NIOS Class 12 Biology Sample Paper-5

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. Which primary photosynthetic pigment acts as the universal reaction centre (P_{680} and P_{700}) in green oxygenic autotrophs and exhibits strong absorption peaks in the blue and red regions of the visible spectrum? **(1)**

(A) Chlorophyll a

(B) Chlorophyll b

(C) Beta-carotene

(D) Xanthophyll

Q2. In a standard Mendelian dihybrid test cross between a heterozygous round yellow pea plant ($RrYy$) and a double recessive wrinkled green parent ($rryy$), what phenotypic ratio of offspring is expected if the two gene loci assort independently? **(1)**

(A) 9 : 3 : 3 : 1

(B) 1 : 1 : 1 : 1

(C) 3 : 1

(D) 1 : 2 : 1

Q3. Which specialized, thick-walled, non-dividing photosynthetic cells in filamentous cyanobacteria such as *Anabaena* and *Nostoc* lack Photosystem II activity and synthesize nitrogenase to fix atmospheric nitrogen under anaerobic micro-conditions? **(1)**

(A) Akinetes

(B) Hormogonia

(C) Heterocysts

(D) Endospores

Q4. During prokaryotic transcription in bacterial cells, which specific dissociable subunit of the RNA polymerase holoenzyme specifically recognizes and binds to the conserved promoter sequence located upstream of the coding transcript? **(1)**

(A) Alpha (α) subunit

(B) Beta (β) subunit

(C) Sigma (σ) factor

(D) Rho (ρ) termination factor

Q5. In a normal clinical electrocardiogram (ECG) recording of the human cardiac cycle, the rapid upward deflection known as the QRS complex directly represents which electrophysiological event? **(1)**

(A) Atrial depolarization leading to atrial systole

(B) Ventricular depolarization leading to ventricular systole

(C) Ventricular repolarization leading to ventricular diastole

(D) Delayed conduction across the atrioventricular junction

Q6. In flowering angiosperms, the mature male gametophyte (pollen grain) shed from the dehiscing microsporangium at the 2-celled stage typically contains: **(1)**

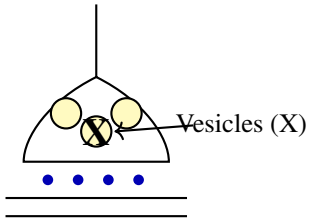
(A) A single undifferentiated haploid microspore nucleus

(B) One larger vegetative tube cell and one smaller generative cell

(C) Two equal-sized vegetative cells and one sperm cell

(D) A tetrad of four functional male gamete nuclei

Q7. Observe the schematic diagram of a chemical synaptic junction shown below. The secretory vesicles inside the presynaptic axon terminal marked 'X' store specialized chemical messengers called: **(1)**



Postsynaptic Dendritic Membrane
Synaptic Terminal Architecture

(A) Neurotransmitters

(B) Neurohormones

(C) Second messengers

(D) Synaptotagmins

Q8. Which class of Kingdom Fungi is characterized by septate mycelium and the exogenous formation of four sexual basidiospores on club-shaped basidia, as represented by *Agaricus* (mushroom) and *Puccinia* (rust)? **(1)**

(A) Phycomycetes

(B) Ascomycetes

(C) Basidiomycetes

(D) Deuteromycetes

Q9. In leguminous root nodules, which red-pink hemoprotein pigment acts as an efficient oxygen scavenger to maintain anaerobic micro-environments essential for nitrogenase enzymatic activity? **(1)**

(A) Myoglobin

(B) Leghemoglobin

(C) Cytochrome c

(D) Plastocyanin

Q10. Which dietary fat-soluble micronutrient serves as an essential cofactor for the hepatic post-translational carboxylation of blood coagulation factors II (prothrombin), VII, IX, and X? **(1)**

(A) Vitamin A (Retinol)

(B) Vitamin D (Calciferol)

(C) Vitamin E (Tocopherol)

(D) Vitamin K (Phylloquinone)

Q11. Down syndrome in humans is an autosomal congenital numerical chromosomal anomaly resulting from trisomy of chromosome 21 (47, XX + 21 or 47, XY + 21). What is the exact number of autosomes present in a somatic cell of a female affected by Down syndrome? **(1)**

(A) 44 autosomes

(B) 45 autosomes

(C) 46 autosomes

(D) 47 autosomes

Q12. In genetic engineering protocols utilizing the bacterial plasmid vector pBR322, insertion of a foreign transgene into the *BamHI* endonuclease recognition site located inside the tetracycline resistance gene (tet^R) causes: **(1)**

(A) Insertional inactivation resulting in susceptibility to tetracycline

(B) Autonomous runaway amplification of plasmid copy number

(C) Constitutive expression of host beta-galactosidase

(D) Immediate lysis of the transformed bacterial cell

Q13. Which living permanent vascular plant tissue consists of elongated sieve tube elements aligned end-to-end and specialized for the bidirectional translocation of sucrose photoassimilates? **(1)**

(A) Xylem tracheids

(B) Xylem vessels

(C) Phloem tissue

(D) Vascular cambium

Q14. Which subset of effector T-lymphocytes expresses CD8 glycoprotein receptors and secretes perforins and granzymes to directly induce apoptosis in virus-infected cells and neoplastic tumor host cells? **(1)**

(A) Helper T-lymphocytes (T_H cells)

(B) Cytotoxic T-lymphocytes (T_C cells)

(C) Plasma B-lymphocytes

(D) Memory B-cells

Q15. Which permanent surgical sterilization procedure in human males involves bilateral excision and ligation of a small segment of the vas deferens to block transport of spermatozoa into ejaculated semen? **(1)**

(A) Tubectomy

(B) Vasectomy

(C) Castration

(D) Intrauterine device insertion

Q16. Which neuroendocrine peptide hormone synthesized in hypothalamic magnocellular nuclei and stored in the posterior pituitary triggers strong rhythmic uterine smooth muscle contractions during parturition? **(1)**

(A) Oxytocin

(B) Vasopressin (Antidiuretic Hormone)

(C) Prolactin

(D) Luteinizing Hormone

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:

The Krebs cycle (Tricarboxylic Acid cycle) takes place inside the mitochondrial matrix during aerobic respiration. Acetyl-CoA derived from pyruvate enters the pathway by condensing with oxaloacetic acid to form a six-carbon tricarboxylic acid. Through successive dehydrogenation and decarboxylation steps, high-energy electron carriers are produced to drive mitochondrial oxidative phosphorylation. **(2)**

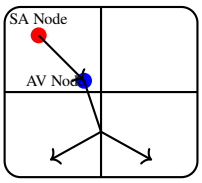
1. Name the six-carbon tricarboxylic acid formed in the initial condensation step of the Krebs cycle.
2. How many molecules of reduced coenzyme NADH + H^+ are produced per turn of the Krebs cycle from one molecule of Acetyl-CoA?

Q18. Complete the following sentences using the words given below:
(xylem, phloem, tracheids, sieve tubes, companion cells) **(2)**

1. In vascular plants, upward conduction of water and inorganic minerals from roots occurs through dead, thick-walled elements called .....and vessels belonging to the .....
2. Organic food synthesized during photosynthesis is translocated throughout the plant body via living, enucleate .associated with nucleated .inside the phloem tissue.

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

The human cardiac conduction system coordinates rhythmic heart contractions. Spontaneous depolarization originates in the right atrial pacemaker node, propagates across atrial myocardium, delays briefly at the atrioventricular junction, and conducts down ventricular bundle branches to stimulate forceful ventricular ejection. **(2)**



Cardiac Conduction Node Pathway

1. What physiological benefit is provided by the brief conduction delay (~ 0.1 seconds) occurring at the Atrioventricular (AV) node?
2. Name the terminal, rapidly conducting myocardial fibers that spread electrical excitation throughout ventricular musculature.

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

1. The biogeochemical cycle wherein rock-bound elements such as phosphorus circulate within biotic and abiotic reservoirs without entering gaseous atmospheric phases is called a ..... cycle.
2. The maximum intrinsic capacity of a biological population to reproduce and increase under ideal environmental conditions is termed its biotic ....

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

Column I	Column II
(a) Cerebrum	(i) Broad band of myelinated commissural fibers connecting cerebral hemispheres
(b) Hypothalamus	(ii) Seat of conscious intelligence, voluntary motor planning, and memory
(c) Medulla oblongata	(iii) Autonomic center controlling heart rate, respiration, and vasomotor tone
(d) Corpus callosum	(iv) Neuroendocrine integration regulating body temperature, hunger, and thirst

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

1. The specialized adventitious root pillars growing vertically downward from horizontal banyan branches to provide mechanical pillar support are called roots.
2. The negatively geotropic breathing roots growing upward out of waterlogged swamp soil in mangrove plants such as *Rhizophora* are called . . . . . .

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

1. In human females, the hormone progesterone secreted by the corpus luteum maintains the secretory endometrial lining required for embryo implantation.
2. Oxytocin is secreted by the anterior pituitary gland and acts directly on testicular Sertoli cells to initiate spermatogenesis.

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

Column I	Column II
(a) Porifera (Sponges)	(i) Jointed appendages and chitinous exoskeleton
(b) Cnidaria (Coelenterates)	(ii) Dorsoventrally flattened acoelomic body with excretory flame cells
(c) Platyhelminthes	(iii) Water canal system with collar cells (choanocytes) and ostia pores
(d) Arthropoda	(iv) Radial symmetry equipped with stinging capsules (cnidocytes)

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

1. The inheritance pattern wherein multiple independent gene loci contribute additively to express a continuous quantitative trait (such as human skin color) is termed .....inheritance.
2. A structural chromosomal aberration involving the physical loss of an internal or terminal chromosome segment is called a .....

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

Column I	Column II
(a) Plasmid pBR322	(i) Natural genetic engineer vector used for introducing genes into dicots
(b) *EcoRI* endonuclease	(ii) Cleaves double-stranded DNA specifically between G and A in 5′−GAATTC−3′
(c) DNA polymerase I	(iii) Extra-chromosomal circular double-stranded cloning vector in bacteria
(d) Agrobacterium Ti plasmid	(iv) Excises RNA primers and fills gap nucleotides during replication repair

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

1. Active immunity is generated when the host immune system synthesizes specific antibodies and memory lymphocytes upon direct antigen exposure.

2. Human malaria is a viral communicable disease transmitted exclusively by the bite of infected male *Culex* mosquitoes.

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

Column I	**Column II**
(a) Promoter sequence	(i) Encode enzymes (beta-galactosidase, permease) for lactose catabolism
(b) Operator region	(ii) Upstream DNA recognition sequence where RNA polymerase binds
(c) Repressor protein	(iii) Regulatory polypeptide synthesized by *i* gene blocking operator transcription
(d) Structural genes (Z, Y, A)	(iv) Intervening DNA sequence between promoter and structural genes

Section: B

Q29. Differentiate briefly between simple fleshy fruits (such as berry) and aggregate fruits (such as etaerio of berries), giving one diagnostic botanical feature and one plant example for each. **(2)**

Q30. State any two structural and functional distinctions between C3 and C4 leaf anatomy (Kranz anatomy) regarding chloroplast dimorphism and bundle sheath cell organization. **(2)**

Q31. (i) Explain briefly the immunopathological mechanism of Erythroblastosis foetalis arising from Rh blood group incompatibility between an Rh-negative mother and an Rh-positive developing fetus.

OR

(ii) Explain the genetic mechanism of incomplete dominance using flower color inheritance in *Mirabilis jalapa* (Four O'clock plant) as an illustrative cross. **(2)**

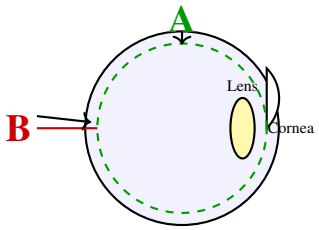
Q32. (i) State two characteristic anatomical features distinguishing Phylum Chordata from Non-Chordata in Kingdom Animalia, giving two representative chordate examples.

OR

(ii) State two diagnostic features of Pteridophytes (vascular cryptogams) and give two representative genus examples. **(2)**

Q33. In a large, randomly mating diploid population of 10,000 field mice in Hardy-Weinberg equilibrium, coat fur color is governed by two alleles: a dominant allele (B) for black fur and a recessive allele (b) for white fur. If 1,600 mice exhibit the recessive white fur phenotype (bb), calculate the exact allele frequencies of b (q) and B (p). Furthermore, calculate the exact number of heterozygous black carrier mice (Bb) expected in this population. **(2)**

Q34. Observe the labelled schematic diagram of a horizontal cross-section through the human eye shown below. Identify the ocular structures indicated by labels 'A' and 'B', and state one primary visual function performed by each. **(2)**



Schematic Cross-Section of Human Eye

Q35. (i) Describe two primary physiological roles performed by thyroid hormones (T_3 and T_4) in regulating human basal metabolic rate and tissue maturation.

OR

(ii) Describe two physiological actions executed by pancreatic insulin in lowering elevated postprandial blood glucose levels. **(2)**

Q36. Define biological nitrification and denitrification in the soil nitrogen cycle. Mention one specific autotrophic nitrifying bacterium and one denitrifying

bacterium. **(2)**

Q37. State two distinctive floral adaptations exhibited by entomophilous (insect-pollinated) angiosperms to attract and reward insect pollinators. **(2)**

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

A. Genetic linkage

B. Phototropism

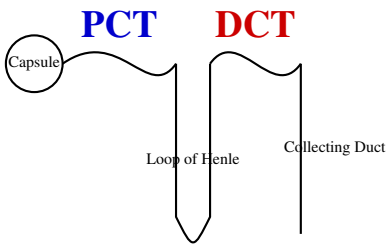
C. Transpiration pull **(3)**

Q39. (i) Describe the sequential molecular events of transcription initiation, elongation, and termination in prokaryotic bacteria, highlighting the roles of sigma (σ) and rho (ρ) factors.

OR

(ii) Describe the structural organization and transcriptional regulation of the *lac* operon in *E. coli* in the absence and presence of lactose inducer. **(3)**

Q40. With the aid of a neat labelled schematic diagram of a human nephron, identify and explain the distinct physiological roles of the Proximal Convoluted Tubule (PCT) and Distal Convoluted Tubule (DCT) in tubular reabsorption and secretion. **(3)**



Functional Segments of Human Nephron

Q41. (i) Describe the causal protozoan pathogen, insect vector species, red blood cell life cycle stages, and classic clinical symptoms of human Malaria.

OR

(ii) Describe the causal enteric bacterium, transmission route, gastrointestinal symptoms, and diagnostic Widal serological test for human Typhoid fever. **(3)**

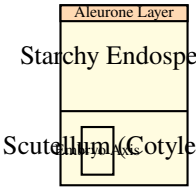
Q42. (i) (a) State Mendel's law of segregation (purity of gametes).

(b) In a monohybrid cross between homozygous purple-flowered pea plants (PP) and white-flowered plants (pp), illustrate the F1 and F2 generations using a Punnett square to derive both genotypic and phenotypic ratios.

OR

(ii) (a) Describe the internal anatomical structure of a typical monocot seed (maize caryopsis grain) highlighting the pericarp, aleurone layer, endosperm, and scutellum.

(b) Explain the functional protective roles of the coleoptile and coleorhiza during embryo germination. **(5)**

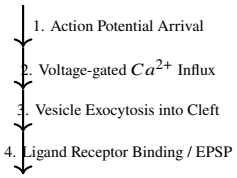


Structure of Monocot Maize Caryopsis Grain

Q43. (i) Describe the sequential ten-step enzymatic reactions of the cytoplasmic glycolytic pathway (Embden-Meyerhof-Parnas pathway) converting one glucose molecule into two pyruvate molecules, detailing substrate phosphorylation and ATP yield.

OR

(ii) Describe the transmission mechanism of a bioelectric nerve impulse across a chemical synapse from presynaptic axon terminal to postsynaptic membrane, detailing calcium influx, vesicle exocytosis, acetylcholine receptor binding, and acetylcholinesterase action. **(5)**



Chemical Synapse Cascade Steps

Detailed Solutions

Q1.

Solution

Concept: Photosynthetic pigments inside chloroplast thylakoid membranes capture photons and channel excitation energy toward specialized reaction centers. While accessory pigments (chlorophyll b, carotenoids, xanthophylls) absorb varied wavelengths and protect against photo-oxidation, Chlorophyll a constitutes the primary universal photosynthetic reaction center (P_{680} in PS II and P_{700} in PS I).

Step 1: Analyze light absorption spectra of plant pigments. Chlorophyll a exhibits dual absorption peaks: one in the blue-violet region ($\sim$ 430 nm) and another in the red region ($\sim$ 660 nm). **Step 2:** Evaluate biochemical function: When Chlorophyll a absorbs photon energy, its reaction center electron gets excited to a higher quantum orbital and is transferred to primary electron acceptors, driving photophosphorylation. **Step 3:** accessory pigments transfer trapped resonance energy to Chlorophyll a reaction centers. Therefore, Chlorophyll a is the universal primary photosynthetic pigment.

Final Answer: Chlorophyll a

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: A test cross crosses an organism showing dominant phenotype with a homozygous double recessive individual ($rryy$) to determine unknown genotype or gene linkage. When genes assort independently, a dihybrid test cross yields four phenotypic classes in equal proportions.

Step 1: Determine gametes produced by the heterozygous F1 dihybrid parent ($RrYy$): Since alleles assort independently, four gamete types form in equal $1:1:1:1$ ratio: RY, Ry, rY, ry. **Step 2:** Determine gametes produced by homozygous recessive parent ($rryy$): Produces only one gamete type: ry. **Step 3:** Combine gametes in test cross fertilization: - $RY \times ry \rightarrow RrYy$ (Round Yellow) = 25% (1/4) - $Ry \times ry \rightarrow Rryy$ (Round Green) = 25% (1/4) - $rY \times ry \rightarrow rrYy$ (Wrinkled Yellow) = 25% (1/4) - $ry \times ry \rightarrow rryy$ (Wrinkled Green) = 25% (1/4) **Step 4:** Thus, the resulting dihybrid test cross phenotypic ratio is exactly $1:1:1:1$.

Final Answer: $1:1:1:1$

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: Biological nitrogen fixation by the enzyme nitrogenase requires strictly anaerobic conditions because oxygen irreversibly inactivates the iron-sulfur catalytic clusters. Filamentous cyanobacteria develop specialized differentiated cells called heterocysts to separate oxygenic photosynthesis from nitrogen fixation.

Step 1: Identify the specialized enlarged, barrel-shaped cells in cyanobacterial filaments (*Nostoc*, *Anabaena*) called Heterocysts. **Step 2:** Analyze structural modifications: Heterocyst walls develop three thick impermeable glycolipid and polysaccharide layers that block atmospheric oxygen diffusion. **Step 3:** Analyze biochemical modifications: Heterocysts degrade Photosystem II activity (preventing intracellular oxygen evolution from photolysis of water) while retaining Photosystem I for cyclic ATP generation needed to power nitrogenase.
Final Answer: Heterocysts

Answer: (C)
Go Back to Question 3

Q4.

Solution

Concept: Bacterial RNA polymerase consists of a core enzyme ($\alpha_2\beta\beta'\omega$) capable of catalyzing RNA 5' to 3' chain elongation but unable to recognize specific promoter initiation sites independently.

Step 1: Examine transcription initiation: To initiate transcription at correct gene loci, the core enzyme binds a dissociable initiation factor called Sigma (σ) factor to form the holoenzyme ($\alpha_2\beta\beta'\omega\sigma$). **Step 2:** Evaluate sigma factor function: The sigma factor recognizes conserved upstream promoter consensus sequences (such as the Pribnow box at -10 and -35 region) and stabilizes local unwinding of DNA double helix. **Step 3:** Once RNA synthesis reaches $\sim 8 - -10$ nucleotides in length, the sigma factor dissociates from the core polymerase, which continues elongation until encountering Rho (ρ) termination signals.
Final Answer: Sigma factor

Answer: (C)
Go Back to Question 4

Q5.

Solution

Concept: An electrocardiogram (ECG) measures surface electrical potentials generated by depolarization and repolarization waves traversing cardiac myocardium during each heartbeat.

Step 1: Analyze the P wave: Represents small upward deflection caused by atrial depolarization spreading from SA node across left and right atria, triggering atrial systole. **Step 2:** Analyze the QRS complex: Represents sharp, large amplitude deflection caused by rapid electrical depolarization sweeping through the thick ventricular myocardium via Bundle of His and Purkinje fibers. **Step 3:** Correlate mechanical event: Ventricular depolarization immediately initiates ventricular systole (contraction) and blood ejection into aorta and pulmonary trunk. Atrial repolarization occurs concurrently but is masked by the QRS wave.

Final Answer: Ventricular depolarization leading to ventricular systole

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: Microsporogenesis inside angiosperm anther sacs produces haploid microspores (n), which undergo asymmetric mitotic division to form mature pollen grains shed typically at the two-celled stage in over 60% of flowering plant species.

Step 1: Examine asymmetric mitosis inside microspore: The haploid microspore divides unequally into two distinct cells enclosed within exine and intine walls. **Step 2:** Identify the Tube cell (Vegetative cell): Larger cell containing abundant food reserves and a large irregularly shaped nucleus; guides pollen tube elongation down style. **Step 3:** Identify the Generative cell: Smaller spindle-shaped cell floating inside vegetative cytoplasm; subsequently divides mitotically inside the growing pollen tube to produce two non-motile sperm cells.

Final Answer: One larger vegetative tube cell and one smaller generative cell

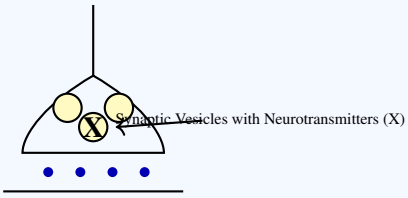
Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: Chemical synaptic transmission converts an electrical action potential arriving at presynaptic axon terminals into chemical neurotransmitter release across the synaptic cleft.



Synaptic Vesicle Exocytosis Mechanism

Step 1: Identify label X: Spherical membrane-bound organelles inside presynaptic terminals called Synaptic Vesicles. **Step 2:** Identify stored chemical contents: Synaptic vesicles pack thousands of neurotransmitter molecules (such as acetylcholine, dopamine, or glutamate). **Step 3:** Explain release mechanism: When depolarization opens voltage-gated calcium channels, Ca^{2+} influx triggers vesicle exocytosis, releasing neurotransmitters into the synaptic cleft.
Final Answer: Neurotransmitters

Answer: (A)
Go Back to Question 7

Q8.

Solution

Concept: Kingdom Fungi taxa are classified by sexual reproductive structures. Basidiomycetes represent advanced macroscopic club fungi including mushrooms, shelf fungi, rusts, and smuts.

Step 1: Review vegetative mycelium: Mycelium is branched, septate, and exists primarily in a secondary dikaryotic ($n + n$) state following somatogamy or plasmogamy. **Step 2:** Review karyogamy and meiosis: Inside specialized club-shaped terminal cells called basidia, two haploid nuclei fuse (karyogamy) to form a transient diploid nucleus ($2n$), which immediately undergoes meiotic division. **Step 3:** Review spore formation: Meiosis generates four haploid nuclei that migrate externally on sterigmata projections at the tip of each basidium, forming four exogenous sexual basidiospores.
Final Answer: Basidiomycetes

Answer: (C)
Go Back to Question 8

Q9.

Solution

Concept: Legume root nodules house symbiotic bacteroids of *Rhizobium* carrying out nitrogen fixation. Because nitrogenase is irreversibly destroyed by free molecular oxygen, root nodules produce Leghemoglobin.

Step 1: Identify the pink-red conjugated hemoprotein present inside host nodule cytoplasm surrounding bacteroids as Leghemoglobin. **Step 2:** Analyze oxygen affinity: Leghemoglobin exhibits an exceptionally high affinity for molecular oxygen, acting as an active oxygen buffer and scavenger. **Step 3:** Explain functional balance: It binds free intracellular O_2 to maintain anaerobic conditions at nitrogenase catalytic sites while facilitating steady oxygen diffusion to bacterial cytochromes for respiration.

Final Answer: Leghemoglobin

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: Blood coagulation involves an enzymatic cascade synthesizing fibrin clots. Several essential clotting factors synthesized in hepatocytes require post-translational carboxylation mediated by Vitamin K.

Step 1: Identify Vitamin K (phylloquinone / menaquinone), a fat-soluble vitamin obtained from green dietary leafy vegetables and intestinal bacterial synthesis. **Step 2:** Explain biochemical action: Vitamin K serves as a cofactor for the enzyme gamma-glutamyl carboxylase in the liver, adding carboxyl groups to glutamic acid residues on prothrombin (Factor II), Factor VII, Factor IX, and Factor X. **Step 3:** Explain physiological importance: Gamma-carboxylation enables these coagulation factors to bind calcium ions (Ca^{2+}) on phospholipid platelet membranes, initiating blood clotting upon vascular injury.

Final Answer: Vitamin K (Phylloquinone)

Answer: (D)

Go Back to Question 10

Q11.

Solution

Concept: Human chromosomal complement comprises 46 chromosomes: 22 pairs of autosomes (44) and 1 pair of sex chromosomes (XX in females, XY in males). Down syndrome results from primary non-disjunction of chromosome 21 during oogenesis or spermatogenesis.

Step 1: Calculate total chromosome count in Down syndrome trisomy 21:

$$\text{Total chromosomes} = 46 + 1 = 47$$

Step 2: Identify sex chromosomes in a female patient: Female possesses normal two X sex chromosomes (XX = 2 sex chromosomes). **Step 3:** Calculate exact number of autosomes by subtracting sex chromosomes from total chromosomes:

$$\text{Autosomes} = 47 - 2 = 45 \text{ autosomes}$$

Final Answer: 45 autosomes

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: Plasmid cloning vector pBR322 contains selectable marker genes encoding resistance to ampicillin (amp^R) and tetracycline (tet^R), allowing identification of recombinant transformants via insertional inactivation.

Step 1: Locate restriction enzyme recognition sites on pBR322: The recognition sequences for *BamHI* and *SalI* lie directly within the coding region of the tetracycline resistance gene (tet^R). **Step 2:** Analyze cloning ligation: When a foreign DNA fragment is spliced into the *BamHI* site, the open reading frame of the tet^R gene is disrupted. **Step 3:** Determine host phenotype: Host bacterial cells containing recombinant plasmids can grow on ampicillin plates but lose ability to synthesize tetracycline resistance protein, becoming susceptible to tetracycline (Insertional Inactivation).

Final Answer: Insertional inactivation resulting in susceptibility to tetracycline

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: Long-distance transport in vascular plants divides into xylem (unidirectional sap conduction) and phloem (bidirectional translocation of synthesized organic solutes).

Step 1: Identify Phloem tissue components: Consists of sieve tube elements, companion cells, phloem parenchyma, and phloem fibers. **Step 2:** Examine sieve tube elements: Living, elongated cylindrical cells placed end-to-end with perforated transverse end walls called sieve plates. **Step 3:** Analyze translocation mechanism: Driven by pressure-flow (mass flow) hypothesis, sucrose is actively loaded into sieve tubes at source leaves, drawing osmotic water influx and creating high hydrostatic pressure pushing sap toward sink organs.

Final Answer: Phloem tissue

Answer: (C)

Go Back to Question 13

Q14.

Solution

Concept: Adaptive cellular immunity depends on T-lymphocytes maturing in the thymus. T-cells differentiate into CD4+ Helper T-cells (orchestrating immune cascades) and CD8+ Cytotoxic T-cells (destroying intracellular pathogens).

Step 1: Identify Cytotoxic T-lymphocytes (T_C cells or CD8+ T-cells), which recognize viral peptide antigens presented on MHC Class I molecules on host cell membranes. **Step 2:** Explain killing mechanism: Upon binding infected target cells, T_C cells release pore-forming proteins called Perforins that puncture the target plasma membrane. **Step 3:** Granzyme proteases enter through perforin pores into target cytoplasm, activating caspase cascades that trigger programmed cell death (apoptosis) of virus-infected or tumor cells.

Final Answer: Cytotoxic T-lymphocytes (Tc cells)

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: Permanent surgical contraception methods (sterilization) interrupt gamete transport ducts, offering highly effective birth control without altering gonadal hormonal secretion or sexual function.

Step 1: Identify Vasectomy, the permanent surgical sterilization procedure performed in human males under local anesthesia. **Step 2:** Describe surgical protocol: A small bilateral incision is made in the scrotum, and a short segment of each vas deferens duct is excised and tied off with non-absorbable sutures. **Step 3:** Evaluate physiological outcome: Testes continue spermatogenesis and testosterone secretion normally, but spermatozoa cannot travel past the ligation site and are reabsorbed epididymally, rendering ejaculated semen completely azoospermic.
Final Answer: Vasectomy

Answer: (B)
Go Back to Question 15

Q16.

Solution

Concept: The neurohypophysis (posterior pituitary) stores and releases two nonapeptide hormones synthesized by hypothalamic neurosecretory neurons: Oxytocin and Antidiuretic Hormone (ADH / Vasopressin).

Step 1: Identify Oxytocin, synthesized in hypothalamic paraventricular and magnocellular nuclei and transported down supraoptic-hypophyseal axons to posterior pituitary axon terminals. **Step 2:** Explain parturition mechanism: At full term, stretch receptors in uterine cervix send neural reflex signals to hypothalamus, stimulating rapid bolus release of Oxytocin into blood circulation (Ferguson reflex). **Step 3:** Oxytocin binds myometrial receptors, inducing forceful peristaltic contractions of uterine smooth muscle pushing the fetus through the birth canal.
Final Answer: Oxytocin

Answer: (A)
Go Back to Question 16

Q17.

Solution

Concept: The Krebs cycle oxidizes Acetyl-CoA ($2C$) derived from pyruvate oxidative decarboxylation inside the mitochondrial matrix, transferring high-energy electrons to NAD^+ and FAD.

Step 1: Analyze initial reaction: Acetyl-CoA ($2C$) condenses with Oxaloacetic acid (OAA, $4C$) and water, catalyzed by Citrate synthase, yielding Citric acid (Citrate, $6C$), a tricarboxylic acid containing three $-COOH$ groups. **Step 2:** Calculate coenzyme reduction stoichiometry per turn (one Acetyl-CoA): - Dehydrogenation of Isocitrate $\rightarrow$ NADH + H^+ - Dehydrogenation of Alpha-ketoglutarate $\rightarrow$ NADH + H^+ - Dehydrogenation of Malate $\rightarrow$ NADH + H^+ Thus, exactly 3 molecules of NADH + H^+ form per cycle turn.

Final Answer: 1. Citric acid (Citrate) 2. Three molecules of NADH + H+

Answer: (See above)

Go Back to Question 17

Q18.

Solution

Concept: Complex permanent vascular plant tissues perform dedicated conduction roles: Xylem conducts water upward, while Phloem translocates synthesized organic photoassimilates.

Step 1: Xylem tissue consists of tracheids, vessels, xylem fibers, and xylem parenchyma. Tracheids and vessels are dead, hollow, lignified tubes conducting water upward from roots via transpiration pull. **Step 2:** Phloem tissue consists of living enucleate sieve tube elements joined end-to-end. Because sieve tubes lack nuclei at maturity, their metabolic activities are directed by closely associated nucleated companion cells connected via plasmodesmata.

Final Answer: 1. tracheids; xylem 2. sieve tubes; companion cells

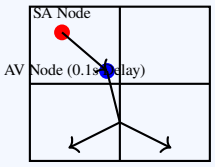
Answer: (See above)

Go Back to Question 18

Q19.

Solution

Concept: Cardiac electrical impulses generated at the SA node conduct through atrial myocardium to the Atrioventricular (AV) node, Bundle of His, and Purkinje fibers.



Cardiac Conduction Timing Flow

Step 1: Analyze AV nodal delay: As action potentials reach the AV node, conduction slows significantly (~ 0.1 seconds) due to smaller fiber diameter and fewer gap junctions. This delay allows atria to complete mechanical contraction and empty blood fully into ventricles before ventricular systole commences. **Step 2:** Identify Purkinje fibers: Rapidly conducting specialized terminal subendocardial fibers branching from Bundle branches throughout ventricular walls, ensuring simultaneous synchronous ventricular contraction.

Final Answer: 1. Allows complete atrial systole and ventricular filling before ventricular contraction commences 2. Purkinje fibres

Answer: (See above)

Go Back to Question 19

Q20.

Solution

Concept: Nutrient cycling and population dynamics define ecosystem balance and growth capacity.

Step 1: Biogeochemical cycles divide into gaseous (carbon, nitrogen) and sedimentary cycles (phosphorus, sulfur). Sedimentary cycles circulate elements weathered from lithospheric rock reservoirs without entering gaseous phases. **Step 2:** Biotic potential (r) represents the theoretical maximum reproductive rate of a biological population under unlimited environmental resources (abundant food, zero disease/predation).

Final Answer: 1. sedimentary 2. potential

Answer: (See above)

Go Back to Question 20

Q21.

Solution

Concept: Human brain structures execute distinct cognitive, autonomic, and endocrine integration roles.

Step 1: Cerebrum is the largest forebrain region governing conscious intelligence, sensory perception, memory, and voluntary motor planning → (a)-(ii). **Step 2:** Hypothalamus integrates autonomic and neuroendocrine functions, controlling thermoregulation, hunger, thirst, and circadian rhythms → (b)-(iv). **Step 3:** Medulla oblongata houses vital autonomic centers regulating heart rate, respiratory cadence, and vasomotor blood pressure tone → (c)-(iii). **Step 4:** Corpus callosum is a dense bundle of commissural myelinated nerve fibers connecting left and right cerebral hemispheres → (d)-(i).

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

Answer: (See above)

Go Back to Question 21

Q22.

Solution

Concept: Root system modifications allow plants to perform specialized mechanical support or respiratory adaptations in hostile environments.

Step 1: In large banyan trees (*Ficus benghalensis*), thick adventitious roots emerge from horizontal aerial branches and grow vertically down into soil like pillars, called prop roots. **Step 2:** In halophytic mangrove plants (*Rhizophora*) growing in oxygen-deficient saline marshy soils, specialized roots grow vertically upward above water level. Equipped with lenticel breathing pores (pneumathodes), these negatively geotropic roots are called pneumatophores.

Final Answer: 1. prop 2. pneumatophores

Answer: (See above)

Go Back to Question 22

Q23.

Solution

Concept: Endocrine hormone regulation of female reproductive cycles and pituitary hormones.

Step 1: Following ovulation, the ruptured follicle transforms into the corpus luteum, secreting abundant Progesterone. Progesterone stimulates vascular and glandular secretory thickening of endometrium, maintaining pregnancy, confirming statement 1 is TRUE. **Step 2:** Oxytocin is a posterior pituitary nonapeptide stimulating uterine contraction and myoepithelial milk ejection. Spermatogenesis inside male testicular Sertoli cells is stimulated by anterior pituitary FSH. Thus, statement 2 is FALSE.

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

Answer: (See above)

Go Back to Question 23

Q24.

Solution

Concept: Invertebrate phyla exhibit distinct diagnostic structural and excretory features.

Step 1: Porifera (sponges) possess a canal system lined by flagellated collar cells (choanocytes) drawing water through ostia pores → (a)-(iii). **Step 2:** Cnidaria exhibit radial symmetry and possess defensive stinging capsules called cnidocytes housing nematocysts → (b)-(iv). **Step 3:** Platyhelminthes (flatworms) are dorsoventrally flattened acoelomates utilizing ciliated flame cells (solenocytes) for osmoregulation and excretion → (c)-(ii). **Step 4:** Arthropoda represent the largest phylum equipped with jointed paired appendages and a chitinous protective exoskeleton → (d)-(i).

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

Answer: (See above)

Go Back to Question 24

Q25.

Solution

Concept: Quantitative genetic inheritance and structural chromosomal mutations.

Step 1: Polygenic (quantitative) inheritance occurs when multiple independent gene pairs contribute additive increments toward a continuous trait, such as human skin pigmentation governed by three loci (A, B, C). **Step 2:** Chromosomal mutations involve structural rearrangement of breaks: loss of an internal or terminal chromosomal segment containing genes is defined as a deletion (deficiency).

Final Answer: 1. polygenic 2. deletion

Answer: (See above)

Go Back to Question 25

Q26.

Solution

Concept: Tools and enzymatic reagents in recombinant DNA cloning and genetic engineering.

Step 1: Plasmid pBR322 is an extra-chromosomal circular self-replicating double-stranded cloning vector engineered with antibiotic resistance markers → (a)-(iii). **Step 2:** Restriction endonuclease *EcoRI* recognizes hexanucleotide palindrome $5' - GAATTC - 3'$ and cuts between G and A yielding sticky ends → (b)-(ii). **Step 3:** DNA polymerase I possesses $5' \rightarrow 3'$ exonuclease activity to excise RNA primers and polymerize DNA into repair gaps during replication → (c)-(iv). **Step 4:** Agrobacterium tumefaciens tumor-inducing (Ti) plasmid naturally transfers its T-DNA into plant genomes, serving as a plant transformation vector → (d)-(i).

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

Answer: (See above)

Go Back to Question 26

Q27.

Solution

Concept: Immunological memory generation versus parasitic pathogen vectors.

Step 1: Active immunity arises when host B-cells and T-cells encounter antigens directly during infection or vaccination, synthesizing endogenous antibodies and long-lived memory cells, confirming statement 1 is TRUE. **Step 2:** Human malaria is caused by red blood cell protozoan parasites (*Plasmodium falciparum*, *P. vivax*) transmitted by bites of female *Anopheles* mosquitoes. Claiming it is a viral disease transmitted by male *Culex* mosquitoes is completely FALSE.

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

Answer: (See above)

Go Back to Question 27

Q28.

Solution

Concept: Transcriptional control components of the inducible *lac* operon in *E. coli*.

Step 1: Promoter sequence (P) lies upstream where RNA polymerase holoenzyme recognizes and binds to initiate transcription → (a)-(ii). **Step 2:** Operator region (O) lies between promoter and structural genes acting as a regulatory switch where repressor protein binds → (b)-(iv). **Step 3:** Repressor protein is constitutively synthesized by regulator gene (i) and binds operator DNA to block RNA polymerase movement → (c)-(iii). **Step 4:** Structural genes (Z, Y, A) encode beta-galactosidase, permease, and transacetylase for lactose catabolism → (d)-(i).

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

Answer: (See above)

Go Back to Question 28

Q29.

Solution

Concept: Angiosperm fruits develop from fertilized ovaries and classify by gynoecium carpel number and pericarp fleshiness.

Step 1: Define Simple Fleshy Fruit (Berry): Fruit develops from a single flower possessing a monocarpellary or syncarpous multicarpellary superior or inferior ovary. The entire pericarp differentiates into a thin epicarp and thick fleshy/pulpy mesocarp and endocarp enclosing numerous seeds inside pulp. *Example:* Tomato (*Lycopersicon esculentum*) or Banana (*Musa paradisiaca*).
Step 2: Define Aggregate Fruit (Etaerio): Fruit develops from a single flower possessing an apocarpous (free, unfused) multicarpellary gynoecium. Each free carpel develops into a separate fruitlet, forming a clustered aggregate (etaerio) on a single receptacle receptacle axis. *Example:* Custard apple (Etaerio of berries) or Strawberry/Raspberry (Etaerio of achenes).
Final Answer: Berry develops from a syncarpous ovary with fleshy pericarp enclosing seeds (e.g., Tomato); Aggregate fruit develops from an apocarpous ovary forming a cluster of fruitlets on one receptacle (e.g., Custard apple).

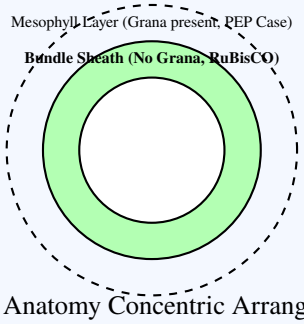
Answer: (See above)

Go Back to Question 29

Q30.

Solution

Concept: C4 tropical plants minimize photorespiratory carbon loss through specialized Kranz (wreath) leaf anatomy partitioning carboxylation spatially across two concentric cell layers.



Kranz Anatomy Concentric Arrangement

Step 1: Chloroplast Dimorphism: C4 leaves exhibit two distinct chloroplast types. Mesophyll chloroplasts are smaller and possess well-developed thylakoid grana stacks (granated) but lack RuBisCO. Bundle sheath chloroplasts are large, agranal (lacking grana stacks so no PS II oxygen evolution occurs), and packed with abundant RuBisCO enzyme. **Step 2:** Cellular Arrangement: C3 leaves lack bundle sheath chloroplasts and perform all carbon fixation inside undifferentiated mesophyll cells. C4 leaves possess a tightly packed ring of bundle sheath cells surrounding vascular bundles (Kranz anatomy) impervious to gaseous oxygen diffusion.

Final Answer: C4 leaves exhibit Kranz anatomy with concentric bundle sheath cells containing large agranal chloroplasts rich in RuBisCO, while mesophyll cells contain granal chloroplasts with PEP carboxylase; C3 leaves lack bundle sheath chloroplasts.

Answer: (See above)

Go Back to Question 30

Q31.

Solution

Concept: Rh maternal-fetal blood incompatibility causes hemolytic disease of the newborn. Incomplete dominance occurs when F1 heterozygotes display an intermediate blended phenotype.

Alternative (i): Step 1: Sensitization during First Pregnancy: When an Rh-negative mother carries an Rh-positive fetus, fetal erythrocytes entering maternal circulation during placental delivery at childbirth stimulate maternal B-cells to synthesize anti-Rh IgG antibodies and long-lived memory cells. **Step 2:** Pathogenesis during Second Pregnancy: If the subsequent fetus is also Rh-positive, circulating maternal anti-Rh IgG antibodies cross the placenta into fetal blood, agglutinating and hemolysis fetal red blood cells, causing severe anemia, jaundice, and hydrops foetalis (Erythroblastosis foetalis). Prevented by intramuscular injection of anti-D Rh immunoglobulin (RhoGAM) to the mother within 72 hours of first delivery.

Alternative (ii): Step 1: Cross setup in *Mirabilis jalapa*: Homozygous red-flowered plant (RR) is crossed with homozygous white-flowered plant (rr). **Step 2:** F1 generation phenotype: All F1 heterozygotes (Rr) bear pink flowers instead of dominant red, demonstrating neither allele is fully dominant over the other (blending incomplete dominance). **Step 3:** F2 generation ratio: Selfing F1 pink ($Rr \times Rr$) yields 1 Red (RR) : 2 Pink (Rr) : 1 White (rr). Thus, genotypic and phenotypic ratios are identical ($1:2:1$).

Final Answer: (i) Maternal anti-Rh IgG antibodies produced after first delivery cross placenta in second pregnancy, destroying Rh+ fetal RBCs causing Erythroblastosis foetalis. (ii) In *Mirabilis jalapa*, crossing Red (RR) and White (rr) yields intermediate F1 Pink (Rr); F2 selfing yields identical 1 Red : 2 Pink : 1 White ($1:2:1$) ratio.

Answer: (See above)

Go Back to Question 31

Q32.

Solution

Concept: Fundamental structural features separate chordates from non-chordates. Pteridophytes represent early vascular seedless land cryptogams.

Alternative (i): Step 1: Diagnostic features distinguishing Chordates: 1. Notochord: Possess a dorsal, solid, flexible skeletal rod (notochord) at some embryo stage (replaced by bony vertebral column in vertebrates); non-chordates lack a notochord. 2. Nerve Cord and Pharyngeal Slits: Possess a single, dorsal, hollow tubular nerve cord and paired pharyngeal gill slits; non-chordates possess a ventral solid double nerve cord and lack gill slits. **Step 2:** Two chordate examples: *Rana* (Frog) and *Homo sapiens* (Human).

Alternative (ii): Step 1: Characteristic features of Pteridophytes: 1. Independent Sporophyte dominance: The primary plant body is an independent diploid sporophyte ($2n$) differentiated clearly into true roots, stem, and leaves (fronds). 2. Vascular tissue differentiation: First terrestrial cryptogams to evolve true conducting vascular tissues (xylem lacking vessels and phloem lacking companion cells). **Step 2:** Two representative genera: *Dryopteris* (Fern) and *Selaginella*.

Final Answer: (i) Chordates possess dorsal notochord, dorsal hollow nerve cord, and pharyngeal slits (e.g., Frog, Human). (ii) Pteridophytes are dominant diploid sporophytes possessing true vascular xylem and phloem tissues (e.g., *Dryopteris*, *Selaginella*).

Answer: (See above)

Go Back to Question 32

Q33.

Solution

Concept: The Hardy-Weinberg equilibrium principle states that allele frequencies and genotype frequencies in a large randomly mating population remain constant across generations in the absence of evolutionary influences. Mathematically:

$$p + q = 1 \quad \text{and} \quad p^2 + 2pq + q^2 = 1$$

where p is dominant allele frequency (B), q is recessive allele frequency (b), q^2 is homozygous recessive genotype frequency (bb), and $2pq$ is heterozygous carrier frequency (Bb).

Step 1: Identify total population size ($N = 10,000$) and number of homozygous recessive white mice ($bb = 1,600$). **Step 2:** Calculate recessive genotype frequency (q^2):

$$q^2 = \frac{1600}{10000} = 0.16$$

Step 3: Calculate recessive allele frequency (q) by taking square root:

$$q = \sqrt{0.16} = 0.40$$

Step 4: Calculate dominant allele frequency (p) using $p + q = 1$:

$$p = 1 - q = 1 - 0.40 = 0.60$$

Step 5: Calculate expected heterozygous carrier genotype frequency ($2pq$):

$$2pq = 2 \times (0.60) \times (0.40) = 0.48$$

Step 6: Calculate exact expected number of heterozygous black carrier mice (Bb):

$$\text{Number of } Bb \text{ mice} = 2pq \times N = 0.48 \times 10,000 = 4,800 \text{ mice}$$

Final Answer: Allele frequency q (white b) = 0.40; Allele frequency p (black B) = 0.60; Expected number of heterozygous carriers (Bb) = 4,800 mice.

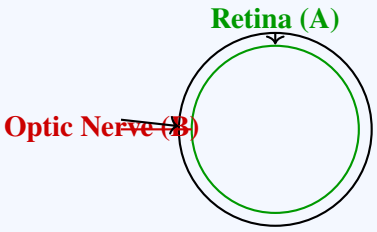
Answer: (See above)

Go Back to Question 33

Q34.

Solution

Concept: The human eye focuses light photons onto photoreceptor layers in the retina, transmitting action potentials via optic nerve fibers to visual cortex.



Detailed Eye Structural Identification

Step 1: Identify structural label A: Retina (innermost nervous sensory coat of the eyeball). **Step 2:** State primary function of A: Contains specialized light-sensitive photoreceptor rod cells (containing rhodopsin for scotopic night vision) and cone cells (containing iodopsin for photopic color daylight vision) that convert incident light photons into graded bioelectric nerve action potentials. **Step 3:** Identify structural label B: Optic Nerve (second cranial nerve exiting the posterior pole of the eyeball at the blind spot). **Step 4:** State primary function of B: Conducts visual sensory nerve impulses generated by retinal ganglion cells away from the eyeball to the lateral geniculate nucleus and occipital visual cortex of the brain for image interpretation.

Final Answer: A = Retina (photoreceptor layer converting light into bioelectric nerve impulses via rods and cones); B = Optic nerve (transmits visual sensory nerve action potentials from retina to occipital brain cortex).

Answer: (See above)

Go Back to Question 34

Q35.

Solution

Concept: Thyroid iodothyronine hormones regulate cellular metabolic rate. Pancreatic beta-cell insulin coordinates postprandial glucose uptake.

Alternative (i): Step 1: Basal Metabolic Rate (BMR) regulation: Thyroxine (T_4) and Triiodothyronine (T_3) bind nuclear receptors across body tissues to stimulate mitochondrial oxidative phosphorylation and oxygen consumption (calorigenic effect), accelerating cellular carbohydrate, lipid, and protein catabolism. **Step 2:** Growth and Neurological Development: Essential for normal physical skeletal maturation and metamorphosis (such as tadpole tail resorption), as well as myelination and dendritic branching of central nervous system neurons during fetal and infant brain development.
Alternative (ii): Step 1: Cellular Glucose Uptake: Insulin binds receptor tyrosine kinases on skeletal muscle myocytes and adipocytes, stimulating rapid translocation of GLUT4 glucose transporters to plasma membranes to accelerate cellular glucose uptake out of bloodstream. **Step 2:** Hepatic Glycogenesis: Insulin activates the enzyme glycogen synthase in hepatocytes and muscle cells to convert absorbed glucose into storage glycogen, while inhibiting gluconeogenesis and glycogenolysis.
Final Answer: (i) Thyroid hormones stimulate mitochondrial oxygen consumption/BMR and promote fetal neurological myelination/maturation. (ii) Insulin stimulates GLUT4 translocation for cellular glucose uptake and activates hepatic glycogenesis to convert glucose into glycogen.

Answer: (See above)

Go Back to Question 35

Q36.

Solution

Concept: Soil nitrogen transformations rely on chemolithotrophic bacteria for nitrification and anaerobic bacteria for denitrification.

Step 1: Define Nitrification: The aerobic biological two-step oxidation of ammonium (NH_4^+) into nitrite (NO_2^-) and subsequently into nitrate (NO_3^-) by soil chemolithotrophic bacteria. *Specific Nitrifying Bacterium:* *Nitrosomonas* (oxidizes ammonia to nitrite) or *Nitrobacter* (oxidizes nitrite to nitrate). **Step 2:** Define Denitrification: The anaerobic biological reduction of soil nitrate (NO_3^-) back into inert molecular nitrogen gas (N_2) or nitrous oxide (N_2O) that escapes into the atmosphere. *Specific Denitrifying Bacterium:* *Pseudomonas denitrificans* (or *Thiobacillus denitrificans*).
Final Answer: Nitrification is aerobic oxidation of ammonia to nitrate (e.g., *Nitrosomonas*); Denitrification is anaerobic reduction of nitrate to gaseous nitrogen (e.g., *Pseudomonas denitrificans*).

Answer: (See above)

Go Back to Question 36

Q37.

Solution

Concept: Entomophilous (insect-pollinated) flowers co-evolve specialized floral structures, fragrances, and nutritive rewards to ensure insect visitation and cross-pollination.

Step 1: Floral Display and Scent: Flowers are large, brightly colored, conspicuous, and emit strong volatile fragrances (sweet scents for bees/butterflies, foul odors for carrion flies) to guide insects visually and olfactorily toward floral organs. **Step 2:** Nutritive Floral Rewards: Flowers develop specialized nectar glands (nectaries) secreting sugar-rich nectar and produce edible, sticky, spiny pollen grains (covered by oily yellow pollenkit coat) that adhere readily to visiting insect bodies.

Final Answer: 1. Brightly colored, conspicuous petals emitting strong fragrances. 2. Production of sugar-rich nectar rewards and sticky pollen grains covered by pollenkit.

Answer: (See above)

Go Back to Question 37

Q38.

Solution

Concept: Precise definition of genetic linkage and plant transpiration/tropism physiology.

Step 1: Define Genetic Linkage (A): The physical tendency of two or more non-allelic genes located closely together on the same chromosome to resist recombination during meiotic crossing over and be inherited together as a single block in offspring. *Example:* Morgan's experiments in fruit fly *Drosophila melanogaster* showing tight physical linkage between genes for yellow body color (y) and white eye color (w) on the X chromosome ($< 1.3\%$ recombination).

Step 2: Define Phototropism (B): The directional growth curvature movement of plant organs in response to unidirectional light stimulation, governed by lateral redistribution of auxin (IAA) toward the shaded side. *Example:* Young coleoptile tips of sunflower or shoot apices of potted plants bending positively toward a sunlit window.

Step 3: Define Transpiration Pull (C): The negative hydrostatic tension (suction force) generated in continuous leaf xylem sap columns when water evaporates out of stomatal cavities during transpiration, pulling water columns upward from roots. *Example:* Dixon and Joly's cohesion-tension transpiration pull lifting water columns up to 100 meters high in giant redwood trees (*Sequoia sempervirens*).

Final Answer: A. Linkage: Co-inheritance of genes on one chromosome (e.g., yellow body/white eye in *Drosophila*). B. Phototropism: Directional bending toward light via auxin (e.g., shoot tips bending to sun). C. Transpiration pull: Negative hydrostatic suction lifting xylem water (e.g., sap ascent in tall redwood trees).

Answer: (See above)

Go Back to Question 38

Q39.

Solution

Concept: Prokaryotic transcription synthesizes mRNA via core polymerase assisted by initiation/termination factors. The inducible *lac* operon regulates lactose catabolism enzymes according to carbon availability.

Alternative (i): Step 1: Initiation: RNA polymerase core enzyme associates with Sigma (σ) factor to form holoenzyme. The sigma subunit recognizes upstream promoter consensus sequences (-10 Pribnow box and -35 region), unwinding localized DNA helix. **Step 2:** Elongation: After synthesizing $\sim 8 - -10$ ribonucleotides, the sigma factor dissociates. The core polymerase travels along the $3' \rightarrow 5'$ DNA template strand, polymerizing complementary ribonucleoside triphosphates ($5' \rightarrow 3'$) at ~ 40 nucleotides/sec. **Step 3:** Termination: Elongation continues until encountering a termination signal. In Rho (ρ)-dependent termination, the hexameric helicase Rho factor climbs along synthesized RNA transcript, catching up to paused polymerase at hairpin structures and unwinding RNA-DNA hybrid to release newly transcribed mRNA.
Alternative (ii): Step 1: Operon Architecture: Consists of regulator gene (i), promoter (P), operator (O), and structural genes Z (beta-galactosidase cleaving lactose), Y (permease), and A (transacetylase). **Step 2:** In absence of lactose (Inducer absent): The active tetrameric repressor protein transcribed continuously by the i gene binds tightly to the operator (O) region. This steric blockade prevents RNA polymerase from moving past the promoter, shutting off transcription (negative repression). **Step 3:** In presence of lactose (Inducer present): Allolactose (derived from ingested lactose) binds specific allosteric sites on the repressor protein, causing conformational inactivation. The inactivated repressor cannot bind operator DNA; RNA polymerase transcribes polycistronic mRNA freely.
Final Answer: (i) Sigma factor initiates promoter recognition; core enzyme elongates mRNA; Rho factor unwinds RNA-DNA hybrid to terminate transcription. (ii) Repressor from i gene binds operator blocking transcription in lactose absence; when lactose inducer binds repressor, operator clears allowing transcription of Z, Y, A genes.

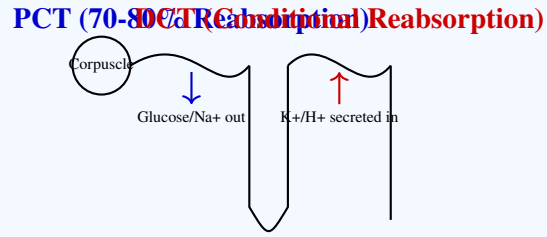
Answer: (See above)

Go Back to Question 39

Q40.

Solution

Concept: Nephron tubular segments perform selective reabsorption of filtered nutrients and active tubular secretion of metabolic wastes to regulate plasma osmolality and acid-base balance.



Tubular Reabsorption and Secretion Dynamics

Step 1: Proximal Convoluted Tubule (PCT) Anatomical Adaptation: Lined by simple cuboidal brush-border epithelium packed with microvilli and mitochondria, expanding surface area enormously. **Step 2:** PCT Reabsorption and Secretion: Reabsorbs virtually 100% of filtered glucose and amino acids by sodium co-transport, and reabsorbs 70–80% of filtered electrolytes (Na^+, Cl^-, HCO_3^-) and water osmotically. Actively secretes H^+, K^+, and ammonia (NH_3) into filtrate to maintain blood pH around 7.4. **Step 3:** Distal Convoluted Tubule (DCT) Role: Lined by simple cuboidal epithelium. Under aldosterone hormone stimulation, performs facultative reabsorption of remaining Na^+ and water. Under parathyroid hormone (PTH) influence, reabsorbs Ca^{2+}. Actively secretes potassium (K^+) and protons (H^+) in exchange for reabsorbed sodium.
Final Answer: PCT brush-border cuboidal cells reabsorb 100% glucose/amino acids and 70-80% electrolytes/water while secreting H+/NH3; DCT performs hormone-dependent facultative reabsorption of Na+/water (via aldosterone) and Ca2+ while secreting K+/H+.

Answer: (See above)

Go Back to Question 40

Q41.

Solution

Concept: Protozoan vector-borne malaria and bacterial enteric typhoid fever require distinct diagnostic and clinical management protocols.

Alternative (i): Step 1: Pathogen and Vector: Malaria is caused by red blood cell protozoan parasites (*Plasmodium falciparum* causing malignant cerebral malaria, *P. vivax*, *P. malariae*). Transmitted through saliva during blood meals of female *Anopheles* mosquitoes. **Step 2:** Erythrocytic Schizogony: Infective sporozoites undergo hepatic multiplication into merozoites. Merozoites invade red blood cells, developing into signet-ring trophozoites and multinucleated schizonts. Rupture of infected RBCs releases thousands of merozoites and toxic hemozoin pigment into plasma. **Step 3:** Clinical Symptoms: Hemozoin release triggers periodic violent paroxysms of shaking chills (rigors) followed by high fever (40°C) recurring every 48 hours, profuse sweating, hemolytic anemia, and splenomegaly.

Alternative (ii): Step 1: Pathogen and Transmission: Typhoid fever is caused by the flagellated Gram-negative enteric bacterium *Salmonella enterica serovar Typhi*. Transmitted via fecal-oral ingestion of food or drinking water contaminated by infected human feces or chronic typhoid carriers. **Step 2:** Clinical Symptoms: Bacteria invade small intestine Peyer's patches and enter lymphatic/systemic circulation, causing sustained step-ladder high fever ($39 - -40$°C), severe abdominal pain, 'rose spots' rash on chest, relative bradycardia, and intestinal ulceration or perforation in severe third-week cases. **Step 3:** Diagnosis and Treatment: Confirmed serologically by the Widal agglutination test detecting anti-O and anti-H somatic antibodies. Treated using fluoroquinolones (Ciprofloxacin) or cephalosporins.

Final Answer: (i) Malaria caused by *Plasmodium* via female *Anopheles* mosquito; RBC rupture releases hemozoin causing recurring 48-hour shaking chills and high fever. (ii) Typhoid caused by *Salmonella typhi* via fecal-oral route; causes sustained step-ladder high fever and intestinal ulcers; diagnosed serologically by Widal test.

Answer: (See above)

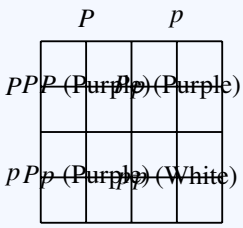
Go Back to Question 41

Q42.

Solution

Concept: Mendelian monohybrid segregation establishes discrete particulate gene inheritance. Monocot caryopsis structure provides specialized scutellar and protective coleoptile sheaths during embryo germination.

Alternative (i): Step 1: Law of Segregation: Allelic pairs governing a trait separate cleanly during meiotic gamete formation without blending, ensuring every gamete receives exactly one pure allele (P or p). **Step 2:** Monohybrid Cross: Homozygous Purple (PP) × White (pp) yields F1 heterozygotes (Pp) all expressing dominant Purple flowers. **Step 3:** F2 Selfing ($Pp \times Pp$) Punnett Square:



Step 4: Derivation of Ratios: - Genotypic ratio: $1PP : 2Pp : 1pp$ (1 : 2 : 1). - Phenotypic ratio: 3 Purple ($PP + 2Pp$) : 1 White (pp) (3 : 1).

Alternative (ii): Step 1: Monocot Seed Structure (Maize grain): A one-seeded fruit (caryopsis) where the outer pericarp fruit wall fuses tightly with the seed coat. **Step 2:** Endosperm and Aleurone: The large upper interior consists of triploid starchy endosperm storing carbohydrate reserves, separated from the embryo by a protein-rich outer layer called the aleurone layer. **Step 3:** Scutellum and Embryo Axis: The embryo contains a single shield-shaped cotyledon called the scutellum positioned laterally alongside the embryonal axis. **Step 4:** Coleoptile and Coleorhiza Functional Roles: The embryonic shoot apex (plumule) is protected by a hollow, conical sheath called the coleoptile that pushes upward through soil abrasions during germination. The embryonic root tip (radicle) is protected by an undifferentiated protective cap called the coleorhiza that ruptures as roots anchor in soil.

Final Answer: (i) Law of segregation confirmed by monohybrid F2 Punnett square yielding genotypic ratio $1PP : 2Pp : 1pp$ (1 : 2 : 1) and phenotypic ratio 3 Purple : 1 White (3 : 1). (ii) Monocot caryopsis contains fused pericarp, proteinaceous aleurone layer, starchy endosperm, and single shield cotyledon (scutellum); coleoptile sheath protects emerging plumule while coleorhiza sheath protects emerging radicle during germination.

Answer: (See above)

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Q43.

Solution

Concept: Glycolysis breaks down glucose anaerobically into two pyruvate molecules in cytoplasm. Synaptic transmission relies on vesicle exocytosis and neurotransmitter-receptor binding across synaptic clefts.

Alternative (i): Step 1: Preparatory Phosphorylation Phase (Energy Investment): 1. Glucose is phosphorylated by Hexokinase consuming 1 ATP → Glucose-6-phosphate. 2. Isomerized by Phosphoglucoisomerase → Fructose-6-phosphate. 3. Phosphorylated by Phosphofructokinase-1 consuming 1 ATP → Fructose-1,6-bisphosphate. 4. Cleaved by Aldolase into two 3-carbon triose sugars: Glyceraldehyde-3-phosphate (G3P) and Dihydroxyacetone phosphate (DHAP). DHAP isomerizes into G3P. **Step 2:** Payoff Phase (Energy Yield per 2 molecules of G3P): 5. Oxidized and phosphorylated by G3P dehydrogenase → two 1,3-bisphosphoglycerate + 2 NADH. 6. Substrate-level phosphorylation by Phosphoglycerate kinase yielding 2 ATP → two 3-phosphoglycerate. 7. Mutated by Phosphoglyceromutase → two 2-phosphoglycerate. 8. Dehydrated by Enolase releasing 2 H_2O → two Phosphoenolpyruvate (PEP). 9. Substrate-level phosphorylation by Pyruvate kinase yielding 2 ATP → two Pyruvate ($3C$). **Step 3:** Net Energetic Yield: Total ATP produced = 4. ATP invested = 2. Net gain = 2 ATP + 2 NADH per glucose.
Alternative (ii): Step 1: Action Potential Arrival: An electrical action potential traveling down the presynaptic axon depolarizes the terminal axolemma, causing voltage-gated calcium channels to open. **Step 2:** Calcium Influx and Exocytosis: Calcium ions (Ca^{2+}) rush inward down their electrochemical gradient, binding synaptotagmin proteins. This stimulates synaptic vesicles containing Acetylcholine (ACh) to fuse with presynaptic membrane and release ACh into the synaptic cleft via exocytosis. **Step 3:** Receptor Binding and Postsynaptic Potential: ACh diffuses across the narrow 20 nm cleft and binds nicotinic ligand-gated Na^+ receptor channels on the postsynaptic dendritic membrane. Channel opening causes sodium influx, generating an Excitatory Postsynaptic Potential (EPSP) that triggers a new postsynaptic nerve impulse. **Step 4:** Signal Termination: Acetylcholinesterase (AChE) enzyme present on postsynaptic membrane rapidly hydrolyzes ACh into acetate and choline, closing receptor channels and allowing presynaptic reuptake.
Final Answer: (i) Glycolysis converts 1 glucose into 2 pyruvate via 10 cytoplasmic steps; invests 2 ATP and yields 4 ATP via substrate-level phosphorylation, giving net yield of 2 ATP and 2 NADH. (ii) Action potential opens voltage-gated Ca2+ channels causing Ca2+ influx; stimulates synaptic vesicles to exocytose acetylcholine across cleft; ACh binds postsynaptic nicotinic receptors causing Na+ influx and EPSP generation, terminated by acetylcholinesterase hydrolysis.

Answer: (See above)

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Answer Key

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