UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (HONS) BIOMEDICAL ENGINEERING

SEMESTER ONE EXAMINATIONS 2024/25

MOLECULAR PRINCIPLES OF BIOMEDICAL ENGINEERING

MODULE NO: BME4002

Date: Tuesday 7th January 2025   Time: 2:00 – 4:00pm

INSTRUCTIONS TO CANDIDATES:

Candidates are advised that the examiners attach importance to legibility of writing and clarity of expression. YOU ARE STRONGLY ADVISED TO PLAN YOUR ANSWERS

There are THREE sections.

Answer ALL questions from Section A and Section B.

Answer ONE question from Section C.

Write all answers in answer booklet.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

Calculators are permitted, but all working must be shown.

A formulae sheet, together with the genetic code table, can be found at the end of the paper.

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SECTION A: Answer ALL questions in this section; 1 mark per question, 29 marks in total.

1. Which of the following are found in both DNA and RNA?
    a. Ribose, phosphate groups, and adenine.
    b. Deoxyribose phosphate groups, and guanine.
    c. Phosphate groups, guanine, and cytosine.
    d. Phosphate groups, guanine, and thymine.

2. What is produced during translation?
    a. tRNA.
    b. mRNA.
    c. Polypeptides.
    d. None of the above.

3. Which of the following correctly describes an isotope?
    a. An element with a negative charge.
    b. Two or more forms of the same element with different mass numbers.
    c. Two or more forms of the same element with different numbers of protons.
    d. An element with an odd number of electrons.

4. Oxygen has the chemical symbol $^{16}_{8}O$. Which of the following unknown elements X is likely to be an isotope of oxygen?
    a. $^{17}_{8}X$
    b. $^{16}_{7}X$
    c. $^{8}_{16}X$
    d. $^{16}_{9}X$

5. If a double-stranded DNA molecule is composed of 25% adenine, how much uracil would be expected?
    a. 0%.
    b. 25%.
    c. 75%.
    d. 37.5%.

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6. Which of the following is a function of the Golgi apparatus?
   a. Transporting proteins around the cell.
   b. Production of ATP.
   c. rRNA synthesis.
   d. Storage of DNA.

7. If 4 moles of $MgCl_2$ are dissolved in 500 mL of water, what is the concentration of the resulting solution?
   a. 0.04 moles.
   b. 8 M.
   c. 20 M.
   d. 4 moles.

8. Enzymes speed up reactions by _____.
   a. Increasing the temperature of reactants.
   b. Lowering the activation energy of a reaction.
   c. Providing energy for reactions.
   d. Being incorporated into the products of a reaction.

9. How many electrons does the element $^{23}_{11}Na^+$ have?
   a. 11.
   b. 12.
   c. 23.
   d. 10.

10. Which of the following statements is correct when mutations occur in DNA?
   a. Mutations only ever occur in protein-coding regions.
   b. Mutations always cause changes to the shape of proteins.
   c. Mutations always cause changes to the protein sequence.
   d. Mutations always cause changes to the DNA sequence.

11. Which of the following RNA sequences would be made from a template strand of DNA with the sequence **3'- TACGTCAGACGAATC -5'**?
   a. 5' – TACGTCAGACGAATC – 3'
   b. 5' – ATGCAGTCTGCTTAG – 3'
   c. 5' – AUGCAGUCUGCUUAG – 3'
   d. 5' – GUTTCGUCUGACGUA – 3'

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12. Which of the following is not a stage of cell signalling?
      a. Transduction.
      b. Response.
      c. Osmosis.
      d. Reduction.

13. Which of the following best describes the intermolecular and intramolecular bonding present in H_2O?
      a. Water bonding, hydrogen bonding, covalent bonding.
      b. Ionic bonding, covalent bonding.
      c. Hydrogen bonding, covalent bonding, Van der Waals' bonding.
      d. dipole-dipole bonding, oxygen bonding, covalent bonding.

14. _____ are pyrimidines; _____ are purines (fill in the blanks).
      a. Adenine and guanine; cytosine and thymine.
      b. Cytosine and guanine; adenine and thymine.
      c. Cytosine and thymine; adenine and guanine.
      d. Uracil and adenine; thymine and guanine.

15. How many pairs of autosomal chromosomes does a human non-sex cell have?
      a. 22.
      b. 23.
      c. 44.
      d. 46.

16. The amino acid valine has the following structure:
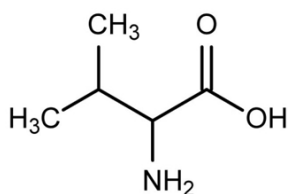
Which of the following best describes the properties of its side chain?
      a. Uncharged, non-polar side chain.
      b. Positively charged, hydrophilic side chain.
      c. Polar, hydrophilic side chain.
      d. Uncharged, polar side chain.

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17. The enzyme used in PCR starts copying at which of the following positions?
    a.   At the transcription start site.
    b.   At any open point.
    c.   At the 3' end of the DNA primers attached to either side of the desired gene.
    e.   At the 5' end of the DNA primers attached to either side of the desired gene.

18. Which of the following statements is **NOT** correct about the phospholipid molecules in the plasma membrane?
    a.   Each phospholipid molecule has two nonpolar tails.
    b.   Each phospholipid molecule has one polar head.
    c.   The phospholipid tails contain polypeptides.
    d.   The phospholipid heads face outward.

19. Triglycerides are used for the long-term storage of energy in cells. Which of the following properties makes them suitable for this?
    a.   Triglycerides are hydrophilic so they can dissolve easily in cells.
    b.   Triglycerides contain many high-energy carbon-oxygen bonds.
    c.   Triglycerides are hydrophobic so they don't attract water into cells.
    d.   None of the above.

20. The bonds between DNA base pairs are:
    a.   Phosphodiester bonds.
    b.   Stronger between A/T vs G/C.
    c.   Weaker than dipole-dipole bonds.
    d.   Peptide bonds.

21. The gene responsible for causing Sickle Cell Anemia is recessive (s). Which of the following genotypes will result in disease?
    a.   Ss.
    b.   SS.
    c.   ss.
    d.   All of the above.

22. How many molecules of DNA would be expected after 10 rounds of PCR, if a single molecule of DNA was used as an initial template?
    a.   1.
    b.   1024.
    c.   10.
    d.   20.

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23. A and B represent two alleles of a gene. Which of the following statements is true about A and B?
    a. A and B contain the DNA sequence for different genes.
    b. A and B are variants of the same gene.
    c. A and B have an identical DNA sequence.
   d. A and B code for non-functional proteins.

24. Which of the following is a desirable property for a polymerase used in PCR?
    a. Hydrophobic.
    b. Expensive.
    c. Low pH.
    d. Thermostable.

25. Which of the following is **not** a step in PCR?
    a. Extension.
    b. Denaturing.
    c. Annealing.
    d. Ligating.

26. The following diagram shows a genetic cross between a yellow (dominant, YY) and a white (recessive, yy) rose:

(a) Cross-fertilization
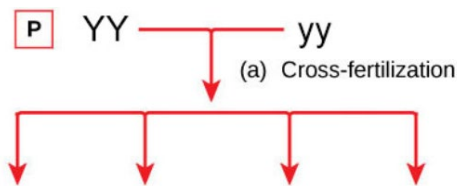
What ratio of yellow to white roses would you expect to see in the F1 generation?
    a. 1:1
    b. 3:1
    c. 2:1
    d. 4:0

27. The absence of double bonds makes a fatty acid:
    a. Saturated.
    b. Hydrogenated.
    c. Oxygenated.
    d. Unsaturated.

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28. Energy is released when:
    a. A phosphate group is added to a molecule of ATP.
    b. A phosphate group is released from a molecule of ATP.
    c. A phosphate group is either added or released from a molecule of ATP.
    d. A nitrate group is released from a molecule of ATP.

29. At pH 1, amino acids are:
    a. Always negatively charged.
    b. Always positively charged.
    c. Always uncharged.
    d. Sometimes charged and sometimes uncharged.

[Total for Section A: 29 marks]

END OF SECTION A – PLEASE TURN THE PAGE FOR SECTION B

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SECTION B: Answer ALL questions in this section; varying marks per question, 36 marks in total.

1. Explain how the four different bases in DNA can code for the 20 amino acids found in proteins.

[6 marks]

2. A patient presents herself at a genetic counselling clinic saying that her and her partner want to have a baby, but she is concerned that any child she has may have the autosomal recessive condition Cystic fibrosis. She herself has the disease and previous tests have shown that her partner is not a carrier for the mutation which causes the disease. With the use of a Punnett square calculate the percentage likelihood of their baby being affected by the disease.

[5 marks]

3. Design the PCR primers (12 bases in length) which would be required to copy the target region (red) of the sequence below (Figure 1). What would be the size (in base pairs) of the resulting product?

```
      |----------------------------------------  Target   --------------------------------------------|
5' TGCCTTCGTACGTGTACACGTGGGACATACGTACACAGGTAGACTGATACCAGTGTCGGAAAT 3'
```

Figure 1: DNA sequence for Question 3

[6 marks]

4. Briefly describe the three stages of transcription and discuss the role of transcription factors in this process.

[6 marks]

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5. Use the formulae sheet at the back of the exam paper to assist you with the following calculations.
   a) What is the concentration of a solution with a volume of 2.5 L containing 300.00 g of calcium phosphate? (M_r = 310.1).

   [2 marks]

   b) Calculate how would you dilute the solution described in part (a) to make 150.00 mL of a 50.00 mM solution.
   [2 marks]

   c) When attempting to make the solution in part (b), you accidentally end up with a volume of 200.00 mL instead of 150.00 mL. What molarity solution do you now have?
   [3 marks]

   [Total 7 marks]

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6. See Table 1 at the end of the paper for the genetic code table. You have been given the following double-stranded sequence of DNA:

5' ATGCCGATCTCATGCCGGTCGACCGTC 3' *Non-template strand*
3' TACGGCTAGAGTACGGCCAGCTGGCAG 5' *Template strand*

    a) Assuming transcription begins at the start of the sequence, what sequence of mRNA would be produced from this sequence during transcription?

[2 marks]

    b) Using the information supplied in Table 1, what amino acid sequence would be produced from your mRNA sequence in part (a) during translation?

[2 marks]

    c) A mutation in this sequence of DNA has resulted in the amino acid proline (Pro) changing to the amino acid alanine (Ala). Write down one possible sequence for the mutated double-stranded DNA, highlighting this change.

[2 marks]

[Total 6 marks]

[Total for Section B: 36 marks]

END OF SECTION B – PLEASE TURN THE PAGE FOR SECTION C

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SECTION C: Answer ONE question only; 35 marks.

1. Write an essay on the Polymerase Chain Reaction. In this essay, you should discuss the purpose of PCR and give a detailed description of its mechanism, including all of the reagents involved and their roles. You should also discuss the application of PCR in the field of biomedical engineering, giving examples where appropriate. You should use diagrams to support your essay.

[35 marks]

OR

2. Using your knowledge of transcription, translation and genetic disease, discuss the following statement:

"Mutations in our DNA always cause disease."

As part of your answer, you should discuss the properties of different amino acids. You should draw the core structure of an amino acid and label its key chemical groups to help you.

[35 marks]

OR

3. Using diagrams to help you, describe in detail the process of DNA replication. Your answer should include the key stages of DNA replication and the molecules involved.

[35 marks]

[Total for Section C: 35 marks]
END OF QUESTIONS – PLEASE TURN THE PAGE FOR FORMULA SHEET

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Formulae sheet and genetic code table – feel free to detach this sheet from the rest of the exam paper

$$\text{Moles} = \frac{\text{Mass}}{M_r}$$

$$\frac{\text{Moles}}{\text{Solvent volume (L)}} = \text{Molarity (M)}$$

$$M_1V_1 = M_2V_2$$

$$\% \text{ error} = \frac{\#_{\text{experimental}} - \#_{\text{theoretical}}}{\#_{\text{theoretical}}} \times 100$$

Table 1: The Genetic Code

Second letter

First letter		U	C	A	G	Third letter
U		UUU, UUC } Phe; UUA, UUG } Leu	UCU, UCC, UCA, UCG } Ser	UAU, UAC } Tyr; UAA Stop; UAG Stop	UGU, UGC } Cys; UGA Stop; UGG Trp	U C A G
C		CUU, CUC, CUA, CUG } Leu	CCU, CCC, CCA, CCG } Pro	CAU, CAC } His; CAA, CAG } Gln	CGU, CGC, CGA, CGG } Arg	U C A G
A		AUU, AUC, AUA } Ile; AUG Met	ACU, ACC, ACA, ACG } Thr	AAU, AAC } Asn; AAA, AAG } Lys	AGU, AGC } Ser; AGA, AGG } Arg	U C A G
G		GUU, GUC, GUA, GUG } Val	GCU, GCC, GCA, GCG } Ala	GAU, GAC } Asp; GAA, GAG } Glu	GGU, GGC, GGA, GGG } Gly	U C A G

END OF QUESTIONS