**Answer Key for “Evolutionary Medicine: An Introduction”  
Case Study**

1. **Define evolutionary medicine in your own words. Why might evolutionary medicine be beneficial to study alongside traditional medical fields like immunology or pathology?**

*The main concept of evolutionary medicine is utilizing the principles of evolution in order to treat medical problems. Evolutionary medicine looks to explain how human traits evolved that seem problematic today through the perspective of natural selection from our evolutionary past. This will provide a more holistic view of illness and should complement traditional medical fields like immunology. More data and perspectives is always a positive thing!*

1. **How do antibiotics influence a bacterial population?**

*Antibiotics influence a bacterial population by acting as a selective pressure, primarily by preventing bacteria from performing essential functions such as reproduction or respiration. As a result, if none of the bacteria are resistant to the antibiotic, the entire population will die out.*

1. **What would happen if a few individuals in the above bacterial population have a gene that causes them to withstand the antibiotics? Moreover, what would happen to the bacterial population over several generations?**

*If a few individuals in the bacterial population have a gene that allows them to survive in the presence of antibiotics (e.g. the gene may be able to detoxify the antibiotic), these few individuals will survive as the rest of the population die. Now, these individuals will clone themselves with that resistant gene, creating a bacterial population that is now resistant to the effects of the antibiotics.*

1. **What will happen when bacteria develop antibiotic resistance?**

*When bacteria develop antibiotic resistance, the bacterial population will no longer be affected by the antibiotic, regardless of the dose or concentration of the antibiotic. At this point, the bacterial population may continue to proliferate, or a new antibiotic may be introduced to the population to kill approximately the entire population.*

1. **How are antibiotic resistance and evolutionary medicine connected?**

*Answers may vary. As mentioned in the case study, evolutionary medicine is “a field that considers medical problems through an evolutionary lens.” Antibiotic resistance is one of those medical problems. Moreover, antibiotic resistance is a consequence of evolution within a bacterial population, meaning it is best treated when doctors consider the problem through an evolutionary lens - the basic idea for evolutionary medicine.*

1. **Over evolutionary time, the human middle ear evolved. Summarize the major change that occurred within the middle ear and how that evolutionary design led to a predisposition for ear infections.**

*The middle ear bones of humans were derived from the lower jaw of their ancestors. With this change, a greater efficiency of hearing was achieved. This evolutionary design, however, led to a predisposition for ear infections as the middle ear was now connected to the pharynx via the eustachian tube. The movement of the bones from the jaw to the middle ear created a passageway between the middle ear and the pharynx which is an ideal environment for bacterial growth.*

1. **If eustachian tubes had evolved larger than their current sizes, what possible consequences could result from this change. Would ear infections still occur? Regardless of your answer, elaborate.**

*Answers will vary. Regardless of what position the student takes, as long as their claim is logical and applies the principles of evolution correctly, their answer should be accepted.*

*For arguments that agree with the statement, students may cite information in the case study, stating that the current size of eustachian tubes do not allow for a lot of fluid to be drained at once. Thus, if the eustachian tubes were bigger, more fluid would be able to pass through, and the likelihood that the fluid would get trapped would decrease significantly.*

*On the other hand, arguments that disagree with the statement could consist of how bacteria can coevolve with their human counterparts, meaning an evolutionary change in humans could lead to an evolutionary change in bacteria. Possibly, despite the decreased possibility of fluid building up, the bacteria could evolve to thrive in a dry environment.*

1. **Do you think natural selection will influence the human body such that it will eventually evolve to prevent ear infections? Explain.**

*Answers will vary. Regardless of what position the student takes, as long as their claim is logical and applies the principles of evolution correctly, their answer should be accepted.*

*For arguments that agree with the statement, students may argue that the human body has evolved to accommodate humans better to the surrounding environment. Besides the middle ear evolving as mentioned in the case study, students may cite other instances of human evolution such as lactose persistence, malaria resistance, etc. Essentially, the key aspect of their argument could be “if the human body has evolved to become better adapted to the environment/resources available, why wouldn’t it be plausible for the human body to adapt to combat the possibilities of bacterial infections?”*

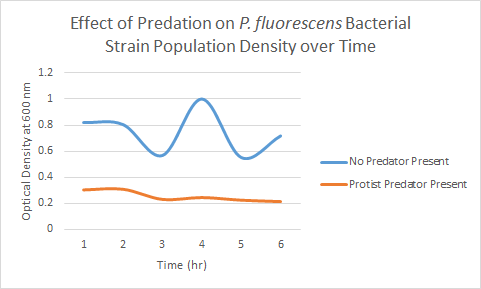
*On the other hand, arguments that disagree with the statement could consist of the fact that bacterial populations can quickly asexually reproduce, and therefore, evolve faster than their human counterparts, implying that bacterial populations will have the upper hand. Moreover, students may argue that, since ear infections do not necessarily prevent reproductive success, it would not seem plausible for a gene that prevents ear infections to be favored or disfavored. Essentially, the key aspect of their argument could be “if the human body is still capable of reproducing despite multiple ear infections, why would something as fairly minor as an ear infection be the driving force for evolutionary change?”*

1. **As mentioned above, the gut biome is filled with bacteria that can affect the effectiveness of the human body’s immune system against pathogens. Describe a plausible mechanism as to how probiotics can help with ear infections.**

*Answers will vary. As long as students provide plausible methods as well as explanations, their answers should be accepted.*

*As mentioned in the case study, probiotics allow a way to introduce beneficial bacteria into the body via the digestive system. If harmful bacteria and pathogens are present in a human, the beneficial bacteria from probiotics could “fight off” the harmful bacteria and prevent them from moving elsewhere in the body. Moreover, gut bacteria are known to aid in digestion; if more gut bacteria are introduced to the body, more resources are available to be absorbed and used for energy. As a result, the body could have more energy to allocate for immune responses toward ear infections, making the responses more effective.*

1. **The following data focuses on a species of bacteria *P. fluorescens* and its predator *T. thermophila*, a species of protist (Friman et. al 2013). The optical density of the bacteria population (an indirect measurement reflecting the overall size of the population) was measured for 6 hours at 1-hour intervals via bacterial dilutions.**
   1. **What can be concluded from the data? Does population density/size tell us anything about coevolution despite frequencies of traits or alleles not being present on the graph? Justify your thoughts.**
   2. **If more data were collected over a longer period of time, for example several months, would coevolution occur? If so, what patterns would you expect to see on the graph? Would you need more data or different types of data to make this determination? Explain.**



*a)*

*From the graph, students should be able to conclude that the bacteria population exposed to a protist predator population is less dense than the bacteria population not exposed to the protist predator population. Students may also observe the cyclic trend of the bacteria population not exposed to the predator population, indicating that the bacteria may be oscillating about their environment’s carrying capacity.*

*Furthermore, students should take a stance on whether or not population density is adequate enough to describe a possible coevolution relationship between bacteria and protists. Answers will vary. Regardless of what position the student takes, as long as their claim is logical and applies the principles of evolution correctly, their answer should be accepted.*

*Students in agreement may argue that, since the bacterial population with the protist population present had smaller population densities overall, it is plausible to assume that the two populations are involved in a coevolutionary relationship and, over time, it is possible for the bacterial population to rise back up again.*

*Students in disagreement may argue that, without information regarding what traits for the bacterial population are beneficial, the bacterial population may not be acting as a selective pressure on the protist population, implying coevolution is not occurring. For example, the bacterial gene pool may not have any genes that provide effective defensive mechanisms against the protists; in this scenario, over time, the bacterial population will be wiped away by the protist population.*

*b)*

*Answers will vary. Regardless of what position the student takes, as long as their claim is logical and applies the principles of evolution correctly, their answer should be accepted.*

*For graph changes over time, if coevolution was occurring, it would be expected to see some oscillations developing with the “protist predator present” line as protists are acting as selective pressures on the bacteria and vice versa. On the other hand, if coevolution was not occurring, it would be expected to see the “protist predator present” line to decrease to 0 as the bacterial population is being killed off due to the population not having any defense mechanisms to act as a selective pressure against the protist population.*

*Regarding the amount of data needed to make the above determination, students who claim enough data has been given may argue that, given the behavior of coevolution, it is expected that the “protist predator present” line of bacteria would either decrease all the way to 0 (coevolution is not occurring) or increase to a certain point (coevolution is occurring). On the other hand, students who claim more data needs to be collected may argue that confounding variables such as temperature and sunlight exposure may have skewed the results, and more experimental trials need to be conducted in order to consider the implications of these variables.*

1. **If traits of humans are influencing the population of a pathogen via coevolution, how might this influence how physicians treat a pathogen, such as a bacterial infection?**

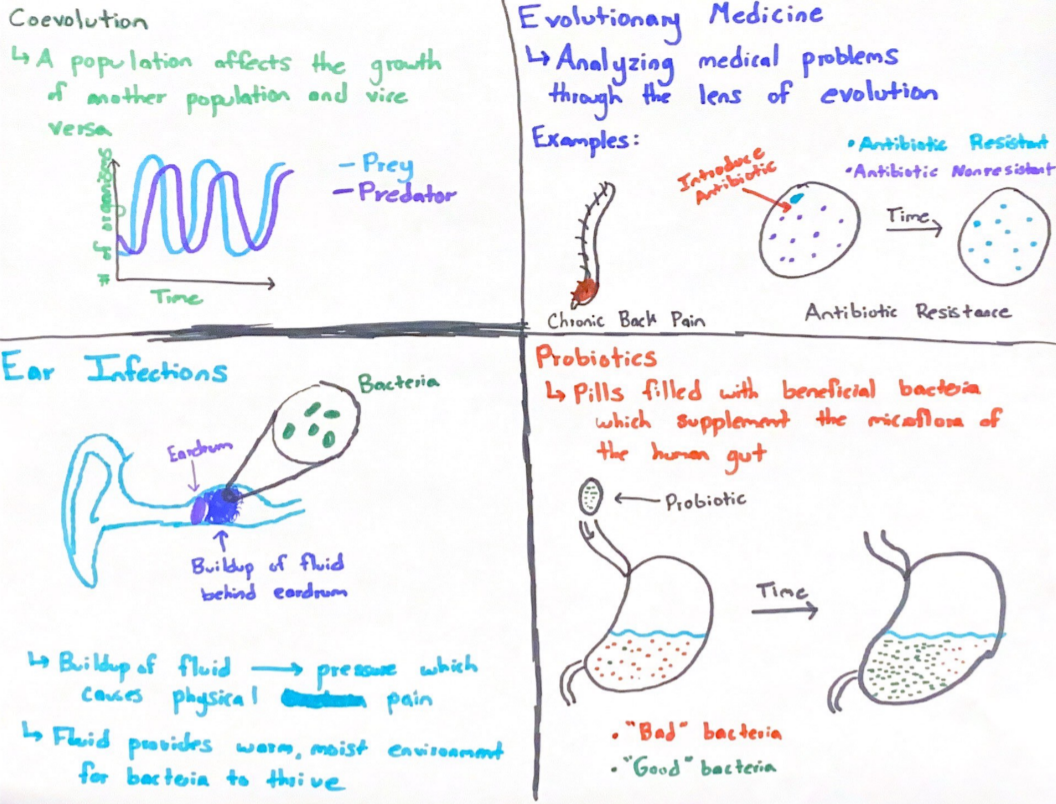
*Answers will vary. Regardless of what position the student takes, as long as their claim is logical and applies the principles of evolution correctly, their answer should be accepted.*

*Understanding coevolution could lead to physicians treating pathogens in a manner that effectively solves the problem in the present yet is cognizant of how the problem will change over time. For example, when prescribing antibiotics for an ear infection, a doctor knows that the bacterial population may develop antibiotic resistance. Rather than disregard this possibility, the doctor would create a plan for antibiotic resistance - whether that involves prescribing a new antibiotic or a new type of medicine to treat the pathogen when the time comes.*

*Furthermore, considering a patient’s traits that might have an effect on the pathogen may be a better assessment of the issue. Continuing the above example, a patient may have high concentrations of earwax compared to the average individual and, thus, their ears are more moist, providing the ideal habitat for bacteria. If earwax can be controlled, it may help with recurring ear infections. If ear infections are controlled then the bacteria is controlled and coevolution will likely be dampened.*

1. **To help summarize what has been learned through this case study, create an infographic that covers at least three of the main topics that have been covered (coevolution, evolutionary medicine, ear infections, probiotics, etc.). Be as creative as possible!**

*Infographics will vary. All that matters is that at least three main topics are covered (*coevolution, evolutionary medicine, ear infections, probiotics, etc.*). Here is an example where four main topics of the case study are discussed (provided by one of the authors):*

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