

FA: 10 passages/figures, 2-6 short answer questions per passage

1. (GGG) A Leg Up

Dr. Dinkeldorf is hard at work creating his newest biotech innovation: Dink's Foot gene editing. Dink's foot is meant to be a rival to other editing techniques like CRISPR and TALENs. The Dink's Foot uses a zinc-finger like domain that binds to only a few specific 20-30bp long sequences, and then a "leg" of fixed size is attached to a nuclease domain that makes cuts a fixed distance away. Assume the leg is rigid, but it is free to rotate.

- a. Are there any cases where Dink's foot is better than a system like CRISPR? Explain your answer.
- b. When would the rotation of the leg cause problems?
- c. What other pathways are needed for successful gene editing with Dink's foot or really any gene editing system?
- d. Are the cuts the Dink's foot makes single stranded or double stranded? Why?

2. (SBI) Blissed to Be Here

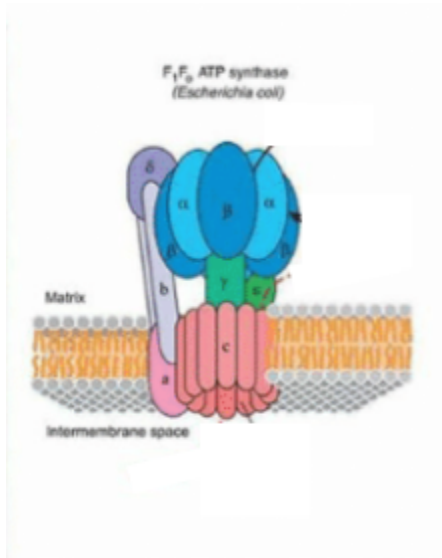
Here is a photograph of the pokemon blissey.



Blissey carries an egg and also reproduces from one. It also is able to eat the egg which is “softboiled”, a reference to the runniness of the yolk. Due to the exotic habitat that it lives in (hospitals in a fictional land), no other biological information can be confirmed aside from what is given in the problem. For each of the following groups below, indicate if there is support that Blissey is in the group, support Blissey is not in the group, or not enough information to make any such judgment. Give justification to your reasoning.

- a. Mammalia
- b. Amniota
- c. Tetrapoda

3. (MCC)



Let's talk about everyone's favorite enzyme: ATP synthase!

- a. ATP synthase straddles the boundary between the mitochondrial matrix and the intermembrane space.
 - i. Does the matrix have a higher or lower pH than the intermembrane space?
 - ii. What process drives this concentration gradient?

ATP synthase spins! Specifically, the c subunits rotate, taking the γ subunit with them. This spinning is driven by the movement of protons into the c subunits and around the axis of rotation on their way to the other side of the inner membrane.

- b. Protons bind to certain amino acid residues in the c subunits of ATP synthase with high affinity. What is the most likely identity of these amino acids?
- c. There's an amino acid residue in the a subunit that prevents protons from traveling against the rotation of the c subunits as they are entering the enzyme. List all the amino acids that could perform this job. Consider the pH of the intermembrane space when answering.
- d. Explain why ATP synthase selectively catalyzes the formation of ATP and not some other molecule, like GTP. Be specific.
- e. The subunits of ATP synthase exist in 3 conformations: free, ADP-bound, and ATP-bound. They transition between states through the action of the γ subunit as it spins.
 - i. Order the 3 states in their correct order of progression. Don't worry about which one comes first, just get the order.
 - ii. Given this ordering, what does it reveal about the function of the γ subunit?

4. (EEE)

In a previously uncharted area of a rainforest, you come upon a new species of amphibian that you have carefully tracked in order to create a life history table, shown below.

Age	Population	Fecundity	Survivorship
0-3	1159	0.0	1.0
3-6	107	5.0	?
6-9	23	2.5	?
9-12	14	1.25	?
12-15	5	0	?

- a. In which age group does this species reach sexual maturity?
- b. What type of selection would you expect this species to undergo?
- c. Calculate the survivorship of each age group following 0-3 to 2 decimal points
- d. What type of survivorship curve would this species exhibit?

5. (ANP) Saturday Night Fever

Joanne is suffering from a fever that has lasted over 2 years. One of the attending physicians bets that it is because Joanne is suffering from an immunodeficiency. A medical resident disagrees and claims it is autoimmune.

- a. What test could you use to test(s) the difference between the two? List two.

- b. After applying your tests, you have found that the disease is in fact autoimmune. Do autoimmune diseases typically involve the innate or adaptive immune system? What type of white blood cell would be responsible for Joanne's disease?

- c. Which organ would normally be responsible for preventing your immune cells from attacking your own tissue?

- d. What type of white blood cell, that usually inhibits the actions of other white blood cells, also prevents your immune cells from attacking your own tissues?

6. (ANP) Glucagon

Glucagon is a hormone produced by the alpha cells of the pancreas. Glucagon travels through the blood and stimulates glycogenolysis and gluconeogenesis in target cells.

- a. Would an increase in blood glucagon level lead to an increase or decrease in blood sugar?

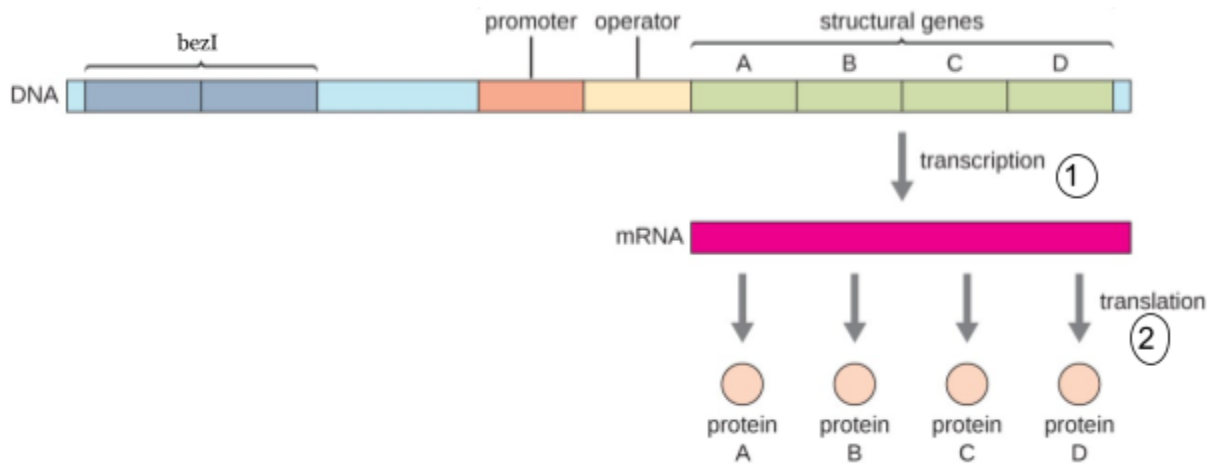
In a hypothetical autoimmune disorder named Alphabetes, the alpha cells of the pancreas are partially or completely destroyed, rendering the ability of the pancreas to produce glucagon greatly reduced or even completely absent.

- a. Would one expect glycosuria (glucose presence in urine) in an individual with this disorder?
- b. Could injections of epinephrine reduce the symptoms associated with this disorder? Why or why not?
- c. Could this disorder be treated by oral administration of glucagon to restore blood glucagon levels? Why or why not?

Glucagon exhibits its effects in cells by binding to glucagon receptors. This receptor is a g-protein coupled receptor and its immediate effect involves raising cytosolic cAMP levels. Phosphodiesterase is an enzyme that breaks the phosphodiester bond in cAMP, and is needed to degrade cAMP to shut down the signaling pathway when glucagon is not present.

- d. Name two reasons why phosphodiesterase does not also destroy the phosphodiester bonds present in genomic DNA, which would be disastrous.
- e. Could a phosphodiesterase inhibitor possibly be an effective treatment for mild Alphabetes? Why or why not?

7. (GGG) The following diagram depicts the organization of the *bezI* operon, which is found in a diploid eukaryote.



Proteins A, B, C, and D are involved in a metabolic pathway that synthesizes molecule F. The proper function of each protein is necessary to produce molecule F. Molecule F can bind to the protein produced by *bezI*, which converts it into an active form. This active form then binds to the operator, and acts to decrease the affinity of RNA polymerase for the promoter sequence. *bezI* is continuously transcribed at a low rate.

- Does *bezI* exert its effects on the quantity of proteins A, B, C, and D in the cell by acting directly on step 1 or 2? Is *bezI* cis-acting or trans-acting?
- Would a mutation in the *bezI* sequence such that its protein product is continuously in its active form, regardless of whether or not molecule F is bound, be dominant or recessive? Would such a mutation be cis-acting or trans-acting?
- If a mutation in *bezI* made its protein product unable to bind to molecule F and thus unable to be activated, which proteins would have elevated expression? Which would have decreased expression?
- Would a loss of function mutation in protein B be dominant or recessive? How would the transcription of proteins A, B, C, and D be affected by such a mutation? (which are elevated and which are decreased)
- Name one process that can decrease the quantity of protein C in the cell without affecting its rate of transcription.

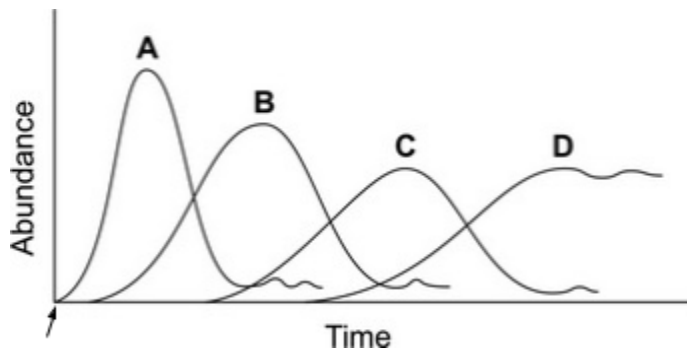
8. (EEE) In 2030, an ecologist surveyed a former forest ecosystem following a recent nearby volcanic eruption. They observe that the ground is now covered in bare rock and no soil is exposed. There is little to no plant life present. He takes this picture of what the landscape looks like in 2030.



Over time, ecologists observe that organisms begin to colonize the area and slowly the ecosystem returns to its original form with abundant plant life.

- Name the process in which organisms first colonize a barren, lifeless environment without soil.
- Would one expect the first species that settle in this environment to be more limited by density-dependent or density-independent factors? Why? Give an example of a possible species.

The relative abundance of 4 different species in this ecosystem are measured over time and shown in the following graph. (the point marked by the arrow represents 2030)



- Could species A be a member of the Poaceae family? Why or why not?
- Would one expect species D to display R- or K-selection? Would its population size be more limited by density-dependent or density-independent factors? Why?

9. (SBI) *C. elegans* is a model organism for many fields of study in biology, especially in developmental biology.

- a. What phylum does *C. elegans* belong to?
- b. What structure does the initial invagination (blastopore) in *C. elegans* eventually form?
- c. The phylum that *C. elegans* belongs to only exhibits longitudinal muscles, (running across the body). Based on this information, along which directions would *C. elegans* undulate in order to move?
- d. Many nematodes such as *C. elegans* exhibit eutely, meaning a fixed number of cells are present in an adult. What technique does this trait allow for?

10. (MCC) In C₃ photosynthesis, which is used in many plant groups, Ribulose biphosphate carboxylase-oxygenase (RuBisCO) is used to fix carbon dioxide into a sugar molecule. However sometimes oxygen is used instead of carbon dioxide, producing an unwanted product that cannot be used to create sugar and needs to be regenerated into RuBP.

- a. In order to regenerate RuBP, an intermediate in the photorespiratory pathway must be passed through the peroxisome. Given that the intermediate is oxidized, what molecule would be formed when oxygen reacts with the intermediate?
- b. Many groups of plants have independently evolved novel pathways to avoid photorespiration. Name 2 of these pathways.
- c. Assuming oxygen is an inhibitor of carboxylase activity in RuBisCO, what type of inhibitor would oxygen be classified as?