

# Supplemental Material

*CBE—Life Sciences Education*

Connell *et al.*

Group # \_\_\_\_\_

Absent today: \_\_\_\_\_ If none check here

There is a molecule found in milk called lactose. It is a simple carbohydrate made of two sugar molecules bound together like this:

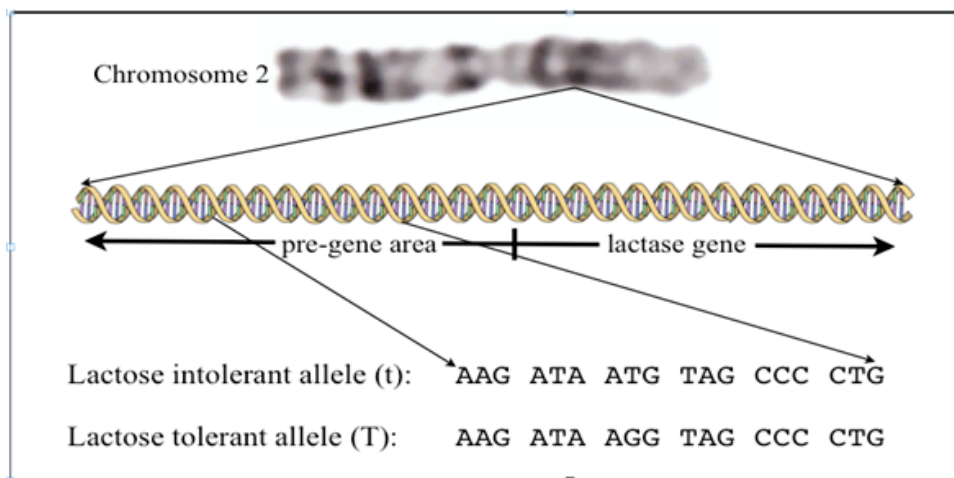


Lactose must get completely broken down into individual sugar molecules in our small intestine before it can be absorbed into our blood and distributed to cells in our body. There is a special protein that is responsible for breaking down lactose, known as lactase.

1. What are the building blocks of proteins like lactase? \_\_\_\_\_
2. How would a protein like lactase be formed by cells in our body? Explain clearly. (Hint: It would start with DNA...)

All people's bodies make lactase as infants in order to digest the sugar in mother's milk. In most people, as soon as you stop drinking milk when you are weaned, your body stops producing lactase. If lactase protein is not being made and you consume lactose in milk, then the bacteria that line your intestines feed on the lactose since your body cannot break it down to absorb it. This leads to gas, bloating, diarrhea, and cramps. The lactase gene is found on Chromosome 2. This is the main portion of the gene (the part that actually tells the cell what the amino acid sequence should be). Just before the lactase gene is another gene that controls when the lactase gene is turned on and off. This pre-gene area normally tells your body to stop making lactase when you stop drinking milk as a child. This diagram shows Chromosome 2 with the pre-gene area followed by the lactase gene. The nucleotides shown are the actual nucleotides from part of the pre-gene area.

Somewhere in human history, there was a mutation in the lactase gene that prevents the pre-gene area from working properly. In this way, a person's body never stops making lactase, allowing a person to continue drinking milk into adulthood.



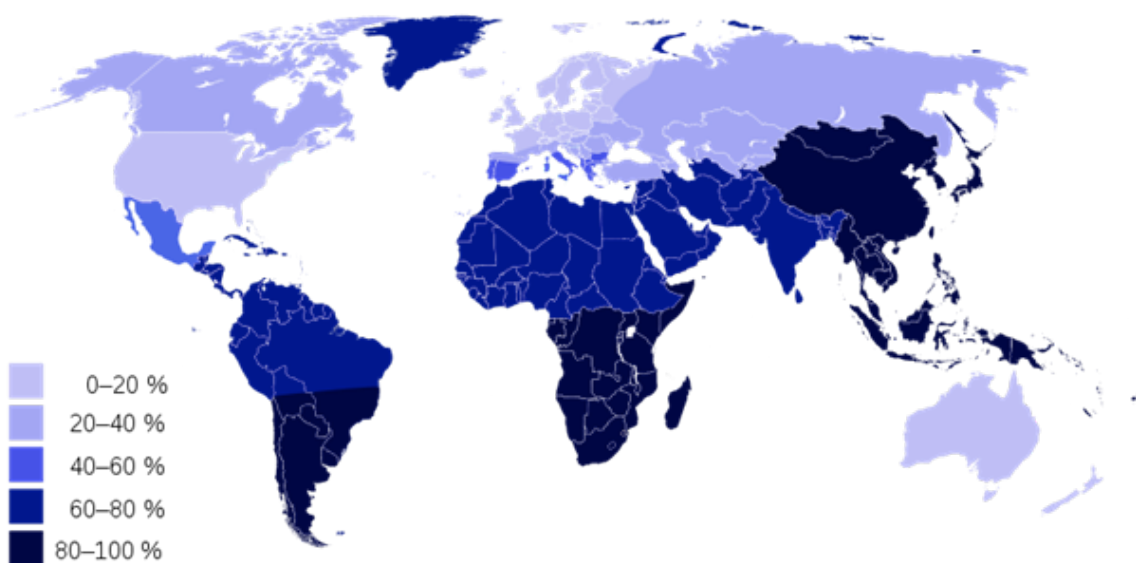
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3. What is one way you can develop a mutation? Where would it need to occur for you to be able to pass it on to your children?

You will notice from the diagram that this mutation is a dominant allele. Thus: Dominant is represented by (T)= lactose tolerant, recessive is represented by (t)= lactose intolerant. Lactose tolerance follows complete dominance.

4. Would two lactose intolerant parents be able to have a lactose tolerant baby? Clearly explain/show the reasoning behind your answer.

Geographic distribution of lactose intolerance. Light colored countries have few lactose intolerant people and lots of lactose tolerant people.



Group # \_\_\_\_\_

Region	People group	% Lactose Intolerant
USA	Caucasian Americans	12
	African American	45
Asia	Chinese	95
	Thai	98
European	Dutch	1
	English	10
	Italian	19
Africa	Bantu peoples (central Africa)	89
Native Peoples	Native North American (Navajo, Miwok, etc.)	100
	Australian Aborigines	85
	Alaskan Eskimo	80
World average		75

5. There are interesting differences in the percentage of lactose tolerant people in different regions of the world. Look carefully at the table and at the world map on the next page. What do you notice about the world map and the table? Describe some of the patterns you see. Does anything surprise you? Does anything stand out to you?

Group # \_\_\_\_\_

6. Milk is a great source of protein, fat, and carbohydrates. Adding milk to the diet in adulthood makes available a large source of energy and nutrients. Most of the regions of the world that are lactose tolerant have a cultural history of dairying (raising animals for milk as well as for meat). Given these facts, **why** would populations that developed dairying have a greater percentage of people that have the mutation for lactose tolerance? Propose an explanation for this observation **using evolution by natural selection**.

#### **Environmental variables can affect phenotype.**

One thing we haven't yet discussed is what happens evolutionarily when a trait is not purely inherited, but is instead a mixture of inheritance and environmental factors. It is clear that if a trait is purely environmental (such as whether you've broken your arm, whether you can drive a car and what languages you can speak), that these traits are not inherited and evolution and natural selection cannot work on them. But what if a trait is determined by a *mixture* of inheritance and environment?

For example, in today's world, there are two ways to get around being lactose intolerant. The most common remedy is to eat a pill containing lactase just before consuming milk products. Lactaid® is simply lactase in pill form or pre-mixed into milk. In addition, there is a possibility of never weaning oneself entirely from milk. The pre-gene area is only triggered if your body senses that you have stopped drinking milk. Within about 3 months, the gene is shut down entirely and permanently. However, if you never go 3 months without drinking milk, then the pre-gene area never gets triggered and you keep on producing lactase throughout your lifetime. Clearly, these strategies (taking lactase pills and making sure you never go 3 months without milk) are environmental, not inherited. That means that lactose intolerance is really determined by a mixture of inheritance and environment.

7. Do natural selection and evolution still work on a trait that is only partly governed by inheritance? Clearly explain the reasoning behind your ideas. *This will not be graded as right/wrong. I am looking for educated rational for your answer.*

## Appendix 2:

The content assessment which was administered at the beginning and the end of the course. Since there is currently no broad concept inventory for Introductory Biology, we used questions from published concept inventories (Klymkowsky and Garvin-Doxas, 2008; D'Avanzo *et al.*, 2010; Nadelson and Southerland, 2010; Fischer *et al.*, 2011) and wrote another 12 questions ourselves so that we could assess over the range of topics covered in our class (40 questions in all). Student scores on all of the questions were used for multiple linear regression analyses. However, for IRT analyses some of the questions did not meet the local independence criterion (see text for details) and were removed from the IRT analyses. These were questions 4, 9, 14, 20, and 40. In addition, other items were internally dependent within pairs, but independent of all other items, so we combined these pairs into new items that were scored on a 0-2 scale (see text for details). These were questions 10 & 11, 12 & 13, and 37 & 38.

### **BIOLOGY 101 Pre-course Assessment 2014**

**Fill out both sides of your scantron sheet completely, including the assessment version.**

**See your instructor after you are finished if you don't remember your student number.**

- **This assessment is being used to help your instructor determine the effectiveness of this course. This is not worth points, although the completion of both pre and post class assessments will qualify you for 5 extra credit points at the end of the quarter. The personal value to you is that the pre/post assessment will help you to see how much you have learned over the course of this class! The types of questions are similar to what you will see on your exams and the assessment spans the breadth of concepts we will cover this quarter.**
- **Choose the best answer for each of the 40 multiple choice questions and mark your scantron clearly. You may use a scratch sheet of paper. Please do not write on this assessment.**
- **Relax and do your best!**

1. Natural selection is the process by which organisms best adapted to their environment survive and reproduce. Natural selection produces evolutionary change by
  - A. Changing the frequency of various versions of genes.
  - B. Reducing the number of new mutations.
  - C. Producing genes needed for new environments.
  - D. Reducing the effects of detrimental versions of genes.
  
2. Many infectious diseases are becoming difficult to treat because of bacterial resistance to antibiotics. Populations of bacteria can become resistant when they are exposed to an antibiotic. What is the best general explanation for how this occurs?
  - A. The antibiotic induces specific mutations in some of the bacteria that make them antibiotic-resistant.
  - B. The antibiotic activates enzymes in bacteria that can destroy the antibiotic.
  - C. The antibiotic increases the bacterial mutation rate, so that resistant mutant bacteria are more likely to arise.
  - D. The antibiotic kills all the bacteria that did not have antibiotic-resistant mutations. Resistant bacteria survive and reproduce.
  
3. A woman has been told she carries a mutation associated with breast cancer. How does this influence her likelihood of developing breast cancer?
  - A. Her risk will be no different from any other healthy woman.
  - B. She will likely not get breast cancer.
  - C. She is at an increased risk for breast cancer.
  - D. She will develop breast cancer once she reaches a certain age.
  - E. Her mutated gene has already begun to cause development of cancer.
  
4. Human synthesized herbicides and insecticides have been used for more than fifty years to control plants and insects in agricultural settings and in the places where we live. In most cases which of the following happens?
  - A. Herbicides and insecticides help maintain ecological balance in human designed ecosystems because they reduce the populations of organisms that have gotten out of control.
  - B. Herbicides and insecticides move in food webs and are, by design, not toxic to non-target organisms like beneficial insects, birds, and humans.
  - C. Because of dilution in the soil and in the water, herbicides and insecticides become so low in concentration that they have little influence on non-target organisms.
  - D. After years of use, herbicides and insecticides that were initially effective in killing pest organisms became less effective until they no longer killed pest organisms.

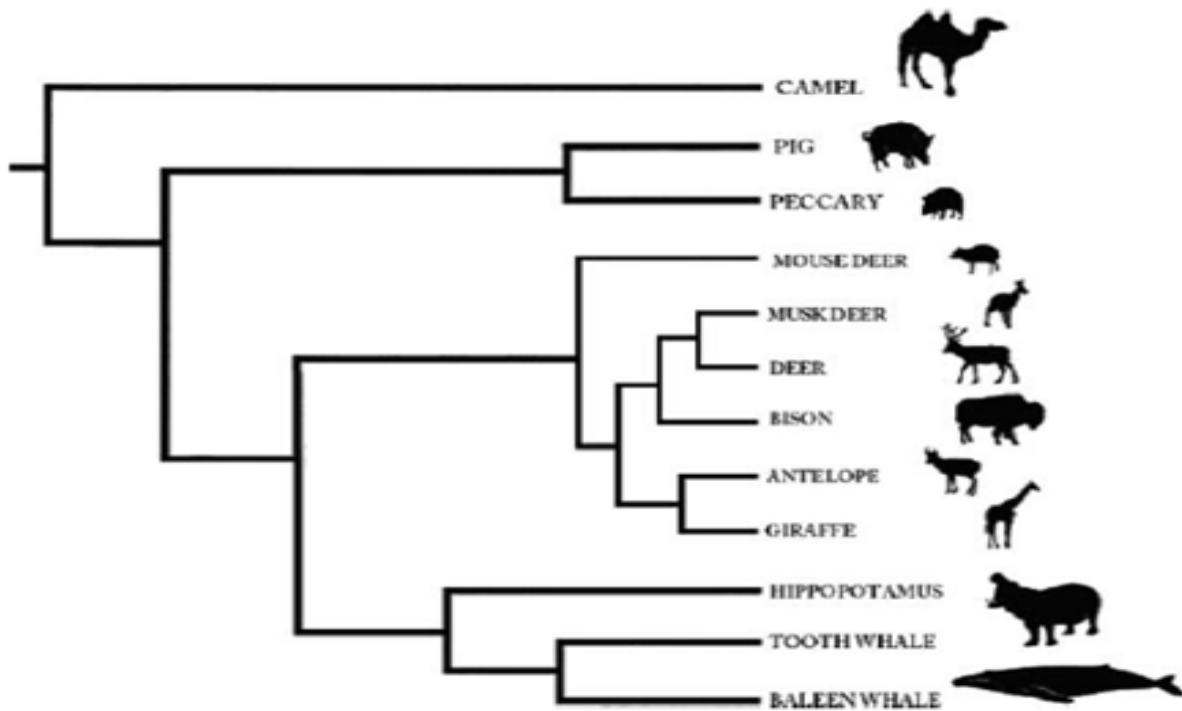


FIGURE 1 The evolutionary tree of some mammals.

5. The whales are classified with a group of mammals which are called even-toed ungulates. Whales have been classified as part of this group along with their closest relative the hippopotamus because:
  - A. Whales and hippos are similar in morphology
  - B. Whales and hippos share a more recent common ancestor
  - C. Whales and hippos have similar diets and habitats
  - D. Whales and hippos evolved from camels
  
6. The chart above suggests that:
  - A. Whales are the most recent animals on the chart to appear
  - B. Baleen Whales and tooth whales are not related to camels
  - C. Whales are more closely related to giraffes than to bison
  - D. Whales are more closely related to deer than to pigs
  
7. The evolutionary history and development of whales has been hotly debated. Recently there has been a major shift in our understanding of the processes used to detail whale evolution. This indicates that:
  - A. Gaps in the fossil records will never allow us to fully understand evolution
  - B. Scientists studying evolution typically present ideas with very little evidence, leaving it to others to find proof of their ideas
  - C. Aspects of evolution are constantly being challenged and explored in light of new evidence
  - D. Much of the science of evolution is based on speculation that can easily be changed when scientists think of new ideas



8. All cell membranes:
- A. Allow free movement of materials into or out of the cell.
  - B. Allow some substances to enter the cell, but prevent all substances from leaving.
  - C. Allow only beneficial materials to enter the cell.
  - D. Allow some substances to pass through, but not others.
9. Phospholipids can form structures like cellular membranes because of
- A. Their inability to bond with water molecules.
  - B. Their inability to interact with other molecules.
  - C. Their ability to bind specifically to other lipid molecules.
  - D. The ability of parts of lipid molecules to interact strongly with water.
10. If a small amount of salt (1 tsp) is added to a large container of water (4 liters or 1 gal) and allowed to set for several days without stirring, the salt molecules will
- A. Be evenly distributed throughout the container.
  - B. Be more concentrated on the bottom of the water.
11. The reason for my answer (to question #10) is because
- A. salt is heavier than water and will sink.
  - B. salt dissolves poorly or not at all in water.
  - C. salt cannot dissolve without stirring there will be more time for settling.
  - D. salt will move from high to low concentration.
12. When a living human blood cell is placed in pure fresh water, the cell will
- A. Shriveled up.
  - B. Swell and burst.
  - C. Remain the same.
13. A water-based blue solution is placed on the left side of a container that is divided by a semipermeable membrane. Pure water is on the right side. As time passes, the right side gradually becomes blue, while the blue color on the left side becomes lighter but the level of liquid on both sides remains the same. This suggests that
- A. Water and dye can both pass through the membrane.
  - B. The dye can pass through the membrane but moves more slowly than water.
  - C. The dye can pass through the membrane but water cannot.
  - D. Atmospheric pressure will always produce equal water levels.

14. Which of the following statements is true?
- A. Genetic drift and molecular diffusion are the result of directed movements.
  - B. Genetic drift and molecular diffusion involve passing through a barrier.
  - C. Genetic drift and molecular diffusion involve random events without regard to ultimate outcome.
  - D. Genetic drift is a random event; diffusion typically has a direction.
15. Cellular respiration in plants takes place in:
- A. The cells of the roots only.
  - B. Every plant cell.
  - C. The cells of the leaves only.
16. In which way are plants and animals different in how they obtain energy?
- A. Animals use ATP; plants do not.
  - B. Plants store energy in sugar molecules; animals do not
  - C. Plants capture energy from sunlight; animals capture chemical energy.
  - D. Animals can synthesize sugars from simpler molecules; plants cannot.
17. You eat a grape high in glucose content. Some of the energy in those glucose molecules will be unusable. What form does unusable energy take?
- A. ATP
  - B. Water
  - C. DNA
  - D. Heat
18. You eat a grape high in glucose content. How could a glucose molecule from the grape provide energy to move your little finger?
- A. The glucose is digested into simpler molecules having more energy.
  - B. The glucose molecule itself reacts and gets transformed into ATP.
  - C. The glucose is turned into energy.
  - D. The energy of the glucose is transferred to ATP.
  - E. The energy of the glucose is transferred to CO<sub>2</sub> and H<sub>2</sub>O.

19. If green algae cells in a buffer solution containing only inorganic salts are placed in a sealed container at room temperature with excess carbon dioxide gas and exposed to light, the cells will:

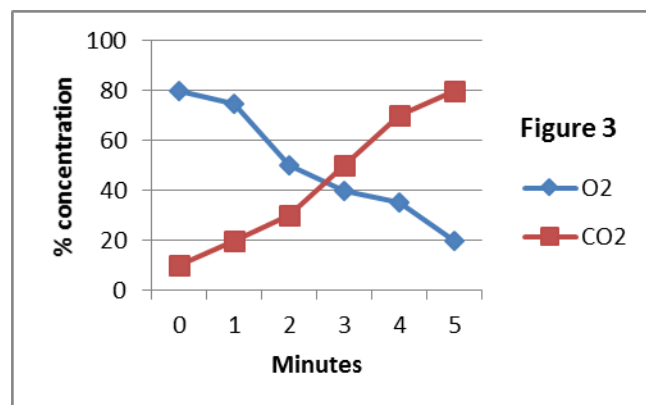
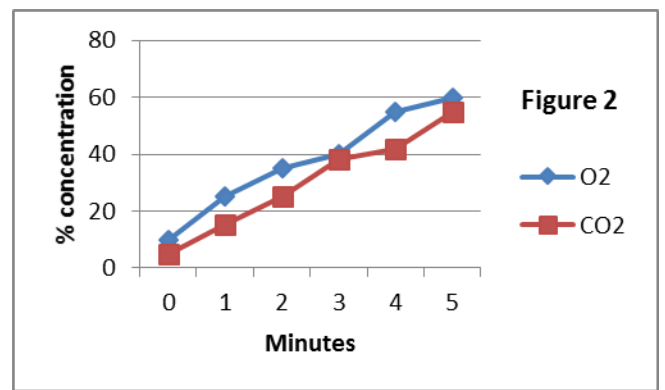
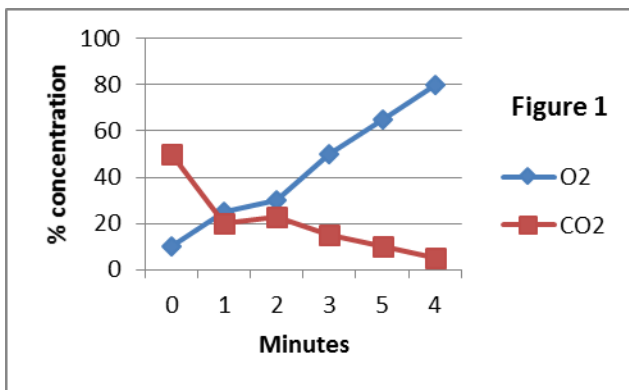
- A. live for many hours and multiply.
- B. live for several hours, but fail to multiply because there is no source of carbon in the buffer solution.
- C. live for several hours, but fail to multiply because no oxygen is present.
- D. die rapidly, because no oxygen is present.

20. Imagine an ADP molecule inside a bacterial cell. Which best describes how it would manage to "find" an ATP synthase so that it could become an ATP molecule?

- A. It would follow the hydrogen ion flow.
- B. The ATP synthase would grab it.
- C. Its electronegativity would attract it to the ATP synthase.
- D. It would actively be pumped to the right area.
- E. Random movements would bring it to the ATP synthase.

21. Review the figures below to determine which statement is true.

- A. Figure 1 accurately represents gas concentrations during photosynthesis.
- B. Figure 2 accurately represents gas concentrations during cellular respiration.
- C. Figure 3 accurately represents gas concentrations during photosynthesis.



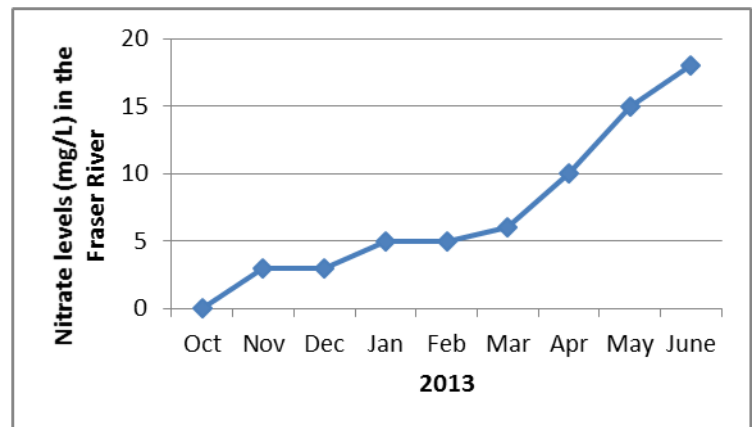
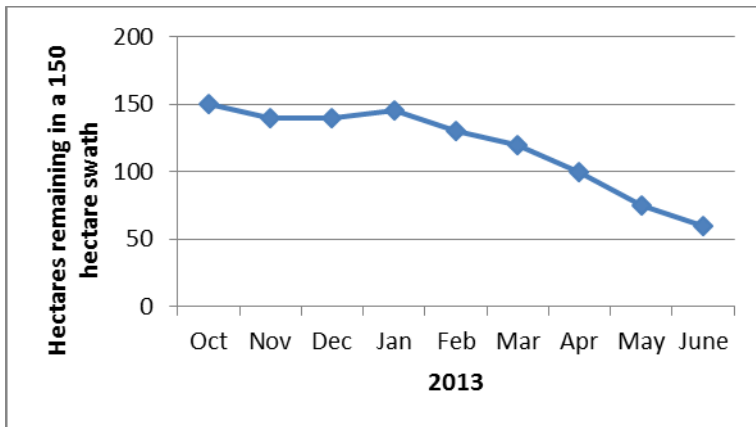
22. Imagine a forest ecosystem. Which of these parameters would be the best predictor of the forest's health?

- A. Total number of organisms in the forest.
- B. Total number of deciduous versus coniferous trees.
- C. Number of disturbances (wind, fire, etc.) in a 6 month period.
- D. Total species diversity in the forest.

23. The intensity of competition between two species increases as:

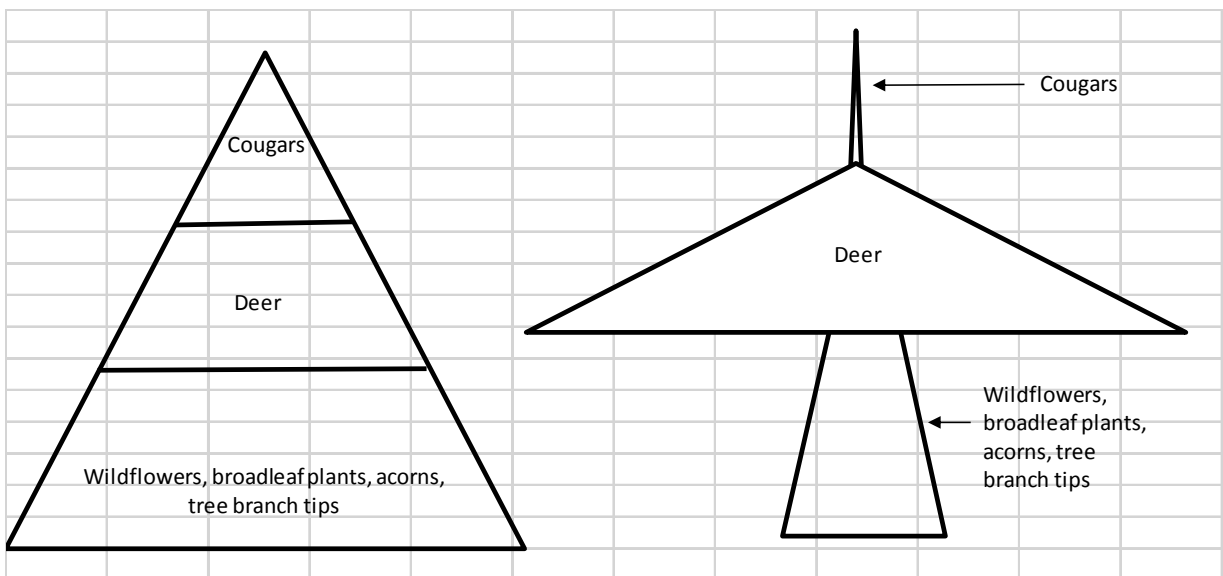
- A. their body size increases.
- B. one species approaches the point of extinction.
- C. the similarity of their requirements and life styles increases.
- D. the size of their shared environment increases.
- E. their reproductive success is reduced

24. Data on logging was taken on a 150 hectare swath of land in the North Cascades between the months of Oct - June 2013 by a team of scientists from UBC. Data on Nitrogen was taken by a team of WWU scientists on a stretch of the Fraser River downstream from the logging site. Both figures are shown next to one another below. What conclusions can you draw from these two figures?



- A. Logging upstream correlates with increased eutrophication downstream in the Fraser River.
- B. Increased logging upstream is correlated with lower nitrate levels in the Fraser River.
- C. Increased logging upstream causes a decrease in eutrophication downstream.
- D. Logging upstream caused eutrophication downstream in the Fraser River.

25. Refer to the logging and nitrate figures above. Choose the most accurate prediction.
- Cutting down additional hectares of trees would decrease nitrate levels in the Fraser River.
  - The last recorded tree stands in the swath were recorded in June 2013 at 60 hectares. If logging stops at 60 hectares, nitrates in the river would decrease.
  - Further logging of this swath would increase eutrophication to the Fraser River.
  - Nitrate levels are merely correlated with logging and should not be used for forestry management decisions/predictions.
26. Compare the two biomass pyramids depicting the diet of cougars and deer in two different scenarios. Given this information, would you consider cougars a keystone species? Why?



- No, while cougars do have an effect on deer, there isn't a significant effect on plant species so overall diversity would not be affected.
- Yes, dwindling cougar populations significantly affect the species diversity of the two lower trophic levels by ballooning the deer population and reducing plant species biomass and diversity.
- Yes, the absence of cougars causes deer to destroy all cougar habitat.
- No, when cougars are absent from the forest deer take on the secondary consumer role in the ecosystem.

27. Hunters come and destroy the last cougar population in a Montana forest due to conflict with cattle. If there was 100 grams of biomass at the cougar level, how many grams of biomass in this food chain would have been consumed to sustain those cougars?

- A. 1 gram of plants, 10 grams of deer
- B. 100 grams of plants, 100 grams of deer
- C. 10,000 grams of plants, 1000 grams of deer.
- D. 100,000 grams of plants, 10,000 grams of deer.

28. Alleles are

- A. DNA
- B. RNA
- C. Proteins
- D. Traits

29. In a diploid organism, what do we mean when we say that a trait is dominant?

- A. It is stronger than a recessive form of the trait.
- B. It is more common in the population.
- C. The trait associated with the allele is present whenever the allele is present.
- D. The allele associated with the trait inactivates the products of recessive alleles.

30. How might a mutation create a new, beneficial function?

- A. If the mutation altered the gene product's activity.
- B. It could not; all naturally occurring mutations are destructive.
- C. If the mutation activated a gene that was harmful.
- D. If the mutation had no effect on the activity of the gene product.

31. A mutation results in a recessive trait becoming dominant; what can you conclude about the mutation?

- A. The mutation resulted in an overactive gene product.
- B. The mutation resulted in a normal gene product that accumulated to higher levels than normal.
- C. The mutation resulted in a gene product for a new trait.
- D. The mutation resulted in an altered DNA sequence.

32. Freckles are completely dominant over no freckles in humans. What is the percent chance that a couple will have a child with freckles if the mother has no freckles and the father is heterozygous for freckles?

- A. 0% chance of having freckles
- B. 25% chance of having freckles
- C. 50% chance of having freckles
- D. 75% chance of having freckles
- E. 100% chance of having freckles.

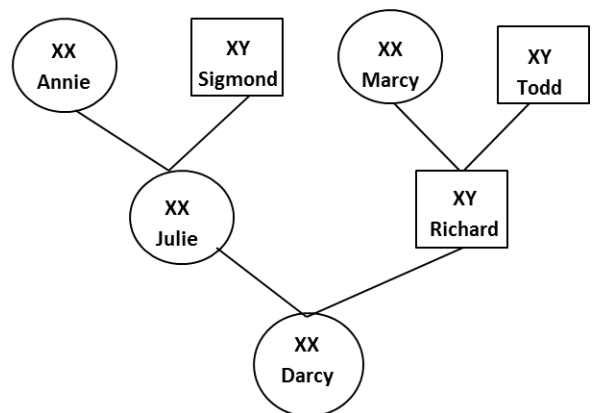
33. There are people in Susan's family who have had Polycystic Kidney Disease (PKD). PKD is a single-gene disease in which clusters of fluid-filled sacs (cysts) form in the kidneys, often leading to kidney failure by the age of 10 and a reduced lifespan. Below is a list of facts that she has gathered from researching 5 generations of her family. Help her to draw conclusions based on these facts.

1. PKD affects men and women equally
2. Symptoms seem to "disappear" in some generations.
3. Her mother had genetic testing done and one gene showed PKD but she doesn't have any symptoms.

- A. PKD is a sex linked disease
- B. PKD is a recessive disease.
- C. PKD is due to a single random mutation that is not heritable.
- D. PKD is a polygenic; the more genes that are mutated, the sicker the individual is.

34. Darcy has noticed that her mom is showing signs of male pattern baldness (heritable, sex-linked condition) and she is getting worried that she may have it to. What are the odds that Darcy will have male pattern baldness if her father Richard wasn't bald?

- A. 0%
- B. 25%
- C. 50%
- D. 100%



35. What feature of DNA is NOT TRUE?

- A. The hydrogen bonds that hold it together are weak and easy to break.
- B. The bases always bind to their correct partner
- C. The sequence of nitrogenous bases does not greatly influence the structure of the molecule.
- D. The overall shape of the molecule reflects the information stored in it.

36. How similar is your genetic information to that of your parents?

- A. You have one copy of each gene from one parent and another from the other parent.
- B. Your set of genes are somewhat similar to your parents but most similar to your grandparents.
- C. You contain the same genetic information as each of your parents, just half as much.
- D. You could have more of one parent's genetic information, depending on the amount of crossing over during fertilization.

37. Humans grow both sexually (meiotically) and asexually (mitotically). Sexual growth involves \_\_\_\_\_ while asexual growth involves \_\_\_\_\_.

- A. a reduction of chromosome number and maximizing genetic variability ..... maintaining chromosome number and minimizing genetic variability.
- B. maintaining chromosome number and maximizing genetic variability ..... reducing chromosome number and minimizing genetic variability.
- C. a reduction of chromosome number and minimizing genetic variability ..... maintaining chromosome number and maximizing genetic variability.
- D. maintaining chromosome number and minimizing genetic diversity ..... reducing chromosome number and maximizing genetic diversity.

38. A single dog skin cell has 78 total chromosomes. How many total chromosomes would be packaged into each gametic cell (egg or sperm)?

- A. 78
- B. 156
- C. 39
- D. 92

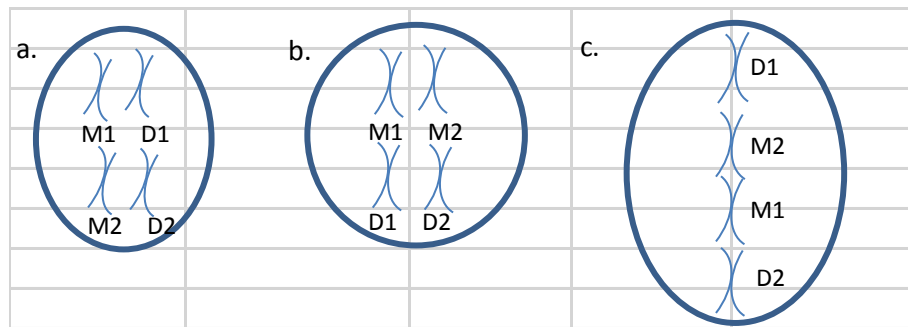
39. A cell in your liver differs from a cell in your skin in both structure and function. This is because the two cells

- A. contain different genes
- B. contain different RNAs
- C. contain different DNAs
- D. A and B
- E. A and C



40. The processes of meiosis and mitosis differ in function. Although both processes in humans begin cell division with a cell that has 92 chromosomes, the daughter cells (e.g. skin cell or a sperm cell) of mitosis versus meiosis look different from one another in terms of chromosome number and genetic variability. Metaphase of mitosis and Metaphase I of meiosis play a primary role in producing those differences.

All three drawings below are of Metaphase with the vertical line indicating the cleavage plane. Which of the drawings would allow for Meiosis to proceed to reduce chromosome number and increase genetic variability?



Please bring your scantron and assessment up to the front once you are finished.