

KEY to the Free Response Exam (Team Round)

Question 1: (SBI) Mystery Seafood

You come across a population of a new organism washed up on a beach. Upon further dissection, you find a scraping structure the organism used to feed, called a radula.

- a. To which animal phylum does this organism belong? (1pt)

Mollusca

- b. Upon further examination, you discover a closed circulatory system and scattered chromatophores used for camouflage. To which class does this animal belong? (1pt)

Cephalopoda

- c. What type of eye would this animal possess? (1pt)

Camera-type eye

Question 2: (EEE) Fiddle me this...

- a. In your own words, describe the difference between a **proximate** and an **ultimate** question with relation to ethology. (2pts)

Proximate → relating to how a behavior's development, causes, triggers, or mechanisms

Ultimate → relating to how a behavior relates to evolution (affects an organism's reproductive success)

- b. Male fiddler crabs are observed to exhibit a peculiar ritual when female crabs are nearby. They will circle around the female and gesture with a beckoning motion using their over-sized and brightly colored claw. They will then repeat this motion, often in unison with other males, dozens of times. (2pts)



- What would be an example of a **proximate** question with respect to this behavior?
- What would be an example of an **ultimate** question with respect to this behavior?

Proximate →

How do male fiddler crabs perform the behavior in unison?

What triggers male fiddler crabs to wave their claws?

How did this behavior develop in each individual? Etc.

Ultimate →

How does a male's claw waving affect its ability to reproduce?

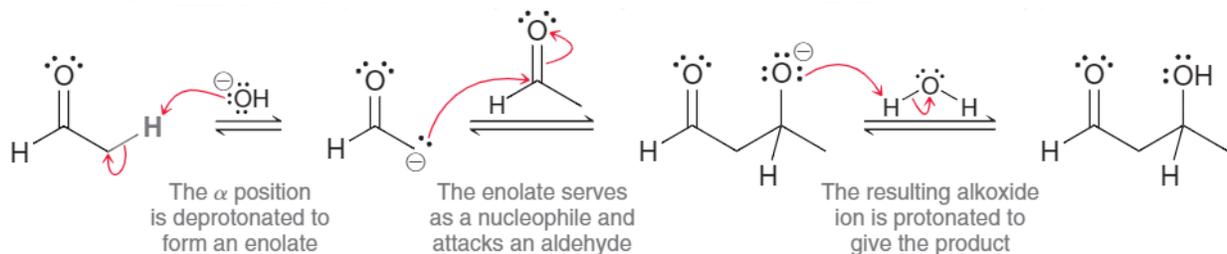
How did this behavior evolve in fiddler crabs? etc.

- c. Given that females are more likely to choose to mate with males that have the largest claws, **what kind of mating system** (monogamy, polyandry, polygyny, etc.) would you expect these fiddler crabs to have? **Why?** (2pts)

Polygyny, because multiple females will end up choosing the males with the largest claws

Question 3: (MCC) Aldol Addition Reactions

Aldol addition is a process where two molecules are joined together, forming a product with an alcohol group, and an aldehyde group. It can also proceed in reverse, known as the retro-aldol reaction. With the mechanism shown below, use your knowledge to answer the following questions regarding biochemical processes.



- a. Name a biochemical pathway in which this reaction is catalyzed by an enzyme (you don't have to name the enzyme) (1 pt).

Glycolysis (aldolase)

- b. For biochemical reactions, briefly explain why these reactions are enzyme-catalyzed, and under what conditions can they be enzyme-catalyzed (2 pt).

lower activation energy, higher rates of reaction; require cofactors, temperature pH etc

- c. Given the biochemical reaction, predict how the outcome might be affected if the reaction takes place at elevated temperature (hint: loss of water) (3 pt).

Aldol condensation, forms unsaturated aldehyde.

Question 4: (GGG) Hardy-Weinberg Equilibrium...Or Is it?

George just learned about Hardy-Weinberg Equilibrium in his AP Biology class and he wants to apply it in the real world. He notices the sheep on his family farm and his dad, who is a geneticist and farmer, tells George that the color of the fur of the sheep is controlled by a gene called Color. The dominant allele is C and the recessive allele is c. The CC sheep are white, Cc sheep are gray, and cc sheep are black. George counted the number of sheep on the farm and got the following data.

Color	White (CC)	Gray (Cc)	Black (cc)
Number of Sheep	98	84	18

- a. Calculate the allele frequency of C and c. (1pt)

C = 0.7; c = 0.3

After a while, these sheep produce another generation and George uses the same method to observe the F1 generation.

Color	White (CC)	Gray (Cc)	Black (cc)
Number of Sheep	45	123	32

- b. It has been a while since he learned about Hardy-Weinberg Equilibrium, so George has forgotten what conditions needed to be met for a population to be in Hardy-Weinberg Equilibrium. **Help George remind what the conditions for Hardy-Weinberg Equilibrium are.** (1pt)

Large Population size

No migration or gene flow

No mutation

Random Mating (Panmixia)

No Selection

1.0 for name all 5, 0.7 to name 4, 0.3 to name 3, 0-2 no credit.

- c. George realized that the chart for F1 generation doesn't look like Hardy-Weinberg, so he wonders whether this sheep population is actually in equilibrium. He vaguely remembers he can use a Chi-Squared test to check, but he forgot the specific procedure. Help George to determine whether the F1 sheep population is in HW equilibrium. **State the degrees of freedom and the chi-square value.** (2pts)

Degrees of freedom (df)	Significance level (α)							
	.99	.975	.95	.9	.1	.05	.025	.01
1	-----	0.001	0.004	0.016	2.706	3.841	5.024	6.635
2	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210
3	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345
4	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277
5	0.554	0.831	1.145	1.610	9.236	11.070	12.833	15.086

$X = 11.07$, $df = 1$, $57.7 > 3.841$, so the population is not in Hardy Weinberg Equilibrium

0.5 point for giving correct conclusion, 1 point for giving Chi-Square value and the work, 0.5 point for giving correct df.

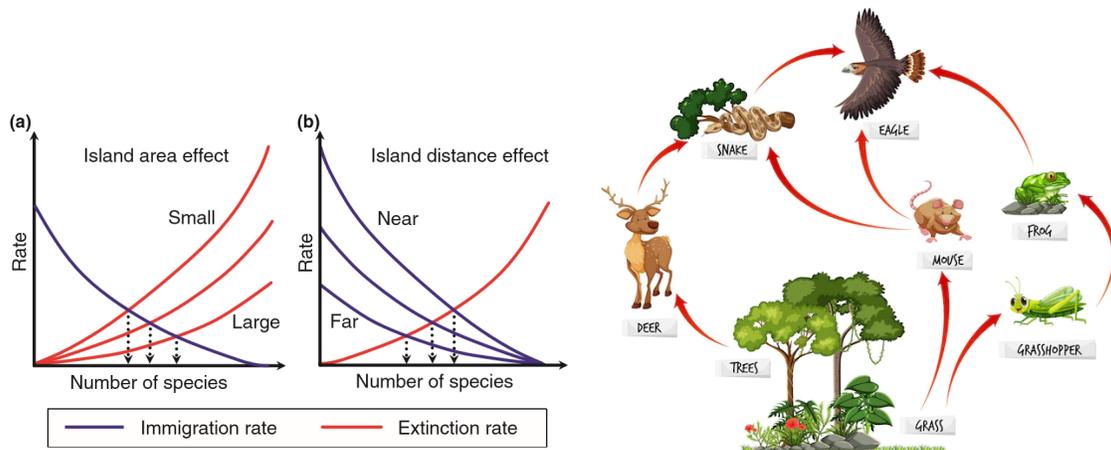
- d. George tried to give a reason why the phenotype frequency changed. He postulates the following four reasons. **Determine whether each reason can explain the shift in phenotype frequency and give a brief explanation to justify your answer.** (2 pts)
- George's dad tends to give black sheep better and more food because black wool is worth more on the market.
 - Significant inbreeding has happened in the sheep population.
 - Sheep migrate between Farmer Bush's farm and Geroge's farm.
 - A nearby wolf thinks black sheep's meat tastes better.

1 is possible as black sheep are a lot more common in the F1 generation. 2 is false because the heterozygous (Gray) Sheep has become a lot more common. 3 is possible as migration could significantly alter the phenotype frequency. 4 is false as black sheep are the more selectively favored group.

0.5 pt is given to each correct statement.

Question 5: (EEE) Biodiversity on Your Beach House

Analyze the graph below and answer the following questions.



- a. Under what conditions would high island biodiversity occur? (2pts)

Near the mainland, large island, and high immigration rate

- b. What famous rule also has to do with the phenomenon of dwarfism or gigantism on certain island species? (1pt)

Foster's rule

- c. DDT is accidentally introduced to an island off the East Coast of the United States. Which organism in the food web shown above would exhibit the highest concentration of DDT in their bodies? (1pt)

Eagle

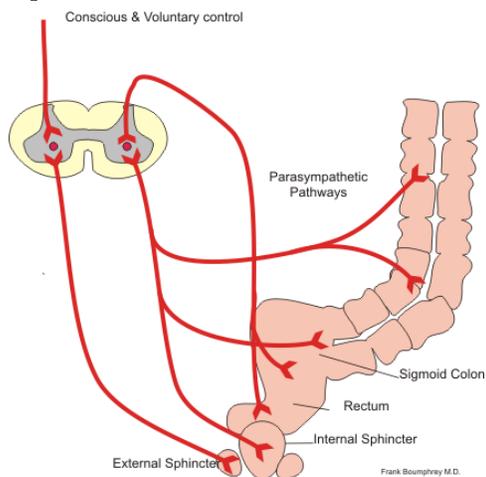
Question 6: (ANP) Gastric Reflexes

Most people are familiar with voluntary reflexes, but involuntary reflexes also occur in areas such as the digestive tract. Answer the following questions regarding these reflexes.

- A. Some reflexes, such as the gastrocolic reflex, cause mass movements in the large intestine after someone eats meals. What stimulus prompts this response? (2pts)

Distention of the stomach signals to the large intestine that food is available for propulsion/food needs to be moved along the digestive tract

- B. From part A, would you think an inflammatory disease such as ulcerative colitis would have the same consequences regarding mass movements in the large intestine? Explain your answer (2pts)

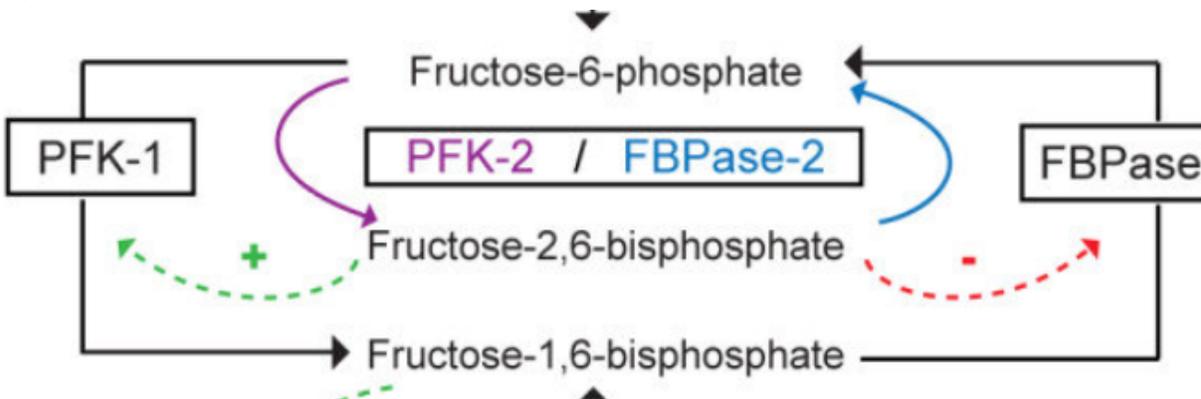


Yes, because ulcerative colitis leads to intense mass movements due to irritation of the gi tract/stool is loose and watery so it goes through the tract much faster and at a much higher rate.

- C. Analyze the above diagram.
- Which nerve innervates the internal sphincter? (1pt) Pudendal
 - The myenteric plexus would send signals to the internal anal sphincter for it to relax before defecation. However, this is a weak signal. What other innervation does the internal anal sphincter receive? (1pt) Parasympathetic

Question 7: (MCC) Our Friend Fru

Our dear friend Fru is studying the regulation of a specific step in the glycolytic/gluconeogenic pathway. He observes that a molecule very similar to fructose-1,6-bisphosphate is a key regulator in this step.



Note: PFK-1 → phosphofructokinase-1, FBPase → fructose 1,6-bisphosphatase, PFK-2 → phosphofructokinase-2, FBPase-2 → fructose-2,6-bisphosphatase

- a. Does fructose-2,6-bisphosphate help activate **glycolysis or gluconeogenesis**? Explain. (2 pts)

Fructose-2,6-bisphosphate activates glycolysis by stimulating PFK-1 (phosphofructokinase-1) and inhibiting fructose 1,6-bisphosphatase

- b. Fru increases the concentration of FBPase-2 in the cell. What effect would this have on the concentration of pyruvate? Glucose? (2 pts)

This would decrease the concentration of pyruvate by preventing the production of fructose 2,6 bisphosphate (decreasing glycolysis). This would increase the concentration of glucose by stimulating gluconeogenesis with the decrease in PFK-1 activation.

- c. Fru adds each of the following hormones to the cell culture. Explain how each of the following hormones would affect PFK-2 and FBPase-2, if at all. (4 pts)

- Insulin
- Vasopressin
- Cortisol
- Glucagon

Insulin-insulin acts to increase glycolysis so the cell uptakes glucose; activates PFK-2 and inactivates FBPase-2

Vasopressin-no effect

Cortisol-no effect**thrown out, not enough context to know and understandable if they put that it does affect the enzymes

Glucagon-glucagon acts to decrease glycolysis so that blood glucose concentrations stay high; activates FBPase-2 and inactivates PFK-2.

Question 8: (ANP) iBALT Induction

Normally not found in the body, inducible bronchus-associated lymphoid tissue (iBALT) are elusive lymphoid structures whose formation is only induced by inflammation and infection. It has been found that their formation in the bronchus region is closely associated with the expression of different chemical signals, including CXCL13, CCL19, and CCL21.

- a. Which body system are iBALTs involved in (1 pt)?

Respiratory/immune system

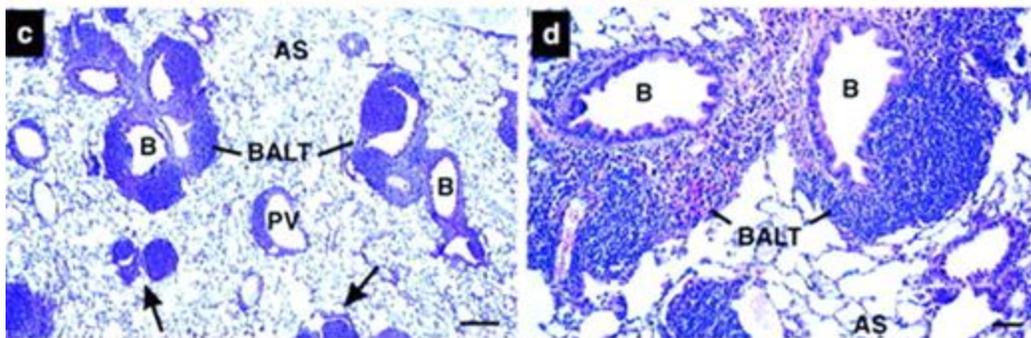
- b. Given what you know about iBALTs, are they considered primary, secondary, or tertiary lymphoid structures (2 pt)?

Tertiary

- c. Previous studies have shown that CXCL13 induces iBALT formation by stimulating the expression of another molecule, CXCR5 on immune cells. The signal is relayed downstream via the phospholipase C pathway. Based on this, what type of membrane receptor is CXCR5 (1 pt)?

G protein coupled receptor

- d. In a patient with asthma, a chronic disease, the formation of BALT is visualized using histological techniques for interleukin-5. Shown below, what type of cell is likely the target of the staining method (2 pt)?



Helper T cell (partial credit for other immune cells?)

Question 9: (SBI) Cleaning up the Tree of Life

Many colloquial names for groups of species are based on shared morphological traits, rather than a shared evolutionary lineage.

- a. In your own words, **define the following terms:** Monophyletic, Paraphyletic, and Polyphyletic. (1pt)
Monophyletic: Including an ancestral taxon and all its descendants
Paraphyletic: A group including an ancestral taxon and only **some** of its descendants.
Polyphyletic: A group of organisms from different evolutionary lineages, without including any common ancestor.

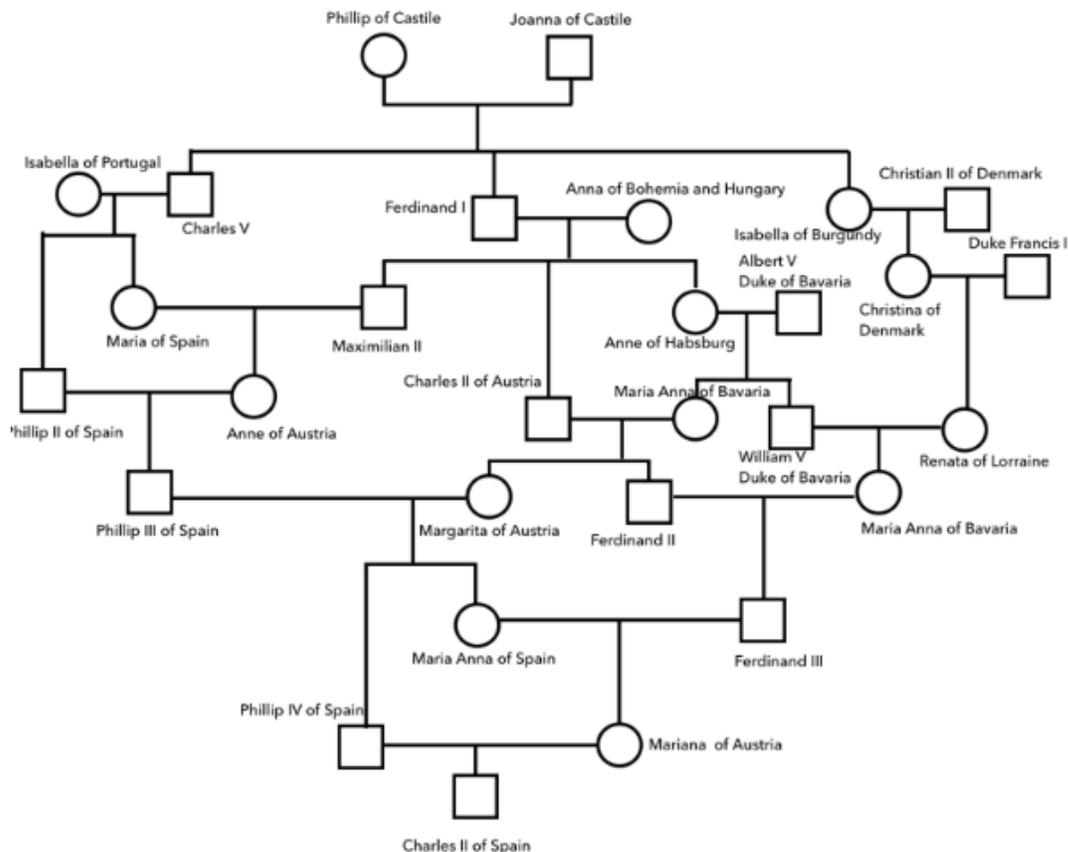
- b. Out of the following common names, **which are monophyletic, which are paraphyletic, and which are polyphyletic?** (3pts)
Worms: Polyphyletic
Sponges: Paraphyletic
Trees: Polyphyletic
Birds: Monophyletic
Crabs: Polyphyletic
Fish: Paraphyletic

- c. Historically, it was nearly impossible for taxonomists to group species based on evolutionary lineage, so they used morphological relationships. What new **technology/data** has allowed modern taxonomists to construct trees **based on evolutionary relationships?** (1pt)
DNA sequencing/molecular evidence

- d. **What evolutionary phenomenon** is likely responsible for species being put together into a polyphyletic group based on shared morphological features? Likewise, **what evolutionary phenomenon** is responsible for some species with shared ancestry being excluded from a paraphyletic group based on morphological features? (1pt)
Convergent evolution, divergent evolution.

Question 10: (GGG) The Last Hapsburg

In the 15th-17th century, the political legitimacy of European monarchies was cemented in familial lineage. This resulted in many consanguineous marriages within royal families to “keep the bloodline pure”. A pedigree for one such royal family, the Hapsburgs, is shown below:



- In general, why are consanguineous marriages normally frowned upon? (1pt)
There is a higher chance of children being homozygous for potentially harmful traits.
- What is the coefficient of relatedness between Maximilian II and his wife? (2pts)
0.125
- If Phillip of Castile is a carrier for a homozygous recessive trait, and assuming that nobody marrying into the family carries an allele for that trait (including Joanna of Castile), what is the probability that Phillip III of Spain will express the trait? (4 pts)
 $15/512^*$
- Given the same situation as question 3, what is the probability that Ferdinand III will express the trait? (4 pts)
 $165/2^{15}^*$

*Questions were thrown out due to a very low number of people getting this question right.