QUIZ - FRQ's – Question & Answer – Unit 2

Questions are taken directly from previous AP Bio Exams-
Answers are NOT official answers but are Mr. Pomeroy's best attempt

AP Question 1:

To investigate whether red blood cells of animals lose the ability to take in glucose from their environment as they age, scientists collected red blood cells from guinea pigs that ranged in age from one day old to seven months old. Scientists incubated an equal number of red blood cells in separate culture dishes that contained a 300 nM solution of radioactively labeled glucose. The amount of radioactively labeled glucose present inside the red blood cells of each group was measured over time.

(a) **Describe** a difference between passive transport and active transport.

(b) **Justify** why the scientists used an equal number of red blood cells in each culture dish as a control.

(c) Glucose transporters are required for the facilitated diffusion of glucose into red blood cells. The scientists claim that the expression of the gene encoding these transporters decreases as guinea pigs age. If the scientists' claim is supported by experimental data, **predict** the effect of increased age on the amount of radioactively labeled glucose present inside the cells of each group.

(d) **Justify** your prediction in part (c).

Question 1 ANSWER

(a) Passive transport and active transport differ fundamentally in the energy requirements for the movement of molecules across cell membranes. Passive transport, such as diffusion or facilitated diffusion, does not require cellular energy (ATP) and moves molecules down their concentration gradient from high to low concentration. In contrast, active transport requires the input of energy (often in the form of ATP) to move molecules against their concentration gradient, from low to high concentration. In the context of glucose transport into red blood cells, facilitated diffusion, a type of passive transport, is used, involving glucose transporters but no energy expenditure.

(b) The scientists used an equal number of red blood cells in each culture dish as a control to ensure that any differences in glucose uptake observed across the samples were not due to variability in cell number. This controls for the possibility that a higher number of cells might take in more glucose simply because there are more cells to do so. By standardizing the number of cells, the experiment focuses on the variable of interest: the ability of red blood cells to take in glucose as they age. Ensuring equal numbers of cells in each dish allows the results to be more directly attributable to differences in the cells' glucose uptake efficiency rather than experimental inconsistencies.

(c) If the scientists' claim is supported and the expression of the gene encoding glucose transporters decreases as guinea pigs age, we can predict that older red blood cells would have a reduced capacity to take in glucose. Therefore, the amount of radioactively labeled glucose present inside the red blood cells from older guinea pigs would be lower compared to younger cells. As the cells age, fewer glucose transporters are available for the facilitated diffusion of glucose, resulting in less glucose entering the cells over the same period of time.

(d) The prediction is justified by the role of glucose transporters in the facilitated diffusion of glucose. These transporters allow glucose to pass through the cell membrane without the need for energy input, but their function depends on their presence and availability. If the expression of these transporters decreases with age, there will be fewer available pathways for glucose to enter the red blood cells. As a result, the rate of glucose uptake would decrease, leading to lower concentrations of glucose inside older red blood cells when measured. This reduction aligns with the scientists' hypothesis that aging impairs glucose transporter expression and, consequently, glucose uptake into red blood cells.

AP Question 2:

The common wild oat is native to regions of Europe and Asia but is an invasive species in central California grasslands. In California, the common wild oat has almost completely replaced some species of native bunchgrass. Researchers found that aphids, a type of small insect that often carries plant viruses, have a much higher reproductive rate in grasslands that include the common wild oat than in grasslands composed of only native bunchgrass species. Additionally, the viruses carried by the aphids appear to affect only the native bunchgrasses and not the common wild oat. Native bunchgrasses infected by the virus have much higher death rates than do native bunchgrasses that are not infected.

(a) Describe the change in the resilience of an ecosystem when there is a decrease in the number of species.

(b) Explain how the addition of the common wild oat affects the number of native bunchgrass plants that can be supported by the California grasslands ecosystem.

(c) Researchers suggest adding ladybugs, predators of aphids, to the California grasslands. Predict the effect of adding ladybugs on the abundance of the native bunchgrass population.

(d) Justify your prediction in part (c).

Question 2 ANSWER

(a) A decrease in the number of species within an ecosystem typically reduces its resilience, making it more vulnerable to environmental disturbances. Resilience refers to an ecosystem's ability to recover from stress or damage while maintaining its essential functions. When species diversity decreases, ecosystems lose functional redundancy, meaning fewer species can fulfill similar ecological roles. In this case, the decline in native bunchgrass species caused by the invasive common wild oat reduces biodiversity, making the ecosystem more susceptible to disruptions, such as disease outbreaks or changes in resource availability. A less diverse ecosystem lacks the variety of interactions and genetic variability that typically buffers against environmental changes, leading to a potentially unstable ecosystem.

(b) The addition of the common wild oat to California grasslands directly reduces the number of native bunchgrass plants that can be supported by the ecosystem. This occurs for several reasons, including competition for resources such as light, water, and nutrients. The common wild oat, as an invasive species, likely has competitive advantages such as faster growth, better resource utilization, or a tolerance to local conditions that native bunchgrasses cannot match. Additionally, the presence of aphids carrying viruses that affect only the native bunchgrasses exacerbates the decline of these species. As the aphids reproduce more rapidly in the presence of the common wild oat, the viruses they carry spread more widely, further increasing the mortality rates of the native bunchgrasses.

(c) Introducing ladybugs, which are natural predators of aphids, would likely lead to a decrease in the aphid population and consequently a reduction in virus transmission. This would positively impact the native bunchgrass population, as the bunchgrasses would experience less viral infection. With fewer aphids to spread the viruses, the bunchgrasses would have a better chance to survive and compete for resources against the common wild oat. Therefore, adding ladybugs would likely result in an increase in the abundance of native bunchgrasses, as the negative pressure from both aphid predation and virus transmission would be reduced.

(d) The prediction that adding ladybugs will increase the native bunchgrass population is justified based on the ecological role of ladybugs as aphid predators. By controlling the aphid population, ladybugs reduce the vectors that transmit viruses harmful to the native bunchgrasses. Fewer aphids mean less viral spread, leading to a decrease in the bunchgrasses' death rates. This biological control measure helps restore some balance to the ecosystem by limiting the negative impact of the invasive common wild oat's indirect facilitation of aphid reproduction. Additionally, since the common wild oat is unaffected by the viruses, controlling aphids targets the invasive species' competitive advantage without directly harming it, allowing native bunchgrasses to recover.

AP Question 3

Fireflies emit light when an enzyme luciferase catalyzes a reaction in which its substrate, D-luciferin, reacts to form oxyluciferin and other products (Figure 1).

In order to determine the optimal temperature for this enzyme, scientists added ATP to a solution containing D-luciferin, luciferase, and other substances needed for the reaction.

They then measured the amount of light emitted during the first three seconds of the reaction when it was carried out at different temperatures.

D-Luciferin + O_2 + ATP ---Luciferase---→ Oxyluciferin _+ CO_2 + AMP + PPi + Light

Figure 1: Light is emitted as a result of the reaction catalyzed by luciferase.

a) **Describe** a characteristic of the luciferase enzyme that allows it to catalyze the reaction.

b) **Identify** the dependent variable in the experiment.

c) **State** the null hypothesis of the experiment

d) A student claims that, as the temperature increases, there will be an increase in the amount of light given-off by the reaction in the first three seconds. **Support** the student's claim.

Question 3 ANSWER

Part (a): Characteristic of the Luciferase Enzyme

Luciferase, like all enzymes, functions as a biological catalyst by lowering the activation energy of the reaction it catalyzes. This characteristic allows the enzyme to facilitate the conversion of D-luciferin to oxyluciferin in the presence of ATP, oxygen, and other necessary cofactors. Enzymes are highly specific to their substrates due to the unique shape of their active sites, which in the case of luciferase, perfectly complements the shape of the D-luciferin molecule. This specificity ensures that the luciferase enzyme binds efficiently with D-luciferin, enabling the reaction to proceed rapidly and emitting light as a by-product.

Part (b): Identification of the Dependent Variable

The dependent variable in this experiment is the amount of light emitted during the first three seconds of the reaction. This is because the scientists measured the light produced as the primary outcome of the enzymatic reaction. The emission of light reflects the progress of the reaction catalyzed by luciferase, and it changes in response to varying conditions, such as the temperature at which the reaction is carried out.

Part (c): Null Hypothesis of the Experiment

The null hypothesis for this experiment would state that temperature has no effect on the amount of light emitted during the first three seconds of the reaction. In other words, any observed changes in light emission are due to random variation and not a result of the temperature change. This hypothesis assumes that light emission will remain constant across different temperatures, implying that temperature is not a significant factor in the reaction rate catalyzed by luciferase.

Part (d): Supporting the Student's Claim

The student claims that increasing the temperature will result in an increase in the amount of light emitted in the first three seconds of the reaction. This claim can be supported by the fact that, within a certain range, increasing temperature generally accelerates the rate of enzyme-catalyzed reactions. As temperature rises, the kinetic energy of the molecules involved in the reaction increases, causing more frequent and effective collisions between luciferase and D-luciferin. This should lead to an increase in the rate of product formation (oxyluciferin and light). However, it's important to note that this trend holds true only up to the enzyme’s optimal temperature, beyond which the enzyme may denature, reducing its effectiveness and, consequently, the amount of light produced.

AP Question 4

Existing isolated brook trout populations in Newfoundland, Canada were once part of a larger population that was fragmented at the end of the most recent glaciation period about 10,000 to 12,000 years ago.

Researchers investigated 14 naturally separated stream populations of brook trout. They found that the populations are all genetically distinct and show differences in morphology.

a) **Describe** the prezygotic barrier that results in these genetically distinct populations.

b) Brook trout with longer fins are able to swim faster than brook trout with shorter fins. In on the Newfoundland streams, the main prey of the brook trout evolved to move faster. For brook trout living in this stream, **explain** the difference in fitness between longer-finned individuals and shorter-finned individuals.

c) If two morphologically and behaviorally distinct populations of brook trout remain isolated for many generations, **predict** the likely impact on both populations.

d) Researchers claim that there are more genetic differences between any-two current brook trout populations than there are between any-single current population and the ancestral brook trout population from which all the trout are descended. Provide reasoning to **justify** their claim.

Question 4 ANSWER

a) Prezygotic barrier that results in genetically distinct populations

The prezygotic barrier that leads to genetically distinct populations of brook trout is **geographic isolation**. When the glaciers retreated at the end of the most recent glaciation period (10,000–12,000 years ago), brook trout populations were separated into isolated streams. Because the populations were physically separated by geographical barriers, there was no gene flow between them. Over time, this geographic isolation prevented interbreeding, allowing the populations to evolve independently and accumulate genetic differences.

b) Difference in fitness between longer-finned and shorter-finned brook trout

In streams where the brook trout's prey evolved to move faster, **longer-finned brook trout** are more fit than shorter-finned individuals because longer fins allow the trout to swim faster. Faster swimming would increase their ability to catch prey, providing a significant **survival and reproductive advantage**. In contrast, shorter-finned trout would be less capable of catching prey, leading to reduced access to resources, lower survival rates, and fewer opportunities to reproduce. Over time, this selective pressure would favor the longer-finned individuals in the population.

c) Impact of isolation on morphologically and behaviorally distinct populations

If two brook trout populations remain isolated for many generations, it is likely that they will continue to diverge genetically, behaviorally, and morphologically due to **natural selection, genetic drift, and mutation**. Over time, these differences could become so pronounced that the two populations may eventually become **separate species**. This process, known as **allopatric speciation**, occurs when populations evolve distinct adaptations to their local environments and lose the ability to interbreed successfully even if they were to come into contact again.

d) Justification for the claim of more genetic differences between any-two current populations than between any-single population and the ancestral population

The researchers' claim can be justified by **genetic drift** and **local adaptation** in isolated populations. Since the populations have been geographically isolated for thousands of years, each one has undergone independent changes in their genetic makeup due to factors like mutation, natural selection, and genetic drift. Over time, these forces accumulate random genetic differences. Since all populations descended from the same ancestral population, any-single current population is still genetically related to the ancestral one. However, when comparing any-two isolated populations, they have each followed separate evolutionary paths, resulting in more **unique genetic differences** between them than between either population and the ancestral population from which they both descended.