Evolution and Human Health

What is a Mismatch Disease?
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Purpose

In this lesson, students are learning about how changes in the environment can influence phenotype of organisms. More specifically, students will be investigating the concept of a mismatch disease and how it relates to many present human phenotypes that are no longer beneficial. Humans have drastically changed their environment which has facilitated the prevalence of osteoarthritis. Data collected from observing the knee joint of human skeletons from 6,000 years ago to present time has shown that the occurrence of osteoarthritis drastically increased after the industrial age.

Audience

This lesson was designed to be used in an introductory high school biology class.

Lesson Objectives

Upon completion of this lesson, students will be able to:

- explain how changes in environment are related to the continuing evolution of humans.
- describe how natural selection does not prevent human disease (such as mismatch disease).
- analyze data to make and defend a claim regarding incidence of osteoarthritis over time.

Key Words

adaptation, mismatch disease, natural selection, osteoarthritis

Big Question

This lesson addresses the Big Question "Where do we come from?"

Standard Alignments

- Science and Engineering Practices
  - SP 4. Analyzing and interpreting data
  - SP 7. Engaging in argument from evidence
- MA Science and Technology/Engineering Standards (2016)
  - HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence, including molecular, anatomical, and developmental similarities inherited from a common ancestor (homologies), seen through fossils and laboratory and field observations.
- NGSS Standards (2013)
  - HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
Common Core Math/Language Arts Standards

CCSS.ELA-LITERACY.RST.9-10.1. Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

Misconceptions Addressed

- This lesson addresses many common misconceptions about evolution, including:
  - Evolution and natural selection are the same thing. (Question 3)
  - Natural selection and evolution produce perfectly adapted organisms (Question 5).
  - Humans are no longer evolving despite being biological entities (Question 2).
- Further information about student misconceptions on this topic can be found [here](#).

Primary Sources

- Bite "Ancient Bodies in a Modern World: Osteoarthritis and Evolutionary Mismatch Diseases" based on:

- Article about human mismatch disease in Discover
  - Wheelwright, Jeff. 2015. “From Diabetes the Athlete’s Foot, Our Bodies Are Maladapted for Modern Life.” *Discover Magazine.* 02 April.

- Misconceptions

Materials

- Copies of the student handout and Science Bite for each student

Time

- This activity should take approximately one 50-minute class period.

Student Prior Knowledge

- Students should have a general understanding of the processes of evolution and natural selection. More specifically heritability, variation and competition (for resources and mates) are the three “pillars” of natural selection. Students should also understand that changes in the environment can turn once beneficial traits into harmful ones. It is also helpful for students to know the basic anatomy of the knee and function of human bone joints.

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Instructions and Teacher Tips

General Procedure

- Have students read through the worksheet and answer the questions as they go, reading the Science Bite when instructed.
- Check in after most students have finished the first four questions to make sure that there aren’t any issues understanding natural selection and evolution that need to be addressed.
- After students have completed the lesson, consider bringing them together as a class or break into small groups to compare answers and to discuss any remaining questions.

Tips, Extensions, and Variations

- This activity could work well with students working in pairs or small groups.
- Students who may have reading or other language disabilities may need additional time to process the Bite. An option is to give these students the Bite to read for homework before the lesson is completed in class. Another option would be to record an audio version of the Bite for a student to listen to prior to the lesson.
- Consider stopping after students read the Bite and having a class discussion about the main ideas. This could help students get on the same page before going on to the more in-depth analysis questions.
- Some students may have trouble interpreting the data regarding knee OA. It maybe be helpful to show just the data table the class before and ask students to summarize what is being presented in the table.
- For Question 10, you could assign each pair or group a different disease so that the whole class learns about each of them. There is a lot of good information out there about each disease. Encourage students to look for reliable and high-quality webpages. A few suggestions:
  - Myopia: National Eye Institute, American Optometric Association
  - Asthma: National Heart, Lung, and Blood Institute; American Academy of Asthma, Allergies, and Immunology; Allergy and Asthma Foundation of America
  - Non-alcoholic fatty liver disease: American Liver Foundation, National Institute of Diabetes and Digestive and Kidney Diseases
  - Inflammatory bowel disease: Crohn’s and Colitis Foundation, American Gastroenterological Association
  - Colon cancer: American Cancer Society, Colorectal Cancer Alliance
  - Acne: American Academy of Dermatology, American Acne Association
  - COPD: COPD Foundation; American Lung Association; National Heart Lung, and

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Type-1 diabetes: American Diabetes Association, Centers for Disease Control
Ovarian cancer: American Cancer Society, National Cancer Institute
Osteoporosis: National Osteoporosis Foundation

If the idea of a mismatch diseases is new to you, there are some helpful videos and articles that explains why many other human traits (not just bone joints) are no longer beneficial and why.

This video was uploaded by The Scope of Science group and includes a very easy to understand explanation of human mismatch traits.

This video was uploaded by Nature Video where Daniel Liberman, aka “the barefoot professor” explains how the human body was engineered to be a superior endurance athlete where shoes are not needed to run!

This article is also a great resource regarding the prevention of the development of mismatch diseases and the what the future of human health may look like.

Background Information and Research Details

Many common human diseases are considered “mismatch” diseases. Because humans are capable of influencing and often controlling their environments through technological and cultural changes (particularly since the industrial revolution), shifts in diet and levels of physical activity have affected many aspects of human health. While the transition from a hunter-gatherer lifestyle to pre-industrial sedentary farming and from farming to post-industrial manufacturing has had considerable benefits for humans and allowed for dramatic population increases, it has also led to many negative outcomes such as increased rates of certain diseases and other health issues. It is important to note that “environment” is not just the world outside the body. For humans it is also diet, medicine, lifestyle, amount of exercise, etc. These factors can and do influence influence evolution.

Osteoarthritis is extremely common in the human population today. It is characterized by the wearing away of protective cartilage in between the joints. Symptoms include pain, tenderness, swelling and loss of flexibility. Many used to believe that osteoarthritis was solely caused by high BMI or overuse of the joint (“wear and tear”) over time. However, a lack of activity and exercise has been linked to a higher occurrence of osteoarthritis while active populations/individuals have historically had fewer occurrences of OA. Thus, this research suggests that regular exercise and activity might prevent some of the causes of OA. However, we only know that OA is triggered by inactivity and scientists are not exactly sure why regular exercise might prevent OA. OA in general is not very well understood.

The term “controlling for” means that those variables were accounted for in a mathematical/statistical model. The effects of these variables on the measured data were accounted for and then excluded from the analysis by determining the impact of these variables on the results and removing them, thus limiting the impact of these variables on the results and measuring only the effects of the variables of interest.
This lesson, and in particular the Big Question discussion (see below) might lead to students wondering about the popular “paleo diet.” These diets suggest that we will feel better and lose weight if we eat like our human ancestors did. While this might seem reasonable in light of mismatch diseases, it turns out to not be that simple. Consider showing your students this video of paleoanthropologist Briana Pobiner discussing the phenomenon of paleodiets and what she thinks about them given that she is an expert on prehistoric human diets.

**Big Question Discussion**

This lesson should get students thinking about the Big Question “Where did we come from?” In particular, students should think about ways that our own bodies reflect our evolutionary history. If you choose to delve into the Big Question, consider the following ideas:

- To open the lesson, warm up your students to the idea of how the environment can influence the characteristics of an organism. What makes up an organism’s environment (the surroundings or conditions in which a person, animal, or plant lives)? How have human environments changed over time? What human phenotypes vary? How does the environment influence the presence or absence of phenotypes?

- Now think about the environment your students now live in. How does this differ from past human environments? How have past human environments affected human biology/phenotypes that still exist today? How are humans a product of their evolutionary history? What sort of evolutionary “baggage” do we as a species carry around with us?

- Next, transition to the idea of the future human. How is our current environment changing? How might that affect the phenotypes of future generations? Encourage students to think about the pace of cultural evolution and how it is much faster than that of human biological evolution. Try to keep the conversation away from fantastical ideas such as “we will all have a third arm to make typing easier.” One way to do this is to remind students that evolution only acts on existing variations. Be on the lookout for common evolution misconceptions such as at the idea that evolution gives organisms what they need to survive.

- After students have completed the lesson and read the Bite, ask these questions in the wrap-up discussion: Is there a way that mismatch diseases can be cured? Prevented? What will happen to the phenotypes of humans if we do not think about mismatch diseases?

**Answers**

1. Describe the process of natural selection. More specifically, describe how heritability, variation and competition (for resources and food) influence the process of natural selection.

The process of natural selection is the idea that individuals have certain inherited traits that increase their fitness (ability to survive and reproduce) at higher rates than other individuals because of those traits. If an individual inherits beneficial forms of genes from its parents, than that organism is more likely able to survive. However it is required that there are multiple forms of genes (and unique combinations of genes) that exist in the population. Sexual reproduction produces offspring that have unique combinations of genes that are necessary for natural selection to occur. In the struggle for survival, living things compete for food, space and mates which results in differential reproductive success. As the environment changes over time, individuals that were once successful may not be anymore, leading to natural selection.
2. Many people think that evolution and natural selection are synonyms—that is, that they mean the same thing. How would you explain the difference to someone?

The process of evolution can be defined as any change over time of living things. Natural selection is a mechanism of evolution and can be defined as the process by which organisms that are best suited to their local environment survive and leave more offspring than individuals who are not as well suited for that same environment.

3. What is the link between natural selection and reproductive success?

Natural selection can only occur if more individuals are born than can survive, there is a natural heritable variation, and there is variable fitness (ability to survive and reproduce) among individuals. Therefore the most reproductively successful individuals most likely have heritable traits that can be passed onto offspring.

4. Are humans perfectly adapted to their environments? In your answer, provide evidence from your everyday experiences.

No. Natural selection acts upon pre-existing traits and only acts upon these. Evolution is not a process that ends with "perfect" organisms. Instead specific inherited traits are selected for based on being better suited to an environment than their competitors.

5. In your own words, define the term “mismatch disease.” Explain why osteoarthritis (OA) may be considered a mismatch disease.

A mismatch disease is an illness that becomes more common and serious because the human body is poorly adapted to the current environment. OA might be a mismatch disease because its largely caused by a change in our lifestyles from prehistoric times to today.

6. Examine the image in Figure 1. What do you notice about the healthy knee joint compared to the knee joint with OA?

The knee joint with OA had less cartilage between the bones.

7. How did scientists determine if the skeletons from the museums had OA?

Scientists observed the knee joint of many skeletons. They looked specifically for evidence of "eburnation" which is the polishing of the bones (shininess) as a result of the bones regularly rubbing together.

8. Examine the graph in Figure 2.

   a. How does the prevalence of OA compare in early and post industrial skeletons?

The prevalence of OA in postindustrial skeletons is much higher than the prevalence in early industrial skeletons.

   b. Citing specific data from the Bite, provide evidence in support your statement above.

The prevalence of knee OA of postindustrial skeletons was approximately 5–22% in skeletons aged 50–80 years respectively. The prevalence of knee OA of early industrial skeletons was approximately 3–9% in skeletons aged 50–80 years respectively. The difference is 2–13% prevalence among the same age groups when the two groups are compared.
9. Will natural selection act to decrease OA in the population? Explain why or why not. *(Hint: look back at your answer to Question 3.)*

No. Natural selection only occurs when fitness is affected and knee OA mostly affects people when they are older, after they have had children.

Some common diseases that may be considered mismatch diseases are shown in **Figure 1** below.

![Figure 1. Common Mismatch Diseases](image)

10. **Connect to the Big Question** Choose one of the mismatch diseases from **Figure 1**. Use the Internet and other reference materials to develop a three-minute oral presentation about the disease. Use the outline below to help you develop your presentation. Be sure to list all websites and references.

*Answers will vary depending on the disease chosen.* Check for reliable sources and completeness of the answers.