



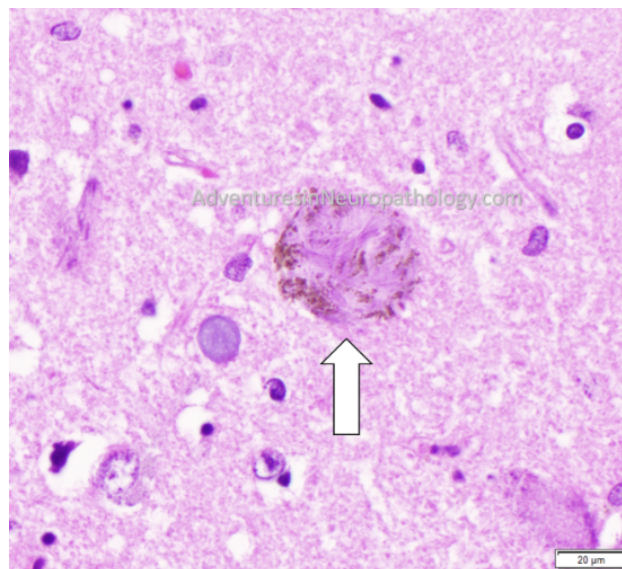
2025 Mitosisphere August Challenge

Part A (MCQ)

Anatomy & Physiology (2 Questions)

Question 1.

Shown below is an image taken from the brain of an individual who suffers from a certain neurodegenerative disease. The region marked by the arrow corresponds to buildups of a mutated version of a certain microtubule associated protein (MAP) that functions in both the structural maintenance of, and transport of nutrients inside neurons.



Which of the following diseases does this individual suffer from?

- A. Parkinson's
- B. Alzheimer's
- C. Schizophrenia
- D. Huntington's
- E. Creutzfeldt-Jakob Syndrome

Solution: *B, Alzheimer's is characterized by the buildup of neurofibrillary tangles from the microtubule associated protein (MAP) tau, surrounded by amyloid beta plaques. These may be seen clearly in the provided image.*

Question 2.

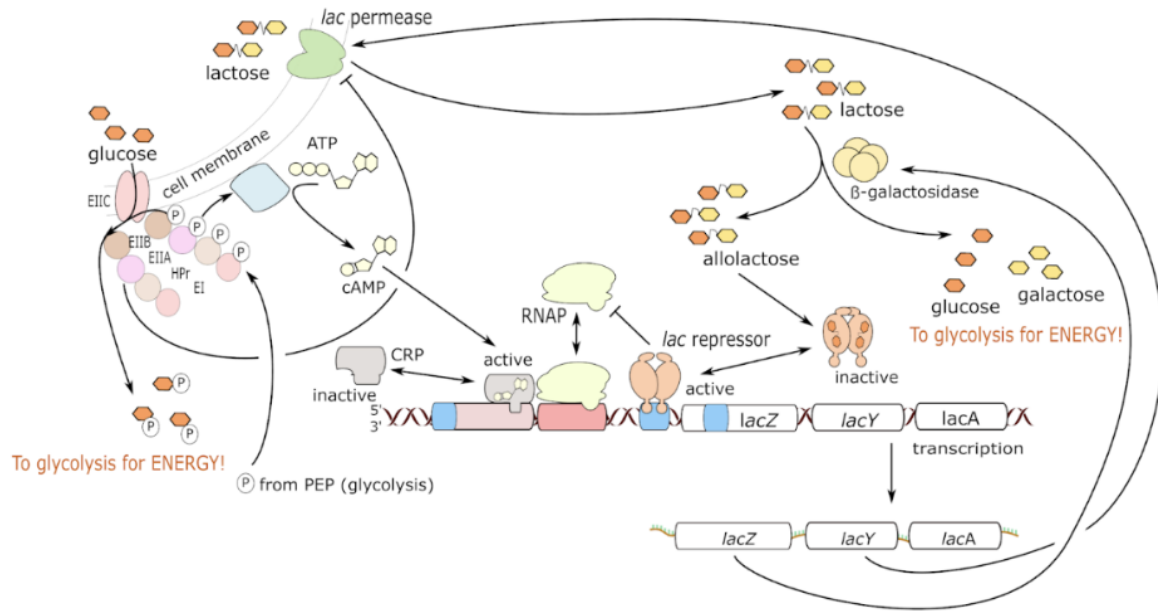
Anish was a staunch advocate of the excretory system being the best in scioly. Understandably, the entirety of BODS believed that he was wrong and Mr. Lahmnaj condemned Anish to suffer a complete failure of his innate immune system. As a result, he developed an immense tumor (not cancer) in the cells of his small intestine due to bacteria invading and preventing the action of both Iron regulatory proteins(IRPs) and Iron regulatory elements(IRES) from acting and instead taking up all of the compound that these (IRPs+IRES) act on. Which of the following antibiotics OR ENZYMES could potentially help Anish survive until he repents? His blood type is AB.

- a. Lactoferrin
- b. Lysozyme
- c. Cl-inhibiting Penicillin Concentrate
- d. N-terminal Tetracycline
- e. AB+-specific aminoglycosides

Solution: A, This question requires both genetics and biological intuition. Firstly, we know that the tumor is due to swelling in his SI. However, this is irrelevant to our discussion. IRPs and IRES are iron control elements (see Brookers Ch. 15 6th edition). Bacteria here could cause an immune response and are therefore taking in too much iron. By adding lactoferrin, the bacteria will be prevented from taking in iron they require to function properly. B is false as there is no real way for lysozyme to be effective. C, D, E, are made up.

Cell Biology (2 Questions)**Question 3.**

Shown below is a model of the lac operon. The lac operon is under dual positive and negative control, regulated by both internal glucose and lactose concentrations. When glucose levels are high, cAMP levels are low and the cell preferentially catabolizes glucose. When glucose levels are low, cAMP levels are high and the cell resorts to lactose catabolism.



If you were to introduce a competitive inhibitor of cAMP phosphodiesterase into a cell under low glucose and high lactose conditions, how would the levels of beta-galactosidase expression compare to that of a cell under the same conditions without this inhibitor, and to that of a cell with high glucose and low lactose without this inhibitor, respectively?

- A. Higher, Higher
- B. Lower, Lower
- C. Higher, Lower
- D. Lower, Higher
- E. Same, Lower

Solution: A, Under low glucose and high lactose conditions, the cell will metabolize lactose. Since the cell is deprived of glucose, cAMP levels will rise, binding to CRP (CAP) which will in turn bind to the lac operon and upregulate lactose metabolism. By introducing a competitive inhibitor of cAMP phosphodiesterase, cAMP levels will rise and the cAMP-CRP complex will bind with even higher affinity, increasing expression of the lac operon. Under high glucose and low lactose conditions, cAMP levels are typically not very high. However, in the presence of a competitive inhibitor of cAMP phosphodiesterase, cAMP levels will be higher than typical and once again the cAMP-CRP complex will bind to the lac operon to increase its affinity for RNA polymerase and increase expression.

Question 4.

If the trp attenuator sequence was modified to change all the tryptophan codons to tyrosine codons, which of the following changes should you also make to make the operon function again? Select all that apply.

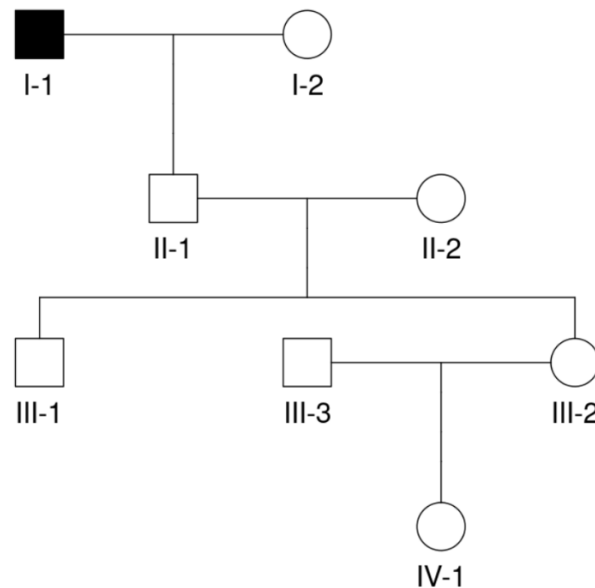
- A. Adding a region downstream of the 4th complementary region that is also complementary
- B. Adding a region upstream of the 1st complementary region that is also complementary
- C. Deleting the 4th complementary region
- D. Deleting the 1st complementary region
- E. Replacing the U-rich attenuator with a G rich attenuator

Solution: *BC*, if tryptophans were replaced with tyrosines, then pausing on the tyrosine codons (which occurs in region 1) needs to signal termination and pausing on the stop codon needs to signal translation, this can be done by essentially shifting over *trpL* which encompasses *B* and *C*. Now, when no translation occurs, new-1 and 2-3 base pairs occur and hairpin forms bc of 2-3, when pausing on tyrosine 2-3 occurs so its terminated, and when stop codon pausing occurs only new-1 occurs and no termination occurs.

Genetics (2 Questions)

Question 5.

The pedigree below shows the inheritance of the rare disease Ivanophia, which is characterized by the sudden desire to reincarnate Ivan the Terrible, the First Tsar of Russia from the years 1533 to 1547. There is a 1% chance that a given unaffected person is a carrier. III-2 (Michaelis) and III-3 (Menten) wants to have a child, (IV-1), Enzyme Kinetics, what is the total probability that Enzyme Kinetics is a carrier or affected? (Ivanophia is an autosomal recessive condition)



- A. 0.25345

- B. 0.34545
- C. 0.25375
- D. 0.15
- E. 0.38125

Solution: $C, (1/2)(1/100)(3/4) + (1/2)(99/100)(1/2) + (1/2)(1/100)(1/2) = 0.25375$.

Question 6.

Ken has been studying the pathway for the synthesis of pigment in a species of garden snail. Ken knows that the pathway for pigment synthesis involves the conversion of a colorless precursor to red pigment by enzyme A, and the conversion of red pigment to yellow pigment by enzyme B. The inheritance pattern for enzyme B is incompletely dominant, where individuals heterozygous for B but having at least 1 A allele are orange. Ken breeds a true breeding red individual with a true breeding white individual. All of the f1 generation is orange. What is the phenotypic ratio you would expect to see if Ken were to self cross the f1 generation?

- A. 1 red : 2 orange : 1 yellow
- B. 9 yellow : 3 red : 4 white
- C. 9 yellow : 3 orange : 3 red : 1 white
- D. 3 yellow : 6 orange : 3 red : 4 white
- E. 6 yellow : 3 orange : 3 red : 4 white

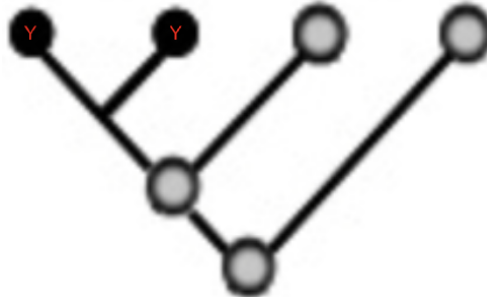
Solution: D, Incomplete dominance + recessive epistasis brings 3 6 3 4, parents are definitely $AAbb$ and $aaBB$ because $AAbb$ is confirmed and the offspring are orange so the white parent is $aaBB$.

Evolution (1 Question)

Question 7.

You are studying the evolution of traits X and Y in marine mammals. You have recorded the data regarding the evolution of the trait below:





Evolution (1 Question)

Using this data, you conclude that trait X is most likely a _____, while trait Y is most likely a _____.

- A. Homoplasy, apomorphy
- B. Apomorphy, homoplasy
- C. Pleisomorphy, synapomorphy
- D. Synapomorphy, pleisomorphy
- E. Apomorphy, synapomorphy

Solution: A, Trait X appeared independently in two different lineages indicating it evolved independently, characteristic of homoplasy. Trait Y appears in a single lineage and appears to have come from a common ancestor indicating apomorphy.

Evolution (1 Question)

Plant Biology (1 Question)

Question 8.

Joseph is clumsy and accidentally dropped decoupling proteins into the plant he recently bought for his girlfriend. Unbeknownst to him, this might lead to a fight pretty soon... The uncoupling proteins were taken up by the plant's root cells, but did not localize anywhere else. Which of the following functions would be most disrupted by Joseph's mistake?

- A. Lateral root formation
- B. Cation exchange
- C. Root hair formation
- D. Polar transport of cytokinins
- E. Perception of gravity

Solution: *B, In order to extract cations from the soil, plants will release protons (H^+ ions) into the soil to displace other cations such as potassium or calcium. Uncoupling proteins would disrupt this since the proton gradient needed for cation exchange, so this would be most directly affected.*

Ecology (1 Question)

Question 9.

A person arrives at a family reunion being held on his grandmother's yacht, located off the coast of Argentina. As he boards the yacht, it begins to tip dangerously when his extremely overweight uncle steps onboard. At this point, five family members are already on the yacht: your grandmother, your grandfather, your daughter, your niece, and your uncle. The grandmother and grandfather are no longer having children. All remaining individuals (daughter, niece, uncle) are assumed to have equal potential to survive and reproduce in the future. Without your help, the people on the yacht have a 30% chance of survival. If you do attempt to help them, their chances of survival increase but you have an 50% chance of dying in the process. Given these conditions, and assuming you want to maximize your genetic contribution to future generations, what is the minimum survival chance for the people on the yacht that would justify risking your life to help them?

- A. 40%
- B. 50%
- C. 80%
- D. 90%
- E. You shouldn't help them at all

Solution: *C, To maximize your genetic contribution, you should only risk helping if the family's survival chance rises above 80%. This is because without helping, you guarantee both your own survival and a 30% chance of theirs, giving you an expected genetic payoff of 1.3. With helping, you only have a 50% chance of surviving, so their survival probability must be at least 80% for the combined expected payoff to exceed 1.3.*

Ethology (1 Question)

Question 10.

Ian loves studying biology and loves penguins just as much. However, Ben the emperor penguin does not love Ian. In order to increase Ben's affection for him, Ian feeds Ben his favorite fish every time he comes close to him, which worked successfully. What type of conditioning is Ian performing on Ben?

- A. Active Avoidance

- B. Negative Punishment
- C. Positive Punishment
- D. Negative Reinforcement
- E. **Positive Reinforcement**

Solution: *E, Positive Reinforcement is correct because Ben gets a positive reward in the form of fish from performing the wanted behavior of getting close to Ian.*

Biosystematics (1 Question)

Question 11.

You're an avid explorer and biologist who went on an expedition last week to Antarctica. There you discovered a group of nonchalant baby emperor penguins that is shown below.



Which family of aves do the penguins belong to?

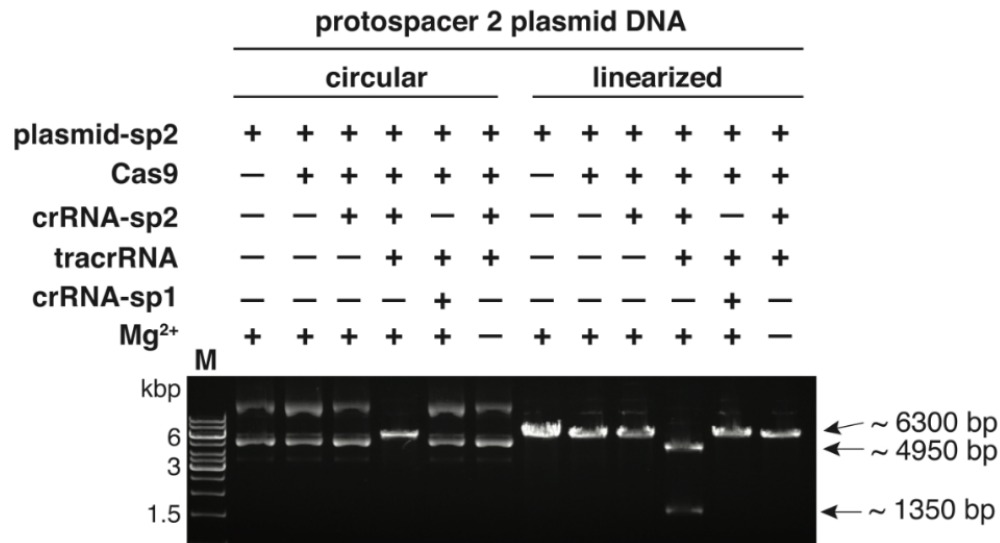
- A. Corvidae
- B. Anatidae
- C. **Spheniscidae**
- D. Trochilidae
- E. Strigidae

Solution: *C, Spheniscidae includes all penguins and only penguins.*

Part B (MTF): 3 Questions

Question 12.

Shown below is data from a gel run by Jennifer Doudna's lab during the study of the CRISPR-Cas9 system.



Based on the data above, which of the following statements is/are TRUE:

- I. The upper bands seen in the circular DNA lanes correspond to nicked plasmids.
- II. CRISPR-Cas9 can only cut circular DNA sequences.
- III. Mg²⁺ is a required cofactor for Cas9 endonuclease activity.
- IV. Both a spacer region and tracrRNA is required for Cas9 endonuclease activity.

Solution: I, III, IV, I is true since nicked plasmids travel less than their in-tact counterparts. While dealing with plasmids, it is a common occurrence for them to occasionally get nicked due to rough handling or strain. II is false since we can clearly see in lane 4 of the linear sample, Cas9 did in fact cut the sample. III is true since in the last lanes of both the linear and circular samples, we can see that the absence of mg2+ leads to no cutting. IV is true since as we can see in lanes 3-5 of both the linear and circular samples, the absence of either one of these elements leads to no cutting. It is only in lane 4 that has both the spacer and tracrRNA where cutting occurs.

Question 13.

Our DNA is organized into 3 letter codons, which code for different amino acids. Mutations in our DNA may result in impaired fidelity of DNA replication as well as improper protein translation. Which of the following statements regarding DNA and mutations is/are TRUE?

		Second letter				
		U	C	A	G	
First letter	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop UGG } Trp	U C A G
	C	CUU } CUC } Leu CUA } CUG }	CCU } CCC } Pro CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } Arg CGA } CGG }	U C A G
	A	AUU } AUC } Ile AUA } AUG Met	ACU } ACC } Thr ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U C A G
	G	GUU } GUC } Val GUA } GUG }	GCU } GCC } Ala GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } Gly GGA } GGG }	U C A G

- I. A 3 nucleotide deletion cannot result in a frame shift mutation.
- II. If you were to introduce a single nucleotide deletion into a sequence, the likelihood of a nonsense mutation increases with sample size.
- III. A male honeybee would be more likely to utilize homologous recombination to repair a double stranded break, while a female honeybee would be more likely to utilize nonhomologous end joining.
- IV. Cysteine's codon indicates that it is likely less commonly incorporated into proteins than serine is.

Solution: I, II, IV, I is true since a 3 nucleotide deletion will always result in the loss of exactly 1 codon, thus it cannot lead to a frame shift. II is true since the likelihood simply just increases with sample size. Since you have more nucleotides that could potentially induce this mutation, the likelihood increases. III is false since honeybees are haplodiploid, and males are haploid. Since males have no template to copy from, they cannot utilize homologous recombination. IV is true since it is more close to a stop codon, which indicates that evolutionarily it likely was utilized less. This is because a deleterious nonsense mutation would be more likely in a cysteine than in a serine.

Question 14.

You isolate eight trp^- mutants. You then perform a complementation test on these mutants. The data is shown below. In the table below, a (+) indicates growth on minimal media, a (-) indicates lack of growth on minimal media.

	m1	m2	m3	m4	m5	m6	m7	m8	WT
m1	-	+	+	+	+	+	+	+	+
m2		-	+	+	+	-	-	+	+
m3			-	+	-	+	+	+	+
m4				-	+	+	+	+	+
m5					-	+	+	+	+
m6						-	-	+	+
m7							-	+	+
m8								-	+

Indicate whether the following mutants are (true) or are not (false) mutants in the same genes.

- I. m1, m2
- II. m2, m6, m7
- III. m3, m5
- IV. m2, m8

Solution: II,III, When two mutants are crossed and are able to grow(+), this indicates they complement each other and are mutants in different genes. Meanwhile, when two mutants are crossed and are not able to grow(-), this indicates they do not complement each other and are mutants in the same gene. Looking at the table, we see that $m1 \times m2$ shows growth(+), so I is false. Next, we see that $m2 \times m6$, $m2 \times m7$, $m6 \times m7$ all do not show growth(-), meaning that II is true. Next, we see that $m3 \times m5$ also does not show growth(-), meaning III is true. Finally $m2 \times m8$ shows growth(+), meaning IV is false.