

60 marks (30%)

PART-II (Open-book)

2¼ hrs.

SECTION-A**1. Solve the following two numerical problems:**

- a. The cross can be represented as: BbLl (brown rabbits with deformed legs) x bbLl (white rabbits with deformed legs). Genotype of the progeny in question is bbLl. [1]

$$\begin{aligned} \text{Probability of getting bbLl from BbLl} \times \text{bbLl} &= P[\text{bb from Bb} \times \text{bb}] \times P[\text{Ll from Ll} \times \text{Ll}] & [2] \\ &= \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}. & [1] \end{aligned}$$

Hence, **25%** of the offspring would be expected to have deformed legs and white fur.

- b. With a single origin of replication that launches two DNA polymerases in opposite direction on the DNA each moving at 100 nucleotides per second, the number of nucleotides replicated in 24 hours will be 1.73×10^7 ($= 2 \times 100 \times 24 \times 60 \times 60$). [2]

$$\text{Total nucleotides to replicate} = 2 \times 3 \times 10^9 \text{ (since a diploid genome has to be replicated)} \quad [1]$$

To replicate all the 6×10^9 nucleotides of DNA in the cell in this time, therefore, will require at least **348** ($= 6 \times 10^9 / 1.73 \times 10^7$) origins of replication. [1]

(The estimated 10,000 origins of replication in the human genome are therefore more than enough to satisfy this minimum requirement.)

2.

- a. Recognition of a virus by cells of the adaptive immune system would be the quintessential step to eliminate the pathogen. Such recognition happens through the viral coat proteins. So, if the immune system is exposed to the viral coat antigens (as part of the vaccine), then memory T- and B-lymphocytes are generated as a consequence of such immune response. These cells would swing into action to swiftly build an immune response against the actual virus when it invades. Hence immunity is conferred. [2]

- b. Producing the vaccine using recombinant DNA techniques would be the risk-free way. [1]

The order-wise major steps to accomplish this are: [2]

- Isolate the gene for the viral coat protein
- Insert the gene into a plasmid
- Allow bacteria to take up the recombinant plasmid
- Culture large amounts of such bacteria in the lab
- Allow protein to be expressed and purify the protein

- 3.** Antibodies bind the antigen but don't kill them; they just target them for destruction by phagocytes. Macrophages act as antigen-presenting cells for the T cells to recognize the foreign antigen. [2]

SECTION-B

4.

- a. No, it does not. While water is split to release electrons (and liberate oxygen) used in the electron transport chain located in the inner membrane of the chloroplast (during light-dependent reactions), CO₂ comes into picture in the Calvin cycle when it is fixed by RubisCO by combining it with RuBP. [3]
- b. No, they are not the same. The start and stop points for transcription are the promoter and terminator, respectively, whereas for translation, the start and stop points are the start codon and stop codon on the messenger RNA that is being translated. [3]
- c. Hypothalamus controls pituitary gland to secrete release hormones for other tropic hormones (TSH, ACTH) that regulate the activity of several other glands. If these hormones are absent, then the respective glandular secretions are affected, altering homeostasis. For example, if TRH is not secreted, then it may lead to hypothyroidism. The hypothalamus also releases ADH that is required for water balance. It is also responsible for temperature, blood pressure homeostasis and the regulation of other bodily activities like thirst, flight-or-flight responses and emotions. Thus, the overall homeostasis would be severely affected if the hypothalamus were damaged. [3]
- d. Menstruation is the sloughing off of the vascular uterine wall (endometrium), owing to a decrease in levels of progesterone produced by the corpus luteum in the ovary. During pregnancy, the placental hormone hCG starts maintaining the corpus luteum (and later assumes its role) so that progesterone levels, and hence the uterine wall, are kept intact. This way, menstruation is prevented throughout pregnancy. [1½]

For ovulation to occur, the follicle should mature (stimulated by FSH) and the egg should develop inside the follicle (stimulated by LH). High levels of progesterone and estrogen present during pregnancy inhibit the hypothalamus and prevent secretion of GnRH, which controls the pituitary release of FSH and LH. In the absence of these two gonadotropins, the follicle does not mature nor can the ovum be released. [1½]
- e. Positive feedback in:
 - (i) Nerve impulse generation: Once sodium ions enter the neuron after receiving the stimulus, they open up more voltage gated channels. [1½]
 - (ii) Hormonal controls in female: Oxytocin released by the pituitary bring about uterine contractions, which in turn stimulate the release of oxytocin. (or) Estrogen stimulates the anterior pituitary to release more FSH and LH, which in turn result in production of more estrogen. [1½]

SECTION-C

5.

- a. The enzyme is converting the amino acids' amino group to keto form, rendering them inappropriate for formation of peptide bonds while the prokaryotic cell walls are being synthesized. [3]
- b. The high rate of enzyme activity is essential to ensure immunity from bacterial pathogens by controlling their proliferation (as it blocks cell wall synthesis). [2]

c. Enzymes are highly selective in their substrate specificity, so the given enzymes do not act on L-amino acids present in the human cells. [3]

6. Every homologous pair can arrange in two possible ways at the metaphase plate with respect to a pole. Hence, the probability that the paternal chromosome of one homologous pair is aligned toward the left side of the plate is $\frac{1}{2}$. The probability that the paternal chromosome of a second homologous pair is also aligned toward the left side of the plate is also $\frac{1}{2}$. Since one homologous pair aligns and assort independently of others, the product rule can be applied. So, the combined probability of any one pole (a gamete) receiving the paternal copy of all the three pairs is $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$. [3]

7. A - Bile salts (or bile) ; B – Pancreatic lipase ; C – Lacteal ; D – Lymphatic duct ; E – Vena cava ; F – heart ; G – aorta ; H – mitochondria ; I – Acetyl CoA ; J – 10 (or 12) [5]

SECTION-D

8. If this segment of RNA encoded part of a larger protein, it would have to be translated in reading frame 1, which is the only one that does not contain a stop codon. The amino acids of this reading frame are: serine-leucine-glycine-threonine.

Frame 1: AGU CUA GGC ACU GA -3'

Frame 2: A GUC UAG GCA CUG A-3'

Frame 3: AG UCU AGG CAC UGA -3'

[3]

9. Because the high energy requirements are entirely met by glycolysis alone, since oxidative phosphorylation process is not operative, cancer cells increase the rate of glycolysis. [1½]

Since glycolysis yields only 2 ATPs, whereas complete cellular oxidation of one molecule of glucose yields 30 ATPs, the difference is 15-fold. [1½]

10. *Answer each of these questions within a few sentences only:*

a. Lipid bilayers assemble because the surrounding water molecules exclude the component lipids; thus, analogy (ii) is the correct one. [2]

[Additional information: If bilayers formed because of attractive forces among the lipids – analogy (i) – the properties of the bilayer would likely be quite different. Molecules “attract” one another by forming specific bonds that hold them together. Such bonding among lipids would make the bilayer less fluid, perhaps even rigid, depending on the strength of the interactions.]

b. Because plants are able to produce their own food, it is not necessary for them to have long-term storage of energy provided by fatty acids. Carbohydrate storage is sufficient for plants. When they need more carbohydrates, they just make them. Animals, on the other hand, need to consume their food therefore their bodies have evolved the ability to store energy in more energy-rich molecules for times of famine.

An alternative explanation would be that since plants are sessile (not moving), unlike animals, they can afford to store the energy as carbohydrates which are certainly less compact form of energy storage as compared to fats. Animals, since they are mobile, need a highly compact form of energy storage, and hence prefer fats. [2]

- c. Mitochondrial production of ATP requires a concentration gradient of H^+ , with a high concentration at the inter membrane space and a low concentration in the matrix. The inner membrane is impermeable to H^+ , but the outer membrane of the mitochondria will allow H^+ to pass through. Thus, placing mitochondria in a low pH buffer produces a H^+ gradient that can generate ATP through ATP synthase. [2]
- d. [2]
- i. Guanine – double-ringed (“bulky”) and 3 H bonds (“extra tightly”)
 - ii. Uracil – not part of DNA
 - iii. Sister chromatids – separated during anaphase into different daughter cells (or)
Complementary DNA strands – separated during DNA replication
 - iv. ATP synthase – rotates and generates ATP using the proton gradient

Bonus question (for 2 marks):

- e. Immunological synapse is the connection that is established between antigen presenting cells (APCs) and the helper T cells – an essential event for mounting both B and T cell responses to an infection. It is formed and strengthened during deep sleep (also known as short wave sleep).
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