



**MERIDIAN JUNIOR COLLEGE**  
JC2 Preliminary Examinations 2017  
Higher 1

CANDIDATE  
NAME

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CIVICS  
GROUP

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INDEX  
NUMBER

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## H1 BIOLOGY

**8875/02**

Paper 2

**15 September 2017**

**2 hours**

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### READ THESE INSTRUCTIONS FIRST

**Do not open this booklet until you are told to do so.**

Write your name, civics group and index number on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

#### Section A

Answer **all** questions.

#### Section B

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

## ANSWER SCHEME

For examiner's Use	
Section A	
1	/ 14
2	/ 7
3	/ 9
4	/ 10
Section B	
5 or 6	/ 20
Total	/ 60

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This paper consists of **12** printed pages.

**[Turn over]**

## Section A

Answer **all** the questions in this section.

### QUESTION 1

Pepsin is an enzyme that digests protein. It is synthesized in the cells of the stomach as a longer, inactive proenzyme called pepsinogen. Secretion of pepsinogen into the acidic environment of the stomach then activates it.

Fig. 1.1 shows the structures of pepsinogen and pepsin. The active site of pepsin is indicated.

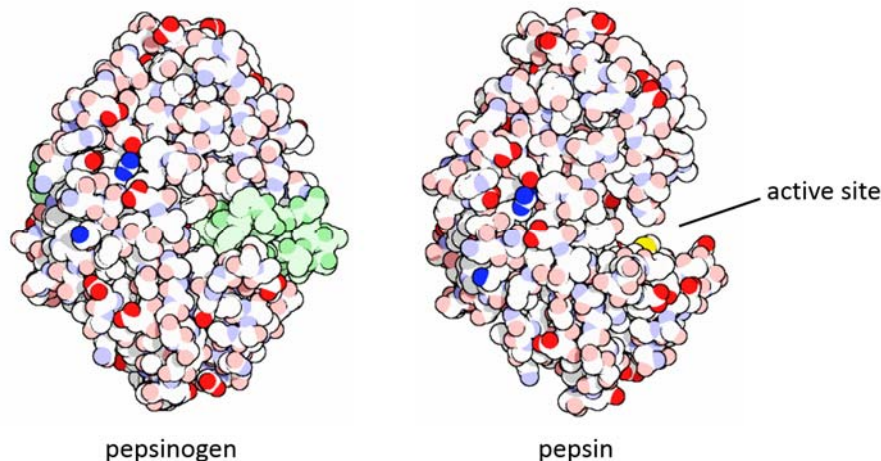


Fig. 1.1

a) With reference to Fig. 1.1, explain how the structure of pepsinogen allows it to be inactive. [2]

- Pepsinogen has extra amino acids in its primary structure, which occupies the active site of pepsin / active site is not exposed.
- Prevents substrate from binding to active site, because it is not complementary in shape to the substrate.

b) Explain how a point mutation on DNA can change the primary structure of pepsin but not its globular structure. [4]

#### [DNA level]

- Single-base substitution on a triplet on DNA on pepsin gene

#### [mRNA level]

- Changes the corresponding mRNA codon, and changes corresponding amino acid

#### [Polypeptide level]

- Amino acid has similar property, hence same R-group interactions occur
- Folding of the polypeptide chain unchanged, hence the 3D configuration of pepsin unchanged

OR

- Amino acid is not involved in the formation of bonds important in maintaining three-dimensional configuration of pepsin
- Folding of the polypeptide chain unchanged, hence the 3D configuration of pepsin unchanged

**Reject:** Silent mutation, since primary structure is changed.

- c) Pepsinogen is secreted by the gastric chief cells of the stomach. These cells also synthesize and secrete gastric lipases that hydrolyze lipids.

Explain how gastric chief cells are structurally adapted for its role. [3]

- Large number of rough endoplasmic reticulum and Golgi apparatus.
- RER – for synthesis of pepsinogen and lipases [context], which are proteins.
- Golgi – for biochemical modification of pepsinogen and lipases and for formation for secretory vesicles

- d) Another enzyme, DNA polymerase, carries out DNA replication with tight coordination of leading and lagging strand synthesis.

Describe **two** structural differences between DNA polymerase and its substrate. [2]

	Features	DNA polymerase	Substrate (DNA)
1	Overall structure	Compact spherical/ globular shape	Double helical shape
2	Monomers	Amino acids	Deoxyribonucleotides
3	Types of different monomers.	20	4
4	Bonds between monomers	Peptide bond	Phosphodiester bond
5	Other bonds supporting overall structure	hydrogen bonds, ionic bonds, disulfide bonds, hydrophobic and hydrophilic interactions	hydrogen bonding between nitrogenous bases, and hydrophobic interaction between stacked bases
6	Elements present	May contain sulphur (e.g. cysteine) <b>OR</b> Carbon, Hydrogen, Oxygen Nitrogen, Sulfur	Phosphorus <b>OR</b> Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorous

e) Fig. 1.2 shows the transport of substances in and out of the nucleus via the nuclear pore.

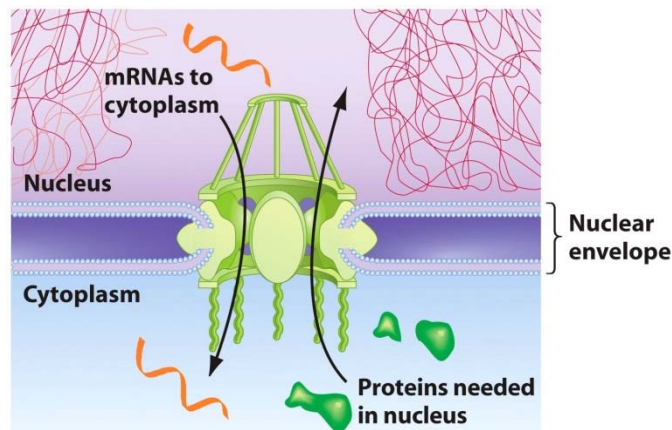


Fig. 1.2

i) Apart from enzymes and proteins that are directly involved in DNA replication and transcription, suggest **two** other substances that are transported from the cytosol into the nucleus. [2]

- Deoxyribonucleotides for DNA replication / ribonucleotides for transcription
- ATP as an energy molecule for energy-requiring processes in the nucleus
- Ribosomal proteins
- Histones (involved in DNA packing but not DNA replication)
- **AVP**

ii) Apart from messenger RNAs that exit the nucleus into the cytosol, suggest **one** other substances that are transported out of the nucleus. [1]

- Ribosomes / 80S ribosomes / large subunit of ribosome / small subunit of ribosome
- Transfer RNA / tRNA
- Nucleoside diphosphates / monophosphates
- **AVP**

[Total: 14]

## QUESTION 2

In 1865, Gregor Mendel performed dihybrid crosses on pea plants for a variety of characteristics including flower colour, flower position and height (length of stem). From his observations he developed a fundamental law of genetics that some genetic characteristics are inherited independently.

For example, pure-breeding pea plants with red flowers on the sides of stems (axial) can be crossed with pure-breeding pea plants with white flowers on the ends of stems (terminal).

All the resultant plants ( $F_1$  generation) have red flowers that are axial.

One set of results for the offspring from self-pollinating these  $F_1$  plants is shown below.

261	red, axial flowers
86	red, terminal flowers
76	white, axial flowers
28	white, terminal flowers

a) Draw a genetic diagram to explain both crosses.

Use the following symbols to represent the different alleles involved:

**R/r** – Flower colour      **A/a** – Flower position [5]

<b>Parental phenotype:</b>	Red, axial flowers	X	White, terminal flowers
<b>Parental genotype (2n):</b>	RRAA	X	rraa
<b>Gametes (n):</b>	RA	X	ra
<b><math>F_1</math> genotype:</b>	RrAa		
<b><math>F_1</math> phenotype:</b>	Red, axial flowers		

Selfing  $F_1$

<b><math>F_1</math> phenotype:</b>	Red, axial flowers	X	Red, axial flowers
<b><math>F_1</math> genotype (2n):</b>	RrAa	X	RrAa
<b>Gametes (n):</b>	RA rA Ra ra	X	RA rA Ra ra

**$F_2$  genotype and phenotype (2n):** [1]

	RA	Ra	rA	ra
RA	RRAA Red, axial	RRAa Red, axial	RrAA Red, axial	RrAa Red, axial
Ra	RRAa Red, axial	RRaa Red, terminal	RrAa Red, axial	Rraa Red, terminal
rA	RrAA Red, axial	RrAa Red, axial	rrAA White, axial	rrAa White, axial
ra	RrAa Red, axial	Rraa Red, terminal	rrAa White, axial	rraa White, terminal

**$F_2$  phenotypic ratio:** Red, axial : Red, terminal : White, axial : White, terminal  
9 : 3 : 3 : 1

**Which is close to observed number:** 261 : 86 : 76 : 28 [1]

b) Explain how different characteristics are inherited independently in dihybrid inheritance. [2]

- Different genes coding for different proteins can be located on different chromosomes
- Based on the law of independent assortment and segregation, alleles of one gene on a chromosome independently assort and segregate from the alleles of another gene on another chromosome, during gamete formation/meiosis.

[Total: 7]

### QUESTION 3

A recent study of populations of the house mouse, *Mus musculus*, on the island of Madeira resulted in the following observations:

- There are six distinct populations.
- The mice are associated with human settlements.
- The populations are located in different valleys separated by steep mountains.
- Each population has a different diploid number of chromosomes

As a result of these observations, it has been suggested that evolution is taking place, leading to the formation of six different species.

Fig. 3.1 is a schematic representation of Madeira showing the distribution of the six populations.

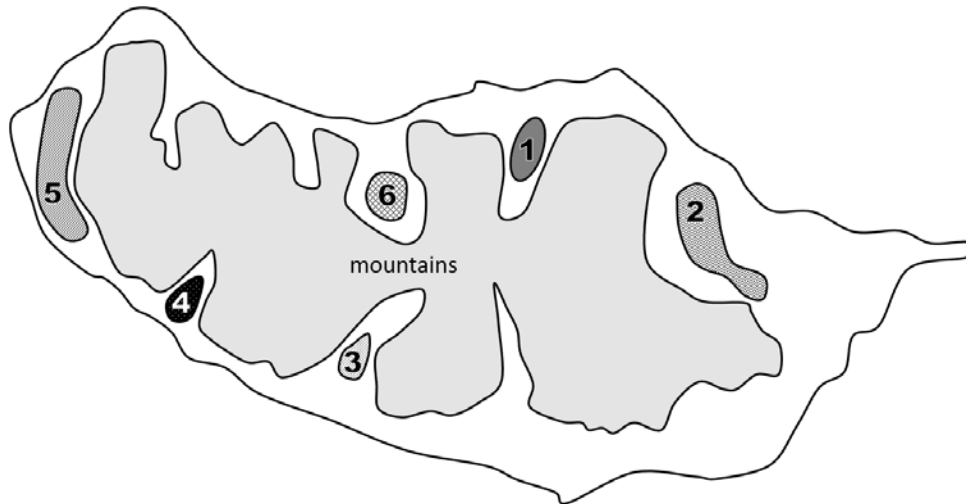


Fig. 3.1

- a) 'It has been suggested that evolution is taking place, leading to the formation of six different species.'

Explain how this process is occurring in the house mouse populations of Madeira. [4]

1. Due to association with human settlements, the mouse population was scattered.
2. Steep mountains serves as geographical barriers for the scattered populations, hence no breeding / gene flow between the separated populations.
3. Different selection pressures in each area where each population resides, hence different alleles are selected for and against.
4. Random mutations also occurred in each population.
5. Results in change in allele frequency / gene pool.
6. Develop different chromosome numbers, hence different species.

b) Explain the likely outcome of individuals from two separate populations being mated in captivity. [2]

- Due to different chromosome number / diploid number
- As there is no pairing of homologous chromosomes in offspring, meiosis cannot take place, thus no gametes will be produced by offspring, hence infertile.

c) Cytochrome c is a protein that is found in all living organisms. Analysis of the amino acid sequences of proteins, such as cytochrome c, provides data that taxonomists use to produce more accurate classifications.

Explain why analyzing the amino acid sequences of proteins could provide useful data for taxonomists. [3]

- DNA codes for amino acid sequences
- Mutations result in altered DNA sequences, which results in differences in amino acid sequences
- Hence, large (small) difference in amino acid sequence between two species reflects distant (close) evolutionary relationship

**[Total: 9]**



#### QUESTION 4

The artificial plasmid, pBR322, was constructed to act as a vector. It has often been used to insert human genes, such as the human insulin gene, into the bacterium, *Escherichia coli*.

The plasmid was constructed to include two genes, each giving resistance to a different antibiotic: an ampicillin-resistant gene and a tetracycline-resistant gene. The plasmid also has a target site for the restriction enzyme, *Bam*HI, in the middle of the tetracycline-resistance gene.

A pBR322 plasmid was cut using *Bam*HI and the cDNA gene for human insulin inserted into it.

Fig. 4.1 shows pBR322 and the recombinant plasmid.

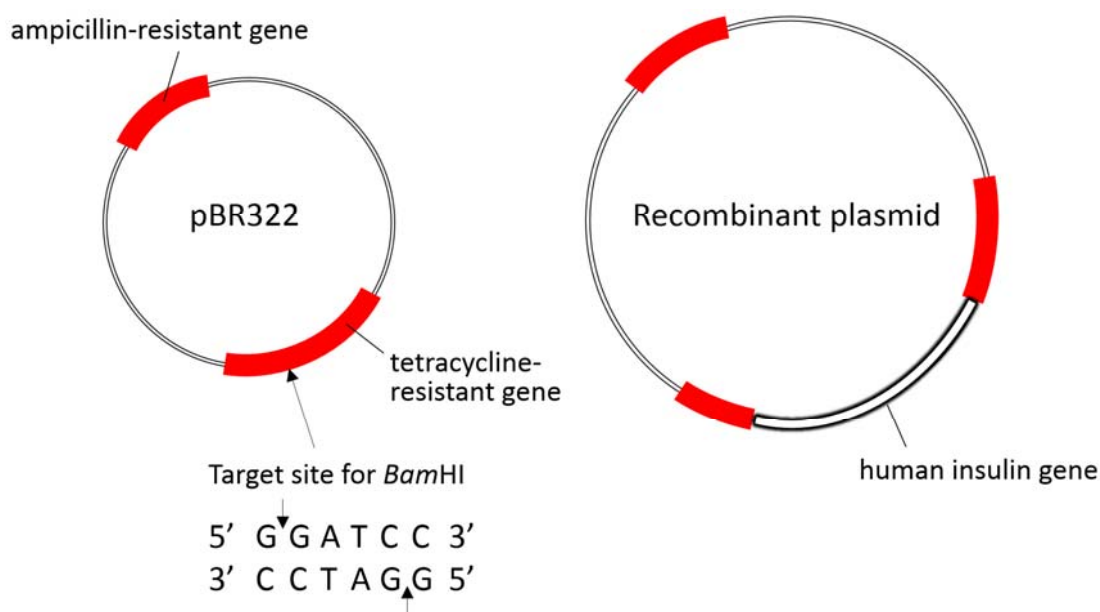


Fig. 4.1

- a) The cDNA of human insulin gene obtained by reverse transcription does not contain sticky ends.

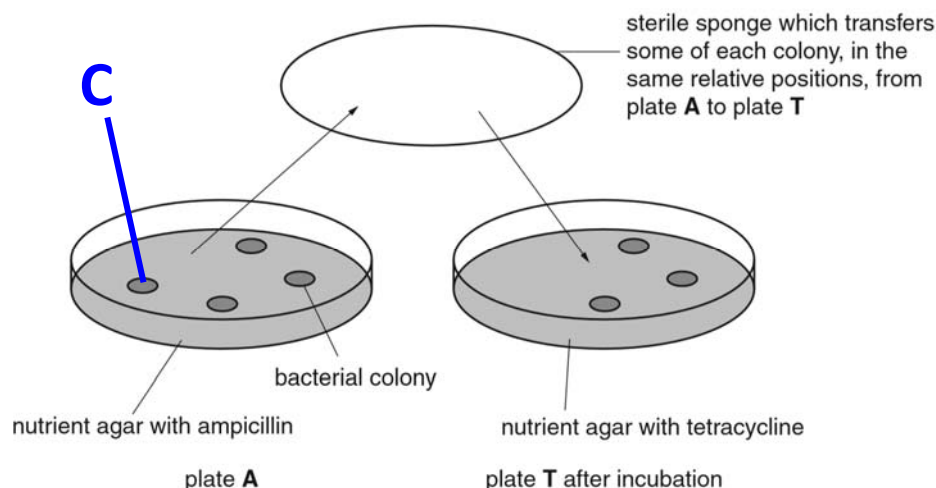
With reference to Fig. 4.1, describe how a cDNA of human insulin gene can be inserted into pBR322 that has been cut by *Bam*HI. [3]

- *Bam*HI linkers are added to the two ends of the cDNA gene and cut with *Bam*HI enzyme to produce *Bam*HI sticky ends GATC and CTAG
- Mix the cDNA with the *Bam*HI-cut plasmid
- Both have same sticky ends, hence can anneal by complementary base pairing through formation of hydrogen bonds
- DNA ligase seals the sugar-phosphate backbone by forming phosphodiester bonds

- b) Bacteria were then mixed with the recombinant plasmids. Those bacteria which had successfully taken up recombinant plasmids were identified using the following steps:

**Step 1** – the bacteria were spread onto culture plates containing nutrient agar and ampicillin and incubated to allow colonies to form

**Step 2** – some bacteria from each of the colonies growing on these plates were transferred to plates (replica plating) containing nutrient agar and tetracycline, as shown in Fig. 4.2.



**Fig. 4.2**

- i) Explain why the bacteria were first spread onto plates containing ampicillin. [2]

- To eliminate bacteria (>99%) which did not take up any plasmid / non-transformed bacteria
- Transformed bacteria took up (recombinant/re-annealed) plasmid, thus acquiring ampicillin-resistant gene on the plasmid
- Hence are resistant to ampicillin and able to survive on ampicillin plate.

- ii) Explain why it is important that on the pBR322 plasmid, the target site for *Bam*HI is in the middle of the tetracycline resistance gene. [3]

- Insertional inactivation / disruption of Tet<sup>R</sup> gene due to insertion of human insulin gene
- Colonies that are ampicillin-resistant but not tetracycline-resistant have taken up recombinant plasmid
- Colonies that survive on Tet plate have taken up the re-annealed plasmid
- Compare Amp plate and Tet plate. Colonies missing on Tet plate but present on Amp plate is the bacteria with recombinant plasmids.

- iii) Use a label line and the letter **C** to identify, on Fig. 4.2, a colony of bacteria that contains the recombinant plasmid. [1]

- c) Plasmid vectors carrying antibiotic-resistant genes are now rarely used in gene technology because of the risk of transferring these genes to other bacteria that are previously susceptible to that antibiotic, hence conferring antibiotic-resistance to these bacteria.

State one type of gene that has replaced antibiotic-resistant genes in plasmid vectors **and** indicate how bacteria carrying this gene can be detected. [1]

Gene	lacZ gene / $\beta$ -galactosidase gene
Detection	bacterial colonies turn blue on X-GAL agar
	green fluorescent protein gene
	bacterial colonies fluoresce green under UV light
	luciferase gene
	bacterial colonies emit light on luciferin agar

**[Total: 10]**

**Section B**  
Answer **all** questions

Write your answers on the separate answer paper provided.  
Your answers should be illustrated by large, clearly labeled diagrams, where appropriate.  
Your answers must be in continuous prose, where appropriate.  
Your answers must be set out in questions (a), (b), etc., as indicated in the question.

**QUESTION 5**

- a) DNA molecules replicate with a high degree of accuracy, yet not always perfectly.

Describe how this occurs and discuss why the survival of a species depends on DNA molecules being stable, yet not *absolutely* stable. [10]

**[How DNA replication takes place accurately] – max 3**

1. DNA is double-stranded, each strand is complementary to the other
2. Each strand acts as the template for synthesis of daughter strand by complementary base pairing (A=T, C≡G)
3. DNA polymerase III with proofreading function / 3'→5' exonuclease activity
4. Able to excise previous nucleotide that is wrongly paired and replace with the correct nucleotide
5. DNA polymerase I with proofreads newly-synthesized daughter strand / 5'→3' exonuclease activity

**[Why DNA replication is not always perfect] – max 3**

6. Exposure to radiation / chemical carcinogens / **AVP**
7. Causes structural damage to DNA + *cite an example below*
  - a) e.g. UV light causes thymine dimer formation
  - b) e.g. chemicals (such as nitrous acid) chemically reacts with base
  - c) e.g. ethidium bromide intercalates into DNA
8. Such structural damage causes wrong nucleotide(s) / extra nucleotide(s) / missing nucleotide(s) to be added during DNA replication.
9. Spontaneous mutation – DNA polymerase adds the wrong base, and is not being rectified.

**[Why survival of offspring depends on DNA being stable] – max 2**

10. **Idea that** Ensures sequence of DNA in genes is intact so that (normal amount of) functional proteins can be made
11. **Idea that** Mutation results in non-functional / hyperactive / overproduction / underproduction of proteins
12. **Ref to** Sickle-cell anemia – Single-base substitution to  $\beta$ -globin gene that causes Hb to crystallize, forming sickle-cell RBC which clogs blood vessels / inefficient O<sub>2</sub> transport
13. **Ref to** Cancer – a result of gain-of-function mutation to proto-oncogenes and loss-of-function mutation tumor-suppressor genes, leading to uncontrolled cell division.

**[Why survival also depends on DNA being not *absolutely* stable] – max 2**

14. **Ref. to** role of mutation in natural selection
  - a. Mutations allow for formation for new alleles
  - b. Provides variation between individuals in a population to allow the population to respond to environmental change
  - c. Survival of the fittest to allow population to evolve, hence prevents extinction of a species

- b) Explain the underlying principles of the polymerase chain reaction (PCR) **and** explain how the specificity of PCR is achieved. [5]

**[Underlying principles in PCR] – max 4**

1. Amplify a segment of DNA from a very minute amount

[Denaturation step]

2. Use of high heat (95°C) to denature template DNA into single-stranded DNA by breaking hydrogen bonds between complementary bases.

[Annealing step]

3. Use of DNA primers to provide a free 3'-OH end for *Taq* polymerase in the elongation step.

[Elongation step]

4. Use of thermostable *Taq* polymerase which does not denature at high temperatures
5. At its optimal temperature at 72°C, it catalyses the addition of deoxyribonucleotides to 3' end of primers by forming phosphodiester bond
6. Thermostable polymerase and excess primers and deoxyribonucleotides allows PCR to be automated over many cycles.

**[How the specificity of PCR is achieved] – max 1**

7. Sequence of DNA primers is complementary to the 3' regions of the sequence to be amplified
8. Length of primers must be sufficiently long (15-25 nucleotides) to ensure it binds only to target region

- c) Describe the process of endocytosis.  
[5]

**[Phagocytosis]**

1. The cell surface membrane extends pseudopodia / cytoplasmic extensions around it the particle.
2. The pseudopodia fuse to form a large vacuole around the particle, known as a phagocytic vesicle.

**[Pinocytosis]**

3. Process whereby a cell invaginates a region of the cell surface membrane, forming a vesicle around a small volume of extracellular fluid.

**[Receptor-mediated endocytosis]**

4. Process by which a cell can acquire specific molecules, even those that may be in low concentrations in the extracellular fluid.
5. The specific molecules bind to complementary protein receptors embedded on the cell surface membrane.
6. After binding, the receptor proteins cluster in regions of the membrane called clathrin-coated pits, which are lined on their cytoplasmic side by a layer of coat proteins
7. Each coated pit forms a vesicle containing the ligand molecules.
8. After the ligand molecules are released from the vesicle, the vesicle (and receptors) is then recycled to the cell surface membrane.

## QUESTION 6

a) Discuss the importance of hydrogen bonding in ensuring the continuity of life.

[10]

### [Role of H-bonds between complementary base pairs]

1. Allows complementary base pairing to occur in nucleic acid interactions

#### [DNA]

2. Stabilizes two DNA strands to form double helical DNA molecule
3. **Ref. to** role of DNA (e.g. storing genetic information)

#### [tRNA]

4. Intra-molecular hydrogen bonding in tRNA allows tRNA to fold into a clover-leaf structure
5. **Ref. to** role of tRNA – carries amino acids to the ribosome for synthesis of polypeptide

#### [rRNA]

6. Intra-molecular hydrogen bonding in rRNA allows rRNA to fold into a precise 3D structure to complex with ribosomal proteins to form ribosome
7. **Ref. to** role of ribosome – translation machinery

#### [During DNA replication]

8. Important in DNA replication, where daughter DNA strand is synthesized via adding complementary deoxyribonucleotides to template DNA to ensure accurate transmission of genetic information.

#### [During transcription]

9. Important in transcription, where RNA is synthesized via adding complementary ribonucleotides to template DNA

#### [During translation]

10. Important in translation, where codons on mRNA complementary base pair with anticodon on tRNA to ensure correct sequence of amino acids forms the polypeptide

### [Role in maintaining protein structure]

11. **Ref. to** maintaining secondary structures ( $\alpha$ -helices and  $\beta$ -pleated sheets) in proteins, formed between peptide regions.
12. **Ref. to** maintaining tertiary/quaternary structure of proteins, formed between R groups.
13. **Idea that Shape** of proteins dictates their specific functions (e.g. in DNA replication and gene expression)

### [Role in enzyme-substrate interaction]

14. **Ref. to** allow substrate to bind weakly to the active site of enzyme

### [Role in solubility]

15. **Ref. to** allows hydrophilic substances to be soluble in aqueous environment to allow reaction to take place

16. **AVP**

**b)** Outline the functions of membranes **within** cells. [5]

1. Form compartments (compartmentalization) within the cell (i.e. formation of organelles).
2. This allows the maintenance of optimal conditions for specialized biochemical reactions to occur.
  - a) E.g. nuclear membrane: encloses DNA and allows DNA replication and transcription to occur
  - b) E.g. Compartmentalization of lysosome keeps the lysosomal lumen at pH 5 (optimal pH for lysosomal acid hydrolases).
  - c) E.g. RER membrane being site of ribosome attachment for translation to take place and provide correct environment for protein folding
  - d) **AVP**
3. Attachment of specific proteins/enzymes within organelle membrane allows enzyme-catalysed chemical reactions to take place in a sequential manner in a metabolic pathway
  - a) E.g. photophosphorylation in the thylakoid membrane of chloroplast
  - b) E.g. Oxidative phosphorylation in the inner mitochondrial membrane
4. Membranes are required for the formation of transport vesicles during intracellular transport.
  - a) E.g. ER vesicles – transport proteins to Golgi for modification
  - b) E.g. Golgi vesicles – transport proteins to their destination e.g. secretion, plasma membrane, other organelles.

5. **AVP**



c) With reference to specific examples, discuss the roles of coenzymes in yeast. [5]

**[NAD]**

1. NAD oxidizes intermediates of the glycolysis, Link reaction, and Krebs cycle, forming NADH.
2. *[A specific example of oxidation step in glycolysis / Krebs cycle that requires NAD]*

**[FAD]**

3. FAD oxidizes intermediates of the Krebs cycle, forming FADH<sub>2</sub>.
4. *[A specific example of oxidation reaction in Krebs Cycle requires FAD]*

**[NAD & FAD]**

5. Both NADH and FADH<sub>2</sub> acts as electron donor in oxidative phosphorylation...
6. ...where they donate electrons to the electron transport chain and is oxidized to NAD and FAD.

**[Coenzyme A]**

7. In link reaction of respiration, coenzyme A combines with 2C compound/acetyl group to produce acetyl CoA...
8. ... which then enters and is oxidized in the Krebs cycle.

**[Total: 20]**