NIOS Class 12 Biology Sample Paper-4

Duration: 180 Minutes **Maximum Marks: 80**

Instructions

- This paper contains **43** Questions. The paper is divided into two sections: **Section A – 40** marks, **Section B – 40** marks.
- **Section A** consists of
  - **Q.No. 1 to 16** – Multiple Choice type questions (MCQs) carrying 1 mark each. Select and write the most appropriate option out of the four options given in each of these questions. An internal choice has been provided in some of these questions. You have to attempt only one of the given choices in such questions.
  - **Q. No. 17 to 28**– Objective-type questions. Q. No. 17 to 28 carry 02 marks each (with 2 sub- parts of 1 mark each). Attempt these questions as per the instructions given for each of the questions 17 –28.
- **Section B** consists of
  - **Q.No. 29 to 37** – Very Short questions carrying 02 marks each to be answered in the range of 30 to 50 words.
  - **Q.No. 38 to 41** – Short Answer type questions carrying 03 marks each to be answered in the range of 50 to 80 words.
  - **Q.No. 42 and 43** – Long Answer type questions carrying 05 marks each to be answered in the range of 80 to 120 words.
- There is **No Negative marking**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section: A

Q1. In an aquatic ecosystem, the ecological pyramid of biomass is typically inverted because: **(1)**

(A) Phytoplankton have a rapid turnover rate and small standing crop supporting a larger standing crop of zooplankton and fish

(B) The thermodynamic transfer of biological energy exceeds 100 percent in marine food chains

(C) Carnivorous fish divide at a faster reproductive rate than photosynthetic algae

(D) Aquatic primary producers lack hard lignified support structures and cannot accumulate biomass

Q2. During the C_4 pathway of carbon fixation in tropical plants such as sugarcane and maize, the primary carbon dioxide acceptor molecule in the mesophyll cells is: **(1)**

(A) Ribulose-1,5-bisphosphate (RuBP)

(B) Phosphoenolpyruvate (PEP)

(C) Oxaloacetic acid (OAA)

(D) 3-Phosphoglyceric acid (3-PGA)

Q3. Which of the following prokaryotic organisms lacks a rigid cell wall entirely and represents the smallest living organism capable of independent growth and reproduction without a host? **(1)**

(A) *Mycoplasma*

(B) *Escherichia coli*

(C) *Nostoc*

(D) *Methanobacterium*

Q4. If an isolated double-stranded genomic DNA molecule contains 28% cytosine bases, what will be the exact percentage of adenine bases in this DNA molecule according to Chargaff's rules? **(1)**

(A) 28%

(B) 22%

(C) 44%

(D) 56%

Q5. Which specialized nodal musculature in the human heart possesses the highest inherent rate of depolarization and acts as the natural pacemaker initiating cardiac contraction? **(1)**

(A) Atrioventricular (AV) node

(B) Bundle of His

(C) Sinoatrial (SA) node

(D) Purkinje network

Q6. In flowering angiosperms, double fertilisation involves the fusion of one sperm nucleus with the egg cell to form the diploid zygote, while the second sperm nucleus fuses with: **(1)**

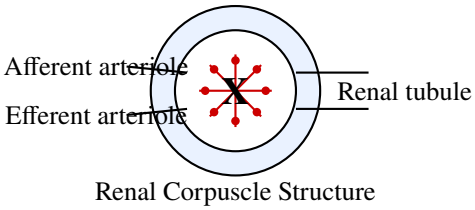
(A) Synergid cells to produce the nutritive suspensor

(B) Antipodal cells to establish seed dormancy

(C) Two polar nuclei (or definitive nucleus) to produce the triploid primary endosperm nucleus (PEN)

(D) Integument layers to form the hardened seed coat

Q7. Observe the simplified cross-sectional diagram of a renal corpuscle (Malpighian body) from a human nephron shown below. The specialized tuft of capillary loops enclosed within the double-walled Bowman's capsule, marked as label 'X', is identified as the: **(1)**



Renal Corpuscle Structure

(A) Glomerulus

(B) Loop of Henle

(C) Vasa recta

(D) Peritubular capillary network

Q8. In the five-kingdom classification system, which class of Kingdom Fungi produces sexual spores endogenously inside specialized sac-like structures called asci, as exemplified by *Saccharomyces* and *Penicillium*? **(1)**

(A) Phycomycetes

(B) Ascomycetes

(C) Basidiomycetes

(D) Deuteromycetes

Q9. Which key metalloenzyme, found exclusively in prokaryotes such as *Azotobacter* and *Rhizobium*, catalyzes the reduction of atmospheric dinitrogen (N_2) to ammonia (NH_3) and requires protection from oxygen? **(1)**

(A) Nitrate reductase

(B) Nitrite reductase

(C) Nitrogenase

(D) Glutamate dehydrogenase

Q10. Prolonged dietary deficiency of iodine impairs the synthesis of thyroxine (T_4) and triiodothyronine (T_3), resulting in compensatory hyperplastic enlargement of the thyroid gland, clinically termed: **(1)**

(A) Simple goitre

(B) Addison's disease

(C) Diabetes insipidus

(D) Tetany

Q11. A male patient diagnosed with Klinefelter syndrome possesses an aneuploid sex karyotype of 47, XXY due to meiotic non-disjunction. How many total chromosomes and inactivated X chromosomes (Barr bodies) are present in his somatic cells? **(1)**

(A) 47 chromosomes and 0 Barr bodies

(B) 47 chromosomes and 1 Barr body

(C) 46 chromosomes and 1 Barr body

(D) 45 chromosomes and 2 Barr bodies

Q12. The transgenic crop variety 'Bt Cotton' carries a cloned insecticidal crystal endotoxin gene ('cry' gene) derived from which common soil bacterium to provide innate resistance against lepidopteran pests? **(1)**

(A) *Bacillus subtilis*

(B) *Agrobacterium tumefaciens*

(C) *Bacillus thuringiensis*

(D) *Pseudomonas putida*

Q13. Which living, simple mechanical plant tissue consists of cells with thick localized pectocellulosic deposits at their corners, providing mechanical support and elasticity to growing leaf petioles and young herbaceous stems? **(1)**

(A) Parenchyma

(B) Collenchyma

(C) Sclerenchyma fibres

(D) Xylem tracheids

Q14. Which immunoglobulin class constitutes approximately 75–80% of total human serum immunoglobulins, can traverse the placental barrier to confer maternal passive immunity to the fetus, and dominates secondary immune responses? **(1)**

(A) IgA

(B) IgM

(C) IgG

(D) IgE

Q15. Which specialized assisted reproductive technique (ART) involves the direct microscopic injection of a single motile spermatozoon into the cytoplasm of a mature oocyte to treat severe male oligospermia? **(1)**

(A) In vitro fertilisation (IVF)

(B) Gamete intrafallopian transfer (GIFT)

(C) Intracytoplasmic sperm injection (ICSI)

(D) Intrauterine insemination (IUI)

Q16. In the human brain, which major hindbrain region integrates sensory signals to maintain body posture, equilibrium, and the smooth coordination of rapid voluntary muscular movements? **(1)**

(A) Cerebrum

(B) Cerebellum

(C) Hypothalamus

(D) Medulla oblongata

Note: Q. No. 17 to 28 are the objective type questions of 2 marks each.

Q17. Read the passage given below and answer the following questions:

Transpiration is the evaporative loss of water vapor from aerial plant parts, occurring predominantly through microscopic stomatal pores on leaves. The rhythmic opening and closing of stomata are governed by changes in the osmotic turgor of two specialized epidermal cells surrounding each stomatal aperture. When potassium ions (K^+) actively accumulate within these cells, water moves inward osmotically, inflating them and pulling the stomatal pore open. **(2)**

1. Name the specialized bean-shaped epidermal cells that flank and regulate the opening of the stomatal pore.
2. Which plant phytohormone is commonly termed the 'stress hormone' because it triggers rapid stomatal closure during drought?

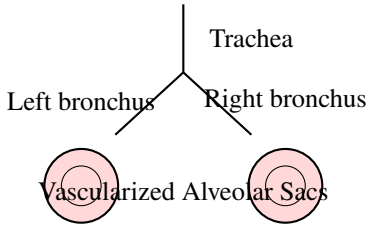
Q18. Complete the following sentences using the words given below:
(nucleoid, plasmid, binary fission, capsid, capsomere) **(2)**

1. In bacterial cells, the chromosomal circular DNA is not enclosed by a nuclear envelope and resides in a cytoplasm region called the .... , while autonomous extra-chromosomal DNA rings are termed a .....

2. The protective outer protein shell surrounding the viral nucleic acid genome is called a ..., which is assembled from identical morphological subunits called .....

Q19. Read the passage and answer the questions that follow it.

The human respiratory tract delivers atmospheric air to the respiratory surface. Air drawn through nasal passages travels via the pharynx, larynx, trachea, and branching bronchial tree, terminating inside clustered, thin-walled vascularized sacs where pulmonary gas exchange occurs across a delicate respiratory membrane. **(2)**



1. Name the microscopic, single-cell thick alveolar sacs in the lungs where diffusion of O_2 and CO_2 occurs.
2. Name the iron-containing conjugated respiratory pigment in human erythrocytes responsible for oxygen transport.

Q20. Fill in the blanks: **(2)**

1. The ecological pyramid illustrating total dry organic weight of organisms present at each successive trophic level per unit area is called a pyramid of .
2. The progressive increase in concentration of persistent non-biodegradable toxicants such as DDT across successive trophic levels in a food chain is termed biological .....

Q21. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	**Column II**
(a) Auxin (IAA)	(i) Promotes cell division and delays leaf senescence
(b) Gibberellic acid (GA_3)	(ii) Volatile gaseous phytohormone inducing fruit ripening
(c) Cytokinin (Zeatin)	(iii) Promotes apical dominance and root initiation
(d) Ethylene	(iv) Promotes internodal elongation and breaks seed dormancy

Q22. Fill in the blanks: **(2)**

1. The functional tubular filtering unit of the vertebrate kidney responsible for ultrafiltration and selective reabsorption is the .....
2. The hairpin-shaped hairpin loop segment of the nephron dipping deeply into the renal medulla that establishes hyperosmotic medullary gradients is called the Loop of .....

Q23. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: **(2)**

1. Insulin hormone is secreted by the beta (β) cells of the Islets of Langerhans in the pancreas and lowers blood glucose levels.
2. Calcitonin is secreted by the parathyroid gland and acts to elevate calcium ion concentration in blood plasma.

Q24. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	Column II
(a) Xylem vessels	(i) Translocation of synthesized organic sucrose solutions
(b) Phloem sieve tubes	(ii) Lateral meristem responsible for secondary girth increase
(c) Vascular cambium	(iii) Upward conduction of sap and dissolved inorganic ions
(d) Stomatal apparatus	(iv) Regulation of transpirational water vapor flux and gas exchange

Q25. Fill in the blanks: **(2)**

1. The biological fusion of a haploid male gamete with a haploid female oocyte to generate a diploid zygote is termed ..... or fertilisation.
2. The rupture of the mature Graafian follicle releasing the secondary oocyte from the ovary under the influence of an LH surge is called .....

Q26. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	Column II
(a) ELISA	(i) Separation of DNA fragments under an electric field
(b) Bioreactor	(ii) Thermostable DNA polymerase utilized in PCR thermal cycling
(c) Gel electrophoresis	(iii) Large fermentation vessel for bulk cultivation of recombinant cells
(d) Taq polymerase	(iv) Diagnostic serological assay utilizing enzyme-linked antibodies

Q27. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement: **(2)**

1. Passive immunity confers immediate protection by transferring pre-formed specific antibodies directly into a non-immune recipient.

2. Acquired Immunodeficiency Syndrome (AIDS) is caused by a double-stranded DNA virus that selectively destroys human B-lymphocytes.

Q28. Match the items in Column I with the most appropriate items in Column II: **(2)**

Column I	**Column II**
(a) Codon	(i) Three-base loop sequence on tRNA recognizing complementary mRNA triplet
(b) Anticodon	(ii) Non-coding intervening sequence in primary transcript excised during splicing
(c) Exon	(iii) Three-nucleotide sequence on mRNA encoding a specific amino acid
(d) Intron	(iv) Expressed coding sequence retained in mature mRNA during translation

Section: B

Q29. Differentiate briefly between simple fleshy fruits (such as drupe) and simple dry dehiscent fruits (such as legume), giving one diagnostic feature and one plant example for each. **(2)**

Q30. State any two structural and biochemical distinctions between cyclic and non-cyclic photophosphorylation occurring in chloroplast thylakoids during light-dependent photosynthetic reactions. **(2)**

Q31. (i) Explain briefly how the human ABO blood group system demonstrates both codominance and multiple allelism.

OR

(ii) Explain the genetic basis of sex-linked recessive inheritance using human haemophilia as an illustrative example. **(2)**

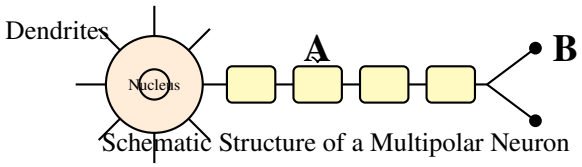
Q32. (i) State two diagnostic morphological characteristics of Kingdom Monera and mention two representative genus examples.

OR

(ii) State two characteristic features of Bryophytes (amphibians of the plant kingdom) and give two representative genus examples. **(2)**

Q33. A healthy adult human subject exhibits a resting heart rate (HR) of 72 beats per minute and a ventricular stroke volume (SV) of 70 mL per beat. Calculate the resting cardiac output (CO) in litres per minute. If strenuous athletic exercise increases the heart rate to 140 beats per minute and stroke volume to 110 mL per beat, compute the percentage increase in cardiac output achieved. **(2)**

Q34. Observe the labelled schematic diagram of a multipolar myelinated neuron shown below. Identify the anatomical structures indicated by labels 'A' and 'B', and state one primary physiological role performed by each. **(2)**



Schematic Structure of a Multipolar Neuron

Q35. (i) Describe two vital endocrine functions performed by the anterior pituitary gland in regulating somatic growth and gonadal maturation.

OR

(ii) Describe two rapid physiological adjustments triggered by adrenaline secretion from the adrenal medulla during acute fight-or-flight emergency responses. **(2)**

Q36. Define biological nitrogen fixation. Name one free-living aerobic diazotrophic bacterium and one symbiotic diazotrophic bacterium associated with leguminous root nodules. **(2)**

Q37. State any two distinctive floral adaptations exhibited by anemophilous (wind-pollinated) angiosperms to maximize pollen capture and dispersal efficiency. **(2)**

Q38. Define the following physiological and genetic terms, illustrating each with one concrete biological example:

A. Pleiotropy

B. Apical dominance

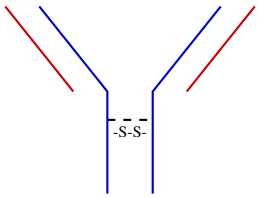
C. Osmoregulation **(3)**

Q39. (i) Describe the sequential chromosomal events distinguishing the five substages of prophase I during meiotic division I (Leptotene, Zygotene, Pachytene, Diplotene, Diakinesis).

OR

(ii) Describe the enzymatic mechanics of chromosomal DNA replication at the replication fork in prokaryotes, highlighting the roles of Helicase, DNA polymerase III, and DNA ligase. **(3)**

Q40. With the aid of a labelled schematic diagram of an immunoglobulin monomer (IgG), describe the structural organization of heavy chains, light chains, interchain disulfide bridges, and the variable antigen-binding sites (Fab). **(3)**



Typical Immunoglobulin Structure

Q41. (i) Describe the vector species, viral causal agent, prominent clinical symptoms, and vector management protocols for Dengue fever.

OR

(ii) Describe the bacterial pathogen, primary transmission route, pulmonary clinical symptoms, and chemotherapy/vaccination measures for human Tuberculosis (TB). **(3)**

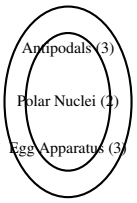
Q42. (i) (a) State Mendel's law of independent assortment.

(b) In a dihybrid cross between homozygous round yellow pea plants ($RRYY$)

and wrinkled green plants ($rryy$), construct a Punnett square to derive the F2 phenotypic dihybrid ratio.

OR

(ii) (a) Describe the internal anatomical structure of a typical angiosperm anatropous ovule before fertilization, illustrated with labeled parts.
(b) Explain the cellular organization of the mature 7-celled, 8-nucleate female gametophyte (embryo sac). **(5)**

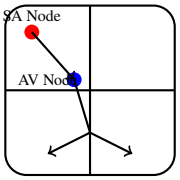


Anatropous Ovule / Embryo Sac Reference

Q43. (i) Describe the biochemical reactions of the photosynthetic C_3 Calvin cycle across three major phases: Carboxylation, Reduction, and Regeneration. State the net ATP and NADPH consumption required to synthesize one hexose glucose molecule.

OR

(ii) Describe the specialized cardiac conduction pathway in humans, tracing depolarization from the Sinoatrial (SA) node through the AV node, Bundle of His, and Purkinje fibres, and explain the cardiac events occurring during ventricular systole. **(5)**



Cardiac Conduction Node Network

Detailed Solutions

Q1.

Solution

Concept: In ecological pyramid analysis, biomass represents the total dry mass of living organisms present at a given trophic level at a specific moment (standing crop). While terrestrial pyramids of biomass are typically upright, aquatic ecosystems display an inverted biomass pyramid due to the dramatic differences in turnover rate and lifespan between producers and consumers.

Step 1: Analyze the standing crop dynamics of microscopic phytoplankton (producers) in marine and freshwater habitats. Phytoplankton have extremely short lifespans and multiply rapidly, resulting in a high metabolic turnover rate. **Step 2:** At any single snapshot in time, the accumulated standing biomass of phytoplankton is relatively small because they are continuously consumed by herbivorous zooplankton and small fish as quickly as they multiply. **Step 3:** Herbivorous zooplankton and larger predatory fish have much longer lifespans and accumulate substantial physical bulk over time. Consequently, the standing crop biomass of consumers exceeds that of the primary producers supporting them. **Step 4:** Evaluate the options: Option A accurately captures this high turnover and small standing crop mechanism, explaining why the biomass pyramid appears inverted even though the underlying energy flow (pyramid of energy) remains strictly upright.

Final Answer: Phytoplankton turnover rate is rapid with small standing crop supporting larger zooplankton biomass

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: Plants adapted to dry, tropical environments utilize the C_4 dicarboxylic acid pathway (Hatch-Slack pathway) to minimize photorespiration. This pathway partitions initial carbon dioxide capture into mesophyll cells and the Calvin cycle into bundle sheath cells (Kranz anatomy).

Step 1: Identify the specialized spatial arrangement in C_4 leaves. Atmospheric CO_2 enters mesophyll cells where it is converted into bicarbonate ions (HCO_3^-). **Step 2:** In mesophyll cytoplasm, the enzyme Phosphoenolpyruvate carboxylase (PEP carboxylase) catalyzes the fixation of CO_2 onto a 3-carbon compound, Phosphoenolpyruvate (PEP). **Step 3:** This primary carboxylation reaction generates Oxaloacetic acid (OAA), a 4-carbon dicarboxylic acid, which is subsequently converted into malate or aspartate and transported into bundle sheath cells for decarboxylation. **Step 4:** RuBP acts as the secondary acceptor inside bundle sheath cells during the Calvin cycle, whereas PEP is the primary CO_2 acceptor in mesophyll cells.

Final Answer: Phosphoenolpyruvate (PEP)

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: Kingdom Monera encompasses all prokaryotic organisms. While bacteria typically possess a rigid peptidoglycan cell wall, certain specialized eubacteria have evolved without any cell wall synthesis pathways, rendering them pleomorphic and naturally resistant to cell-wall targeting antibiotics such as penicillin.

Step 1: Review the cellular characteristics of *Mycoplasma* (formerly known as PPLO - Pleuropneumonia Like Organisms). They are bounded solely by a triple-layered sterol-containing plasma membrane. **Step 2:** Because they lack a rigid murein wall, *Mycoplasma* cells assume variable shapes (pleomorphism) and can pass through standard bacterial filtration membranes. **Step 3:** Measuring around 0.1 to 0.3 micrometers in diameter, they represent the smallest free-living autonomous cells capable of reproduction on cell-free artificial media under facultative anaerobic conditions. **Step 4:** *E. coli*, *Nostoc*, and *Methanobacterium* all possess distinct cell wall polymers (peptidoglycan or pseudomurein).

Final Answer: *Mycoplasma*

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: Erwin Chargaff formulated stoichiometric rules governing nucleotide composition in double-stranded DNA. Chargaff's rule states that purine content always equals pyrimidine content ($A + G = T + C$), with adenine specifically pairing with thymine ($A = T$) and guanine pairing with cytosine ($G = C$).

Step 1: Identify the given base concentration: Cytosine ($[C]$) = 28%. **Step 2:** According to complementary base pairing rules in double-stranded DNA, the molar percentage of Guanine ($[G]$) equals Cytosine:

$$[G] = [C] = 28\%$$

Step 3: Calculate the combined percentage of Guanine and Cytosine ($G - C$ pairs):

$$[G] + [C] = 28\% + 28\% = 56\%$$

Step 4: Determine the remaining percentage accounted for by Adenine and Thymine ($A - T$ pairs) out of the 100% total nucleotide pool:

$$[A] + [T] = 100\% - 56\% = 44\%$$

Step 5: Since Adenine pairs equimolarly with Thymine ($[A] = [T]$), divide the remaining percentage by 2:

$$[A] = \frac{44\%}{2} = 22\%$$

Final Answer: 22%

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: The human heart exhibits myogenic automaticity, meaning electrical excitation originates within specialized myocardial cardiac tissue without external nerve stimuli. The cardiac conduction system includes the SA node, AV node, Bundle of His, and Purkinje fibres, arranged in a hierarchy based on intrinsic rhythmicity.

Step 1: Locate the Sinoatrial (SA) node situated in the upper right wall of the right atrium near the opening of the superior vena cava. **Step 2:** Compare inherent rates of spontaneous depolarization across nodal tissue: the SA node generates action potentials at 70–75 impulses per minute, the AV node at 40–60 per minute, and Purkinje fibres at 20–35 per minute. **Step 3:** Because the SA node possesses the fastest rate of phase 4 spontaneous diastolic depolarization, it dominates the cardiac cycle and overrides lower ectopic pacemakers. **Step 4:** Thus, the SA node acts as the physiological primary pacemaker establishing normal sinus rhythm.

Final Answer: Sinoatrial (SA) node

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: Double fertilisation is a defining reproductive characteristic of angiosperms discovered by Nawaschin. When the pollen tube discharges two haploid male gametes into one synergid of the embryo sac, two distinct fusion events take place concurrently.

Step 1: First fertilization event (Syngamy or Generative fertilisation): One haploid male gamete (n) fuses with the haploid egg cell (n) to form the diploid zygote ($2n$), which develops into the embryo. **Step 2:** Second fertilization event (Triple fusion or Vegetative fertilisation): The second haploid male gamete (n) migrates toward the central cell and fuses with the two haploid polar nuclei (or pre-fused diploid secondary nucleus). **Step 3:** This triple fusion produces the triploid ($3n$) Primary Endosperm Nucleus (PEN) inside the primary endosperm cell. **Step 4:** The PEN undergoes repeated mitotic divisions to generate the nutritive endosperm tissue required for developing embryo nourishment.

Final Answer: Two polar nuclei to form triploid primary endosperm nucleus (PEN)

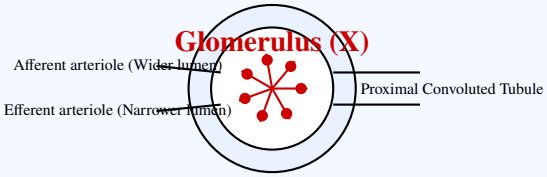
Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept: The nephron begins with an expanded filtering unit called the renal corpuscle (Malpighian body), which performs ultrafiltration of blood plasma under high hydrostatic pressure.



Detailed Renal Corpuscle Filtration Unit

Step 1: Examine the anatomical components of the renal corpuscle: a cup-like double-walled epithelial invagination called Bowman's capsule surrounding a dense capillary network. **Step 2:** Blood enters this capillary network via the afferent arteriole (having a wider lumen) and exits via the efferent arteriole (having a narrower lumen), generating glomerular hydrostatic pressure. **Step 3:** The compact capillary tuft labeled 'X' is precisely defined as the Glomerulus. **Step 4:** Podocytes lining the visceral layer of Bowman's capsule wrap around glomerular capillaries to form filtration slits for plasma ultrafiltration.

Final Answer: Glomerulus

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: Fungi are classified into major classes based on mycelial structure, mode of spore formation, and fruiting bodies: Phycomycetes, Ascomycetes (sac fungi), Basidiomycetes (club fungi), and Deuteromycetes (imperfect fungi).

Step 1: Review characteristic features of Ascomycetes (sac fungi). Their vegetative mycelium is septate and branched (except unicellular yeast). **Step 2:** Asexual reproduction occurs via exogenous conidia produced on specialized conidiophores. **Step 3:** Sexual reproduction involves plasmogamy and karyogamy followed by meiotic division inside sac-like cells called asci (singular: ascus). **Step 4:** Typically, eight haploid ascospores are formed endogenously inside each ascus, which are housed within fruiting bodies called ascocarps (*Saccharomyces*, *Penicillium*, *Aspergillus*).

Final Answer: Ascomycetes

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept: Biological nitrogen fixation requires the conversion of stable molecular nitrogen ($N \equiv N$) into ammonia (NH_3), catalyzed by the specialized enzymatic machinery present restrictedly in diazotrophic bacteria.

Step 1: Identify the catalytic complex Nitrogenase, which consists of two iron-sulfur proteins: the Fe-protein (dinitrogenase reductase) and the Mo-Fe protein (dinitrogenase). **Step 2:** Nitrogenase reduces N_2 through step-wise proton and electron additions requiring high ATP expenditure (16 ATP per N_2 fixed):

$$N_2 + 8H^+ + 8e^- + 16\text{ATP} \xrightarrow{\text{Nitrogenase}} 2NH_3 + H_2 + 16\text{ADP} + 16P_i$$

Step 3: Because the active Fe-S clusters of nitrogenase are rapidly irreversibly oxidized and inactivated by molecular oxygen (O_2), nitrogen-fixing bacteria develop protective mechanisms (such as leghemoglobin oxygen-scavenging in legume root nodules).
Final Answer: Nitrogenase

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept: Iodine is an essential trace dietary mineral required by thyroid follicular cells for iodination of tyrosine residues on thyroglobulin to synthesize T_3 and T_4 hormones.

Step 1: When dietary iodine intake is chronically deficient, blood levels of thyroxine drop, causing negative feedback reduction on the hypothalamus and anterior pituitary. **Step 2:** In response, the anterior pituitary secretes high quantities of Thyroid Stimulating Hormone (TSH). **Step 3:** Continuous TSH stimulation induces hyperplasia and hypertrophy of thyroid follicular epithelial cells as the gland attempts to capture any circulating iodine. **Step 4:** This visible enlargement of the thyroid gland in the neck without signs of hyperthyroidism or malignancy is termed Simple Goitre (or endemic colloid goitre).
Final Answer: Simple goitre

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: Klinefelter syndrome is a sex-chromosome numerical anomaly (aneuploidy) occurring in phenotypic males carrying an extra X chromosome (47, XXY).

Step 1: Calculate total chromosome count: Normal human somatic cells contain 46 chromosomes ($2n$). The presence of an extra X chromosome raises the chromosome complement to 47. **Step 2:** Apply Mary Lyon's X-inactivation hypothesis: In any mammalian somatic cell, all X chromosomes in excess of one are condensed and inactivated into Barr bodies during embryogenesis. **Step 3:** Calculate Barr body number using the formula:

$$\text{Number of Barr bodies} = \text{Total X chromosomes} - 1$$

$$\text{Barr bodies} = 2 - 1 = 1$$

Step 4: Thus, a somatic nucleus of a Klinefelter patient exhibits 47 chromosomes and exactly 1 Barr body attached to the nuclear membrane.
Final Answer: 47 chromosomes and 1 Barr body

Answer: (B)
Go Back to Question 11

Q12.

Solution

Concept: Agricultural biotechnology utilizes recombinant DNA techniques to express specific genes providing pest resistance, reducing reliance on synthetic chemical insecticides.

Step 1: Identify the soil bacterium *Bacillus thuringiensis* (Bt), which produces intracellular crystalline inclusions during sporulation. **Step 2:** These crystals consist of endotoxins encoded by specific 'cry' genes (such as *cryIAc* and *cryIIAb* effective against cotton bollworms). **Step 3:** When ingested by lepidopteran caterpillars, alkaline gut pH dissolves the crystal, releasing protoxins that are cleaved by proteases into active toxins binding midgut epithelial receptors. **Step 4:** This creates pores causing cell lysis, gut paralysis, and insect death. Cloning *cry* genes directly into cotton plants produces insect-resistant Bt Cotton.
Final Answer: *Bacillus thuringiensis*

Answer: (C)
Go Back to Question 12

Q13.

Solution

Concept: Simple plant tissues are classified based on cell wall composition and living state: Parenchyma (thin-walled, living), Collenchyma (corner-thickened, living), and Sclerenchyma (lignified, dead).

Step 1: Examine the anatomical features of Collenchyma cells: they are living, elongated cells possessing dense cytoplasm and large vacuoles. **Step 2:** Cell walls show uneven, primary deposits of cellulose, hemicellulose, and pectin localized predominantly at the angles/corners of the cells. **Step 3:** Because pectin absorbs water and provides flexibility, collenchyma confers high tensile strength and elasticity, allowing leaf petioles and young stems to bend in wind without snapping. **Step 4:** Sclerenchyma fibers are dead and lignified, offering rigid non-flexible support.
Final Answer: Collenchyma

Answer: (B)
Go Back to Question 13

Q14.

Solution

Concept: Five major classes of human immunoglobulins (IgG, IgA, IgM, IgE, IgD) execute distinct immunological effector functions based on heavy chain isotype structure.

Step 1: Analyze Immunoglobulin G (IgG), a monomeric antibody comprising about 75–80% of circulating serum immunoglobulins. **Step 2:** Due to its specific Fc receptor affinity and small molecular size (~ 150 kDa), IgG is the only antibody subclass capable of actively crossing the human placenta during gestation. **Step 3:** This placental transfer provides essential natural passive immunity to the newborn during its first six months of life. **Step 4:** Furthermore, IgG is the predominant antibody synthesized during memory-mediated secondary immune responses, opsonic phagocytosis, and complement activation.
Final Answer: IgG

Answer: (C)
Go Back to Question 14

Q15.

Solution

Concept: Assisted Reproductive Technologies (ART) address varied etiologies of human infertility through in vitro micromanipulation of gametes and embryos.

Step 1: Review cases of severe male factor infertility characterized by extreme oligospermia (low sperm count) or asthenozoospermia (poor sperm motility), where standard IVF fails because sperm cannot penetrate the zona pellucida. **Step 2:** Identify Intracytoplasmic Sperm Injection (ICSI): using specialized micromanipulators under an inverted microscope, an embryologist holds a mature MII oocyte with a suction pipette. **Step 3:** A single viable spermatozoon is aspirated into a sharp glass micropipette and injected directly across the oolemma into the oocyte cytoplasm. **Step 4:** Following fertilization and zygote cleavage in culture, the embryo is transferred to the maternal uterus.
Final Answer: Intracytoplasmic sperm injection (ICSI)

Answer: (C)
Go Back to Question 15

Q16.

Solution

Concept: The vertebrate brainstem and hindbrain coordinate involuntary physiological drives and complex motor control. The hindbrain comprises the pons, cerebellum, and medulla oblongata.

Step 1: Examine the Cerebellum (little brain), characterized by a convoluted outer cortex containing highly branched Purkinje neurons. **Step 2:** The cerebellum receives continuous sensory feedback from vestibular semicircular canals (inner ear), proprioceptors in muscles/joints, and motor intention signals from the cerebral cortex. **Step 3:** It compares planned motor commands with actual bodily movement in real time, executing rapid sub-conscious corrective adjustments. **Step 4:** This integration maintains bodily equilibrium, postural muscle tone, and smooth fine coordination of skilled voluntary movements (writing, running, balancing).
Final Answer: Cerebellum

Answer: (B)
Go Back to Question 16

Q17.

Solution

Concept: Stomatal regulation balances transpirational cooling and CO_2 assimilation. Guard cells possess specialized radial cellulose microfibrils that cause differential bowing when turgor rises.

Step 1: Identify the specialized pair of reniform (bean-shaped in dicots, dumbbell-shaped in grasses) epidermal cells enclosing the stomatal pore as Guard Cells. **Step 2:** During drought stress, roots and wilting mesophyll cells synthesize Abscisic acid (ABA). **Step 3:** ABA binds plasma membrane receptors on guard cells, stimulating efflux of potassium (K^+) and malate anions while inhibiting K^+ influx. **Step 4:** Water exits guard cells osmotically into subsidiary cells, causing flaccidity and immediate pore closure to conserve water.

Final Answer: 1. Guard cells 2. Abscisic acid (ABA)

Answer: (See above)

Go Back to Question 17

Q18.

Solution

Concept: Prokaryotic and viral organization represent distinct organizational levels. Prokaryotes are cellular organisms with localized naked DNA, whereas viruses are acellular nucleoprotein entities.

Step 1: In bacterial cells, the double-stranded circular DNA chromosome aggregates in an irregularly shaped central cytoplasmic zone lacking a histone coat or membrane, defined as the nucleoid. **Step 2:** Small, self-replicating circular double-stranded DNA rings conferring antibiotic resistance are termed plasmids. **Step 3:** In viruses, the genetic core (DNA or RNA) is shielded from extracellular nucleases by an external protein shell called a capsid. **Step 4:** The capsid is arranged symmetrically from repeating geometric morphological polypeptide units called capsomeres.

Final Answer: 1. nucleoid; plasmid 2. capsid; capsomeres

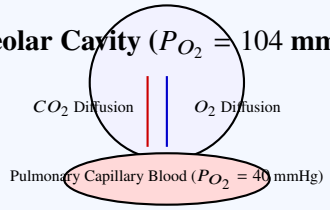
Answer: (See above)

Go Back to Question 18

Q19.

Solution

Concept: Mammalian pulmonary gas exchange relies on Fick's law of diffusion across a microscopic blood-air barrier comprising alveolar epithelium, basement membrane, and capillary endothelium.



Respiratory Membrane Gas Exchange Dynamics

Step 1: Identify the functional terminal respiratory units: Alveoli (singular: alveolus), providing an immense surface area ($\sim 70 - -100$ m^2). **Step 2:** Oxygen diffuses along its partial pressure gradient (104 mmHg inside alveoli down to 40 mmHg in deoxygenated pulmonary capillary blood). **Step 3:** Inside red blood cells, oxygen binds reversibly to the Fe^{2+} heme ions of the conjugated tetrameric protein Haemoglobin to form oxyhaemoglobin (HbO_2).

Final Answer: 1. Alveoli 2. Haemoglobin

Answer: (See above)

Go Back to Question 19

Q20.

Solution

Concept: Trophic relationships express energy transfer and toxin accumulation along food chains.

Step 1: Quantifying dry organic weight of organisms at successive trophic levels per square meter yields an ecological pyramid of biomass ($g/$m^2). **Step 2:** Consider lipophilic, non-biodegradable synthetic chemicals like DDT or heavy metals (mercury). **Step 3:** When ingested by primary consumers, these toxins are neither metabolized nor excreted, accumulating in adipose tissue. **Step 4:** As predators consume numerous prey items over their lifespan, toxin concentration multiplies exponentially at each ascending trophic level, a phenomenon called biomagnification.

Final Answer: 1. biomass 2. biomagnification

Answer: (See above)

Go Back to Question 20

Q21.

Solution

Concept: Plant growth regulators (PGRs) direct development, differentiation, and stress responses.

Step 1: Auxin (Indole-3-acetic acid) produced at shoot tips suppresses lateral bud growth (apical dominance) and initiates adventitious root formation in cuttings → (a)-(iii). **Step 2:** Gibberellic acid (GA_3) breaks seed dormancy by inducing hydrolytic alpha-amylase production and stimulates dramatic internodal stem elongation (bolting) → (b)-(iv). **Step 3:** Cytokinins (Zeatin) synthesize in root apices, promote cell cytokinesis, and delay leaf chlorophyll degradation (Richmond-Lang effect) → (c)-(i). **Step 4:** Ethylene (C_2H_4) is a gaseous hormone that triggers climacteric fruit ripening and abscission → (d)-(ii).

Final Answer: (a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)

Answer: (See above)

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Q22.

Solution

Concept: Mammalian urinary homeostasis requires ultrafiltration, reabsorption, and countercurrent multiplication within nephrons.

Step 1: Each human kidney contains approximately one million microscopic tubules called nephrons that filter plasma to produce urine. **Step 2:** Between the proximal and distal convoluted tubules lies a hairpin-shaped loop consisting of descending and ascending limbs dipping into the renal medulla. **Step 3:** Discovered by Friedrich Henle, the Loop of Henle operates a countercurrent multiplier system with vasa recta capillaries to reabsorb water and produce hypertonic urine.

Final Answer: 1. nephron 2. Henle

Answer: (See above)

Go Back to Question 22

Q23.

Solution

Concept: Blood glucose and calcium homeostasis depend on antagonistic hormonal feedback loops.

Step 1: Beta (β) cells of pancreatic islets secrete Insulin when blood glucose rises after a meal. Insulin accelerates cellular glucose uptake and glycogen synthesis (glycogenesis), confirming statement 1 is TRUE. **Step 2:** The parafollicular C-cells of the thyroid gland secrete Thyrocalcitonin (Calcitonin) when plasma calcium levels elevate. **Step 3:** Calcitonin inhibits osteoclastic bone resorption and lowers blood calcium concentration. Conversely, Parathyroid Hormone (PTH) elevates calcium. Thus, statement 2 is FALSE.

Final Answer: 1. True (T) 2. False (F)

Answer: (See above)

Go Back to Question 23

Q24.

Solution

Concept: Plant vascular anatomy and stomatal structures perform distinct conducting and regulatory functions.

Step 1: Xylem vessels are dead, lignified tubular conduits responsible for upward transpirational conduction of sap and inorganic minerals from roots $\rightarrow$ (a)-(iii). **Step 2:** Phloem sieve tube elements conduct synthesized organic sugars (sucrose) from source leaves to sink tissues $\rightarrow$ (b)-(i). **Step 3:** Vascular cambium is a cylindrical lateral meristem generating secondary xylem and phloem, increasing stem girth during secondary growth $\rightarrow$ (c)-(ii). **Step 4:** The stomatal apparatus regulates transpirational water vapor loss and atmospheric CO_2/O_2 exchange $\rightarrow$ (d)-(iv).

Final Answer: (a)-(iii), (b)-(i), (c)-(ii), (d)-(iv)

Answer: (See above)

Go Back to Question 24

Q25.

Solution

Concept: Human sexual reproduction involves gametic fusion and cyclical ovarian release under pituitary gonadotropin control.

Step 1: The union of a haploid spermatozoon (n) with a haploid ovum (n) resulting in karyogamy and diploid zygote ($2n$) formation is defined as syngamy (fertilisation). **Step 2:** Around day 14 of the menstrual cycle, anterior pituitary secretion of Luteinizing Hormone (LH) surges dramatically. **Step 3:** This LH surge induces follicular wall digestion and expulsion of the secondary oocyte arrested at metaphase II into the fallopian tube, a process called ovulation.
Final Answer: 1. syngamy 2. ovulation

Answer: (See above)
Go Back to Question 25

Q26.

Solution

Concept: Recombinant DNA protocols rely on specialized analytic instruments and thermostable enzymes.

Step 1: ELISA (Enzyme-Linked Immunosorbent Assay) detects viral antibodies or antigens using enzyme-conjugated antibodies producing quantifiable color changes → (a)-(iv). **Step 2:** A bioreactor is a large stainless steel cultivation system providing optimal aeration, pH, and temperature for growing microbial or mammalian cells to produce recombinant proteins → (b)-(iii). **Step 3:** Agarose gel electrophoresis resolves restriction fragments under an electric field based on molecular length and negative phosphate charge → (c)-(i). **Step 4:** Taq polymerase isolated from thermophilic bacterium *Thermus aquaticus* withstands 95°C denaturation during PCR amplification → (d)-(ii).
Final Answer: (a)-(iv), (b)-(iii), (c)-(i), (d)-(ii)

Answer: (See above)
Go Back to Question 26

Q27.

Solution

Concept: Immunology differentiates natural/artificial active versus passive immunity and viral pathogenesis.

Step 1: When pre-formed antibodies (such as anti-tetanus serum or snake antivenom) are administered to provide rapid temporary neutralizing protection, it is classified as passive immunity, confirming statement 1 is TRUE. **Step 2:** AIDS is caused by the Human Immunodeficiency Virus (HIV), which is an enveloped retrovirus containing two identical single-stranded RNA molecules and reverse transcriptase. **Step 3:** HIV selectively binds CD4 surface receptors on Helper T-lymphocytes (T_H cells), destroying them and crippling cellular immunity. Thus, claiming it is a double-stranded DNA virus attacking B-cells is FALSE.

Final Answer: 1. True (T) 2. False (F)

Answer: (See above)

Go Back to Question 27

Q28.

Solution

Concept: Molecular genetics defines structural transcript units and decoding triplet sequences.

Step 1: A codon is a sequence of three successive nucleotides on messenger RNA (mRNA) that encodes a specific amino acid during translation → (a)-(iii). **Step 2:** An anticodon is a complementary triplet on the anticodon loop of transfer RNA (tRNA) that base-pairs with the mRNA codon → (b)-(i). **Step 3:** Exons are coding sequences retained in spliced mature mRNA that express polypeptide sequences → (c)-(iv). **Step 4:** Introns are non-coding intervening sequences in eukaryotic primary pre-mRNA excised by spliceosomes → (d)-(ii).

Final Answer: (a)-(iii), (b)-(i), (c)-(iv), (d)-(ii)

Answer: (See above)

Go Back to Question 28

Q29.

Solution

Concept: Angiosperm fruits develop from ripened ovaries post-fertilisation and are categorized by pericarp texture (fleshy versus dry) and dehiscence mechanism upon maturity.

Step 1: Define simple fleshy fruits (Drupe): Fruit develops from a monocarpellary superior ovary. At maturity, the pericarp differentiates clearly into three distinct anatomical layers: an outer leathery epicarp, a middle fleshy or fibrous mesocarp, and an inner stony hard endocarp enclosing the seed. **Step 2:** Example of Drupe: Mango (*Mangifera indica*) or Coconut (*Cocos nucifera*). In mango, the edible portion is the juicy mesocarp. **Step 3:** Define simple dry dehiscent fruits (Legume or Pod): Fruit develops from a monocarpellary unilocular superior ovary. Upon reaching maturity, the dry pericarp splits open along both dorsal and ventral sutures to release seeds. **Step 4:** Example of Legume: Garden pea (*Pisum sativum*) or Gram (*Cicer arietinum*).
Final Answer: Drupe has a fleshy mesocarp and hard stony endocarp (e.g., Mango); Legume is a dry fruit dehiscing along both sutures at maturity (e.g., Garden pea).

Answer: (See above)

Go Back to Question 29

Q30.

Solution

Concept: Photophosphorylation synthesis of ATP uses light-driven electron transport across thylakoid membranes via cyclic or non-cyclic pathways depending on ATP/NADPH demand and PS II activity.

Electron Pathways in Photophosphorylation

Step 1: Photosystems involved: Non-cyclic photophosphorylation utilizes both Photosystem II (P_{680}) and Photosystem I (P_{700}) operating in series (Z-scheme), whereas cyclic photophosphorylation involves only Photosystem I (P_{700}). **Step 2:** Photolysis of water and products generated: In non-cyclic photophosphorylation, water splitting occurs at PS II, releasing molecular O_2 and protons, yielding both ATP and NADPH $+H^+$. In cyclic photophosphorylation, no photolysis occurs, oxygen is not evolved, and only ATP is synthesized without NADPH formation.
Final Answer: Non-cyclic uses PS II + PS I producing ATP, NADPH, and O_2; Cyclic uses only PS I producing exclusively ATP without O_2 release.

Answer: (See above)

Go Back to Question 30

Q31.

Solution

Concept: Inheritance patterns can deviate from simple Mendelian dominance through multiple alleles controlling a single gene locus, or through gene linkage on sex chromosomes.

Alternative (i): Step 1: Multiple Allelism: The human ABO blood group gene locus (I) located on chromosome 9 exists in three distinct allelic forms in the human gene pool: I^A, I^B, and i. Since an individual diploid human carries any two of these three alleles, it illustrates multiple allelism. **Step 2:** Codominance: Alleles I^A and I^B encode distinct glycosyltransferase enzymes adding specific antigenic sugars (A antigen and B antigen) to erythrocyte surfaces, whereas allele i produces no functional enzyme (recessive). **Step 3:** When a heterozygous individual inherits both I^A and I^B (I^AI^B genotype), neither allele masks the other; both enzymes function simultaneously, expressing both A and B surface antigens (Blood group AB).

Alternative (ii): Step 1: Sex-linked recessive inheritance occurs when a mutant gene is located on the differential non-homologous region of the X chromosome (X^h). **Step 2:** Human haemophilia A is caused by mutation in the gene encoding blood clotting Factor VIII on the X chromosome. **Step 3:** Males (XY) are hemizygous; inheriting a single mutant X^h chromosome from a carrier mother (XX^h) causes phenotypic haemophilia because there is no normal allele on the Y chromosome. Females require two mutant alleles (X^hX^h) to manifest disease, making males significantly more susceptible to criss-cross sex-linked disorders.

Final Answer: (i) ABO locus has 3 alleles (I^A, I^B, i) showing multiple allelism; I^AI^B heterozygotes express both A and B antigens showing codominance. (ii) Haemophilia is X-linked recessive; hemizygous males (X^hY) express disease from a single mutant maternal allele.

Answer: (See above)

Go Back to Question 31

Q32.

Solution

Concept: Biological classification segregates prokaryotes (Monera) from primitive terrestrial non-vascular cryptogams (Bryophyta).

Alternative (i): Step 1: Diagnostic features of Kingdom Monera: 1. Prokaryotic cellular organization: Cells lack a membrane-bound nucleus and membrane-bound cytoplasmic organelles (mitochondria, chloroplasts, endoplasmic reticulum). 2. Ribosome and cell wall structure: Possess 70S cytoplasmic ribosomes and a rigid cell wall composed primarily of peptidoglycan (murein). **Step 2:** Two representative bacterial genera: *Escherichia* (*E. coli*) and *Nostoc* (cyanobacterium). **Alternative (ii): Step 1:** Characteristic features of Bryophytes: 1. Amphibious plant habit: Although bryophytes live on moist terrestrial soil, they require external liquid water for flagellated antherozoids to swim to the archegonium to achieve fertilization. 2. Gametophyte dominance: The main plant body is a independent haploid gametophyte (n) lacking true roots, stems, or vascular tissues (xylem/phloem), to which the dependent diploid sporophyte attaches. **Step 2:** Two representative genera: *Riccia* (liverwort) and *Funaria* (moss).

Final Answer: (i) Monera lack nuclear membranes and have peptidoglycan walls (e.g., *Escherichia*, *Nostoc*). (ii) Bryophytes require water for fertilization and have dominant haploid gametophytes (e.g., *Riccia*, *Funaria*).

Answer: (See above)

Go Back to Question 32

Q33.

Solution

Concept: Cardiac Output (CO) is the total volume of blood pumped by each ventricle per unit time (minute), expressed mathematically as the product of Heart Rate (HR) and Stroke Volume (SV):

$$CO = HR \times SV$$

Step 1: Identify given physiological parameters at rest:

$$\text{Resting } HR_1 = 72 \text{ beats/min}, \quad \text{Resting } SV_1 = 70 \text{ mL/beat}$$

Step 2: Calculate resting cardiac output (CO_1):

$$CO_1 = 72 \times 70 = 5040 \text{ mL/min} = 5.04 \text{ L/min}$$

Step 3: Identify physiological parameters during strenuous exercise:

$$\text{Exercise } HR_2 = 140 \text{ beats/min}, \quad \text{Exercise } SV_2 = 110 \text{ mL/beat}$$

Step 4: Calculate exercise cardiac output (CO_2):

$$CO_2 = 140 \times 110 = 15400 \text{ mL/min} = 15.40 \text{ L/min}$$

Step 5: Calculate percentage increase in cardiac output ($\Delta CO\%$):

$$\Delta CO\% = \left(\frac{CO_2 - CO_1}{CO_1} \right) \times 100$$

$$\Delta CO\% = \left(\frac{15400 - 5040}{5040} \right) \times 100 = \left(\frac{10360}{5040} \right) \times 100 \approx 205.56\%$$

Final Answer: Resting CO = 5.04 L/min; Percentage Increase = 205.56%

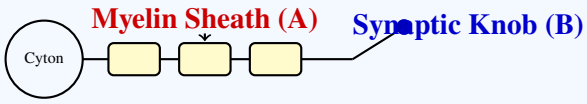
Answer: (See above)

Go Back to Question 33

Q34.

Solution

Concept: Neurons conduct rapid bioelectric impulses along axon fibers insulated by myelin and terminate at synaptic knobs to release chemical neurotransmitters.



Labelled Neuron Transmission Components

Step 1: Identify structural label A: Myelin Sheath (or Schwann cell insulating layer wrapping the axon core). **Step 2:** State the function of A: Acts as a high-resistance electrical insulator that prevents ionic leakage across the axolemma and accelerates impulse conduction velocity via saltatory conduction jumping between Nodes of Ranvier. **Step 3:** Identify structural label B: Axon terminal (Synaptic knob / bouton). **Step 4:** State the function of B: Houses synaptic vesicles packed with neurotransmitters (such as acetylcholine); upon calcium influx during depolarization, releases neurotransmitters across the synaptic cleft to stimulate postsynaptic neurons or effectors. **Final Answer:** A = Myelin sheath (accelerates impulse conduction via saltatory conduction); B = Axon terminal / Synaptic knob (releases neurotransmitters across synaptic cleft).

Answer: (See above)

Go Back to Question 34

Q35.

Solution

Concept: The endocrine system maintains metabolic rate, growth, and survival response through hormone signalling cascades from the pituitary and adrenal medulla.

Alternative (i): Step 1: Growth Hormone (GH / Somatotropin): Secreted by anterior pituitary somatotrophs, GH stimulates hepatic production of insulin-like growth factors (IGF-1), accelerating chondrogenesis at epiphyseal plates, longitudinal bone growth, protein synthesis, and muscle mass accumulation during childhood. **Step 2:** Gonadotropins (FSH and LH): Follicle Stimulating Hormone (FSH) stimulates ovarian follicle maturation in females and spermatogenesis in male Sertoli cells. Luteinizing Hormone (LH) triggers ovulation and corpus luteum formation in females, and stimulates Leydig cells to synthesize testosterone in males.
Alternative (ii): Step 1: Cardiovascular and respiratory stimulation: Adrenaline binds beta-adrenergic receptors on heart pacemaker cells, increasing heart rate and cardiac output while causing bronchodilation to maximize pulmonary oxygen intake. **Step 2:** Metabolic mobilization: Adrenaline stimulates hepatic glycogenolysis (breakdown of glycogen into glucose) and adipose lipolysis, flooding blood plasma with readily accessible glucose and fatty acids to fuel skeletal muscle contraction during stress.
Final Answer: (i) Pituitary secretes Growth Hormone (bone/tissue growth) and Gonadotropins FSH/LH (follicle development/testosterone synthesis). (ii) Adrenaline increases heart rate/bronchodilation and accelerates glycogenolysis to elevate blood glucose during emergencies.

Answer: (See above)

Go Back to Question 35

Q36.

Solution

Concept: Biological nitrogen fixation converts atmospheric nitrogen gas (N_2) into ammonia (NH_3) by living diazotrophic microorganisms utilizing the enzyme nitrogenase under physiological conditions.

Step 1: Define biological nitrogen fixation: The reduction of inert atmospheric dinitrogen gas into bio-available ammonia by prokaryotic microorganisms utilizing ATP and the enzyme complex nitrogenase. **Step 2:** Identify one free-living aerobic nitrogen-fixing bacterium: *Azotobacter* (or *Beijerinckia*), which fixes nitrogen independently in well-aerated soils. **Step 3:** Identify one symbiotic nitrogen-fixing bacterium: *Rhizobium*, which invades root hair cells of leguminous plants (pea, gram, soybean) and establishes mutualistic root nodules.
Final Answer: Definition: Reduction of atmospheric N_2 to NH_3 by prokaryotes. Free-living aerobic: *Azotobacter*; Symbiotic: *Rhizobium*.

Answer: (See above)

Go Back to Question 36

Q37.

Solution

Concept: Anemophilous (wind-pollinated) plants do not invest energy in nectar or colorful petals; instead, they adapt their floral architecture for aerodynamic pollen release and capture.

Step 1: Pollen grain characteristics: Anemophilous flowers produce enormous quantities of small, dry, smooth, and lightweight pollen grains (often winged as in *Pinus*) so they remain airborne over vast horizontal distances. **Step 2:** Stigma and stamen architecture: Stamens possess long filaments with well-exposed, versatile anthers that swing freely in air currents to release pollen. Stigmas are large, well-exposed, and feathery or hairy (as in maize cob silks) to effectively trap drifting pollen grains from the air stream.

Final Answer: 1. Production of abundant, dry, lightweight pollen grains. 2. Large, well-exposed feathery stigmas to capture airborne pollen.

Answer: (See above)

Go Back to Question 37

Q38.

Solution

Concept: Clear definition of genetic and physiological mechanisms illustrated by classic biological examples.

Step 1: Define Pleiotropy (A): A genetic phenomenon where a single pleiotropic gene locus influences multiple, seemingly unrelated phenotypic traits or biochemical pathways. *Example:* Phenylketonuria (PKU) in humans, caused by mutation in the gene encoding phenylalanine hydroxylase; this single enzyme deficiency causes mental retardation, reduced hair pigmentation, and skin hypopigmentation.

Step 2: Define Apical Dominance (B): The physiological phenomenon where the growing apical shoot bud inhibits the growth and sprouting of lateral (axillary) buds situated below it, mediated by downward basipetal transport of auxin (IAA). *Example:* In tea plantations and hedge trimming (decapitation), removal of apical buds stops auxin supply, stimulating lateral buds to grow vigorously into bushy branches.

Step 3: Define Osmoregulation (C): The active physiological maintenance of appropriate water potential, osmotic concentration, and electrolyte balance within bodily fluids of an organism independent of external fluctuations. *Example:* Freshwater amoeba utilizes a contractile vacuole to continuously pump out excess hypotonic osmotic water influx; human kidneys regulate nephron water reabsorption via ADH.

Final Answer: A. Pleiotropy: One gene affecting multiple traits (e.g., Phenylketonuria). B. Apical dominance: Apical bud suppressing lateral buds via auxin (e.g., pruning tea bushes). C. Osmoregulation: Maintenance of water/salt balance (e.g., contractile vacuole in Amoeba).

Answer: (See above)

Go Back to Question 38

Q39.

Solution

Concept: Meiotic prophase I achieves genetic recombination via homologous synapsis and crossing over. Bacterial DNA replication achieves rapid semi-conservative duplication using specialized replication fork enzymes.

Alternative (i): Step 1: Leptotene: Chromatin threads condense into visible, thin, beaded chromosomes attached by telomeres to the nuclear envelope (bouquet stage). **Step 2:** Zygotene: Homologous maternal and paternal chromosomes pair lengthwise along their length (synapsis) mediated by the synaptonemal complex, forming bivalents. **Step 3:** Pachytene: Chromosomes condense further to reveal four distinct chromatids (tetrads). Non-sister chromatids of homologous chromosomes undergo crossing over mediated by the enzyme recombinase, exchanging genetic material at recombination nodules. **Step 4:** Diplotene: The synaptonemal complex dissolves; homologues separate except at points of genetic crossover, forming X-shaped structures called chiasmata. **Step 5:** Diakinesis: Chiasmata undergo terminalization moving toward chromosome tips; nucleolus and nuclear envelope disintegrate, preparing spindle attachment. *Significance of Crossing Over:* Reciprocal exchange of alleles breaks linkage groups and produces novel genetic combinations in gametes, driving evolutionary variation.

Alternative (ii): Step 1: DNA Helicase binds the replication origin (*oriC*) and unwinds parental DNA double helix by breaking hydrogen bonds, exposing single-stranded templates stabilized by SSB proteins. **Step 2:** DNA Polymerase III is the main holoenzyme complex that continuously synthesizes the leading strand ($5' \rightarrow 3'$) and discontinuously synthesizes Okazaki fragments on the lagging strand by adding deoxyribonucleotides complementary to the template. **Step 3:** DNA Ligase forms covalent phosphodiester bonds between adjacent 3'-OH and 5'-phosphate termini of adjacent Okazaki fragments after RNA primer removal by DNA pol I, sealing the lagging sugar-phosphate backbone.

Final Answer: (i) Five substages: Leptotene (condensation), Zygotene (synapsis), Pachytene (crossing over via recombinase), Diplotene (chiasmata formation), Diakinesis (terminalization). Recombination generates variation. (ii) Helicase unwinds double helix; DNA Pol III synthesizes leading/lagging strands; DNA Ligase joins Okazaki fragments.

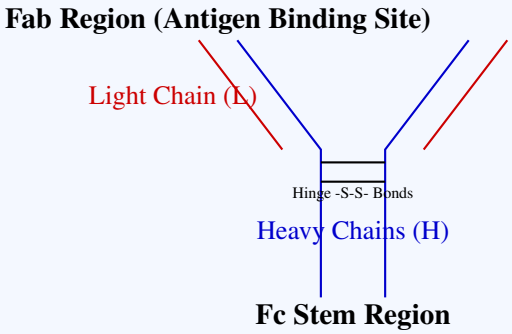
Answer: (See above)

Go Back to Question 39

Q40.

Solution

Concept: Antibodies (immunoglobulins) are symmetrical Y-shaped glycoproteins synthesized by plasma B-cells. The classic monomeric structure represented by IgG consists of four polypeptide chains held together by covalent disulfide bonds.



Step 1: Polypeptide Chain Organization: The molecule consists of two identical Heavy (H) chains ($\sim$ 50 kDa) and two identical Light (L) chains ($\sim$ 25 kDa), designated as an H_2L_2 tetrameric configuration. **Step 2:** Disulfide Bridges: Inter-chain disulfide bonds ($-S-S-$) link each light chain to a heavy chain, and link the two heavy chains together across a flexible proline-rich hinge region. **Step 3:** Variable and Constant Regions: The amino-terminal (N-terminal) ends of both heavy and light chains show high amino acid sequence diversity, forming the Variable domains (V_H and V_L). **Step 4:** Antigen-Binding Sites (Fab): The combination of one V_H and one V_L domain forms a pocket complementary to a specific antigenic epitope. Each monomer possesses two identical antigen-binding sites (Fab arms). **Step 5:** Constant Stem (Fc): The carboxyl-terminal (C-terminal) halves form the crystallizable fragment (Fc), mediating effector actions like complement fixation and macrophage binding.

Final Answer: Structure comprises two heavy and two light chains (H_2L_2) linked by disulfide bonds. N-terminal variable domains (V_H and V_L) form two specific antigen-binding sites (Fab), while the Fc stem mediates immune cell attachment.

Answer: (See above)

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Q41.

Solution

Concept: Vector-borne viral fevers (Dengue) and airborne bacterial pulmonary infections (Tuberculosis) require specific diagnostic and epidemiologic intervention strategies.

Alternative (i): Step 1: Vector and Causal Agent: Dengue fever is transmitted by the bite of infected female daytime-biting *Aedes aegypti* mosquitoes. The causal agent is Dengue Virus (DENV), a single-stranded RNA flavivirus with four serotypes (DENV 1–4). **Step 2:** Major Clinical Symptoms: High sudden-onset fever (40°C), severe retro-orbital headache behind the eyes, intense myalgia and arthralgia ('break-bone fever'), maculopapular skin rash, and in severe Dengue Hemorrhagic Fever (DHF), thrombocytopenia (sharp drop in platelet count) causing internal hemorrhage and shock. **Step 3:** Vector Management: Eliminating stagnant water in flower pots, coolers, and discarded tires to eliminate mosquito breeding sites; applying larvicides (Temephos) or introducing larvivorous fish (*Gambusia*) into ponds; using aerosol insecticides and window screens.

Alternative (ii): Step 1: Causal Agent and Transmission: Tuberculosis (TB) is caused by the rod-shaped acid-fast bacterium *Mycobacterium tuberculosis*. Transmission occurs through inhalation of aerosolized respiratory droplets expelled when an infected patient coughs or sneezes. **Step 2:** Clinical Symptoms: Chronic persistent cough lasting over three weeks producing blood-streaked sputum (hemoptysis), evening low-grade fever, drenching night sweats, progressive weight loss, fatigue, and chest pain due to pulmonary tubercle lesions. **Step 3:** Prevention and Treatment: BCG (Bacillus Calmette-Guérin) vaccination administered to neonates provides immunity. Active infection is cured using DOTS (Directly Observed Treatment, Short-course) multi-drug anti-tubercular chemotherapy comprising Rifampicin, Isoniazid, Pyrazinamide, and Ethambutol for 6–9 months.

Final Answer: (i) Dengue transmitted by *Aedes aegypti* mosquito carrying flavivirus; causes high fever, severe joint pain, and thrombocytopenia; controlled by stagnant water removal and larvicides. (ii) TB caused by airborne *Mycobacterium tuberculosis*; causes chronic bloody cough, night sweats, weight loss; treated by BCG vaccine and 6-month DOTS antibiotic course.

Answer: (See above)

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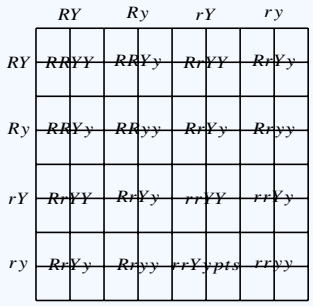
Q42.

Solution

Concept: Independent assortment predicts dihybrid ratios (9 : 3 : 3 : 1). Angiosperm ovules contain a 7-celled, 8-nucleate female gametophyte.

Alternative (i): Law of Independent Assortment: Alleles of distinct gene pairs segregate independently during gamete formation if located on different chromosomes.
Dihybrid Cross: F1 hybrid $RrYy$ (Round Yellow) forms gametes RY, Ry, rY, ry in a 1 : 1 : 1 : 1 ratio.
Punnett Square & F2 Distribution:



F2 Phenotypic Ratio: 9 Round Yellow ($R\_Y\_$) : 3 Round Green (R_yy) : 3 Wrinkled Yellow ($rrY\_$) : 1 Wrinkled Green ($rryy$).

Alternative (ii): Anatropous Ovule Structure: Inverted 180°. Main parts: funiculus (stalk), hilum (attachment site), chalaza (base), integuments (protective layers), micropyle (narrow pore), and central nutrient-rich nucellus.
Embryo Sac Organization (7 cells, 8 nuclei): 1. *Egg Apparatus (Micropylar):* 1 haploid egg cell (gamete) + 2 synergids (with filiform apparatus to guide pollen tube). 2. *Antipodal Cells (Chalazal):* 3 haploid nutritive cells. 3. *Central Cell:* 1 large cell containing 2 haploid polar nuclei (fuse to form a diploid secondary nucleus).

Final Answer: (i) Law of independent assortment verified by 4×4 Punnett square showing a phenotypic ratio of 9 : 3 : 3 : 1. (ii) Anatropous ovule features a funicle, hilum, nucellus, and micropyle; its mature embryo sac exhibits a 7-celled, 8-nucleate structure.

Answer: (See above)

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Q43.

Solution

Concept: Photosynthetic carbon reduction (C_3 cycle) drives autotrophic hexose synthesis inside stroma. The specialized cardiac electrical conduction pathway orchestrates mechanical ventricular pumping.

Alternative (i): Step 1: Stage 1: Carboxylation: Ribulose-1,5-bisphosphate (RuBP, a 5-carbon sugar) combines with atmospheric CO_2 catalyzed by the stromal enzyme RuBisCO. This forms an unstable 6-carbon intermediate that immediately cleaves into two molecules of 3-Phosphoglyceric acid (3-PGA, the first stable 3-carbon compound). **Step 2:** Stage 2: Reduction: Each 3-PGA molecule is phosphorylated by ATP into 1,3-bisphosphoglycerate, which is subsequently reduced by NADPH into Glyceraldehyde-3-phosphate (G3P / triose phosphate). For every 6 turns of the cycle fixing 6 CO_2, 12 triose phosphate molecules form; 2 condense to generate one hexose glucose molecule ($C_6H_{12}O_6$). **Step 3:** Stage 3: Regeneration: To sustain continuous cycle operation, the remaining 10 triose phosphate molecules undergo complex enzymatic rearrangements consuming ATP to regenerate 6 molecules of RuBP primary acceptor. **Step 4:** Total Energetic Stoichiometry: Fixation of each CO_2 molecule requires 3 ATP and 2 NADPH. To synthesize one full molecule of glucose (6 CO_2 fixed):

$$\text{Total ATP consumed} = 6 \times 3 = 18 \text{ ATP}$$

$$\text{Total NADPH consumed} = 6 \times 2 = 12 \text{ NADPH}$$

Alternative (ii): Step 1: Cardiac Conduction Pathway: 1. SA Node: Spontaneous depolarization initiates an excitation wave sweeping across right and left atrial myocardium at 1 m/s. 2. AV Node: The impulse converges at the Atrioventricular (AV) node situated in the lower interatrial septum, where conduction deliberately delays by $\sim$ 0.1 seconds to allow complete atrial emptying before ventricles contract. 3. Bundle of His & Purkinje Network: The impulse rapidly travels down the Bundle of His bifurcating into left and right bundle branches within the interventricular septum, distributing quickly along Purkinje fibres ($\sim$ 4 m/s) to excite ventricular myocardial myocytes simultaneously from apex toward base. **Step 2:** Mechanical Events during Ventricular Systole: 1. As ventricular myocardium depolarizes (QRS complex on ECG), ventricular contraction elevates intraventricular pressure sharply above atrial pressure. 2. Atrioventricular (Tricuspid and Bicuspid/Mitral) valves snap shut producing the first heart sound (S_1, 'Lubb') preventing backflow into atria. 3. As ventricular pressure surpasses systemic aortic pressure (80 mmHg) and pulmonary trunk pressure (10 mmHg), semilunar valves force open, ejecting 70 mL stroke volume into circulation during ventricular ejection phase.

Final Answer: (i) C_3 Calvin cycle proceeds via Carboxylation (forming 3-PGA via RuBisCO), Reduction (forming G3P), and Regeneration (rebuilding RuBP); net synthesis of 1 glucose requires 18 ATP and 12 NADPH. (ii) Cardiac impulse travels SA node $\rightarrow$ AV node (0.1s delay) $\rightarrow$ Bundle of His $\rightarrow$ Purkinje fibres; ventricular systole closes AV valves (S_1 sound) and opens semilunar valves to eject stroke volume.

Answer: (See above)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	B	3	A	4	B	5	C
6	C	7	A	8	B	9	C	10	A
11	B	12	C	13	B	14	C	15	C
16	B								