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Evolution of the Virus: Teaching Macroevolution through Microevolution

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Rationale:

The broad scope of evolution finds a home in the tenth grade biology curriculum, in almost any state or district, right between genetics and population studies. In Connecticut, and specifically New Haven, it is forced to be covered in a matter of days, and rushed to be completed before the standardized tests arrive in early March. Of utmost importance is the students' understanding of the mechanism of natural selection, and how it has controlled speciation and change for millions of years. Unfortunately this is a topic which is difficult for most ninth and tenth graders to grasp, and is at most only alluded to at this point in their academic career. To add to their minimal skill base, this topic is weighted heavily in most standardized tests, especially the Connecticut Academic Performance Test (CAPT) which students must pass in order to graduate or be forced to take an extra half credit of science. Not passing the CAPT in two attempts leads to many delayed graduations, and teacher performance is often judged year to year on CAPT results.

On top of the above concerns weighs a surprising resistance to the topic of evolution due to its perception of going against many of the Christian Religions. Regardless of a teacher's stance on how religion plays into evolution, it is a hurdle that must be crossed. A substantial portion of students resist evolution study based on hardened perception of faith; refuse to take part in the topic seriously knowing they can still pass the class only to find themselves at a distinct disadvantage when it comes time to take the CAPT. For this reason it is imperative to find a way to introduce the material in a manner that all students will accept, and ensure the state standards can be addressed without being lost in mire of religious debate. It is not the role of a classroom science teacher to sway opinion, but it is the teacher's job to ensure their students have the skills to succeed.

After several years of teaching in New Haven, I have found several methods to be successful in covering the topic of evolution, based on the interests and beliefs of my students. Students do not resist the History of Evolution, and it should be taught in a traditional manner. The mechanisms and practical applications of evolution however, should be approached much differently. I have found that many students find a distinct interest in viruses and other pathogens that cause illnesses. This is convenient because many current topics can be discussed, and the topic of disease and health offers many interdisciplinary learning opportunities. It is also important to point out that even the most resistant learner consistently finds no problem discussing evolution of microbes, so long as the topic does not broach the idea of mammalian evolution. For this reason, teaching evolution of viruses and microbes satisfies the needs of the diverse learners of an inner city classroom. Simply teach the mechanisms of evolution and apply them to viruses at a grade appropriate level.

I do not feel that this is making exceptions for students; rather this method is catering to needs of our diverse students. It is the individual teacher's choice if they wish to continue this unit with macroevolution, or use this unit alone or in conjunction with the unit on viruses and bacteria. This unit's main objective is to teach evolution, using viruses and pathogens as the model.

Unit Objectives

This is intended for use in the high school biology curriculum. It will begin with an introduction (or review) of viruses and how they interact with organisms. This portion of the unit should be used to reflect on prior learning of the characteristics of living things and the role of organisms within and ecosystem. This topic will introduce vocabulary on population studies and incorporate prior learning on ecosystems, biomes, and the interdependencies of organisms in a system. At this point students should know what a virus is and how it replicates.

Natural Selection is implemented as the main theme for the unit. A hands-on activity will be conducted to show how selection pressures shape the evolution of an organism. This activity will incorporate new vocabulary, and students should begin applying natural selection to real life situations, and move into genetic evolution and how it applies to behavior.

The medical implications of pathogens and how they are affected by evolution will be introduced. Students will investigate current topics of disease and determine what role evolution has played on the pathogen, victim, and treatment.

The unit will conclude with a look back at evidence for evolution and a comparison of microevolution to macroevolution. Interpretation of the fossil record as evidence for evolution over geologic time will precede an investigation of cultural evolution and the rate of change or current epidemics and disease. The prose of this unit will give a brief overview of viruses and natural selection.

Outline of Unit

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b) What is a virus
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e) Viral Replication

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Overview

What is life and where do viruses fit in?

At the beginning of any high school biology textbook will be a section characterizing life as having orderly structure, producing offspring, growing and developing, and adjusting to changes in the environment. These four characteristics are for the most part standard in the study of biology, as is the idea viruses are non-living. Yet regardless of the text, students will be quick to see that viruses could easily be considered living things. More important is the role viruses play on life, and how they have shaped and been a part of evolution, not only by their presence and contribution to shared genetics, but by their role as a selection pressure.

Looking at the four characteristics of life, viruses certainly satisfy structure, reproduction and adjustments, and growth and development can be debated. They possess genes, adapt to hosts, and play a role in evolution of other species. For these reasons viruses fit into the web of life and belong in biological study. When one looks at a holistic definition of life, which has been modified over the years to account for new finds and smaller and smaller things, viruses are non-living for many reasons. A more reductionism approach however, would account for only the most critical attributes of the living, the ability to replicate, and clearly consider viruses to be living entities. If viruses continue to be considered non-living, it will be harder and harder to justify this stance as research moves forward.

What is a virus?

Defining a virus is simple when considering what it does not do than to categorize what it can. Simply put, a virus is a biological entity that possesses a genome made form DNA or RNA surrounded by a protein casing. Some have a protective envelope similar to a plasma membrane that protects them when outside a cell. Viruses are the most abundant biological entities on the planet and incredibly diverse. They habituate every niche and habitat on earth. Viruses are parasites in that they use a host cell to replicate at the hosts expense, although it is a broad misconception that all viruses are directly harmful. Upon exiting the host cell, they are complete and full, and do not experience a period of growth. (Edwards, 2005, 504)

Viruses have evolved various shapes and forms of simplicity, though the simplest of viruses behave similar to the most complex. While studying biology, it is easy to make the assumption that the true role of life is to propagate more life, and the virus is no different. Viruses make more viruses, regardless of impact on the host, and the cycle continues.

The minute nature of viruses makes them a particularly difficult entity for students. Sub-microscopic, roughly 1/100th the size of bacteria, makes them impossible to study under conventional microscopes presenting a hurdle for students. Clear images from electron microscopes showing form and structure does make them more accessible.

The gray of living or non-living is best described to students with the example of a seed. A plant seed obviously has a role in life, but is not itself alive, yet it can be killed. It carries genetic information but cannot reproduce in this state. This concept helps illustrate to students that some of these matters are left up to interpretation, while there is little room to argue that they belong in the study of Biology.

Origin

Virus origin is highly speculative. The possibilities of being a descendent of a large pathogen or the remnant of primordial soup are notable hypotheses; though the more widely accepted idea is of viruses being a genetic component that escaped from cells. Regardless of accepted theory, it is known that viruses are ancient forms. Traces of viral DNA in other organism's genomes, roughly 8% of human gnome is made up of virus-derived genes, support several viral origin hypotheses while indicating that viruses are as old as cellular life. (Morse, 1994, 3)

Structure, evolve to interact

Virus morphology is widely diverse ranging from 10 to 1400 nanometers in four major shapes. Helical or tube shaped, icosahedral or spherical, enveloped, borrowing a membrane from a host cell or organelle, and complex. The latter includes the familiar shape of the bacteriophage resembling a lunar landing module, with its capsid holding nucleic acid sitting atop a tail with legs. Commonly this is the shape most students will associate with viruses. Shape is a major portion of the identity of a particular virus and is often a component of classification.

Structure of viruses presents a nice opportunity to apply natural selection. Once students begin to grasp selection, asking them why certain structures persist can invoke quality discussion. Students will opine that certain structures are better than others while certain conditions favor others. This is a fundamental concept that must be enforced throughout the unit, and in doing so will ease the transition to macroevolution later.

Viral Replication

How a virus replicates is an essential concept for students to understand, especially in terms of differentiating between viral and bacterial diseases. Once genetic material has entered the cell, two processes may take place. The lytic cycle, beginning with attachment to cell and injection of the nucleic acid, uses the energy of the cell to replicate the viral nucleic acid and proteins. Once the parts are assembled, complete viruses are released to repeat the cycle. A typical lytic cycle takes as little as thirty minutes and can make thousands of new viruses. Students will equate this cycle with a rapid response time if you relate it to human disease.

The more complicated lysogenic cycle allows for the genetic material to become part of the host cells genetic material in the form of a provirus. Any cell replication that occurs will also replicate the provirus within the chromosome of the cell until it eventually leaves the chromosome to engage in the lytic cycle. The provirus allows for viral latency and delayed reaction and symptoms to disease. This concept always invokes active discussion of disease within a classroom and is ideal to present with information on typical dormancies of diseases. An initiating activity with students choosing which reproductive cycle is likely based on dormancy works well to enforce the topic and procure discussion. Most high School biology texts describe several viral diseases, systems and incubation periods, allowing for students to see the time it takes for a virus to reach levels of symptomatic infection.

The unique attachment protein for individual viral strains presents the next opportunity to introduce natural selection. Students quickly gravitate to the idea that some things work while others do not, and this presents an excellent opportunity to further enforce the idea of selection pressure. Since each virus has proteins for attachment to specific host cells, each virus can only attach to those cells is matches to. Presenting to students the idea of an environment that does not offer an adequate host will lead them to discover the idea that certain traits are selected for, and the shape of a virus is no different. If a virus cannot attach to a host cell, it cannot reproduce.

Genetic Mutation and Natural Selection

Natural selection is the mechanism that drives evolution. The process occurs when a heritable trait makes survival more likely, and becomes more common in a population over time. Preceding this unit, students should have some background knowledge of heredity and genes. The next step the students must make is to understand that some traits that are inherited may make an organism more successful, and therefore more likely to reproduce, and ultimately likely to pass that trait to offspring. A genetic change can result in a mutation and contribute to variation in the gene pool. Less favorable ones are weeded out by natural selection, while beneficial mutations may accumulate and lead to a variation or new species. Students grasp quickly when the trait is visible, while the idea of single gene variation is tougher to grasp. Since a single gene could influence fitness, or reproductive success, any gene can be selected for. Water glasses in an inexpensive furnished apartment that has been repeatedly rented could represent a gene and be explained by selection. Various glasses came into the apartment, fragile ones broke while the attractive ones were stolen. Odd, ugly, or nonfunctional glasses were discarded. The remainders are sturdy, ugly, and functional. Natural selection worked to make a water glass that works best in that particular environment. (Koella, 2008, 8)

The term micro-evolution refers to rapid change, possibly a single generation while macro-evolution refers to long term change over millions of years. High School students relate well to micro-evolution in that there seems to be little resistance in accepting. Although micro-evolution does not equate microbe evolution, presentation of this material as a short term change, happening to microbes seems to flow smoothly into class discussions. It is important to stress that all organisms evolve, some rapidly, and some over geologic timescales; but all are influenced by natural selection.

Many examples should be given to students, and it is most beneficial if the students are allowed to create their own. A simple Google search can provide thousands of images and diagrams showing natural selection, and once the vocabulary and basic concepts are presented, most students will quickly make their own examples. A good example to start with is one that most students will recognize, bacteria and penicillin. Not only does this example offer review opportunity on cells, a chance to introduce the difference in bacteria and viruses, but most students will recognize that there are several types of antibiotics, and that some do not work on certain patients. Students know that bacteria are alive, and antibiotics kill the bacteria cells in our bodies that make us sick. Present to the students that not all of the bacteria cells may be affected by penicillin can lead to penicillin resistance in bacteria because those bacteria unaffected reproduce and likely produce offspring also unaffected by the medicine.

Selection pressure and the staying power of a trait

As mutations happen, they will ultimately be determined to be advantages or deleterious through selections pressures. As environments are complex, pressure can come from various directions. Competition for resources, predation, reproductive ability, and change in environmental conditions are a few examples of pressures that inhibit the ability to reproduce. Mutations that occur can be advantageous, deleterious or neutral. Advantageous traits may seem insignificant, but they accumulate over generations and can lead to increased fitness and possibly to a new species. A single trait that is beneficial can be passed on eventually overtaking the original population. (Domingo, 2008, 66)

Selection pressures such as predation are easiest for students to grasp. An example of a snowshoe hare with longer feet allowing it to run faster on snow avoiding the wolf is common to nearly every high school biology text. Students can grasp that this trait helps avoid capture by the predator and will likely be passed on. Over time, the whole population of hares may have this phenotypic expression.

Viruses are as susceptible to selection pressures as mammals. A change in environement may destroy the virus altogether, while a mutation to a surface protein may inhibit its ability to attach to a cell and render it unable to reproduce. Conversely, viruses may adapt to a host's immune system by the mutation of the epitope, a surface protein, making them undetectable or by a mutation to the reverse transcriptase enzyme that assists in the building of viral DNA. (Freeman & Herron, 2004, 17)

Evidence of Evolution both big and small

Crucial to this unit is evidence for evolution. Most students are familiar with mainstream images of apes turning into man, but lack the information needed to comprehend this concept. It is at this point where resistance from theological views begins to set in.

Living species offer direct examples of evolution happening in real time. Most notable is the peppered moth reacting to selection pressure by its population darkening in color to match the industrial pollution and lack of light colored lichens on trees common to the suburban areas outside of British industrial zones. Once pollution control was established, pollution decreased, lichens returned, and the moths lightened in color. This famous example sets up many classroom activities and is thoroughly discussed in most texts. Behavioral and microbe evolution offers many short term examples. (Drickamer, 2004, 66)

Examination of the fossil record led to the Law of Succession. Modern living forms are strikingly similar to the most recent fossil record in their locale suggesting a pattern of relation. Current species are descended from ancestors, with modifications that allow them to be successful in current conditions. As the ideas become clearer that species change through time, transitional species that possess characteristics of modern and ancestral forms; further this pattern. Most students are aware of the theory that birds are the modern descendents of dinosaurs, the species Archaeopteryx clearly appears to be a bird like dinosaur, complete with feathers, and will solidify this point of succession. (Freeman, 2004, 43)

Relatedness among organisms does not have to be proven through DNA analysis. Simple study of organisms reveals vestigial structures, such as eye sockets in blind fish and hipbones in whales, suggesting relatedness to organisms that utilize these structures. Virtually unrelated species have homologous structures suggesting common ancestry. Modern genetics have revealed that all organisms share not only the structure and mechanism of genetic material, but large amounts of the material as well. Shared flaws in the genetic material provide further evidence for evolution and common ancestry among living things.

Geology presents vast evidence of environmental change, and the fossil record reflects this. Fossils of aquatic species found in desert areas and tropical plant fossils in polar zones suggest the massive changes Earth has undergone over millennia. The fossil record indicates that life has changed with it.

The law of Uniformitarianism shows that the processes that are undergoing geologically currently, have been for millennia. This allows for the fossil record to be dated accurately and the age of the Earth to be determined. When the age of the Earth is put in context, time is allowed for the slow process of evolution to take effect on the diversification of species. The converse argument of Creationism places the Earth's age at 6000 years, and suggests that all species are created independently and extinct species were wiped out by a catastrophe, probably Noah's great flood. (Freeman, 2004, 57)

Viruses offer evidence for evolution in their ability to mutate and evolve. HIV has evaded drug manufacturers by its ability to mutate rapidly within a host and create versions that are unaffected by medicines. A single cold season in any school building suggests mutating viruses adapting to conditions.

Evolution and medicine

District and national standards call for students abilities to rationalize how evolution affects medical treatment of disease. An in-depth discussion of evolutionary medicine may not be appropriate for most 10th grade classrooms however the students should be able to apply natural selection to pathogen born illnesses. Presenting this concept as the body representing an environment for the parasite (bacteria or virus), with immune response and medicine representing selection pressures can afford the instructor an opportunity to review all concepts in an inter-curricular research/writing assignment.

The high genetic variability of HIV as a result of reverse transcriptase and a rapid replication rate has led to long term failure of medicinal treatments. Inside a single host many variants of the virus form, resulting in a high probability that a version will form that is unaffected by drug treatments. Azidothymidine (AZT) was commonly used to treat HIV infections. It inhibits reverse transcriptase blocking the virus's ability to transfer its genetic material to the host cell. In time the population of viruses evolves so that the virions themselves form enzymes that are not disrupted, functioning normally transcribing DNA within the host cell. HIV evolves to overcome selection pressures presented by the immune system and drug treatment. (Freeman, 2004, 10)

The swine flu and HIV, diseases we all relate to

Current pandemics of the swine flue and HIV can be used to present evolution in medicine. Many articles are available on the two (see student resources) that are reading level appropriate. Currently there is much research on HIV, in particular its behavior inside the host and ability to mutate rendering medicine and immune system response ineffective.

HIV presents an excellent case study for evolution itself. Its origin is becoming clearer as research continues, and it is now known that its many strains have evolved from a family of viruses that infect primates; and leapt to other species, notably humans, more than once. This ability to mutate and infect several species is a contributing factor to the ineffectiveness of medical treatment. Discussion by students can lead to reveal the natural selection process of HIV, using medicine and the human immune system as selection pressures.

The current pandemic of H1NI virus is indicative of a virus's ability to mutate and adapt to hosts. Normally a virus such as influenza has the ability to infect a particular species. One that infects birds does not infect humans because it is not equipped to do so. As a virus mutates or mixes with another strain, it can form a hybrid or new strain that can now infect a new host species. These changes represent the mutations necessary for evolution in all species. Adaptations within the human immune system can represent selection pressure upon this illness causing pathogen.

Evolutionary pitfalls, what the students think and how to change their minds

This unit is intended to afford the instructor a path to teaching evolution that avoids the common pitfalls of the topic. Researching evolutionary history is inappropriate for this age group as the reading material is often to difficult and confusing, and unnecessary for this grade level. The most common resistance from students comes in the form of human evolution and the idea that man evolved from a simpler form. Inner-city students are often challenged with a strong faith base, and perceive evolution as something that refutes their faith.

This does not have to be the case, and the material should be adapted to the audience. A common argument for origins of all species of life is that these changes require far too much time for this to be possible as mutations create minute differences over large periods of time. Evidence for the age of the Earth sometimes works best at the beginning of the unit and is infallible to most students. Looking at evolution as a process that all living things undergo satiates this problem somewhat, and focusing on microbe evolution and micro-evolution makes this transition smoother, removing morality and ethical arguments. Teachers should be prepared for the argument that man did not come from apes, and have a retort ready that disarms while not provoking further argument. A former student once stated in class "If we came from monkeys, there wouldn't be monkeys anymore." A better retort might not be found.

Vocabulary

Following is a list of vocabulary that must be introduced with this unit. All of the following words are commonly used in National Science Curriculum and are found on most National, State and District Exams. It is up to the individual teacher to decide if it is appropriate to present them as a list, or imbed them into lessons. Special needs students will likely benefit from receiving this list at the beginning of the unit.

> Virus: disease causing, nonliving particles composed of an inner core of nucleic acids surrounded by a capsid; replicate inside living cells called host cells
> Bacteria: prokaryotic, unicellular microorganisms
> Reproduction: production of offspring by an organism; a characteristic of all living things
> DNA: double stranded genetic material, Deoxyribonucleic acid
> RNA: ribonucleic acid, single stranded DNA
> Parasite: one organism that benefits at the expense of another, usually another species
> Evolution: gradual change in a species through adaptations over time
> Adaptation: evolution of a structure, behavior, or internal process that enables an organism to respond to environmental factors and live to produce offspring
> Mutation: any change or random error in a DNA sequence
> Natural Selection: mechanism for change in populations; occurs when organisms with favorable variations survive, reproduce, and pass on their variations to the next generation
> Micro-Evolution: the occurrence of small-scale changes in allele frequencies in a population, over a few generations, also known as change below the species level
> Macro-Evolution: change that occurs at or above the level of species
> Selection Pressure: any aspect of the environment that influence the success of an organism
> Predator: an organism that feeds on other organism
> Environment: biotic and abiotic surroundings to which an organism must constantly adjust; includes air, water, weather, temperature, other organisms, among other factors
> Competition: interaction between organisms or species, in which the fitness of one is reduced by the presence of the other
> Law of Succession: the kinds of animals and plants found as fossils change through time, the same kinds of fossils in rocks are found in different places, allowing the rocks for different areas to be the same age

Fossil: physical evidence of an organism that lived long ago that scientists use to study the past; evidence may appear in rocks, amber, or ice
Homologous structure: structures with common evolutionary origins; can be similar in arrangement, in function, or both; provides evidence of evolution from a common ancestor; forelimbs of crocodiles, whales, and birds are examples
Vestigial structure: a structure in a present-day organism that no longer serves its natural purpose, but was probably useful to an ancestor; provides evidence of evolution
Uniformitarianism: assumes that the same natural processes that occur in the universe today, have occurred in the universe in the past
Epidemic: occurs when many people in a given area are affected with the same disease at about the same time; more occurrences than what is considered normal
Pandemic: a large epidemic, affecting an entire country or the whole world
Fitness: likelihood of an organism to successfully reproduce.
Theory: explanation of natural phenomenon supported by a large body of scientific evidence obtained from many different investigations and observations

Lesson Plans

Lesson One-Build a better Virus

Essential Questions:

What is the difference between bacteria and viruses?

What components are found in all viruses?

How do viruses bind to cells?

This lesson provides students an opportunity to explore the diversity of viruses. In groups students make models of viral structures that infect humans and label them appropriately. Using Popsicle sticks, tooth picks, straws, and various candies such as gumdrops, licorice rope, and gummy bears, students make models of the viruses that commonly infect humans. Instructors should note that structures are complete and include all parts, including receptors and viral envelopes as these structures are often overlooked by students and weigh heavily on a virus's ability to survive inside a host and bind to cells. Follow up discussion to the lesson should include discussion of how the structure of a virus differs from a cell, size and scale, and what parts of a virus are susceptible to natural selection within a host. A model of a cell to accompany student models can enrich discussion and facilitate learning. Most student textbooks have sufficient diagrams and pictures for students to use as a resource. Teachers should provide a worksheet with expected vocabulary to be used.

Lesson Two- Geologic Timeline

Essential Questions:

How old is the Earth and how does the fossil record show its age?

How does the fossil law of succession show changes in life over time?

This lesson provides a basis for geologic time and should be completed early in the unit as the focus comes to evolution of all organisms. Students will create their own color coded timeline showing all the epochs and eras from the creation of the Earth to present day. They will label their timeline with points of first life, complex organisms, mammals etc. This lesson is valuable to refute common misconceptions from the New Earth theory and makes the time needed for evolution appear readily available.

Depending on available time and student availability a model timeline can be provided, or students can create their own. This lesson can be powerful if large sheets of paper are available, such as sheet rolls. If ten feet is available per group, student work can be hung in the classroom as an attractive reference display throughout the unit. As the Earth is approximately 4.6 billion years old, making 46 million year segments makes the conversion somewhat easier for students. A 100 yard football field as an example makes this transition smooth with one end zone representing Earth's formation and the other present day, students can approximate eons and epochs within the units. Teachers must provide a list of eras appropriate to display, and a list of events to be labeled, such as first unicellular life and the introduction of mammals, to fill out the timeline.

Lesson Three- Virus Natural Selection

Essential Questions:

How does the process of genetic mutation and natural selection relate to the evolution of species?

How do structural and behavioral adaptations increase the changes for organisms to survive in their environment?

This lesson enforces the principle of natural selection mimicking the virus-host relationship. Students will use a Styrofoam bowl as a host, with various small holes punched in it to represent selection pressures within the host such as fever, immune response, medicine, cellular defenses, and various sized beans as viruses. Students will add a specific amount of beans and shake the bowl noting the viruses that fall through are dead and the remainders have been selected for and reproduce. Several rounds of this activity represent generations, and one bean will ultimately survive as the fittest. Depending on the size of the holes and beans available, starting populations should be between five and ten of each species. Survivors double after each generation to represent success and reproduction. Assessment will be of a population graphs depicting the different virus species. Students are to choose the selection pressure they wish to represent and write how it has impacted this population of microbes.

Many students will realize that the largest beans will survive, so it is important that they make the connection that the larger beans will represent the virus most fit to survive the pressure. The assessment allows opportunity to discuss population dynamics and develop data collection and graphing skills.

Notes

Teacher Resources

Books

Biggs. 2005. Biology: The Dynamics of Life. McGraw Hill. A High School Biology text, the teacher's edition offers lecture, discussion cues, and demonstrations.

Diamond. 1992. The third chimpanzee. Harper Perennial. This book is an excellent discussion of the human animal and its relativity to other species. Presents human evolution as a discussable topic introducing behavioral and societal evolution in a new light, it is loaded with fodder for class discussion.

Deak & Sawyer. 2007. The last human. Yale University Press. This picture book and text offers fascinating look at hominid ancestors with vivid picture and recreations. It is perfect to have on hand for discussion of human evolution.

Dembski. 2004. The design revolution. Inter Varsity Press. A book refuting evolution and discussing the intelligent design theory, it can be somewhat disturbing yet enlightening to instructors to read intelligently crafted arguments against evolution, especially to those instructors anticipating a strong resistance to the topic.

Domingo. 2008. Origin and Evolution of Viruses. Academic Press. This college level text offers a survey of how evolutionary thought illuminates medical science.

Freeman & Herron. 2004. Evolutionary Analysis. Pearson/Prentice Hall. An introductory college text discussing evolutionary concepts; the first chapter offers in depth analysis of HIV.

Nesse & Williams. 1996. Why We Get Sick: The New Science of Darwinian Medicine. Vintage. A highly readable tome of evolutionary medicine; this book will offer many examples to the instructor and put many concepts of evolution into health and body context.

Websites

Johanson & Marable. 2009. Becoming human. The Institute of Human Origins. http://www.becominghuman.org/. This interactive website travels through time and shows the path of hominid evolution with interviews, site visits, and visuals.

Student Resources

Books and selected readings

Appenzeller. 2008. Tracking the next killer flu. National Geographic. October 2005. This article presents a journalistic review of the latest Influenza virus epidemic. May be difficult reading for some students, selections can be used to fill out the knowledge base of student about inter species viruses. It contains a graphic showing the relative sizes of historical epidemics.

Biggs. 2005. Biology: The Dynamics of Life. McGraw Hill. This is a quality High School Biology text to be used as a student reference.

Walsh. 2009. How to prepare for a pandemic. Time Magazine. May 18, 2009 pgs 30-33. This article is a concise review of how vaccines work; it contains a vivid graphic of viruses and vaccines.

Websites

Johanson & Marable. 2009. Becoming human. The Institute of Human Origins. http://www.becominghuman.org/. This interactive website travels through time and shows the path of hominid evolution with interviews, site visits, and visuals, it is an excellent enrichment activity that can be used at the end of the unit to further evolutionary study.

MacPhee & Marx. 1997. What killed the mammoth? The American Museum of Natural History. http://www.amnh.org/sciencebulletins/biobulletin/biobulletin/story981.html. This website is set up like a web quest discussing a hyper-disease hypothesis as a reason for mammoth extinction. Attractive visuals of archeological sites with reading level appropriate content on viruses, disease, and evolution.

Watson. 1997. Fossil Succession. US Geological Survey. http://pubs.usgs.gov/gip/fossils/succession.html. This website offers a reading level appropriate printable reading on the formation of fossils and the laws of fossil succession.

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Domingo. 2008. Origin and Evolution of Viruses. Academic Press

Drickamer. 2002. Animal Behavior. McGraw Hill

Edwards & Rohwer. 2005. Viral meta-genomics. Nature, 3, 504-510 June 2005

Freeman & Herron. 2004. Evolutionary Analysis 3rd Edition. Pearson/Prentice Hall

Hurst. 2000. Viral Ecology. Academic Press

Koella & Stearns. 2008. Evolution in Health and Disease. Oxford

Morse. 1994. The Evolutionary Biology of Viruses. Raven Press

Nesse & Williams. 1996. Why We Get Sick: The New Science of Darwinian Medicine. Vintage

Appendix

Implementing District Standards

The following standards are to be addressed in this unit. They represent the National and district standards that 10th grade Biology students must fulfill. The instructor must be sure to incorporate lecture and assignments that fulfill these objectives within the unit as the suggested lessons do not address all of the fully. National standards are generally skill and inquiry based and need to be enforced during activities.

Content Standards: Biology

D.31 Describe the similarities and differences between bacteria and viruses

D.32 Describe how bacterial and viral infectious diseases are transmitted; and explain the roles of sanitation, vaccination, and antibiotic medications in the prevention and treatment of infectious diseases.

D.39 Describe the difference between genetic disorders and infectious diseases.

D.41 Explain how the fossil record provides a scientific explanation for evolution.

D.40 Explain how the process of genetic mutation and natural selection are related to the evolution of species.

D.42 Describe how structural and behavioral adaptations increase the changes for organisms to survive in their environments

National Standards

DINQ1 Identify questions that can be answered through scientific investigation

DINQ2 Read, interpret and examine the credibility and validity of scientific claims in different sources of information.

DINQ3 formulate a testable hypothesis and demonstrate logical connections between the scientific concepts guiding the hypothesis and the design of the experiment.

DINQ9 Articulate conclusions and explanations based on research data, and assess results based on the design of the investigation.

DINQ10 Communicate about science in different formats, using relevant science vocabulary, supporting evidence and clear logic