IISER Biology Sample Paper-1

Duration: 45 Minutes **Maximum Marks: 60**

Instructions

- This paper contains **15** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1** marks.
- Unattempted questions carry **0** marks.
- Only one option is correct for each question.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. A multi-allelic trait in a diploid plant species is controlled by a single gene locus with three alleles: A_1, A_2, and A_3. The allele frequencies in a large, panmictic, Hardy-Weinberg equilibrium population are $p = 0.5$, $q = 0.3$, and $r = 0.2$ respectively. If A_1 is completely dominant over A_2 and A_3, and A_2 is completely dominant over A_3, what is the total frequency of individuals expressing the A_2 phenotype in this population?

(A) 0.09

(B) 0.21

(C) 0.30

(D) 0.15

Q2. During an experiment, isolated mammalian mitochondria are suspended in a buffered solution containing oxygen and succinate. The rate of oxygen consumption is steady. When an excess amount of Oligomycin (an inhibitor of the F_o subunit of ATP synthase) is added, oxygen consumption drops dramatically. Subsequent addition of which of the following compounds would successfully restore the high rate of oxygen consumption without generating ATP?

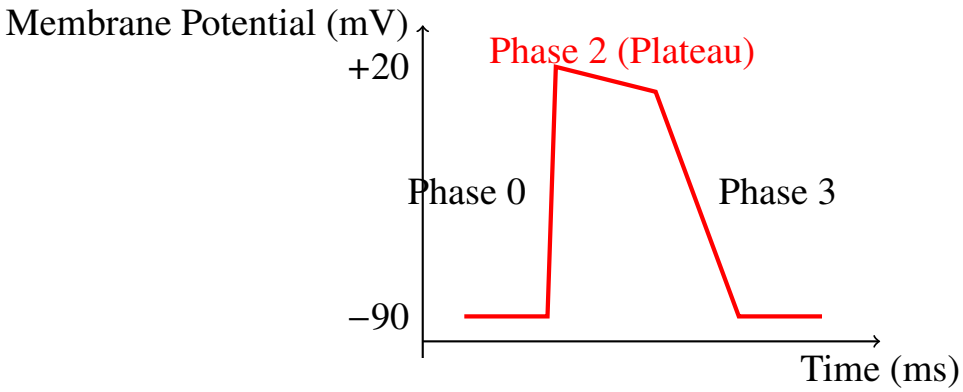
(A) Rotenone

(B) 2,4-Dinitrophenol (DNP)

(C) Antimycin A

(D) Sodium Azide

Q3. The physiological tracing below illustrates a typical non-periodic recording of a ventricular action potential from a human cardiac contractile myocyte. Identify the primarily responsible transmembrane ion current driving the sustained plateau phase labeled as phase 2 in this electrical scheme.



(A) Fast inward Na^+ current

(B) Transient outward K^+ current

(C) Inward Ca^{2+} current via L-type channels

(D) Outward K^+ current via delayed rectifier channels

Q4. A mutant strain of *Arabidopsis thaliana* exhibits a total loss-of-function mutation in the gene encoding the enzyme Phosphoglycolate Phosphatase. When these mutant plants are grown under atmospheric conditions, which of the following metabolic outcomes is expected to manifest immediately upon shifting them from dark to high-intensity light conditions?

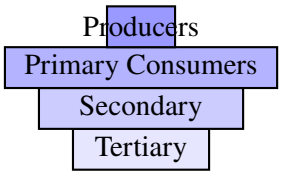
(A) Enhanced rate of Calvin-Benson cycle carbon fixation.

(B) Accumulation of toxic 2-phosphoglycolate, depleting chloroplast phosphate pools.

(C) Overproduction of oxaloacetate inside the mesophyll cell cytoplasm.

(D) Complete arrest of cyclic photophosphorylation in thylakoid membranes.

Q5. The simplified ecological model below represents an Eltonian pyramid of numbers for an open marine ecosystem. Which of the following biological communities is characteristically associated with inverted biomass profiles that contradict this inverted number schema?



(A) Phytoplankton-dominated open oceans where primary producers possess rapid turnover times.

(B) Intertidal rocky shores where macroalgae provide heavy permanent anchoring mass.

(C) Terrestrial climax oak forest ecosystems with massive primary tree producers.

(D) Desert scrubland ecosystems with ephemeral annual vegetation covers.

Q6. During mammalian oogenesis, the first meiotic arrest occurs during embryonic development, holding the primary oocytes at the diplotene stage of prophase I. What primary physiological trigger is directly responsible for signaling the resumption of meiosis I in a specific dominant follicle during the adult ovarian cycle?

(A) A local drop in progesterone levels within the secondary follicle.

(B) The sudden surge of Luteinizing Hormone (LH) from the anterior pituitary.

(C) Complete mechanical breakdown of the zona pellucida grid matrix.

(D) The binding of fertilizing spermatozoa to ZP3 glycoproteins.

Q7. A molecular biologist designs a cloning strategy using a plasmid vector that carries an ampicillin resistance gene (amp^R) and a *lacZ* alpha-peptide sequence with an internal Multiple Cloning Site (MCS). After ligating a foreign cDNA fragment into the MCS and transforming competent *E. coli* cells, the plates are supplemented with ampicillin, IPTG, and X-gal. Which colony selection phenotype confirms the successful integration of recombinant plasmids?

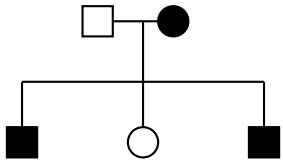
(A) Blue colonies that grow robustly on ampicillin plates.

(B) White colonies that grow robustly on ampicillin plates.

(C) White colonies that completely fail to grow on ampicillin plates.

(D) Blue colonies that undergo rapid cell lysis on selection media.

Q8. The pedigree chart below tracks a rare metabolic condition across three human generations. Based on the segregation pattern shown, determine the most definitive mode of inheritance governing this trait.



(A) X-linked Recessive

(B) Autosomal Recessive

(C) Mitochondrial / Maternal Inheritance

(D) Y-linked / Holandric Expression

Q9. A biochemist processes a mammalian cell extract via differential centrifugation. Fraction A contains high enzymatic activity of Acid Phosphatase, Fraction B contains high activity of Catalase, and Fraction C displays robust activity of Succinate Dehydrogenase. Identify the correct organelle composition matching Fractions A, B, and C respectively.

(A) Lysosome, Peroxisome, Mitochondrion

(B) Peroxisome, Lysosome, Chloroplast

(C) Golgi Apparatus, Endoplasmic Reticulum, Lysosome

(D) Mitochondrion, Peroxisome, Ribosome

Q10. An individual is stranded in a desert without water for 24 hours. Which of the following physiological counter-regulatory adjustments takes place within their renal nephrons to conserve body fluid balance?

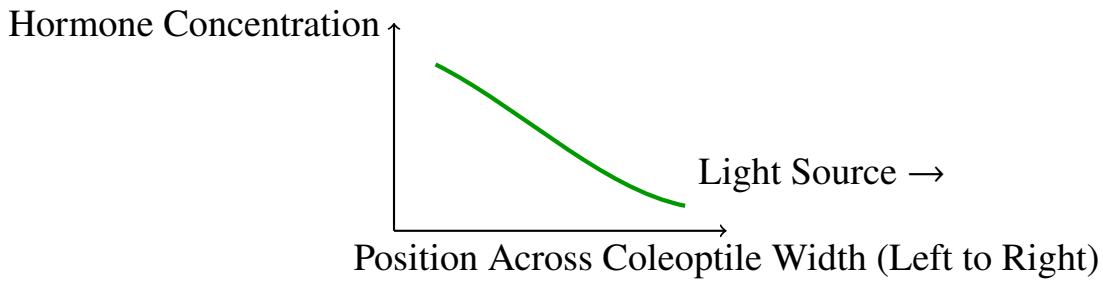
(A) Downregulation of Aquaporin-2 channels in the collecting duct cells.

(B) Decreased firing of hypothalamic osmoreceptors with low plasma osmolarity.

(C) Increased secretion of Renin from juxtaglomerular cells, leading to elevated Angiotensin II levels.

(D) Decreased urea reabsorption into the inner medullary interstitium.

Q11. The tracking graph below measures the internal concentration of a plant hormone inside the elongation zone cells of a coleoptile following a unidirectional lateral light exposure arriving from the right hand side ($+x$ axis). Identify this hormone and its redistribution direction.



(A) Abscisic Acid; moves actively towards the illuminated side.

(B) Auxin (IAA); undergoes lateral transport towards the shaded side.

(C) Gibberellic Acid; gets selectively degraded by blue light on the shaded side.

(D) Ethylene; rapidly diffuses away out of the shaded vascular boundary.

Q12. According to the island biogeography theory proposed by MacArthur and Wilson, which of the following combinations of geographic island configurations is predicted to preserve the HIGHEST equilibrium species richness over evolutionary time spans?

(A) A small island located close to the mainland continent.

(B) A large island located far away from the mainland continent.

(C) A small island located far away from the mainland continent.

(D) A large island located close to the mainland continent.

Q13. In flowering plants (Angiosperms), double fertilization is a defining developmental milestone. If a plant species with a somatic chromosome number of $2n = 24$

completes a successful double fertilization event, what are the exact definitive ploidy numbers found within the cells of the functional embryo and the primary endosperm tissue respectively?

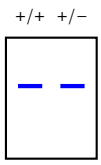
(A) Embryo = 24; Endosperm = 36

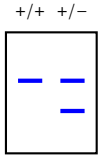
(B) Embryo = 12; Endosperm = 24

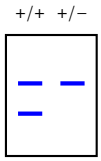
(C) Embryo = 24; Endosperm = 24

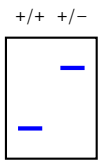
(D) Embryo = 36; Endosperm = 48

Q14. A molecular diagnostic assay uses gel electrophoresis to trace a DNA restriction digest profile. Which of the following digital lane readouts accurately represents a homoduplex wild-type pattern (+/+) compared to a heterozygous deletion tracking lane (+/−)?

(A) 

(B) 

(C) 

(D) 

Q15. A translation assay evaluates a synthetic mRNA sequence containing a repeating sequence profile: 5′-UCU CUC UCU CUC . . . -3′. When this template is translated in a cell-free execution setup, it yields a polypeptide consisting of alternating Serine (Ser) and Leucine (Leu) residues. A different repeating triplet template 5′-UCO UCO UCO UCO . . . -3′ yields three distinct homopolymers: Poly-Ser, Poly-Leu, and Poly-Pro. Based on this historical genetic code data, which specific codon definitively codes for Leucine?

(A) UCU

(B) CUC

(C) UCC

(D) CCU

Detailed Solutions

Q1.

Solution

Concept: For a single autosomal gene locus with multiple alleles in Hardy-Weinberg equilibrium, the sum of the allele frequencies is $p + q + r = 1$. The frequency distribution of the genotypes is given by the expansion:

$$(p + q + r)^2 = p^2 + q^2 + r^2 + 2pq + 2pr + 2qr$$

Solution:

We are given the following parameters for the alleles:

- A_1 (frequency $p = 0.5$), completely dominant over A_2 and A_3.
- A_2 (frequency $q = 0.3$), completely dominant over A_3.
- A_3 (frequency $r = 0.2$), recessive to both.

An individual will express the A_2 phenotype only if their genotype does not contain the completely dominant A_1 allele, and contains at least one A_2 allele. Therefore, the eligible genotypes expressing the A_2 phenotype are:

- Homozygous A_2A_2, with a population frequency of q^2.
- Heterozygous A_2A_3, with a population frequency of $2qr$.

Summing these frequencies gives the total phenotypic frequency:

$$\text{Frequency}(A_2 \text{ phenotype}) = q^2 + 2qr$$

$$\text{Frequency}(A_2 \text{ phenotype}) = (0.3)^2 + 2(0.3)(0.2) = 0.09 + 0.12 = 0.21$$

Final Answer: $\boxed{0.21}$

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: Oligomycin arrests respiration by blocking proton flow through the F_o subunit of ATP synthase, which builds up an insurmountable electrochemical proton gradient across the inner mitochondrial membrane. Respiration can be uncoupled from ATP synthesis by agents that allow protons to leak back across the membrane.

Solution:

Let's analyze the effects of the provided compounds on the blocked respiratory chain:

- **Rotenone:** Inhibits Complex I. Since succinate feeds electrons directly into Complex II, Complex I inhibition will not restore respiration.
- **2,4-Dinitrophenol (DNP):** Acts as a **protonophore (uncoupler)**. It transports protons directly across the inner mitochondrial membrane into the matrix, bypassing the blocked ATP synthase. This dissipates the proton motive force, allowing the electron transport chain to resume rapid oxygen consumption without producing any ATP.
- **Antimycin A:** Inhibits Complex III, which would completely shut down electron flow from succinate to oxygen.
- **Sodium Azide:** Inhibits Complex IV, halting oxygen consumption entirely.

Final Answer: 2,4-Dinitrophenol (DNP)

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: The unique shape of the ventricular action potential in contractile myocytes features a long plateau (Phase 2) that prevents tetanus. This phase is governed by a balance between inward depolarizing and outward repolarizing currents.

Solution:

Let's review the ionic currents characterizing each phase of a ventricular action potential:

- **Phase 0 (Rapid Depolarization):** Driven by the opening of voltage-gated fast Na^+ channels (I_{Na}).
- **Phase 1 (Initial Repolarization):** Driven by the transient outward activation of K^+ channels (I_{to}).
- **Phase 2 (Plateau):** Sustained by a prolonged inward flux of **Ca^{2+} ions via L-type calcium channels** ($I_{Ca,L}$), which counterbalances the outward repolarizing flux of K^+ ions.
- **Phase 3 (Rapid Repolarization):** Driven by the closure of L-type calcium channels and dominant outward K^+ efflux via delayed rectifier channels (I_K).

Final Answer: Inward Ca^{2+} current via L-type channels

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept: Phosphoglycolate phosphatase (PGP) is a key enzyme in the photorespiratory salvage pathway (C2 cycle). It hydrolyzes 2-phosphoglycolate, which is generated when RuBisCO acts as an oxygenase under high light and atmospheric conditions.

Solution:

When RuBisCO fixes oxygen instead of carbon dioxide, it produces one molecule of 3-phosphoglycerate (3-PGA) and one molecule of 2-phosphoglycolate.

- In a mutant lacking **Phosphoglycolate Phosphatase**, 2-phosphoglycolate cannot be converted to glycolate.
- This causes an immediate toxic accumulation of 2-phosphoglycolate inside the chloroplast stroma.
- Because the phosphate group remains trapped within 2-phosphoglycolate, it depletes the available stromal inorganic phosphate (P_i) pool required for ATP synthesis, severely impairing both the light reactions and the Calvin-Benson cycle.

Final Answer: Accumulation of toxic 2-phosphoglycolate, depleting chloroplast phosphate pools.

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: An Eltonian pyramid of numbers shows the total number of individual organisms at each trophic level. In marine ecosystems, a tiny number of large zooplankton or fish can be supported by a small number of microscopic phytoplankton, producing an unconventional numbers profile. However, biomass profiles look different.

Solution:

Let's analyze the biomass relationships across ecosystems:

- In **phytoplankton-dominated open oceans**, the primary producers (phytoplankton) are microscopic and possess an extremely high turnover rate. They divide and are consumed rapidly.
- Consequently, at any given single moment, the standing crop biomass of these producers is significantly *smaller* than the biomass of the longer-lived primary consumers (zooplankton) that feed on them.
- This yields a characteristically **inverted pyramid of biomass** (base-narrow), contrasting sharply with the structural schema of the pyramid of numbers.

Final Answer: Phytoplankton-dominated open oceans where primary producers possess rapid turnover times.

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: Resumption of the first meiotic division in mammalian oocytes is held in check by high follicular cAMP levels. The preovulatory gonadotropin signal relieves this inhibition.

Solution:

Primary oocytes remain arrested in the diplotene stage (dictyate) of prophase I from embryonic development until puberty. During each adult ovarian cycle:

- The surge of **Luteinizing Hormone (LH)** secreted by the anterior pituitary binds to receptors on the surrounding granulosa cells of the dominant Graafian follicle.
- This hormone cascade disrupts gap junction communications, causing a drop in the intra-oocyte concentration of cyclic AMP (cAMP) and cyclic GMP (cGMP).
- The drop in cAMP inactivates protein kinase A (PKA), triggering the activation of Maturation Promoting Factor (MPF), which signals the oocyte to complete meiosis I.

Final Answer: The sudden surge of Luteinizing Hormone (LH) from the anterior pituitary.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: Blue-white screening relies on alpha-complementation of the β-galactosidase enzyme encoded by the *lacZ* gene. Insertion of a foreign DNA fragment into the Multiple Cloning Site (MCS) disrupts the coding sequence, leading to insertional inactivation.

Solution:

Let's look at the selection outcomes for cells grown on media containing ampicillin, IPTG, and X-gal:

(a) **Ampicillin Selection:** Only cells that successfully take up a plasmid carrying the ampicillin resistance gene (amp^R) can survive and form colonies. Non-transformed cells will die.

(b) **Disruption Status (*lacZ*):**

- If the plasmid is **non-recombinant** (no insert), the *lacZ* alpha-peptide sequence is functional. It complements the host cell enzyme fragment to produce functional β-galactosidase, which cleaves X-gal, turning the colony **blue**.
- If the plasmid is **recombinant** (successful insert integration), the *lacZ* reading frame is disrupted. No functional β-galactosidase is made, X-gal remains intact, and the colony stays **white**.

Therefore, successful recombinants form white colonies that grow robustly on ampicillin plates.

Final Answer: White colonies that grow robustly on ampicillin plates.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: Analyze the inheritance pattern by tracking how the trait is passed down through generations from affected parents to their offspring.

Solution:

Let's evaluate the transmission characteristics shown in the pedigree:

- In Generation I, the mother (female, circle) is affected, while the father (male, square) is unaffected.
- This couple produces three offspring in Generation II: two males (squares) and one female (circle).
- Both sons inherit the trait and are affected, whereas the daughter is completely normal.

Let's match this with the inheritance modes:

- **Mitochondrial/Maternal Inheritance:** An affected mother passes the trait to **all** of her children. Since the daughter is unaffected here, this mode is ruled out.
- **X-linked Recessive:** An affected mother (X^aX^a) must pass an affected X^a chromosome to all of her sons. Because sons receive their sole X chromosome from their mother, **100% of her sons will be affected**. The daughter receives a normal X^A chromosome from her unaffected father (X^AY), making her a heterozygous carrier (X^AX^a) with a normal phenotype.

This matches the pedigree perfectly, establishing X-linked recessive as the mode of inheritance.

Final Answer: X-linked Recessive

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: Identify sub-cellular organelles based on their unique, characteristically diagnostic metabolic marker enzymes.

Solution:

Let's assign each fraction to its corresponding organelle by matching the high-activity marker enzymes:

- **Fraction A (Acid Phosphatase):** Acid phosphatase is a hydrolytic enzyme that functions optimally under acidic conditions. It is the classic marker enzyme for **lysosomes**.
- **Fraction B (Catalase):** Catalase is an antioxidant enzyme responsible for breaking down toxic hydrogen peroxide (H_2O_2) into water and oxygen. It is the definitive marker enzyme for **peroxisomes**.
- **Fraction C (Succinate Dehydrogenase):** Succinate dehydrogenase participates in both the Citric Acid Cycle (Krebs cycle) and the inner membrane electron transport chain (Complex II). It serves as a reliable marker enzyme for **mitochondria**.

Final Answer: Lysosome, Peroxisome, Mitochondrion

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: Dehydration triggers homeostatic responses coordinated by the renin-angiotensin-aldosterone system (RAAS) and antidiuretic hormone (ADH) to minimize fluid loss and conserve blood volume.

Solution:

When an individual is deprived of water for 24 hours:

- Blood volume and blood pressure drop, which decreases perfusion to the kidneys.
- This drop in pressure is sensed by the juxtaglomerular apparatus, triggering an **increased secretion of Renin** from the juxtaglomerular cells.
- Renin converts angiotensinogen to angiotensin I, which is then converted by ACE to **Angiotensin II**. Angiotensin II acts as a potent vasoconstrictor and stimulates aldosterone release to conserve sodium and water.
- *Incorrect options note:* Hypothalamic osmoreceptors would increase firing due to *high* plasma osmolarity, and Aquaporin-2 channels would be *upregulated* by ADH to maximize water reabsorption.

Final Answer: Increased secretion of Renin from juxtaglomerular cells, leading to elevated Angiotensin II levels.

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept: Phototropism in plant coleoptiles is mediated by the asymmetrical lateral redistribution of auxin in response to a directional light stimulus (the Cholodny-Went hypothesis).

Solution:

Let's analyze the data provided in the tracking graph:

- The unidirectional light source is positioned on the right-hand side ($+x$ axis).
- The hormone concentration curve is high on the left side (shaded side) and drops sharply toward the right side (illuminated side).
- This hormone is **Auxin (Indole-3-acetic acid / IAA)**. When directional blue light hits the coleoptile, phototropins induce lateral transport of auxin away from the light, causing it to accumulate on the shaded side.
- The higher concentration of auxin on the shaded side promotes cellular elongation there, causing the coleoptile to bend toward the light source.

Final Answer: Auxin (IAA); undergoes lateral transport towards the shaded side.

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The equilibrium model of island biogeography states that the number of species on an island is determined by a balance between the immigration rate of new species and the extinction rate of established species.

Solution:

Let's analyze how island size and isolation affect these rates:

- **Immigration Rate:** Islands that are **close to the mainland** have a higher immigration rate because it is easier for dispersing organisms to reach them.
- **Extinction Rate:** Islands that are **large** can support larger population sizes and offer a wider variety of habitats, which significantly lowers the risk of species extinction.

Therefore, a **large island located close to the mainland** combines the highest immigration rate with the lowest extinction rate, preserving the highest equilibrium species richness.

Final Answer: A large island located close to the mainland continent.

Answer: (D)

Go Back to Question 12

Q13.

Solution

Concept: Determine ploidy levels in angiosperm double fertilization by identifying the fusing cells: a haploid sperm fuses with a haploid egg to form the embryo, while a second haploid sperm fuses with a diploid central cell to form the endosperm.

Solution:

The plant species has a diploid somatic chromosome number of $2n = 24$. This means its haploid gametic number is $n = 12$. During the double fertilization event:

(a) **Embryo Formation:** One haploid sperm cell ($n = 12$) fertilizes the haploid egg cell ($n = 12$) to form a diploid zygote ($2n$).

$$\text{Embryo chromosome count} = 2n = 24$$

(b) **Endosperm Formation:** The second haploid sperm cell ($n = 12$) fuses with the binucleate central cell containing two polar nuclei ($2n = 24$) to form the triploid primary endosperm tissue ($3n$).

$$\text{Endosperm chromosome count} = 3n = 3 \times 12 = 36$$

Final Answer: $\boxed{\text{Embryo} = 24;\ \text{Endosperm} = 36}$

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: Gel electrophoresis separates DNA fragments by size, with smaller fragments migrating faster toward the positive electrode (bottom of the gel). A wild-type homoduplex contains identical alleles, while a heterozygous deletion mutant possesses two different alleles of distinct sizes.

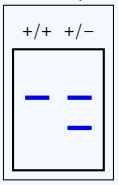
Solution:

Let's analyze what the restriction digest profile should look like for each lane:

- **Wild-type Lane (+/+):** The individual is homozygous for the wild-type allele. Since both chromosomes carry the same fragment size, the digest will yield a **single distinct band** at its characteristic migration distance.
- **Heterozygous Deletion Lane (+/−):** The individual carries one intact wild-type allele (+) and one mutant allele with a deletion (−). The deletion makes the mutant fragment smaller. Therefore, this lane must display **two distinct bands**: one matching the wild-type band position, and a second faster-migrating band below it.

Looking at the options, **Option (B)** perfectly illustrates this layout: a single band in the +/+ lane, and two bands in the +/− lane (the upper one aligned with the wild-type band and a lower, smaller fragment band).

Final Answer:



Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: Deduce codon assignments using historical cell-free translation data from repeating synthetic mRNA polymers.

Solution:

Let's break down the reading frames for both synthetic templates:

(a) **Template 1 (5′-UCU CUC UCU CUC . . . -3′):** This repeating dinucleotide contains two alternating codons: 5′-UCU-CUC-UCU-CUC- . . . -3′. This template produces a polypeptide with alternating **Serine (Ser)** and **Leucine (Leu)** residues.

$$\{\text{UCU, CUC}\} \rightarrow \{\text{Ser, Leu}\}$$

(b) **Template 2 (5′-UCC UCC UCC UCC . . . -3′):** This repeating trinucleotide can be read in three different frames depending on where translation initiates:

- Frame 1: UCC-UCC-UCC $\cdots \rightarrow$ Poly-Ser
- Frame 2: CCU-CCU-CCU $\cdots \rightarrow$ Poly-Pro
- Frame 3: CUC-CUC-CUC $\cdots \rightarrow$ Poly-Leu

By comparing the two templates, we see that **CUC** is the only codon present in both assays that matches the production of Leucine (it is in the alternating pool of Template 1 and forms a homopolymer in Frame 3 of Template 2). Therefore, CUC definitively codes for Leucine.

Final Answer: CUC

Answer: (B)

Go Back to Question 15

Answer Key

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