# Nov 2017 H2 Bio Paper 3

**N17P3Q1**

**(a) (i)** State what is meant by a genetic disease and explain how genetic diseases are caused. [4]

1. Disease is a health / physiological impairment as a result of;
2. ***Mutation**** in the DNA;
3. which could have occurred in the individual with the disease, or inherited from parents;
4. The mutation can be in the form of a nucleotide substitution, insertion or deletion;
5. which would cause a change in the mRNA codon and subsequently, a change in the amino acid in the protein resulting in a loss-of-function;
6. Or could have resulted in a premature stop codon, producing a truncated protein;
7. Mutations could also be at the chromosomal level, where there is a change in the number of chromosomes or chromosomal translocation, duplication, deletion or inversion;

**(ii)** Justify the claim that the PKU phenotype is the result of genotype and the environment acting together. [2]

1. The PKU phenotype would only be observed in individuals that are homozygous recessive for the disease allele (genotype);
2. and when phenylalanine is present in the diet of the individual (environment);

**(iii)** Describe **two** ways in which these molecules are similar in structure and explain why these features are important for their function. [4]

Both molecules have

1. an amino group ($NH_2$/$NH_3^+$);
2. a carboxyl group ($COOH$/$COO^-$)

Importance to function:

3. to participate in condensation reaction;
4. to form peptide bonds in the production of proteins;

**(b) (i)** Suggest, in outline, a procedure that could determine whether or not a PKU allele is present. [4]

1. Extract genomic DNA from cells obtained in the blood / from a mouth swab;
2. Carry out ***polymerase chain reaction (PCR)**** using ***primers**** complementary to regions flanking the PKU allele;
3. Cut the amplified fragment using ***restriction enzyme**;*
4. Carry out ***gel electrophoresis**** to separate the fragments according to size,
5. Carry out ***Southern blot**** and use radioactive probes complementary to the PKU allele to detect specific fragments
6. Carry out RFLP analysis: compare with restriction patterns for known genotypes to determine unknown genotype;

A: after PCR – carry out DNA sequencing & compare with known DNA sequences of the normal allele and the PKU allele

**(ii)** Predict and explain the effect of this treatment on the result of the Guthrie assay for a baby that is homozygous for the PKU allele. [3]

3. The results of the test would be a false negative, showing wrongly that the baby does not have PKU;
4. No colony / reduced colony diameter would be observed;
5. Despite high levels of phenylalanine in baby's blood, which should have allowed for bacterial growth;
6. Bacteria growth was inhibited / bacteria was killed by the antibiotics present in the blood;

**(iii)** Suggest how β-2-thienylalanine inhibits bacterial growth. [3]

1. β-2-thienylalanine competes with phenylalanine for the ***active site**** of;
2. ***Aminoacyl-tRNA synthetase****, that joins ***phenylalanine**** to its tRNA;
3. β-2-thienylalanine is incorporated into polypeptides instead of phenylalanine, resulting in a change in the primary structure / amino acid sequence;
4. Tertiary structure / 3D conformation of the protein is thus changed;
5. producing non-functional bacterial proteins which resulted in bacterial growth being inhibitied;

**(c)** With reference to Fig. 1.1, and the information given, explain how loss of function of enzyme **Q** causes poor intellectual and behavioural development as well as very fair skin and hair. [4]

1. Loss of function of enzyme Q stops conversion of ***phenylalanine**** to ***tyrosine****;

Less tyrosine results in:

2. less ***thyroxine**** which leads to poor brain development;
3. less ***melanin**** which causes fair skin and hair;
4. less ***dopamine**** which results in poor transmission of nerve impulses;

**(d) (i)** In Scandinavia, 1 in 140 people are carriers of the PKU allele. Complete Table 1.1 by calculating the frequency of newborn babies positive for PKU that would be expected in Scandinavia. You should show your working. [2]

P(PKU) = P(Carrier parent 1) X P(Carrier parent 2) X P(child affected)
=1/140 x 1/140 x ¼ = 1/ 78400 or one in 78 400

**(ii)** Explain how evolution could have resulted in PKU being more common in the Northern European population compared to that of sub-Saharan Africa. [4]

1. The frequency of PKU in cold and wet, Northern Europe is the highest in the world where 1 in10 000 are sufferers while sub-Saharan Africa which is hot and dry is lower by 10 times; (Quote data)
2. This is because fungi thrive in cold and wet climates in North Europe but not in sub-Saharan Africa which is hot and dry. This means increased likelihood of renal cancer in North Europe as the fungi produces, ochratoxin A; (link climate to fungi to cancer)
3. Homozygotes for the normal PKU alleles are selected against in North Europe as they are not protected against ochratoxin A;
4. Homozygotes of PKU alleles are selected against because they have metabolic deficiencies that result in poor intellectual and behavioural development;
5. When both selection pressures are applied, as happens in North Europe, the heterozygotes are selected for as they resistant to ochratoxin A while they do not suffer the developmental deficiencies of PKU;
6. This is called ***heterozygote advantage****, a form of balancing selection where both alleles are selected for under specific circumstances found in North Europe but not found in Africa;

**(a)** Explain the normal function of blood stem cells. [4]

1. Blood stem cells are unspecialized cells which are ***multipotent**; (Reject- toti/ pluri)
2. Ability to ***self-renew**** and ***proliferate****
3. to maintain a constant pool of stem cells;
4. Ability to ***differentiate**** into specialized cells in the blood, eg red blood cell, lymphocytes (name 1 eg)
5. to replace dead cells that died;

**(b)** Outline the roles of the named T lymphocytes in fighting infection. [4]

1. The named T lymphocytes are T helper cells / lymphocytes;
2. A particular ***naïve T cell**** will have T cell receptors (TCR) that can specifically recognise the peptide of peptide:MHC complex on the antigen presenting cell (APC;
3. The APC secretes cytokines that will activate the naïve T cells which will undergo clonal expansion and differentiation to form effector and memory T cells ;
4. ***T helper cells**** secrete cytokines that stimulate/activate specific naïve ***B cells**** to become antibody-secreting ***plasma cells****;
5. ***Memory T cells**** when re-exposed to the same pathogen/antigen, will recognize it and mount a faster and stronger secondary immune response;

**(c)** Comment on the ethical aspects of this new therapy. [2]

1. Unforeseen circumstances from T cells lacking CCR5 / immune response might be affected if T cells do not have CCR5 receptor;
2. Unintended changes in DNA as a result of gene editing may contribute to development of cancer;
3. Blood stem cells are multipotent and hence cannot form a whole organism, hence no debate of whether or not a life is “sacrificed”;
4. Potential to cure patients completely so patients no longer have to be on lifetime anti-viral therapy;
5. AVP eg. Accessibility to treatment

**N17P3Q3**

**(a)** Outline how photosynthesis produces triose phosphate. [4]

1. During carbon fixation stage, $CO_2$ is combined with ***ribulose bisphosphate (RuBP)**, catalysing this reaction is RuBP carboxylase (RUBISCO);
2. to form an unstable 6 carbon molecule which;splits up immediately into 2 molecules of ***glycerate phosphate**** (GP);
3. NADPH is the reducing power used to ***reduce**** GP to ***glyceraldehyde-3-phosphate**** (G3P), and ATP provides a source of energy;
4. ***ATP**** and ***NADPH**** are products from the light-dependent reaction;

**(b)** Explain the biochemical reasons why leaf and stem growth rates decrease at temperatures both above and below the optimum ranges, as shown in Table 3.1. [3]

1. At temperatures above the optimum range, enzymes involved in leaf and stem growth ***denature****,
2. At temperatures below the optimum, rate of enzymatic reactions decreases;
3. At lower temperature, enzyme and substrate molecules have lower ***kinetic energy**** resulting in lower frequency of formation of ***enzyme-substrate complex****;

**(c)** Use the data in Table 3.1 for leaf and stem growth, seed production and temperature above which crop fails to justify your answer. [3]

1. Soybean, *Glycine max*;
2. With an increase of 2°C, maximum temperature can reach 37°C which is above the temperature at which crop fails for maize (35°C);
3. Mean temperature will rise to 29°C which is within the range for optimum growth of leaf and stem (25-36°C);
4. Temperature range for optimum seed production is higher in soybean as compared to maize, hence soybean would be able to produce more seeds at a higher mean temperature / Quote data;

**N17P3Q4**

**(a)** Describe the reproductive cycle of an enveloped virus such as influenza and explain why this is referred to as a reproductive cycle, not a life cycle [15]

Part I: Describe reproductive cycle of enveloped virus with reference to influenza

Attachment

1. Influenza virus attaches to epithelial cells of the respiratory tract;
2. ***Hemagglutinin**** binds to complementary ***sialic acid**** receptors on the host cell;

Entry

3. Virus enters by ***endocytosis**** : host cell membrane ***invaginates**** and the virus is placed in an endocytic vesicle / endosome;
4. Endosome fuses with a ***lysosome**** , resulting in a lowering of pH;
5. Lowered pH causes viral envelope to ***fuse**** with the vesicle membrane, releasing the ***nucleocapsid**** into the cytosol;
6. Capsid proteins are degraded by enzymes and the 8 segments of viral RNA genome enter the nucleus;

Replication

7. In the nucleus: ***RNA-dependent RNA polymerase**** uses the RNA genome (negative strand RNA) as a ***template**** to synthesis a complementary RNA strand (positive strand RNA);
8. Complementary RNA strand moves into the cytosol and serves as the mRNA;
9. Which is used as a template for ***translation**** to synthesise viral structural components;
10. Capsid proteins are synthesised by free ***ribosomes**** in the cytosol;
11. Glycoproteins are synthesised by ***ribosomes**** at the ***rough endoplasmic reticulum**** and are eventually embedded into the host cell membrane;
12. Complementary RNA strand also used as a ***template**** for synthesis of new viral genome by RNA-dependent RNA polymerase;

Assembly and formation of new virions

13. Assembly of new viral progeny: Capsid proteins associate with glycoproteins at the cell membrane, nucleoproteins associate with RNA genome and then interact with the capsid proteins;
14. The host cell membrane ***evaginates**** and the newly formed viruses leave the host cell by ***budding***;
15. acquiring the host cell membrane with the embedded viral glycoproteins;
16. ***Neuraminidase**** facilitates the release of the viruses by cleaving the sialic acid residues from the host cell receptor;

Part II: Why is this a reproductive cycle and not a life cycle

17. Not considered a life cycle as virus is not living;
18. Features of virus that causes it to be classified as non-living: (max 2)
    - Acellular

- Capabilities without a host cell:
  - No metabolic activity, eg No respiration
  - No growth and development
  - No reproduction
  - No response to stimuli, eg no movement

QWC: Both Part I and Part II addressed

**(b)** Discuss the possible impact of global warming on seasonal and geographical patterns of viral disease. [10]

1. Global warming is an increase in atmospheric temperatures around the world;
2. Increased temperature decreases survival of virus and hence lowers human exposure to virus;

Seasonal pattern;

3. With global warming, there are more extreme weather events with summer being hotter and winters being colder;
4. Survival of virus decreases in the hotter summer months due to higher temperature; ORA
5. Colder winters results in an increase incidences of viral diseases such as influenza in winter months; ORA

Geographical pattern:

6. Temperature decreases with increased latitude;
7. Higher incidence of viral diseases around the equator / at lower latitudes vs higher latitudes;

Ref to viral diseases involving a vector, eg. Dengue fever:

8. Mosquito vector, *Aedes aegypti*, lives and breeds in moist tropical regions;
9. With global warming, the duration for development/life cycle of mosquito from first instar to emergence is shorter;
10. As an increase in temperature increases their metabolic processes by increasing rates of enzyme-catalysed reactions;
11. resulting in faster development rate and decreasing the length of reproductive cycles and stimulating hatching of eggs;
12. More mosquitoes result in greater transmission of dengue fever;
13. Increased temperature also results in shorter extrinsic incubation period as virus can reproduce faster in mosquito vector;

Seasonal pattern:

14. Hotter summer months results in an increase incidence of dengue fever in summer;

Geographical pattern:

15. Global warming results in temperate regions becoming warmer, such that conditions become more suited for the survival of Aedes mosquitoes;
16. Mosquitoes will thus move to higher latitude so they spread to new areas expanding their distribution;
17. Global warming also results in higher altitudes becoming warmer, thus mosquitoes will be able to colonise altitudes higher up the mountain;

QWC: to address both changes in seasonal and geographical patterns with regards to viral diseases, citing specific examples.

**N17P3Q5**

**(a)** Outline the differences between typical prokaryotic and eukaryotic cells and state the methods by which these differences can be shown. [15]

| Feature | Eukaryotic cell | Prokaryotic cell (bacteria) | Method |
|---|---|---|---|
| **Cell size** | Larger: 10-100μm in diameter | Smaller: 0.5 - 5μm in diar | Light/electo rn microscopy |
| **Nucleus** | Nucleus with nuclear envelope present; | No true nucleus / No nuclear envelope | Light/electron microscopy |
| **Genetic material** | Linear DNA associated with many proteins;<br>Found in membrane bound nucleus;<br>No plasmids | Circular DNA associated with few histone-like proteins;<br>Found in a region of the cytoplasm known as the nucleoid region;<br>Plasmids present | Restriction digest and electrophoresis |
| **Ribosome for protein synthesis** | 80S;<br>Ribosomes may be attached to ER or free in cytoplasm | 70S;<br>No ER present. Ribosomes free in cytoplasm. | Electron microscopy |
| **Organelles** | Many;<br>Many membrane bound organelles present; | Few;<br>No membrane bound organelles; | Electron microscopy / Differential centrifugation |
| **Cell walls** | Composed of cellulose in plants & chitin in fungi | Composed of peptidoglycan or murein | Gram staining for prokaryotes |
| **Flagella** | Complex:<br>9+2 arrangement of microtubules;<br>Intracellular (enclosed by plasma membrane);<br>200 nm in diameter | Simple:<br>➔Lacking microtubules - just a single strand of protein;<br>Extracellular (not enclosed by plasma membrane);<br>20 nm in diameter | Electron microscopy / immunofluoresence |

QWC: link method to feature to be distinguished

**(b)** Explain the expected problems of trying to classify the prokaryotes present in the human prokaryotic microbiome community and describe the advantages of using molecular methods for this process. [10]

Part I: Expected problems

Prokaryotes in the human microbiome are

1. Small and therefore difficult to distinguish morphologically;
2. similar in structure in terms of shape or cell wall or function and therefore difficult to classify;

(For example they may **use oxygen the same way** (aerobic or anaerobic) or **obtain energy the same way** (autotrophs or heterotrophs) and hence will be difficult to distinguish between them and classify them;

3. reproduce asexually/undergo conjugation/transduction and therefore difficult to identify/distinguish
4. some may be difficult to grow culture in the lab and hence difficult to study
5. defining species in bacteria is difficult if we use biological concept of species as bacteria divide asexually by binary fission

Part II: Advantages of using molecular methods

1. They can be used to compare **all organisms** which **share common genes.**
2. They can be used to compare organisms that are **morphologically indistinguishable** due to **convergent evolution** or because they are **closely related**.
3. Molecular methods are **objective** as molecular character states are unambiguous (e.g. A, C, G & T) whereas some morphological characters, such as those based on the shape of a structure or colour, can be less easy to distinguish objectively.
4. They are **quantitative** as molecular data can be **converted into numerical form** and **statistical analysis** performed to determine **degree of relatedness** by calculating nucleotide differences between organisms.
5. **Changes in nucleotide sequences accumulate over time with clockwork regularity** and this forms the basis of the molecular clock. We can thus **estimate the time of speciation** of modern to ancient species.
6. Some molecular differences may not be reflected as a morphological difference while small genetic differences may not result in a major phenotypic difference. This means that molecular data **does not underestimate nor exaggerate differences** unlike morphological analysis.
7. Molecular methods offer a **large set of characters to be studied quickly**. Each nucleotide position can be considered a character to distinguish between species.
8. Nucleotide sequences for a rapidly increasing number of genomes & amino acid sequences for many proteins can be **accessed from electronic databases for comparative study & classification of all life.**
9. **Specimens need not be complete or alive for comparative analysis** so long as the molecules survive degradation.