

AP[®] BIOLOGY 2014 SCORING GUIDELINES

Question 2

Mammalian milk contains antibodies that are produced by the mother’s immune system and passed to offspring during feeding. Mammalian milk also contains a sugar (lactose) and may contain proteins (protein A, protein B, and casein), as indicated in the table.

MILK COMPONENTS IN DIFFERENT MAMMALS

Character	Cat	Cow	Horse	Human	Pig
Lactose	+	+	+	+	+
Protein A	+	+	+	+	+
Protein B	–	+	+	–	+
Casein	–	+	+	–	+
+ indicates the presence of the character, and – indicates the absence of a character					

- (a) Using the data in the table, **construct** a cladogram on the template provided to indicate the most likely evolutionary relationships among the different mammals. **Indicate** on the cladogram where each of the characters most likely arose in the evolutionary process, and **justify** the placement of the characters on the cladogram. (3 points maximum; LO 1.18, 1.19)

NOTE: Points are earned in one column only.

<div style="display: flex; justify-content: space-between;"> <div style="text-align: left;"> <p>1 point</p> </div> <div style="text-align: right;"> <p>1 point</p> </div> </div>	<div style="display: flex; justify-content: space-between;"> <div style="text-align: left;"> </div> <div style="text-align: right;"> <p>1 point</p> </div> </div>
Justification (1 point)	Justification (1 point)
Lactose and Protein A arose in a common ancestor to all 5 animals. Protein B and Casein arose only in the common ancestor to the pig/cow/horse clade/branch.	Lactose, Casein, Protein A, and Protein B arose in a common ancestor to all 5 animals. Protein B and Casein were lost in the common ancestor to the cat/human clade/branch.

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Question 2 (continued)

- (b) Describe FOUR steps in the activation of the mother’s specific immune response following exposure to a bacterial pathogen. Predict how the mother’s immune response would differ upon a second exposure to the same bacterial pathogen a year later. **(5 points maximum; LO 2.29).**

Description **(1 point each; 4 points maximum)**

- Endocytosis of antigen by dendritic cell/macrophage/B-cell
- Degradation of antigen
- Antigen complexed with MHC molecule
- Presentation of antigen on surface of cell
- Recognition of antigen on surface of antigen presenting cell by (helper) T-cell
- Activation of signal transduction mechanism in T-cell
- Activation of (helper) T-cell
- (Helper) T-cells release chemicals that recruit/activate B-cells
- Antigen recognition by B-cell
- Activation of signal transduction mechanism in B-cell
- Activated B-cell or T-cell will clone itself
- Plasma cells/B-cells produce antibodies
- Antibodies recognize antigen
- Antibody binding to antigen is specific
- Memory B cells/memory helper T cells are produced

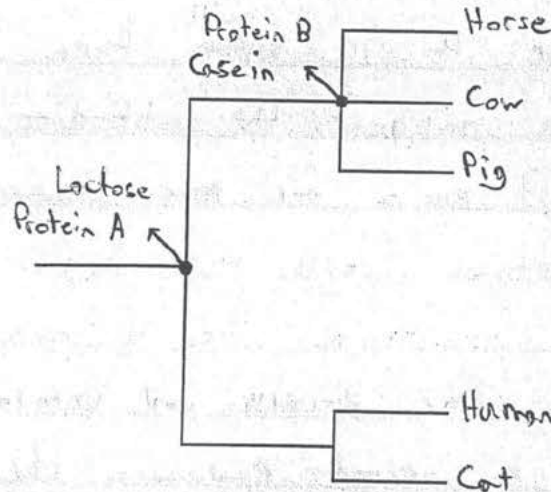
Prediction **(1 point)**

- Results in more rapid immune response
- Presence of memory cells
- Greater production of antibodies
- Antibodies circulate longer
- Antibodies have a greater affinity for the antigen

- (c) **Predict** the most likely consequence for a nursing infant who is exposed to an intestinal bacterial pathogen (e.g., *Salmonella*) to which the mother was exposed three months earlier. **Justify** your prediction. **(2 points maximum; LO 4.9, 2.40, 2.36)**

NOTE: Points are earned in a single row only.

Prediction (1 point)	Justification (1 point)
Infant will be protected/not get sick	Antibodies are passed to infant <i>in utero</i> /via breast milk/infant receives B-cells in breast milk
Infant will become sick/die	Insufficient antibodies were transferred to the offspring/infant exposed to high infecting dose of the pathogen



2A,

a.) Both Human and cats lack Protein B and casein so they would be grouped together and they would have a common ancestor. Furthermore, Horses, Pigs and Cows all possess every trait so they would be grouped together. Since all the species possess Lactose and Protein A it would have to arise in a common ancestor for all the species. Therefore, Protein B and Casein would have to arise in the common ancestor of Horses, Cows and pigs.

b.) A macrophage will phagocytose the pathogen it will then present the antigen to a helper T-cell. The macrophage will be known as an antigen presenting cell. The ~~antigen~~ antigen will bind to receptors on the helper T-cell. Afterwards the helper T-cell will release cytokines that will signal B-cells and Cytotoxic T-cells. This known as the humoral response (B-cells) and cell mediated response (Cytotoxic T-cells)

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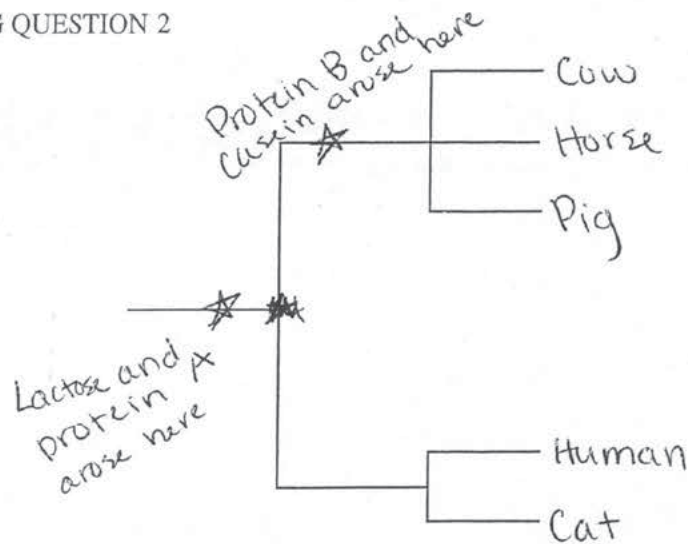
2A₂

respectively. The B-cells ~~will~~^{will} then produce antibodies to combat the antigens. The antibodies will then clump antigens making it easier for macrophages to phagocytose them. The cytotoxic T-cells will recognize and destroy cells that have been infected by the antigen. After the antigen is dealt with some B-cells and cytotoxic T-cells will remain. During a second exposure the response would be way quicker, ~~once the antigen~~ due to left over B-cells and cytotoxic T-cells that are specific to that antigen. So these cells will instantly produce antibodies and attack infected cells. The second response would be much quicker and more organized.

C.) The infant would already have antibodies that were given to it by its mother via passive immunity. Then the antibodies would make it significantly easier for the ~~non-~~ non-specific immune system of the infant to get rid of the antigens. Furthermore the infant could also have inherited cytotoxic T-cells ^{from its mother} that will help destroy ~~the~~ cells infected by the antigen. The infant would most likely survive due to passive immunity.

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2 B,



- A) ~~Humans and cats were placed on the cladogram to be closest in relation because~~
- A) Lactose and protein A were placed at the beginning of the cladogram before the mammals diverged because lactose and protein A are present in the milk of all of the featured animals. Therefore, they must have arisen before the evolutionary pathways diverged. Protein B and Casein were placed after the pathways diverged along the pathway of the cow, horse, and pig because these 2 characters are found in cows, horses, and pigs, but not in humans or cats. Therefore, it must have evolved after the ~~split~~ pathways diverged somewhere along the ^{shared} evolutionary pathway of ~~the~~ the cow, horse, and pig.
- B) When exposed to the pathogen, an antigen presenting cell will engulf the pathogen and then presents its antigen on the outside of the cell. Helper T cells will ~~send out a signal~~ send out a signal that there is a pathogen which activates

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2 B₂

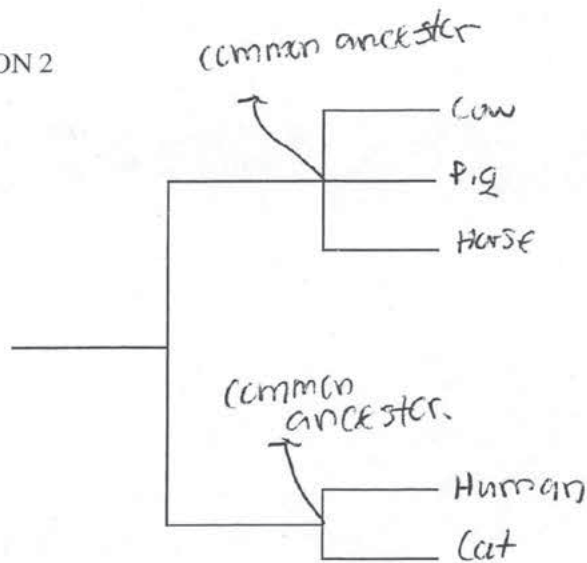
B cells. B cells will then bind to the antigen and create antibodies that fit the antigen. The ~~antigen~~ antibodies will bind to the antigens to mark those cells for destruction.

Memory T cells will ~~store~~ store the shape of antigen in its "memory" for faster destruction if the pathogen is encountered again. A second exposure to this pathogen will result in a much faster reaction because the memory T cells will recognize the pathogen's shape and immediately start defending the body from the pathogen.

c.) The infant's immune system will likely recognize the pathogen and target it for destruction, because the infant was likely inside its mother during the mother's exposure to the pathogen, the infant's immune system should recognize the pathogen from when it was inside the infant's mother.

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2c.



a) The cow, pig, and horse are placed under the same ~~common~~ recent common ancestor on the cladogram because they all contain Lactose, Protein A, Protein B, and Casein. As a result of that, it can be inferred that the cow, pig, and horse are ^{and evolutionarily} genetically similar to one another in regards to their nucleotide sequences. That is why they placed next to each other under the same recent common ancestor. However, when looking at the human and cat they both lack ~~the~~ Protein B and Casein. In this respect they could be evolutionary similar to each other and are ~~more~~ more closely related to each other ~~than~~ than they are to the cow, pig, and horse. So it is likely that the human and cat share a different common

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2C2.

ancestor than the cow, pig, and horse. All due to the presence of those proteins.

10) In response to a bacterial pathogen the first step consists of the pathogen being absorbed by a ^{or spotted by a dendritic cell.} macrophage. The second step is the macrophage becoming a class 2 MHC antigen presenting cell and binding to a specific antigen receptor on a helper T cell. The third step is the Helper T cell then secreting ~~of~~ cytokines that activate B cells. ~~The B~~ The fourth and final step is the B cell producing antibodies that will lyse the macrophages containing the pathogen. A year later the mother's immune response would occur at a faster rate because she ~~produced~~ created memory cells during the first invasion. The memory cells will immediately recognize the receptors on the pathogen and trigger the production of antibodies and cytotoxic T-cells.

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JC₃

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

c) The infants adaptive immunity will kick in. Similar to how a vaccine works, the infants body will create memory T or B cells that will recognize the intestinal pathogen more quickly because it was introduced as a weak strain first by the mother's breastmilk.

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Question 2

Question 2 was written to the following Learning Objectives in the AP Biology Curriculum Framework: 1.18, 1.19, 2.29, 2.36, 2.40, 4.9

Overview

Question 2 focuses on the evolutionary history of mammals and on the role of the immune system in responding to infection by a specific pathogen. The question asks students to use the presence or absence of derived characters in milk to construct a cladogram indicating the evolutionary relationships of the mammals. Students were asked to justify the placement of the derived characters on the cladogram. Students were then asked to describe the activation of the immune system in response to the infection. Finally, students were asked to predict the most likely consequence for a nursing infant who is exposed to a pathogen to which the mother was exposed three months earlier and to justify their prediction with evidence.

Sample: 2A

Score: 10

The response for Sample 2A earned 1 point in part (a) for constructing the cladogram. The response earned 1 point for indicating the position of each of the four derived characters on the cladogram. The response earned 1 point for the justification that lactose and protein A are present in all the species and therefore arose in a common ancestor of all the species, and Protein B and casein arose in a common ancestor of only the horse, cow, and pig.

In part (b) the response earned 1 point for describing endocytosis of the antigen by macrophages. The response earned 1 point for describing the presentation of the antigen on the surface of the macrophage. The response earned 1 point for describing the recognition of the antigen by the helper T cell. The response earned 1 point for describing the release of chemicals by helper T cells that signal/activate B cells. The response earned 1 point for predicting that the second exposure to the antigen results in a more rapid immune response.

In part (c) the response earned 1 point for the justification that antibodies are transferred to the nursing infant in breast milk and 1 point for predicting that the infant will be protected/not get sick

Sample: 2B

Score: 8

The response in Sample 2B earned 1 point in part (a) for constructing the cladogram. The response earned 1 point for indicating the position of each of the four derived characters on the cladogram. The response earned 1 point for the justification that lactose and protein A arose in the common ancestor and are therefore present in all of the species and Protein B and casein arose only on the branch leading to the horse, cow, and pig.

In part (b) the response earned 1 point for describing the engulfment of the pathogen by an antigen presenting cell. The response earned 1 point for describing the presentation of the antigen on the surface of the antigen presenting cell. The response earned 1 point for describing the activation of B cells by signals from helper T cells. The response earned 1 point for describing that B cells produce antibodies. The response earned 1 point in part (b) for predicting that the second exposure to the antigen will result in a quicker immune response.

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Question 2 (continued)

Sample: 2C

Score: 6

The response in Sample 2C earned 1 point in part (a) for constructing the cladogram.

In part (b) the response earned 1 point for describing the endocytosis of the pathogen by macrophages. The response earned 1 point for describing the presentation of the antigen on the surface of the antigen presenting cell. The response earned 1 point for describing the recognition of the antigen by helper T cells. The response earned 1 point for describing the activation of B cells by cytokines. The response continued to describe the production of antibodies by B cells but the description points had already been earned. The response earned 1 point in part (b) for predicting that the second exposure to the antigen will result in a quicker immune response.