Learning concepts in evolution with malaria as the case study

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Introduction

Biology majors at Spelman College are typically interested in pursuing a career in medicine. Therefore the introductory Biology class covering Ecology, Evolution and Biodiversity, uses case studies related to human health and welfare to teach basic concepts in biology to maximize student interest and therefore, advance their learning. This case study based introductory Biology class has been taught at Spelman for the last four years (from 2006 to present). Such an approach has proved to be very successful in improving students' content knowledge in the course of the semester (Pai et al, in press) and more significantly students perceive their learning experience in case study based class to be superior to the traditional lecture only class (Pai 2009, Pai et al in press).

Malaria as a case study to teach about evolution

The materials presented in this case study package are used in the above mentioned introductory Biology class for majors in the second module on evolution.

This module uses malaria as a case study for learning basic concepts in evolutionary biology. The main idea of this case is to use malaria as an evolutionary force (Pai et al in press). At this point in the semester, students have already learned basic concepts in ecology from the ecology module and are therefore able to understand the interaction between organisms and their environment over an evolutionary timescale better such as the one presented in the case study here.

In the first of the four case study assignments, students learn about malaria as a selective agent on human populations. This assignment is a video describing the emergence and spread of sickle cell mutation in human Hemoglobin as a story (see references). Students should be able to understand the mechanism of natural selection through this case study.

In the second week students are asked to read a chapter on sickle cell disease (Bloom 1995) and where it is common. This assignment is designed to allow them to make connections between concepts in population genetics such as Hardy Weinberg equilibrium, gene flow, natural selection, random versus non-random mating etc.

In the latter two assignments another evolution story related to malaria—that of drug resistance in malaria parasites is used. Instructors may also use the emergence of insecticide resistance in the malaria vector mosquitoes for additional assignments. Again, these assignments also facilitate in students' making connections between concepts in population genetics such as Hardy Weinberg equilibrium, gene flow, natural selection, random versus non-random mating etc. In addition, they are asked to articulate the importance of evolutionary theory to medicine.

Structure
This module is taught over four weeks using short case study assignments each week (Pai et al in press). Each week students learn new concepts in the first two hour long lecture sessions of the week, such as nature of evolutionary thinking, natural selection, mutation, adaptation, population genetics etc. Later that same week, in the third lecture, students get to apply these concepts in their case study assignment. Typically they have to watch a video or read an article and answer questions that are based on the video or article, on their own with minimal instructor guidance. After the first case study which the students do in class, the other three are assigned as homework. Students are strongly encouraged to work in groups of 2 to 3 for these assignments. Students are then asked to submit their written work prior to the start of the in-class case study session.

The assignments get more difficult each week with the easiest one being in the first week and the hardest one in the last week. Each week, after the graded assignments are returned, there is a follow up with a class discussion on the case study assignments. These discussions enable the instructor to quickly correct student misconceptions.

Discussion:
This case has been taught with great success at Spelman College since 2006. Students evaluations suggest that the structure, content and format of the case as presented above is effective in enhancing student learning (Pai et al, in press). However these materials can be easily adapted to a wide variety of classrooms. Below I discuss some suggestions for adaptations.

1. Use of clickers: The questions included in the PowerPoint in this case study package are the ones that a large proportion of students (typically ~30% or more) get wrong. These may be used as 'clicker' questions if the instructors use 'clickers' in their classrooms. However, even when 'clickers' are not available- these questions can be adapted to promote class-wide discussion; for example, instructors may simply use show of hands to quickly gauge student's level of understanding.

2. Degree of difficulty of questions: Because these questions are intended to promote discussion they are relatively simple and often true or false questions. Other instructors may choose to rewrite the questions with a more standardized multiple choice format.

3. Format of classroom discussion: When discussing the questions, students should be allowed to discuss their answer with their peers and then select an answer. From past experience, it is evident that this promotes a better understanding of the concepts behind the questions posed and most students get the 'clicker' questions right in the classroom though they often get these same questions wrong in the assignment (their average grade in the assignments is a ~ C and their average grades on clicker questions

is ~B). However in other classrooms, if the students are at a higher skill level the time spent on discussion can be shortened.

4. Time frame: Although the above structure has worked well for the introductory class in our institution, it would be possible to easily adapt these resources for other types of classes. For example instructors might be able to select only one or two of the assignments rather than use all four. Alternatively, it should be possible to combine some of the assignments for a more advanced class. It is also conceivable that for classes that have longer class time, the instructor could use several pieces all at once.

5. Objectives: This case is focused on enabling students' learning of evolutionary biology using malaria as a case study. Therefore malaria is only presented as an important evolutionary selective agent. However instructors may be able to include additional details on malaria such as clinical significance of the disease and treatment options by simply assigning a reading or directing the students to a web site.

Survey results revealed that students at Spelman appreciate this structure and the materials in the case study (Pai et al in press). Specifically the assessment aimed to determine if this pedagogical approach was 1) interesting and/or useful to the students, 2) effective in improving students' knowledge, and 3) thought to be more effective in enhancing students' learning experience compared to the previous traditional biology class. The results of these three assessment activities revealed that students rated their interest in case study work to be high and that their subject knowledge was significantly enhanced from this class. Most interestingly, a comparison of students' evaluation of their learning experiences in the old and the new case-study based introductory biology class, even with the same instructor, showed that they rated their learning to be significantly better in the case study based class. Together these data suggest that the case study based approach was more effective in engaging students and enhancing their learning.

Learning Objectives:

From these case study assignments students should be able to:

1. explain how mutations may be neutral, beneficial or harmful depending on the environment
2. list conditions for natural selection to take place
3. discuss how natural selection acts on individuals but evolution is seen at a population level
4. predict whether the mutation will spread or not when given the nature of a mutation and the nature of the environment it is in
5. propose explanations for why people in different parts of the world differ with respect to sickle cell frequency
6. explain how drug resistance arises in malaria parasites
7. explain how evolution is not goal oriented

8. propose explanations for why different parts of the world where malaria is prevalent, differ with respect to malaria parasite drug resistance
9. predict what would happen if infected people or mosquitoes moved from populations with drug resistant malaria, to populations without drug resistant parasites
10. propose solutions to controlling malaria using evolutionary thinking
11. state the main point of a table and a figure
12. state the main point of an article in the context of the class
13. give two examples of how evolutionary thinking is relevant to human health and disease management

Key words:
case study, Evolution, natural selection, malaria, sickle cell, drug resistance, Hardy- Weinberg, gene flow, mutation

Teaching Materials

a) Included are the assignment questions for each case study
b) References for each case study
c) PowerPoint lecture with 'clicker' questions for classroom discussion, with notes on notes page of the slide for instructors
d) PowerPoint lecture: student version

Sequence of case study assignments

Week 1:

Concepts covered in lecture:

evolution
natural selection
mutation
adaptation

Case study:

Watch video: "A mutation story" http://www.pbs.org/

Discuss how prevalent sickle cell is in African American population (see Bloom 1995, Lerner 1995)

Assignment: see PowerPoint.

Week 2:

Concepts covered in lecture:

Hardy-Weinberg
allele frequencies
gene flow
genetic variation
evolution is not goal oriented

Case study:

Read chapter from Bloom (1995)

Assignment:

Case study 2: Sickle gene frequency in various populations

1. Although the sickle cell gene is very common in Africa (as many as 40% of people in some African tribes carry that gene) it is not common in North America. Consider <u>each</u> of the following statements and evaluate whether they might possibly explain why there is such a difference between the two continents? Justify your answer.

a) because the sickle mutation may not have arisen in America
b) because the sickle cell gene did not confer an advantage to people in America in the absence of malaria but did confer an advantage to people in Africa in the presence of malaria
c) because the sickle cell gene did not cause sickle cell disease in Africa

2. The article states that "The HbS mutation did not develop for the purpose of protecting people against malaria –it developed by chance." Explain how it is possible for something that appears by chance to become common in the population?

3. Consider <u>each of the following</u> statements. Evaluate whether each of the following might be evidence for the malarial hypothesis for commonness of sickle cell gene in certain populations? Justify your answer.

a) that malaria and sickle cell disease share common geographic distribution
b) that even within national boundaries association between malaria and sickle cell disease are strong
c) that the mutation for sickle cell gene (gene frequency) is more common in populations than expected by chance

4. What question/s do you have after reading this article that you would like to discuss in class?

See PowerPoint

Week 3:

Concepts covered in lecture:

Hardy-Weinberg
allele frequencies
gene flow
genetic variation
evolution is not goal oriented

Case study:

Read BBC news article (2005)

Assignment:

Case Study 3: Drug resistance in malaria

1. What is the main point of the article?
2. What are the implications of that finding for malaria control?
3. Natural selection takes place as follows:
   i. There is variation among individuals in a population
   ii. That variation is heritable
   iii. Some individuals are more successful at survival and reproduction than others and leave more offspring in the population.
   iv. Over time, the population resembles the more successful individuals

   Imagine a population of malaria parasites inside a patient. Draw the process of natural selection showing each of the above.

See PowerPoint

Week 4:

Concepts covered in lecture:

Hardy-Weinberg
allele frequencies
gene flow
genetic variation
evolution is not goal oriented

Case study:

Read WHO report study from Bloland (2001)

Assignment:

Case Study 8: Drug resistance in malaria parasites

Study the table carefully. And describe how the data in the table might be related to any THREE of the following: (bonus points for trying all 4)
(Hint: imagine the populations of malaria parasites, humans, and/or the mosquitoes in different regions and how they may be subjected to the following)

a) Natural selection
b) Gene flow
c) Genetic drift
d) Mutation

See PowerPoint

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