2023 Nov P2 answers

Question 1

(a) With reference to Fig. 1.1, explain the effect of increasing the external concentration of glucose on the rate of uptake of glucose into a cell.[3]

1. As external concentration of glucose increases, the rate of glucose uptake into the cell increases steeply at first, but the increase slows down and eventually reaches maximum rate at a plateau.
2. As glucose is ***polar****, and hence hydrophilic, glucose molecules would be repelled by the hydrophobic core of the phospholipid bilayer.
3. The entry of glucose requires transmembrane carrier proteins, but at high external glucose concentration, the carrier proteins become saturated and become a limiting factor and hence the rate of uptake plateaus.
4. As the external concentration increases, the concentration gradient is steeper and hence the rate of uptake by facilitated diffusion increases.

(b) Explain why there is no uptake of glucose into the cell at X even though glucose is present outside the cell.[1]

1. There is no diffusion gradient between the cytosol and the solution outside the cell as the concentration of glucose in the cell and outside the cell is the same.

(c) With reference to Fig. 1.2, explain the flip-flop mechanism for the transport of fatty acid molecules across the cell surface membrane, including the role of hydrogen ions. [5]

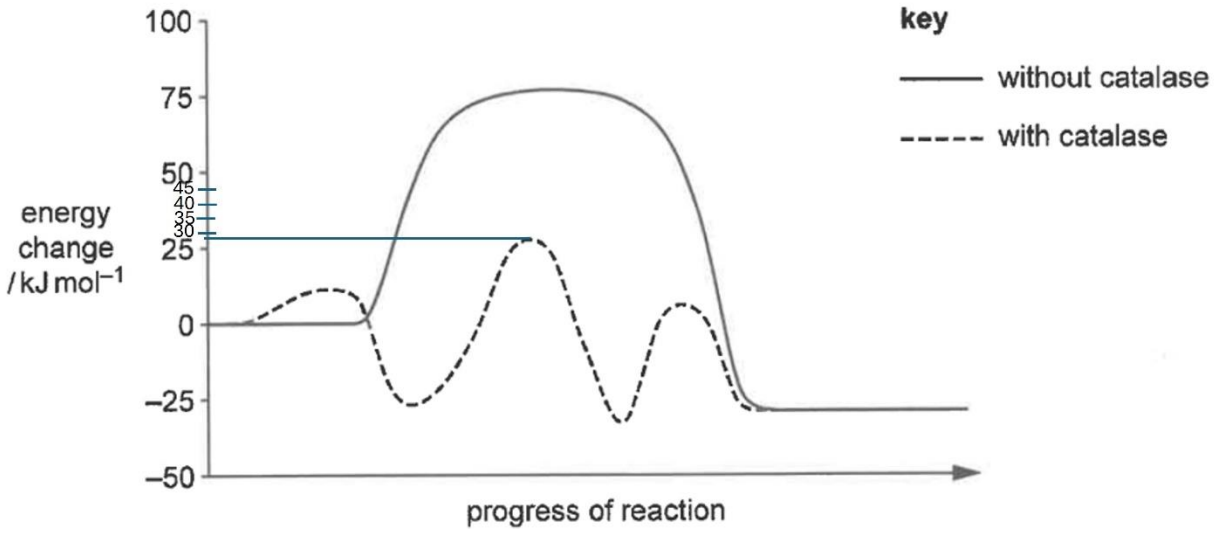
1. Positively charged H^+ ions surround the negatively charged carboxyl groups to reduce the negative charge and allow the fatty acid molecule to be embedded on the top half of the phospholipid bilayer;
2. The fatty acid molecule is orientated in such a way that the hydrophobic non-polar hydrocarbon tail is embedded between the hydrophobic non-polar hydrocarbon tails of the phospholipid in the top half of the phospholipid bilayer;
3. And the negatively charged carboxylic acid group is between the charged phosphate head of the phospholipid molecules;
4. Positively charged H^+ ions then bind to the negatively charged carboxylic acid group to neutralise the negative charge so that the non-polar fatty acid molecule can flip within the hydrophobic core of the phospholipid bilayer without being repelled;
5. Once the non-polar fatty acid molecule is embedded at the lower half of the phospholipid bilayer, the H^+ ions dissociate from the carboxyl group that now orientates outwards towards the internal cytosolic side of the cell;

[Total: 9]

Question2

(a) Explain how the change in activation energy shown in Fig. 2.1 affects the rate of a catalase-controlled reaction.[2]

1. Enzyme lowers ***activation energy**** by forming 3 different enzyme-substrate complexes required for chemical reaction to take place**,** from 75kJ mol^{-1} without enzyme to 28 kJ mol^{-1} with enzyme;
2. Increases number of substrate molecules with the required energy to cross the ***activation energy**** barrier so the reaction can proceed faster.



(b) (i) With reference to Fig. 2.2, state what can be concluded from the results of the investigation.[3]

1. Lower temperature of 35ºC is the most ideal for storage compared to higher temperature (40ºC to 50ºC);
2. Catalase stored at 35ºC retained 72% activity after 1.6 hours while higher temperatures had lower activity (quote from any other temperature);
3. Catalase lost its activity the fastest when stored at higher temperatures (quote relative activity or reference to gradient from 0.0 to 0.2 hours);
4. Within 1.6 hours, storage at temperatures at or above 45ºC resulted in loss or almost complete loss of activity, but 35 ºC and 40 ºC still retained 50% to 70% activity;
5. AVP; Activity decreased when stored at all temperatures, indicating that storage is not idea for catalase;

(c) Explain the effect of storage temperature on the activity of catalase, as shown in Fig. 2.2. [5]

1. the higher the storage temperature, the greater the amount of thermal agitation / intramolecular vibrations;
2. at temperatures beyond the optimum temperature of an enzyme, weak interactions such as hydrogen bonds, ionic bonds and hydrophobic interactions between R groups will break;

3. the 3D conformation will be lost, resulting in ***denaturation****
4. the ***active site**** of catalase is no longer ***complementary in shape**** and charge to the substrate and the activity decreases;
5. enzymes exposed to increased temperatures for longer durations will have lower activity;

[Total: 10]

Question 3

(a) Name the parts of Fig. 3.2 labelled B, C and D. [3]

B : peptidoglycan cell wall
C : cytoplasm
D : transport channel protein

(b) With reference to Fig. 3.2, suggest how environmental DNA fragments enter the bacterial cell. [3]

1. Double-stranded DNA passes through the peptidoglycan cell wall and binds to protein A;
2. which is attached to a membrane bound transmembrane channel protein at the outer surface of the phospholipid bilayer of the bacterial cell membrane;
3. The hydrogen bonds between the 2 strands of the DNA are broken and only a single DNA strand enters the cytosol via the channel protein;

(c) Two other ways in which DNA can enter bacterial cells are transduction and conjugation. Describe how DNA enters bacterial cells by transduction and conjugation. [4]

transduction

General transduction

1. A ***phage**** infects a ***bacterium****, injecting its viral genome into the host cell
   The bacterial DNA is degraded into small fragments, one of which may be randomly packaged into a ***capsid**** head during the spontaneous ***assembly**** of new viruses;
2. Upon cell lysis, the defective phage will infect another bacterium and inject bacterial DNA from the previous host cell into the new bacterium;
3. The foreign bacterial DNA can replace the homologous region in the recipient cell's chromosome if ***crossing over/homologous recombination**** takes place, possibly allowing the expression of a different allele from the previous host;

OR

Specialised transduction

4. A ***temperate phage**** infects a ***bacterium****, injecting its viral genome into the host cell
   The viral DNA is integrated into bacterial chromosome forming a ***prophage**** which may be improperly excised to include adjacent segment of bacterial DNA during an ***induction**** event;
5. Bacterial DNA may be packaged into a capsid head during the spontaneous ***assembly**** of new viruses;
6. Upon cell lysis, the defective phage will infect another bacterium and inject bacterial DNA from the previous host cell into the new bacterium;

7. The foreign bacterial DNA can replace the homologous region in the recipient cell's chromosome if ***crossing over/homologous recombination**** takes place, possibly allowing the expression of a different allele from the previous host;

Conjugation

8. ***Sex pilus**** of F^+ ***bacterial cell**** makes contact with a F^- ***bacterial cell**** and retracts to bring the F^- cell closer so a ***mating bridge**** is formed between the 2 cells;
9. One of the 2 strands of the plasmid DNA in F^+ cell is nicked and transferred from the F^+ cell to the F^- cell through mating bridge (via rolling circle mechanism) as the other DNA strand is used as a template for elongation;
10. The single strand F plasmid DNA circularises in F^- cell and is used as a ***template**** to synthesise a complementary strand for a double-stranded F plasmid DNA resulting in F^+ cell;

[Total: 10]

Question 4

(a) (i) Use the equation to calculate the melting temperature at which this primer DNA sequence separates from template DNA:

TCGACTTCCTCGMCC

Tm = 64.9 + [41 x (2 + 7-16.4) / (3 + 4 + 2 + 7)]
= 64.9 – 18.96
= 45.9 ºC

melting temperature = 45.9 ºC [1]

(ii) Use your knowledge of DNA structure to suggest why an increased proportion of bases containing cytosine and guanine will increase the melting temperature. [2]

1. Base pair cytosine and guanine has 3 hydrogen bonds compared to 2 hydrogen bonds between adenine and tyrosine
2. Increases in H bonds allow the DNA to be more heat stable and higher temperature is needed to increase the kinetic energy of the molecule to break more H bonds

(d) Suggest the consequence for the results of a polymerase chain reaction of using low annealing temperatures. [1]

1. Less DNA product will be produced at the end of polymerase chain reaction

or

2. Primers may bind to sequences that are not perfectly complementary, leading to the amplification of unintended DNA fragments

(b) Describe the advantages of using the polymerase chain reaction.[3]

1. PCR is sensitive as only a minute amount of source DNA is required to amplify a large amount of DNA products
2. By using specific primers, PCR can selectively amplify a particular segment of DNA
3. PCR is fully automated within the thermocycler.
4. It can amplify millions of targeted DNA segment rapidly and efficiently

(c) State the limitations of the polymerase chain reaction.[3]

1. *Taq* polymerase lacks proofreading ability as errors occurring early in PCR reaction will get compounded with each replication cycle
2. Success of PCR requires knowledge of sequences flanking target region to be amplified.
3. DNA fragments to be amplified are limited to about 3 kb. Further increase in length of target sequence decreases efficiency of amplification.
4. Minute amounts of contaminant DNA may result in unwanted DNA sequences being amplified to significant amounts.

[Total: 10]

Question 5

(a) Name the stages of meiosis shown in Fig. 5.1. [2]

stage P Metaphase I

stage Q Anaphase I

stage R Metaphase II

stage S Anaphase II

(b) Describe similarities and differences between stage Q and stage S. [3]

similarities
1. Both stages involve shortening kinetochore microtubules,
2. Pulling chromosomes to opposite ***poles**** of the cell;

differences
3. Stage Q does not involve division of centromere, whereas in stage S centromeres divide;
4. Stage Q involves separation of ***homologous chromosomes****, whereas stage S involves separation of ***sister chromatids****;

(c) (i) Name this event and the stage of meiosis in which it occurs.[2]

event Crossing over

stage Prophase I

(c) (ii) Explain why stage R does not generate genetic variation in the absence of this event [1]
Sister chromatids would be genetically identical without crossing over.

(d) Complete Fig. 5.2 to show the chromosomes and alleles that are present in the daughter cell from the first meiotic division, the first polar body and the second polar body.

You should assume that the event named in (c)(i) has not occurred. [2]

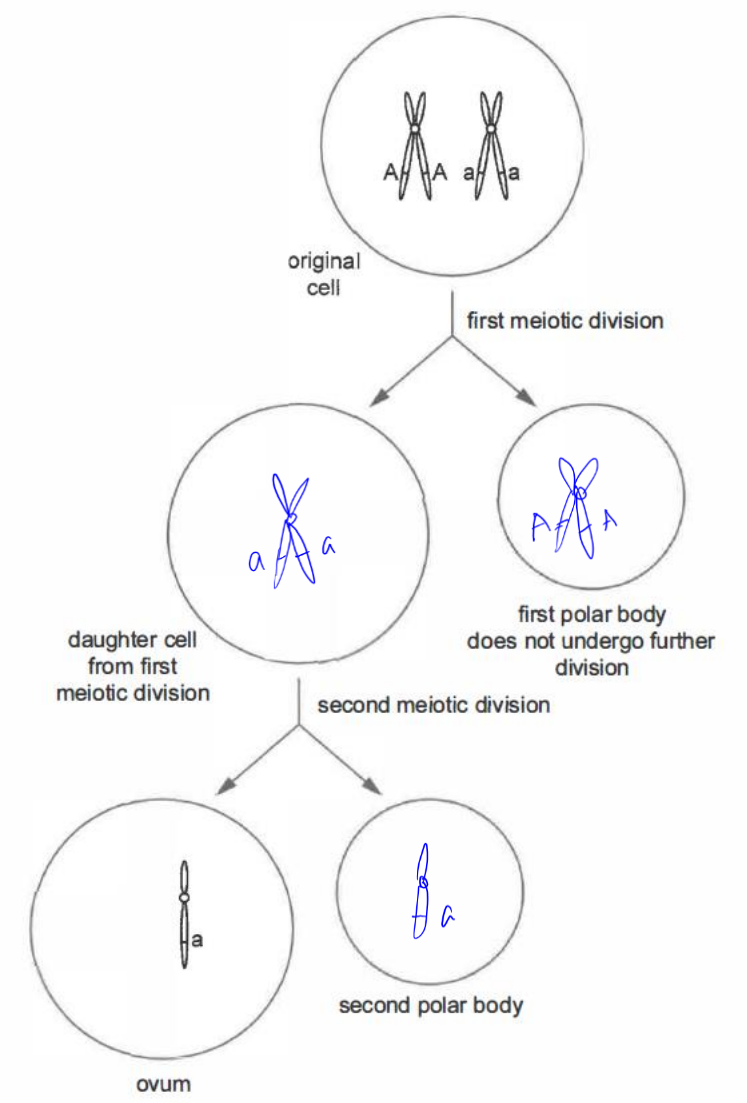


Fig. 5.2

[Total: 10]

Question 6

(a) State the coat colour shown by labrador retrievers with the following genotypes.[1]

eeBb .....yellow.....

EeBb .....black.....

(b) Explain the coat colour of labrador retrievers with the genotype Eebb. [3]

1. Eebb = brown coat colour
2. Allele E of one gene codes for a functional enzyme E, which converts the yellow coat pigment to brown coat pigment
3. With Ee, there is still one functional allele to convert yellow to brown
4. If Allele B of another gene is present, it codes for enzyme B, which converts the brown coat pigment to black coat pigment
5. Since the genotype is bb, there is no functional enzyme B thus resulting in Eebb having brown coat colout

(c) Draw a genetic diagram to explain the results of this cross. Indicate the expected phenotypic ratio of the offspring.
Use the symbols B, b, E and e to represent the alleles. [5]

Parental phenotype Black labrador X black labrador
Parental genotype **BbEe** X **BbEe**

Correct parental phenotype + genotype [1]
Correct gametes [1]

Meiosis
Gametes **BE** **Be** **bE** **be** X **BE** **Be** **bE** **be**

Random fertilization

Femaleegametes \ Male gametes	**BE**	**Be**	**bE**	**be**
BE	**BBEE** black	**BBEe** black	**BbEE** black	**BbEe** black
Be	**BBEe** black	**BBee** yellow	**BbEe** black	**Bbee** yellow
bE	**BbEE** **black**	**BbEe** black	**bbEE** **brown**	**bbEe** brown
be	**BbEe** **lack**	**Bbee** **yellow**	**bbEe** **brown**	**bbee** **yellow**

First generation genotypic ratio *[1]* 9 B_E_: 3 bbE_ : 4 _ _ ee
Black brown yellow

First generation phenotypic ratio 9 black: 3 brown : 4 yellow

(d) Name the type of gene interaction shown in Fig. 6.1. [1]

Epistasis

[Total: 10]

Question 7

(a) With reference to Fig. 7.1, explain the movement of protons into the intermembrane space using the large protein complexes. [4]

1. Reduced NAD transfer their high energy electrons to the electron acceptors/first electron carrier of the ***electron transport chain****, and get re-oxidised in the process to NAD;
2. As electrons are passed down electron carriers/large protein complexes of the ***electron transport chain**** arranged in linear sequence of increasing electronegativity;
3. the energy released is coupled to the pumping of H^+ from the ***matrix**** into the ***intermembrane space**** to generate a proton motive force/proton gradient;
4. The ***hydrophobic core**** of the phospholipid bilayer of the double membrane of the mitochondrion is impermeable to H^+ which are charged and thus hydrophilic, preventing H^+ ions from passing through;

(b) Explain the role of oxygen in oxidative phosphorylation.[3]

1. Oxygen acts as a ***final electron acceptor**** at the end of the ***electron transport chain**** (ETC) and combines with H^+ and electrons to form ***water**** in the matrix;
2. By removing electrons, oxygen reoxidises the ETC so that ***NADH**** and ***$FADH_2$**** can continue to donate electrons to the chain, and maintain the flow of electrons along the ETC, thereby allowing ***oxidative phosphorylation**** to continue to produce ***ATP****;
3. In the absence of oxygen, the coenzymes ***NAD**** and ***FAD**** cannot be regenerated to accept more H atoms from link reaction and Krebs cycle, and so these reactions and oxidative phosphorylation eventually stop.

(c) Compare the role of reduced NAD in aerobic respiration with the role of reduced NADP in photosynthesis. [3]

Roles	Reduced NAD	Reduced NADP
Formation	Reduced NAD is formed from NAD during oxidation by dehydrogenation;	Reduced NADP is formed from reduction of NADP when combined with H+ and electron as catalysed by NADP reductase;
Usage	Reduced NAD donates high energy	Reduced NADP serves as reducing

	electron to the electron transport chain during ***oxidative phosphorylation****;	power by reducing glycerate-3-phosphate (GP)/ phosphoglyceric acid (PGA) to form glyceraldehyde-3-phosphate (G3P) during ***Calvin cycle****;
Role upon regeneration of their oxidised coenzyme	Reduced NAD regenerates to form NAD which are used in glycolysis, link reaction and Krebs cycle, allowing aerobic respiration to continue;	Reduced NADP regenerates to form NADP which is used as final electron acceptor during non-cyclic photophosphorylation allowing the light-dependent reaction of photosynthesis to continue;

[Total: 10]

Question 8

(a) With reference to Fig. 8.1, explain how the molecular structure of the G-protein linked receptor relates to its function. [5]

1. G protein linked receptor (GPCR) a seven pass transmembrane protein consisting of ***7 α-helices**** connected by three intracellular and three extracellular peptide loops.
2. The intracellular domain/cytoplasmic side of GPCR has a ***G protein binding site**** that allows binding of a G protein.
3. The extracellular loops has a ***ligand binding site**** at which a ***specific**** signaling molecule can bind to the GPCR.
4. When a ligand binds to the ligand binding site at the extracellular side of a GPCR it causes a ***conformational change**** of the intracellular domain /at the cytoplasmic side of the GPCR,
5. The activated GPCR can then activate an associated G protein by binding to it and triggering an exchange of its bound GDP for a GTP.
6. As a transmembrane protein that is embedded in a cell's plasma membrane, it is folded such that amino acid residues with the hydrophobic R groups are interacting with the hydrophobic core of the phospholipid bilayer of the plasma membrane and amino acids with hydrophilic R groups are arranged inwards as well as at the surfaces where they interacts with the aqueous exterior medium/cyplasmic and extracellular regions/hydrophilic phosphate heads of phospholipid bilayer.

(b) Explain how the release of cAMP leads to a cellular response. [5]

1. cAMP binds and activates ***protein kinase A**** (PKA);
2. Activation of PKA will initiate a sequential activation of kinases resulting in a phosphorylation cascade;
3. That eventually activate ***glycogen phosphorylase****
4. Signaling amplification occurs where number of activated product is always greater than those in preceding step example phosphorylase kinase can phosphorylate and activate many molecules of glycogen phosphorylase;

5. A large number of activate glycogen phosphorylases break down glycogen to generate a high yield of glucose;
6. During the cellular response, there will also be a decrease in the rate of glycolysis, AVP an increase in the rate lipid and protein breakdown (gluconeogenesis);
AVP ref to upregulation expression of genes e.g. glycogen phosphorylase gene
AVP ref to down regulation of expression genes e.g. glycogen synthase gene

[Total: 10]

Question 9

(a) With reference to Fig. 9.1, suggest how these two species of palm tree may have evolved by sympatric speciation. [5]

1. An ***ancestral**** palm grew on Lord Howe Island, an isolated island off the coast of Australia, that had two soil types in close proximity to each other - older volcanic soil and younger calcareous soils;

2. When the palms that normally grew on volcanic soil started to grow on calcareous soil, a flowering time difference arose as a physiological response to growing on a different soil type;

3. Thus ***physiological isolation**** prevented ***interbreeding**** and hence ***disrupted gene flow**** between the two sub-populations of palms growing in the two types of soil although they were in close proximity;

4. This resulted in evolutionary changes occurring independently within each sub-population. i.e. different genetic changes from accumulation of ***mutations****, as well as changes in allele frequencies through ***genetic drift**** and ***natural selection**** occurred within each sub-population;

5. There existed variation in the two sub-populations and palms with favourable traits that were better adapted had a selective advantage to the specific soil conditions and were selected for, increasing frequency of favourable alleles and survived, reproduced and passed on their alleles to the next generation;

6. Over hundreds and thousands of successive generations each sub-population became genetically distinct, ***reproductively isolated**** species, *Howea forsteriana* and *Howea belmoreana* which are unable to ***interbreed**** to form ***fertile*, viable**** offspring;

(b) A student concluded that Fig. 9.2 shows that Lord Howe Island was originally colonised by a species of plant that was a common ancestor for *Howea*, *Laccospadix* and *Linospadix*. Explain whether or not this conclusion is correct. [2]

1. According to Fig. 9.2, the common ancestor for *Howea*, *Laccospadix* and *Linospadix* existed about 11.5 million years ago;
2. From the information given in the question, Lord Howe island was only formed 6.9 million years ago and so there could not have been a species of plant that

colonised Lord Howe island, that was a common ancestor of *Howea*, *Laccospadix* and *Linospadix*;

(c) State the types of evidence that can be used to establish the phylogenetic relationships between species. [3]

1. DNA, RNA (nucleotide) sequences and amino acids sequences;
2. of homologous genes;
3. or homologous anatomical structures can be used to establish phylogenetic relationships between species;
4. from fossils;

[Total: 10]

Question 10

(a) With reference to Fig. 10.1, describe the differences in the immune response of infected people with mild symptoms and infected people with severe symptoms.[3]

T cells

1. (appearance of the T cells) For people with mild symptoms, the T cells were circulating in the blood earlier from the 2nd day but for the people with severe symptoms, T cells were only circulating in blood only on the 12th day.
2. (highest level of T cells) For people with mild symptoms there was generally more T cells, where the highest level of T cells were circulating in the blood occurred on day 7 and the level was 8x that of the highest level of T cells for people with mild symptoms that started from day 23
3. (General trend) For people with mild symptoms, the T cell numbers increased from day 2 to the highest level on day 7 and then decreased gradually to the 30th day, but for people with severe symptoms, the T cells increased from zero on day 12 to the highest level on day 23 and remained at constant levels up to day 30.

Antibodies

4. (appearance of antibodies) There was earlier appearance of antibodies for those with severe symptoms from day 11, but for those with mild symptoms antibodies were circulating 3 days later on day 14.

(b) Suggest and explain what vaccination for this virus needs to achieve in order to give long-term protection against severe symptoms. [2]

1. Vaccination exposes the individual to a harmless form of a pathogen to induce a specific adaptive immune response resulting in formation of ***memory T and B cells****;
2. ***Memory B and T cells**** when exposed to the same virus, will recognise it and mount a faster and stronger and longer lasting secondary immune response that can occur before the 11th day for both T cells and production of antibodies;

3. Earlier appearance of the cytotoxic T cells will allow removal of virus-infected cells by apoptosis through action of perforins and granzymes
   Or
   Earlier production of antibodies by plasma B cells will allow the circulating virus particles to be neutralised and removed by phagocytes through agglutination and opsonization
   ➔ Prevent viruses from replicating and causing severe symptoms

[Total: 5]

Question 11

(a) Describe the changes shown in Fig. 11.1 from 1802 to 2012. [2]

1. In 1802, glaciers can be found at height of 4820 m but it 2012, the glaciers receded and can only be found at higher altitude from 5260 m.
2. In 1802, vegetation was growing from 4400 to 4600 m, but in 2012, vegetation extended their range from 4400 to 5120 m.

(b) Suggest how human activity may account for the changes shown in Fig. 11.1. [4]

1. Human activity such as (any one example) increase combustion of fossil fuels for electricity/industrial processes, such as in cement works/burning land and vegetation to clear land for agriculture etc releases greenhouse gases (GHG) like carbon dioxide and methane (any one example)
2. Increase Greenhouse gases (GHG) allow short-wave radiation from the sun to pass through to heat the Earth's surface which radiate out-going long-wave radiation/infra red/heat which is absorbed and re-emitted by the GHGs back to the Earth's surface;
3. This leads to increased trapping of radiation/heat resulting in warmer temperatures at higher altitudes
4. Resulting in the melting of glaciers at lower altitudes and more favourable (warmer) temperatures at higher altitudes for vegetation to grow.

[Total: 4]