TIPS, TRICKS & TECHNIQUES

EvMedEd: A Teaching Resource for Integrating Medical Examples into Evolution Education

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Abstract

Teaching evolution using medical examples can be a particularly effective strategy for motivating students to learn evolutionary principles, especially students interested in pursuing medical and allied health careers. Research in the area of evolutionary medicine has expanded the number of ways in which evolution informs health and disease, providing many new and less widely known contexts that can be adopted for classroom use. However, many instructors do not have time to locate or create classroom materials about evolutionary medicine. To address this need, we have created EvMedEd, a resource repository to help instructors who want to integrate more medical examples into their evolution instruction or instructors who are teaching a course on evolutionary medicine. Some resources are designed to be more appropriate for a high school or introductory biology audience, whereas others are more advanced. We encourage instructors to access this curated website and to share their own teaching materials with this community.

Key Words: *evolution; health; medicine; evolutionary medicine; online resource; student-centered.*

Medically relevant applications of evolutionary principles illustrate how evolutionary biology is important to our day-to-day lives (Varki, 2012). However, increased awareness of the growing number of ways in which evolution informs an understanding of health and disease would be useful for evolution instructors. Here, we introduce EvMedEd.org, an online resource to help instructors integrate medically relevant examples of evolution into their biology courses or develop their own course devoted to evolutionary medicine – a multidisciplinary field focused on these applications.

○ Why Teach Evolution through Medical/Health Examples?

Many students whose interest in the life sciences stems from a desire to work in medicine or allied health careers (Cooper et al., 2019) may not realize that evolution is relevant to their career interests. Evolution is not only a core concept in biology (AAAS, 2011; Brownell et al., 2014), but is now a core competency for pre-medical students (AAMC-HHMI, 2009). While medical professionals are traditionally taught how disease happens, a foundation in evolutionary biology equips them to also understand why their patients are vulnerable to disease in the first place (Nesse et al., 2010).

Using medically relevant examples to teach evolutionary principles can help build and maintain student interest in learning evolution (Antolin et al., 2012), particularly for students interested in health careers. Motivational theories of learning suggest that content relevance is a key ingredient for designing stimulating learning experiences (Keller, 2009). Perceiving that a task, such as learning evolution, is important for one's own goals has been shown to be important for student persistence in obtaining that goal (Wigfield & Eccles, 1992). Thus, when designing evolution instruction to engage pre-health students, those students may benefit from the use of medical examples that make explicit how evolution is relevant to both their personal lives and their career interests (Keller, 2009). With the potential for increased student motivation and growing recognition that evolution is an important basic science for medical professionals (Nesse et al., 2010), we argue that medicine provides a powerful context for teaching evolution that should be more prominent in biology classrooms.

○ Evolutionary Medicine Offers Many Examples of How Evolution Helps Us Understand Disease

The range of evolutionary applications to medicine expands far beyond commonly used classroom examples such as antibiotic resistance, providing a rich pool of relevant, but currently underused, examples to implement in classrooms. Evolution is transforming our understanding of cancer (Greaves & Maley, 2012), including the discovery that lowering the dosage of chemotherapy can be a more effective treatment strategy (Gatenby et al., 2009). Carrying the apolipoprotein E4 allele is a major risk factor for developing Alzheimer's disease in industrialized populations, but

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in a hunter-forager population with a high parasite load, this allele actually slows cognitive decline (Trumble et al., 2016). Researchers have debated for years whether tuberculosis in New World populations reached these populations upon the arrival of Columbus or through some mechanism independent of European colonialists. However, analysis of DNA from lesions in ancient skeletons in Peru suggest that cases of TB in the New World were transmitted from seals (Bos et al., 2014). These examples, alongside others in evolutionary medicine, offer a captivating context for students to learn and apply evolutionary principles. They illustrate the relevance of evolutionary tools and lenses to medicine and provide a more comprehensive understanding of human disease.

Teaching evolution through medical examples also provides opportunities to reinforce students' understanding of the nature of science. Teaching the nature of science is an important antecedent to promoting evolutionary understanding and acceptance (Dunk et al., 2017; Scharmann, 2018; Nelson et al., 2019). Teaching the nature of science helps reduce perceived conflict for students who view evolution, and human evolution in particular, as controversial (Scharmann et al., 2005; Barnes & Brownell, 2017). Because the types of questions central to evolutionary medicine rarely have simple answers and require a consideration of all possible hypotheses, evolutionary medicine further amplifies the importance of the nature of science. For example, asking students to hypothesize why we are susceptible to nearsightedness can generate many possible hypotheses. Indeed, the complexities of disease etiology, human biological and cultural variation, and the intricacies of evolutionary processes lead to numerous plausible hypotheses that are often difficult to test. Teaching evolution through medical examples provides many opportunities for students to learn that science is about uncertainty, and that their responsibility as scientists is to systematically test and evaluate how the world works.

○ EvMedEd – A Resource to Help Integrate More Medical Examples

Instructors who want to integrate medical examples into their evolution courses and units of study may not know where to begin. Existing resources for learning about and teaching evolutionary medicine are extensive but decentralized. They include case studies (e.g., National Center for Case Study Teaching in Science, http://sciencecases.lib.buffalo.edu/cs), curricula for high school students (e.g., Beardsley et al., 2011), online videos and podcasts, textbooks, and journal articles. However, for an instructor unfamiliar with this landscape, finding appropriate materials or accurate information may be daunting. To help instructors integrate more medical examples into their evolution curriculum, we have created an online resource called EvMedEd that provides online educational resources in evolutionary medicine.

EvMedEd is a free, online, open-access resource for evolution and medicine education. It is sponsored by the International Society of Evolution, Medicine, and Public Health and the Arizona State University Center for Evolution and Medicine. EvMedEd provides links to over 1600 online resources curated for quality by evolutionary medicine experts, including online videos, websites, books, journal articles, and podcasts.

EvMedEd also provides teaching materials for instructors, including teaching modules that can be included in classrooms, course syllabi with reading lists, PowerPoint slides, assignments, and assessment materials for measuring student understanding of core concepts in evolutionary medicine. These resources have been developed with best practices in mind, and many are student-centered activities. Links to peer-reviewed articles about how to improve teaching in evolutionary medicine (e.g., core concepts in evolutionary medicine or approaching evolutionary medicine from an interdisciplinary perspective) are also included and more will be added as they become available.

EvMedEd is also home to a growing catalog of medically relevant examples (MREs) of evolution, including overviews of completed or ongoing research studies, current debates in evolutionary medicine, and case studies that illustrate applications of evolution to medicine. Each MRE includes a brief background, an elaboration on which core principles it exemplifies, and links to articles, videos, and classroom materials relevant to that example. MREs are searchable by

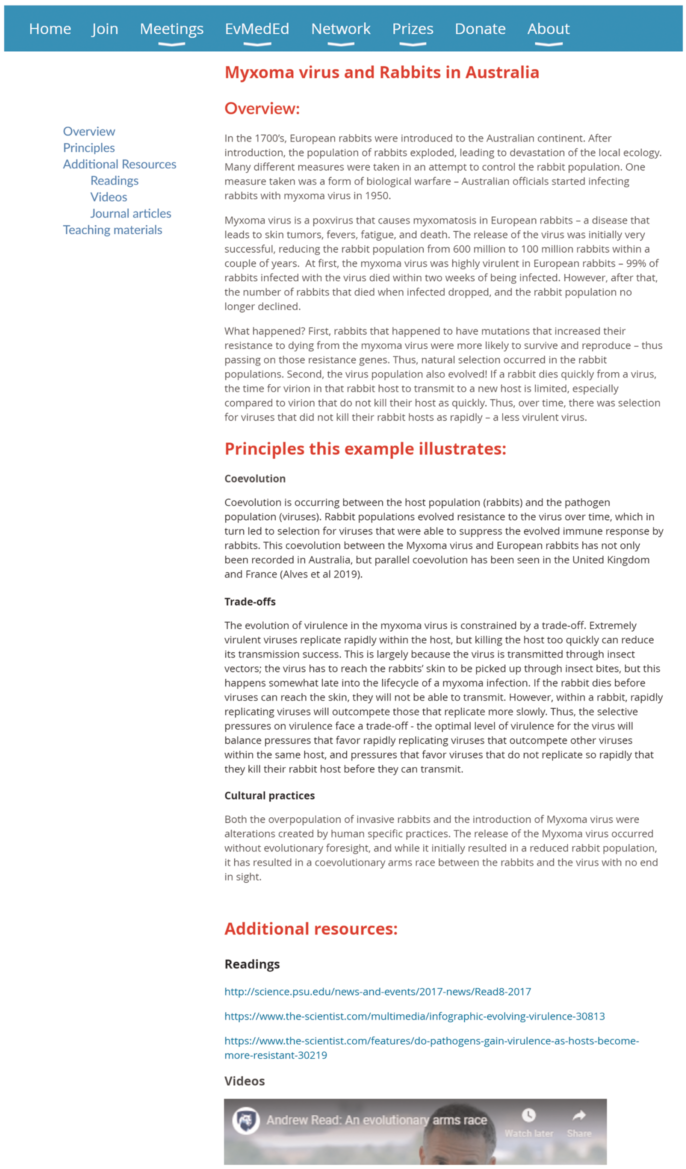

Figure 1. Example page from EvMedEd's catalog of medically relevant examples.

A	B
Humans crave foods high in fat, sugar, and salt even though these are unhealthy in excess. This preference was advantageous in past environments where fat, sugar, and salt were a rare commodity and important sources to eat when they were available.	Humans all have a blind spot where the optic nerve enters the eyeball. Nerves and vessels then run between the light and the retina, a suboptimal system shared with all vertebrates.
C	**D**
Fever is conserved among many species as a response to pathogens. Although fever is sometimes treated as an illness itself, it is a response to fight off pathogens.	Methicillin-resistant *Staphylococcus aureus* (MRSA) can cause infections that are difficult to treat, as evolved resistance to antibiotics, including methicillin, commonly emerges. Many cases of MRSA are associated with hospitals, where antibiotics are frequently used.
E	**F**
Dental cavities became common in populations that underwent a change from hunting and gathering to agriculture. Untreated, cavities can lead to dangerous and sometimes deadly infections.	Ovarian cancer is more common in women with shorter androgen receptor (AR) genes, but these short AR genes also increase the survival of egg cells and overall fertility.

G	H
The human immune system is able to respond to pathogens by recognizing specific antigens present on the surface of those pathogens. However, the bacterium *Neisseria gonorrhoeae*, which causes gonorrhea, has an evolved the ability to alter the antigens present on its surface and evade human immune systems.	When falling forward, humans often break the radius, one of the bones in the arm, at a point near the wrist. A thicker radius bone would help prevent this common fracture from occurring. However, a thicker wrist would reduce mobility of the wrist joint.
I	**J**
Allergies and autoimmune disorders are more common among individuals who have been raised in modern environments where exposures to chronic infections are less common, leading some to hypothesize that something about the lack of exposure to certain pathogens leads to these disorders.	Diarrhea during gastrointestinal infections often helps clear out pathogenic bacteria.

K	L
Some scientists hypothesize that morning sickness early in pregnancy, which consists of nausea and vomiting, may have evolved to protect the fetus from harmful toxins present in foods. There is some evidence of a correlation between foods that are toxic to the fetus and strong-tasting foods that morning sickness leads pregnant mothers to avoid.	A single nucleotide polymorphism (SNP) in the *ALOX15* gene leads to increased bone mineral density in pre-menopausal women, decreasing the risk of dangerous bone fractures early in life. However, after menopause, it causes decreased bone mineral density and increases risk for osteoporosis.
M	**N**
Men are more susceptible to infection than women. A main driver of this difference is that testosterone, a hormone critical for male sexual maturity and reproduction, interferes with immune function.	Appendicitis can be fatal if the appendix swells and bursts due to infection. Some scientists suggest that the appendix is just a left over remnant of a previously useful organ.
O	
HIV, the virus that leads to AIDS, is a retrovirus that infects human T cells. HIV can be treated using the antiretroviral medication azidothymidine (AZT). However, doctors recommend treatment with multiple drugs, as HIV often becomes resistant to AZT during single therapy.	

Figure 2. Cards used in an evolutionary medicine card-sorting activity available on EvMedEd.

both the principles they exemplify (e.g., trade-offs, phylogeny) and the topics they touch on (e.g., infectious disease, mental health). This allows instructors to find examples and resources based on the need to teach specific evolutionary principles or medical topics. One MRE is the story of Myxoma viruses and rabbits in Australia (Figure 1), where a virus was released in an attempt to control a growing population of invasive rabbits. While the effort was successful at first, the virus eventually stopped killing rabbits. Not only did rabbit populations evolve resistance, but the virus populations evolved to be less virulent over time. This exemplar provides a means to teach host–pathogen coevolution and trade-offs between virulence and transmission, while also offering an opportunity for students to improve their ability to design experiments, which is well established as challenging for students (Brownell et al., 2013; Dasgupta et al., 2014).

An example of an evidence-based teaching activity available on EvMedEd is a card-sorting activity designed to introduce evolutionary medicine and six main reasons for why bodies remain vulnerable to disease despite the action of natural selection. This activity is designed for use in introductory biology classrooms with students who already have a basic understanding of evolution. Students are given cards, each of which contains a statement with a suggested evolutionary explanation for a human vulnerability for a specific ailment or disease (Figure 2). When invited to sort the cards into categories, students tend to focus initially on surface features, such as the kind of disease. They are then presented six main evolutionary explanations for vulnerability to disease:

(1) Mismatch between aspects of human bodies and novel environments

(2) Pathogens that evolve faster than humans do

(3) Constraints on what natural selection can do

(4) Trade-offs that keep any trait from being truly "perfect"

(5) Traits that increase reproduction at the cost of health

(6) Protective defenses, such as pain and fever

After exposure to this framework, students get a chance to use it as they sort the cards again.

○ A Call for Contributors

EvMedEd is intended to be a grassroots effort and welcomes your contributions. Descriptions of teaching modules, innovative class activities, and course syllabi are all welcome. We expect that EvMedEd will develop over time as more resources are added and as new advances in evolutionary medicine shape the field. For more information, please visit the website at EvMedEd.org.

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