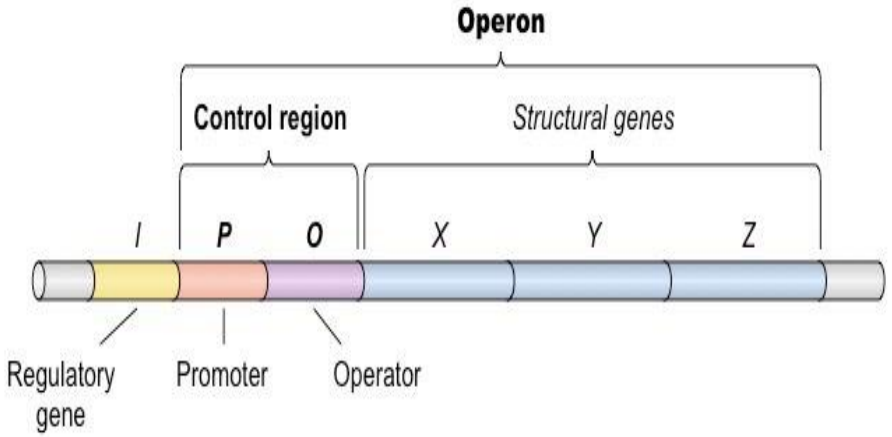
Question 9

Different cells within an organism have different proteins. In some cases different proteins can be coded for by the same gene.

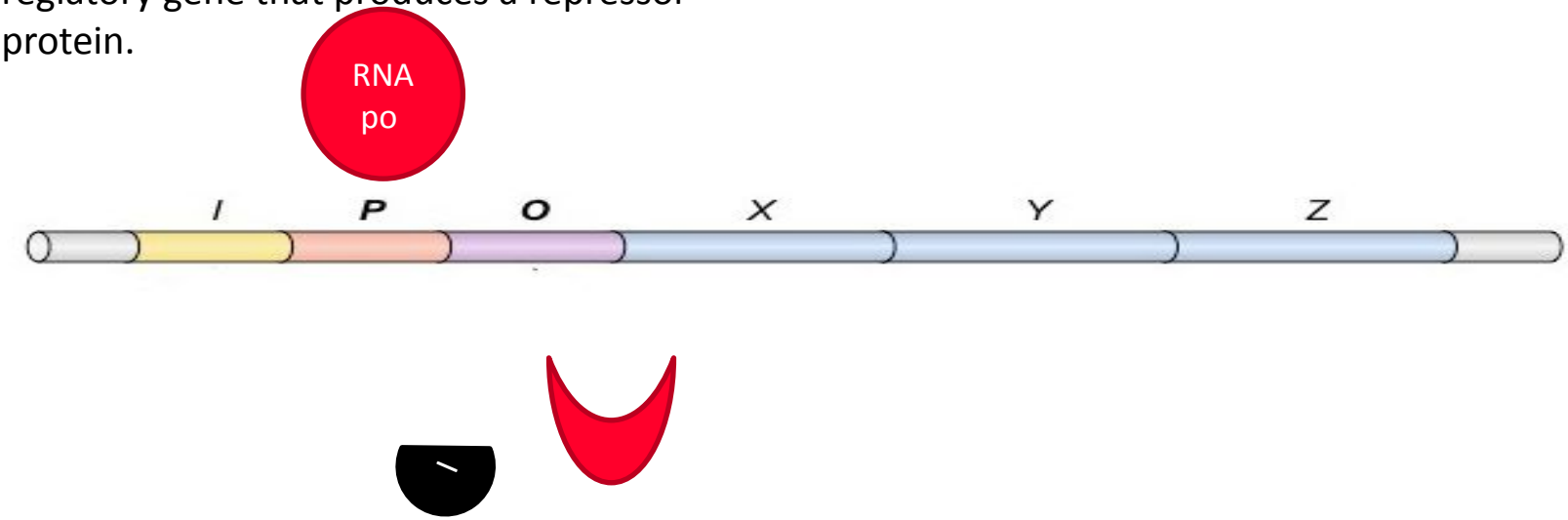
Explain how the expression of a single gene can lead to the production of different proteins. 3 marks

Gene regulation basics

- Genes are arranged into sections called operons.
- Operons differ between prokaryotic and eukaryotic system.

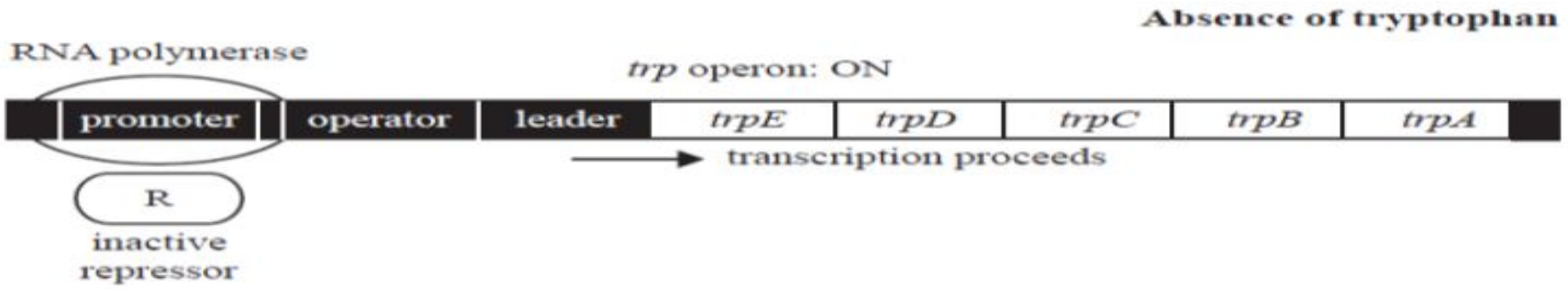


- A basic operon is composed of a promoter region, an operator region and strctural genes. (POG)
- The operons function is then reulated by a reglatory gene that produces a repressor protein.

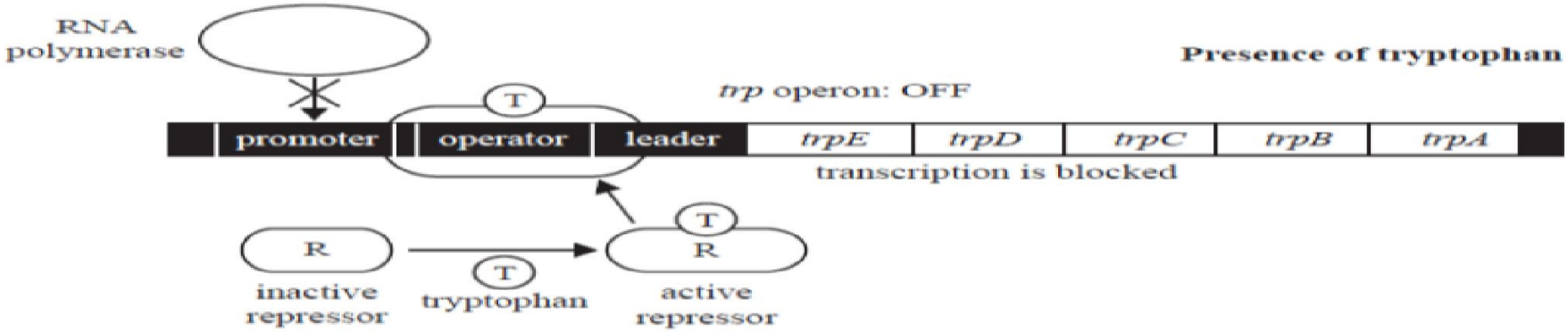


Gene regulation: Tryptophan. (trp: repressible)

The natural state of the gene is the **ON** position, where the repressor does not attach to the operator and does not block the enzyme RNA polymerase. Therefore continuous transcription and translation

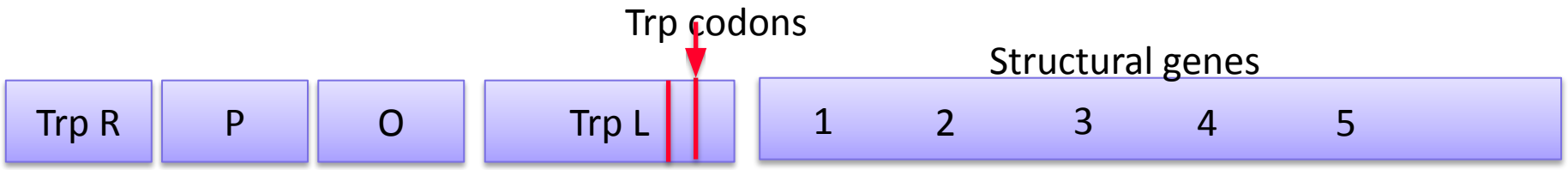


In the **OFF** position the repressor is activated by the presence of tryptophan. The Repressor attaches to the operator and blocks the RNA polymerase access to the gene. Therefore transcription is prevented.



Gene regulation: Tryptophan attenuation and basal rate

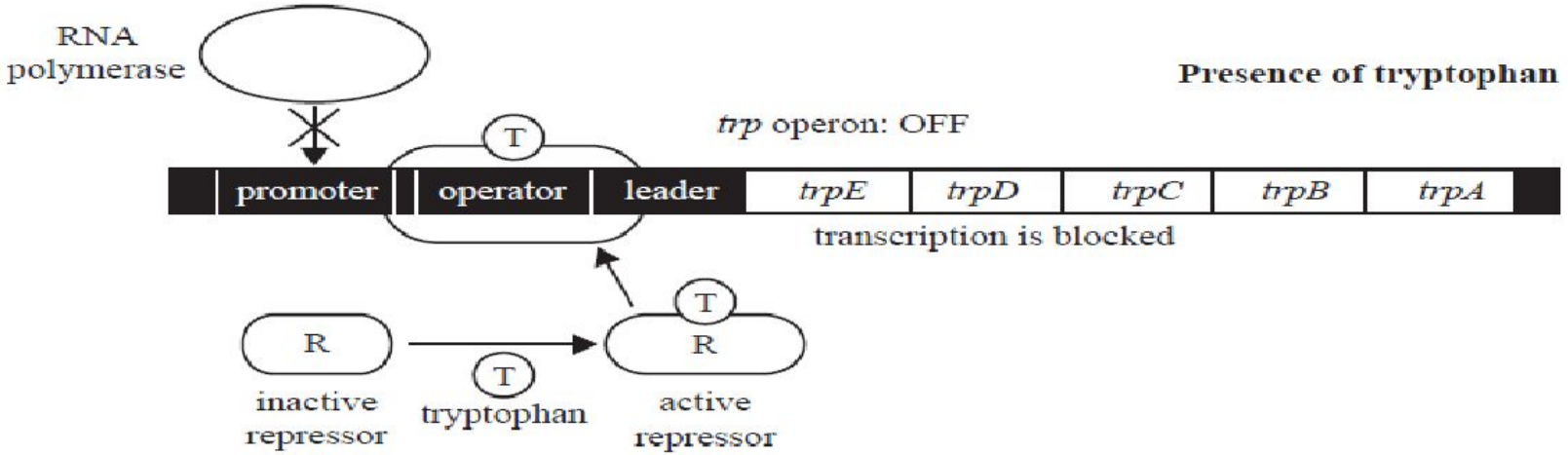
The active tryptophan repressor that blocks RNA polymerases access to the operator and the downstream structural genes is not 100% effective.
It will occasionally disconnect and allow RNA polymerase to access and transcribe the structural genes and therefore produce tryptophan at a low basal rate. To overcome this the LEADER SECTION (trp L) AND ATTENUATORS (hair pin folds) are used.

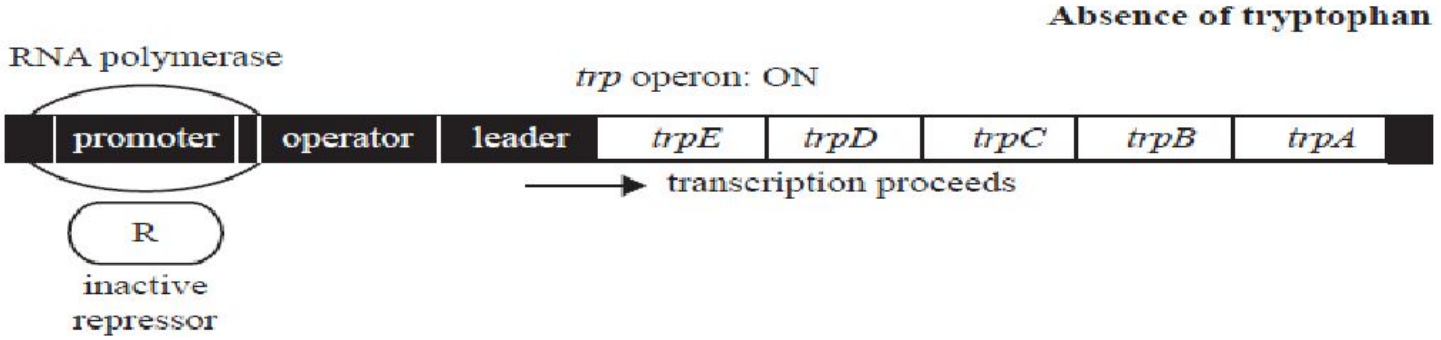


When trp is low the RNA polymerase will transcribe Trp L and the structural genes.
Translation occurs just behind transcription. The Ribosome will pause at the trp codons to wait for tryptophan tRNA to become available. During this wait the mRNA folds to create a hair pin loop (2/3 region). This loop allows the ribosome to complete translation and produce trp.

When trp is high the ribosome does not need to pause in the trp L region The allows a terminator hairpin loop to form between the 3 /4 region. The hairpin causes the ribosome to disengage from the mRNA and trp is not produced.

In *Escherichia coli* (*E. coli*) bacteria, the five genes that code for the enzymes involved in the synthesis of the amino acid tryptophan are regulated. The five genes are grouped together in an operon referred to as the *trp* operon. The diagrams below illustrate how the genes are regulated.

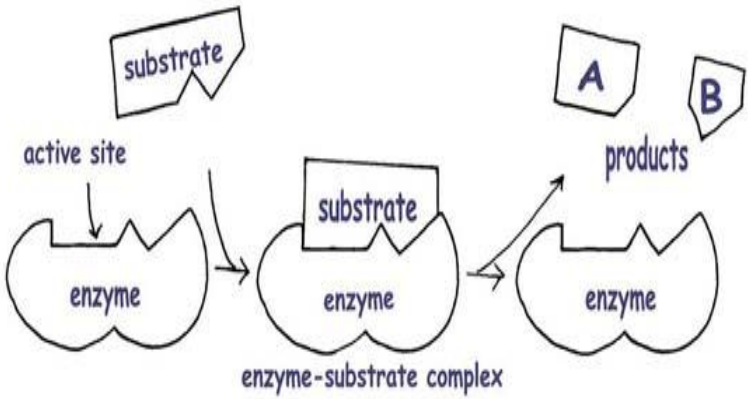


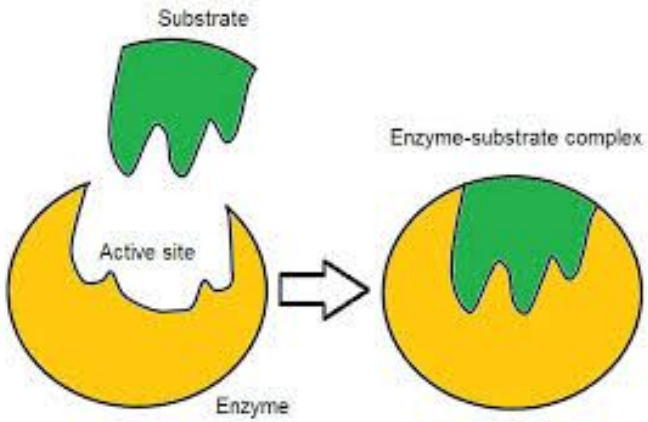


b. Describe how changes to the level of tryptophan in the cell changes the level of transcription of these five genes. Refer to the role of both the promoter and the operator in your response. 5 marks

Enzymes:.

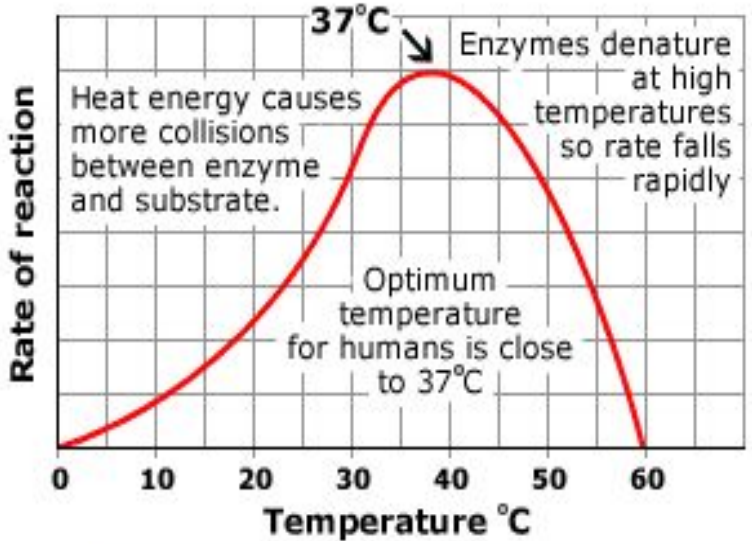
- Enzymes are proteins, and their actions are generally specific, each enzyme catalysing only one type of reaction.
- The enzymes specificity is related to its 3 dimensional structure.
- Enzymes are biological catalysts and as such are not used up in the specific reaction but are recycled.



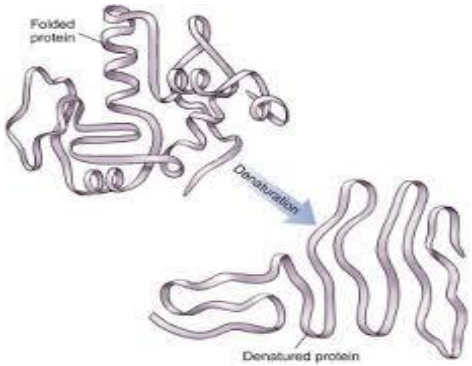


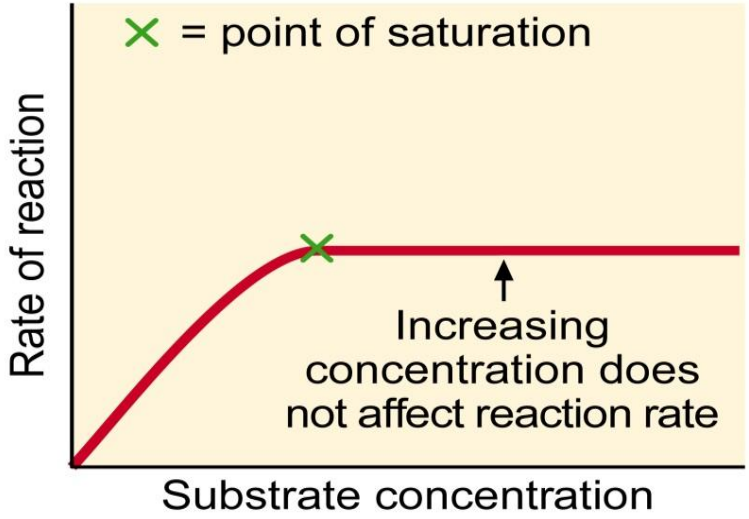
Enzymes make reactions take place more easily via lowering the amount of energy required to start the reaction. They DO NOT change the direction of the reaction nor do thy change the amount of product produced

Factors affecting Enzyme operation:



1) Temperature: Above an enzymes critical temperature the H+ bonds holding the tertiary or quaternary structure break and the active site is slowly destroyed (process of denaturation)



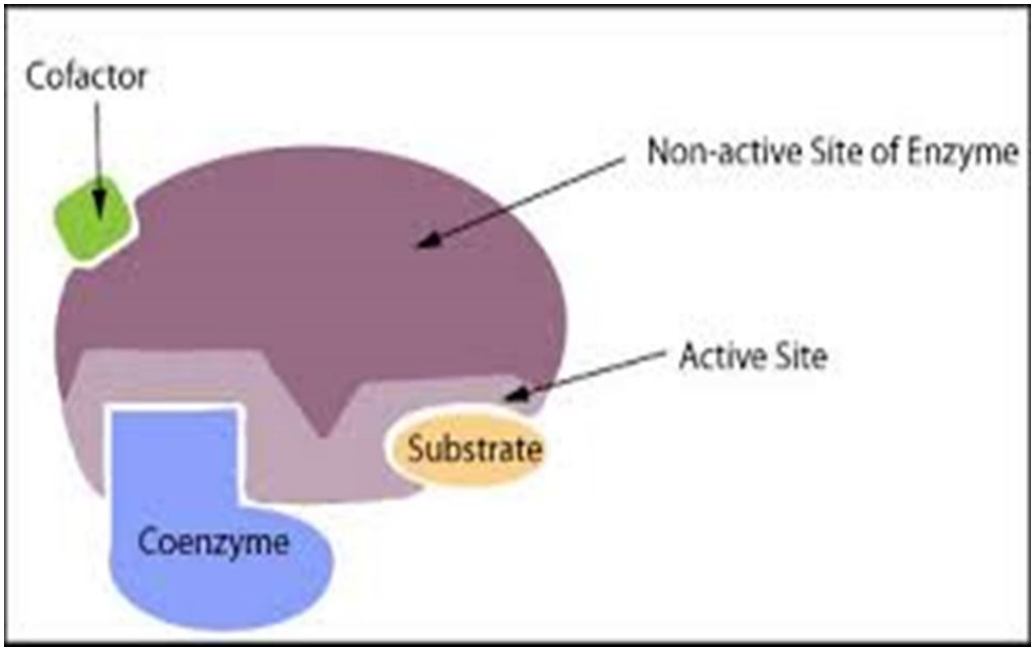


2) Concentration: A reaction will only accelerate while there is an excess of enzymes to substrate. Therefore when all available enzyme active sites are full of substrate the reaction stops accelerating.

3) Enzymes may require the presence of a co-factor or a coenzyme in order to facilitate their function.

Coenzymes are organic molecules that are required by certain enzymes to carry out catalysis. E.g. NAD^+

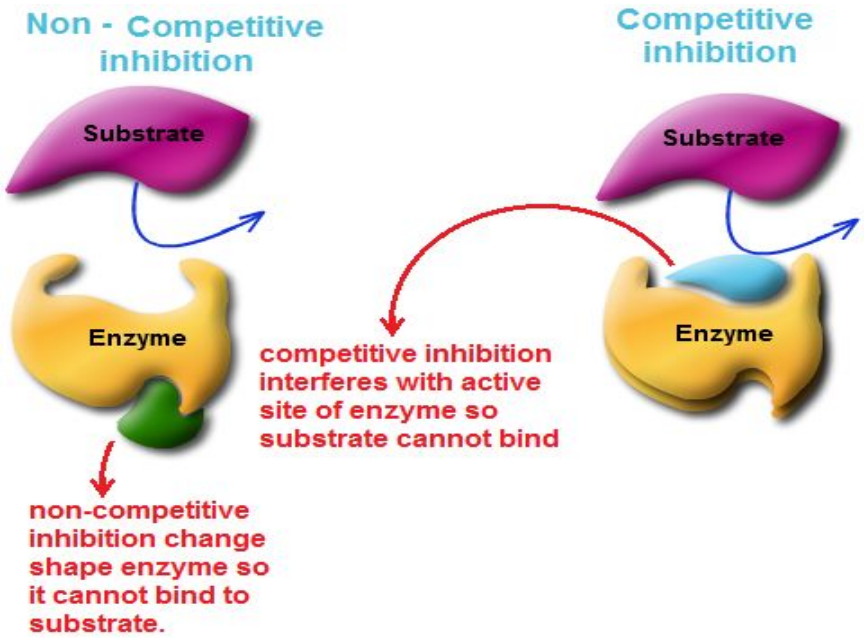
Cofactors are often classified as inorganic substances that are required for, or increase the rate of, catalysis.



Enzymes generally work in concert with other enzymes in biochemical pathways. As such the function of one enzyme is generally dependent upon the functioning of another.

4) Enzyme inhibitors:

molecules or compounds that bind to enzymes and result in a decrease in their activity. An inhibitor can bind to an enzyme and stop a substrate from entering the enzyme's active site and/or prevent the enzyme from catalysing a chemical reaction. There are two categories of inhibitors.



Non competitive inhibition:

Non competitive inhibitors do not bind to the active site of the enzyme but to another region called the “allosteric site”, which then may alter how the enzymes active site interacts with the given substrate.

Competitive inhibition:

Competitive inhibitors bind directly to the active site and out compete the natural substrate for access to the given active site.

The concept of rational drug design is based on this principle.

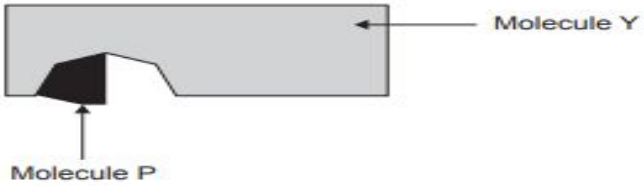
Question 11

The diagram below represents a generalised biochemical process.

Which one of the following statements is correct?

A. Molecule Y represents the substrate.
B. Molecule X represents an enzyme.
C. Structure A is an active site.
D. Molecule Z is a reactant.

Another molecule, Molecule P, can bind to part of Structure A of Molecule Y, as shown below.



Question 12

Consider a mixture containing molecules of X, molecules of Y and molecules of P. The rate of production of Molecule Z and Molecule W is measured and found to change in the presence of Molecule P. In the presence of Molecule P, increasing the concentration of Molecule X increases the rate of production of Molecule Z and Molecule W.

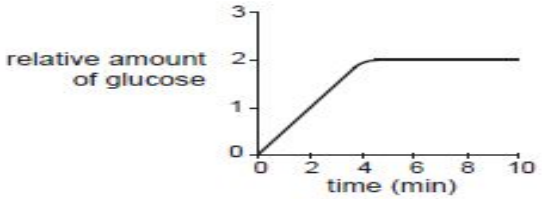
Which one of the following statements is correct?

A. Molecule X changes shape in the presence of Molecule P.
B. Molecule P is considered a reversible inhibitor.
C. Molecule Y is denatured by Molecule P.
D. Molecule P is made from monomers of nucleotides.

Question 13

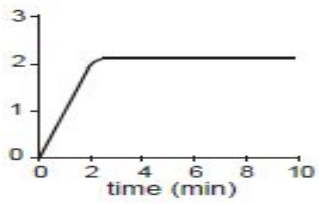
Two test tubes where set up using 5 mL of lactose syrup and 0.5 mL of lactase. Test tube **one** was incubated at 37°C, while test tube **two** was incubated at 15°C. Both tubes were incubated for 10 minutes.

In another experiment, test tube **three** was compared with test tube **four**. Each tube contained 5 mL of lactose syrup. Tube **three** contained 0.5 mL of lactase and tube **four** contained 0.25 mL of lactase. The two tubes were incubated at 15°C and monitored for 10 minutes.
The result for test tube **three** is shown below.

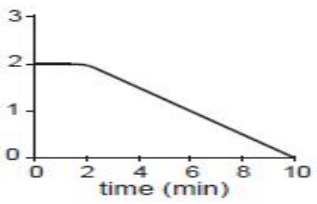


The graph of results for tube **four** would resemble

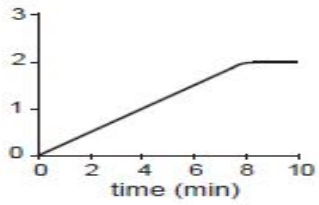
A.



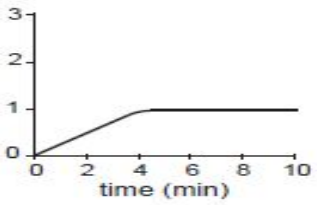
B.



C.



D.

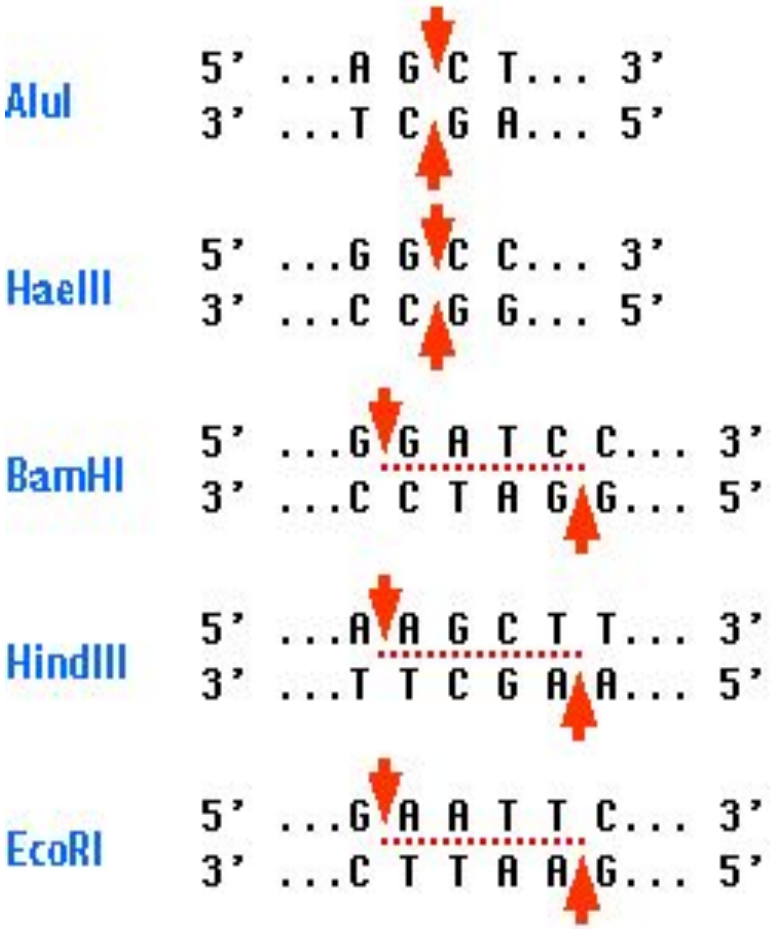


Genetic engineering tools and techniques :

1) Restriction enzymes:

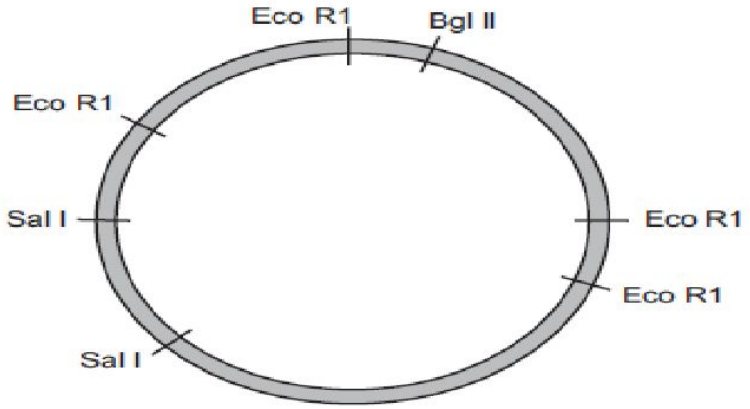
Restriction enzymes cut at specific nucleotide sequences. For example the R.E HindIII cuts at AAGCTT sequence while the R.E Bgl II cuts at the sequence AGATCT.

Hundreds of such cutting enzymes exist, they naturally occur within halophile bacterial species and usually its just a matter of finding 2 enzymes that are going to cleanly cut the desired DNA fragment out.



Question 14

The following diagram indicates the cutting sites of three different restriction enzymes on a particular bacterial plasmid.



If the plasmid was incubated with the restriction enzyme *Eco* R1, the number of pieces of DNA obtained would be

A. two.
B. three.
C. four.
D. seven.

Question 15

Consider the DNA sequence below and the associated list of restriction enzymes with their corresponding recognition sites.

AACTTTAGCCCCGGGAGCACGAATTCGGATGCTTGCTCGATAGCAACGTC
TTGAAATCGGGGCCCACGTGCTTAAGCCTACGAACGAGCTATCGTTGCAG

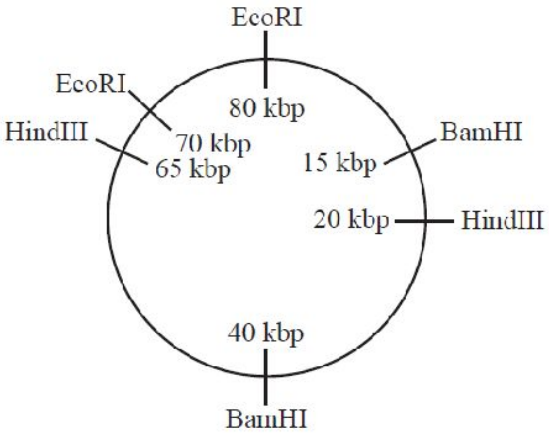
Restriction enzyme	Binding site
*Eco*RI	G A A T T C
*Sma*I	C C C G G G
*Taq*I	T C G A

If the DNA strand shown above was mixed with all three restriction enzymes, how many strands would be formed?

A. 1
B. 2
C. 3
D. 4

Question 16

Consider the following plasmid that has a total length of 80 kbp. The recognition sites for three restriction enzymes are shown.



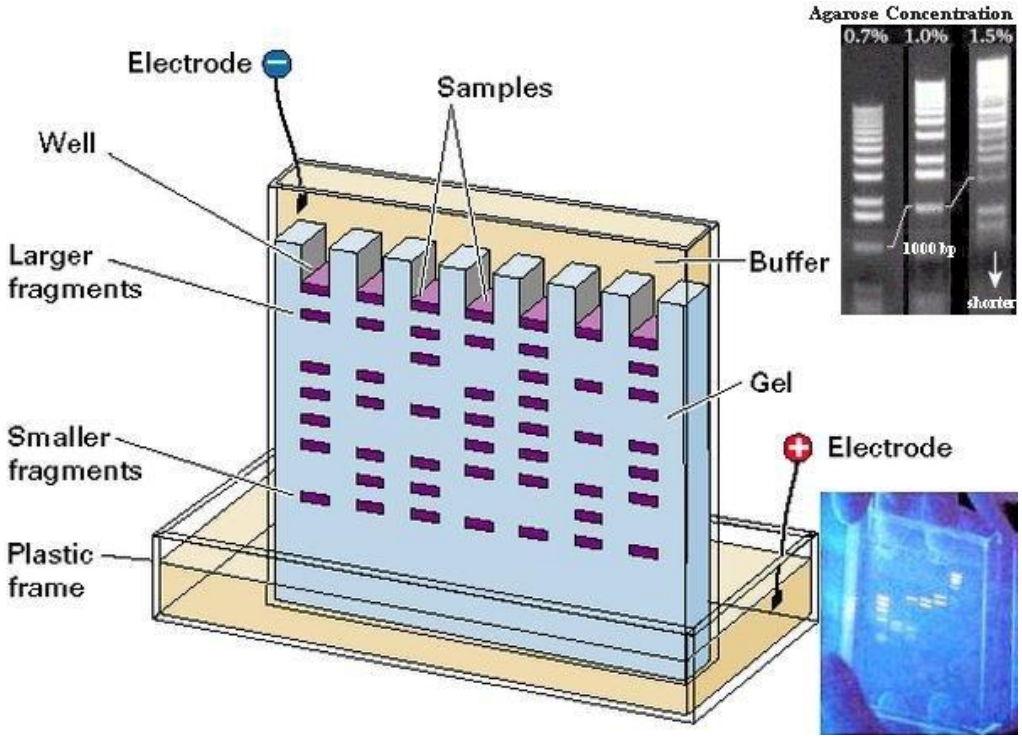
The plasmid above was treated with both restriction enzymes EcoRI and BamHI.

How many fragments of DNA would be produced and what would be the respective lengths of these fragments?

	Number of fragments	Lengths (kbp)
A.	4	5, 15, 25, 40
B.	4	10, 15, 25, 30
C.	6	15, 20, 40, 65, 70, 80
D.	6	5, 10, 15, 20, 25, 30

2) Gel Electrophoresis:

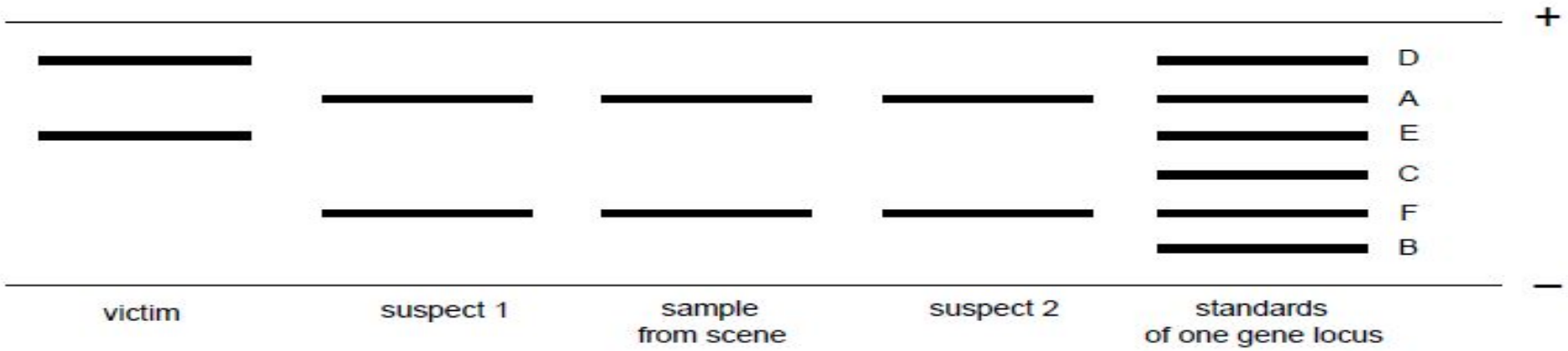
Gel electrophoresis is a method that is based on the principle of causing DNA fragments to migrate towards a positive electrode (as DNA has a overall negative charge) while forcing it to move through a matrix called agarose. The agarose matrix is designed to allow small fragments to travel through quickly while slowing down the larger fragments.



Question 17

Small pieces of DNA of differing length can be compared to determine whether or not a sample could have come from a particular person. In a case, samples of DNA from the victim and the crime scene were compared with samples from two suspects.

The DNA samples were treated with restriction enzymes, amplified and run through gel electrophoresis. The results for one gene locus are shown in the diagram below.

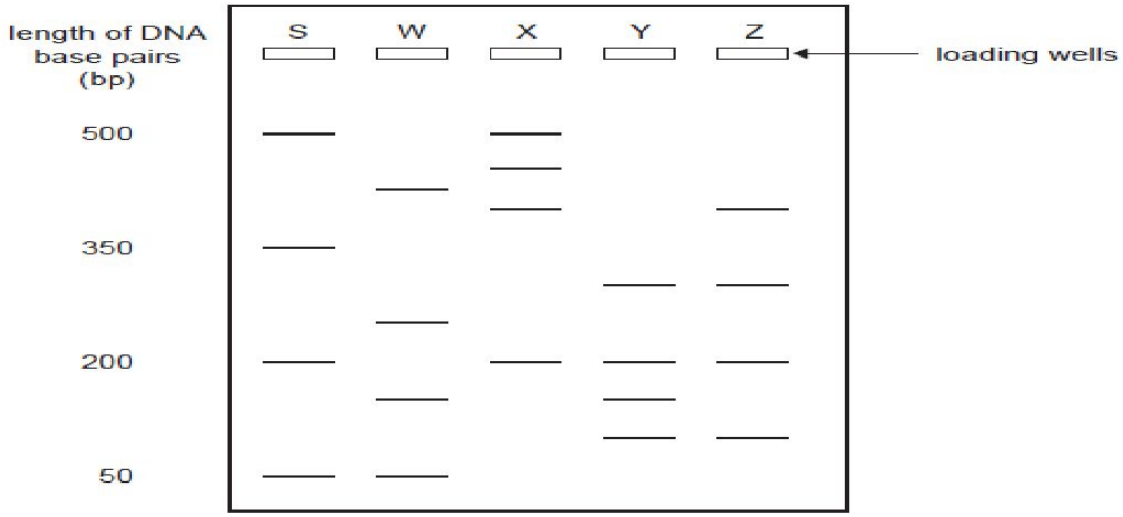


d. Draw an arrow on the right-hand side of the diagram to indicate the direction of movement of the DNA fragments.

e. What do the standards consist of, and what is their purpose?

f. From these results, give a conclusion which could be drawn about the sample taken from the crime scene.

Four samples of DNA were loaded into four different wells in lanes W, X, Y and Z. A standard ladder was loaded into the well in lane S. The results of gel electrophoresis are shown below.



Question 18

Which lane represents a sample that was loaded with DNA fragments of four different lengths: 100 bp, 150 bp, 200 bp and 300 bp?

A. W
B. X
C. Y
D. Z

Question 19

Which lane contains the band that is closest to the negative electrode?

A. W
B. X
C. Y
D. Z

DNA profiling

DNA profiling is a technique by which individuals can be identified and compared via their respective DNA profiles

- Within the non-coding regions of an individual's genome there exists satellite DNA – long stretches of DNA made up of repeating elements called *short tandem repeats* (STRs)
- As individuals will likely have different numbers of repeats at a given satellite DNA locus, they will generate unique DNA profiles

The owners of a young dog want to verify the parentage of their dog. They obtained a DNA profile for their young dog and compared it with the profiles of four older dogs. The profiles were made using many short tandem repeat (STR) markers, each marker having alleles of different lengths. The size of an STR marker is measured by the number of base pairs in the marker. The results for four of the STR markers are shown in the table below.

	Base pairs per allele				
STR marker	**Young dog**	**Dog 1**	**Dog 2**	**Dog 3**	**Dog 4**
1	110, 125	110, 120	110, 120	125, 130	125, 130
2	153, 155	150, 153	150, 155	155, 160	150, 160
3	100, 100	100, 105	100, 107	100, 109	100, 100
4	234, 248	200, 234	200, 234	200, 248	200, 248

Question 20

Based on the information given, the parents of the young dog could be

A. Dog 1 and Dog 2.

B. Dog 1 and Dog 3.

C. Dog 2 and Dog 3.

D. Dog 3 and Dog 4.

Question 21

Which of the STR markers is the least useful in verifying the parents of the young dog?

A. STR marker 1

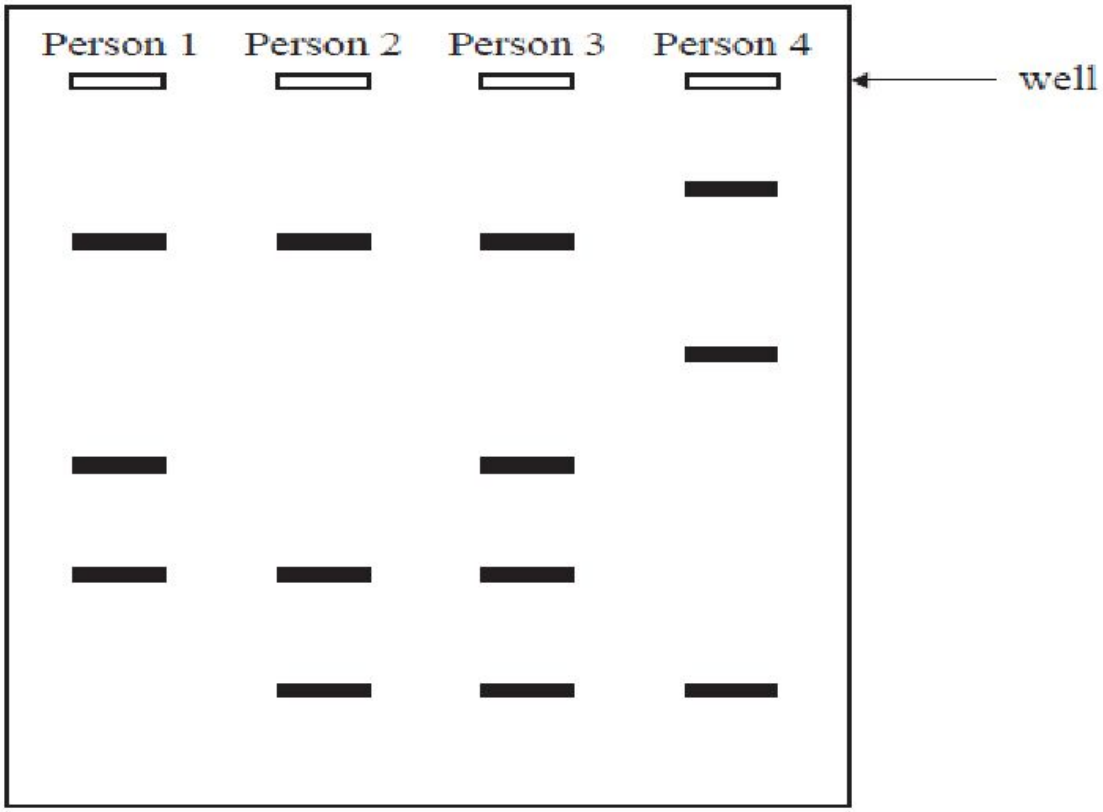
B. STR marker 2

C. STR marker 3

D. STR marker 4

Question 22

The amplified DNA fragments were separated using gel electrophoresis. The results are shown below.



Which one of the following conclusions can be made based on the results shown?

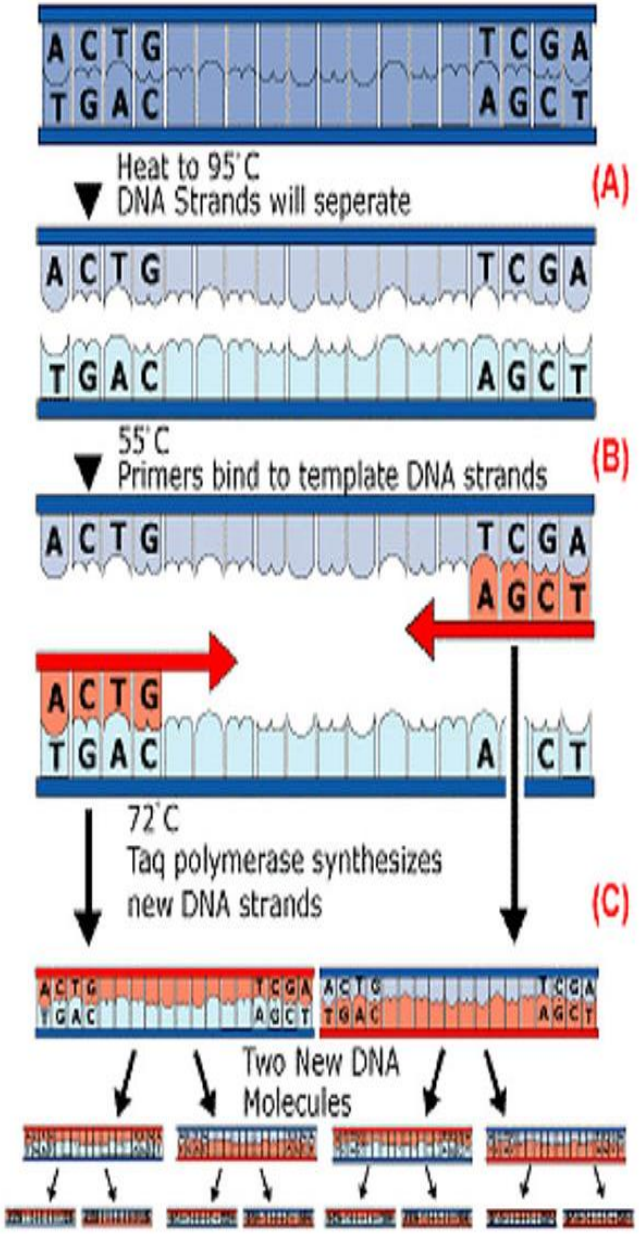
A. Person 4 could be the father of Person 1.

B. Person 2 could be the mother of Person 3.

C. Person 4 and Person 2 are identical twins.

D. Person 1 is not a biological brother of Person 3.

3) Polymerase Chain Reaction (PCR):



a) The DNA sample is heated in order to separate the two strands. The temperature depends on the base make up of the DNA sample, more G/C bases means that a higher temperature is required due to the increased number of hydrogen bonds. Usually 94 degrees for 2 minutes. **DENATURED 94 degrees**

b) Short segments of single stranded DNA, known as primers are added to the separated DNA strands. These primers are complementary to a particular point in the DNA, be it a start or stop codon.
ANNEAL at 54 degrees

c) The Taq polymerase enzyme is added to the mix and uses the primers as a starting point and extends them so that two complete strands of DNA are formed. In order to do this a supply of nucleotides must also be in the mix. **EXTENSION 72 degrees**

Question 23

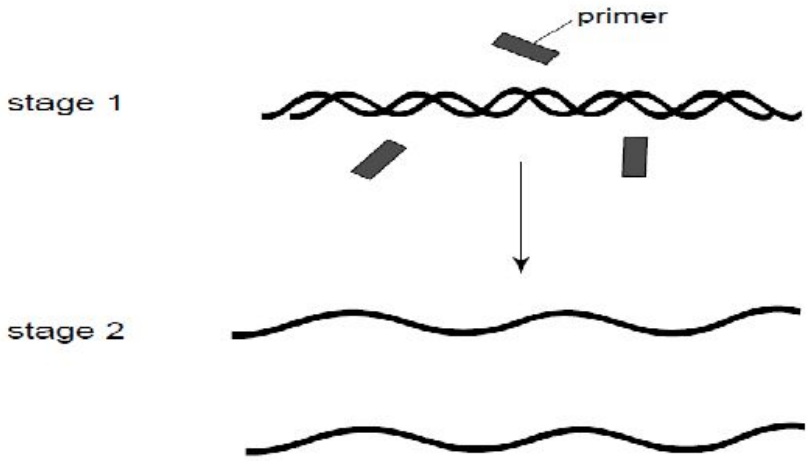
Victoria Police forensic scientists conduct DNA profiling using samples taken from crime scenes. Traces of DNA of less than 1 nanogram can be amplified and then profiled.

a. Name the process which is used to amplify the DNA.

_____

1 mark

Below is a diagram showing part of this process.



b. What must be done between stages 1 and 2 to separate the strands of the DNA molecule?

_____

1 mark

c. Complete and label the diagram at stage 2.

2 marks

Question 24

Genetic information in humans can be obtained by DNA profiling.

In DNA profiling, the polymerase chain reaction is used by a scientist to amplify a particular sequence of DNA.

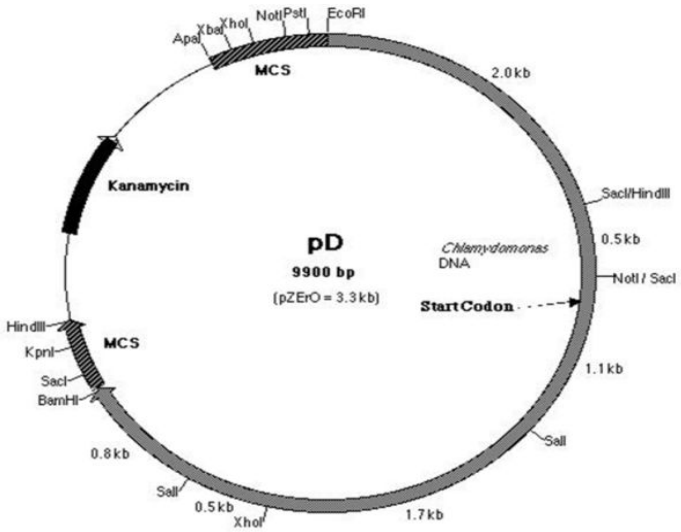
a. Briefly describe the steps of this technique.

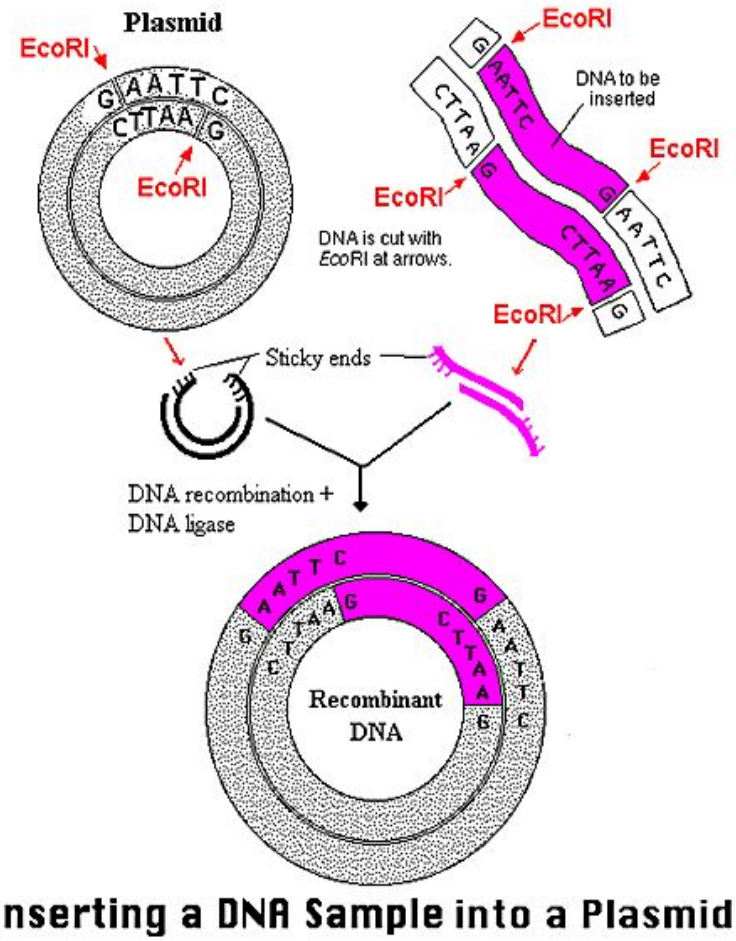
4 marks

4) Plasmids and Ligation:

To test the isolated gene fragment and determine if it produces the desired protein it needs to be integrated into a vector which can then be moved into a bacterial construct for testing.

The enzyme Ligase is used for sticking DNA fragments together.



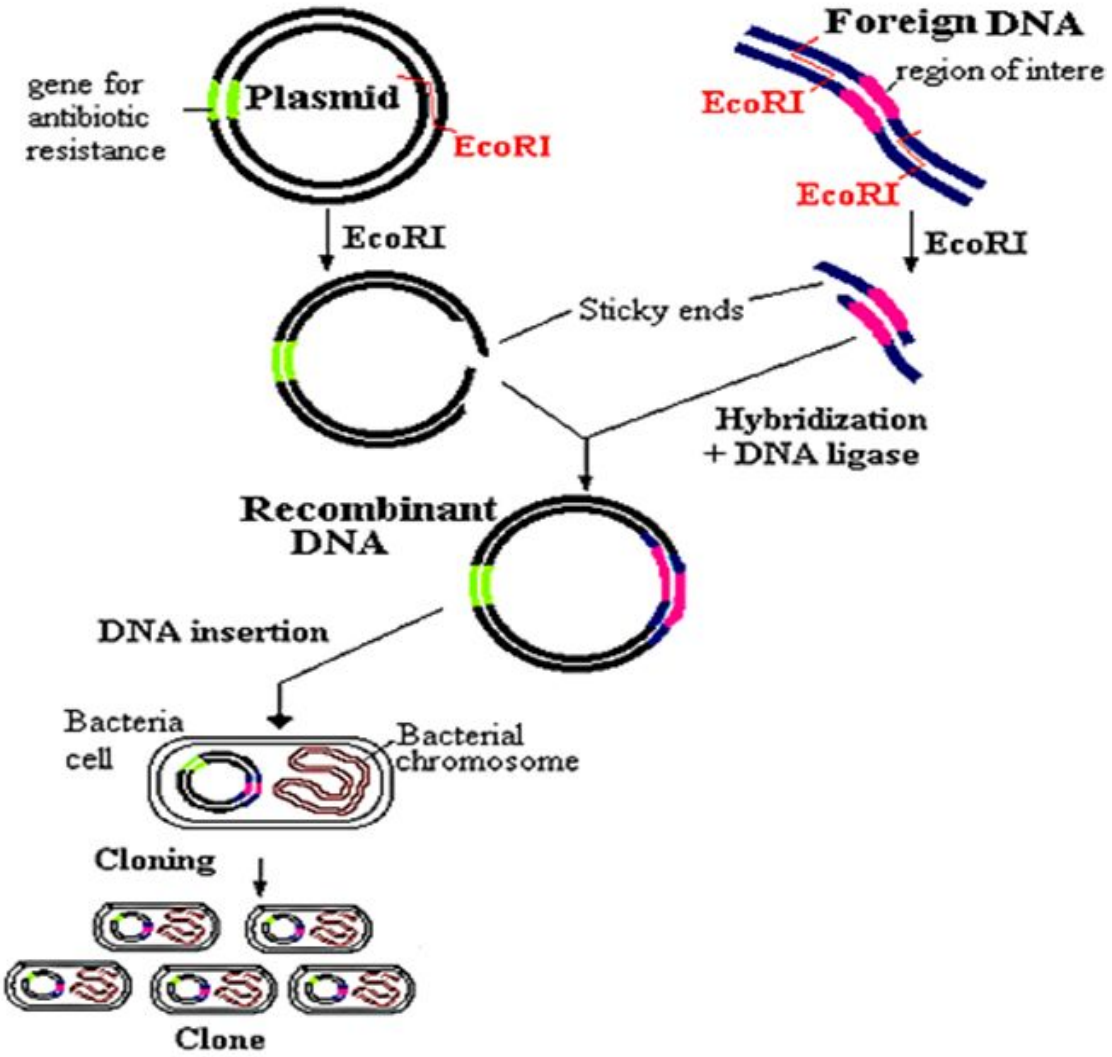


Inserting a DNA Sample into a Plasmid

5) Transformation:

Transformation is the process by which the recombinant plasmid is placed into a bacteria in order to determine if the gene of interest is producing the desired protein.

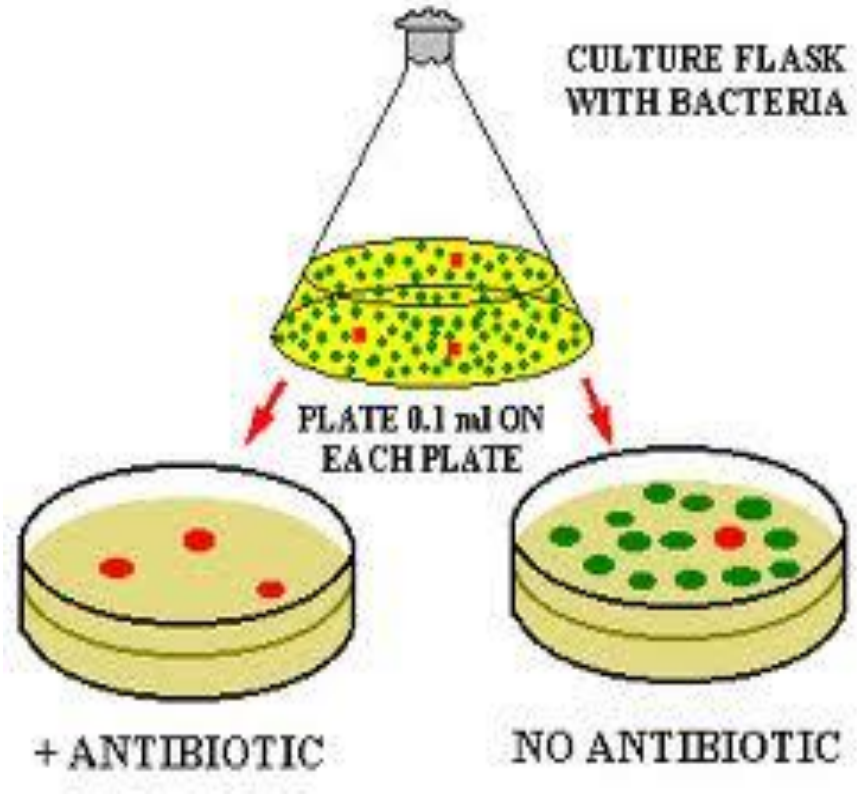
The bacteria is exposed to a solution of Calcium Chloride, which changes the permeability of the outer cell wall. The bacteria then goes through a process of heat shock and cold shock to stimulate the bacteria to take up the plasmid.



6) Growth of recombinant bacteria with selective agent:

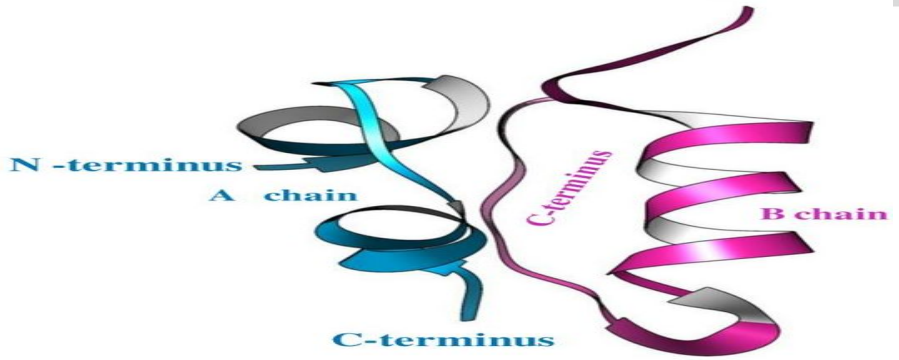
Transformation does not have a 100% strike rate. Some bacteria will accept the plasmids, while others won't. A selective agent was initially built into the plasmid to overcome this shortfall. The selective agent is usually antibiotic resistance. Therefore the bacteria is grown in a medium that has the selective agent present. Only those bacteria that have taken up the plasmid will be able to grow.

Transgenic vs genetically engineered.



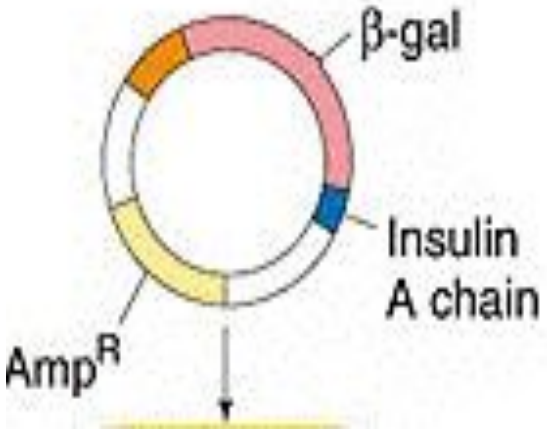
Synthetic Human Insulin and fusion proteins

1) Human insulin is composed of 2 polypeptide chains. An A chain and a B chain. It is therefore a quaternary structure.



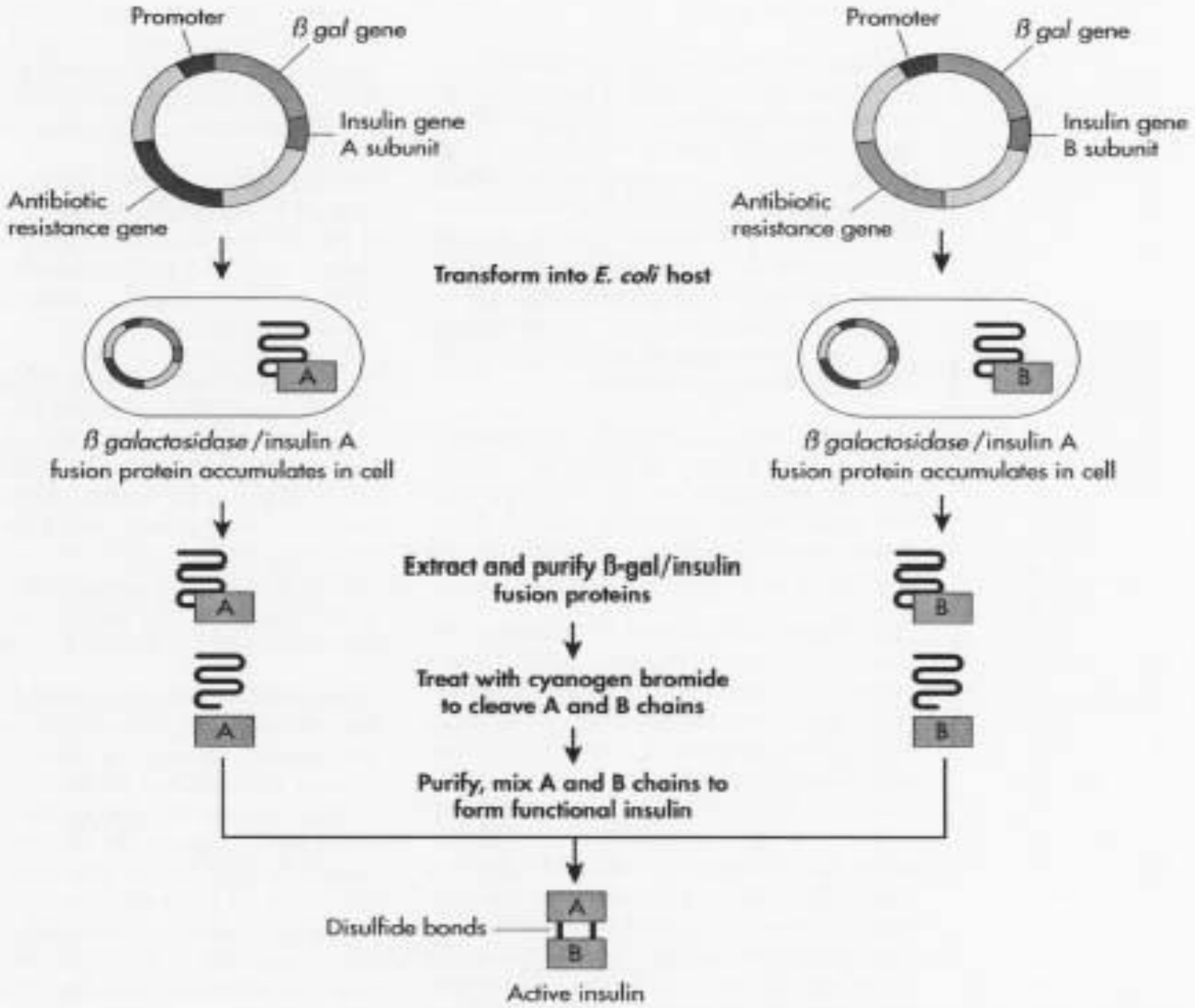
2) The A chain and the B chain are synthesised separately on separate plasmids in separate bacteria. They are joined together later in order to form functional insulin.

3) The plasmid used has antibiotic resistance selectable markers to allow for recombinant plasmid selection.

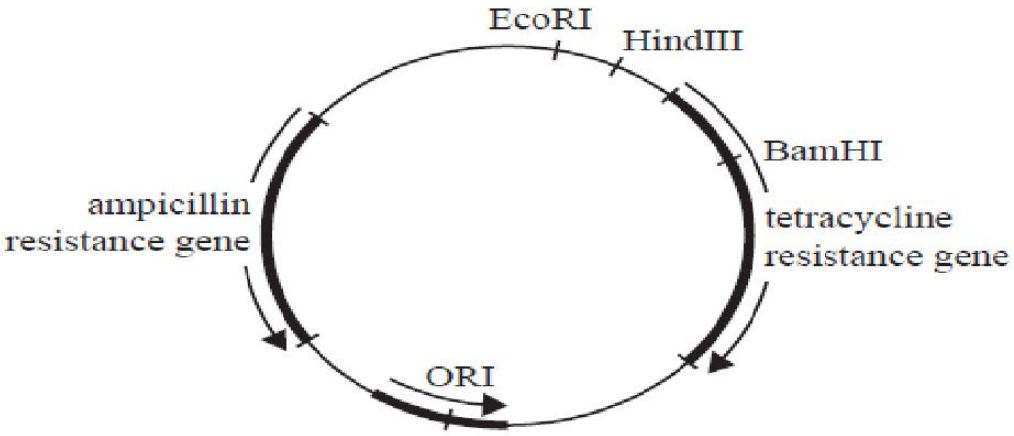


4)The insulin chain that is inserted into the plasmid has been modified to remove all introns as prokaryotes don't have Introns.

5) The plasmid also has the gene Beta galactosidase. The beta gal gene has 2 functions. A) its an additional selectable marker. B) The beta gal gene is an inducible operon and therefore can regulate A chain production.


Promoter
β gal gene
Insulin gene
A subunit
Antibiotic
resistance gene
Promoter
β gal gene
Insulin gene
B subunit
Antibiotic
resistance gene
Transform into E. coli host
A
B
β galactosidase / insulin A
fusion protein accumulates in cell
β galactosidase / insulin A
fusion protein accumulates in cell
A
A
B
B
Extract and purify ß-gal/insulin
fusion proteins
Treat with cyanogen bromide
to cleave A and B chains
Purify, mix A and B chains to
form functional insulin
A
B
Disulfide bonds
Active insulin

A particular bacterial plasmid contains recognition sites for three endonucleases: EcoRI, HindIII and BamHI. The plasmid also contains two antibiotic resistance genes – ampicillin resistance gene and tetracycline resistance gene – and an origin of replication (ORI). The diagram below shows the positions of these plasmid components.



Question 25

Which one of the following is a correct statement about the procedure?

A. The endonuclease BamHI would have been used to cut the plasmids.

B. The human insulin gene would have been joined to the plasmids using DNA polymerase.

C. The recognition site for EcoRI would have the same base sequence as the recognition site for HindIII.

D. Bacterial cells containing the human insulin gene would be resistant to both ampicillin and tetracycline.

Question 26

The *E. coli* cells that had been successfully transformed were isolated and then transferred to a nutrient solution. Exposure to particular environmental conditions resulted in the production of insulin by these cells.

Which one of the following is a true statement about insulin?

A. Insulin is an enzyme.

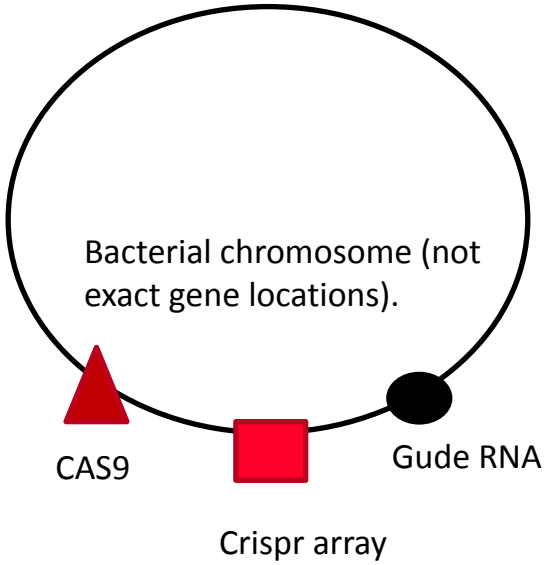
B. Nucleotides are the monomers of insulin.

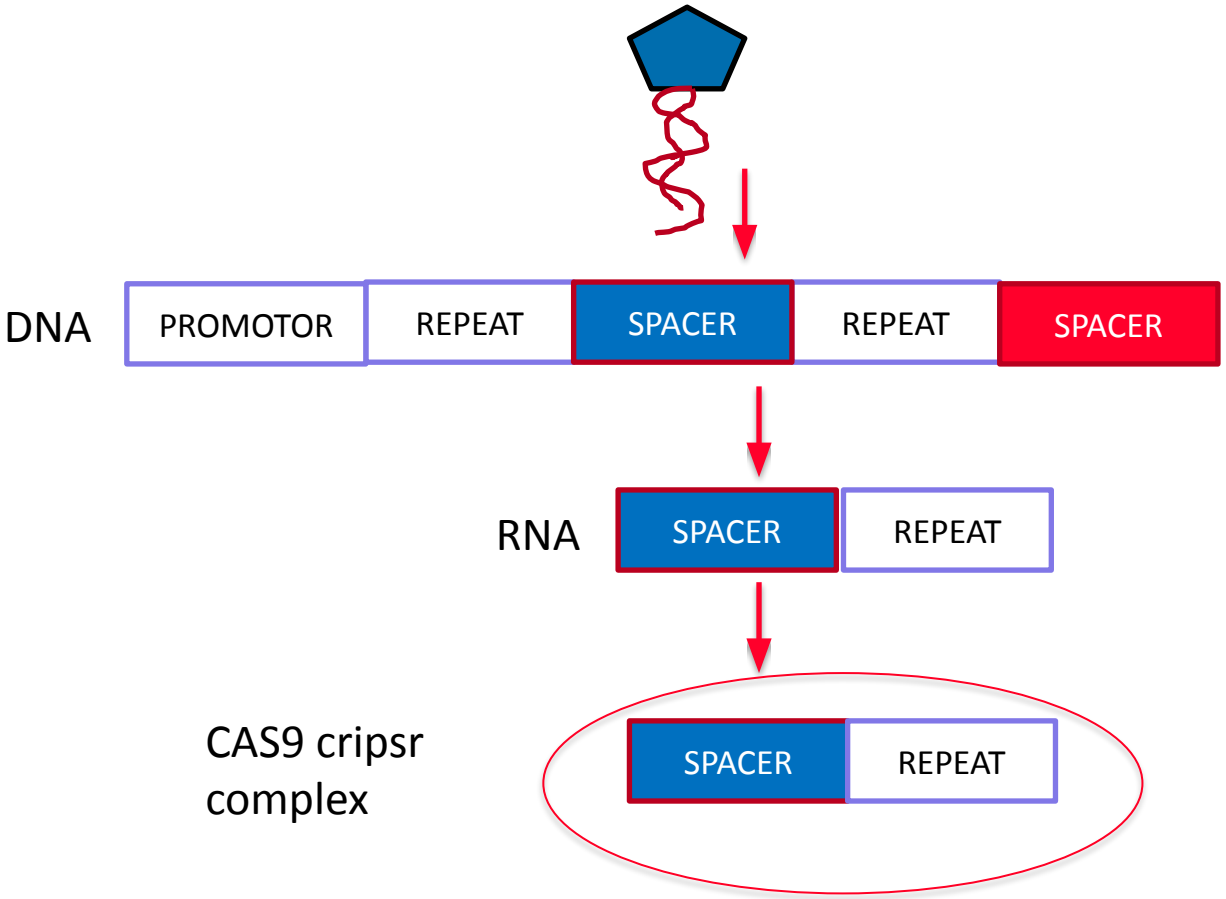
C. The tertiary structure of the insulin molecule is critical for its functioning.

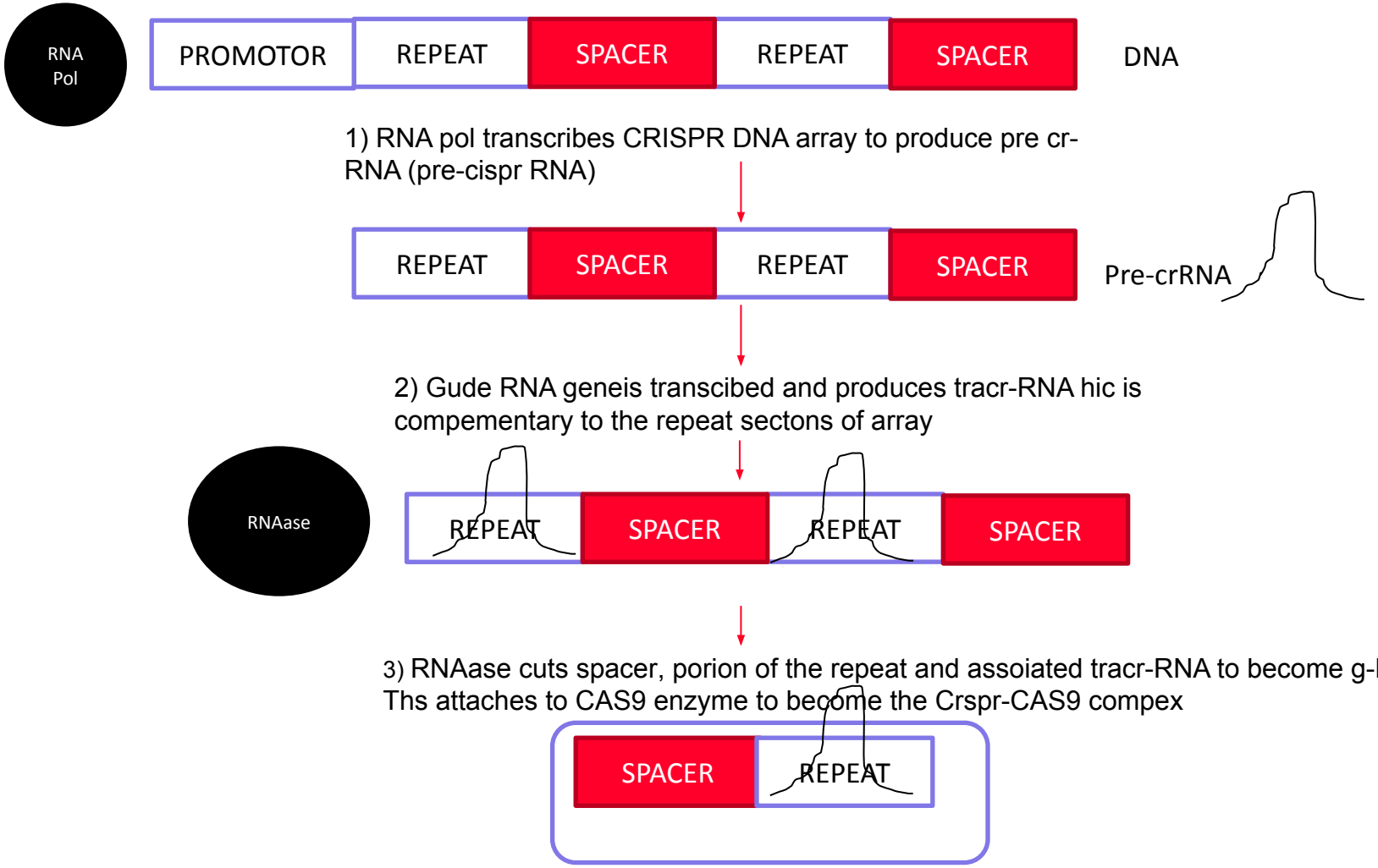
D. The secondary structure of the insulin molecule is the sequence of the monomers in the molecule.

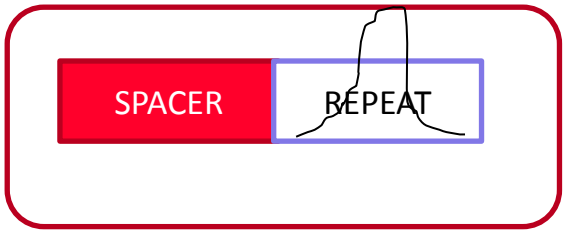
Crispr Clustered Regularly Interspaced Short Palindromic Repeats

When a bacteria encounters a virus it has the ability to genetically store some of the viral genetic material within its own genome (Crispr array). This allows the bacteria to directly target the virus in the future via an endonuclease (DNA cutting enzyme) alled CAS9.

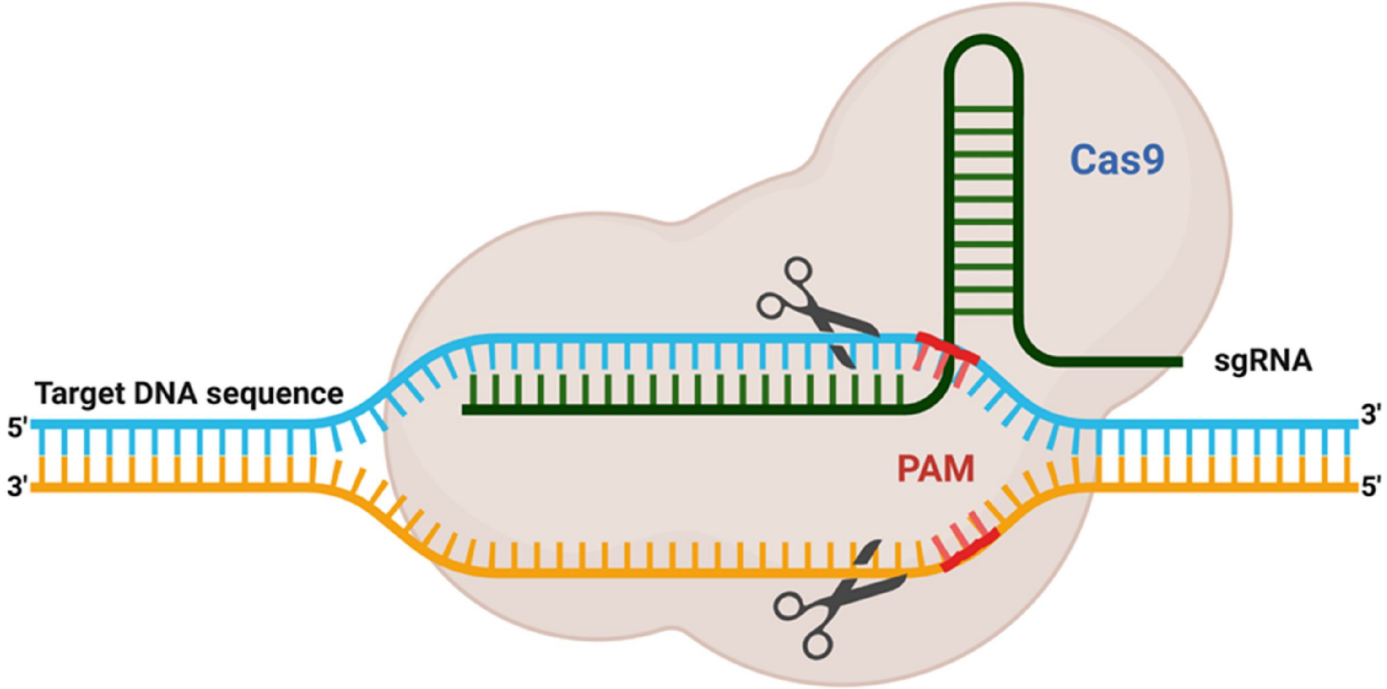


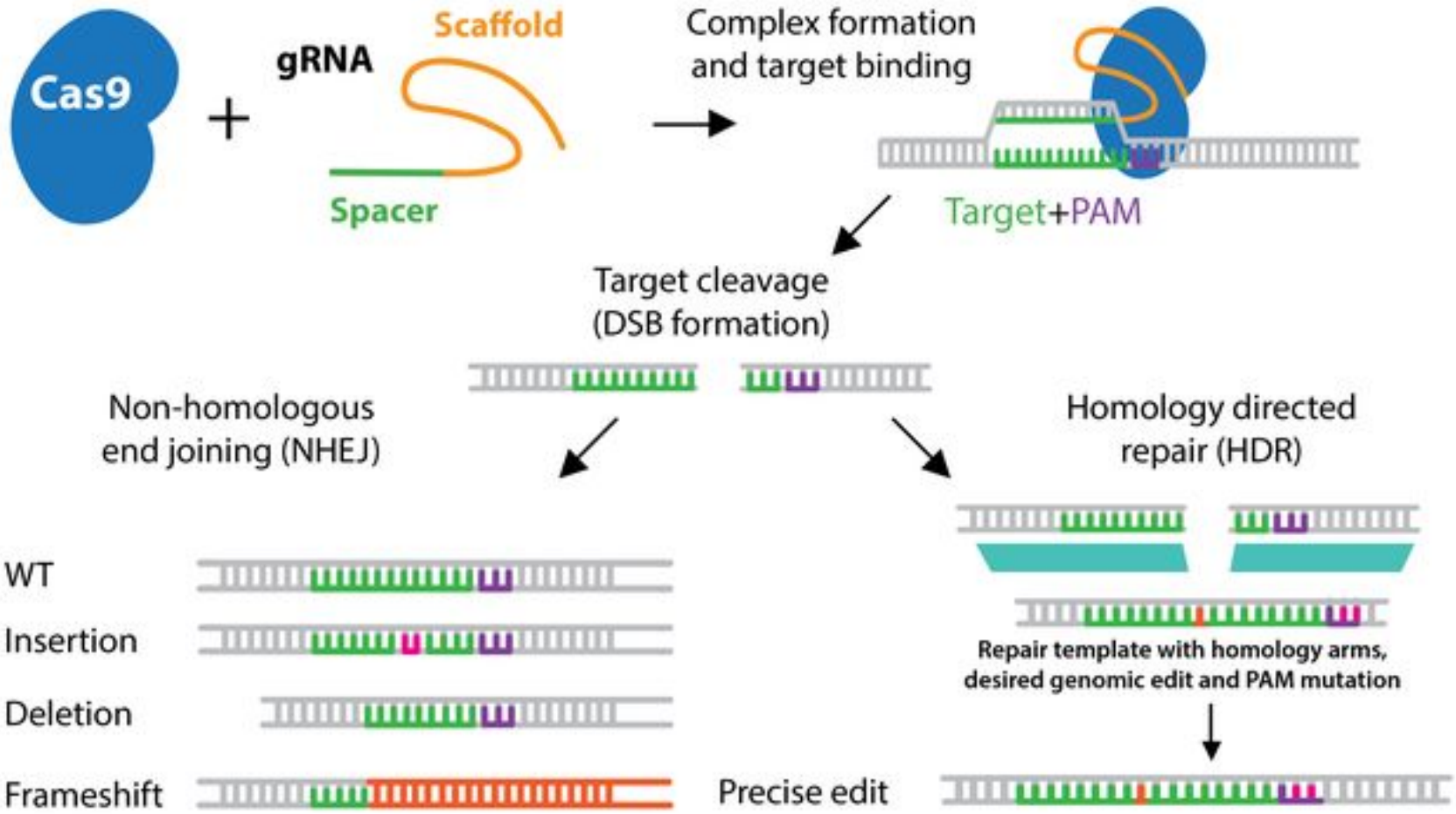



RNA Pol
PROMOTOR
REPEAT
SPACER
REPEAT
SPACER
DNA
1) RNA pol transcribes CRISPR DNA array to produce pre cr-RNA (pre-cispr RNA)
REPEAT
SPACER
REPEAT
SPACER
Pre-crRNA
2) Gude RNA geneis transcibed and produces tracr-RNA hic is compementary to the repeat sectons of array
RNAase
REPEAT
SPACER
REPEAT
SPACER
3) RNAase cuts spacer, porion of the repeat and assoiated tracr-RNA to become g-RA. Ths attaches to CAS9 enzyme to become the Crspr-CAS9 compex
SPACER
REPEAT



- Cripr-CAS9 complex is able to recognise any DNA that the gRNA is complementary to and then cut it at a specific point creating blunt DNA fragments. This inactivates the bacteriophage DNA or silence it. It has specificity due to the PAM sequence.




Cas9
gRNA
Scaffold
Spacer
Complex formation
and target binding
Target+PAM
Target cleavage
(DSB formation)
Non-homologous
end joining (NHEJ)
Homology directed
repair (HDR)
WT
Insertion
Deletion
Frameshift
Repair template with homology arms,
desired genomic edit and PAM mutation
Precise edit

Question 27

Gene editing refers to modifications made to the genome of a living organism. CRISPR-Cas9 is one method that is frequently used to edit genes. This method relies on clustered regularly interspaced short palindromic repeats (CRISPR) and the endonuclease protein Cas9, which occur naturally in bacteria.

a. Describe the function of the endonuclease protein Cas9 in bacteria. 2 marks

Gene editing with CRISPR-Cas9 relies on the Cas9 protein and single guide RNA (sgRNA) molecules. A molecule of sgRNA synthetically produced by scientists is shown below.

Describe the role played by the Cas9 protein in the editing of the gene. Refer to the sgRNA molecule in your response. 2 marks

Bioethics

There are **3 main** approaches to bioethics

Consequence based approach:

This is focused on outcomes. Sometimes referred to as 'The ends justifies the means'.
This is looking to maximise the positive outcomes, and minimise the negative outcomes, with less regard to the actions taken to get there.

Duty rule based approach:

This is focused on a system of laws/beliefs/duties that cannot be broken.
Could be thought of as 'The ends cannot justify the means'.
Actions must follow the rules to maintain the system, regardless of whether that action is good or the outcome is good.

Virtues based approach:

Does not focus on rules or outcomes, but simply the 'goodness' of an action.
E.g. Being honest is inherently good, regardless of whether it causes you to break a rule, or cause some harm.

There are 5 **concepts** in bioethics, that can be used to help explore the 3 **approaches**.
Concepts are ideas which can help to make decisions using the approaches.
The five concepts are **Integrity, Justice, Beneficence, Non-maleficence** and **Respect.**

Integrity: concept of maintaining a strict adherence to honesty, data and evidence

Justice: commitment to fairness. That means that all people have equal access to any benefits, and that harm doesn't disproportionately affect one group of people.

Beneficence: simply the concept of maximising benefit. It is a way of considering how much benefit a course of action will cause

Non- maleficence: concept of avoiding harm. It is a way of considering how much harm a course of action will cause, and if it can't outweigh the benefits, it shouldn't be taken

Respect: . Taking respect into account in your approach, should mean that you value a persons beliefs, culture, freedom, autonomy and their right to make decisions

Match a bioethical concept to the following statements. **(Integrity, Justice, Beneficence, Non-maleficence, Respect)**

1) Scientists should always share their results with the public, even if the results disprove their work.

2) Scientists should design their experiments and the potential outcomes from the experiments in a way that benefits as many people as possible.

3) Scientists need to consider how their research is accessed by the community and how the research may benefit some groups more than others.

4) Scientists should acknowledge that their research often carries risk, and should consider ways of avoiding unnecessary dangers when designing and carrying out the experiment

5) Scientists should consider the different values and beliefs of various communities when researching and carrying out their experiments.

Question 29

Precision medicine can be used to develop anticancer drugs that target and silence the gene or genes that cause a particular cancer. The government does not provide funding for many of these drugs and patients may need to spend upwards of $100 000 for one course of the treatment, when many courses of the treatment are likely to be needed to prolong life. This leads to unequal access to these lifesaving drugs in society.

In terms of bioethics, this situation shows a lack of

A. care.
B. justice.
C. respect.
D. integrity.

Question 30

A new drug to treat malaria is being trialled by scientists.

To apply the concept of non-maleficence to their research, the scientists should ensure that

A. any harm to the participant resulting from the trial is not disproportionate to the benefits obtained from using the new drug.
B. data that shows the new drug is ineffective is not published.
C. consent is obtained from all of the participants in the trial.
D. the participants experience only the benefits of the trial.

Aerobic respiration:

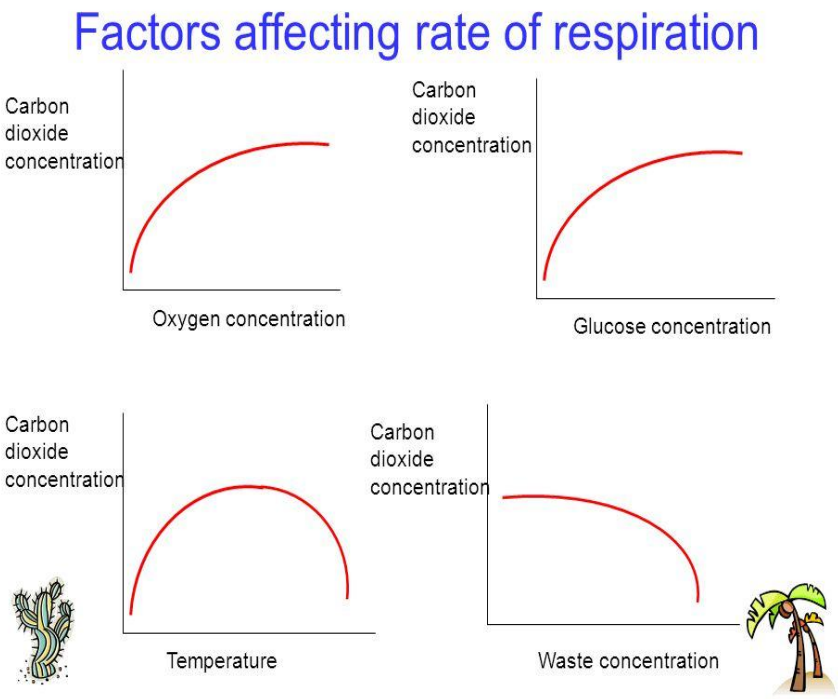
	LOCATION	INPUTS	OUTPUTS
Glycolysis	cytoplasm	glucose, 2ADP, 2Pi, NAD	2ATP, NADH
Krebs	mitochondrial matrix	pyruvate, O_2, 2ADP, 2 Pi, NAD, FAD	$FADH_2$, 2ATP, CO_2, NADH
Electron Transport	mitochondrial cristae	NADH, $FADH_2$, O_2	26 or 28 ATP, H_2O

Anaerobic respiration:
In the absence of oxygen only 2ATP is created for every glucose broken. Pyruvate is then converted into lactic acid as a bi-product.

Fermentation:
In the absence of oxygen only 2ATP is created for every glucose broken. Pyruvate is then converted into Ethanol as a bi-product.

Factors that affect the rate of cellular respiration:

1) **Temperature:** Based on Enzymic principles. As temperature increases the rate of reaction will also increase unil the temperature gets too high and rate is affected by denaturation of enzymes.
2) **Glucose concentration**: As glucose increases, rate of reaction will increase to a point. This point is based on enzyme availability and substrate concentration etc
3) **Oxygen concentration**: As Oxygen increases, rate of reaction will increase to a point. This point is based on enzyme availability and substrate concentration etc
4) **Concentration of waste material** (Carbon dioxide or alcohol): As waste products increase, the rate of respiration will decrease.

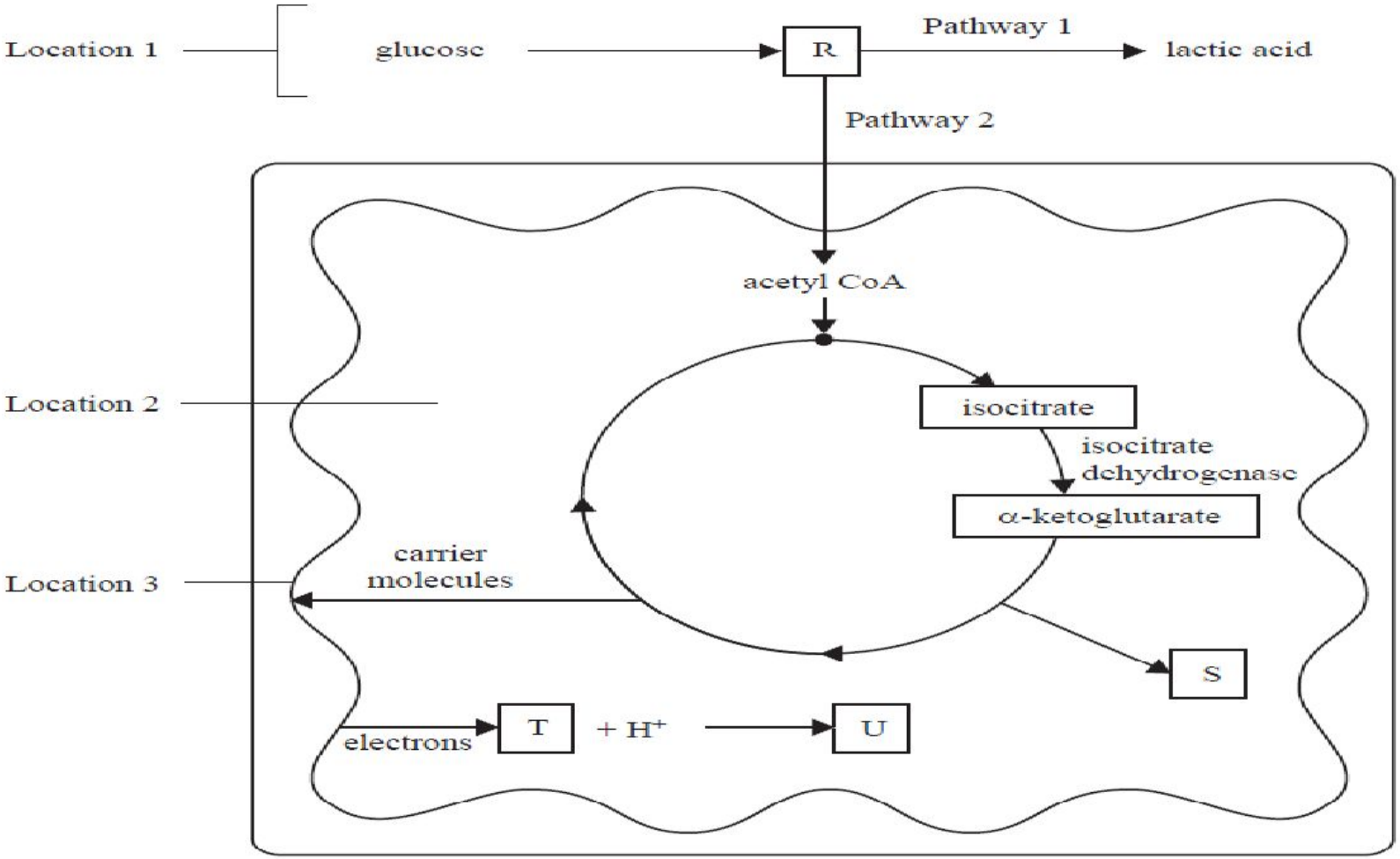


Biomass and fermentation

Anaerobic digestion is **another method of converting biomass into energy**. In this process, organic material is broken down by bacteria, in the absence of oxygen, to create methane-rich biogas. This can then be burned to generate heat and electricity.

Use the following diagram to answer the next 3 questions

The diagram below outlines the general biochemical pathways in cellular respiration in an animal cell.



Question 31

Biochemical pathways 1 and 2 are similar in animal cells because they

A. create a high yield of ATP.

B. cycle the coenzyme NAD^+.

C. occur in the mitochondrion.

D. produce carbon dioxide gas.

Question 32

Assume that oxygen levels are maintained.

If glucose supply to this animal cell were to

A. decrease, then the movement of molecule R into Location 2 would increase.

B. increase, then the production of molecule S would decrease.

C. increase, then the production of lactic acid would increase.

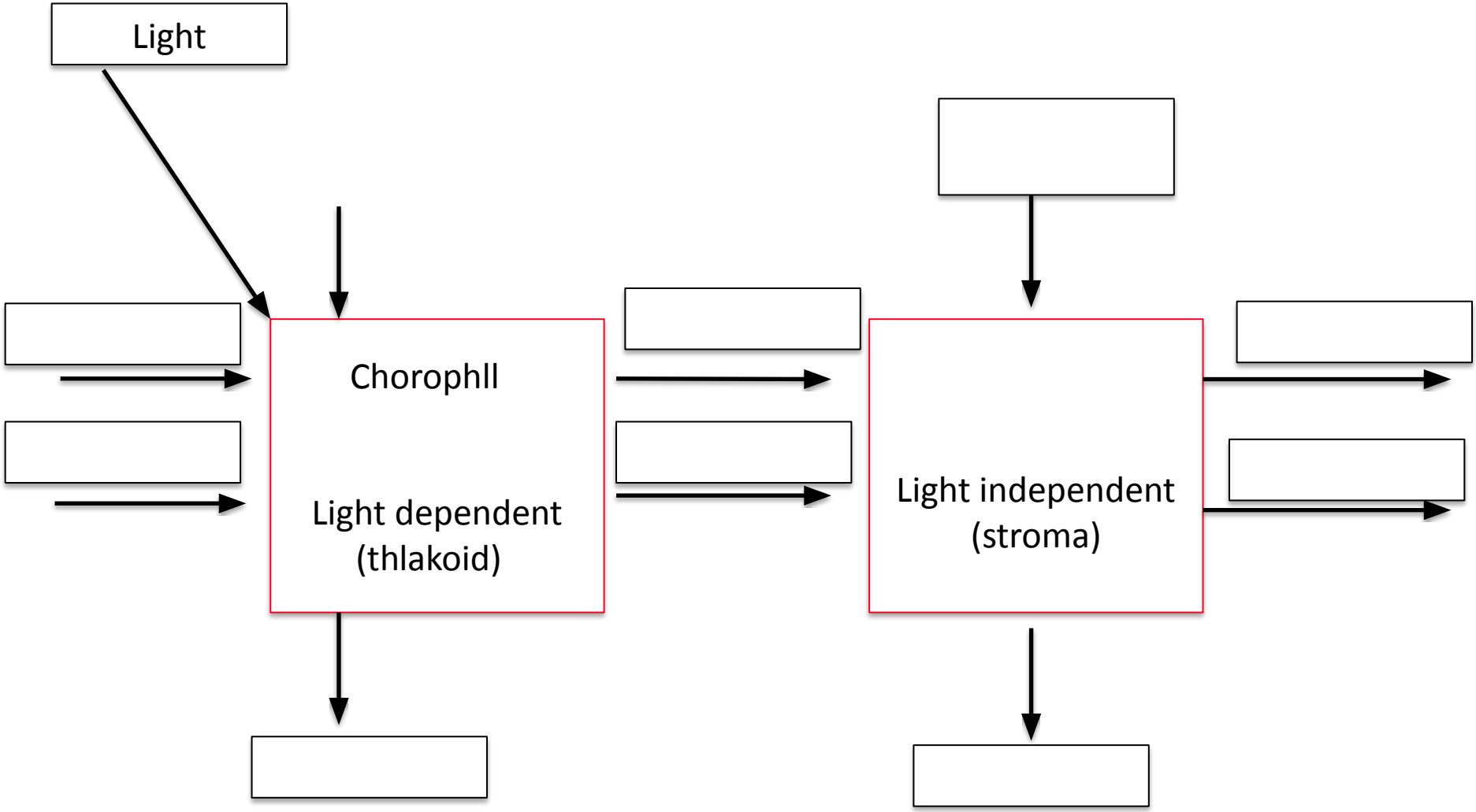
D. decrease, then ATP yield would decrease.

Question 33

Which of the following correctly states an input, an output and the ATP yield for Location 3?

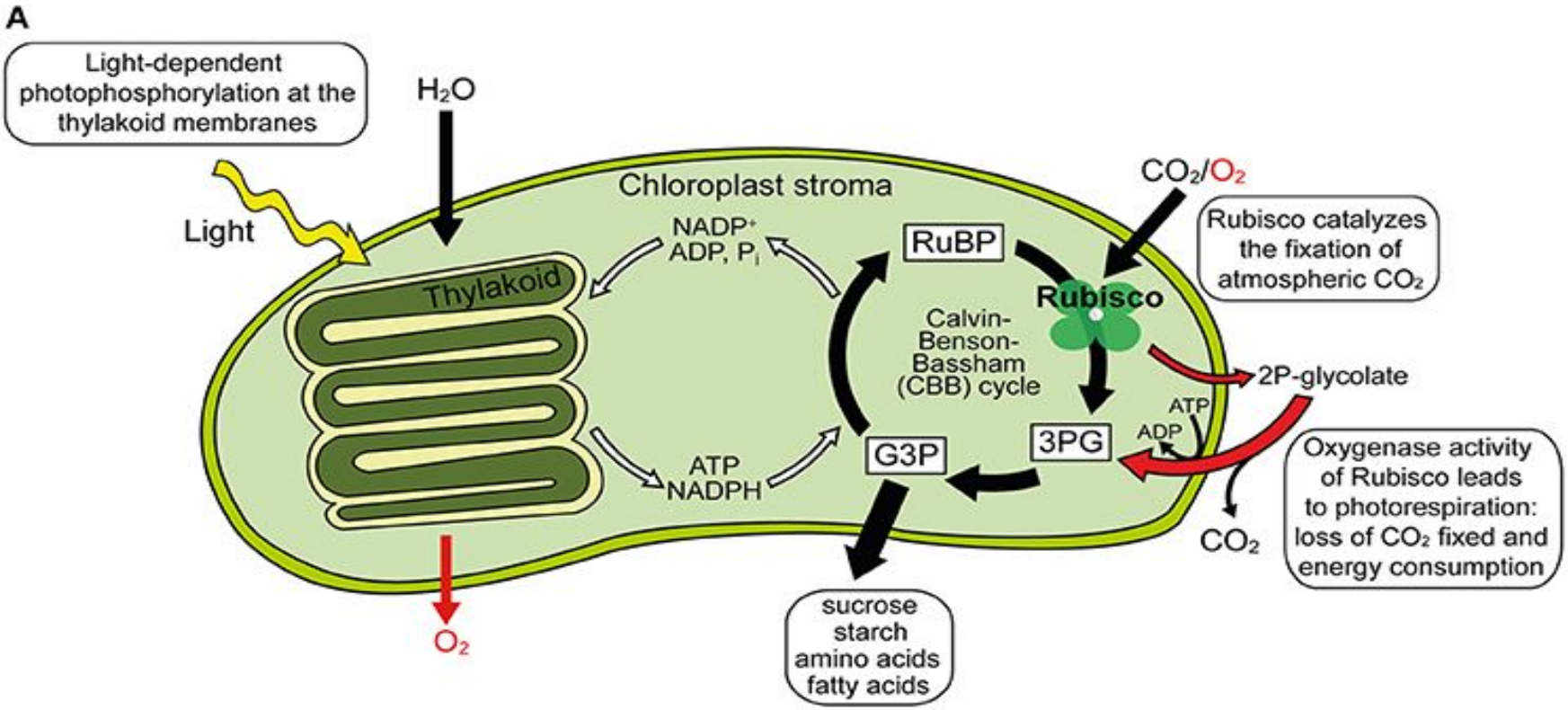
	Input 'T'	Output 'U'	ATP yield
A.	oxygen	water	26–28
B.	NAD^+	oxygen	26–28
C.	carbon dioxide	water	26–28
D.	NAD^+	carbon dioxide	30–32

Photosynthesis:

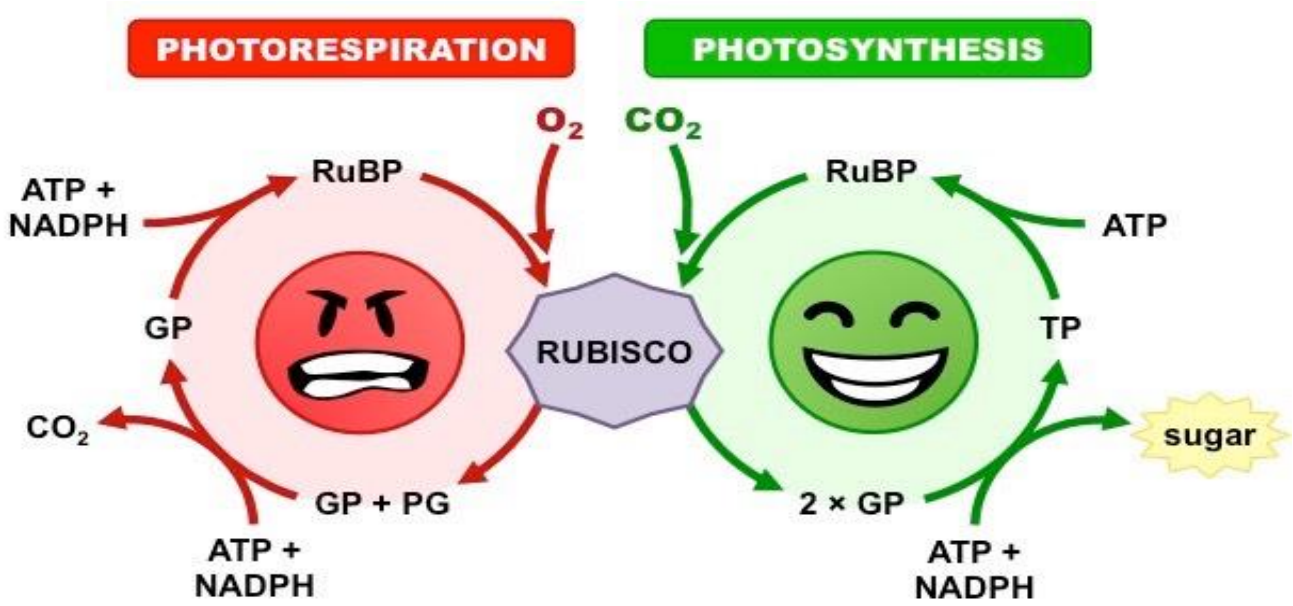


Light independent reaction: (rubisco/RuBp, C3 and C4)

- Rubisco is the primary enzyme that enables carbon dioxide to be converted into Glucose.
- Rubisco is responsible for taking the x1 C molecule of Carbon dioxide out of the air and then "fixing" it to another x5 carbon molecule called Rubp.
- This Rubp molecule then cut in half (PGA) and has some Hydrogens attached to it via NADPH (light reaction) using some if the ATP generated in the light reaction. To become G3P
- The two G3P molecules are then modified again and are joined together into glucose.
- Glucose being made with x2 G3P's is referred to as C3 plants.



Rubisco mode of action:

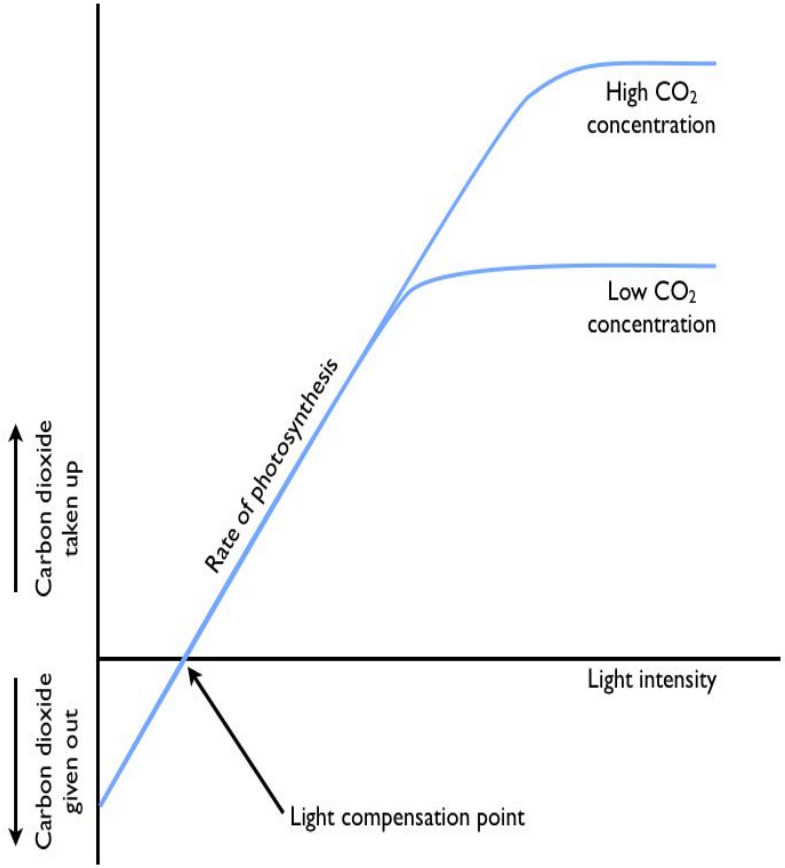


-In high carbon dioxide/low oxygen environments the Rubisco enzyme operates normally and produces glucose via carbon dioxide fixation.

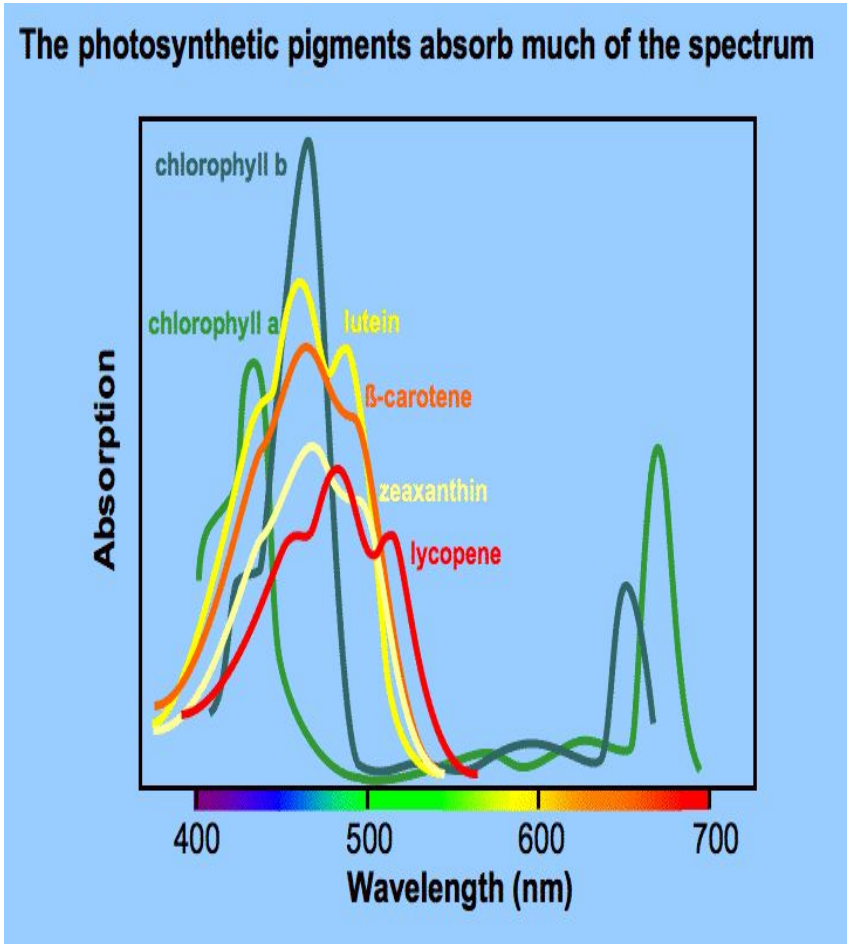
- In low carbon dioxide/high oxygen environments the Rubisco enzyme operates differently. It will use oxygen and ATP to produce Carbon dioxide.

Factors affecting rate of photosynthesis:

Carbon Dioxide concentration:

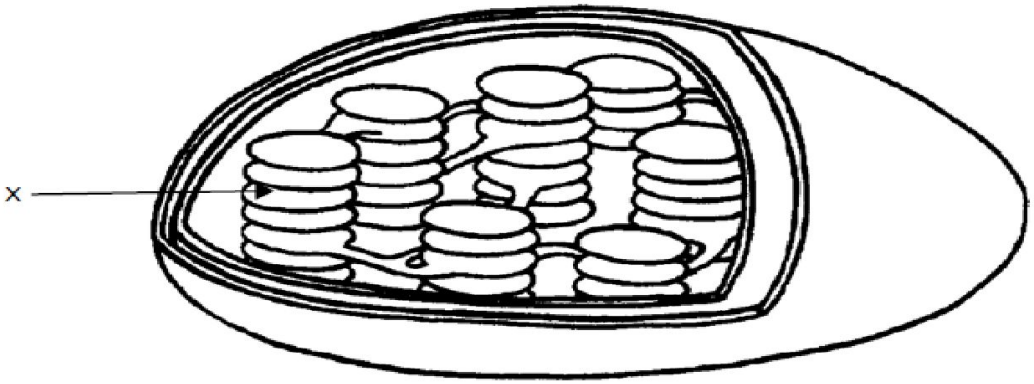


Light frequency and absorbance:



Question 34

Below is a diagram of a chloroplast



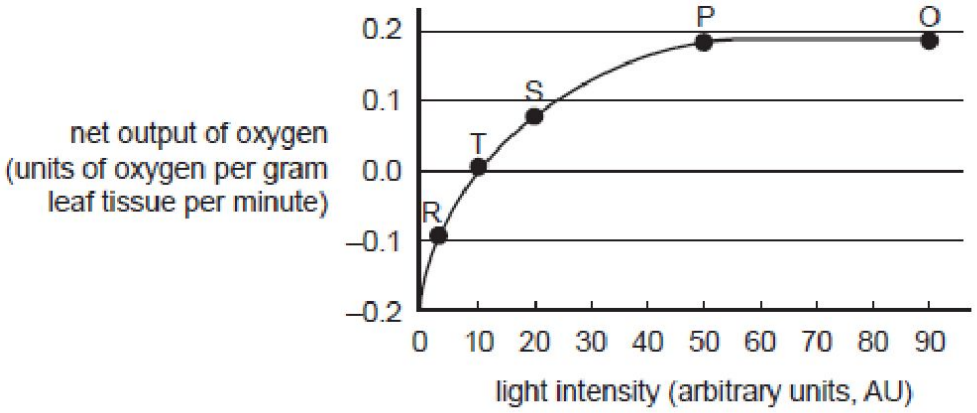
a. Name the structure labelled X. 1 mark

_____

b. Complete the following table by referring to the diagram above and your knowledge of photosynthesis. 3 marks

Name of the stage of photosynthesis that occurs at X	_____	
Two input molecules that are required for reactions at X	1. _____	2. _____
Two output molecules that result from the reactions at X	1. _____	2. _____

The graph below shows the net output of oxygen in spinach leaves as light intensity is increased. Temperature is kept constant during the experiment.



Question 35

The rate of oxygen output remains constant between points P and O because

A. heat has denatured the enzymes involved in the photosynthesis reactions.

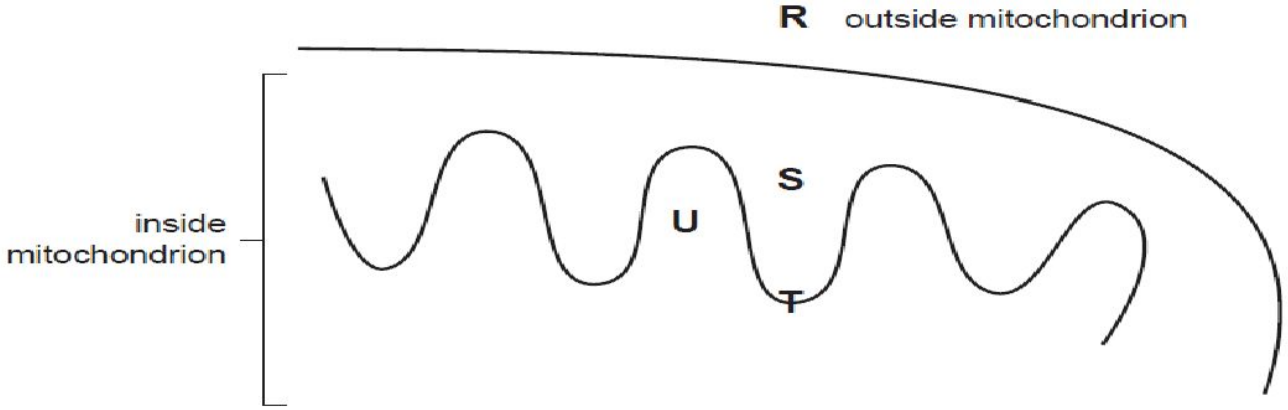
B. the concentration of available carbon dioxide limits the rate of photosynthesis.

C. the light intensity has damaged the chlorophyll molecules present in the spinach chloroplasts.

D. high levels of oxygen produced at point P have accumulated around the spinach leaves, resulting in no more oxygen being produced.

Question 36

The diagram below shows a section through a part of a mitochondrion.



The sites of the pathways in aerobic respiration are

A. R – glycolysis, S – Krebs cycle, T – electron transport chain.
B. U – glycolysis, T – Krebs cycle, R – electron transport chain.
C. R – glycolysis, U – Krebs cycle, T – electron transport chain.
D. T – glycolysis, R – Krebs cycle, S – electron transport chain.

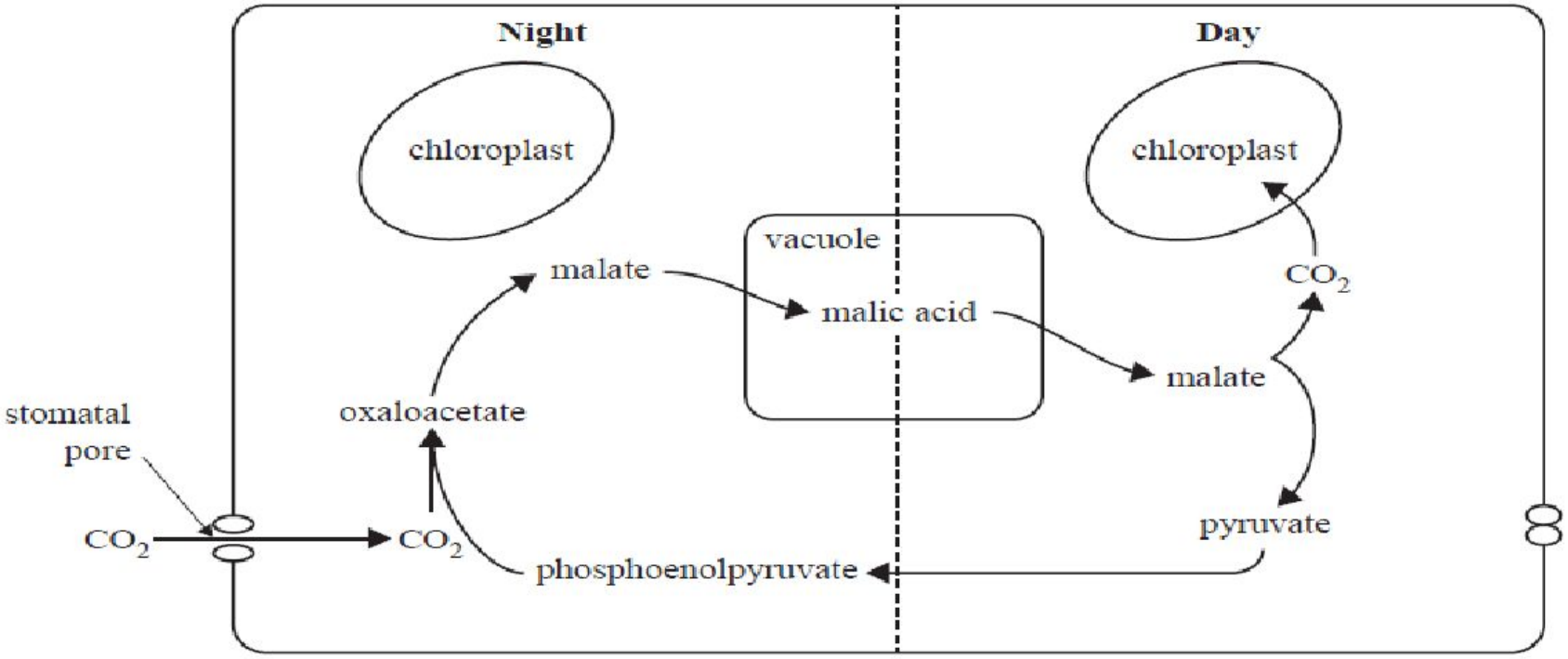
Question 37

Which of the following gives the inputs and outputs of the electron transport chain in an animal cell?

	Inputs	Outputs
A.	NADH, ADP, oxygen, P_i	ATP, NAD^+, water
B.	NADH, ADP, water, P_i	ATP, NAD^+, oxygen
C.	NAD^+, ADP, oxygen, P_i	NADH, ATP, water
D.	NADPH, ADP, water, P_i	$NADP^+$, ATP, oxygen

Question 38

A simplified overview of the CAM pathway in an agave leaf cell

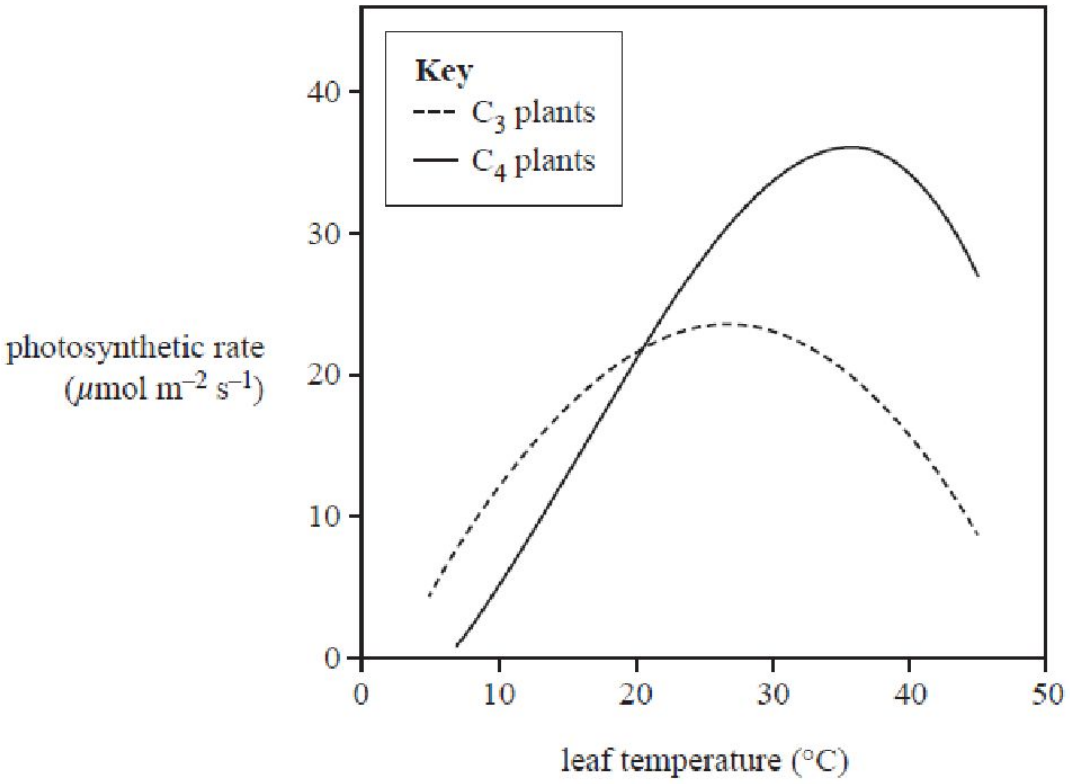


Source: adapted from IN Forseth, 'The ecology of photosynthetic pathways', *Nature Education Knowledge*, 3(10):4, Figure 6

a. What primary advantage does an agave plant have in using the CAM pathway compared to C_3 plants? 1 mark

Question 39

The graph below shows the effect of leaf temperature on the rate of photosynthesis in C_3 and C_4 plants.



This graph shows that

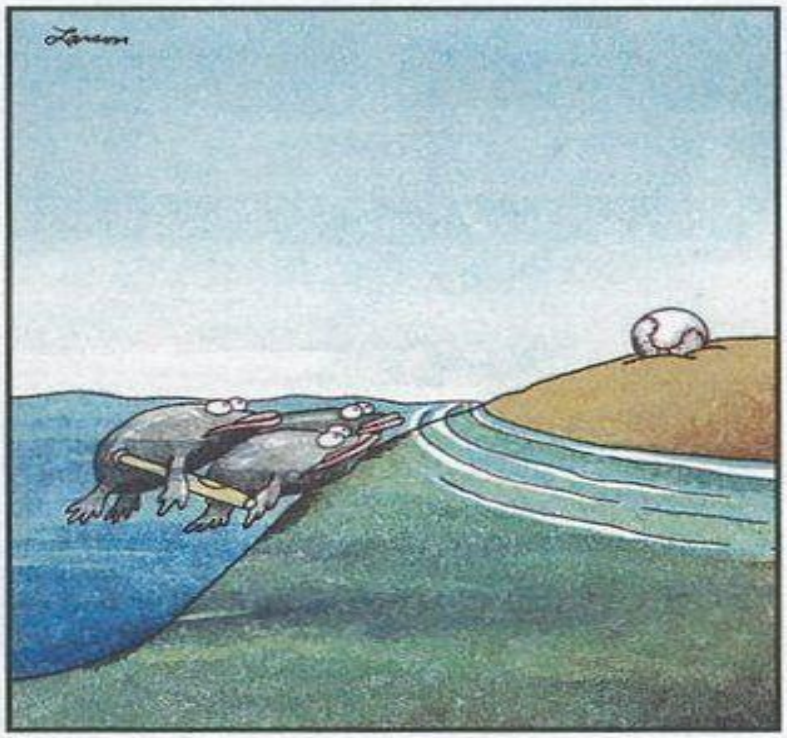
A. C_4 plants have a higher photosynthetic rate than C_3 plants across all temperatures.

B. maximum enzyme efficiency occurs at the same temperature in C_3 and C_4 plants.

C. the optimum temperature for photosynthesis in C_3 plants is 35 °C.

D. the photosynthetic rate of C_3 and C_4 plants is the same at 20 °C.

Biology Unit 4 Review



Great moments in evolution

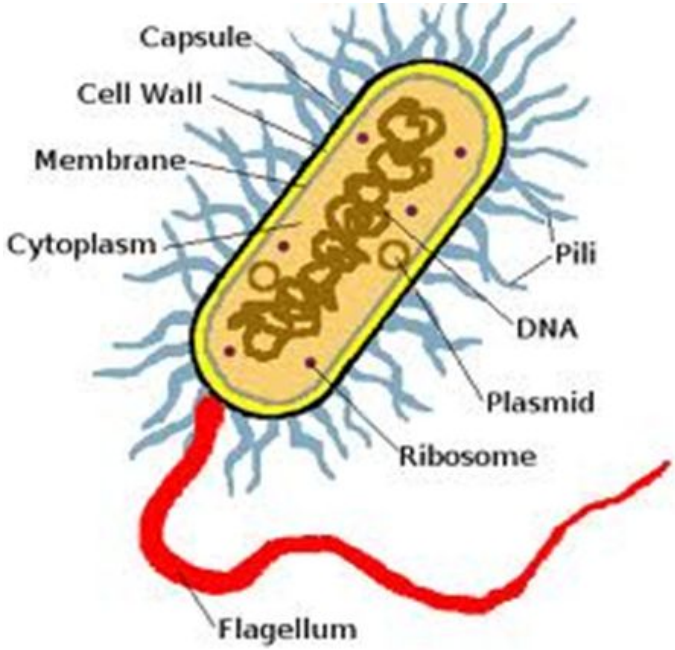
IMMUNOLOGY

Disease causing organisms:

- A disease is any change that impairs the function of an individual in some way; that is, it harms the individual.
- A pathogen may be non-cellular (virus, prions), cellular agents (bacteria, fungi) or a multicellular organism (worms)
- Most pathogens are transmissible. Transmission is generally via airborne means but can also include blood, spit, and sputum.

Bacteria:

- PROKARYOTES (Cell wall and a single chromosome usually in the shape of a circular DNA strand).



Bacteria can cause disease in humans if:

1. They can enter a person who can act as a host.

2. They have the capacity to reproduce within the host.

3. They act adversely on tissues in their host (exotoxins, adverse enzyme production)

Viruses:

-Viruses are the smallest known reproductive "cell".

-Viruses comprise nucleic acid (DNA or RNA) surrounded by one or more coats of protein.

-Viruses are unable to reproduce without the presence of a host cell in which to enter and utilize.

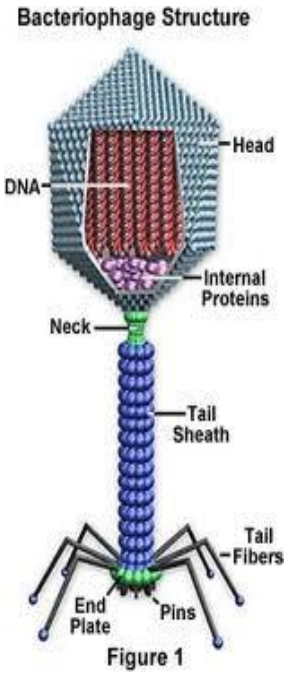
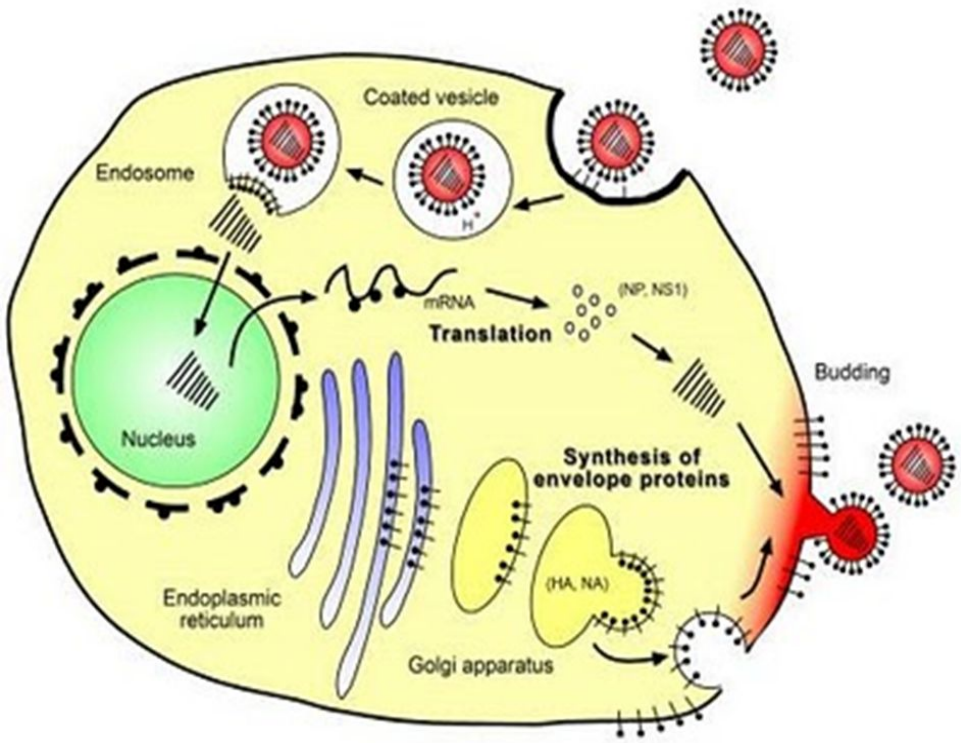


Figure 1



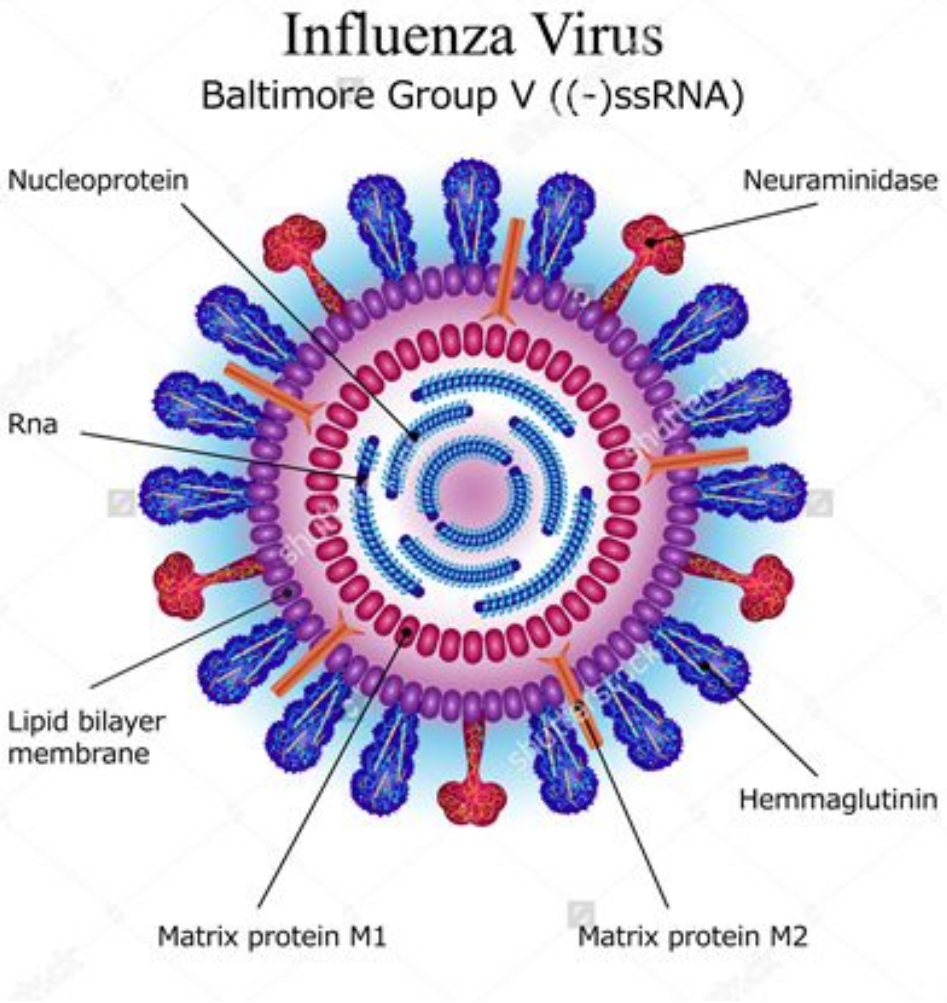
1) Virus adheres or is taken up by cell.

2) Viral nucleic acid moves to nucleus where it is transcribed.

3) Viral mRNA is then translated

4) Viral protein is then packaged

The Flu virus example:



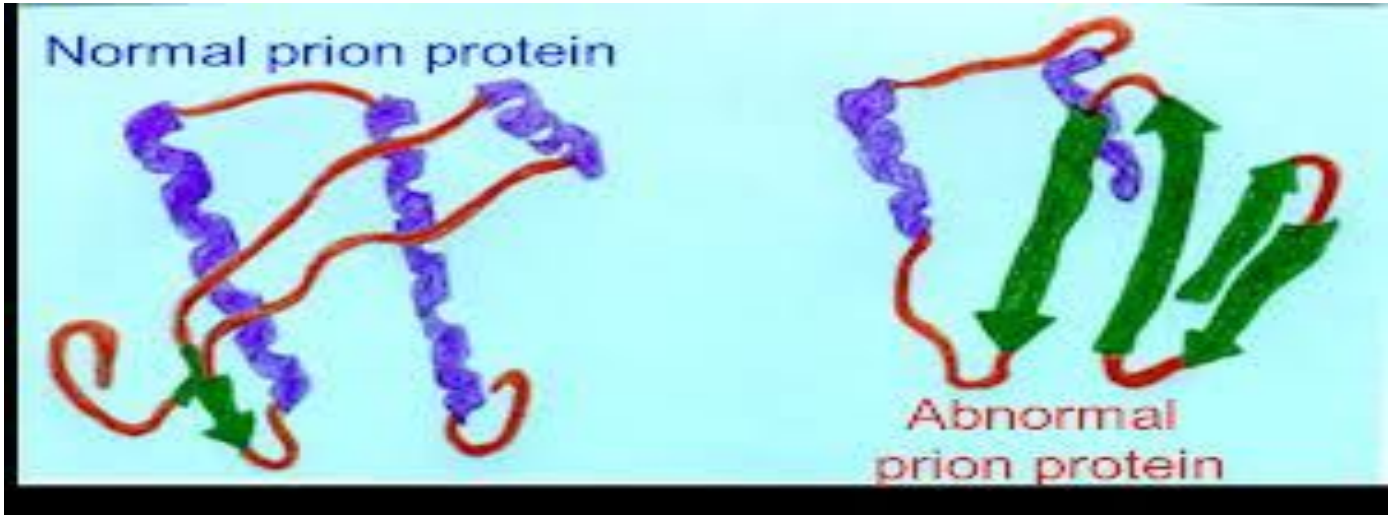
- The influenza virus has two main antigenic proteins, which come in a variety of types
- The flu virus like many viruses van undergo antigenic drift and antigenic shift.
- Antigenic drift are random mutations in the viral genome that can change the makeup of the surface proteins
- Antigenic shift is where the virus can gain the ability to move between different species and gain new viral surface markers.

Eukaryotic pathogens:

- Organisms which have a membrane-bound nucleus and contain many different structures (organelles) which are held in place by a complex network of fine filaments.
- Eukaryotic pathogens may also have multiple life cycles which may involve a number of intermediate forms. Eg Worms

Prions

- One non cellular unit that is believed to be smaller than a virus is called a prion. Prions cause diseases such as CJD (mad cow disease). They differ from viruses as they don't contain either DNA or RNA but rather rely on the configuration of their protein coat (Prion Protein or PrP) to stimulate the desired result usually via accumulating in a specific location.



Immunology:

- Material that is made by the body's cells is recognized as "self" by the immune system (recognition of Major histocompatibility complex).
- Material that is foreign to the body is classified as "non-self" by the immune system and a defense is mounted. Non self is often referred to as “antigens”
- Self cells are covered in a protein marker known as MHC I (except for red blood cells which have a separate marker system)
- The immune system is covered in a protein marker known as MHCII

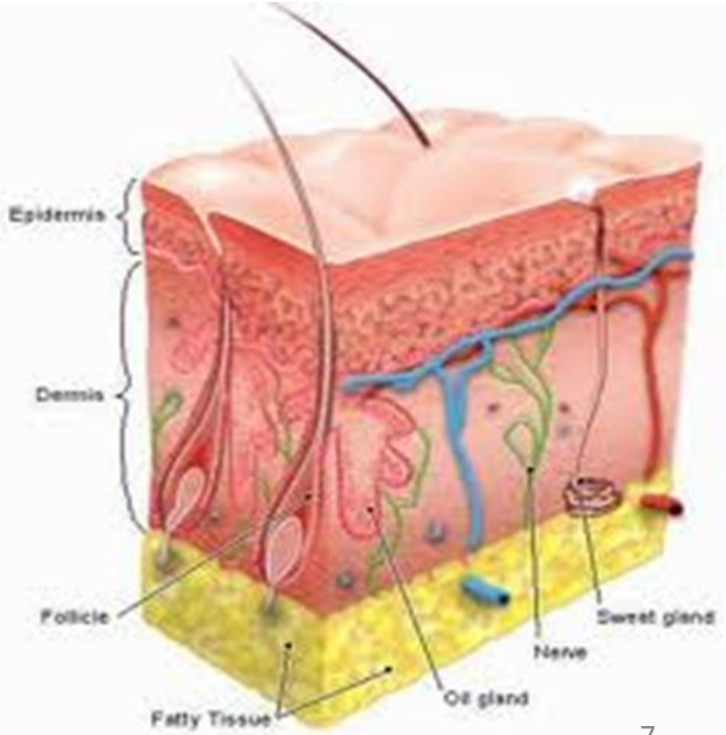
Non specific Immunity

1) First line of Defense

i) Intact Skin: fatty acid/ sweat production and constant shedding usually prevents bacteria from colonizing

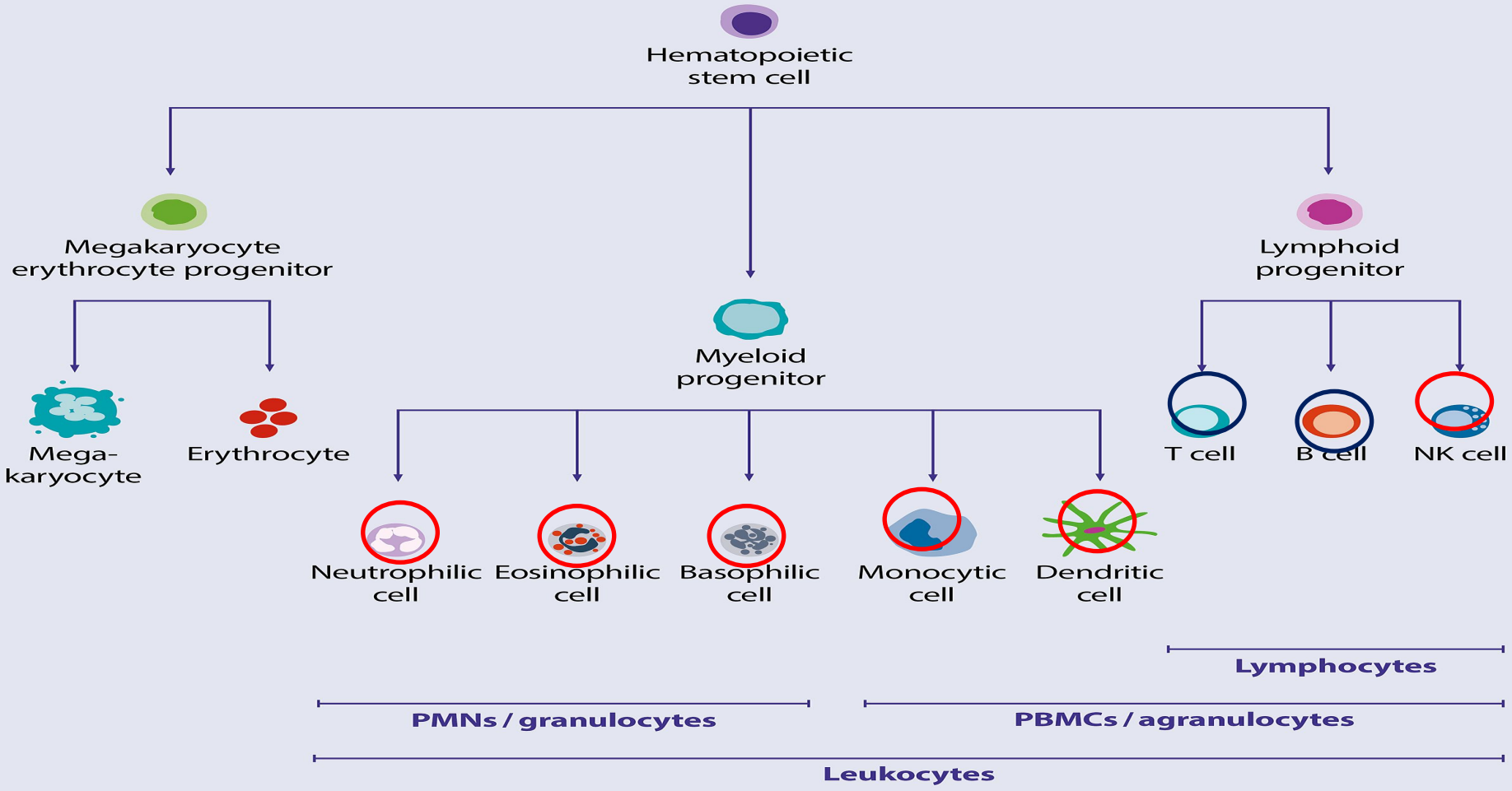
ii) Mucous membranes: Bacteria also are removed via the action of sneezing or coughing.

iii)Natural or residential flora: Good bacteria cover all colonisable surfaces of the human body, which in turn prevents transient bacteria from successfully colonizing.



Normal Skin

White blood cell differentiation



Innate

specific

2) The second line of defense: (non –specific defense)

Component	Function
Macrophage	Activated (mature) form of a cell called a monocyte. Able to detect non self and destroy via phagocytosis. Can act as an antigen presenting cell.
Neutrophil	The most numerous phagocyte. Able to detect non self. Release cyto-toxic chemicals to destroy non self.
Eosinophil	Able to detect non self. Usually involved in larger targets such eukaryotic parasites.
Natural killer cells	Innate lymphocytes that can respond to a wide variety of non self targets
Mast cells	Found in membranes. Are not directly involved in destroying non self but have a role in up regulating immune response via cytokines
Complement	A series of interlocking proteins that can be used to identify non self, co ordinate phagocytic attack and can destroy some cellular pathogens.
Dendritic cells	Cells that can detect non self antigen. Can release cytokines (chemical signals) and act as antigen presenting cell

Question 40

Cellular agents capable of causing infection of body cells include

A. prions.

B. toxins.

C. DNA viruses.

D. Gram-negative bacteria.

Question 41

Higher than normal levels of eosinophils are commonly associated with

A. presentation of antigens to lymphocytes in the lymph nodes.

B. conditions such as parasitic infections and allergic asthma.

C. viral invasion of host cells.

D. swelling due to bruising.

Question 42

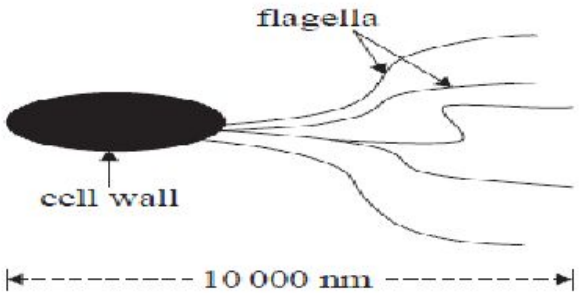
Whooping cough (pertussis) is caused by the *Bordetella pertussis* bacterium. The bacteria are spread from one person to another when someone with the infection coughs and fine droplets containing the bacteria are transmitted. When pertussis infections are detected, the health department of the relevant state government must be notified.

Which of the following gives the best combination of procedures to stop the transmission of *B. pertussis* between unvaccinated people?

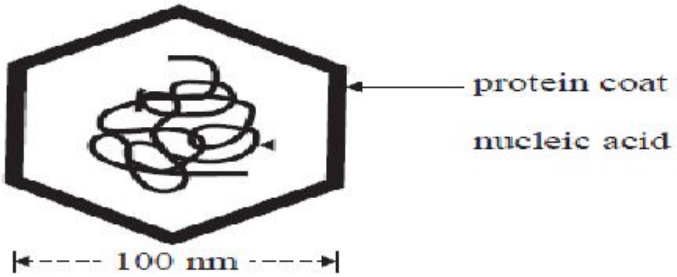
A.	cleaning surfaces with disinfectant	physical distancing
B.	wearing masks	physical distancing
C.	washing hands	closing windows
D.	wearing masks	closing windows

Question 43

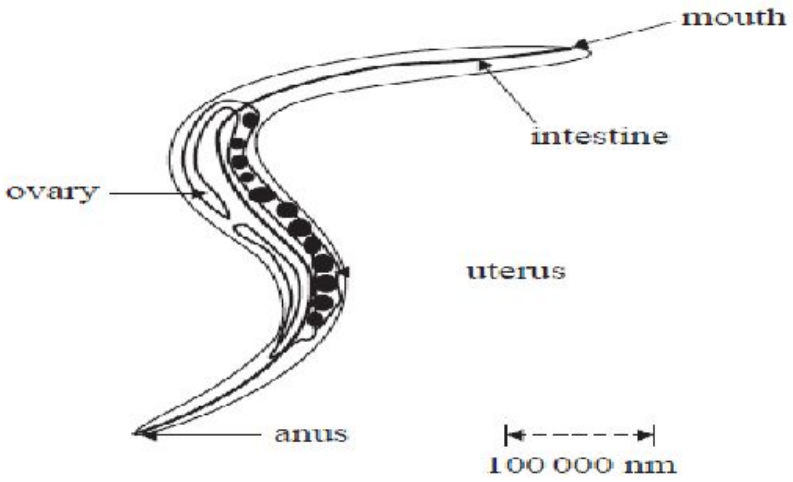
The following diagrams represent various types of plant and mammal pathogens. The approximate size of each pathogen is indicated by a scale bar.



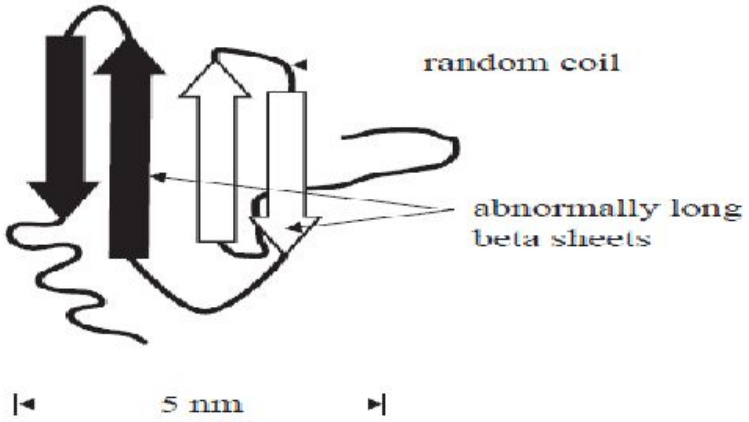
Pathogen W



Pathogen X



Pathogen Y



Pathogen Z

Which of the pathogens above are considered to be cellular?

A. W, X and Y
B. X, Y and Z
C. W and Y
D. X and Y

Question 44

First-line defence mechanisms in humans include

A. development of fever.
B. action of phagocytes.
C. use of antibiotics.
D. presence of cilia.

Question 45

Nonspecific defences of the immune system that act against bacteria include

A. antibodies.
B. phagocytes.
C. interferons.
D. plasma cells.

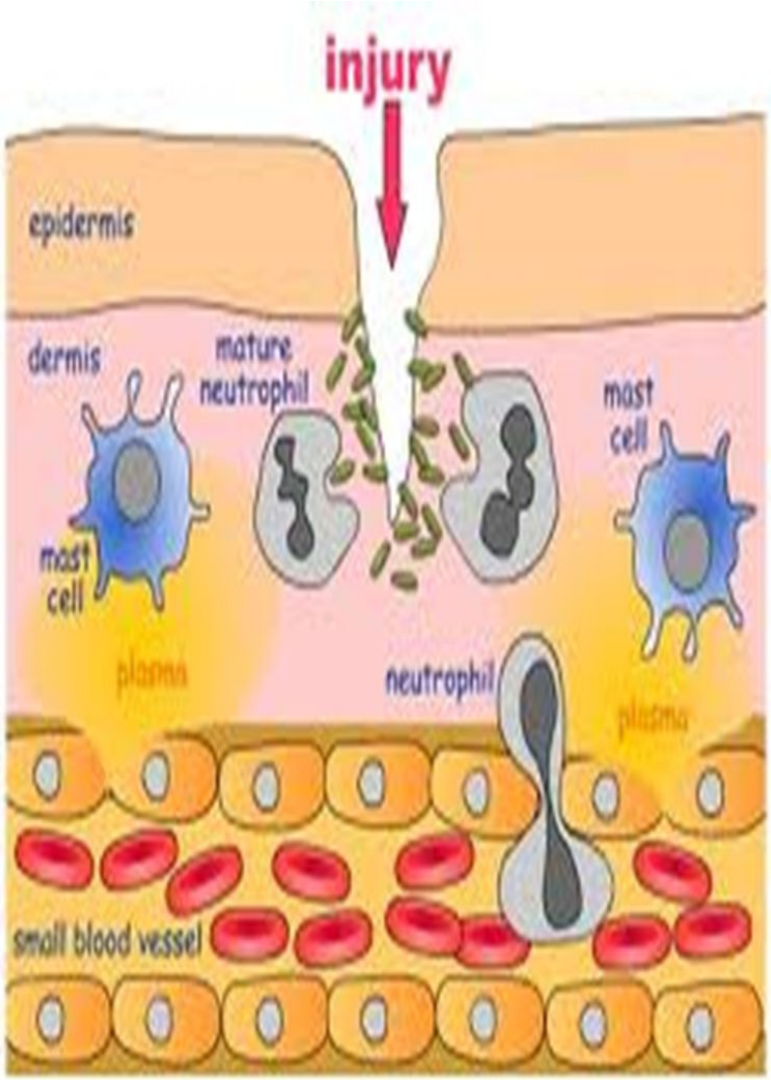
Question 46

Macrophages are large white blood cells that

A. give rise to monocytes.
B. engulf bacteria and destroy them.
C. produce proteins called 'complement proteins'.
D. secrete bacterial-destroying enzymes into the bloodstream.

Inflammation:

- Inflammation is a reaction to the infection and occurs when the arterioles in the area around the point of entry (wound) dilate, resulting in an increased blood supply to the area.
- The release of **histamine** by mast cells and **basophils** increases the permeability of the vascular tissue and the level of arteriole dilation.
- Phagocytes in the area then produce more **histamine**, which attracts more phagocytes to wound.



Complement proteins:

The complement system consists of many proteins that act as a cascade, where each enzyme acts as a catalyst for the next.

i) **Opsonization-**

ii) **Activation of Macrophages**

iii) **Lysis of the target cell**

Primary and Secondary Lymphoid Organs

Primary Lymphoid Organs

- Also called "central lymphoid organs"
- It is where immature lymphocytes develop
- Organs where differentiation, proliferation and maturation of stem cells into immuno competent cells take place.

Includes:

- Thymus
- Bone Marrow

Secondary Lymphoid Organs

- It is where antigen is localized so that it can be effectively exposed to mature lymphocytes.
- initiate adaptive immune response.

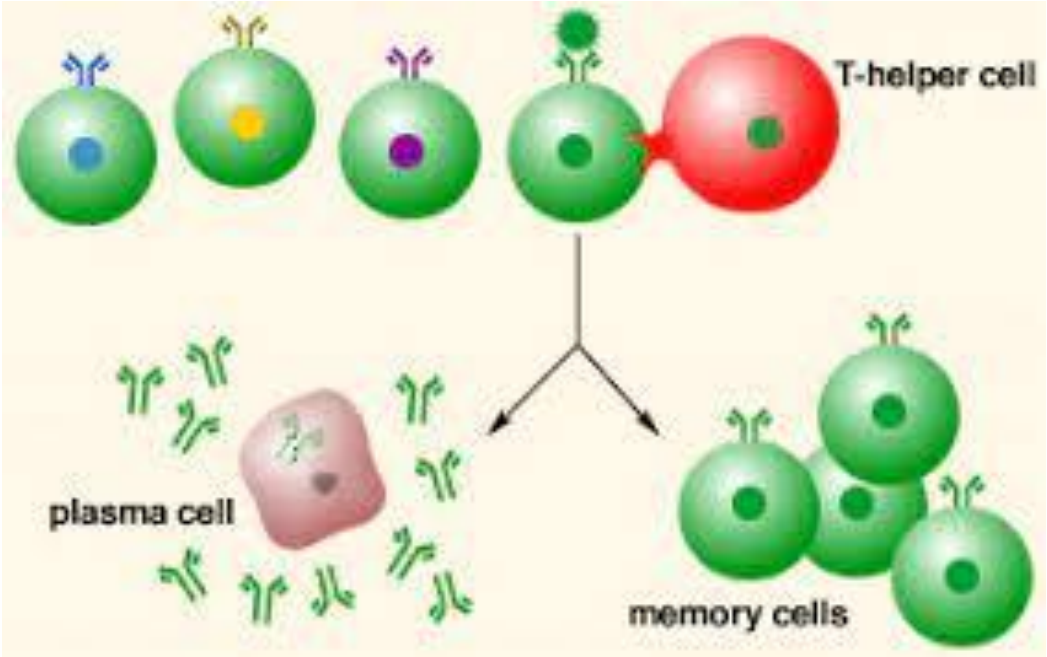
Includes:

- Spleen
- Lymph Nodes
- Tonsils
- Appendix
- Peyer's patches

Specific Immunity

3) Third line of defense:

- Clonal selection theory. Lymphocytes are produced in the bone marrow. Some mature in the bone marrow to produce **B cells**. Others leave the bone marrow before they are fully developed and travel to the thymus where they differentiate into mature **T cells** (thymus dependent cells).



- Undifferentiated T cells are stimulated to differentiate via APC MHCII interaction.
- Undifferentiated B cells are activated via direct interaction with antigen.
- T cell/APC complex allows for the differentiation of Th, Tm and Tc cells.
- Th cells, via a cytokine message will interact with activated B cells and cause a differentiation.
- B cells will differentiate into either Bp or Bm cells.
- B plasma cells are rapidly cloned and produce antibodies.
- Bm cells remain in the node for future secondary infection where they can revert back to plasma cells for a faster response.

Antibodies:

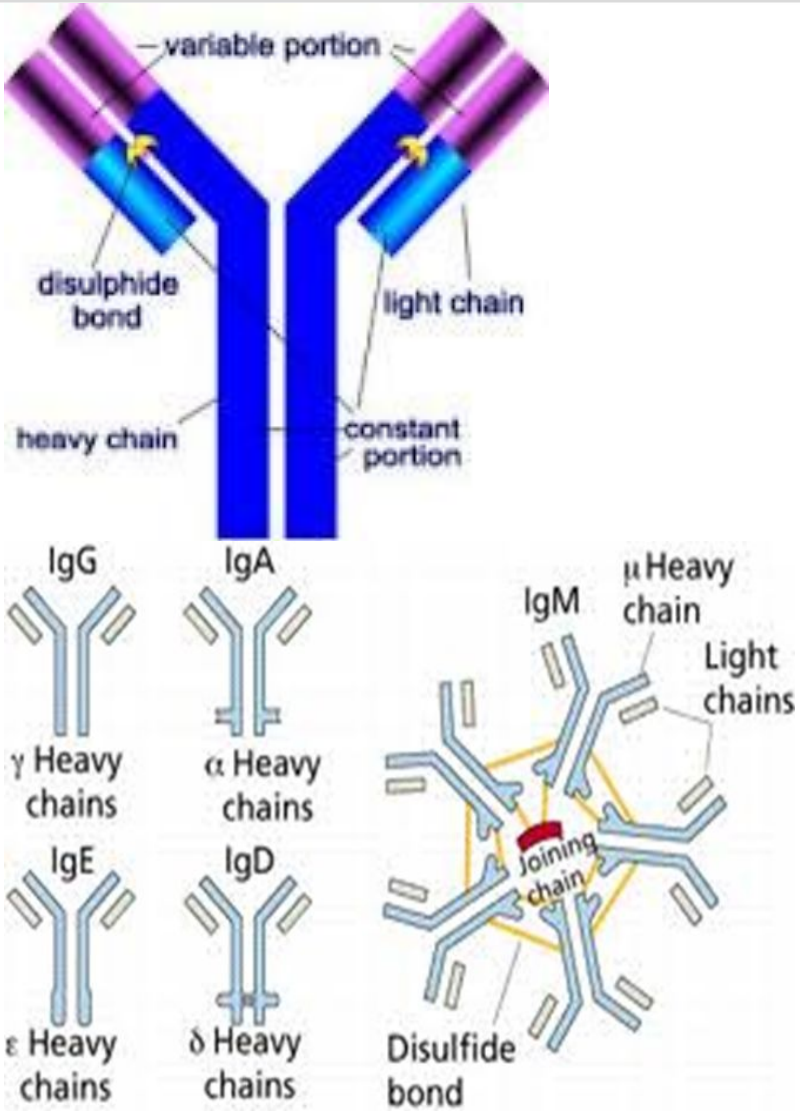
Antibodies are produced by plasma cells. Plasma cells are differentiated B cells. Upon receiving cytokine messages B cells are able to re-arrange their DNA via splicing) to produce antigen specific antibodies.

Antibodies attach to specific antigenic surfaces and allows the immune system to target non self particles more effectively.

Different classes of antibody are made up of different numbers of basic antibody units.

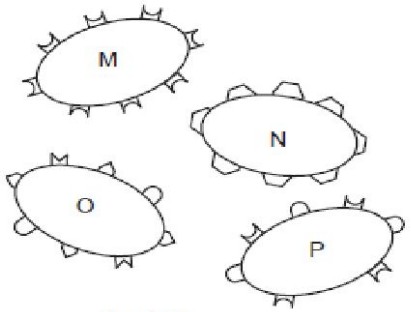
IgG, IgD and IgE are made up of a single molecule.

IgA is made up of two and IgM is made up of 5 molecules.

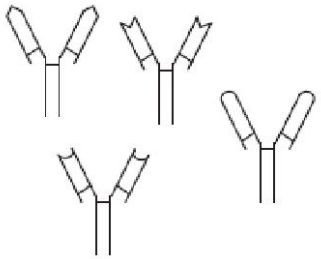


Question 47

A young woman stood on a dirty, rusty nail. The following diagrams show bacteria isolated from the wound and a range of antibodies that were already present in her body.



bacteria

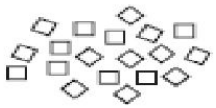

antibodies

The microorganism most likely to cause a severe infection is

A. M.
B. N.
C. O.
D. P.

Question 48

This diagram shows a group of antigens.



An appropriate antibody to use against these antigens would be type

A.

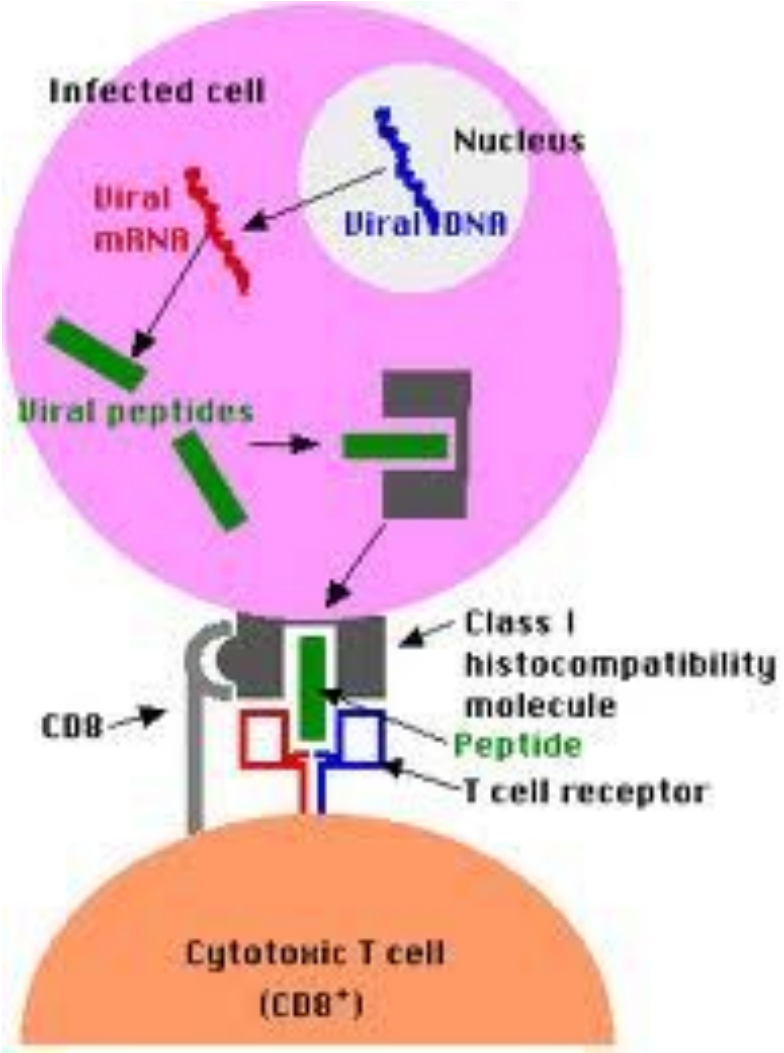

B.


C.


D.


Cytotoxic T cells:

- Another type of T cell, **cytotoxic T cells (Tc)**, kills body cells that have been infected with a virus or can destroy a cell that needs to undergo apoptosis.
- Tc cells have the ability to recognize MHC class 1 markers (markers that are located on all self cells except for red blood cells).
- Tc cells cannot kill free viral particles they are only effective when the virus has penetrated a cell and the cell sends off specific messages.



Active immunity:

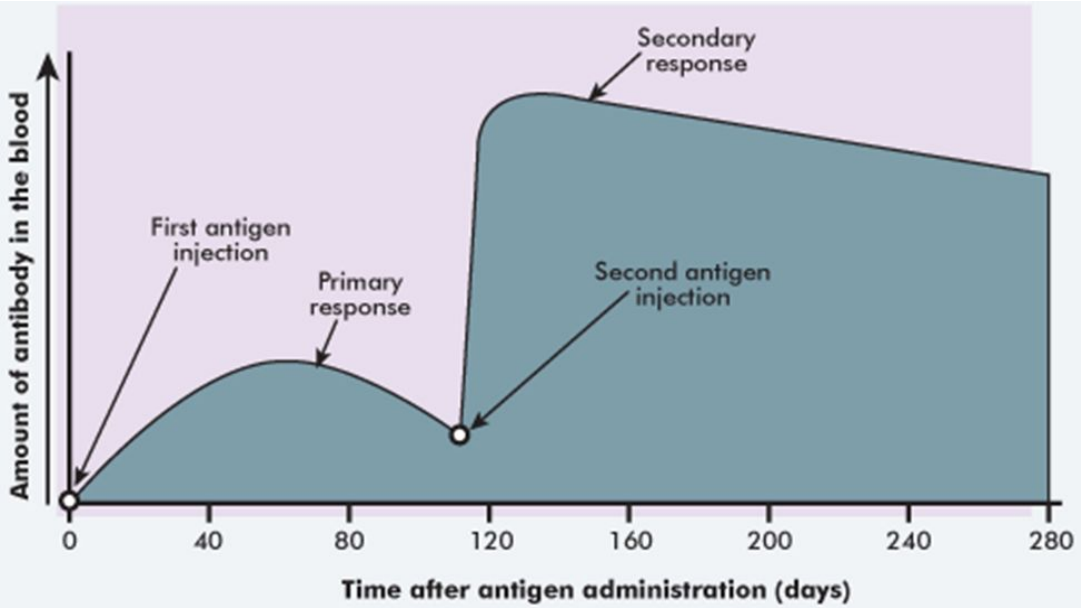
Active immunity can occur naturally or in an induced fashion but essentially both methods revolve around the pre-existing immune system.

Natural active immunity:

This is the natural process whereby the immune system is exposed to a particular disease-causing agent, which triggers off a complex series of events that eventually leads to specific antibodies being produced.

Induced(artificial) active immunity:

The immune system can be forced to produce specific antibodies for a particular disease-forming agent by deliberately presenting it with one. This is achieved via vaccines.



i) Natural vaccines: Cow pox, T.B

ii) Attenuated vaccines: Polio, Measles, Mumps.

iii) Killed vaccines:Polio, Cholera, Plague.

iv) Sub-cellular vaccines: E.g. Hep B, Meningococcal.

v) Toxoid vaccines: E.g. Tetanus, Diphtheria.

Passive immunity:

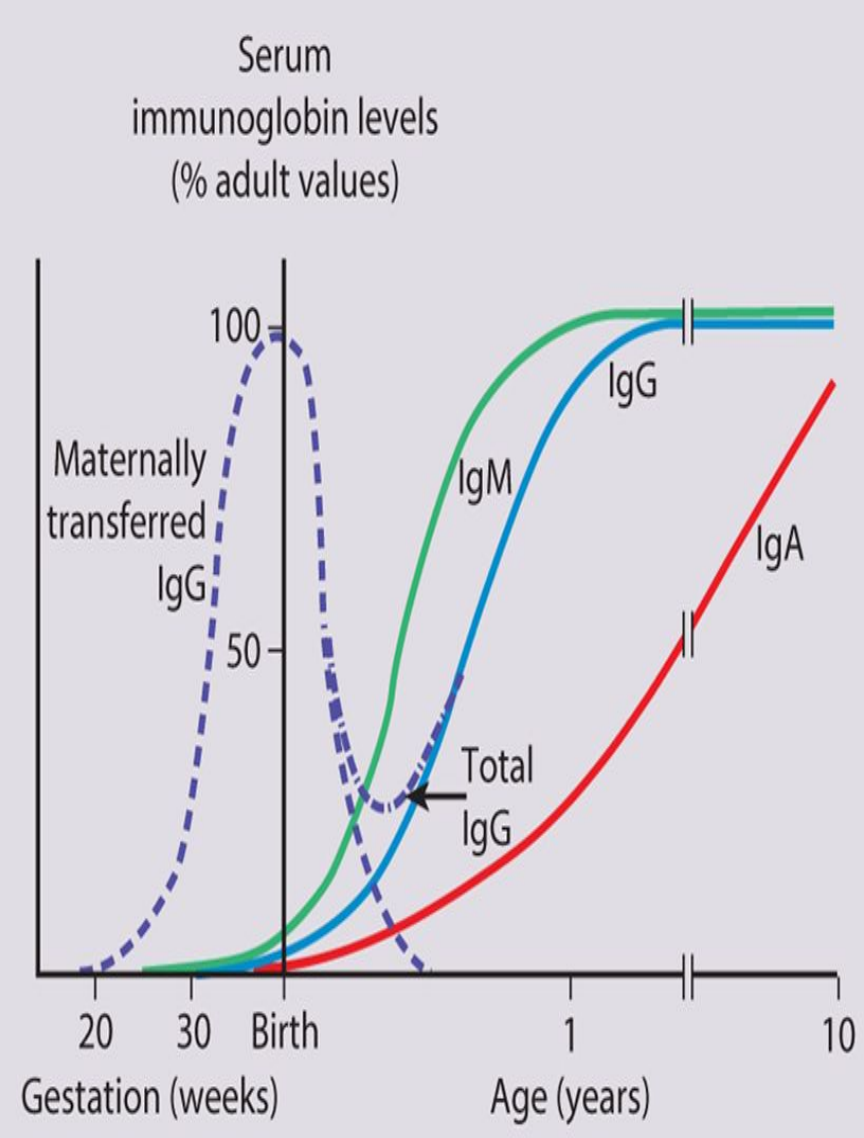
Passive immunity is the process whereby the bodies own immune system doesn't have to make antibodies in order to fight the infection. Rather they are introduced in their fully differentiated form.

Natural passive immunity:

The only time that this occurs is when a developing fetus receives antibodies i) Cross the placenta or ii) via mother's milk.

Induced (artificial) passive immunity:

When you go to the blood bank and choose to donate plasma you are essentially giving your pre-formed antibodies away for use in other people depending on if you have been pre-exposed to the disease- causing agent that the person needs the specific antibodies for.

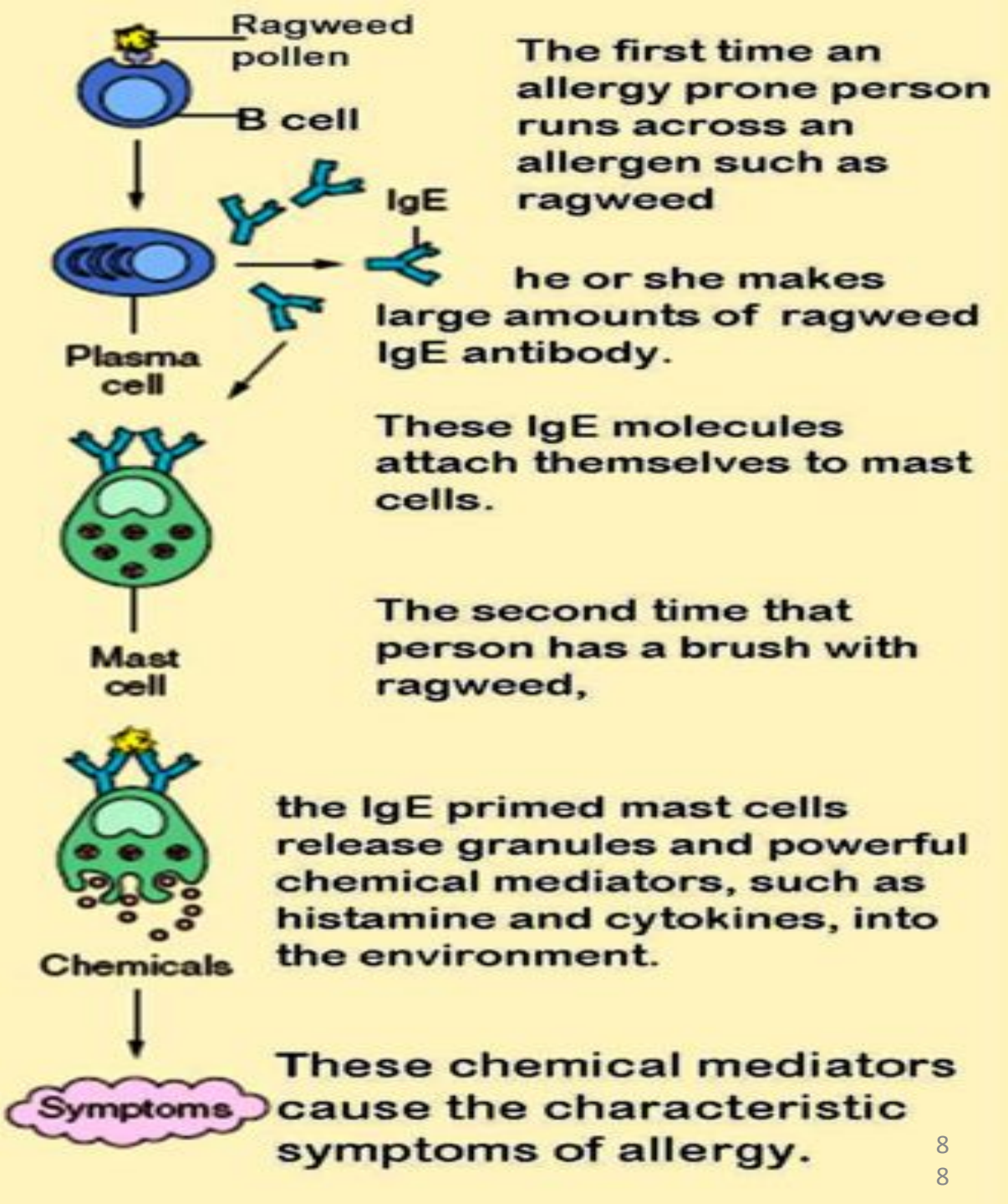


Allergies:

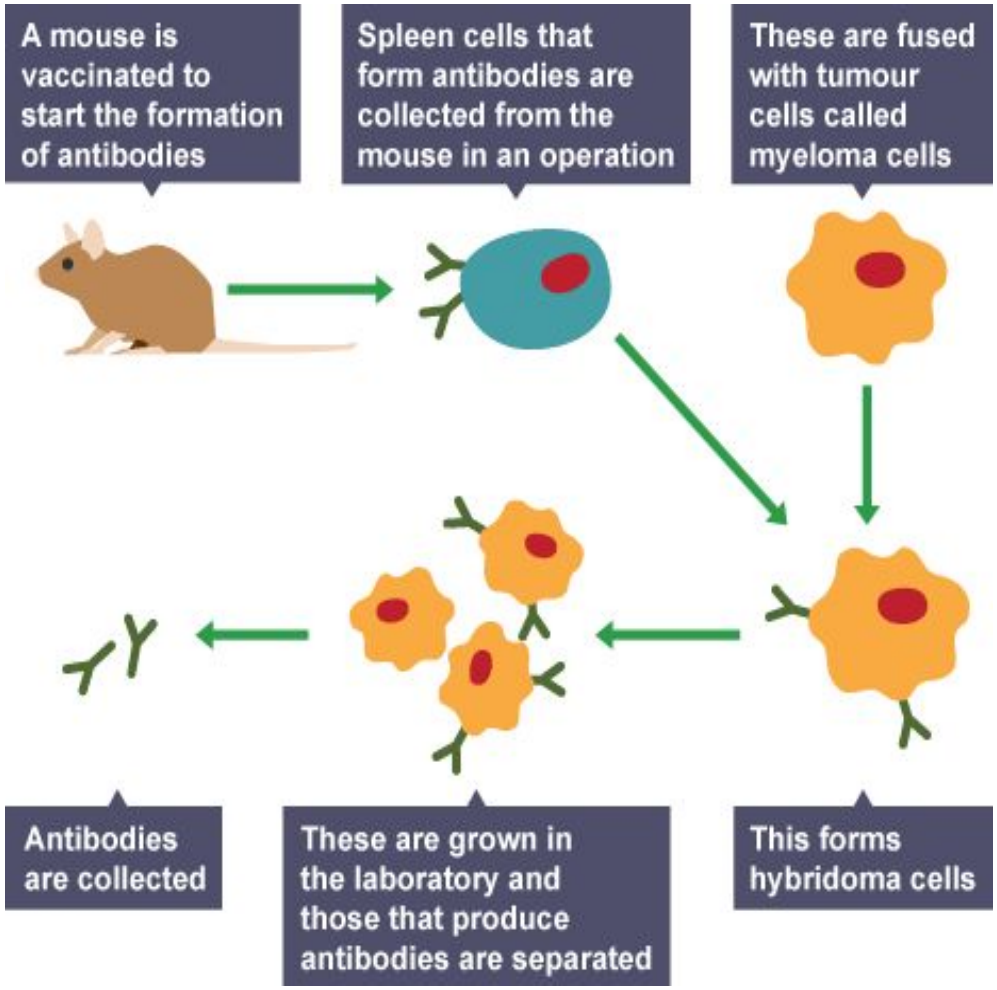
Also called hypersensitivity reaction.

Type 1 reactions are characterized by an allergic reaction that occurs immediately following contact with an antigen referred to as an **allergen.**

Allergic reactions involve the normal APC pathway (Th and B cells to produce specific antibodies) with the production of **IgE** antibodies. **IgE** antibodies then bind with mast cells that subsequently become sensitized to the specific antigen and react upon subsequent interaction with the antigen in a hypersensitive fashion= allergy.



Monoclonal antibodies



Monoclonal antibodies are laboratory-produced molecules engineered to serve as substitute antibodies that can restore, enhance, modify or mimic the immune system's attack on cells that aren't wanted, such as cancer cells.

The tumour cell replicates forever, only producing this single type of antibody.

This can be an antibody that binds to specific proteins on **cancer** cells.

It could also be an antibody that binds to **cytokines**. This could minimise the action of autoimmunity.

Question 49

Monoclonal antibodies can be produced and used to treat different types of cancers.

Which one of the following is a correct statement about monoclonal antibodies?

A. Monoclonal antibodies are carbohydrate molecules.

B. Monoclonal antibodies produced from the same clone of a cell are specific to the same antigen.

C. Monoclonal antibodies pass through the plasma membrane of a cancer cell and attach to an antigen within the cell.

D. Monoclonal antibodies produced to treat stomach cancer will be identical to monoclonal antibodies produced to treat breast cancer.

Question 50

Rabies is a viral disease spread to people by infected animals. A person bitten by an infected animal should be given an injection of specific antibodies.

Following the injection, this person should have

A. natural active immunity.

B. artificial active immunity.

C. natural passive immunity.

D. artificial passive immunity.

Question 51

In Addison's disease, the immune system attacks cells of the adrenal organs. These cells are progressively destroyed.

This form of disease could be due to

A. T cells recognising adrenal cells as antibodies.

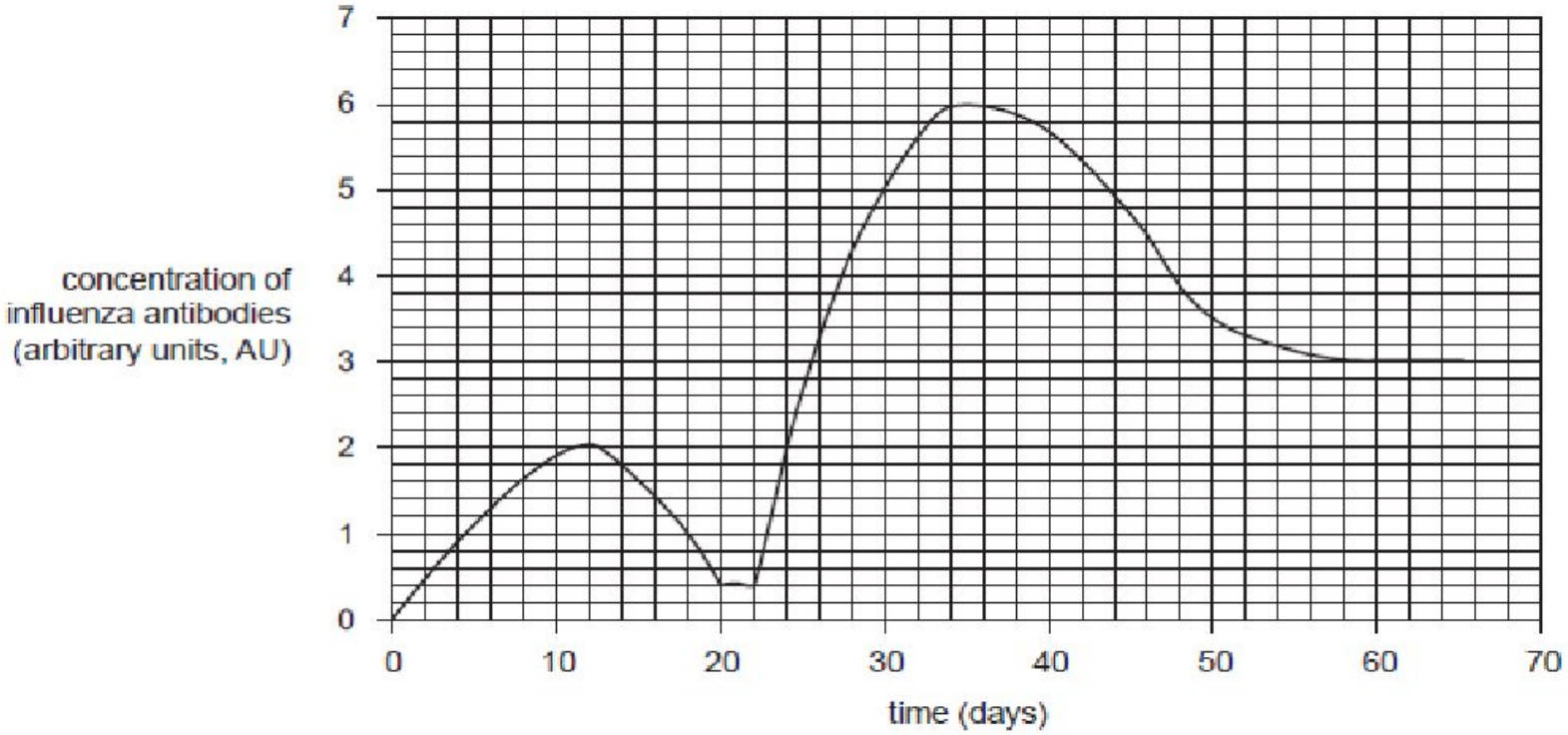
B. the failure of blood complement proteins to be activated.

C. the failure of the immune system to recognise adrenal hormones as self.

D. the immune system failing to recognise cells of the adrenal organs as self.

Question 52

A daily blood sample was obtained from an individual who received a single vaccination against a particular strain of the influenza virus. The individual had no prior exposure to this strain of influenza. The graph below shows the concentration of antibodies present in the individual's blood for this strain of influenza over a period of 65 days.



Which one of the following conclusions can be made using this data?

A. Memory B cells were activated by exposure to the same strain of the influenza virus on day 22.

B. B plasma cells specific to this strain of influenza were most numerous on day 12.

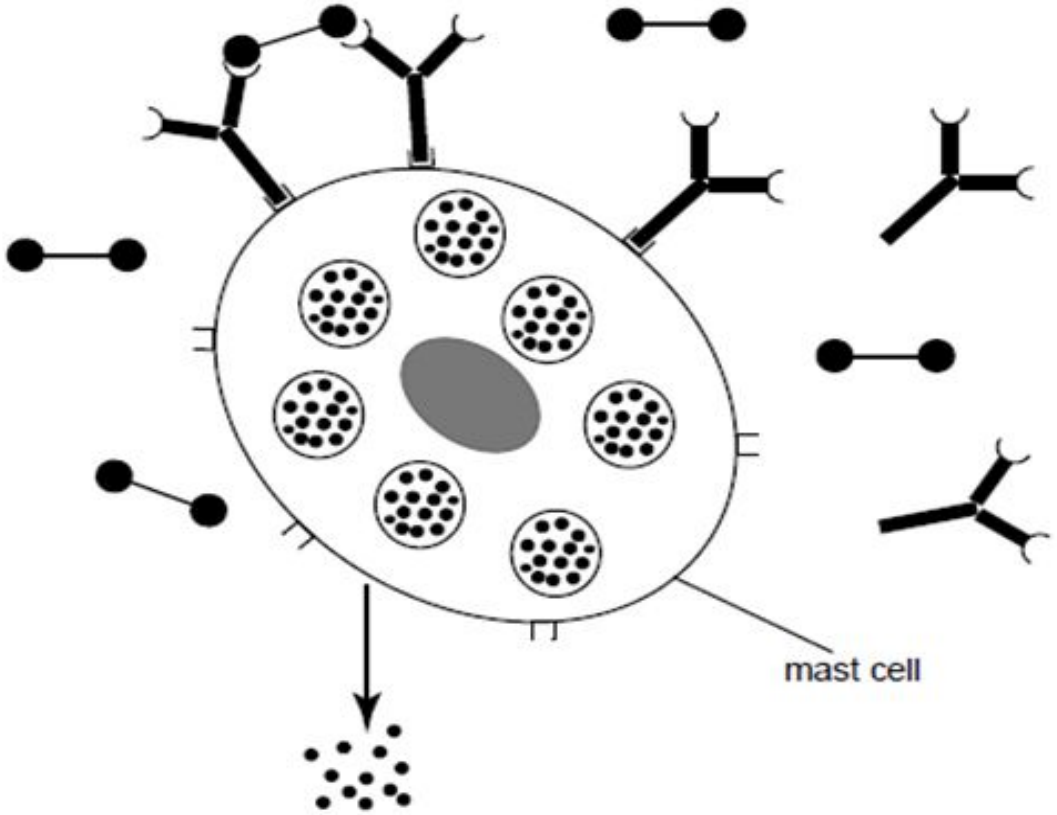
C. Herd immunity to this particular strain of influenza was achieved by day 55.

D. The vaccination containing weakened influenza antigens occurred on day 10.

Question 53

Mast cells are found in a number of different tissues and play an important role in allergic reactions.

Consider the following diagram.



Label **at least three** appropriate parts of the diagram related to the activation and action of a mast cell.

Referring to the diagram and labels you have entered, outline the order of events that occur during allergic reactions.

Question 54

In an infected individual, the smallpox virus will come into contact with components of the innate immune system, including various antigen-presenting cells.

Describe the role of antigen-presenting cells in the activation of the adaptive immune response against the smallpox virus. 3 marks

Adaptive immunity consists of responses to intracellular and extracellular threats.

Explain how the adaptive immune system responds to an intracellular pathogen. 3 marks

Variation and Evolution:

- Population: A group of the same species living together in the same region at a given time.
- Variation of traits (characteristics) may exist within members of a population.
- Variation can come in the form of:

i) Structural: -Humans that posses more than 5 digits is called polydactyly.

ii) **Biochemical:** -Example found in the ABO antigens of humans.

iii) **Physiological:** In the human population such differences are seen in peoples ability to taste certain chemicals, to smell particular odors.

iv) **Behavioural:**- Exemplified in dog breeds where certain dogs may retrieve whereas others like the water.

v) **Developmental:** Exemplified by adult animals displaying traits not found in the juvenile animal and visa versa.

vi) **Geographic:**
-Depending on location animals of the same species will differ in appearance

Causes of variation:

-**Environmental** and **genetic** factors are involved in determining variants within a population.

Environmental factors:

- Identical twins which therefore have identical genotypes may still differ in their phenotypes depending on environment. Nutritional deficiencies may allow one child to develop rickets while the other will have normal bone structure.

- Another example within the animal kingdom would be bees. Variation in the food and pheromone's that are supplied to the larvae determine whether she will become a sterile worker or a fertile queen bee.

- Environmental factors can also be at work within in the uterus where a developing fetus is susceptible to viral agents and ingested chemical substances which can either enter the mothers blood steam or cross the uterine barrier.

E.g.

Thalidomide- the loss of limbs

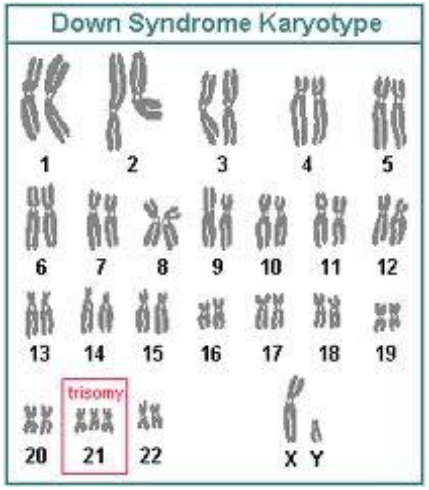
Alcohol- low birth weight and brain damage

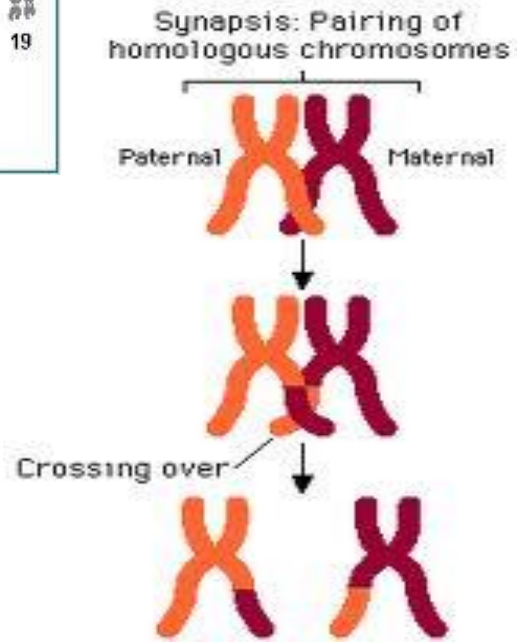
Rubella virus- hearing and vision defects.

Genetic factors:

Variation due to recombination:

- The crossing over between homologous chromosomes, meiosis and the segregation of alleles produces new **recombination's** of genes and is the main cause of variation within a population of **sexually-reproducing** species.
-The more chromosomes that are involved the greater the chances of recombination.





Variation due to changes in chromosome number

- Every species has a characteristic number of chromosomes, a gain or a loss in terms of the total numbers results in variation.

- Humans can also be used as an example in the case of Down syndrome, which comes about because of an extra chromosome occurring at position 21 of 23.

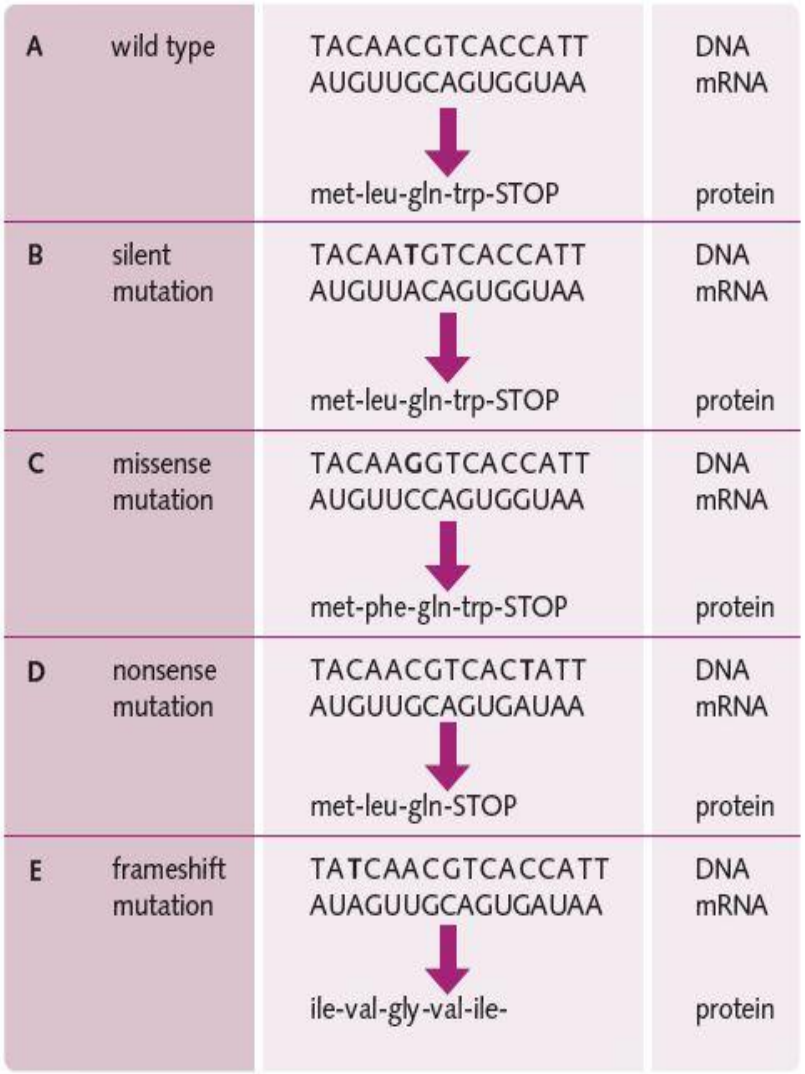
Mutation:

- Gene mutation is the process, which produces new alleles of genes in various species and so generates genetic variation.

- Mutations can be broken up into three broad categories
  - i) Point mutations
  - ii) Frame shift mutations
  - iii) Block mutation

- Germ-line mutations are the source of mutational variation within a species as the trait needs to be passed onto the next generation. Somatic mutations end when the individual dies.

- Germ line mutations can be spontaneous or may be the result of exposure to mutagenic agents such as radiation, or several types of chemical.

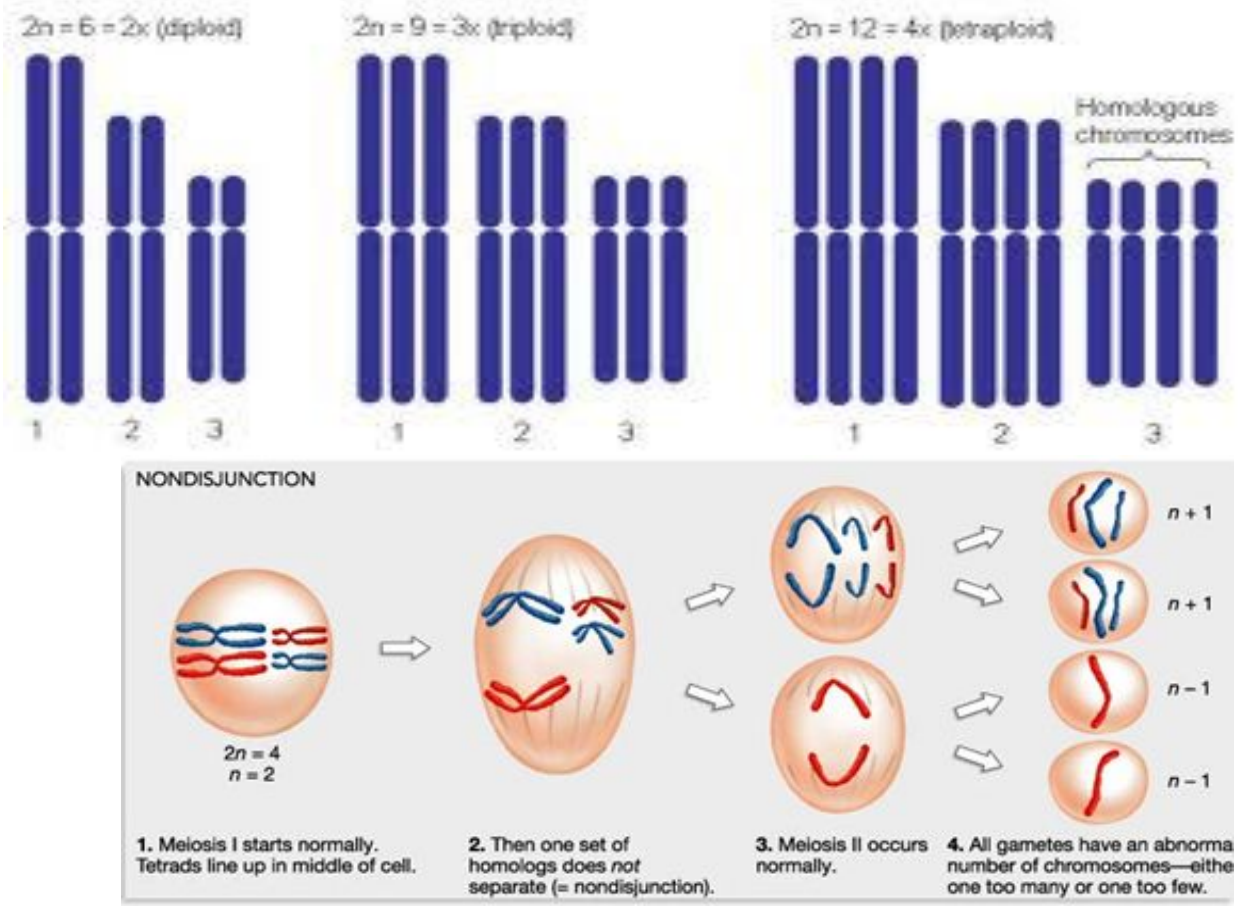


Block Mutations (Chromosomal alterations)

Addition, deletion, duplication, inversion, translocation

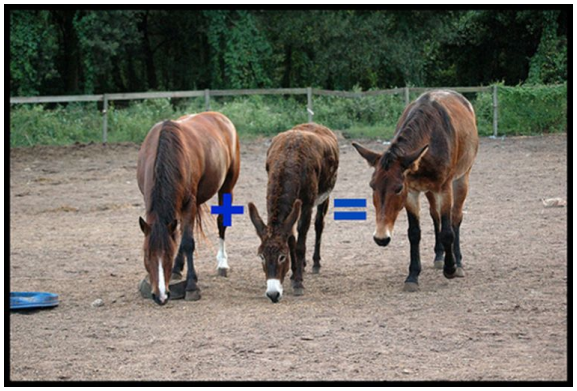
Polyploidy: Is a term used to describe cells and organisms containing more than two paired homologous sets of chromosomes.

Aneuploidy: Is an abnormal number of chromosomes, and is a type of chromosome abnormality. An extra or missing chromosome is a common cause of genetic disorders (birth defects).



Gene Flow:

Flow of genes between populations. Gene flow is genetic exchange, resulting usually from the movement of animals from one population to another followed by the exchange of genes.



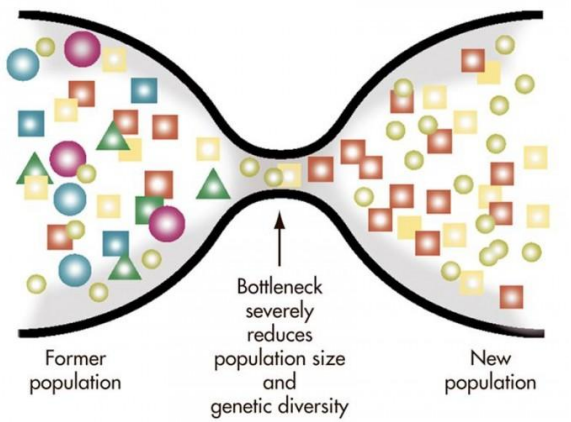
Genetic Drift:

Genetic drift is the change in the frequency of alleles from generation to generation caused by CHANCE ALONE. Its influence is usually greatest in small populations.

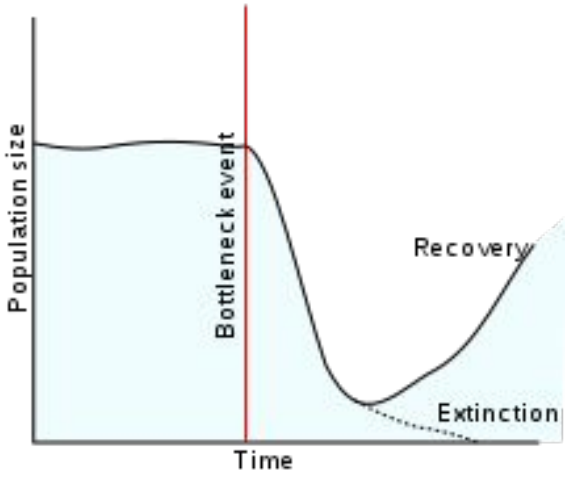
i) Bottleneck effect

ii) Founder effect

Genetic Bottleneck via gene drift

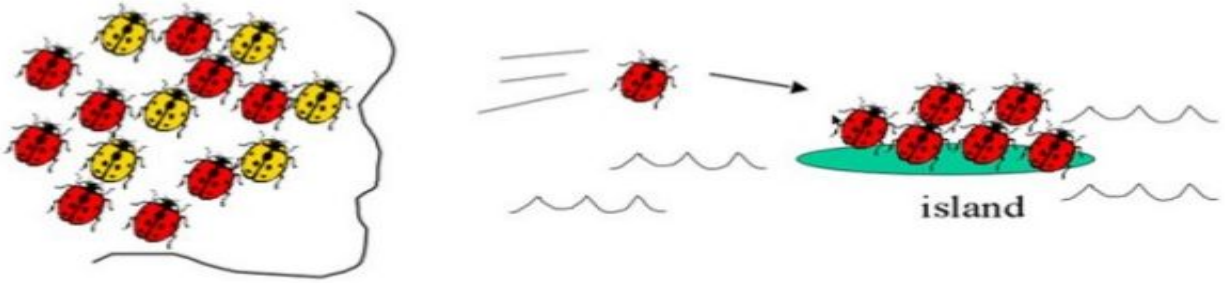


Random removal of variants from a population. This decreases gene pool diversity. Increasing population number after the bottle neck does not increase genetic diversity of the gene pool. This results in unfavourable gene pool dynamics.



Founder effect

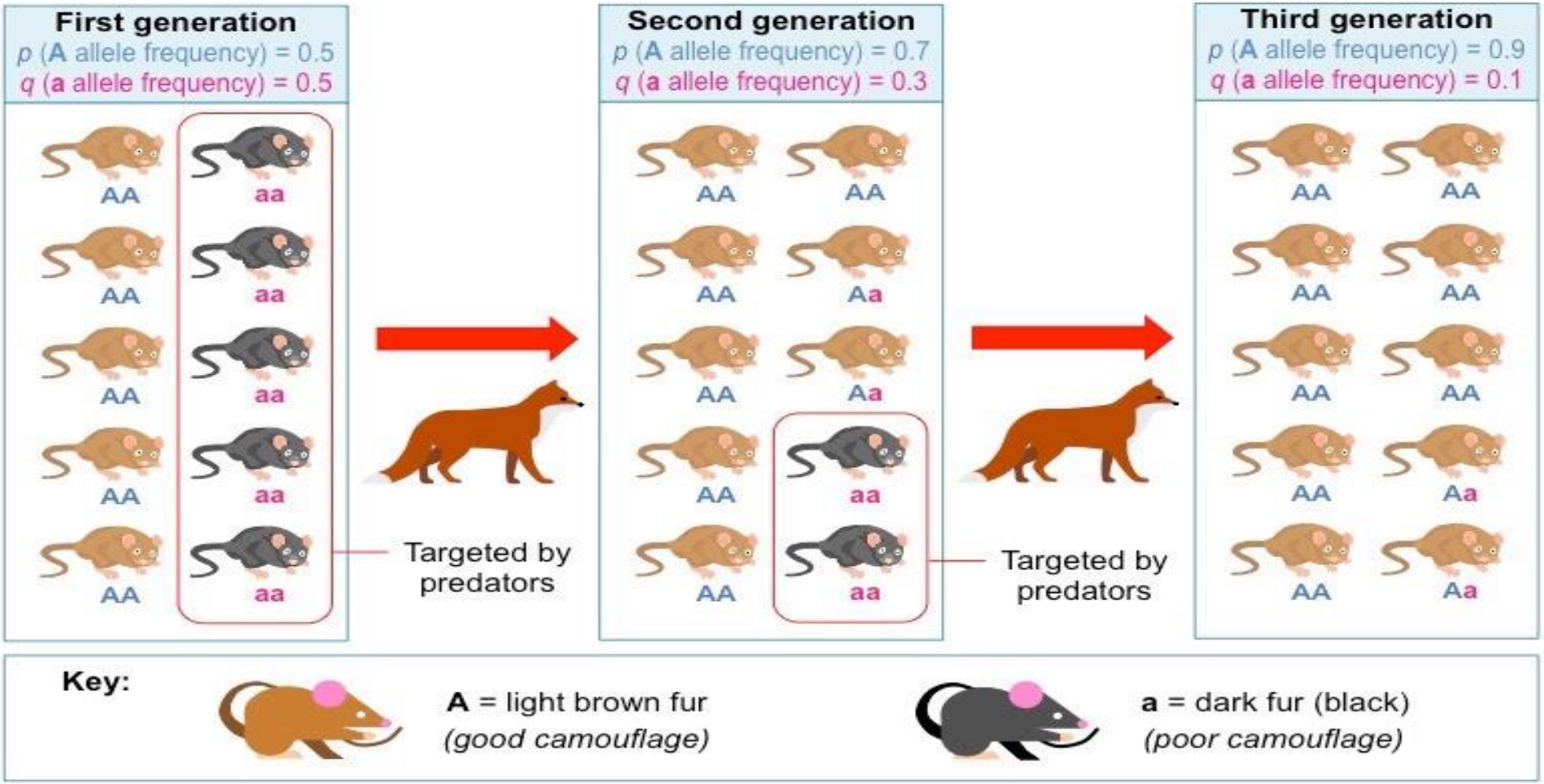
- **founder effect**: a few individuals from a population start a new population with a different allele frequency than the original population



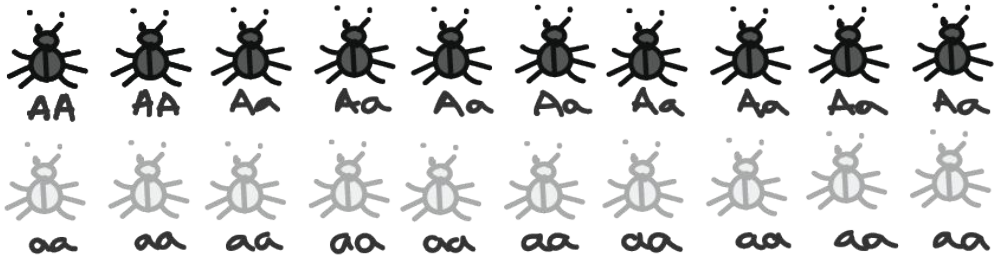
Allele Frequencies

- The genetic information present in a population of organisms is known as a gene pool.

The genetic information that is present in a gene pool is expressed in terms of frequencies (proportions) of the various alleles in a population. **Alleles can have a frequency between 0 and 1.**



Small population of 20 beetles:



ALLELE FREQUENCIES:

Freq. of allele A = p = 12/40 = 0.3

Freq. of allele a = q = 28/40 = 0.7

GENOTYPE FREQUENCIES:

Freq. of AA = 2/20 = 0.1

Freq. of Aa = 8/20 = 0.4

Freq. of aa = 10/20 = 0.5

Allele frequency change:

- Allele frequencies change over time due to; selection, migration and chance.
- Under natural conditions, members of a population compete with each other for access to living space, energy supplies and mating partners in their habitat.
- Members of a population are also exposed to competition from other species, to predation, to parasites and to disease causing organisms.

The phenotype that makes the greater contribution to the gene pool in the next generation has **a higher fitness value** and is said to have **a selective advantage.**

Level of selection

The level of selection on phenotypes in a population can vary.

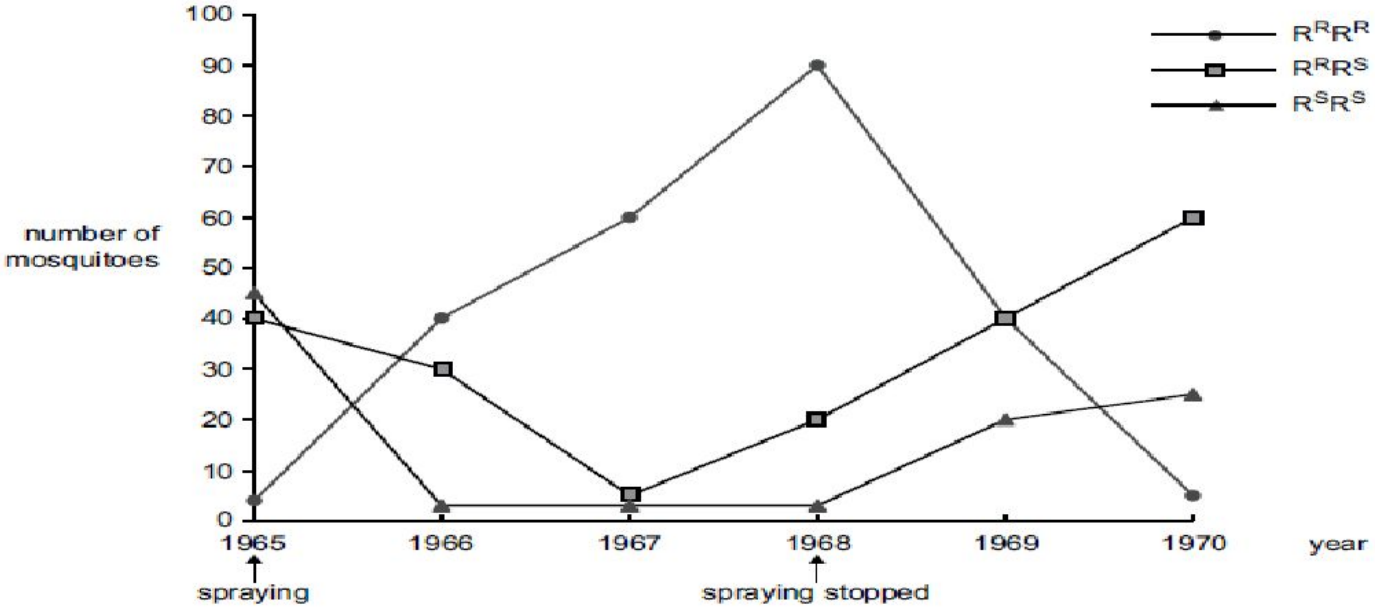
Artificial selection:
Human interference in the normal process of natural selection, where genetic variants that would not normally be selected for due to natural selective pressures can proliferate and pass on their genes. SELECTIVE BREEDING

Natural selection:
Random genetic variants may have a selective advantage over other members of the same population due to the particular selective agent.

Question 55

In the mosquito there is a gene locus which has two alleles, R^R= resistant and R^S= sensitive, which are involved in resistance, in particular to the insecticide DDT.

The graphs below show the number of mosquitoes of the 3 phenotypes (and genotypes) collected from 1965, when DDT was first used, through to 1970, two years after the spraying of DDT stopped.



From the data it is possible to conclude that

A. the frequency of the R^S allele is greater than the frequency of the R^R allele in 1968.

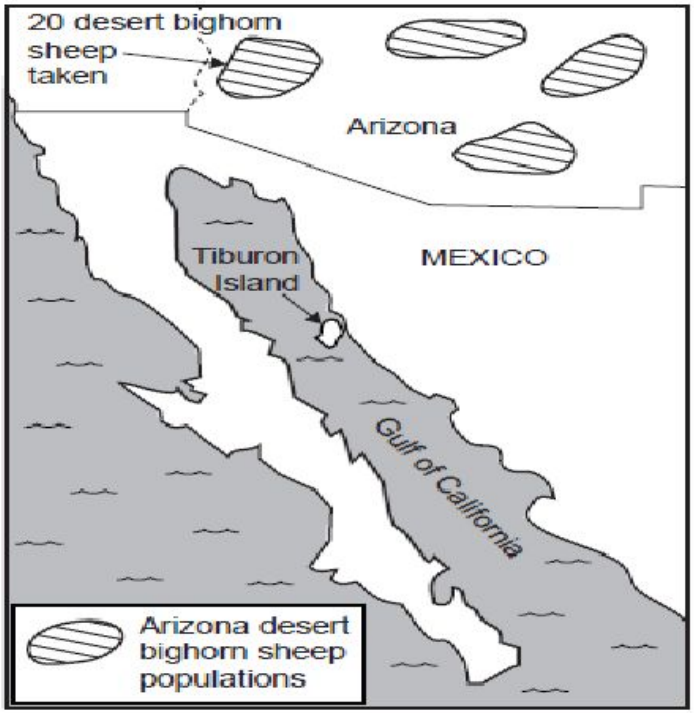
B. many generations after the removal of DDT the R^R allele would disappear from the population.

C. after removal of DDT from the environment in 1968, having the R^R R^R genotype reduces the chance of survival.

D. between 1967 and 1968 in the presence of DDT in the environment, the mosquitoes with the R^R R^S genotype are the most likely to survive.

Question 56

Tiburon is an isolated island off the coast of Mexico. Desert bighorn sheep became extinct on this island hundreds of years ago. In 1975, 20 desert bighorn sheep were taken from a population in the American state of Arizona (shown on the map below) and were re-introduced to Tiburon Island. By 1999, the population of desert bighorn sheep on Tiburon Island had risen to 650.



Which one of the following statements about this 1999 population of desert bighorn sheep on Tiburon Island is correct?

A. The gene pool of this population will be identical to the gene pool of the Arizona populations.

B. This population has less genetic variation than the Arizona populations and is an example of the founder effect.

C. This population will have become a new species because the mutation rate on Tiburon Island will be much higher than in Arizona.

D. Having been through a population bottleneck, the current population will now show increased genetic variation compared to the Arizona populations.

Question 57

The variation in allele frequencies between several isolated populations can be due to genetic drift.

Genetic drift is likely to be observed when

A. there is gene flow.

B. the mutation rate is high.

C. there are strong selective pressures.

D. a population is reduced to a few individuals.

Question 58

Northern elephant seals, *Mirounga angustirostris*, were nearly hunted to extinction in the 1890s, with only about 20 individuals left at the end of the century. The population has now grown to more than 120 000. In the 1890s, southern elephant seals, *Mirounga leonina*, were not as severely hunted and currently there are estimated to be 600 000 southern elephant seals.

Based on this information, it is true to say that

A. northern elephant seals have evolved as a result of the 'founder effect'.

B. northern elephant seals would show less genetic variation than southern elephant seals.

C. southern elephant seals would have experienced greater genetic drift than northern elephant seals.

D. the mutation rate in northern elephant seals would have been greater than in southern elephant seals.

Question 59

Unlike many domesticated animal species, sheep have a diverse gene pool. The Merino breed of sheep is particularly diverse.

This means that the Merino breed of sheep

A. has been through a genetic bottleneck.

B. will be very susceptible to infectious disease.

C. will show a high frequency of genetic disorders.

D. has a good chance of surviving environmental change.

Question 60

A newborn baby was diagnosed with Patau syndrome. Her karyotype showed three copies of chromosome 13.

This is an example of

A. frameshift mutation.

B. block mutation.

C. aneuploidy.

D. polyploidy.

Question 61

The Australian Sheep Breeding Values is a genetic selection program aimed at improving traits such as growth rate, wool quality, fibre diameter and parasite resistance.

The effect of selective breeding programs such as this one on the genetic variation of a population over time is best explained by

A. an increase in the gene pool through the selection of alleles that enhance the survival of a population.

B. a decrease in the gene pool of the population through the selection of particular alleles by humans.

C. no change to the allele frequency due to the bottleneck event taking place within this population.

D. an increase in gene flow leading to an increase in the variety of alleles.

Mechanisms of evolution: (natural selection) (bacterial/viral examples)

i) Reproduction: Reproduction of organisms in a population produces descendant populations.

ii) Excess potential offspring: The reproductive potential of parents is much greater than the actual number of descendant offspring that survive.

iii) Variation: Members of a population may vary. Variation that is genetically based is passed on to offspring.

iv) Selection: Environmental resources are limited, so there is competition between individuals. Individuals that can compete successfully will leave a greater proportion of offspring than less successful individuals. In this way characteristics are selected.

v**) Adaptation over time: Environments change over time. Heritable characteristics that suit a particular environment will be selected. Populations diverge over time and become adapted to the new conditions.**

vi) Chance effects: In small populations, shifts in the frequency of certain characteristics can also occur by chance.

vii) Divergence and Speciation: When populations are geographically isolated and thus cannot interbreed, divergence over time may result in them becoming different species.

The formation of new species.

Speciation involved two steps.

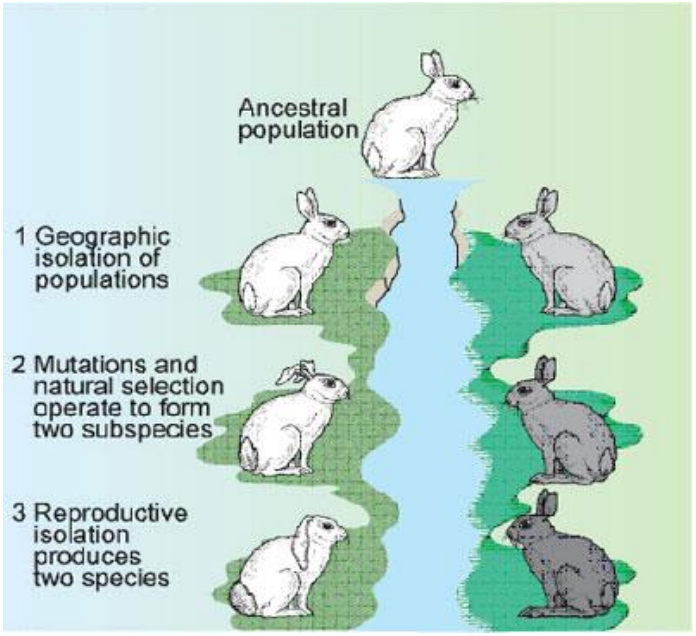
1**. Physical isolation of populations**. Isolated populations accumulate genetic differences due to different selection processes and genetic drift.

2. This step occurs over time and involves divergent evolution. **Divergence** results in the accumulation of different features in the isolated populations, both in appearance and at the molecular level. Eventually, enough differences accumulate so that the new daughter species is unable to interbreed with the original.

Allopatric speciation:
Occurs when members of a population are split into two separate
groups, each of which is exposed to different selective forces. The
lack of gene flow also speeds up the rate of speciation.
The main requirements are

i) Isolation (Lack of gene flow)

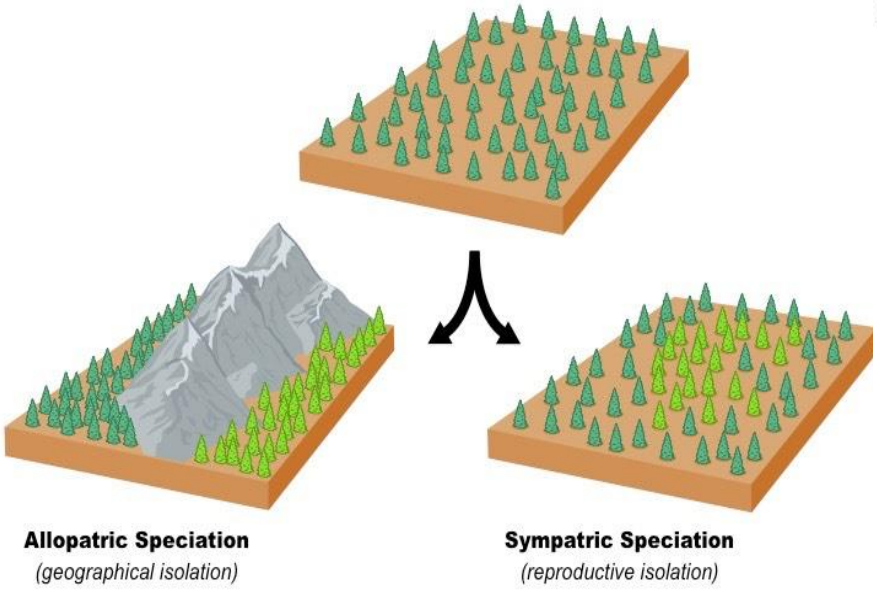
ii) Differing selective pressures



The formation of new species.

Sympatric speciation:

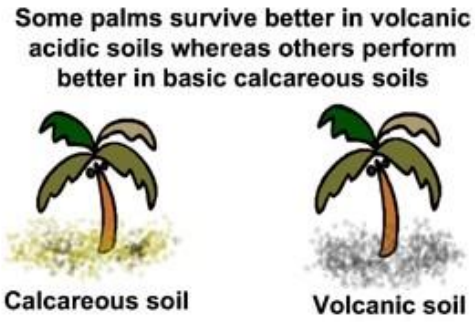
Sympatric speciation occurs when there are no physical barriers preventing any members of a species from mating with another, and all members are in close proximity to one another.



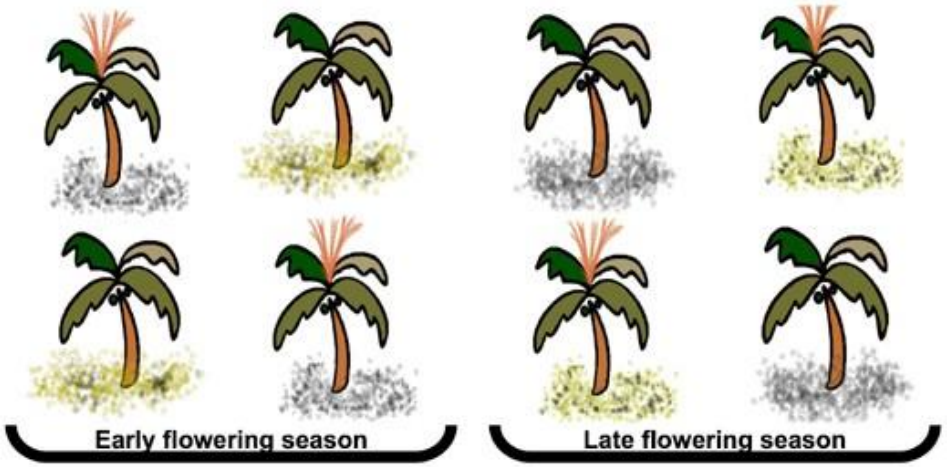
Allopatric Speciation
(geographical isolation)

Sympatric Speciation
(reproductive isolation)

Disruptive selection



Assortative mating



Palms growing in calcareous soil tend to flower later than palms growing in volcanic soils

Question 62

In these examples, allopatric speciation gave rise to new species of Darwin's finches and sympatric speciation gave rise to new species of *Howea* palms. These speciation events are different, but also have some similarities.

Which one of the following is a similarity between the two types of speciation?

A. The emergence of new species relies on the presence of a geographical barrier.

B. The new species can produce viable and fertile offspring with the ancestral species.

C. Both occur through the reproductive isolation of individuals in a population.

D. The new species are identical to the ancestral species.

Question 63

Geographical isolation is important in assisting the process of

A. adaptation.

B. gene flow.

C. speciation.

D. fossilisation.

Question 64

Streptococcus pneumonia is a bacterium which causes pneumonia in humans and may show resistance to antibiotics.

a. How would antibiotic resistance have first occurred in the *Streptococcus pneumonia* population?

_____

1 mark

b. The incidence of antibiotic resistant *Streptococcus pneumonia* has increased in the last 15 years. Approximately 40% of infections by this bacterium are resistant to commonly used antibiotics.

i. Explain how the increase in bacteria resistant to antibiotics has occurred.

_____

_____

_____

_____

_____

_____

_____

_____

ii. What is the selective agent associated with the increase in antibiotic resistance in *Streptococcus pneumonia*?

_____

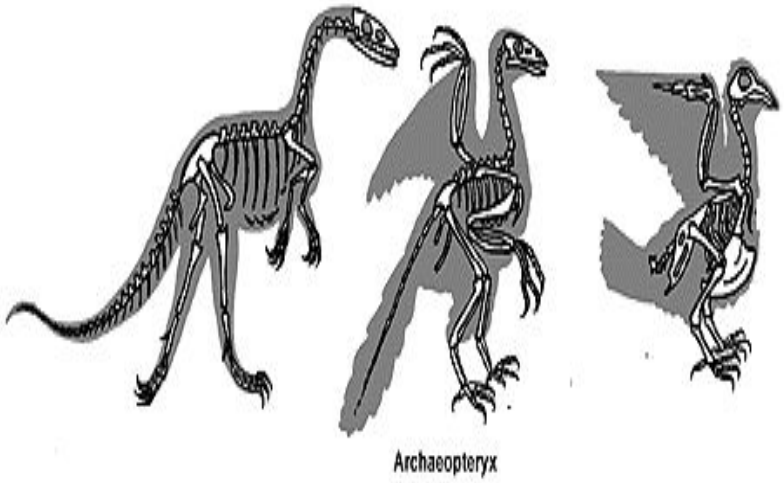
3 + 1 = 4 marks

Evidence for evolution.

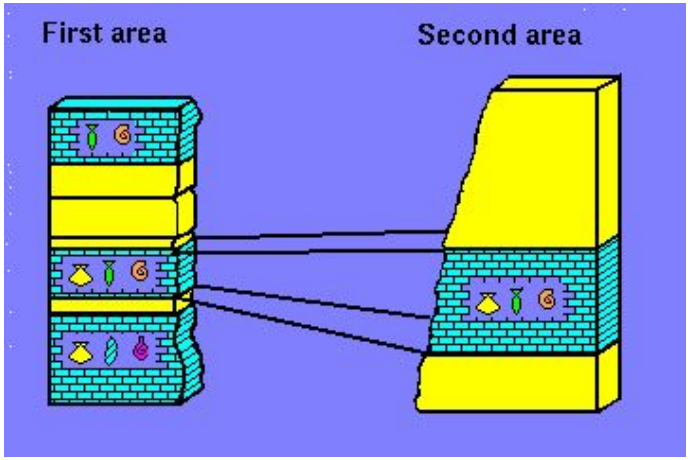
- The evidence for evolution comes from several sources.
    i) fossil records/ transitional fossils.
    ii) comparative anatomy
    iii) comparative biochemistry

i) Fossilization occurs when an organism is buried and entombed by sediments such as sand silt or mud, then under pressure they undergo **mineral exchange** with the surrounding rock. This is as opposed to preservation which as a process does not involve mineral exchange.

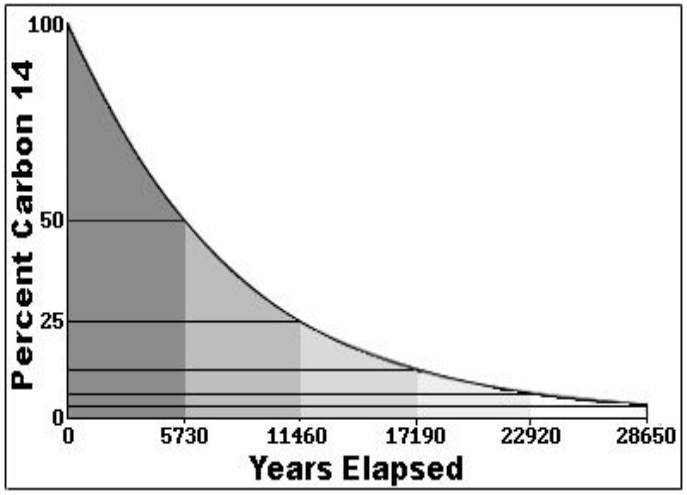
Fossils can be compared to modern day creatures in order to determine possible structure and function.



i) Relative dating:
This process involves determining the age of the rock around the fossil or using index fossils to determine the approximate age of the fossil in question. This is not an absolute means of age testing.
An Index fossil is a creature that was wide spread and died out globally at the same time. Hence it can be used as an index point in the rock strata.

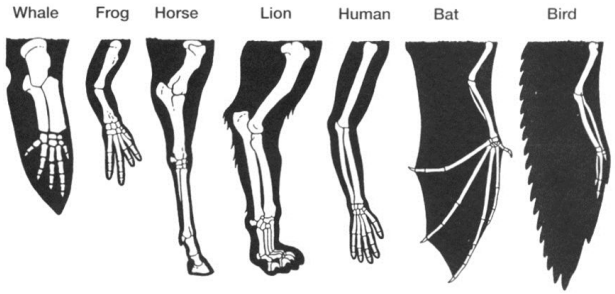


ii) Absolute dating: This process involves the direct assessment of the age of the fossil via radio isotopic means. The process relies of the fact that the half life of specific elements is known and can be used to accurately determine the age of the fossil. I.e carbon dating.

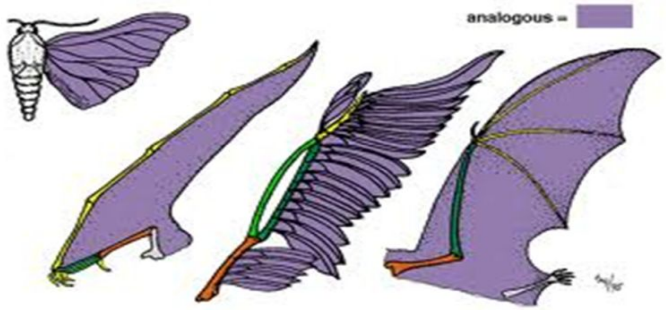


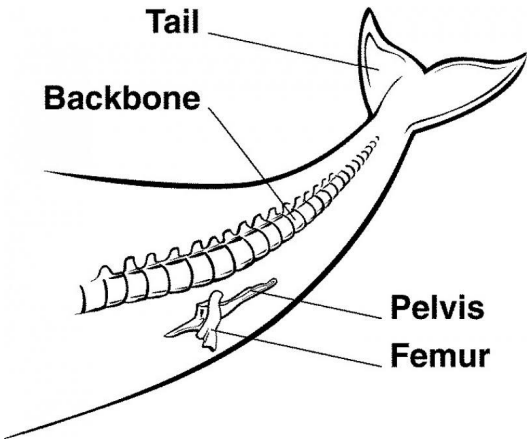
Comparative anatomy

<u>Homologous Features</u>: Same structure, different function.



<u>Analogous features</u>: Same function, different structure.





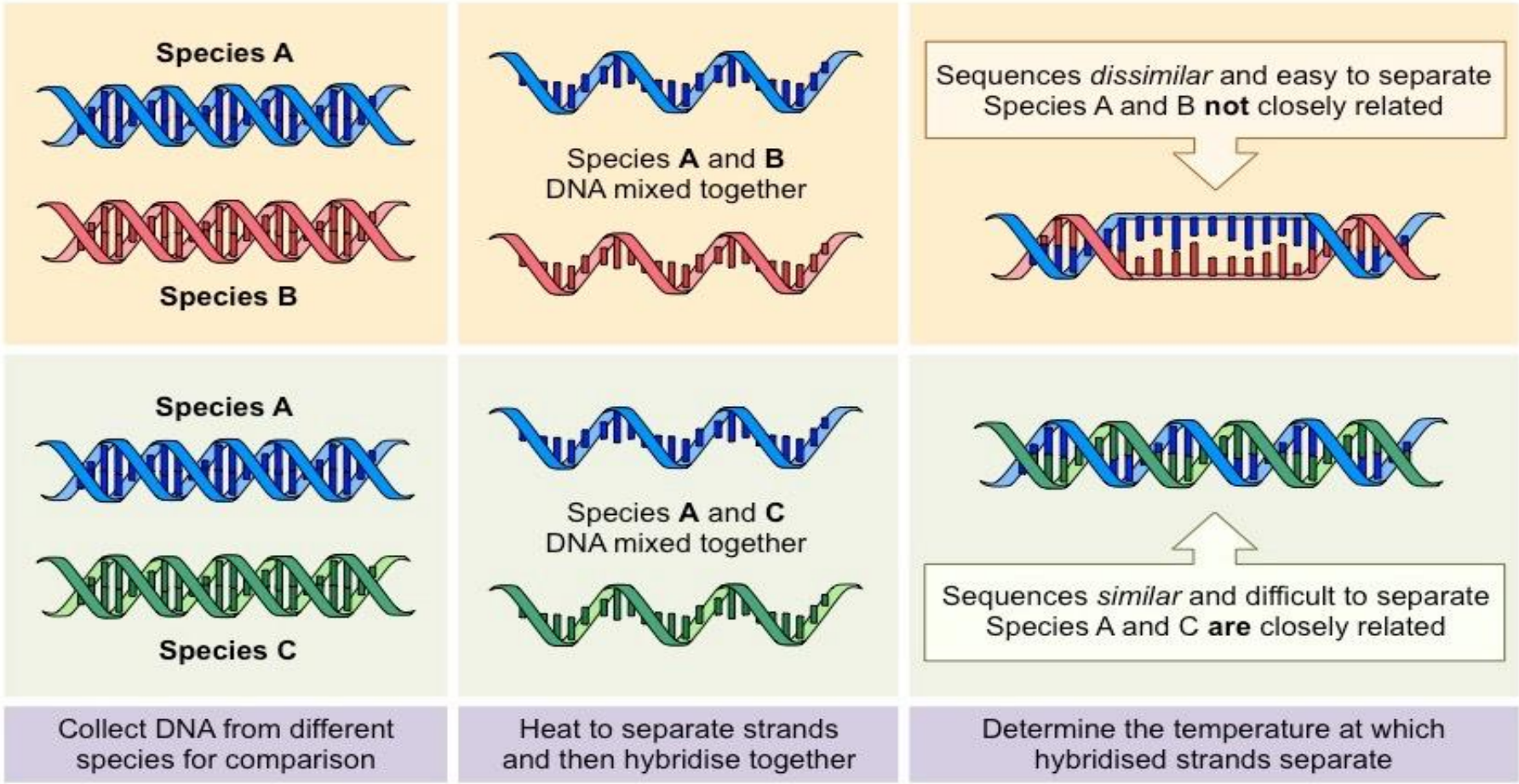
<u>Vestigial features</u>: Remnants of structures that ancestors used but are now non functional or not used.

Comparative biochemistry:

i) Molecular hybridization

Chromosomal DNA or Mitochondrial DNA hybridization can be used to determine genetic relatedness.

Mitochondrial analysis is more accurate due to a known mutation rate and maternal inheritance. Molecular clock.



ii) **Comparing proteins**:

Living organisms share some enzymes that catalyse steps in essential energy transfer reactions. One enzyme found in organisms from all of the five kingdoms is known as cytochrome c.

The longer the period since two species diverged from a common ancestor, the more time has been available for changes to occur in a protein present in both species. Therefore the more differences that are observed.

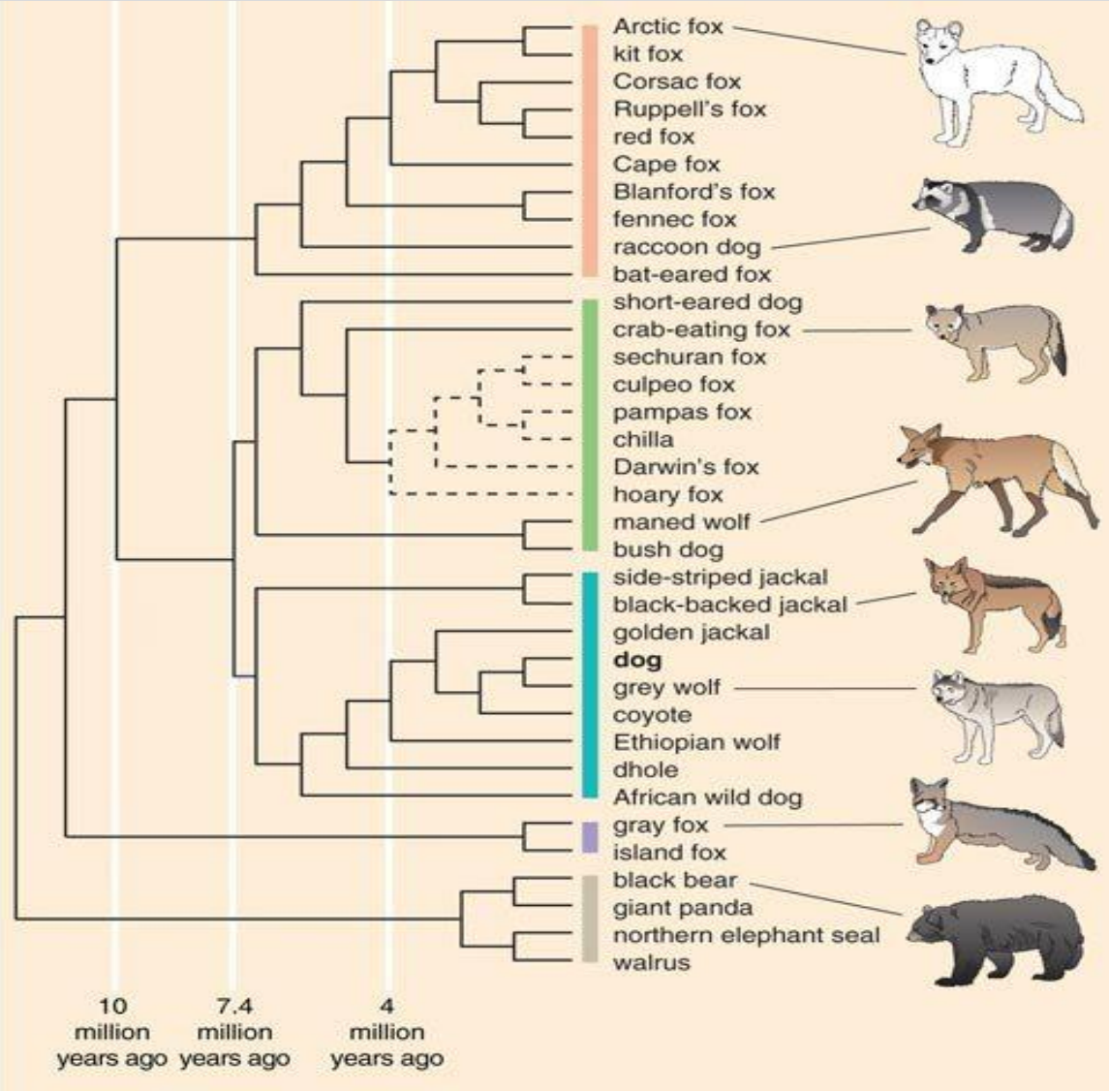
Cytochrome *c* Evolution

Organism	Number of amino acid differences from humans
Chimpanzee	0
Rhesus monkey	1
Rabbit	9
Cow	10
Pigeon	12
Bullfrog	20
Fruit fly	24
Wheat germ	37
Yeast	42

A

Species	Gene Similarity	Protein Similarity
Chimpanzee	99.6%	100%
Dog	91.3	95.2
Fruit fly	72.4	76.7
C. elegans (a roundworm)	68.2	74.3

Phylogenetic trees



Phylogenetic trees can be constructed from

i) DNA hybridization evidence.

ii) mt DNA hybridization evidence

iii) Protein comparison

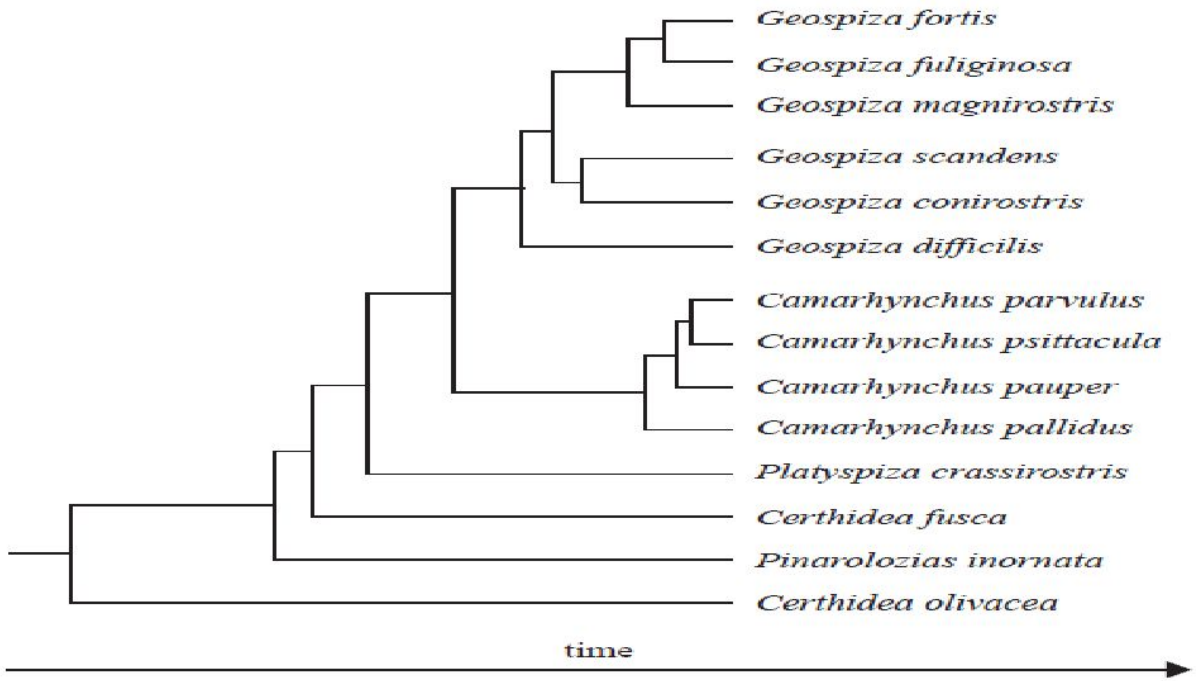
iv) Anatomical comparison

v) Breeding success.

A phylogenetic tree illustrates the time at which species shared a common ancestor.

The more recent the common ancestor to more related the species and visa versa.

There are 14 species of Darwin's finches inhabiting the Galápagos Islands. These finch species share a common ancestor, the dull-coloured grassquit, which is found on mainland South America. The finch species are similar in body size, shape and colour, with noticeable differences observed in their beak shape and size. The phylogenetic tree below shows divergence from the finches' grassquit ancestor.



Question 65

Refer to the phylogenetic tree displaying the divergence of Darwin's finches.

Which of the following pairs of finches share a more recent common ancestor?

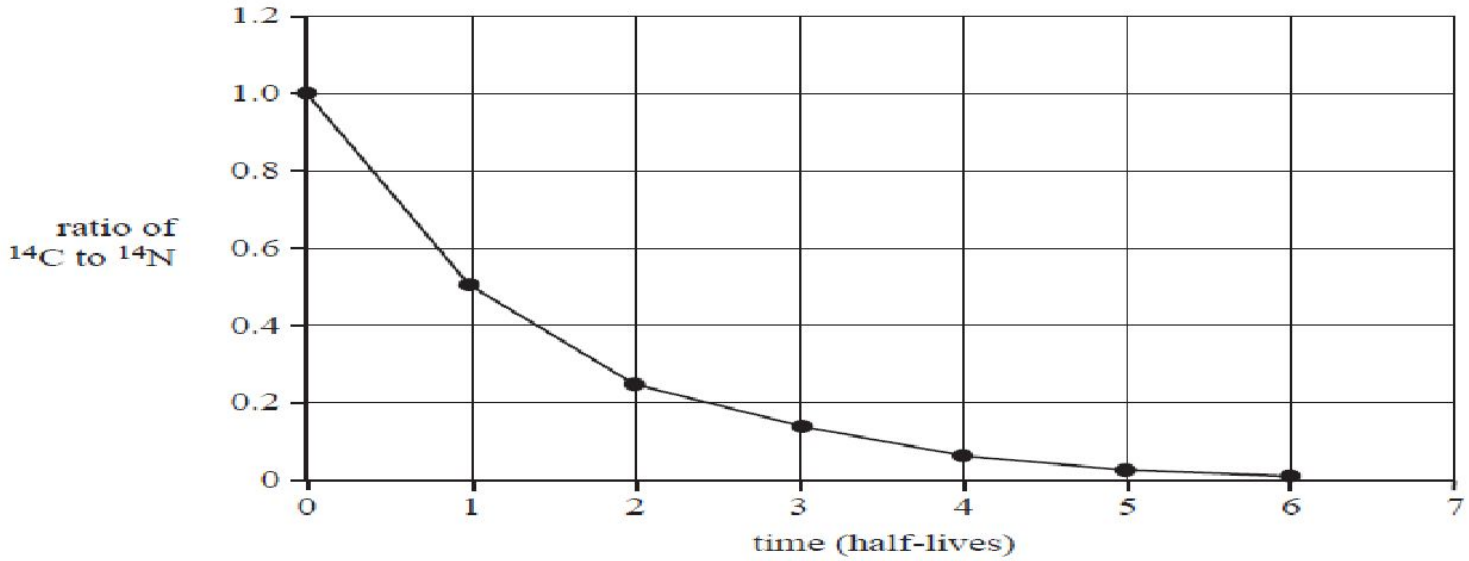
A. *C. fusca* and *C. olivacea*

B. *G. scandens* and *G. conirostris*

C. *P. inornata* and *C. olivacea*

D. *C. pauper* and *C. pallidus*

One method for dating fossils uses carbon-14 (^{14}C). When an organism dies, the unstable ^{14}C atoms begin to break down into nitrogen-14 (^{14}N) atoms. The graph below shows the ratio of ^{14}C to ^{14}N. The half-life of ^{14}C is approximately 6000 years.



Question 66

If the ratio of ^{14}C to ^{14}N in a fossil is 0.2, approximately how old would the fossil be?

A. 6000 years

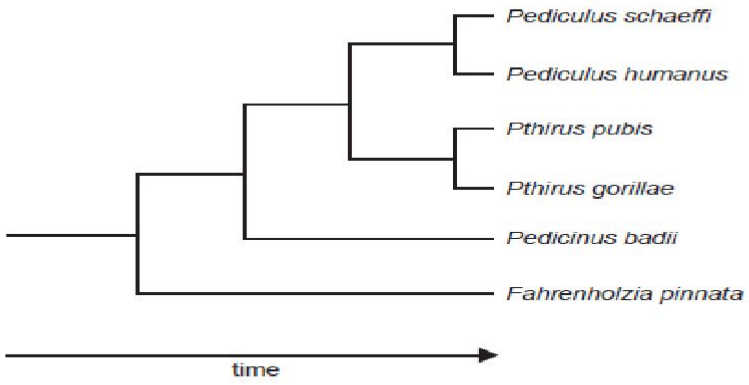
B. 12 000 years

C. 15 000 years

D. 18 000 years

Question 67

Consider the following phylogenetic tree for different species of lice. The tree has been constructed based on molecular and morphological data.



This information suggests that

A. *Pedicinus badii* shares a more recent common ancestor with *Pthirus gorillae* than with *Fahrenholzia pinnata*.

B. *Pediculus humanus* is more closely related to *Pedicinus badii* than it is to *Pthirus pubis*.

C. the six species of lice would have evolved by convergent evolution.

D. *Pediculus schaeffi* is the ancestor of *Pediculus humanus*.

Question 68

Two types of bird were originally thought to be different species. However, recently a group of biologists has agreed that they are the same species.

The biologists must have found out that the two types of bird

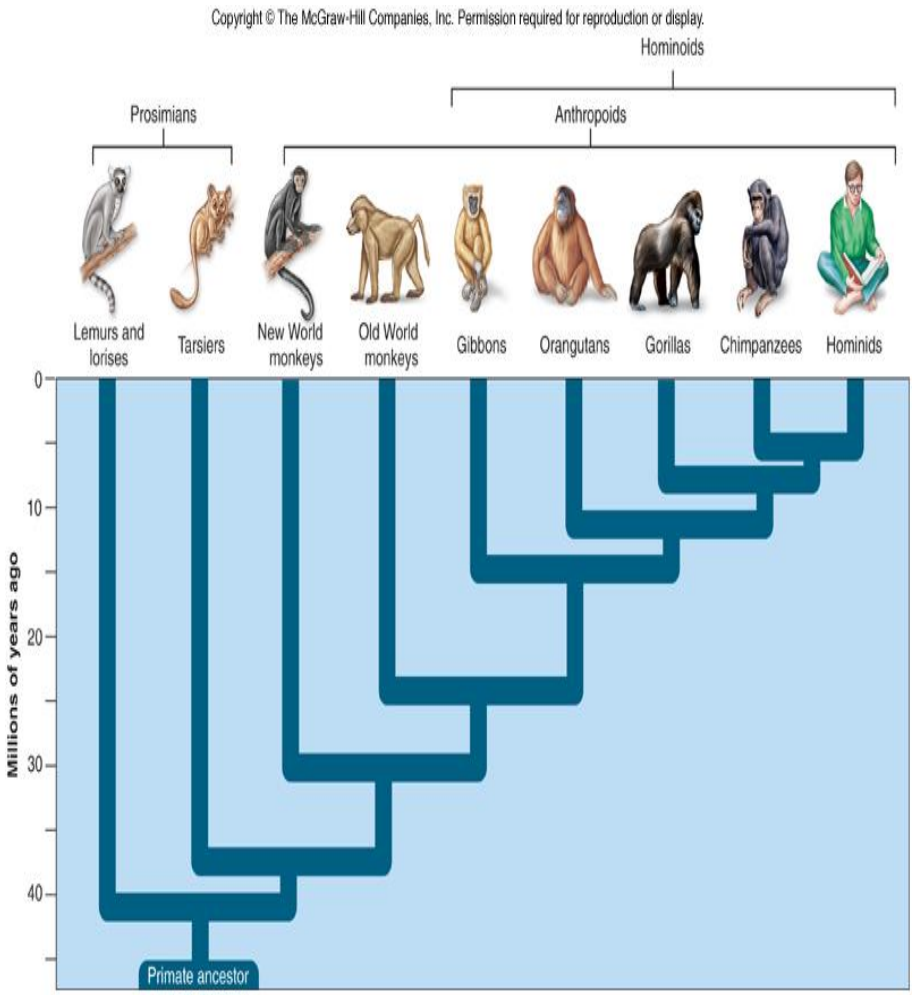
A. look alike enough to be thought one species.

B. are separated by a geographical barrier.

C. successfully interbreed in nature.

D. live in the same habitat.

Hominid evolution:



- Today's primates include lemurs, new world monkey's and old world monkey's including humans.
- All of the different kinds of primates living today gradually evolved over a period of at least 65 million years.

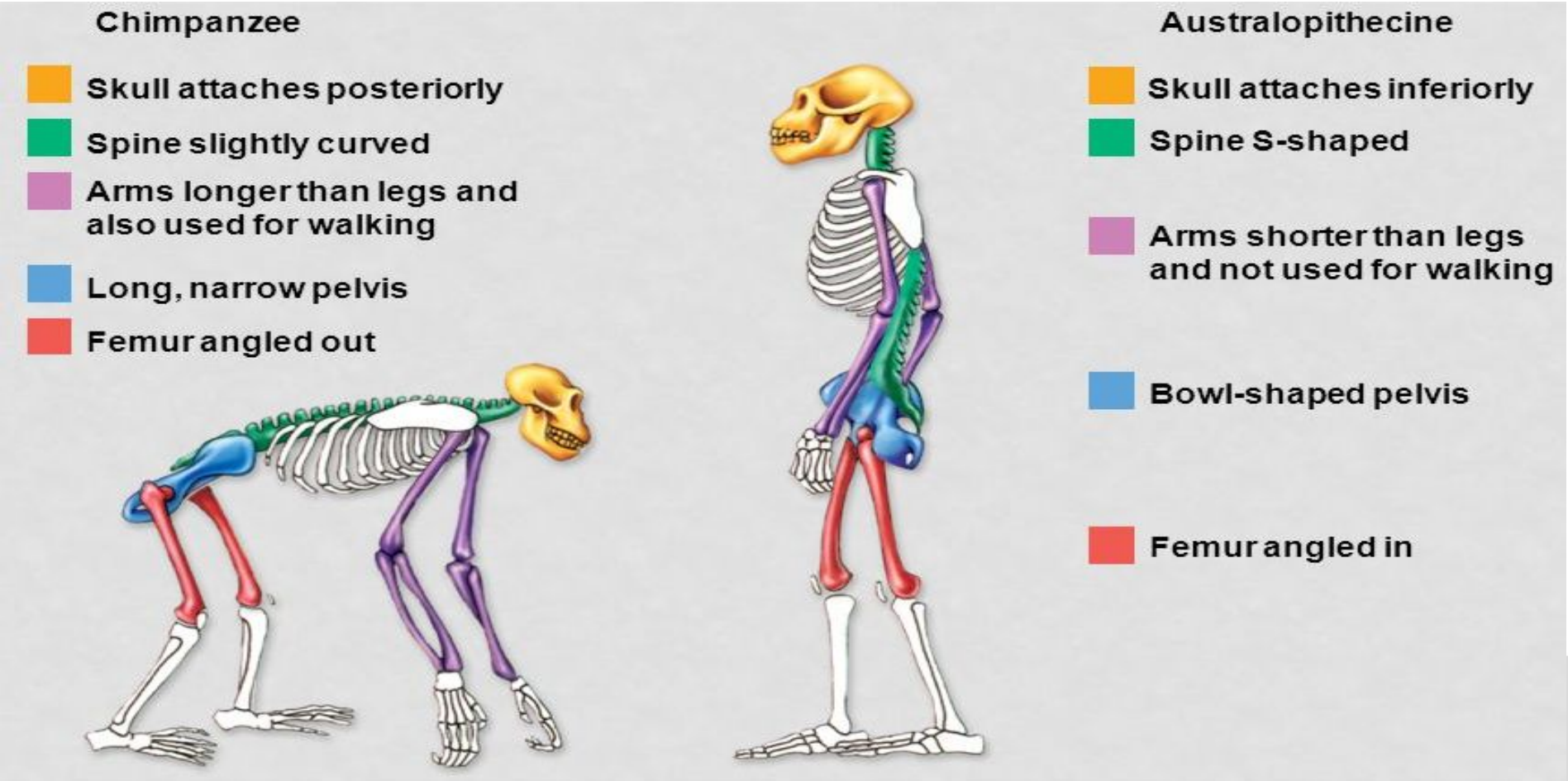
- When we talk about the human line diverging from the African ape line, this does not mean that humans evolved from chimps or gorillas. It means that at some time in the past the human line and the African ape line shared a common ancestor.

Hominin vs Hominoid

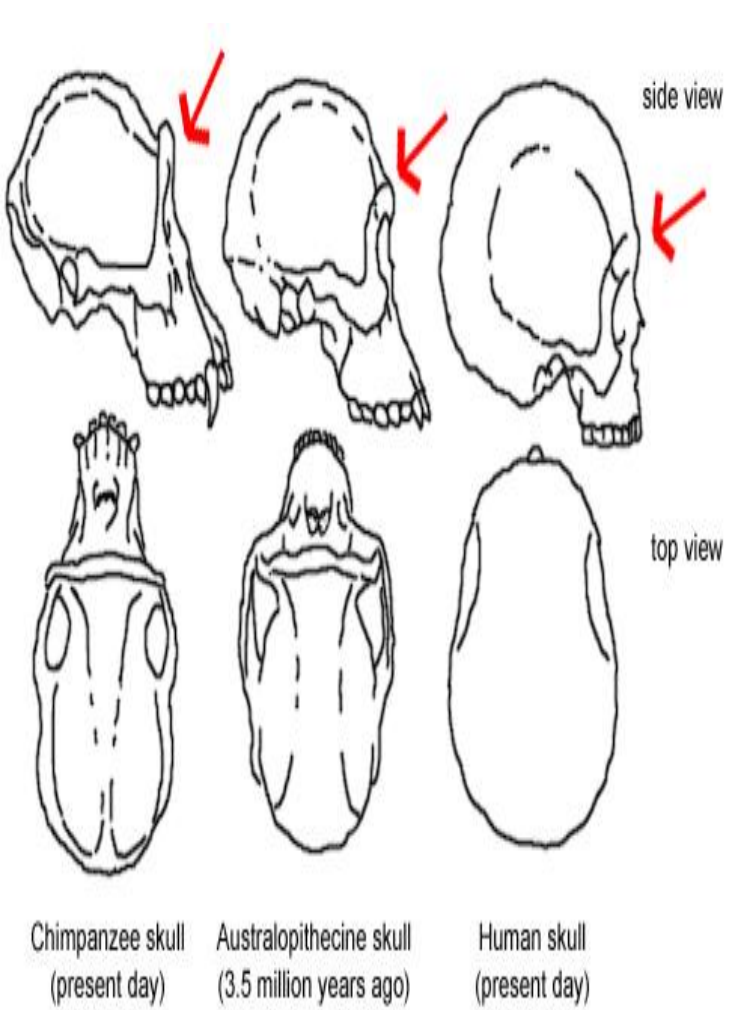
Hominin vs Hominoid

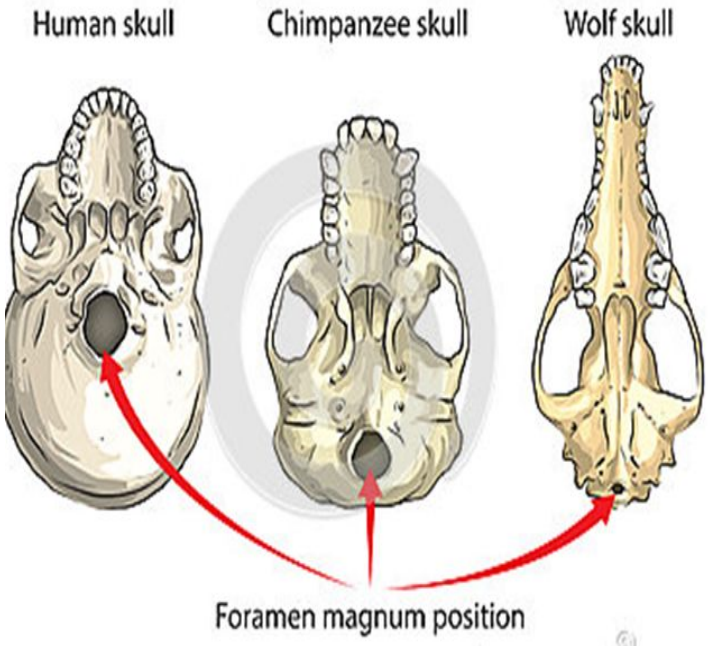
Hominin: the group consisting of modern humans, extinct human species and all our immediate ancestors (including members of the genera *Homo*, *Australopithecus*, *Paranthropus* and *Ardipithecus*).

Hominoid: the group consisting of all modern and extinct Great Apes (that is, modern humans, chimpanzees, gorillas and orang-utans plus all their immediate ancestors).



Human evolutionary changes over time:

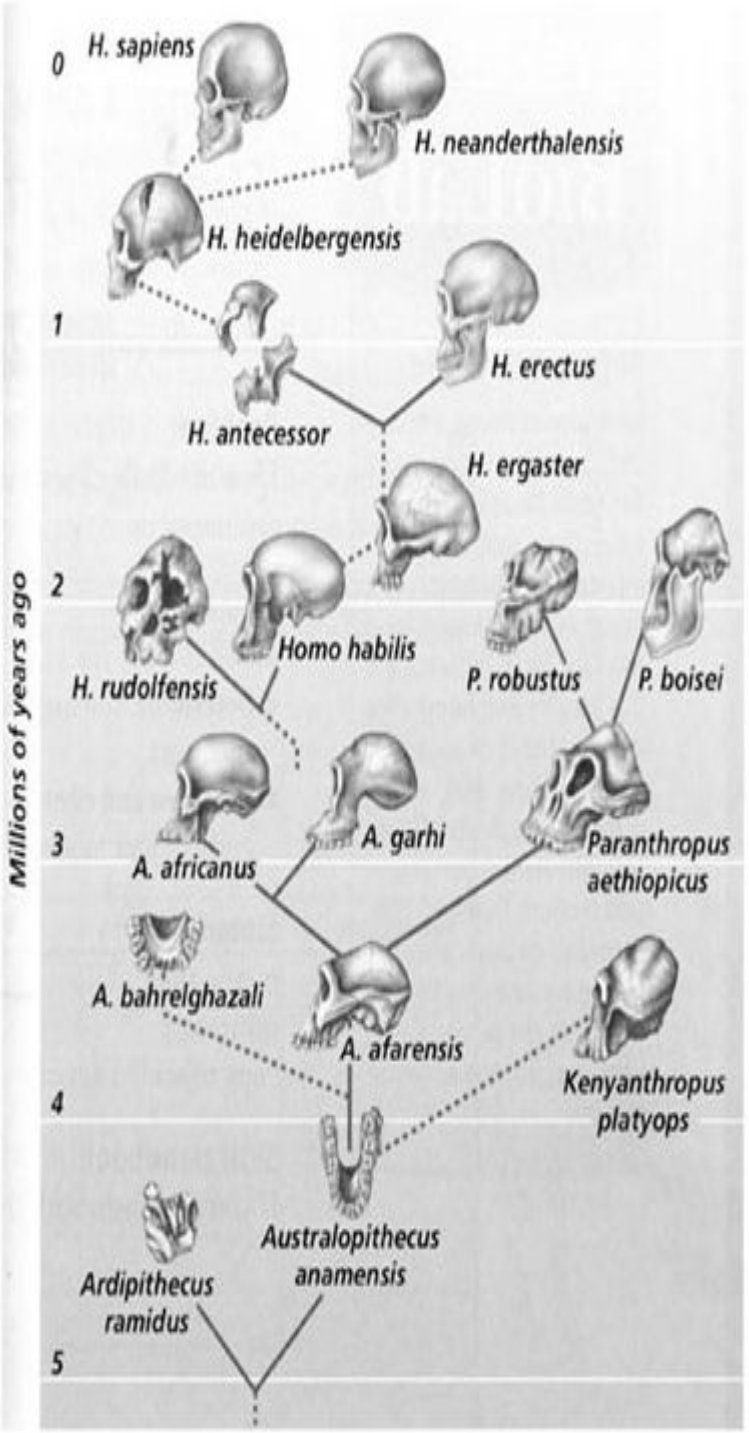




i) Upright locomotion, arm to leg length variation

ii) Spinal position into skull/ Jaw size / teeth size

iii) Skull shape and brain pan size



Australopithecus*:* 4-5 mya, small animals which walked upright, brain volume of
350 – 500 cc.

Homo habilis*:* The 'Handy man', 2.5 mya, used tools, brain volume of 500-800 cc.

Homo ergaster/erectus*:* 1 – 2.5 mya, advanced tool use, 1000-1250 cc brain volume.

H. neanderthalis*:* 300 000 – 30 000 ya.
Brain volume 1200 – 1700
H. Sapiens: 200 000 ya to present. 1350 cc.

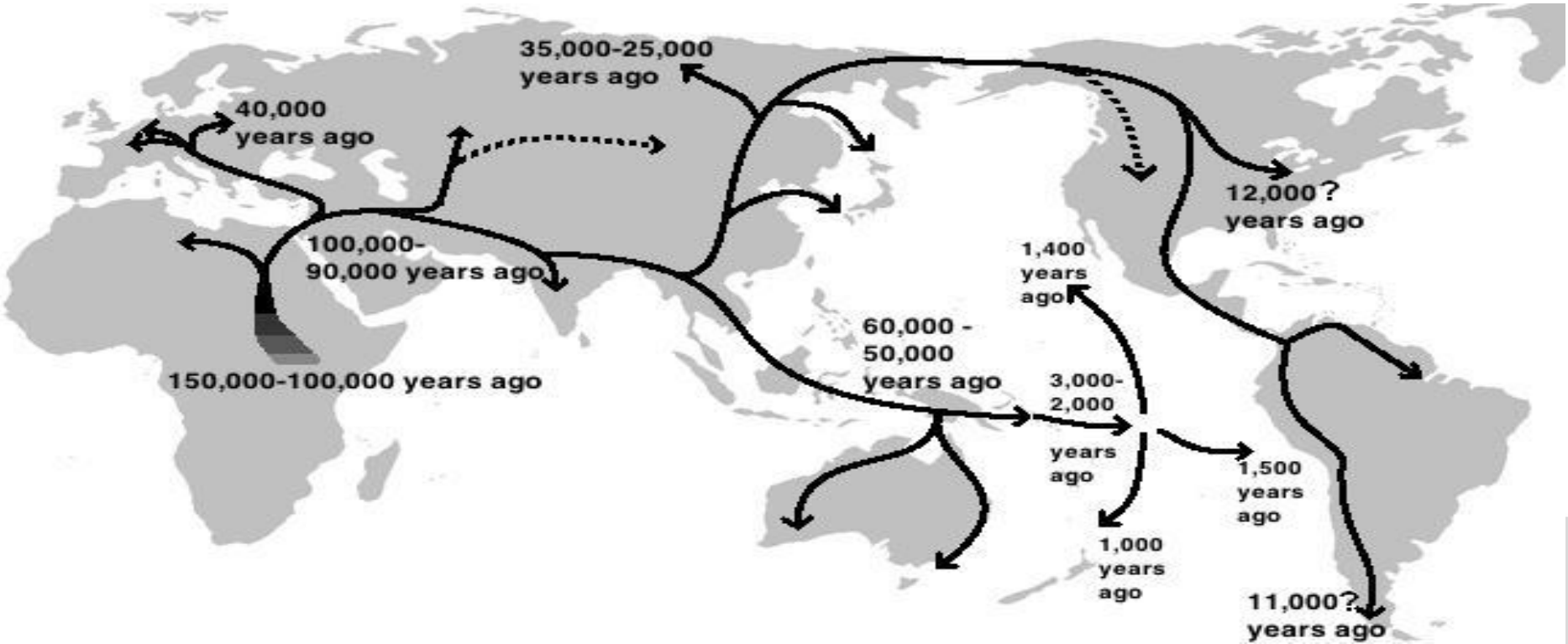
How accurate is the fossil record of humans?
The fossil record is, and always will be, incomplete.
It is made up of fragments of a forgotten era, preserved by fluke.
This leaves an opportunity for gaps, misinterpretation, or at the worst – fraud.

Out of Africa Hypothesis:

There are two competing theories about where modern humans arose.

Out of Africa:
Homo sapiens evolved due to selective pressures in Africa, and migrated around the world after this. Current mtDNA analysis tens to indicate this hypothesis

Multiregional:
Homo ergaster migrated around the world, and different populations of Homo sapien arose independently.



Question 69

The pictures below show views of skulls from *Homo erectus* and *Homo sapiens*.

skull set 1

skull set 2

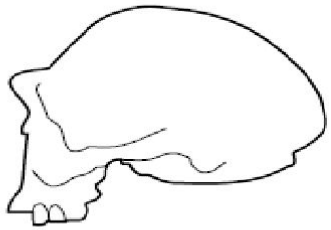
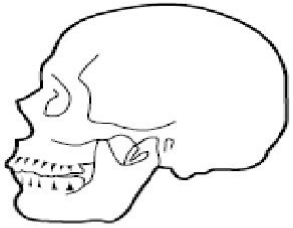
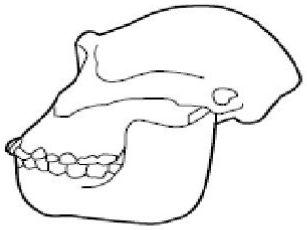
b. With reference to two structural features of the skull, which skull set represents *Homo erectus*? Justify your choice.

Skull set _____

Justification_____

Question 70

Below are three images of fossil hominin skulls.

		
Skull 1	Skull 2	Skull 3

Which sequence best shows the order from the most ancient fossil skull to the most modern fossil skull?

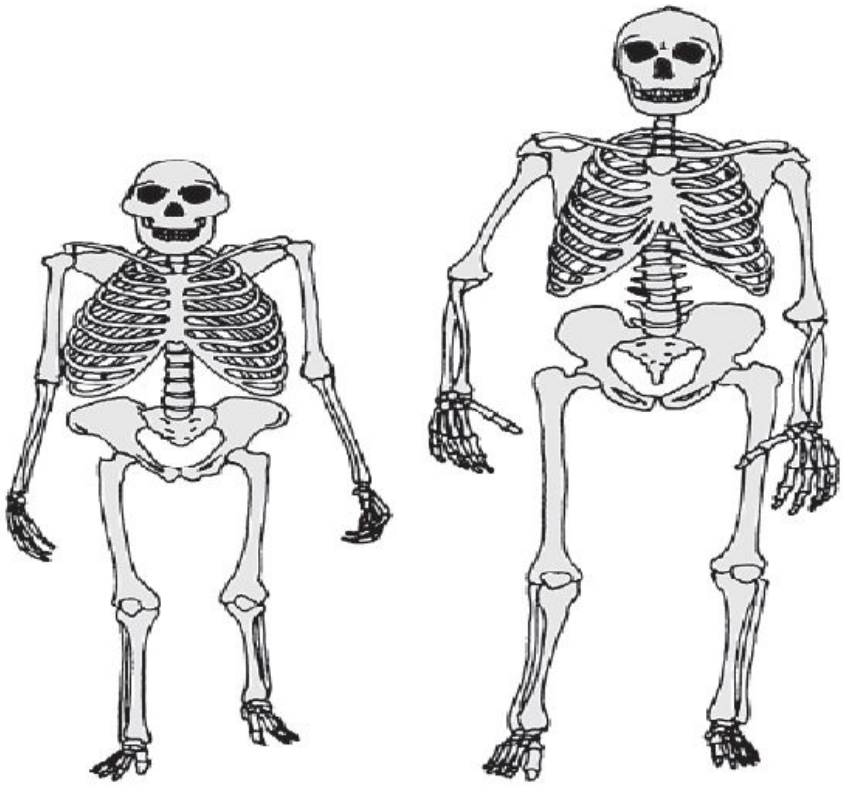
A. Skull 3, Skull 1, Skull 2
B. Skull 1, Skull 2, Skull 3
C. Skull 3, Skull 2, Skull 1
D. Skull 1, Skull 3, Skull 2

Question 71

A feature that is shared by both hominins and primates but not by all mammals is

A. bipedal stature.
B. five cusps on the molar teeth.
C. narrow and protruded rib cages.
D. relatively larger brains compared to overall body size.

Question 72



Australopithecus africanus

Homo neanderthalensis

The diagram above shows the skeletons of *Australopithecus africanus* and *Homo neanderthalensis*.

Based on the limb structures of each skeleton, which one of the following is a feature that would confirm both species moved by bipedal locomotion?

A. size of the heel bone

B. length of the femur and tibia

C. longer arm-to-leg length ratio

D. alignment of the big toe with the other toes

Question 73

Shown below is a photograph of a skull of *H. erectus georgicus*. Scientists compared this skull to that of modern humans (*Homo sapiens sapiens*).

Source: Rama

b. Describe any **two** features of the skull shown in the photograph above that allowed scientists to determine that this was a much earlier species of the genus *Homo* than modern humans (*H. sapiens sapiens*). 2 marks

_____

_____

d. Fifteen different skeletons of *H. naledi* were found in the cave. It was noted that they were all of different ages.

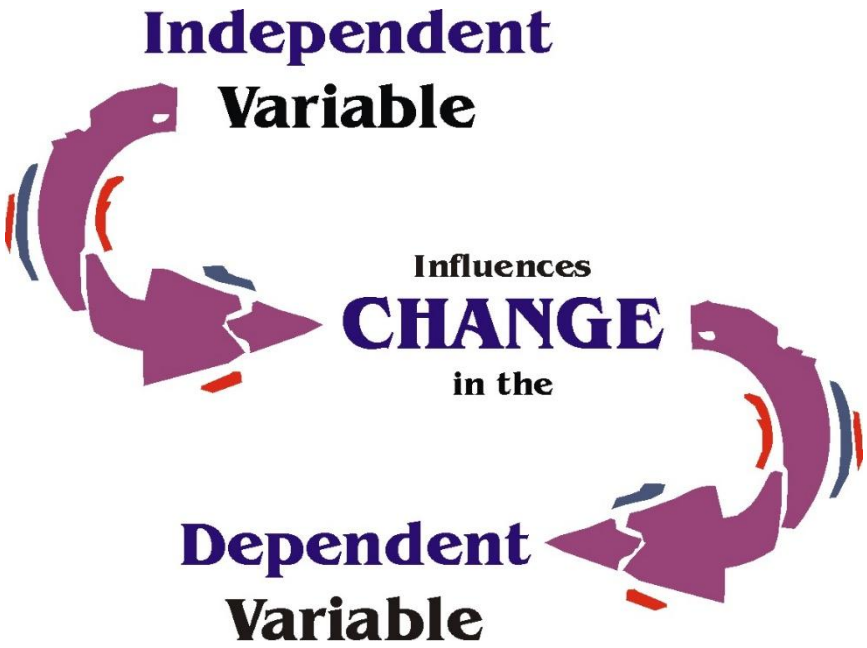
Describe **two** pieces of evidence that scientists could have looked for in the cave to indicate cultural evolution within this species. 2 marks

_____

Experimental design

What do we need to complete an experiment:

- A hypothesis is a statement that can be tested.
- It must be a prediction.
- It must be testable.
- It must link directly to your results.

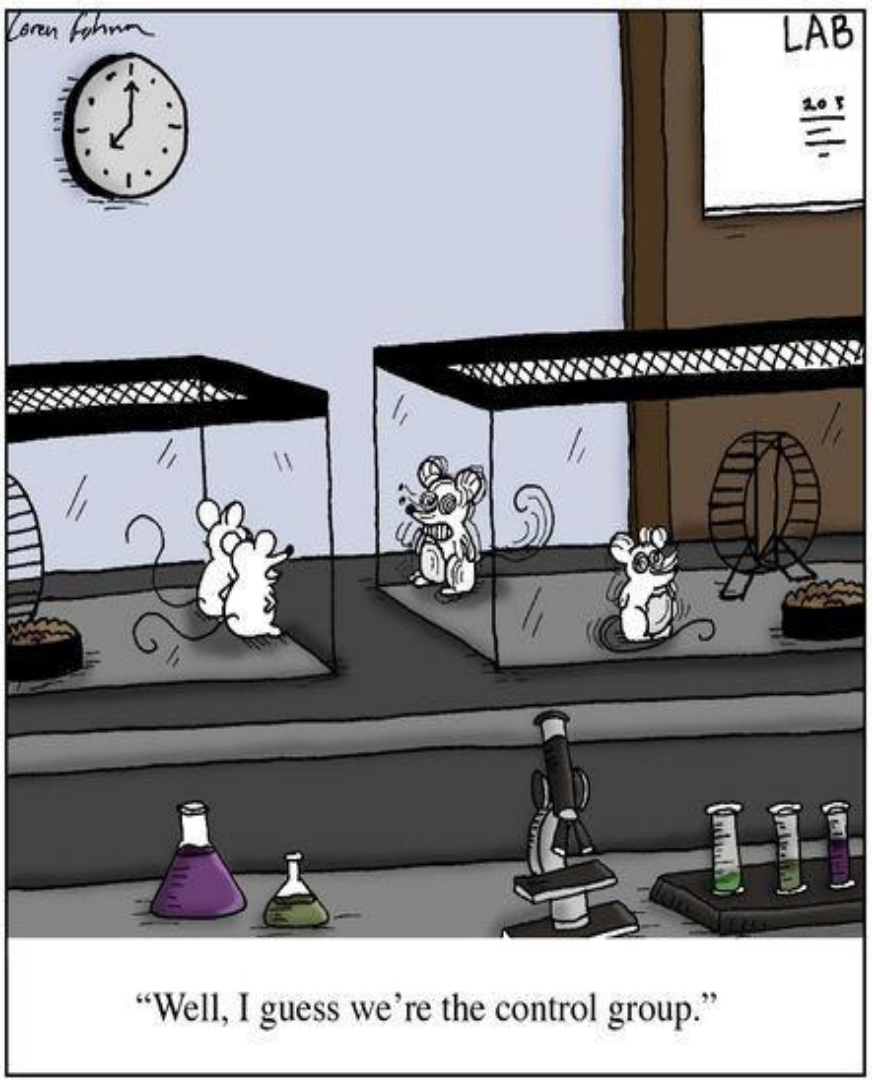


Variables:

- A variable is simply a 'thing that changes'.
- An experiment needs variables, or it's not an experiment
- **The independent variable** is not dependent on the results. It is the thing you change to set up the experiment.
- **The dependent variable** is measured. It is the results. It is the thing that the experiment changes.

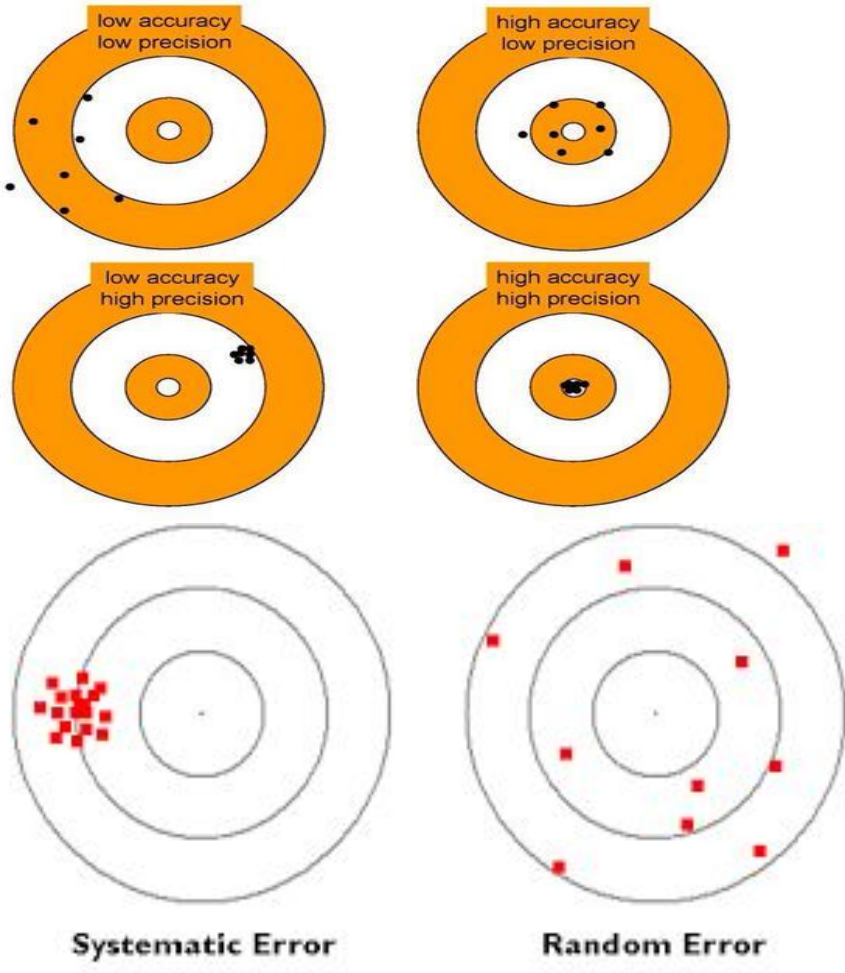
Errors and Controls:

- There are always going to be more variables in your experiment than you want.
- This is bad. You want your **independent variable** to be the only variable impacting results. Otherwise you can't tell what you're measuring.
- **A control is designed to eliminate extraneous variables.**
- A control should **replicate the entire testing procedure excluding the independent variable.**



Accuracy and Precision

- **Accuracy** is how close your measurement is to the correct value.
- **Precision** is how close together your set of measurements are.



- **A systematic error** is a fault with the experiment. It causes all your tests to be inaccurate.
- **A random error is** a fault due to one measurement. It causes your testing to lack precision

Four groups of students carried out an experiment in which the effect of glucose concentration on the fermentation rate of yeast was measured. The fermentation rate was determined by the rate of temperature change of the fermenting mixture.

Before beginning the experiment, each group practised measuring the temperature of water and checked the group's thermometer against an electronic thermometer that gave a true measure of temperature.

The following results were obtained during the practice.

Group	Each group's thermometer readings (°C)			Electronic thermometer reading (°C)
	1st measurement	2nd measurement	3rd measurement	
1	18.0	17.0	17.5	20.1
2	18.0	18.0	18.5	20.5
3	21.0	21.0	20.5	19.9
4	18.0	19.0	21.0	20.2

Question 74

Which one of the following statements is correct?

A. Group 1's measurements are the most accurate but the least precise.

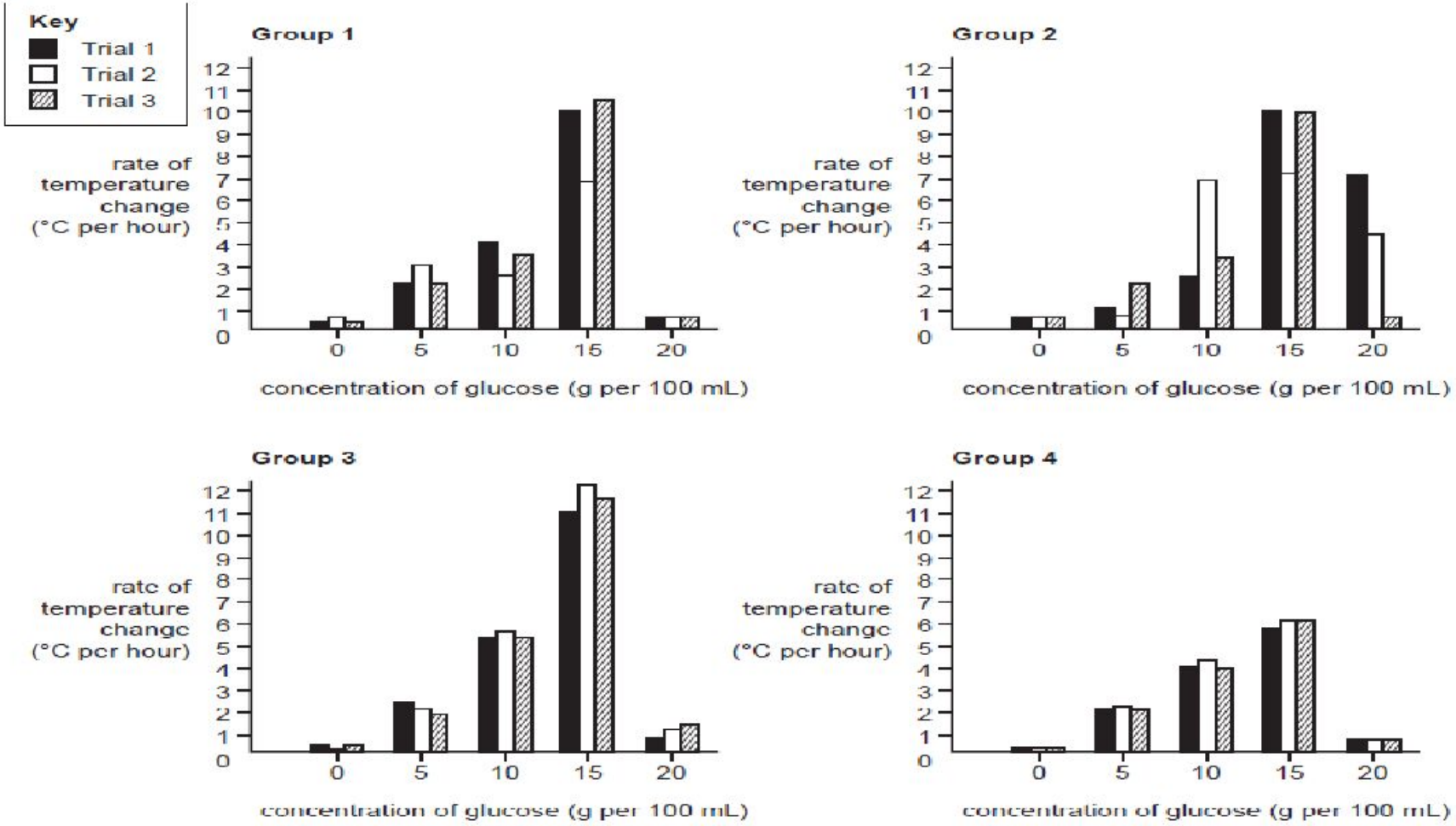
B. Group 2's measurements are accurate but not precise.

C. Group 3's measurements are precise but not accurate.

D. Group 4's measurements are both accurate and precise.

Question 75

Each group conducted the experiment three times (Trial 1, Trial 2, Trial 3). Five different concentrations of glucose were used in each trial. Each group plotted its results on a graph. The black bar represents Trial 1, the white bar represents Trial 2 and the striped bar represents Trial 3.



Which one of the following statements about the experiment's results can be concluded from the graphs?

A. Group 1's results are more valid than the other groups', but less reliable.

B. Group 2's results are less reliable, but more precise and accurate.

C. Group 3's results are the most accurate and reliable.

D. Group 4's results are more reliable than the other groups'.

Question 76

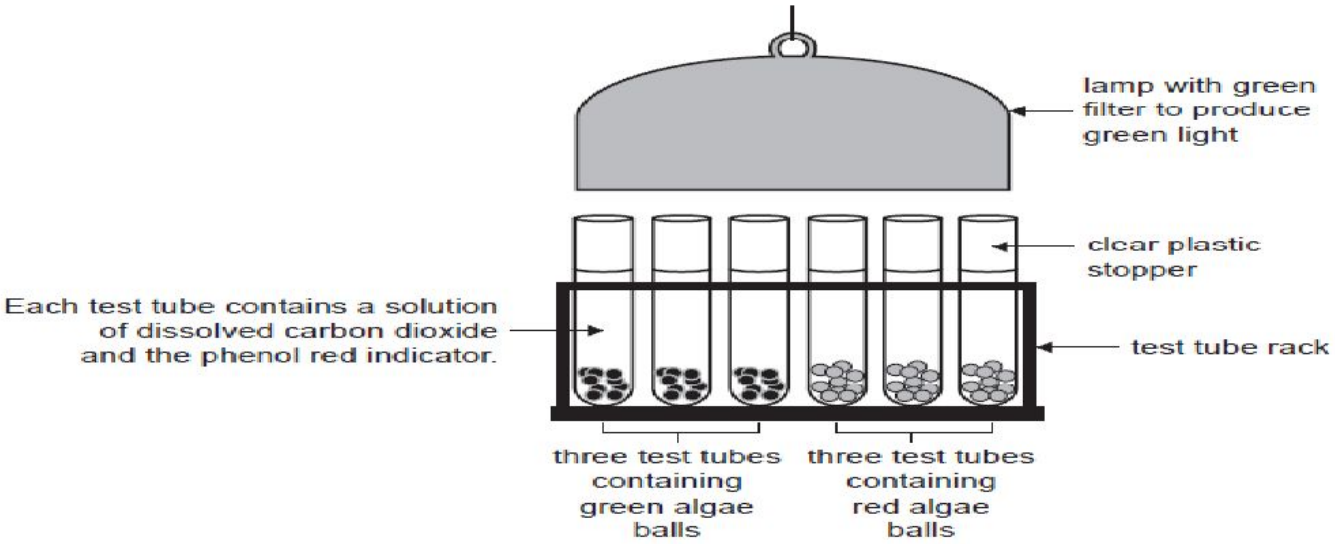
Elsa read that red algae survive at greater water depths than green algae because of a pigment in the red algae called phycoerythrin. This pigment enables the algae to absorb more of the green light available at greater water depths. Elsa decided to investigate this by carrying out an experiment.

Using a standard technique, the single-celled algae were trapped in jelly balls. One set of balls contained green algae and another set contained red algae.

To measure the rate of photosynthesis, Elsa used a stopwatch and the pH indicator phenol red. Phenol red changes colour in solutions with different concentrations of carbon dioxide. In low carbon dioxide concentrations, phenol red is pink and in higher carbon dioxide concentrations it is yellow.

Elsa placed the jelly balls into test tubes and covered them with a solution containing dissolved carbon dioxide. Phenol red indicator was added to each solution.

The diagram below shows the set-up of Elsa's experiment.



a. State the hypothesis that Elsa was testing. 1 mark

b. List three variables that would need to be controlled to ensure the experiment produced valid results. 3 marks

c. State the independent variable and the dependent variable in this experiment. 2 marks

d. What results would disprove the hypothesis of Elsa's experiment? 2 marks

Question 11a.

Marks	0	1	Average
%	80	21	0.2

Examples of possible responses include:

- that red algae photosynthesise faster than green algae in green light
- that red algae use CO_2 faster than green algae when exposed to green light.

Question 11b.

Marks	0	1	2	3	Average
%	8	31	45	16	1.7

Controlled variables (three of):

- number of balls in each tube
- number of drops of phenol red added
- the volume of CO_2 present initially/initial pH
- temperature
- amount of algae

As the colour and level of carbon dioxide changed during the experiment, students were required to acknowledge the amount at the beginning of the experiment.

Question 11c.

Marks	0	1	2	Average
%	24	32	44	1.2

Independent variable: type of algae

Dependent variable: level of CO_2/time for colour change/colour of solution/pH

Question 11d.

Marks	0	1	2	Average
%	44	51	5	0.6

The hypothesis would be refuted/not supported if the indicator changes or changes faster with the green algal balls than the red algal balls and if both changed at the same rate/gave the same results.

The answer to this question was dependent upon the student's answer to part a.