UPCATET Agriculture Botany Sample Paper-9

Duration: 20 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **25** Multiple Choice Questions.
- Each correct answer carries **+4** mark. Incorrect answer: **−1** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. An anatomical investigation of an unknown halophytic xerophyte reveals an atypical anomalous secondary growth pattern. The cambium arises in a normal position but functions abnormally, producing alternating concentric bands of xylem and phloem interspersed with heavily lignified conjunctive tissue. Concurrently, the mechanical security of its rigid stem relies on a specialized hypodermal layer. Identify the true structural configuration of this specimen from the choices below:

(A) Anomalous secondary growth via a single persistent cambium, supplemented by a multiseriate chlorenchymatous hypodermis.

(B) Anomalous secondary growth via successive rings of accessory cambia, supplemented by a heavily sclerified, fibrous hypodermis.

(C) Primary vascular anomalies featuring medullary bundles, protected by an epidermal collenchymatous sheath.

(D) Cortical vascular bundle inversion accompanied by an unlignified parenchymatous pericycle.

Q2. A legume breeder observes a rare genetic homeotic mutation in a cross-pollinated population of *Cajanus cajan* (pigeon pea). In the mutant floral architecture, the specialized structures responsible for enclosing and mechanically protecting the diadelphous stamens and the single carpel fail to fuse along their anterior margins, remaining as two separate, free lateral units. Which specific component of the typical papilionaceous corolla has been structurally disrupted by this mutation?

(A) Vexillum

(B) Alae

(C) Carina

(D) Lodicules

Q3. A comparative developmental analysis is conducted on the root apical meristem (RAM) of monocotyledonous vs dicotyledonous agricultural crops. An investigator discovers a highly quiescent center characterized by low mitotic activity, minimal RNA synthesis, and depressed protein turnover. Under which specific microenvironmental stress condition does this quiescent center abruptly switch into an active proliferative zone to regenerate damaged initial cells?

(A) Severe hypersaline osmotic stress inducing systemic abscisic acid (ABA) collapse.

(B) Mechanical ablation or acute ionizing radiation targeting the actively dividing surrounding initials.

(C) Hyper-optimal exogenous application of gibberellic acid (GA_3) under waterlogged conditions.

(D) Photoperiodic shifts triggering sudden floral evocation within the root cortical parenchyma.

Q4. The structural configuration of the endodermis in primary roots acts as a strict physiological checkpoint. In a mutant line of *Zea mays*, the biosynthetic pathway for suberin deposition is completely knocked out, preventing the formation of Casparian strips. What is the immediate biophysical consequence on radial water and solute transport across this mutant root?

(A) Complete cessation of the symplastic pathway, forcing all water through the unregulated apoplastic continuum.

(B) Uncontrolled, non-selective apoplastic influx of toxic ions into the stele, accompanied by an inability to maintain root pressure.

(C) Accelerated transcellular active transport of macronutrients due to reduced physical resistance at the pericycle interface.

(D) Complete structural collapse of the xylem vessels owing to hyper-turgor pressure within the cortical cells.

Q5. An agronomist evaluates the structural mechanics of the compound inflorescence of a certain grain legume. The inflorescence possesses a main axis that continues to grow, while the lateral branches exhibit a highly condensed, sympodial arrangement mimicking a single macro-flower. This complex architectural morphology is structurally classified as a:

(A) Thyrse (Mixed panicle with racemose main axis and cymose lateral branches)

(B) Corymbose Verticillaster

(C) Coenanthium with an invaginated fleshy receptacle

(D) Compound Hypanthodium

Q6. An anatomical investigation of a mature, weathered stem from a commercial woody vine crop reveals an unusual structural anomaly. The primary vascular cambium operates normally for a limited period but eventually ceases its activity entirely. It is replaced by successive layers of accessory cambia that arise outside the original vascular cylinder within the deep cortical parenchyma or pericycle, creating concentric rings of secondary tissue. In which specific crop plant is this distinct anatomical configuration a diagnostic feature?

(A) *Beta vulgaris*

(B) *Boerhavia diffusa*

(C) *Mirabilis jalapa*

(D) *Bougainvillea spectabilis*

Q7. The phyllode of *Acacia auriculiformis* and the cladode of *Ruscus aculeatus* represent classical paradigms of evolutionary modification. At a strict ontogenetic and anatomical level, how do these two structures differ from one another?

(A) The phyllode is a modified stem with limited growth, while the cladode is a modified petiole with indefinite growth.

(B) The phyllode is a modified petiole or rachis exhibiting leaf-like anatomy, whereas the cladode is a modified green stem of limited growth capable of photosynthesis.

(C) Both are homologous structures derived entirely from the stipular primordia of highly evolved desert succulents.

(D) The phyllode displays exarch xylem architecture, while the cladode maintains endarch siphonostelic bundles without an epidermis.

Q8. Microscopic examination of the mechanical tissue of a wind-exposed cucurbit stem reveals specialized patches of living mechanical tissue showing heavily thickened primary walls composed of cellulose and pectin, with prominent thickening concentrated specifically at the corners where several cells meet. Which statement correctly characterizes this tissue type?

(A) Sclerenchyma fibers possessing highly lignified secondary walls with numerous bordered pits.

(B) Angular collenchyma, which retains protoplasmic vitality and exhibits high tensile strength but lacks elasticity when calcified.

(C) Angular collenchyma, capable of plastic extension, heavily hydrated, and completely devoid of secondary lignification.

(D) Brachysclereids (stone cells) displaying concentric rings of suberized lamellae.

Q9. A high-throughput molecular marker screening confirms the taxonomic placement of a newly developed oilseed crop within the family Brassicaceae (Cruciferae). Which combination of unique diagnostic floral characters must this crop display to validate this taxonomic grouping?

(A) Actinomorphic symmetry, pentamerous calyx, monadelphous stamens, and a caruncle-bearing seed.

(B) Cruciform corolla, tetradynamous androecium (2 + 4 stamens), bicarpellary syncarpous ovary with a false septum called a replum.

(C) Zygomorphic corolla, papilionaceous petals, diadelphous stamens (9 + 1), and marginal placentation.

(D) Epigynous flower, syngenesious anthers with basal placentation, and a modified pappus calyx.

Q10. A geneticist crosses a pure-breeding yellow-seeded variant of an ornamental cereal grass with a pure-breeding white-seeded mutant. The resulting F_1 generation produces entirely purple seeds. Upon selfing the F_1 individuals, the F_2 progeny displays a complex phenotypic segregation ratio of $9/16$ purple, $3/16$ yellow, and $4/16$ white. Which specific genetic interaction mechanism operates between the two non-allelic loci governing seed pigmentation in this crop?

(A) Recessive epistasis

(B) Dominant epistasis

(C) Duplicate genes

(D) Polymeric gene action

Q11. The Poaceae (Gramineae) family dominates global cereal production. Structurally, the grain or fruit of wheat, rice, and maize is not a simple naked seed but a specialized complex entity. Select the precise description of this structure:

(A) Achene, where the pericarp remains completely separate from the seed coat except at a basal point.

(B) Caryopsis, an indehiscent single-seeded fruit in which the pericarp is completely fused and inseparable from the underlying testa.

(C) Cremocarp, which splits at maturity into two distinct single-seeded mericarps supported by a carpophore.

(D) Regma, derived from a multicarpellary pistil that dehisces explosively via elastic valves.

Q12. A mutation breeding program in *Cicer arietinum* (Fabaceae) yields a phenotypic variant with severely altered floral architecture. The vexillum (standard petal) fails to develop, while the alae (wings) and carina (keel) remain intact. How does this structural deficit directly interfere with the pollination biology of this agricultural crop?

(A) It halts self-pollination completely because the vexillum is solely responsible for secreting the nectar rewards.

(B) It disrupts the descending imbricate aestivation mechanism, exposing the reproductive organs prematurely and inducing uncontrolled cross-pollination or desiccation.

(C) It causes an immediate shift from zygomorphic to complete actinomorphic wind-pollination via anther extrusion.

(D) It forces the plant to undergo obligate cleistogamy due to overproduction of standard petal inhibitors.

Q13. A pharmaceutical firm wants to extract specialized tropane alkaloids (hyoscyamine and scopolamine) from agricultural field crops. Which crop combination from the following options should be selected to maximize production based strictly on their botanical family classification?

(A) *Datura stramonium* and *Atropa belladonna* (Solanaceae)

(B) *Medicago sativa* and *Glycine max* (Fabaceae)

(C) *Sorghum bicolor* and *Pennisetum glaucum* (Poaceae)

(D) *Brassica oleracea* and *Raphanus sativus* (Brassicaceae)

Q14. The character state 'gynandrous condition' paired with a specialized 'pollinium' mechanism represents an elite evolutionary adaptation for entomophilous pollination. Although rare in standard field crops, this botanical feature is prominently exploited in classifying which advanced medicinal plant group related to wild agro-ecosystems?

(A) Liliaceae (onion and garlic group)

(B) Asclepiadaceae / Apocynaceae (Calotropis complex)

(C) Malvaceae (cotton and okra group)

(D) Asteraceae (sunflower group)

Q15. Consider the unique inflorescence type known as a Cyathium, characteristic of certain agro-forestry and ornamental plants within the Euphorbiaceae family. Which of the following statements accurately summarizes its structural composition?

(A) It contains a single, naked central female flower surrounded by numerous scorpioid cymes of naked male flowers, all enclosed in a cup-shaped involucre of bracts.

(B) It consists of a deeply invaginated fleshy receptacle forming a hollow cavity lined internally by male flowers at the top and female flowers at the bottom.

(C) It is a modified condensed spike where every individual flower is completely bisexual and lacks any bract protection.

(D) It features a flat, disc-like receptacle bearing marginal ray florets and central disc florets with syngenesious anthers.

Q16. A crop physiology experiment monitors the photosynthetic rate of sugarcane (C_4) versus wheat (C_3) under escalating atmospheric CO_2 concentrations paired with elevated thermal stress. At an ambient temperature of 42°C and low internal intercellular CO_2 (C_i), the carboxylation efficiency of wheat drops catastrophically compared to sugarcane. What molecular event explains this performance divergence?

(A) RuBisCO in wheat shifts its kinetic property toward its oxygenase activity due to decreased O_2/CO_2 solubility ratio at high temperatures, driving massive photorespiratory loss.

(B) PEP carboxylase in sugarcane undergoes thermal denaturation, preventing malate transportation to bundle-sheath cells.

(C) The C_4 pathway runs out of ATP molecules because cyclic photophosphorylation is completely blocked above 35°C.

(D) Wheat down-regulates its Photosystem II reaction centers via non-photochemical quenching to specifically synthesize callose plugs.

Q17. A legume crop physiologist isolates a temperature-sensitive mutant line of *Rhizobium leguminosarum*. At a permissive temperature of 22°C, root nodule development and atmospheric nitrogen fixation proceed normally. However, when the soil temperature is raised to a restrictive 34°C, nitrogenase activity drops to zero within hours, despite the presence of functional leghemoglobin. Biochemical analysis reveals that the structural integrity of the nitrogenase enzyme complex remains intact, but the specific electron-transfer flow from the bacterial respiratory chain to the MoFe-protein is completely blocked. Which specific multi-subunit iron-sulfur protein or electron donor is primary target of this temperature-induced block?

(A) The Fe-protein (dinitrogenase reductase), which fails to undergo the MgATP-induced conformational change required to alter its redox potential and transfer electrons to the MoFe-protein.

(B) Cytochrome *c* oxidase, which fails to generate the transmembrane proton motive force necessary for direct substrate carboxylation.

(C) Plastocyanin, which undergoes irreversible thermal denaturation and disrupts the cyclic photophosphorylation pathway of the host plant.

(D) Bacteroid outer membrane porins, which stop the passive counter-flux of malate and succinate into the host plant cytoplasm.

Q18. A mutant line of *Oryza sativa* displays stomatal complexes that fail to close even under severe drought conditions or direct exogenous treatment with high levels of abscisic acid (ABA). Molecular characterization reveals a loss-of-function mutation in a crucial guard-cell anion channel. Which ion channel is defective, and why does its failure prevent stomatal closure?

(A) The inward-rectifying K^+ channel (KAT1); its failure blocks K^+ entry, causing mandatory hyperpolarization.

(B) The slow vacuolar (SV) calcium channel; its failure keeps internal vacuolar calcium levels permanently exhausted.

(C) The SLAC1 (Slow Anion Channel 1); its failure prevents the efflux of anions (Cl^- and malate^{2-}), preventing the plasma membrane depolarization required to activate outward-rectifying K^+ channels.

(D) The aquaporin PIP2 channel; its failure traps water inside the cytoplasm via covalent bonding.

Q19. During the biochemical operations of the Tricarboxylic Acid (TCA) cycle in plant mitochondria, a critical regulatory checkpoint exists where a multi-enzyme complex catalyses an irreversible oxidative decarboxylation that bridges glycolysis to the Krebs cycle. Which specific co-factors are strictly required for the optimal performance of this pyruvate dehydrogenase complex (PDH)?

(A) Thiamine pyrophosphate (TPP), Lipoic acid, Coenzyme A (CoA-SH), FAD, and NAD^+.

(B) Biotin, Pyridoxal phosphate, Adenosine triphosphate (ATP), and $NADP^+$.

(C) Ascorbate, Plastoquinone, Tetrahydrofolate, and Cytochrome *c*.

(D) Flavin mononucleotide (FMN), Ubiquinone, and Ferredoxin.

Q20. The Non-Photochemical Quenching (NPQ) pathway protects the photosynthetic apparatus of crop plants from photoinhibition during sudden high-light spikes. The core mechanism requires the rapid enzymatic interconversion of xanthophyll pigments. Choose the correct molecular sequence of this protective cycle when a plant transitions from shade to intense, damaging sunlight:

(A) Zeaxanthin is rapidly oxidized to Violaxanthin by the enzyme violaxanthin de-epoxidase under alkaline stromal conditions.

(B) Violaxanthin is rapidly converted into Antheraxanthin and then into Zeaxanthin by the enzyme violaxanthin de-epoxidase, activated by a low (acidic) thylakoid lumen pH.

(C) Neoxanthin absorbs excess photons and converts them into metabolic heat through direct cleavage into abscisic acid precursors.

(D) Lutein shifts directly into a triplet excited state to synthesize singlet oxygen species within the stroma lamellae.

Q21. A seed physiology specialist analyzes the respiratory quotient (RQ) of germinating oilseeds (such as castor or mustard) during their initial radical emergence phase. The measured RQ value is consistently found to be approximately 0.70. What does this value indicate regarding substrate utilization and metabolic processing?

(A) Pure carbohydrate oxidation occurs through the standard pentose phosphate pathway without any alternative terminal oxidase activity.

(B) Highly reduced lipid substrates (fatty acids) are undergoing highly oxygenic β-oxidation and glyoxylate cycle processing, requiring more oxygen consumption relative to carbon dioxide evolution.

(C) Anaerobic fermentation is running concurrently, producing excessive carbon dioxide relative to oxygen utilization.

(D) Organic acids (such as malate or citrate) are being broken down directly under extreme hypoxia.

Q22. A cytogenetic examination of a trial population of an interspecific tetraploid crop species reveals a high degree of pollen sterility. Meiotic analysis at diakinesis shows aberrant chromosome configurations where non-homologous segments have reciprocal exchanges, leading to the formation of characteristic cross-shaped quadrivalents. What specific structural chromosomal aberration is responsible for this meiotic pathology?

(A) Large-scale homozygous paracentric inversions creating dicentric bridges during Anaphase I.

(B) Reciprocal translocation (segmental interchange) between non-homologous chromosomes, leading to alternate or adjacent segregation patterns.

(C) Intercalary deletions spanning the main ribosomal RNA cistrons within the nucleolar organizer region.

(D) Simple tandem duplications inducing loop formations during the leptotene stage.

Q23. In an advanced genetic mapping experiment using two linked loci controlling stem pigmentation (P/p) and leaf shape (L/l) in a diploid crop, a testcross of a dihybrid individual ($\frac{PL}{pl}$) yields the following progeny distribution: Parental types = 84%, Recombinant types = 16%. What is the precise genetic distance separating these two loci, and what would be the expected frequency of recombinants if the dihybrid parent was in a repulsion phase ($\frac{Pl}{pL}$)?

(A) 16 cM; Expected recombinant frequency remains exactly 16% because linkage phase does not alter map distance.

(B) 8 cM; Expected recombinant frequency drops to 0% due to phase inversion barriers.

(C) 32 cM; Expected recombinant frequency scales up to 84% because recombination is suppressed in repulsion.

(D) 42 cM; The loci undergo independent assortment during the repulsion phase.

Q24. The eukaryotic cell cycle is strictly governed by the sequential activation and destruction of highly specific protein complexes. During plant somatic cell division (mitosis), a multi-subunit ubiquitin ligase known as the Anaphase-Promoting Complex/Cyclosome (APC/C) must trigger the destruction of a key regulatory protein to initiate the sudden physical separation of sister chromatids. Identify this target protein and its mechanism:

(A) Lignin polymerase; its destruction permits the breakdown of the persistent nuclear envelope.

(B) Securin; its destruction releases the active enzyme separase, which then cleaves the cohesin complex holding the sister chromatids together.

(C) Kinesin motor proteins; their degradation triggers the depolymerization of astral microfilaments.

(D) Histone H_1; its destruction induces immediate chromatin decondensation at the metaphase plate.

Q25. A plant breeder crosses a pure-breeding white-flowered mutant line of *Pisum sativum* with another independently isolated pure-breeding white-flowered mutant line. Surprisingly, all F_1 progeny display wild-type purple flowers. When the F_1 generation is selfed, the resulting F_2 population segregates into a strict ratio of 9 purple : 7 white. What genetic interaction mechanism explains this phenotypic distribution?

(A) Dominant Epistasis, where a dominant allele at one locus masks the phenotypic expression of alleles at a second locus.

(B) Duplicate Recessive Epistasis (Complementary Gene Action), requiring at least one dominant allele at both distinct loci to produce the purple phenotype.

(C) Inhibitory Gene Interaction, where a single dominant suppressor gene actively blocks the pigment pathway.

(D) Polygenic additive inheritance involving three independent codominant loci running in parallel.

Detailed Solutions

Q1.

Solution

Concept: Anomalous secondary growth via successive rings of accessory cambia is a characteristic feature of several families within the order Caryophyllales (such as Nyctaginaceae and Amaranthaceae). In these plants, a series of concentric, additional cambia arise outside the original vascular cylinder in the pericycle or deep cortex, producing alternating rings of xylem and phloem embedded in a lignified conjunctive tissue. This structural adaptation is often accompanied by a heavily sclerified, fibrous hypodermis to provide high mechanical stability.

Solution:

Let's analyze the anatomical configurations described in the problem:

- **Accessory Cambia Activity:** In typical dicotyledonous stems, a single cambial ring produces secondary xylem inwardly and secondary phloem outwardly. However, in many halophytic or xerophytic members of the Caryophyllales, the primary cambium ceases function early. It is replaced by **successive rings of accessory cambia** arising in the outer parenchymatous pericycle or inner cortex.
- **Tissue Differentiation:** Each new accessory cambium divides to produce patches of secondary xylem inwardly and secondary phloem outwardly. Simultaneously, the interspersed ground cells divide and differentiate into a heavily lignified **conjunctive tissue** matrix, forming alternating concentric bands of vascular tissues.
- **Mechanical Reinforcement:** To support the rigid stem architecture against physical lodging and structural collapse during moisture deficits, the outer tissue layer features a highly specialized, **heavily sclerified, fibrous hypodermis** situated directly beneath the epidermis.

This combination aligns perfectly with Option (B), distinguishing it from primary anomalies like medullary bundles or single persistent abnormal cambia.

Final Answer: Anomalous secondary growth via successive rings of accessory cambia, supplemented by a heavily sclerified, fibrous hypodermis.

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: The papilionaceous corolla (characteristic of the sub-family Papilionoideae in the family Fabaceae) displays a distinct arrangement of five petals with descending imbricate aestivation. The innermost, anterior pair of petals are fused along their lower margins to form a boat-shaped structure called the carina (or keel), which encloses and protects the reproductive organs (stamens and pistil).

Solution:

The specialized floral architecture of the pulse crop *Cajanus cajan* relies on a precise organization of its five corolla petals:

(a) **Vexillum (Standard):** The largest, outermost posterior petal that overlaps the lateral ones in the bud stage and acts as a visual advertisement for pollinators.

(b) **Alae (Wings):** Two free lateral petals that flank the central assembly and serve as landing platforms for foraging insects.

(c) **Carina (Keel):** The innermost, anterior structural unit. It is ontogenetically derived from two distinct petal primordia that normally **fuse along their anterior margins** to form a protective, boat-shaped housing. This shield completely encloses the diadelphous staminal column ($[9]+1$) and the single superior carpel, keeping them safe from premature mechanical damage, dehydration, and non-specific insect pillaging.

Because the homeotic mutation described prevents these two anterior units from fusing—leaving them as separate, free lateral components—the structural identity of the **carina** has been directly disrupted.

Final Answer: $\boxed{\text{Carina}}$

$\boxed{\textbf{Answer: (C)}}$

Go Back to Question 2

Q3.

Solution

Concept: The quiescent center (QC) is a central core of slowly dividing cells within the root apical meristem (RAM). The QC maintains the surrounding actively dividing stem cell initials in an undifferentiated state; it acts as an emergency reservoir that transitions into an active, proliferative zone to regenerate the meristem if those surrounding initial cells are destroyed by mechanical ablation or ionizing radiation.

Solution:

The root apical meristem (RAM) is organized around a specialized cellular domain called the **quiescent center (QC)**:

- **Basal Physiological State:** Under optimal, un-stressed growth conditions, cells within the QC divide at a dramatically lower rate (10× to 20× slower) compared to the surrounding initial cells. They exhibit reduced rates of RNA transcription, low protein synthesis, and a prolonged G1 phase of the cell cycle. This slow metabolism minimizes the accumulation of spontaneous DNA replication mutations.
- **Functional Role:** The primary function of the QC is to emit local short-range signaling molecules (such as the transcription factor WUSCHEL-RELATED HOMEOBOX 5, or WOX5) that prevent the adjacent stem cell initials from differentiating prematurely.
- **Emergency Activation:** Because the actively dividing initials surrounding the QC are highly sensitive to environmental stressors, they are the first to undergo programmed cell death when exposed to **acute ionizing radiation** or direct **mechanical ablation**.
- **Regeneration Mechanism:** When these surrounding initials are destroyed, the inhibitory signal balance changes. The QC cells abruptly exit their dormant state, re-enter the active cell cycle, and undergo rapid asymmetric divisions to fully restore and rebuild the damaged stem cell niche.

Final Answer: Mechanical ablation or acute ionizing radiation targeting the actively dividing surrounding initials.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: The Casparian strip is a ring-like band of suberin deposition embedded within the anticlinal (radial and transverse) cell walls of the root endodermis. It serves as a waterproof barrier that blocks the apoplastic movement of water and dissolved solutes, forcing them to cross the semi-permeable plasma membrane into the living symplast to enter the vascular cylinder. Without it, non-selective solute movement occurs, and root pressure drops.

Solution:

Let's analyze the biophysical role of the endodermal checkpoint in radial water and solute transport:

(a) **Normal Apoplastic Barrier:** Water and dissolved mineral ions absorbed from the soil move relatively freely through the porous cellulose matrix of cell walls (the apoplastic continuum) across the root cortex. Upon reaching the single-layered endodermis, the hydrophobic **Casparian strip** blocks this apoplastic path.

(b) **Selective Filtration:** Because the cell wall path is blocked, all water and solutes must cross the plasma membrane of endodermal cells, shifting into the symplastic pathway. This lets the plant selectively uptake essential macronutrients via specialized transporter proteins while excluding heavy metals or toxic salts.

(c) **Consequences of a Knockout Mutation:** In a mutant corn line where suberin synthesis is completely knocked out, the Casparian strip fails to form. This removes the physical barrier, allowing an **uncontrolled, non-selective apoplastic influx** of water and potentially harmful soil ions directly into the xylem vessels of the stele.

(d) **Loss of Root Pressure:** Additionally, because the endodermis is no longer a waterproof seal, the vascular cylinder can no longer maintain a concentrated solute gradient. Solutes simply leak back into the cortex via passive apoplastic diffusion, destroying the osmotic gradient needed to generate and maintain **root pressure** during periods of low transpiration.

Final Answer: Uncontrolled, non-selective apoplastic influx of toxic ions into the stele, accompanied by an inability to maintain root pressure.

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: A thyrse is a mixed or compound inflorescence characterized by an indeterminate (racemose) main growth axis that continues to elongate, while the lateral branches show a determinate (cymose) or condensed branching pattern. This combination frequently creates a compact, dense arrangement that can visually resemble a single compound flower structure.

Solution:

To classify the complex architectural morphology of the grain legume inflorescence described, let's analyze its structural components:

- **Main Growth Axis:** The primary axis is indeterminate, meaning its terminal apical bud continues to grow and produce new nodes over time without ending in a terminal flower. This is a classic **racemose** pattern.
- **Lateral Branching:** The branches that arise from the main axis display a highly condensed, determinate arrangement where each branch ends in a terminal flower, with subsequent growth continuing from lateral sub-buds. This is a **sympodial (cymose)** pattern.
- **Mixed Architecture:** An inflorescence that combines an indeterminate main axis with determinate, cymose lateral branching is structurally classified as a **thyrse** (or a mixed panicle).

This arrangement packs the flowers closely together along the lateral axes, creating a dense pseudanthium display that helps attract insect pollinators. This structure is distinct from a verticillaster (condensed axillary cymes in whorls) or a hypanthodium (an inverted, hollow fleshy cup, as seen in figs).

Final Answer: $\boxed{\text{Thyrse (Mixed panicle with racemose main axis and cymose lateral branches)}}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 5

Q6.

Solution

Concept: Anomalous secondary growth via successive rings of accessory cambia is a characteristic taxonomic feature of several arborescent or climbing genera within the family Nyctaginaceae. In the popular woody vine crop *Bougainvillea spectabilis*, the primary cambium ceases activity early and is replaced by successive concentric rings of extra-fascicular cambia arising in the pericycle, forming distinct bands of vascular tissue embedded in lignified conjunctive parenchyma.

Solution:

Let's evaluate the structural traits of the plant specimens listed to find the correct match:

(a) *Beta vulgaris* (Amaranthaceae) exhibits concentric rings of accessory cambia, but it is an herbaceous root crop (sugar beet), not a woody vine.

(b) *Boerhavia diffusa* and *Mirabilis jalapa* are herbaceous members of the Nyctaginaceae family that display anomalous vascular bundles, but they lack a long-lived, woody vine stem structure.

(c) *Bougainvillea spectabilis* is a commercial, woody, climbing ornamental vine crop belonging to the family **Nyctaginaceae**.

Its old stems exhibit a classic diagnostic anomaly: the primary cambium ceases function after a short period. New **accessory cambia** then differentiate in a concentric sequence further outward within the pericyclic parenchyma. Each successive cambial layer divides to produce secondary xylem inwardly, secondary phloem outwardly, and heavily lignified conjunctive tissue between the bundles. This process forms the dense, ringed, resilient wood necessary to sustain its climbing habit over many years.

Final Answer: $\boxed{\text{Bougainvillea spectabilis}}$

Answer: (D)

Go Back to Question 6

Q7.

Solution

Concept: A phyllode and a cladode are distinct architectural adaptations to arid environments. A phyllode is a modified, flattened petiole or rachis that assumes leaf-like functions and anatomy while the true leaves are reduced or absent. In contrast, a cladode is a modified green stem or branch of limited growth that performs photosynthesis and may bear small leaves or flowers at its nodes.

Solution:

Let's compare the ontogenetic origins and anatomical structures of these two xerophytic adaptations:

- **Phyllode (*Acacia auriculiformis*):** This structure is a modification of the **foliar apparatus**. In response to dry conditions, the regular lamina fails to develop or falls off early. The **petiole or parts of the rachis** flatten out, develop chlorophyll, and expand into a blade-like structure. Anatomically, it retains features of leaf tissue, such as a localized vascular pattern and a lack of true nodal/internodal divisions along its photosynthetic plane.

- **Cladode (*Ruscus aculeatus*):** This structure is a modification of the **cauline apparatus**. It arises from an axillary bud and is a **green, flattened stem branch of limited growth** (often only one or two internodes long). Because it is a stem modification, it displays stem anatomy under the microscope, including an endarch siphonostele or dictyostele, and it can produce true flowers or leaves from the nodes located along its surface.

This distinction confirms that Option (B) accurately describes their structural differences, whereas the other options conflate their growth patterns or tissue types.

Final Answer: $\boxed{\text{The phyllode is a modified petiole or rachis exhibiting leaf-like anatomy, whereas the cladode is a modified green stem of limited growth capable of photosynthesis.}}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: Angular collenchyma is a living mechanical tissue characterized by primary cell walls that are unevenly thickened, with cellulose and pectin deposits concentrated primarily at the angles or corners where multiple cells meet. This tissue remains metabolically active, lacks secondary lignification, and is capable of plastic extension to support rapidly elongating organs like cucurbit stems.

Solution:

Let's analyze the microscopic features of the mechanical tissue described in the problem:

(a) **Wall Composition:** The primary cell walls are composed of **cellulose, hemicellulose, and high concentrations of hydrophilic pectin**. There is no secondary cell wall deposition and a complete absence of **lignification**, meaning the tissue remains highly hydrated and pliable.

(b) **Thickening Pattern:** The deposition of these cell wall components is not uniform. It is concentrated at the cell corners where several walls join, which is the defining characteristic of **angular collenchyma**.

(c) **Vital Status:** Unlike sclerenchyma, collenchyma cells retain their living protoplasts at maturity, allowing them to adjust their wall structure in response to mechanical stresses like wind.

(d) **Biomechanical Performance:** Because its walls are non-lignified, angular collenchyma can undergo **plastic extension**. This allows it to stretch alongside growing tissues, providing tensile strength without restricting the elongation of young stems or petioles, such as those found in the family Cucurbitaceae.

Final Answer: Angular collenchyma, capable of plastic extension, heavily hydrated, and completely devoid of secondary lignification.

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: The family Brassicaceae (Cruciferae) is characterized by a stable suite of diagnostic floral markers: a cruciform corolla consisting of four clawed petals arranged in a cross, a tetradynamous androecium made up of six stamens arranged in two whorls (2 short outer + 4 long inner), and a bicarpellary syncarpous superior ovary that becomes falsely bilocular due to a false internal partition wall called the replum.

Solution:

To validate the taxonomic placement of an oilseed variety within the family Brassicaceae, the specimen must exhibit several distinctive floral traits:

- **Cruciform Corolla:** The whorl contains four distinct, diagonal petals. Each petal is differentiated into a narrow basal claw and a broad, spreading limb, arranged in the shape of a cross.
- **Tetradynamous Androecium:** The flower contains six total stamens organized in a 2 + 4 configuration: two short lateral stamens in the outer whorl, and four long median stamens in the inner whorl.
- **Replum-bearing Gynoecium:** The pistil consists of a superior, bicarpellary, syncarpous ovary. While initially unilocular with parietal placentation, it develops a thin, membranous false septum known as a **replum** that divides the chamber into two false compartments.

Option (B) lists this complete combination of characters, which distinguishes the Brassicaceae from families like Solanaceae (Option A), Fabaceae (Option C), or Asteraceae (Option D).

Final Answer: Cruciform corolla, tetradynamous androecium (2+4 stamens), bicarpellary syncarpous ovary with a false septum called a replum.

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: Recessive epistasis occurs when a homozygous recessive genotype at one gene locus masks or suppresses the phenotypic expression of alleles at an independent second locus. This gene interaction modifies the standard 9 : 3 : 3 : 1 Mendelian dihybrid di-hybrid ratio into a characteristic 9 : 3 : 4 segregation pattern in the F_2 generation.

Solution:

Let's analyze the inheritance pattern of seed coat color described:

(a) **Parental and F_1 Generation:** Crossing a pure-breeding yellow variant ($AAbb$) with a pure-breeding white mutant ($aaBB$) yields a uniform F_1 generation with a purple phenotype ($AaBb$). This indicates that the production of the purple pigment requires the cooperative interaction of dominant alleles from both distinct genes.

(b) **F_2 Segregation Analysis:** Selfing the $AaBb$ individuals generates a population distributed across the four standard Mendelian classes in a sixteenth-based ratio:

$$9\ A\_B\_ : 3\ A\_bb : 3\ aaB\_ : 1\ aabb$$

(c) **Epistatic Interaction Alignment:**

- The $9/16$ $A\_B\_$ individuals carry dominant alleles at both loci, allowing the complete biosynthetic pathway to run and producing the **purple** phenotype.
- The $3/16$ A_bb individuals lack a dominant allele at the second locus, resulting in the intermediate **yellow** phenotype.
- The remaining individuals include the $3/16$ $aaB\_$ and $1/16$ $aabb$ classes. Here, the homozygous recessive condition at the first locus (aa) acts epistatically, completely blocking the pathway and masking the expression of the B or b alleles. This collapses both classes into a single phenotypic group ($3+1 = 4$), producing the **white** phenotype.

The resulting 9 : 3 : 4 ratio matches the calculated distribution of $9/16$ purple, $3/16$ yellow, and $4/16$ white, confirming the presence of **recessive epistasis** (complementary-type masking).

Final Answer: $\boxed{\text{Recessive epistasis}}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 10

Q11.

Solution

Concept: A caryopsis is a simple, dry, indehiscent single-seeded fruit characteristic of the family Poaceae. In this fruit type, the pericarp (outer fruit wall) is completely and inseparably fused with the underlying testa (seed coat) during development, forming a single, integrated grain structure.

Solution:

Let's evaluate the structural classification of the fruit harvested from staple cereal crops like wheat, rice, and maize:

- **Achene:** A simple dry fruit that resembles a caryopsis but differs because the pericarp remains distinct from the seed coat, attached to it only at a single basal point (as seen in some Ranunculaceae members).
- **Cremocarp:** A dry schizocarpic fruit characteristic of the Apiaceae family that splits into two single-seeded mericarps at maturity.
- **Caryopsis (Grain):** The diagnostic fruit type of the family **Poaceae**. It develops from a superior, monocarpellary unilocular ovary. As the fruit matures, the pericarp undergoes extensive cellular compression and merges directly with the underlying coat of the single seed (**the testa**). This complete fusion creates an inseparable layer, meaning the entire grain functions mechanically and structurally as a single unit.

This structural integration protects the internal starch-rich endosperm and embryo from mechanical and environmental damage during storage and dispersal.

Final Answer: $\boxed{\text{Caryopsis, an indehiscent single-seeded fruit in which the pericarp is completely fused and inseparable from the underlying testa.}}$

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The vexillum (standard petal) is the large, posterior outermost petal in the descending imbricate aestivation pattern of a papilionaceous flower. Its main biological function is to enclose and protect the inner wing and keel petals in the bud stage, and to act as a prominent visual signal to attract pollinating insects.

Solution:

Let's analyze the structural consequences of a mutation that prevents the development of the vexillum in *Cicer arietinum* (chickpea):

(a) **Aestivation Breakdown:** Papilionaceous flowers utilize a specialized arrangement called **descending imbricate aestivation**. In the bud, the large posterior vexillum folds over and tightly encloses the two lateral alae (wings), which in turn overlap the two anterior fused carina (keel) petals.

(b) **Loss of Protection:** Without the vexillum, this structural sequence is broken. The inner flower parts lose their primary protective shield in the bud stage, exposing the delicate stamens and carpel to early mechanical stress, drying winds, and premature insect encounters.

(c) **Impact on Pollination:** Chickpeas are naturally adapted for specialized insect pollination or coordinated self-pollination within the closed petal envelope. Exposing these reproductive organs prematurely can lead to **uncontrolled cross-pollination** by non-specific vectors or cause the tissues to dry out and fail before fertilization occurs.

Final Answer: It disrupts the descending imbricate aestivation mechanism, exposing the reproductive organs prematurely and inducing uncontrolled cross-pollination or desiccation.

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: Tropane alkaloids such as hyoscyamine and scopolamine are secondary metabolites synthesized primarily within certain genera of the family Solanaceae. The species *Datura stramonium* (jimsonweed) and *Atropa belladonna* (deadly nightshade) are classic botanical sources that produce high concentrations of these compounds.

Solution:

To optimize the commercial extraction of specialized tropane alkaloids, a firm must select crops based on their biochemical profiles and taxonomic classifications:

- **Tropane Alkaloids Compound Profile:** Hyoscyamine and scopolamine are anticholinergic drugs that act as competitive antagonists at muscarinic acetylcholine receptors. Their biosynthesis is highly localized within specific evolutionary lineages.
- **Solanaceae Alignment:** The family **Solanaceae** (the nightshade family) possesses the metabolic pathways needed to produce these alkaloids. Specifically, the genera *Datura* and *Atropa* contain high concentrations of these compounds in their leaves, roots, and seeds.
- **Specimen Matching:** Selecting ***Datura stramonium*** and ***Atropa belladonna*** maximizes the yield of these raw materials. Families like Fabaceae (legumes), Poaceae (grasses), or Brassicaceae (crucifers) do not produce tropane alkaloids, synthesizing different secondary metabolites instead (such as flavonoids, cyanogenic glycosides, or glucosinolates).

Final Answer: Datura stramonium and Atropa belladonna (Solanaceae)

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: The combination of a gynandrous condition (where stamens are fused with the carpel structure) and a specialized pollinium mechanism (where pollen grains are bound together into a single mass) is a key diagnostic adaptation for insect pollination in the family Asclepiadaceae (Apocynaceae complex).

Solution:

Let's analyze the evolutionary adaptations described in the problem:

(a) **Gynandrous Structure:** In typical flowers, the stamens and pistil remain structurally separate. In a gynandrous flower, the filaments and anthers fuse directly with the style or stigmatic disc of the gynoecium, creating a single, central reproductive column.

(b) **Pollinium Mechanism:** Instead of releasing individual, powdery pollen grains, the entire pollen content of an anther sac is bound together by a sticky glycoprotein matrix into a single, cohesive unit called a **pollinium**. Two adjacent pollinia are joined by a translator arm to a central adhesive clip (the corpusculum).

(c) **Taxonomic Distribution:** This specialized pollination mechanism is highly developed in two main lineages: the Orchidaceae (orchids) and the **Asclepiadaceae** (commonly represented in wild agro-ecosystems by the *Calotropis* complex). In the Asclepiadaceae, this fusion forms a five-angled structural unit known as a gynostegium, which coordinates pollen transfer via insects.

Final Answer: $\boxed{\text{Asclepiadaceae / Apocynaceae (Calotropis complex)}}$

$\boxed{\textbf{Answer: (B)}}$

Go Back to Question 14

Q15.

Solution

Concept: A cyathium is a highly specialized, condensed pseudanthium inflorescence characteristic of the genus *Euphorbia* (family Euphorbiaceae). It consists of a single central female flower reduced to a solitary stalked pistil, surrounded by multiple male flowers each reduced to a single stamen, all enclosed within a cup-shaped involucre formed by fused bracts.

Solution:

Let's analyze the structural components of a cyathium inflorescence:

- **Involucre Chamber:** A collection of protective bracts fuses together to form a cup-shaped structure called an involucre. The rim of this cup often bears nectar-secreting glands to attract insect pollinators.
- **Central Female Flower:** Located at the exact center of the cup is a solitary female flower. It is highly reduced (naked), lacking sepals and petals, and consists purely of a tricarpellary, syncarpous pistil supported on a long pedicel that often bends over the rim at maturity.
- **Surrounding Male Flowers:** Arranged around this central female flower are multiple male flowers organized in scorpioid cymes. Like the female flower, each male flower is reduced to its evolutionary minimum: a single stamen attached to a pedicel, with a distinct joint marking the stem interface.

This combination mimics the appearance of a single, perfect flower, which distinguishes it from the hollow, enclosed receptacle of a hypanthodium (as seen in figs) or the flat disc of a capitulum (as seen in sunflowers).

Final Answer: It contains a single, naked central female flower surrounded by numerous scorpioid cymes of naked male flowers, all enclosed in a cup-shaped involucre of bracts.

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: At high temperatures, the ratio of dissolved CO_2 to O_2 in leaf tissues decreases because CO_2 solubility drops more rapidly than O_2 solubility. This shift drives the bifunctional enzyme RuBisCO in C_3 plants (like wheat) to favor its oxygenase activity over carboxylation, leading to a severe increase in photorespiratory carbon loss. In contrast, C_4 plants (like sugarcane) use PEP carboxylase to concentrate CO_2 around RuBisCO, maintaining high photosynthetic efficiency under these conditions.

Solution:

Let's break down the biochemical basis for the performance difference between these two photosynthetic pathways under high thermal stress (42°C):

(a) **Gas Solubility Shifts:** As ambient temperatures rise, the absolute solubility of both oxygen (O_2) and carbon dioxide (CO_2) gases decreases in the aqueous environment of the leaf cell. However, CO_2 solubility drops much more sharply than O_2 solubility, leading to an increased O_2/CO_2 ratio around the photosynthetic enzymes.

(b) **RuBisCO Kinetic Behavior:** The core carboxylating enzyme in C_3 plants, RuBisCO, is a bifunctional catalyst. When the O_2/CO_2 ratio increases at high temperatures, RuBisCO shifts its activity toward its **oxygenase function**. It fixes O_2 onto ribulose-1,5-bisphosphate instead of CO_2, initiating the photorespiratory (C_2) cycle. This process can waste up to 25–40% of the plant's fixed carbon and energy.

(c) **The C_4 Concentrating Advantage:** Sugarcane avoids this limitation by using a spatial separation mechanism. Initial carbon fixation is handled in the mesophyll cells by **PEP carboxylase**, an enzyme with a high affinity for bicarbonate (HCO_3^-) and no oxygenase activity. The fixed carbon is transported as malate into the bundle-sheath cells and decarboxylated, creating a high local concentration of CO_2 that suppresses RuBisCO's oxygenase activity even at high temperatures.

Final Answer: RuBisCO in wheat shifts its kinetic property toward its oxygenase activity due to the decreased O_2/CO_2 solubility ratio at high temperatures, driving massive photorespiratory loss.

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept: The nitrogenase enzyme complex consists of two primary protein components: the Fe-protein (dinitrogenase reductase) and the MoFe-protein (dinitrogenase). The Fe-protein acts as the obligate electron donor to the MoFe-protein; this transfer requires a conformational change driven by MgATP binding to alter its redox potential. If this step is blocked, nitrogen fixation ceases completely.

Solution:

Let's analyze the biochemical mechanism of electron transfer within the nitrogenase complex during biological nitrogen fixation:

- **Complex Architecture:** The functional nitrogenase apparatus contains two highly conserved multi-subunit proteins: the smaller homodimeric **Fe-protein** (dinitrogenase reductase) and the larger heterotetrameric **MoFe-protein** (dinitrogenase).
- **Electron Transfer Cascade:** Electrons derived from bacterial metabolism flow from ferredoxin or flavodoxin to the Fe-protein. The Fe-protein must then bind two molecules of MgATP. This binding induces a critical **conformational change** that drops its redox potential from -310 mV to -420 mV.
- **Inhibitory Block:** This conformational shift allows the Fe-protein to transiently dock with the MoFe-protein, transferring an electron alongside ATP hydrolysis. If a temperature-sensitive mutation blocks this MgATP-induced conformational change or prevents proper docking at 34°C, the transfer of electrons to the catalytic MoFe-protein stops entirely. Without this electron flow, the reduction of atmospheric N_2 to NH_3 drops to zero, even if leghemoglobin is present and the individual protein structures remain intact.

Final Answer: $\boxed{\text{The Fe-protein (dinitrogenase reductase), which fails to undergo the MgATP-induced conformational change required to alter its redox potential and transfer electrons to the MoFe-protein.}}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: The SLAC1 (Slow Anion Channel 1) is a primary channel responsible for mediating the efflux of anions (such as Cl^- and malate^{2-}) from guard cells during stomatal closure. A loss-of-function mutation in SLAC1 prevents this anion efflux, blocking the plasma membrane depolarization required to activate outward-rectifying K^+ channels and leaving the stomata open under drought or ABA treatment.

Solution:

Stomatal closure in response to drought stress or Abscisic Acid (ABA) signaling is regulated by coordinated ion fluxes across the plasma membrane of guard cells:

(a) **Normal Closing Cascade:** Binding of ABA activates signaling pathways that trigger the opening of anion channels on the plasma membrane. The primary channel for this slow-type anion current is **SLAC1**.

(b) **Depolarization Switch:** When open, SLAC1 allows accumulated anions (Cl^- and malate^{2-}) to flow out of the cytoplasm down their electrochemical gradients. This rapid loss of negative charges **depolarizes** the plasma membrane.

(c) **Potassium Efflux Activation:** This positive shift in membrane potential activates voltage-gated **outward-rectifying K^+ channels** (such as GORK). Potassium ions then rush out of the cell, followed by water via osmosis, which decreases turgor and closes the stomatal pore.

(d) **Impact of SLAC1 Failure:** In a mutant line lacking a functional SLAC1 channel, the efflux of anions is blocked. As a result, the membrane cannot undergo the sustained depolarization needed to open the outward-rectifying K^+ channels. Potassium and water remain trapped inside the guard cells, keeping them turgid and preventing the stomata from closing even under severe drought or high ABA levels.

Final Answer: The SLAC1 (Slow Anion Channel 1); its failure prevents the efflux of anions (Cl^- and malate^{2-}), preventing the plasma membrane depolarization required to activate outward-rectifying K^+ channels.

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept: The Pyruvate Dehydrogenase Complex (PDH) is a multi-enzyme assembly that catalyzes the irreversible oxidative decarboxylation of pyruvate into acetyl-CoA, bridging glycolysis with the Tricarboxylic Acid (TCA) cycle. This complex requires five specific catalytic co-factors to operate: Thiamine pyrophosphate (TPP), Lipoic acid, Coenzyme A (CoA-SH), FAD, and NAD^+.

Solution:

The pyruvate dehydrogenase complex (PDH) is located within the mitochondrial matrix and consists of three catalytic enzymes: pyruvate dehydrogenase (E_1), dihydrolipoyl transacetylase (E_2), and dihydrolipoyl dehydrogenase (E_3).

To catalyze the conversion of pyruvate to acetyl-CoA, this complex requires the coordinated action of five distinct co-factors:

- **Thiamine Pyrophosphate (TPP):** Bound to E_1, it binds and decarboxylates the incoming three-carbon pyruvate molecule, releasing CO_2.
- **Lipoic Acid (Lipoamide):** Attached to E_2, its disulfide group acts as an electron acceptor and a flexible arm that transfers the remaining acetyl group from E_1 to E_2.
- **Coenzyme A (CoA-SH):** Serves as the substrate acceptor at E_2, reacting with the acetyl group to form the final product, **acetyl-CoA**.
- **FAD (Flavin Adenine Dinucleotide):** Bound to E_3, it re-oxidizes the reduced lipoamide arm, accepting two electrons and two protons to form $FADH_2$.
- **NAD^+ (Nicotinamide Adenine Dinucleotide):** Acts as the final electron acceptor, oxidizing $FADH_2$ back to FAD and leaving the complex ready for another catalytic cycle while producing NADH + H^+.

Option (A) accurately lists all five required co-factors, distinguishing it from alternative options that include unrelated vitamins or photosynthetic intermediates.

Final Answer: $\boxed{\text{Thiamine pyrophosphate (TPP), Lipoic acid, Coenzyme A (CoA-SH), FAD, and } NAD^+.}$

$\boxed{\textbf{Answer: (A)}}$

Go Back to Question 19

Q20.

Solution

Concept: The xanthophyll cycle is a photoprotective mechanism within non-photochemical quenching (NPQ) that helps protect the photosynthetic apparatus from excess light energy. Under intense sunlight, a low (acidic) pH within the thylakoid lumen activates the enzyme violaxanthin de-epoxidase, which rapidly converts violaxanthin into antheraxanthin and then into zeaxanthin, which safely dissipates excess excitation energy as heat.

Solution:

When a crop plant transfers from shade to intense, potentially damaging sunlight, its photosystems absorb more light energy than can be utilized by carbon assimilation. To prevent photoinhibition, the plant activates the xanthophyll cycle:

(a) **Lumen Acidification:** Excess electron transport leads to a rapid accumulation of protons (H^+) within the thylakoid lumen, causing its pH to drop below 5.5.

(b) **Enzyme Activation:** This low, acidic lumen pH activates the membrane-bound enzyme **violaxanthin de-epoxidase (VDE)**.

(c) **Pigment Interconversion:** Activated VDE acts on the pigment pool within the light-harvesting complexes, removing epoxy groups to convert the diepoxide **violaxanthin** into the monoepoxide intermediate **antheraxanthin**, and finally into the epoxide-free carotenoid **zeaxanthin**.

(d) **Energy Dissipation:** Zeaxanthin directly interacts with excited chlorophyll states, trapping excess singlet excitation energy and dissipating it safely as thermal energy (heat). This prevents the formation of destructive singlet oxygen species. When the plant returns to low-light conditions, the process is reversed by the stroma-facing enzyme violaxanthin epoxidase.

Final Answer: Violaxanthin is rapidly converted into Antheraxanthin and then into Zeaxanthin by the enzyme violaxanthin de-epoxidase, activated by a low (acidic) thylakoid lumen pH.

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept: The Respiratory Quotient (RQ) is the ratio of the volume of carbon dioxide (CO_2) evolved to the volume of oxygen (O_2) consumed during cellular respiration. For highly reduced chemical substrates like lipids and fatty acids, oxidation requires a larger amount of oxygen relative to the amount of carbon dioxide released, resulting in a characteristic RQ value of approximately 0.70.

Solution:

The Respiratory Quotient (RQ) is calculated using the following relationship:

$$RQ = \frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ consumed}}$$

Let's analyze what a value of 0.70 indicates during the germination of oilseeds like castor or mustard:

- **Substrate Composition:** Oilseeds store their primary energy reserves in the form of triacylglycerols (fats). Compared to carbohydrates (which have a typical RQ = 1.0), lipids are highly reduced molecules containing relatively few oxygen atoms relative to their carbon and hydrogen chains.
- **Metabolic Pathways:** During the initial radicle emergence phase, these stored lipids are broken down into fatty acids and oxidized via **β-oxidation** and the **glyoxylate cycle** to generate sucrose for the growing embryo.
- **Stoichiometry of Oxidation:** Because of the reduced nature of these fatty acids, their complete oxidative breakdown requires a substantial amount of atmospheric oxygen to convert the hydrogen atoms to water, while releasing a lower proportion of CO_2 molecules. For example, the oxidation of the typical fatty acid oleic acid follows this balance:

$$C_{18}H_{34}O_2 + 25.5\ O_2 \rightarrow 18\ CO_2 + 17\ H_2O \implies RQ = \frac{18}{25.5} \approx 0.705$$

This low ratio confirms that the seedling is actively metabolizing lipid reserves rather than carbohydrates or organic acids.

Final Answer: $\boxed{\text{Highly reduced lipid substrates (fatty acids) are undergoing highly oxygenic } \beta\text{-oxidation and glyoxylate cycle processing, requiring more oxygen consumption relative to carbon dioxide evolution.}}$

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept: Reciprocal translocations involve the exchange of chromosome segments between non-homologous chromosomes. During prophase I of meiosis (diakinesis), heterozygous reciprocal translocations cause the four participating chromosomes to line up together, forming a characteristic cross-shaped quadrivalent structure. This configuration can lead to abnormal segregation and high pollen sterility.

Solution:

Let's analyze the meiotic behavior of the chromosome configuration described:

(a) **Structural Rearrangement:** A **reciprocal translocation** occurs when two non-homologous chromosomes break simultaneously and exchange segments. When an individual is heterozygous for this translocation, it carries one normal and one translocated copy of each chromosome.

(b) **Meiotic Pairing Dynamics:** During the zygotene and pachytene stages of Prophase I, homologous chromosome segments must pair up precisely. To maximize pairing between these exchanged segments, all four chromosomes align together, forming a distinctive **cross-shaped quadrivalent cluster**.

(c) **Diakinesis Visualization:** As the chiasmata terminalize during diakinesis, this cross-shaped structure remains visible under the microscope as a ring or chain of four chromosomes.

(d) **Sterility Consequences:** At Anaphase I, this quadrivalent segregates via alternate or adjacent patterns. Adjacent segregation moves non-homologous centromeres carrying duplicated or deleted segments into the same gamete. This genetic imbalance creates unbalanced gametes, leading to high pollen abortion rates and structural sterility in the trial crop population.

Final Answer: Reciprocal translocation (segmental interchange) between non-homologous chromosomes, leading to alternate or adjacent segregation patterns.

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept: The genetic distance between two linked loci is equal to the recombination frequency observed in a testcross, where 1% recombination represents 1 centimorgan (cM). This genetic distance is a property of the physical separation between the loci on the chromosome and remains constant regardless of whether the alleles are in a coupling or a repulsion linkage phase.

Solution:

Let's break down the genetic calculations step by step:

(a) **Map Distance Determination:** The testcross of the dihybrid individual in the coupling phase ($\frac{PL}{pl}$) yields a recombinant frequency of exactly 16%. According to the principles of genetic mapping established by Alfred Sturtevant, the recombination frequency translates directly into map distance:

$$\text{Genetic Distance} = \text{Recombination Frequency} \times 100 = 16 \text{ cM}$$

(b) **Linkage Phase Independence:** The arrangement of alleles on the homologous chromosomes can vary between the **coupling phase** ($\frac{PL}{pl}$) and the **repulsion phase** ($\frac{Pl}{pL}$). However, changing this configuration does not alter the physical sequence or the distance separating the two loci on the chromosome.

(c) **Repulsion Frequency Prediction:** If the parent is in the repulsion phase ($\frac{Pl}{pL}$), the parental gametes shift to $\underline{Pl}$ and $\underline{pL}$, while the recombinant gametes become $\underline{PL}$ and $\underline{pl}$. Because the physical distance between the genes is unchanged, the probability of a crossover occurring between them remains the same. The expected frequency of recombinants will remain exactly **16%**.

Final Answer: $\boxed{\text{16 cM; expected recombinant frequency remains exactly 16\% because linkage phase does not alter map distance.}}$

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: The initiation of sister chromatid separation at the metaphase-to-anaphase transition is regulated by the Anaphase-Promoting Complex/Cyclosome (APC/C). The APC/C acts as an E3 ubiquitin ligase that targets the inhibitory protein securin for degradation; this releases the active enzyme separase, which cleaves the cohesin rings holding the sister chromatids together.

Solution:

During mitotic somatic cell division, the cell must ensure that sister chromatids separate only after all chromosomes are properly aligned along the metaphase plate and attached to the spindle apparatus. This transition is regulated by a molecular switch:

- **Cohesin Complex Retention:** Throughout metaphase, sister chromatids are held together along their lengths by a ring-shaped protein complex called **cohesin**.
- **Separase and Securin Interaction:** The enzyme responsible for cutting this cohesin ring is **separase**. Under normal conditions, separase is kept inactive by its binding partner, an inhibitory chaperone protein called **securin**.
- **APC/C Activation:** Once the spindle assembly checkpoint is satisfied, the **Anaphase-Promoting Complex/Cyclosome (APC/C)** is activated. The APC/C functions as a multi-subunit ubiquitin ligase that labels **securin** with polyubiquitin chains, targeting it for rapid destruction by the 26S proteasome.
- **Chromatid Separation:** The degradation of securin releases active **separase**. Separase then cleaves the core kleisin subunit of the cohesin complex, breaking the rings holding the sister chromatids together. This allows the spindle fibers to pull the separated chromatids toward opposite poles of the cell, initiating anaphase.

Final Answer: Securin; its destruction releases the active enzyme separase, which then cleaves the cohesin complex holding the sister chromatids together.

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: Duplicate recessive epistasis (also known as complementary gene action) occurs when a homozygous recessive genotype at either of two independent loci masks the phenotypic expression of dominant alleles at the other locus. In a dihybrid cross ($AaBb \times AaBb$), this interaction modifies the standard 9 : 3 : 3 : 1 Mendelian ratio into a characteristic 9 : 7 segregation pattern in the F_2 generation.

Solution:

Let's analyze the genetic basis of the flower color inheritance described in *Pisum sativum*:

(a) **Complementation in the F_1 Generation:** Crossing two true-breeding white mutant lines ($AAbb \times aaBB$) yields an F_1 generation where all individuals display the wild-type purple phenotype ($AaBb$). This indicates that the two mutant lines carry mutations in different genes within the same biosynthetic pathway, and each parent provides the functional dominant allele missing in the other.

(b) **F_2 Phenotypic Segregation:** Selfing the $AaBb$ F_1 generation creates a population distributed across the four standard Mendelian classes:

$$9\ A\_B\_ : 3\ A\_bb : 3\ aaB\_ : 1\ aabb$$

(c) **Biochemical Pathway Requirements:** For the plant to synthesize the purple anthocyanin pigment, both sequential steps in the biochemical pathway must function correctly. This requires at least one functional dominant allele at both loci ($A\_B\_$), which accounts for $9/16$ of the population.

(d) **Recessive Masking effect:** If an individual is homozygous recessive at either locus (A_bb, $aaB\_$, or $aabb$), the pathway is blocked, and the plant cannot produce the colored pigment, resulting in a white flower. Combining these three classes yields: $3 + 3 + 1 = 7$.

This distribution produces the modified **9 purple : 7 white** phenotypic ratio, confirming the presence of **duplicate recessive epistasis** (complementary gene action).

Final Answer: Duplicate Recessive Epistasis (Complementary Gene Action), requiring at least one dominant allele at both distinct loci to produce the purple phenotype.

Answer: (B)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	B	4	B	5	A
6	D	7	B	8	C	9	B	10	A
11	B	12	B	13	A	14	B	15	A
16	A	17	A	18	C	19	A	20	B
21	B	22	B	23	A	24	B	25	B