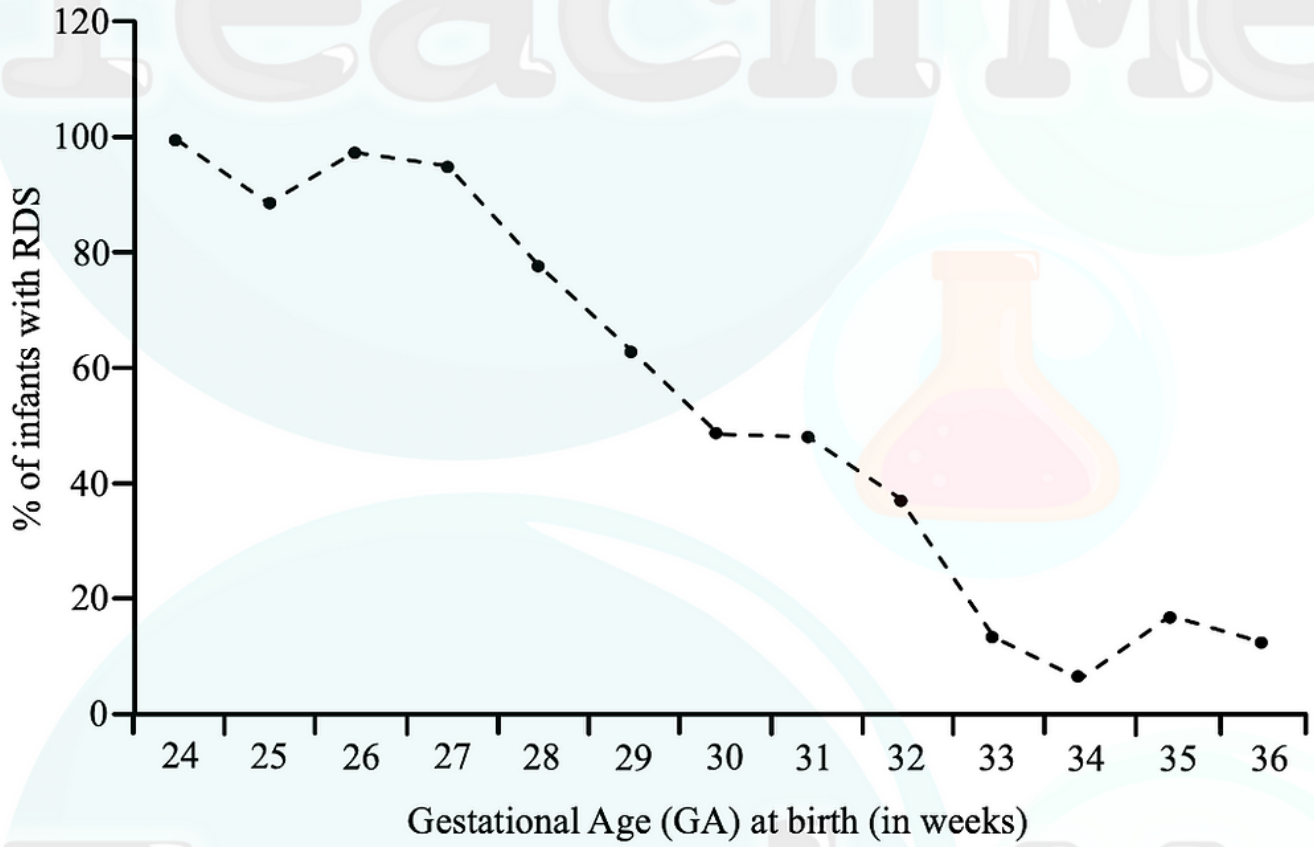
Section A

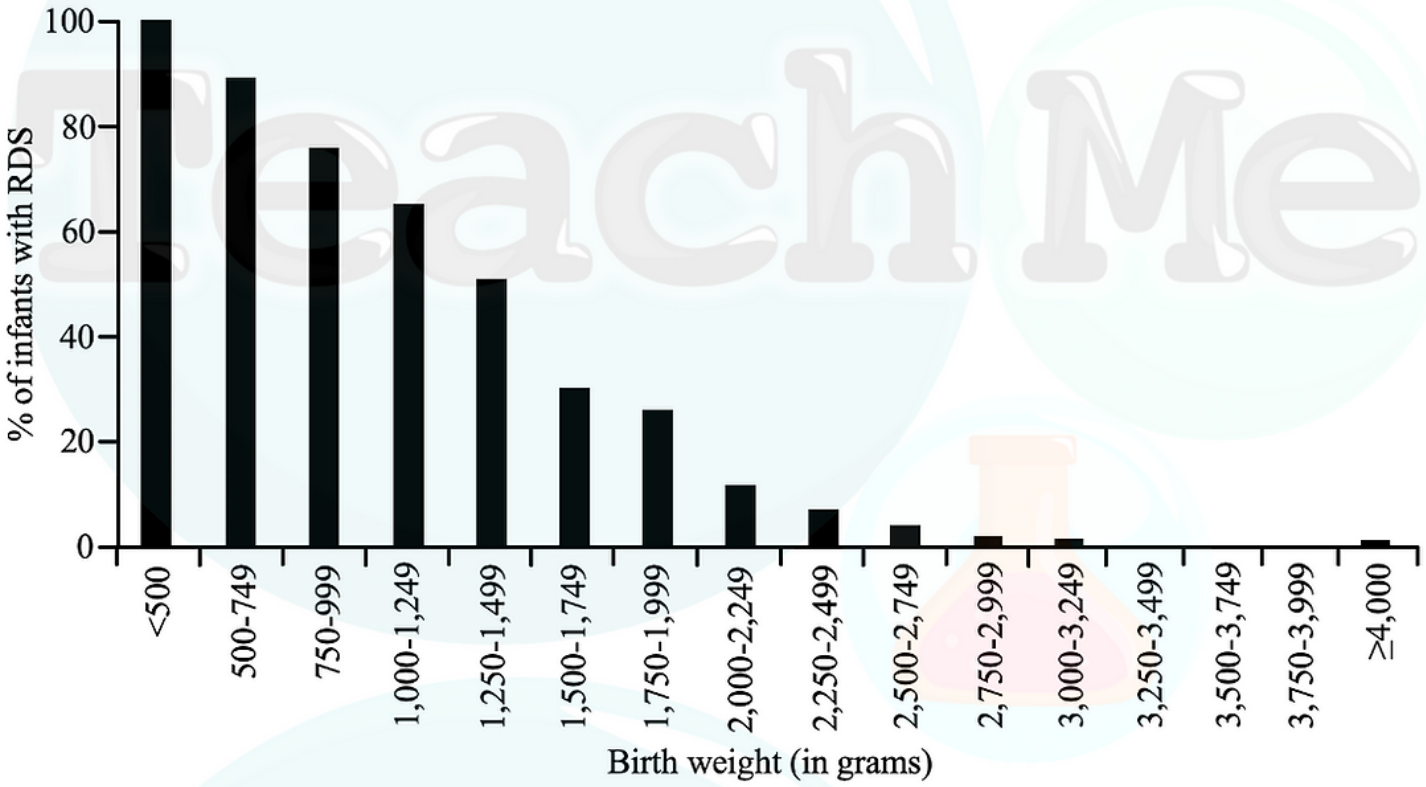
Answer **all** questions. Answers must be written within the answer boxes provided.

1. A neonatologist recorded the number of premature infants with Respiratory Distress Syndrome (RDS) that he treated in the past year. RDS is a common condition in premature infants most often characterized by insufficient production of surfactant, a substance critical for reducing surface tension in the lungs and preventing alveolar collapse. When comparing his observations with the Gestational Age (GA) of the infants at birth, he found the following trend:



(a) Describe the relationship between gestational age and the percentage of infants diagnosed with Respiratory Distress Syndrome (RDS). [1]

The birth weight of an infant is strongly correlated to their chances of survival. The neonatologist therefore assigns each newborn into a weight category: Extremely Low Birth Weight (ELBW) <1,000g – Very Low Birth Weight (VLBW) <1,500g – Low Birth Weight (LBW) <2,500g – Normal Birth Weight (NBW) 2,500g-4,000g and High Birth Weight (HBW) >4,000g.



(b) What can be inferred about the relationship between birth weight and lung maturity based on the graph and other information given? [2]

(c) Calculate the approximate difference in percentage of infants with RDS between the 500-749g and the 1,250-1,499g category. [1]

(d) A new mother gives birth to an extremely preterm baby weighing 1.154 kg. Assign the baby's birth weight to a weight category and predict their approximate risk of RDS. [2]

(e) Propose a reason which would explain the percentage of infants with RDS in the high birth weight category. [1]

The treatment of RDS aims at improving oxygen levels and supporting the underdeveloped lungs. The administration of a surfactant compensates for the deficiency of natural surfactant, reducing surface tension in the alveoli. Various surfactant preparations have been perfected (synthetic or modified natural) such as Curosurf, Alveofact, Exosurf and Pumactant; each varying in their composition.

Component	% Composition				
	Curosurf (modified natural)	Alveofact (modified natural)	Exosurf (synthetic surfactant)	Pumactant (synthetic surfactant)	Natural Surfactant
Phospholipids	98	87	82	100	82
Cholesterol	0	9.5	0	0	8
Free fatty acids	0.5	0.5	0	0	1.5
Proteins	1.5	3	0	0	8
Others	0	0	18	0	0.5

(f) State which surfactant preparation's composition resembles natural surfactant the most. [1]

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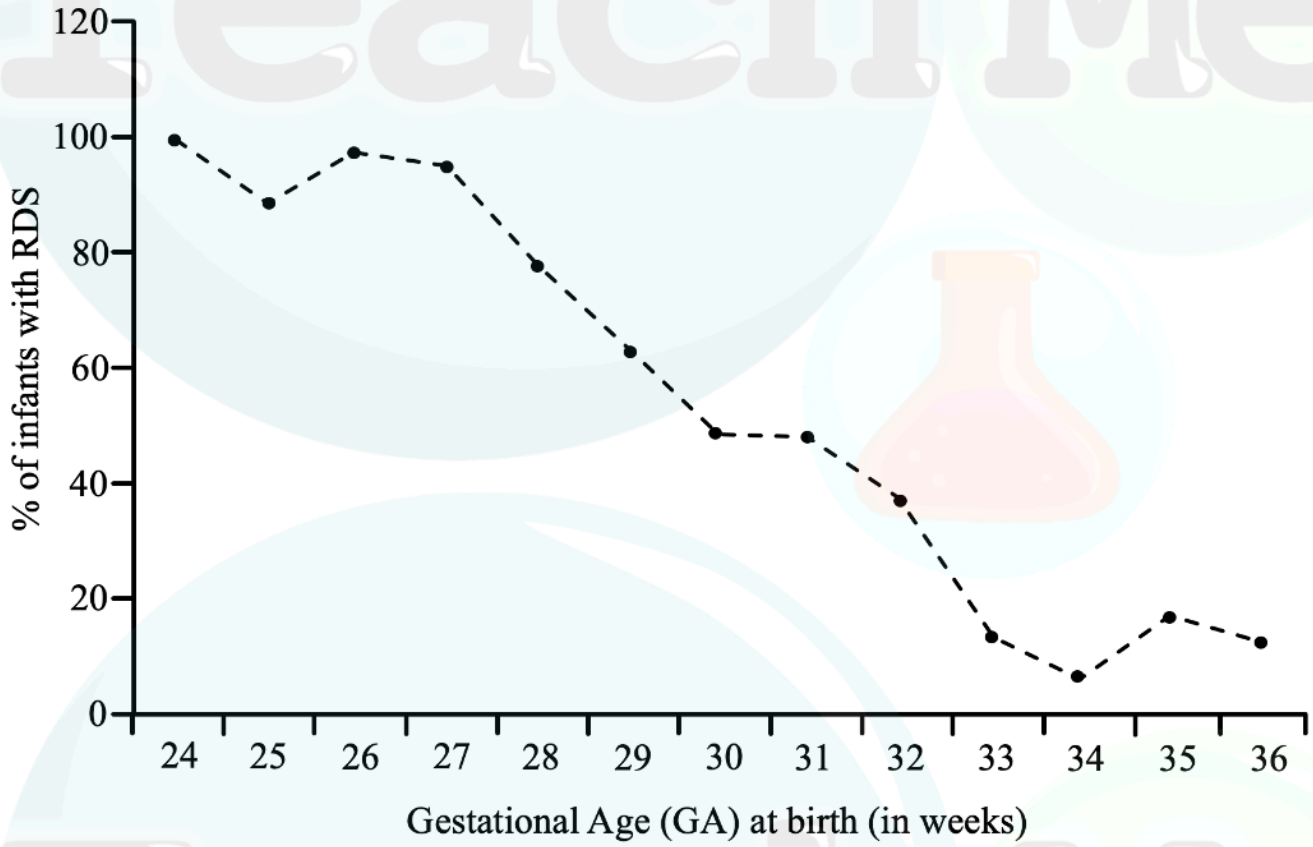

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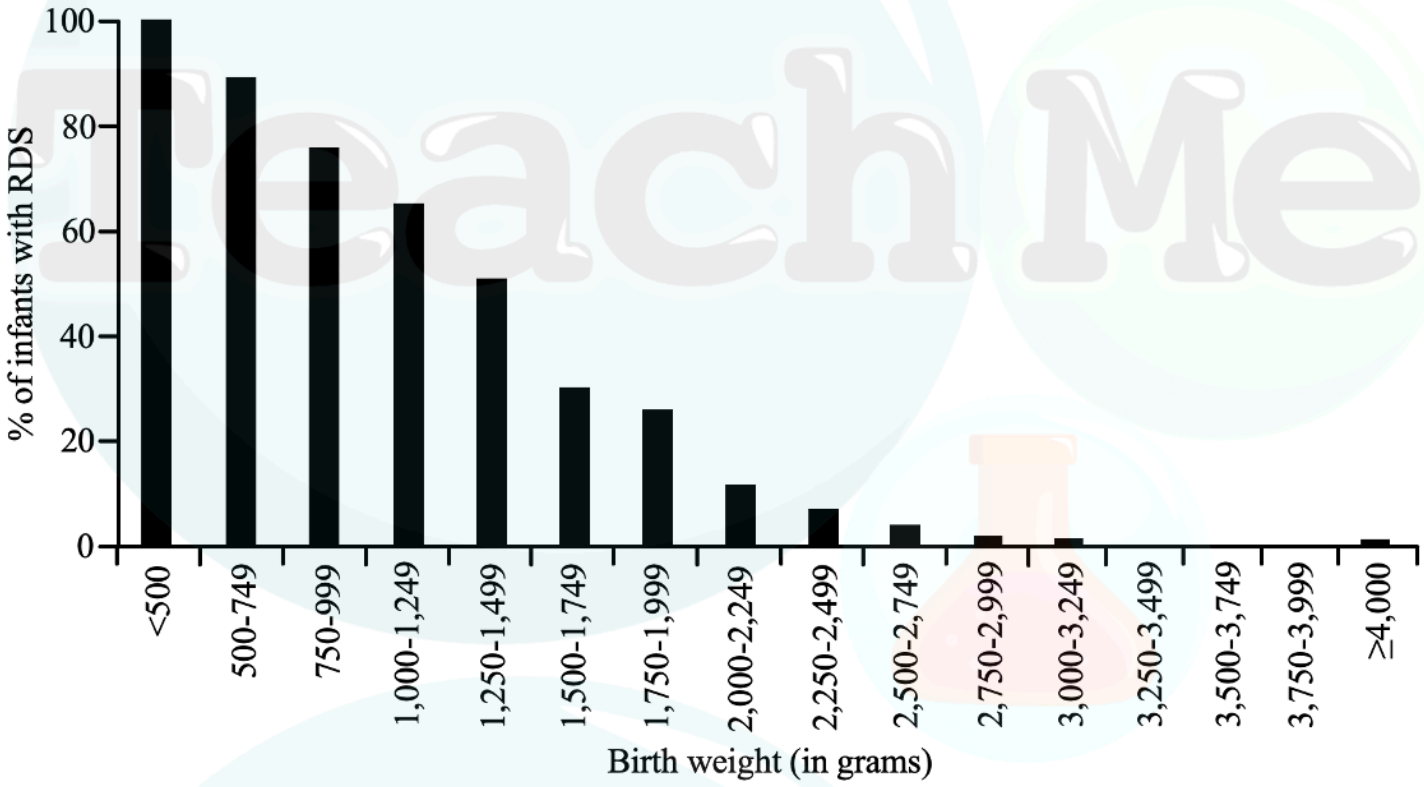

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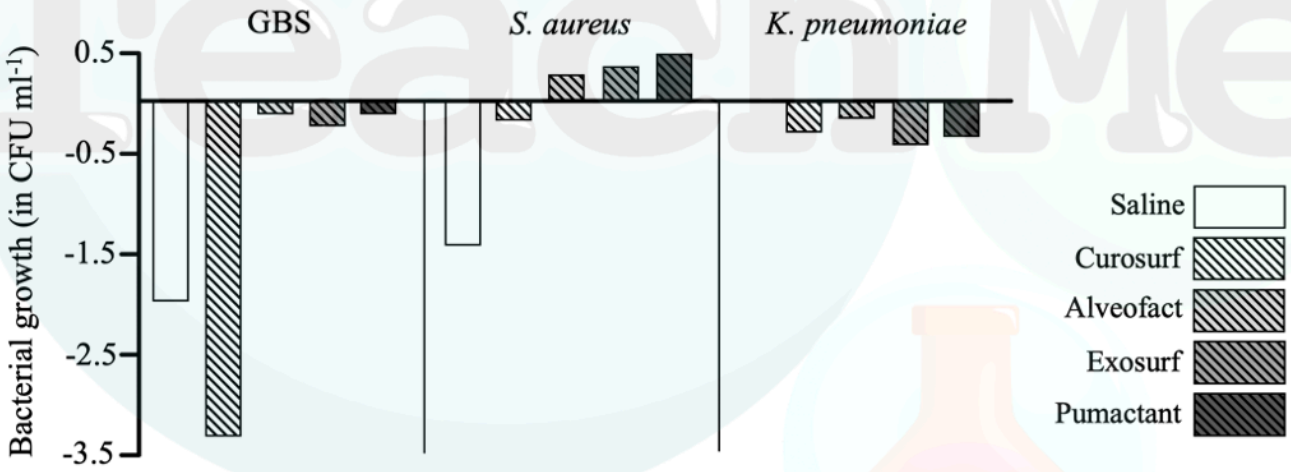
Bacterial pneumonia is another prevalent condition in premature neonates which commonly occurs simultaneously with RDS. It was theorized that the administration of surfactant in the treatment of RDS exacerbated bacterial growth and therefore lead to more severe cases of pneumonia in the premature neonates.

Three common pneumonia-causing pathogens; Group B *Streptococcus* (GBS), *Staphylococcus aureus* (*S. aureus*) and *Klebsiella pneumonia* (*K. pneumonia*) were placed in the different surfactant preparations. Then the effect of each surfactant was measured as an increase or decrease bacterial growth compared with growth without surfactant in colony forming units (CFU) per milliliter.



(g) Compare the effect of Curosurf and Pumactant on bacterial growth. [2]

(h) Outline the purpose of growing the three bacterial species in a saline solution. [1]

(i) Evaluate the following statement: [2]

"Phospholipids play the largest role in surfactant anti-bacterial properties."

(j) Discuss the use of Curosurf for all premature infants as a preventative measure for neonatal pneumonia. [2]

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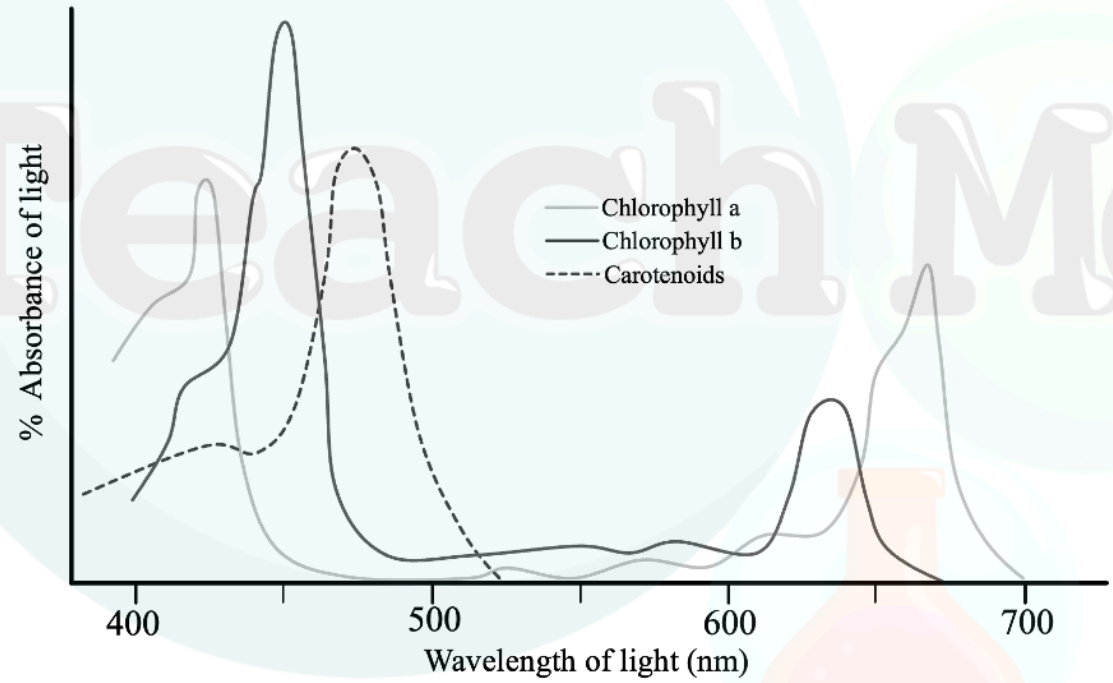
2. Photosynthesis relies on pigments absorbing specific wavelengths of light. The absorption spectrum of pigments like chlorophyll corresponds closely to the action spectrum, linking light absorption to photosynthetic efficiency.



Green is least absorbed according to the absorption spectrum above.

(a) (i) Outline why leaves appear green despite not being absorbed by leaves. [1]

(ii) Which color of light is most well absorbed by chlorophyll a? [1]

During the light dependent part of photosynthesis, Chlorophyll's primary role is to capture light energy and transfer it to electrons. This subsequently leads to their excitation and exit from the chlorophyl molecules.

(b) (i) Based on your understanding of photosynthesis, outline two potential pathways for the utilization of these energized electrons. [2]

(ii) Name the molecule that provides electrons to chlorophyll during photosynthesis. [1]

(c) State the main product of the Calvin cycle, occurring during the light independent part of photosynthesis. [1]

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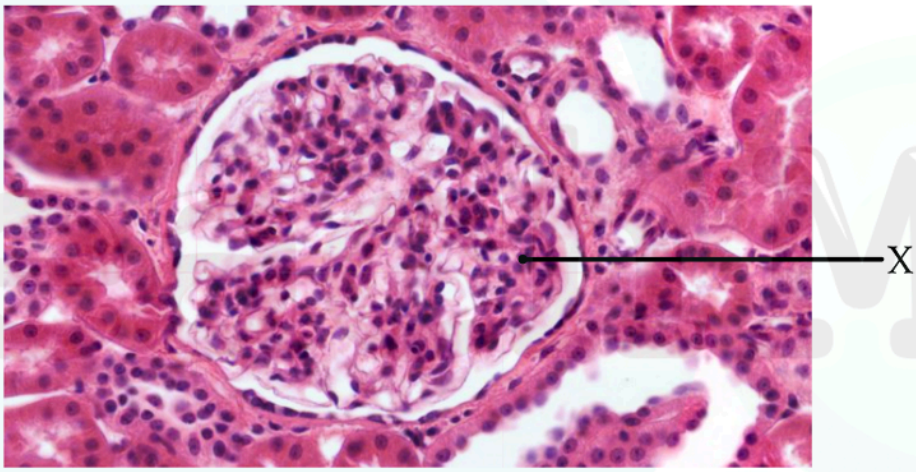
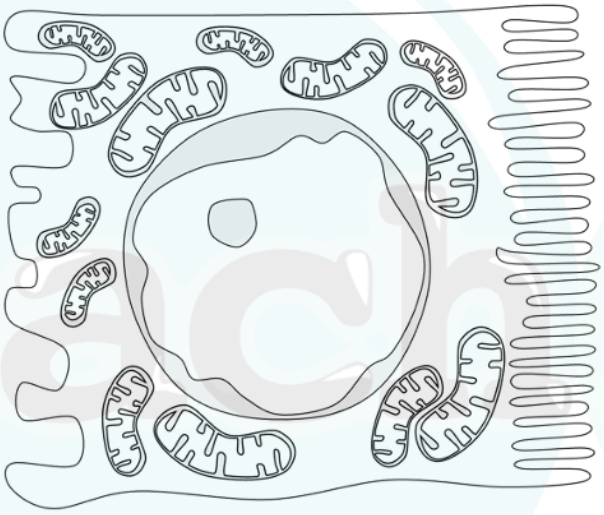
3. Our body's blood composition is maintained in a dynamic equilibrium, with nutrients continuously delivered to the body's cells and waste products efficiently removed. The kidney plays a vital role in regulating this balance, ensuring optimal blood composition and overall homeostasis.



(a) (i) Name the network of capillaries labelled X. [1]

(ii) Name two substances in the blood, which should not present in the urine in a healthy individual. [1]

Below is a cell from the proximal convoluted tubule.



(b) The PCT carries out selective reabsorption. Name three structural features that aid in this process. [3]

(c) (i) Outline the location of the nephron in the kidney. [2]

(ii) Suggest a way in which the loop of Henle may be modified in a desert animal such as a camel. [1]

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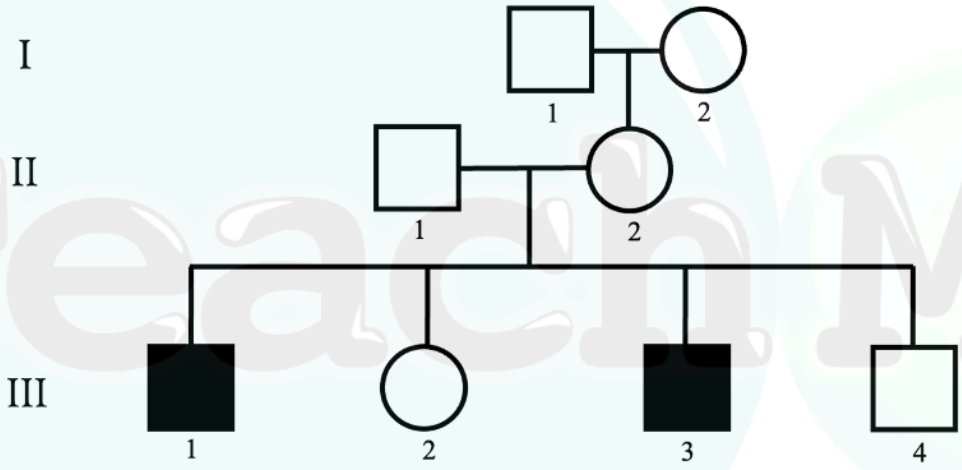
4. Hemophilia is a X-linked inherited disorder, characterized by the inability of the body to effectively carry out blood clotting. The pedigree below shows a family's inheritance pattern for hemophilia.



(a) Deduce the genotype of individual II-2. [1]

(b) Explain why more human males are affected by hemophilia than females. [2]

(c) Predict how the inheritance pattern of the disorder would change if it were autosomal recessive instead of sex-linked. [2]

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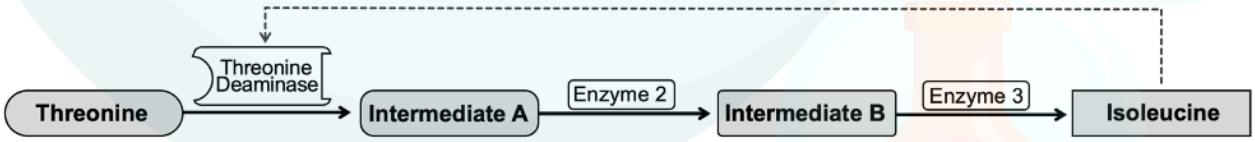
5. Enzymes orchestrate the flow of life's chemical reactions, yet their influence is often tempered by inhibition, to ensure cellular product synthesis is effectively controlled.

(a) Define the term "enzyme". [2]

The amino acid isoleucine can be synthesized from threonine in a linear metabolic pathway. Isoleucine plays a role in the regulation of this pathway by inhibiting an enzyme called threonine deaminase early in the chain at times when isoleucine is in abundance in the body. This is known as end-product in inhibition.

[1]



(b) (i) This is an example of which kind of feedback mechanism? [1]

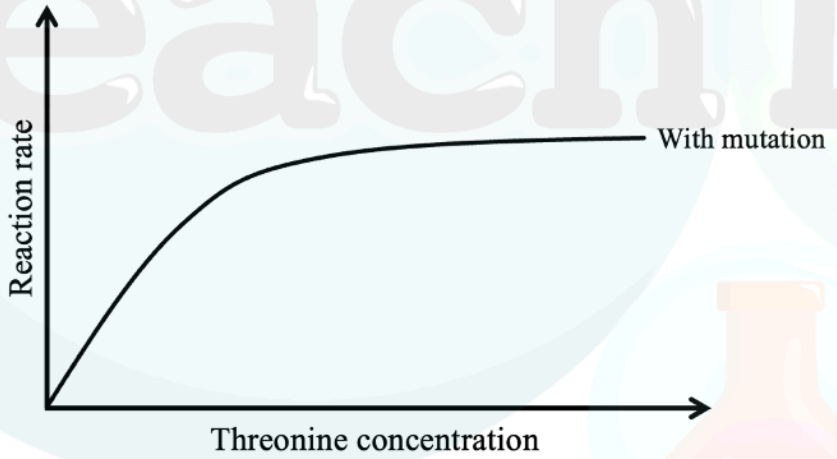
(ii) With which site the enzyme Threonine Deaminase does isoleucine interact? [1]

A single base insertion in the gene that codes for threonine deaminase results in a frameshift mutation that renders isoleucine unable to carry out end-product inhibition. Prior to and the hours following this mutation, a scientist tested the blood values for threonine and isoleucine hourly as seen in the table below.

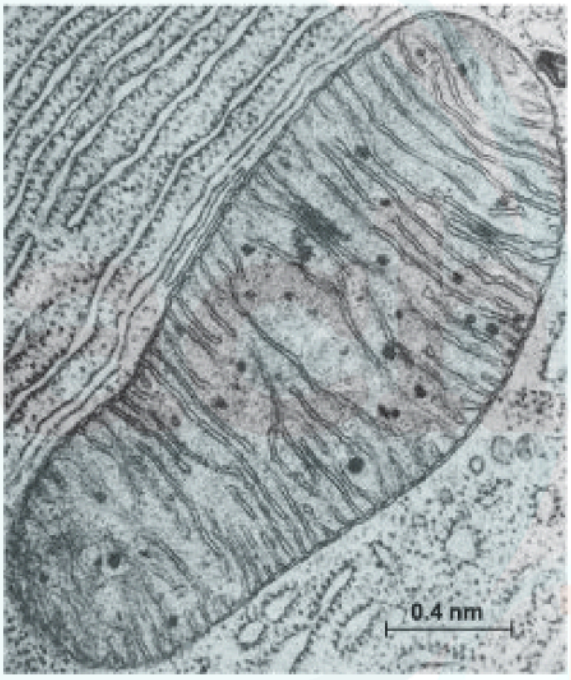
	Time (hours)	**Isoleucine Concentration** (μM)	**Threonine Concentration** (μM)
(before mutation)	**0**	50	200
	1	55	190
	2	65	170
	3	80	140
	4	100	100
	5	130	60
	6	170	30

(c) (i) Suggest how this mutation could have resulted in this change in threonine and isoleucine values. [2]

(ii) The graph below shows the reaction rate of threonine deaminase with increasing substrate concentration. Illustrate how this curve would change prior to the mutation. [1]



6. Below is a transmission electron micrograph (TEM) image taken of a mitochondrion.



(a) (i) Name an animal cell that does not have this organelle. [1]

(ii) State two cellular processes that require ATP. [1]

(b) State with a reason, from which parent mitochondrial DNA is inherited. [1]

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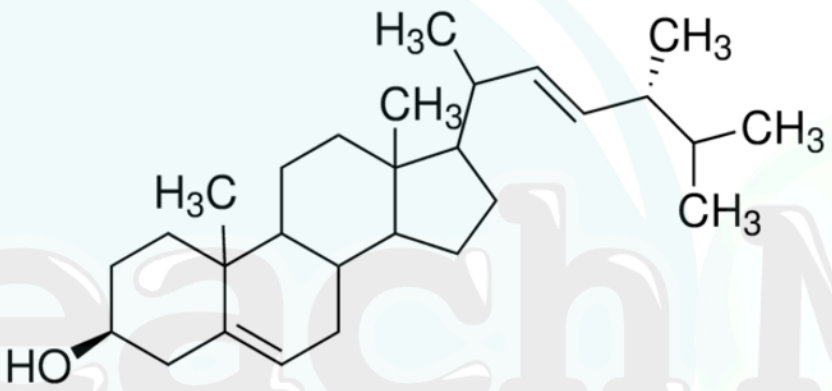
7. Below is the chemical structure of a steroid, specifically cholesterol.



(a) (i) Which macromolecule does cholesterol belong to? [1]

(ii) Describe how the fluidity of the plasma membrane is influenced by the presence of unsaturated fatty acids and cholesterol. [2]

(b) Explain how the sodium-potassium pump contributes to the transport of glucose into the cells of the small intestine. [3]

Section B

Answer **two** questions. One additional mark is available for the construction of your answer. Answers must be written within the answer boxes provided.

8. Hormones are chemical messengers transported through the bloodstream, and they play a pivotal role in regulating countless physiological processes including puberty.

(a) Outline the mechanism of action of steroid hormones in cellular signaling. [4]

(b) Distinguish between the processes of spermatogenesis and oogenesis. [7]

(c) Briefly outline the role of the phytohormone auxin in plant shoot phototropism. [4]

9. The function carried out by a biological entity, can be explained when taking into consideration the intricate structure that comprises it.

(a) Explain the surface area to volume ratio's importance as a limit to cell size. [7]

(b) Discuss the unique structural adaptations of the mitochondria in relation to its function. [4]

(c) Describe how changes in microenvironment of a cell can alter the activity of a protein. [4]

10. DNA serves as the blueprint of life, and each living organism possesses its own unique set. However, with evolution a populations gene pool allele frequency may change.

(a) Explain the process of DNA replication in a prokaryotic cell. [8]

(b) Outline how sexual reproduction promotes genetic variation in a population. [3]

(c) Outline how mutations may lead to antibiotic resistance in bacteria. [4]

References:

1. **Graph**
   Adapted and modified from Bae CW, Hahn WH. *Surfactant Therapy for Neonatal Respiratory Distress Syndrome: A Review of Korean Experiences over 17 Years*. J Korean Med Sci. 2009 Dec;24(6):1110-1118.

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   Table
   Adapted from *Clinical and Diagnostic Laboratory Immunology,* 2000, 7(5), pp. 817-822.

   Bar Graph
   Adapted from: Rauprich P, Möller O, Walter G, Herting E, Robertson B.2000. *Influence of Modified Natural or Synthetic Surfactant Preparations on Growth of Bacteria Causing Infections in the Neonatal Period*. Clin Diagn Lab Immunol7:.https://doi.org/10.1128/cdli.7.5.817-822.2000

2. **Graph**
   Adapted and modified from Pareek, Sunil & Sagar, Narashans & Sharma, Sunil & Kumar, Vinay & Agarwal, Tripti & Aguilar, Gustavo & Yahia, Elhadi. (2017). Chlorophylls: Chemistry and Biological Functions.

3. **Image**
   "Biology Learning Resources." *TeachMe*, www.tchme.org/.

   Diagram
   "Biology Learning Resources." *TeachMe*, www.tchme.org/.

4. **Diagram**
   "Biology Learning Resources." *TeachMe*, www.tchme.org/.

5. **Flow chart**
   "Biology Learning Resources." *TeachMe*, www.tchme.org/.

   Table
   "Biology Learning Resources." *TeachMe*, www.tchme.org/.

   Graph
   "Biology Learning Resources." *TeachMe*, www.tchme.org/.

6. **Image**
   Ho, Mae-Wan. (2013). Cancer a redox disease. ACNEM. 32. 12-18.
   https://www.researchgate.net/figure/Electron-micrograph-of-a-mitochondrion-in-a-cell-of-the-bat-pancreas-by-Keith-Porter_fig1_256809470

7. **Molecular Structure**
   "Biology Learning Resources." *TeachMe*, www.tchme.org/.