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Towards an Understanding of Disease Burdens in Developing and Developed Nations

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Rationale

Environmental Science Class

We are nearing the end of our unit on population: I have displayed a slide with a graph of the world's population growth from the late 18th century to the present. I point to the exponential curve and the projected 7 billion people and warn the class, "We are placing great stresses on the earth's ecosystem… the world's nations have too many people". The next graph shows the relative contributions of developed and developing nations to our growing population. Poorer developing nations are experiencing rapid growth, while higher income developed countries have little growth while the population in a few countries is actually contracting. Some students immediately object to the inequity. Is it fair that countries with more resources have less people, while those with more people have to survive with less? Why can some countries control their population while others cannot? Is this why poorer countries have so many diseases and wars? What does economics have to do with this? A great debate ensues. As students propose answers, other questions arise. Malala Yousafzai, the young Nobel laureate, had recently met with girls from our school. They remember that she told them that not all women in her culture have access to education: the conversation moves to issues of women's rights in developing countries. Do they want to have so many children? Do women have a voice in the matter? Do some countries force people NOT to have children? Do people's culture or religion influence them? The discussion goes on for almost an hour: we are still "arguing" when the bell rings signaling the end of the period.

This was an excellent science class: not only did my students understand the data presented to them, but they were able to formulate and answer a series of highly provocative questions about the social, cultural, and political implications hidden in the data. Their insights and perspectives were critical, informed, and complex. The nature of the discussion allowed them to engage in their learning in ways that were meaningful, personally relevant, and educative.

I begin my curriculum unit with this vignette from my environmental science class as it exemplifies the kind of learning environment that allows students to maximize their learning potential. It is the kind of atmosphere I hope to create for this unit.

I teach at the Philadelphia High School for Girls, an all girls' public high school in the northeast section of Philadelphia. Our students are selected from all of Philadelphia's neighborhoods thus we have a relatively diverse student body. The total population is nearly 1300, of which 66% are African American, 17% Asian; 10% Latino; 5% White with an approximately 2% mixture of African, and Caribbean. Students attending our school must have a minimum of a 3.5 GPA, and have advanced or proficient scores in state standardized assessments.

While most students can perform well on assessments that rely on the recall of content knowledge, many struggle with academic tasks that require them to analyze data, criticize an opinion, or form an argument supported by evidence. Although test scores suggest that they "know" the science content many do not connect the classroom content to larger societal issues that affect their everyday lives. Neither do they use their science knowledge to inform perspectives and decisions that affect their health and well-being.

The Common Core Science Literacy Standards (Common Core Initiative), that inform this unit suggest that teachers regularly provide opportunities for students to evaluate the science that informs topical social and cultural issues, engage in substantive discussions that explore the impact of science on society, and take critical stances on the science - technology that informs and continually transforms their lives (Bucher and Manning). Engaging in these discursive practices fosters a deep understanding of science content, as it requires students to use their knowledge in ways that are personally relevant, meaningful, and educative. The vignette that opens this unit exemplifies this kind of learning.

The guiding principle of my environmental science curriculum is the belief that we all have a responsibility to engage in and promote practices that protect the viability of ecosystems throughout the world: all life on our planet is interconnected and interdependent. An underlying theme in our curriculum is that human activities that pollute our environment threaten the viability of organisms living in various ecosystems. In the past, as we explored the effects of pollutants on living organisms, I realized that although I knew the general effects of environmental toxins on other species, my understanding of how pollution affects human health was limited. This deficiency in my content knowledge limited my ability to engage my students in the kinds of critical discussions I feel are important in my science classrooms. As I struggled with the content, I came to the realization that in order to fully challenge my students, I needed to learn more about the processes that affect human health.

Our health depends on an array of chemical reactions, physiological systems, and cellular processes that help maintain a relatively constant internal environment. These internal processes are primarily dependent on our genetic makeup (our genotype) as all of the requisite information for the proper functioning of our bodily systems is encoded in our DNA. Our health is however not solely dependant on our genetic makeup as there are countless pathogens and toxic substances in our environment that can occasion serious disease. Thus our health depends on the interaction of our genotype with the environments in which we live.

The study of one's personal health however requires a global perspective as our local environments are interconnected with ecosystems throughout the world. Recent climatic changes, the outbreaks and transmission of lethal diseases, and the continuing evolution of new pathogens that emerge anywhere on the planet, provide evidence for the interdependent nature of our health today. Thus, in order to fully understand our personal health; we must analyze it from a global perspective.

Global Determinants of Health

Analysis of the global burden of disease data (Sepulveda and Murray) revealed that the effect of the

environment on human health differs according to a nation's degree of economic development. Data from the 194 member states that comprise the World Health Organization showed that communicable (neo-natal, maternal, and childhood) diseases were the primary causes of death in lower income developing nations, while in higher income developed nations, non-communicable diseases occasioned the most deaths (World Health Organization-a; World Health Organization).

The high rates of communicable diseases in developing nations results from the lack of infrastructures that provide clean water and sanitation. The poverty of these nations also limits their ability to provide adequate health care for its citizens: thus pathogens in the environment occasion most deaths. Such is not the case in developed nations with robust economies that can provide advanced health care and a "relatively" pathogen free environment. In these economies, ischemic heart disease and cancers, (which are diseases that arise later in life, but are also linked to environmental causes), are the predominant causes of death.

Unit Goals

This unit will provide students the opportunity to analyze the effects of environmental toxins and pathogens on human health. We will analyze these effects at the cellular level because that is where diseases ultimately originate (Robbins & Coltran). Cancer, for example, results from the complex interaction of cancer genes and aberrant cells; obligate pathogens (either DNA or RNA viruses) rely on the cell's genetic processes to replicate themselves. Pathogens will often alter their genetic code to mask their appearance, or change their surface proteins in order to evade host's immune responses. Thus a central goal of this unit will be to analyze the genetic and cellular components of health and disease

Data on global disease burdens show a strong correlation between a nation's degree of economic development and the health of its citizens (World Health Organization). I will engage the class in the analysis of health statistics from the World Health Organization's 2015 report on global health (WHOb). The intent of these lessons is to encourage a critical debate as to why some countries have such poor infrastructures and why health varies with demographic variables such as race, gender, and degree of economic development. It is my hope that these investigations will foster a critical awareness of how the environment affects human health.

Context of Unit within the Environmental Science Curriculum

My units on air, water, and soil contamination end with a study of population dynamics as increased human population exacerbates the effects of pollutants on our ecosystems.

We use the demographic transition model (Scruggs), to evaluate how population growth varies with degree of economic development. Developed nations (with more progressive social perspectives) have stable or declining birth rates: developing nations (with more rigid beliefs) have exponentially increasing populations. Central to this analysis is the discussion of a society's social, cultural, and religious perspectives since these beliefs affect how a society modulates its birth rate and hence its population. Economic development also determines a nation's ability to provide adequate health care, clean water, and a pathogen / toxin free environment. These differing realities provide a perfect forum in which to explore how environmental factors affect health and disease burdens in developing and developed nations.

Although students in my environmental science class have already completed a year of biology, I will review the concepts of DNA, RNA, the genetic code and protein synthesis as these topics are central to understanding the ways in which pathogenic microbes, and cancer cells proliferate and cause disease. The unit will unfold in

two distinct phases.

Unit Structure

Phase One: Constructing Background Knowledge

- Health and Disease
- Bacteria and Viruses
- Immune System
- Cancer

Phase Two: Critical Analysis of Global Health Data (194 member Nations) (WHOa) (WHOa)

- WHO: Life Expectancy (by Gender and SES)
- WHO: Cause Specific Mortality and Morbidity (By SES, Age, and Gender)
- WHO: Global Disease Burden (By SES, Age, and Gender)
- WHO: Selective Infectious Diseases
- WHO: Health Related Millennium Goals Analysis *(WHOd*)

Health

Health is defined by many as the sensation of well being, of feeling “sound in body and mind”. For others, health is merely the absence of disease. Each of these definitions is essentially correct as one’s health depends on the functioning of an array of chemical reactions, cellular processes, and biochemical interactions throughout the body. If all of these major bodily systems are functioning within a narrow set of parameters, homeostasis is maintained and we “feel healthy”. Homeostasis is the state in which bodily systems remain within a narrow set of parameters that are maintained through a complex series of negative and positive feedback loops. A variety of chemical reactions, organ systems, and biochemical processes maintain body temperature, pH range, calcium, glucose, phosphate levels, and water balance in our body. Major systems such as the nervous, endocrine, lymphatic and urinary systems maintain other critical processes within necessary values.

Bodily systems maintains homeostasis through the regulation of these various physiological and chemical processes while at the cellular – genetic level the orderly process of cell division through mitosis provides the mechanism for precise cell proliferation, processes in other cellular organelles support the body’s metabolic needs; while the orderly translation / transcription of DNA facilitates the synthesis of the proteins needed for life.

DNA Replication and Protein Synthesis

DNA encodes an organism’s genetic makeup (the genome). DNA is a double stranded helical molecule consisting of a ribose sugar, a phosphate backbone and four nitrogenous bases: (**A**denine, **G**uanine, **C**ysteine,

and **T**hymine). The strands are complementary to each other: which means that base pairs are held together by hydrogen bonds in the following order: Guanine – Cytosine, Adenine –Thymine: G-C and A-T). The sequence of base pairs encodes the information necessary to synthesize proteins used throughout the body. When a particular protein sequence is needed, the DNA molecule opens and the necessary sequence of bases is transcribed onto an RNA template. There is a slight variation in base pairing rules as there is no Thymine in RNA; thus A pairs with U in the RNA template. Once transcription is completed the DNA molecule closes and the RNA template moves to the Endoplasmic reticulum where ribosome translate the segment of RNA into a sequence of amino acids. The ribosome read the template in sets of three: as each trio of bases corresponds to a given amino acid. Once completed, the chain of amino acids will fold into a characteristic shape of the protein. Serious diseases and disorders can result if the sequence of base pairs is altered. Insertion or deletion of a base, a gene, or a chromosome lead to frame shifts in the RNA template that result in the synthesis of abnormal or defective proteins.

Alteration of DNA (or RNA) sequences is a mechanism that many pathogens use to alter their genetic characteristics. Such alterations allow some to evade immune responses, become resistant to medications, or continually evolve thus making it impossible to create a vaccine.

Disease

Whenever homeostasis is disrupted, bodily systems can respond and attempt to return to their normal state. Disease occurs when cells, or bodily systems cannot reestablish homeostasis. As a result structural, biochemical, and functional changes occur within cells, tissues, and organs. While many diseases are the result of genetic errors, most arise from the complex interaction of genetic variations and environmental factors. Environmental factors include chemical agents, toxins, pathogens, (viruses and bacteria in the air, water, or soil) and the individual's life style.

Genetic Errors

Errors in the genetic code can be either at a single point (an error in one base), at a single gene, or involve a whole chromosome (deletion or addition of one complete chromosome); multigenic errors, however, cannot be isolated to a single gene or chromosome. These genetic diseases arise from internal malfunctions: their genesis is independent of environmental factors: they are solely dependent on the person's genotype. Complex multigenic diseases can arise as a result of errors in the genotype, however they involve interaction with "environment." In the case of these diseases, the genomic aberration creates a predisposition towards a disease. The exposure to toxins, pathogens, or the person's life decisions will determine the incidence of the disease.

Pathogens

Pathogens are disease-causing microorganisms that invade the body and disrupt the proper functioning of bodily systems in a variety of ways. There are four major classes of pathogens: viruses, bacteria, protozoa, and helminthes. These pathogens live in a variety of environments, however they are most prevalent in water environments. Water borne microbial pathogens are the leading cause of death and disease in developing countries.

Microbial Water Borne Pathogens

Microbial enteric pathogens are implicated in a wide variety of diseases. These diseases are the result of ineffective wastewater treatment, which affects sanitation and hygiene. The death rates from the resulting infectious diseases affect mostly children in developing nations. Poor water quality accounts for 3.1% of deaths worldwide and 3.7% of all DALY (Disability Adjusted Life Years). It is estimated that 90% of the disease burden attributed to poor water quality occurs in developing nations, with 80% of the fatalities being children (Ashbolt). Cholera and typhoid are the most prevalent diseases caused by enteric pathogens, (World Health Organization), followed by various serogroups of rotaviruses, and parasitic protozoa. The diseases cause generally extreme cases of diarrhea resulting in dehydration, malnutrition, and eventually death. In developed societies, the risk of infection from these pathogens is relatively small given that the quality of water, sanitation, and hygiene limit the virulence of these infectious agents. Children, the aged and immunologically compromised remain at risk, however access to quality health technologies limits morbidity when infections arise.

Viruses

Viruses are obligate pathogens: they do not have the cellular mechanisms needed to self-replicate. They do however contain a segment of genome (either RNA or DNA), the necessary enzymes to invade a cell and use it to reproduce, and thence spread throughout the body.

Cancer

Water borne microbes are not a major source of disease in developed nations since water treatment, sanitation, and hygiene effectively reduce the incidence or enteric pathogens. In these nations, carcinogenic agents in the air, water, and soil contribute to the relatively high rates of cancer, which are major sources of mortality and disease. There are many (known and suspected), carcinogens that result from industrial processes, toxic waste, and secondary air pollution. Cancer arises as a result of mutations in our genetic code. While some cancers are the result of inherited defects, most are the result of acquired mutations occasioned by our contact with carcinogens in the environment. While most mutated cells are eliminated by our immune response, over time some survive. A cancerous tumor typically develops from a single mutated cell, however as the tumor grows, cells acquire new capabilities that allow them to aggressively reproduce, develop their own blood supply (angiogenesis), invade tissues and organs while evading apoptosis and all other signals that might limit their growth. There are two categories of genes that are implicated in all cancers: proto-oncogenes and tumor suppressor genes. In normal bodily functions, proto-oncogenes are responsible for signaling orderly and limited replication of cells, while tumor suppressor genes function to limit cell division. Oncogenes result from alterations in the genetic code of proto-oncogenes, which then trigger uncontrolled cellular replication. Mutations in tumor suppressor genes disable mechanisms that limit cell growth, or target cancerous cells for apoptosis. There are approximately 140 known cancer-causing genes (approximately 60 oncogenes and 80 tumor suppressor genes) that affect various cellular functions.

Exposure to environmental toxins

Hazardous Waste Disposal and Carcinogens

Data collected in recent years has shown an increase in the incidence of various types of cancers for residents exposed to hazardous wastes, (Johnson), those living in close proximity to hazardous waste disposal sites (Cancer Surveillance Program), or solid waste incinerators (Garcia-Perez, Fernandez-Navarro and Castello).

Toxic wastes stored in landfills also leach into soils, groundwater, or (in the case of volatile compounds) vaporizes into the air (Bakare, Alimba and Alabi). Each of these forms of solid waste leachate is a potential carcinogen.

The Immune System

The immune system is a collection of specialized cells, plasma proteins, and molecules that serve to protect us from harmful substances. The system is composed of two complementary components: the innate and the adaptive (or acquired) immune response. Each system is especially designed to recognize and eliminate any foreign agent (antigen) that invades our bodies.

The Innate Response

The innate system is a quick response mechanism composed of the epithelia of the (epidermis, gastrointestinal, respiratory, genital-urinary, reproductive tracts), several types of phagocytic cells (macrophages, Natural Killer, and neutrophils), dendrites, and various plasma proteins (members of the complement system). Epithelial cells and epithelial mucosa provide both physical and chemical protection against microbes. The tightly bound epithelia block the entry of microbes, while the mucosa secretes antimicrobial proteins and lymphocytes that effectively kill infectious agents. Microbes that breach these initial defenses are met by cells that detect their presence and recruit phagocytes to kill them. The resulting inflammation (heat, redness, swelling and pain) results from the migration of these various cells to the area of infection. The inflammation occurs as the many cells converge on a microbe; the pus associated with infections is released by neutrophils (a type of macrophage) as they die.

The Adaptive Response

Antigens (microbes or any foreign substance) that evade the innate response trigger the adaptive immune system. Dendrites will initially take the substance into the lymphatic system thence to the lymph nodes where T (thymus derived) and B (bone marrow derived) lymphocytes activate the immune response. These cells form two distinct components of the adaptive system: the humoral response, which employs B lymphocytes to respond to extracellular toxins and microbes, and the cell mediated response which uses T cells to defend against intracellular toxins. A second important distinction is that T cells are active phagocytes that travel to and eliminate antigens. B cells secrete antibodies (also called immunoglobulin) that respond to antigens in a variety of ways: IgG and IgM identify microbes and marks them for phagocytosis, IgA eliminates pathogens from epithelial mucosa, IgE protects against parasites: IgG is also active in the placental tissue where it protects newborns until their immune systems develops.

Long-term immunity results when B cells “remember” the characteristics of a given antigen. When injected with a vaccine (a weakened strain of a given pathogen) the adaptive system activates B-lymphocytes that secrete antibodies that recognize and target the antibody. The B cells also form memory B cells that will remember the specific characteristics of the antigen. These B cells will provide protection in the event of a real infection.

Evasion of Immune Responses

Our immune system is well equipped to provide protection from most pathogens. Our genome is well suited as a result of the evolutionary pressures that have selected for protections against such a wide array of pathogens. Pathogens, however, continue to evolve and develop new strategies and mechanisms to evade immunological responses. Many pathogens are able to alter their surface proteins and thus avoid detection by our immune system. This antigenic variation allows viruses to infect host cells before they are detected.

Our adaptive immune system has developed an array of mechanisms as a defense against antigens. In order to attack antigens, the immune system must first recognize the intruder. Many microbes have developed mechanisms that allow them to change their surface proteins so that they become unrecognizable to the immune system. Many of these mechanisms occur at the genetic level allowing pathogens to modify their surface antigens or cellular processes so that they can disable, confuse, or disrupt immune responses. Well-known examples are the HIV and influenza viruses that are able to regularly recombine their RNA sequences so that they express a different genetic makeup. This is the reason that a vaccine for HIV has been so difficult to synthesize and why we need new strains of influenza vaccine each season.

Global Burden of Disease

“Of all the forms of inequality, injustice in health care is the most shocking and inhumane”

Dr. Martin Luther King Jr., in a speech to the Medical Committee for Human Rights, 1966 (Physicians for a National Health Program)

Health and Socioeconomic status

Health is determined by two factors: the genotype and the interaction of the genotype with world outside the body: the environment. Although one’s genotype may occasion disease, it presents a predisposition to given illnesses that arise because of interaction with one’s environment. In this respect, the quality of the environment is important, as toxins, carcinogens, and other potentially lethal substances exist within polluted air, water, or soil. Examining global health data, one is struck by the manner in which life expectancy and diseases vary with socioeconomic status, gender, and age. . Although all human beings have almost identical genotypes (we share 99.5% of our DNA), our “environments” have a drastic effect on our health. An analysis of Global Disease Burden data evidences the influence these demographic variables have on the quality and longevity of life (WHOb).

Data compiled by (Sepulveda and Murray) show that mortality rates are influenced by a society’s degree of economic development, by age, race, and gender. For example the most prevalent diseases in Sub Saharan Africa are infectious diseases, which affect mostly women and young children while the rate of death in high income economies (such as Eastern Europe and the United States) for similar diseases is almost negligible. This disparity is due principally to the improved infrastructure, sanitation, and nutrition of women and children in developed economies. African nations and other economically distressed nations (such as Haiti) have limited economic resources and little ability to provide access to clean water, or adequate nutrition to women and children. “The burden of communicable, maternal, neonatal and nutritional diseases in [Sub-Saharan Africa] exceeds the [Years of Lost Life] scale” (Sepulveda and Murray 1276). A similar analysis of other metrics

(life expectancy or Disability Adjusted Life Years) provides additional evidence that communicable infectious diseases are more prevalent amongst the poor in developing (and underdeveloped) economies.

Unit strategies / Activities

Phase One: Constructing Background Knowledge

Day One

Topic:Health and Disease

Essential Questions: What is health? How does our body maintain a state of optimal health? Can everyone maintain a state of optimal health?

Objective: To define health and describe the bodily systems that maintain homeostasis.

Standards: CCSS.ELA-Literacy. RST.11-12.9 & NGSS: MS-LS1-5

Strategies: Students will complete a health survey that will form the basis of a class discussion on heath. The discussion will focus on the definition of health as the result of the internal processes that maintain homeostasis and the external environment in which we live. Central to the discussion will the interaction of the environment and genotype. The ongoing question will be whether all people have the same ability to maintain optimal health. The goal of the unit is to determine how and why environmental factors affect human health.

Direct Instruction: I will review the concept of homeostasis as the coordinated network of bodily systems, chemical reactions, and cellular mechanisms that help maintain a state of optimal health. We will include one's genotype, mitosis and protein synthesis as essential internal processes that maintain our health. The effect of environment on health is the central theme of this unit, thus it is important to clearly define it as all of the external factors that affect human health. This includes culture, socioeconomic status, gender, race, and personal life decisions (one's lifestyle).

Classroom Activity: The class will complete the Health Survey questionnaire, then engage in a discussion. Answers to the survey and discussion will be used to write a narrative summary of the classwork.

EXTENSION NARRATIVE: Write a narrative in your journal. Using answers to health questionnaire and discussion notes to answer the day's essential questions. Explain how your lifestyle and environment affect your health.

Materials: Health Survey: See Appendix B

Day Two

Topic: Bodily Systems and Homeostasis

Essential Questions: What is Homeostasis? What bodily systems help maintain homeostasis? What cellular

processes help maintain homeostasis? What happens if the DNA molecule is not replicated with fidelity?

Objective: To describe the system that maintains homeostasis.

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: HS-LS1-2

Strategies: The class will begin with a review of bodily systems (physiological, chemical, and cellular processes) that maintain homeostasis. The review will be conducted as a group activity, which will assess prior knowledge of these systems.

Once the review is completed, we will focus on cellular processes of DNA replication and protein synthesis since these topics are central to our analysis of how pathogens use their genomes in the process of infection or evasion of immune responses. This work will begin with an activity that explores the processes of DNA replication during mitosis.

Direct Instruction: I will display the structure of the DNA molecule, its chemical composition, the nitrogenous bases, and the base-pairing rules. I will also explain the role of the various enzymes that initiate and control the cycle (with an emphasis on the processes that end cellular replication).

Classroom Activity: The class will complete the homeostasis and bodily systems matching activity. Each group will be given a different segment of a DNA molecule to use in their modeling of DNA replication. The work will require them to explain the processes (signals and enzymes) that initiate replication and the mechanisms that end the cycle.

EXTENSION ACTIVITY: Choose any two bodily systems: predict what will happen if one of the bodily systems fails to maintain its normal state? What happens if the DNA molecule is not replicated with fidelity?

Materials: Homeostasis and bodily systems matching activity. Segments of DNA (~~ 40-50 bp).

Day Three

Topic: Protein Synthesis

Essential Questions: What occurs when errors occur in the replication or transcription of our genetic code? How does DNA direct the synthesis of proteins?

Objective: To apply base pairing rules in the translation of DNA to RNA. To apply the genetic code in the translation of RNA to amino acid sequences.

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: HS-LS1-1

Strategies: A central focus of this unit is on the manner in which bacteria and viruses use their genomes to infect hosts or evade immune responses. This lesson centers on the transcription of DNA to RNA and the subsequent translation to amino acid sequences. The lesson will provide an opportunity to discuss the role that diet plays in supplying our bodies with the proper balance of amino acids. This will be the first “News You Can Use” segment of this unit. Errors in these genetic processes (either in the DNA code or in the translation to RNA) can lead to the synthesis of malformed proteins, or alterations of the cell’s structure. While variations in these genetic processes are harmful or potentially lethal in human organisms, genomic variation is one the mechanisms pathogens use to evade the immune response and increase their virulence.

Direct Instruction: I will review base pairing rules for the translation of DNA to RNA as well as the method of translating RNA base pairs to amino acids using the genetic code. I will explain the types of errors that occur in the genome, and how those errors affect protein synthesis and the cell's ability to maintain homeostasis.

Classroom Activity: The class will use their DNA sequences from day one, to create an RNA template. Once the template is complete, the class will apply the genetic code to "synthesize" an amino acid sequence from the RNA strand. Once this activity is complete, each group will be given their original DNA sequence with one of the four errors. Students will then 'synthesize a new protein and compare it to the correct sequence.

EXTENSION: What are the essential amino acids you need to eat each day?

What foods provide you with these essential amino acids?

Materials: DNA sequences from day one, Genetic Code chart; Essential Amino Acids Chart, Proteins needed in the diet: food groups pyramid

Day Four

Topic: What is disease?

Essential Questions: What is disease? What is the role of the environment in disease? How do pathogens cause disease? Do diseases change over time? Is the risk from environmental pathogens (microbes) the same in for all people in all societies?

Objective: To describe the four types of pathogens: to differentiate between bacteria and viruses. To analyze the effect of the environment on the prevalence and virulence of pathogens.

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: HS-LS 4.4

Strategies: A central theme in this unit is that our health is determined by our genotype and its interaction with the external environment. The first three classes of this unit have explored internal processes that depend on our genotype. This class begins the analysis of the ways in which the external environment affects health.

To begin the lesson the class will answer the day's essential question and define disease from their perspective. Additional focus questions are listed in the discussion guide in Appendix B. (This will be a collaborative discussion format in which groups will determine their responses to essential questions, and then take turns presenting their opinions to the class. Each member of the group will take turns as presenter. The class recorder will take notes that will be used as part of the reflective summary. This will be the discussion format throughout the unit). Once we have completed the discussion, we list the diseases that are most virulent now, those that are emerging, and those that are no longer a threat to our world. To complete the day's work, the class will view the video from the NIH titled, "Infectious Diseases Then and Now": available at: https://science.education.nih.gov/supplements/nih1/Diseases/activities/activity1.html

Students will complete a video viewing guide, which they will use to review their responses to the discussion questions.

Direct Instruction: There will be no direct instruction as this day's activities are predominantly student based. The teacher's role is that of facilitator and participant.

Classroom Activity: Group discussion and video viewing. Answers to both discussion guide questions will be recorded in health journal; class will write a paragraph that summarizes the day's two question sets.

EXTENSION: Research one of the day's diseases. Historical time, cause (pathogen), clinical effects, treatment, geographical location, and

Materials: Disease discussion questions, video viewing guide, and access to NIH video.

Day Five

Topic:Microbial Pathogens

Essential Questions: What is the difference between bacteria and viruses?

Objective: To differentiate between viruses, bacteria, and other microbes. To analyze how viruses replicate inside hosts. To describe how microbial pathogens cause disease in hosts.

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: HS-LS 4.4

Strategies: Pathogens in the environment cause disease when they are able to bypass the immune systems, compromise bodily systems, and damage or kill cells. Bacteria and other microbes are able to reproduce and infect hosts directly. Viruses need to exploit the host's cellular mechanisms in order to reproduce and affect disease. We will first study these two major sources of disease. We will study other pathogens (prions, protozoa, and fungi) in our independent study of water borne microbes. The class will begin with an analysis of diseases discussed during the previous lesson (and those from the extension homework). We will note which diseases bacteria cause and which viruses cause. We will then engage in a modeling activity that compares / contrasts the ways in which bacteria and viruses reproduce and infect hosts.

Direct Instruction: Bacteria are prokaryotic cells that are able to reproduce inside a host, while viruses are obligate pathogens that require a host cell's reproductive mechanism. I will show a brief animation that reviews the mechanism of viral infections. Once the review is complete, the class will begin to set up the Bacterial Lab.

Classroom Activity: Review of mechanism of viral infection. Day 1 of Bacterial Lab: setting materials, making solution, preparing agar plates.

EXTENSION: Complete Pre-Lab analysis questions

Materials: Agar plate, culture of *P.fluorescens,* nutrient broth, nutrient broth with kanamycin, and Agar plate with kanamycin: sufficient material for 16 pairs of students.

Lab instructions located in Appendix A

Day Six

Topic:Bacterial Lab Day 2

Essential Questions: What are the dangers in the excessive use of antibiotics? How do bacteria become resistant to antibiotics? What is the importance of genetic variability in natural selection?

Objective: To explore the manner in which bacteria develop resistance to antibiotics.

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: HS-LS 1-1

Strategies: The class will engage in a laboratory activity that demonstrates how bacteria develop resistance to antibiotics. Strains of the bacterium *Pseudomonas fluorescens* from will be cultured in differing environments. One sample will be mixed with a nutrient broth containing kanamycin: and cultured on agar plates containing the antibiotic. A second sample will not be in contact with the antibiotic. The first set of 2 plates will be cultured for 3 days; a second set of four plates will be cultured for an additional 3 days. The class will note the growth of bacteria on each set of plates. Each pair of students will be responsible for answering post lab questions. Included in the post lab analysis are three writing prompts that question the overuse of antibiotics and antibacterial products in our society.

Direct Instruction: I will distribute lab procedures to each pair of students, and make certain all supplies are available.

Classroom Activity: Lab procedure is located in Appendix B.

Materials: Agar plates, and Agar plates with kanamycin, culture of *P.fluorescens,* nutrient broth, nutrient broth with kanamycin: sufficient material for 16 pairs of students.

Day Seven

Topic:The Innate Immune System

Essential Questions: How does our body protect against pathogenic invasion? What is the difference between the innate and the adaptive immune response?

Objective: To differentiate the innate and the adaptive immune response. To describe the processes of innate immune response.

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: MS-LS1-3 & HS-LS 4-4

Strategies: Following the study of the ways in which pathogens cause diseases,

The class will explore the bodily systems and structures that protect us from diseases. We will first look at the structures and mechanisms of the innate immune system, then focus on the different cells and systems of the adaptive immune system. We will study the innate immune system through direct instruction, modeling activities, and video presentations.

Direct Instruction: I will compare and contrast the two immune responses: with an emphasis on the cells, and components of the innate response.

Classroom Activity: The class will view an animation that compares the physical and cellular components of the innate system and adaptive immune responses. They will be also view an animation of that shows the innate system (neutrophils) responding to a microbe. The class will then be given a scenario in which a pathogen breaks through the epithelium. They will have to describe how each component of the innate system responds to the invading microbe.

EXTENSION: Why does your skin get red and swollen when an infection occurs?

Materials: Immune system animation located at:
http://media.hhmi.org/biointeractive/click/immunology_primer/01.html:

Innate system video located at: http://www.niaid.nih.gov/topics/immunesystem/Pages/immuneCells.aspx

Immune Response scenario sheet.

Day Eight

Topic:The Adaptive Immune System

Essential Questions: How does the adaptive immune system remember and recognize antigens? How do we acquire immunity through vaccines? Why are vaccines important in a complex society?

Objective: To explain how acquired immunity develops. To evaluate the merits of vaccination

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: MS-LS1-3 & HS-LS 4-4

Strategies: Our analysis of the adaptive immune system will require modeling of how the body creates antibodies for specific antigens, how antigens are recognized, and cleared from the body. An essential part of this discussion will be devoted to the ways in which immunizations work, and why they are important in large interactive society. This will offer us the first opportunity to engage in a critical debate as to the reasons for and against vaccination: (there are likely some students in our school community who refuse these technologies). A summary essay that explains the manner in which adaptive immunity arises will form part of the critical essay that explains why immunizations are necessary:

Direct Instruction: I will review the functions of cells of this system through the interactive video titled, "Cells of the adaptive immune system." The video explains how adaptive immunity develops and how B cells are able to remember antigens.

Classroom Activity: Students will view the video presentation.

EXTENSION: Read the articles: What are vaccines and How Vaccines Work: Explain how the adaptive immune system helps to create immunity.

Materials: Immune system animation located at: http://www.hhmi.org/biointeractive/cells-immune-system

Vaccine articles located at: http://www.niaid.nih.gov/topics/vaccines/understanding/Pages/whatVaccine.aspx

Day Nine

Topic: Bacteria Lab Day 3

Essential Questions: What are the dangers in the excessive use of antibiotics? How do bacteria become resistant to antibiotics? What changes occurred in their genomes?

Objective: To explore the manner in which bacteria develop resistance to antibiotics

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: HS-LS 1-1

Strategies: The class will analyze the differing colonies on their agar plates. Results should show that bacteria grown in contact with the karamycin are resistant to it, while those not in contact with the antibiotic have failed to thrive.

Direct Instruction: Inspection of the agar plates will provide an opportunity to discuss how and why the bacterial have become resistant to the karamycin. I will review the concepts of mutation in response to environmental factor. I will discuss the bacteria's ability to alter their genome and relate this to the ways in which other pathogens antigenic variation to evade our immune response.

Classroom Activity: Inspection of agar plates, measuring colony growth, and answering post lab questions.

EXTENSION: Explain why too many antibiotics are not good for you? Explain why you should always complete the entire dose of antibiotics your doctor prescribes. How does the bacteria's ability to alter its genome explain why it is difficult to develop vaccines that protect against viruses like the flu or HIV?

Materials: Post lab conclusion questions located in Appendix A.

Day Ten – Eleven

Topic:Cancerous Tumors

Essential Questions: How do cancerous cells proliferate? What are the effects of the various types of oncogenes?

Objective: To differentiate between proto-oncogenes and tumor suppressor genes and explain how mutations in these genes foster cancerous tumors.

Standards: CCSS.ELA-Literacy. RST.11-12.9 and NGSS: HS-LS 1-1

Strategies: Cancerous tumors result from the uncontrolled proliferation of cells. This lesson explores the manner in which beneficent genes mutate into cancer causing agents. Students will differentiate and categorize the genes that foster cancerous tumors.

Direct Instruction: Proto-oncogenes and tumor suppressor genes serve important function in normal cell functions. Mutations in these genes result in the formation of cancerous cells that go on to form cancerous tumors. There are approximately 140 known mutations (~ 60 oncogenes; ~ 80 tumor suppressor genes) that cause cancer. The mutations affect three broad types of cellular functions: cell growth and survival, genome maintenance (proofreading DNA replication), and processes of cell differentiation. Alteration of any of these processes leads to the accumulation of mutations that eventually cause cancer. This lesson focuses on the ways in which these mutations alter normal cell reproduction.

Classroom Activity: This lesson begins with a viewing of a brief video: *Cancer as a Genetic Disease*" by Dr. Charles Sawyer, which surveys research on the number and type of cancer causing genes. The class will complete a video viewing guide. Once the video is complete students will view a listing of oncogenes and tumor suppressor genes. Each student will select two genes of their choice to investigate. Using either the Genetics Home Reference or the HGNC websites they will then list the chromosomal location, type of gene, how it fosters malignancy and the cancers associated with the mutated gene.

EXTENSION: To complete this lesson, the class will view excerpts from the film *Erin Brockovich,* which chronicles the effects of carcinogens in water (hexavalent chromium) on the health of families living near industrial sites. The film provides a link between the two parts of this unit as it explores the difficulties that arise when attempting to prove a causal link between environmental pollution and human health.

Materials: *Cancer as a Genetic Disease"* video from the HHMI website: available at:

http://bcove.me/jcxt7l7l. Cancer as a Genetic Disease video viewing guide located in Appendix A

Genetics Home Reference website: http://ghr.nlm.nih.gov/

HUGO Gene Nomenclature Committee website: http://www.genenames.org/

Erin Brockovich film available on Netflix

Phase Two: Critical Analysis of Global Health Data

The analysis of the Global Burden of Disease data begins the second phase of this unit, which considers how cultural, socioeconomic, and political factors influence health. Statistics on mortality rates worldwide are systematically organized and analyzed through several reports from the WHO (World Health Organization). The main source of data for this phase of the unit will be the WHO 2015 World Health Summary and its compendium of health statistics (WHOa). This latest report archives health statistics from the organization's 194 member states. These reports assemble data of the causes of death, due to a variety of diseases (global disease burden), per year and by country.

Two additional data sources will be *Global and Regional Mortality from 235 Causes of Death* by (Lozana, Naghavi and Foreman), which gathers data of mortality rates over the last 20 years for 187 countries worldwide, and the *States of Global Health* report by Sepulveda and Murray.

It is important to note that data collection is problematic as not all countries have effective systems of collecting and reporting morbidity data. Thus there is a more certain understanding of health / morbidity statistics in developed countries than there is for developing nations. The data in these articles (and in all subsequent data sets) depicts only relationships between demographic variables. The class will have to first determine if a relationship exists thence propose arguments that explain their observations. The work of these lessons will be to find evidence to support their arguments. In some cases I will provide evidence through direct instruction, through web-quests, or through directed reading. During the latter days of this phase students will be allowed to engage in independent research of given topics. Each of the following lessons will require from 1-3 days to complete.

Day Twelve –Thirteen

Topic:Global Life Expectancy

Essential Questions: Is life expectancy the same throughout the world? What factors affect life expectancy? How do gender, economic condition, and age affect mortality?

Objective: To explore how life expectancy varies with degree of economic development, gender and age.

Standards: **CCSS.ELA-Literacy.RST.9-10.1** & **CCSS.ELA-Literacy.RST.11-12.8**

Strategies: Data from the WHO Global Health Observatory (GHO) provides statistical analysis of a variety of health indicators. The class will first examine statistics (presented as interactive graphs) on adult mortality rates. Each of the graphs disaggregates the data by gender, country, and WHO region. The class will evaluate the data as it varies with these variables. The class will also analyze data on Infant mortality and maternal mortality rates. The goal of this lesson is to discover the relationship between economic status, gender, age, and life expectancy.

Direct Instruction: I will show students how to navigate the WHO website so that they can easily access and manipulate the various graphs and data sets. Each graph provides filters that allow one to reorganize the data by gender, country, region, and degree of economic development. I will provide each group a series of analysis questions that will serve as a guide as they explore the data.

Classroom Activity: The class will access data sets using laptop computers. The interactive nature of the graphs allows students to scroll over countries to compare data. They can also filter the graphs by gender, region, country, and degree of economic development. The class will have to determine the relationship that exists in the data and propose an explanation as to why life expectancy varies with these variables.

Materials: Graphs: Life expectancy at birth

http://gamapserver.who.int/gho/interactive_charts/mbd/life_expectancy/atlas.html

Maternal mortality rates:

http://gamapserver.who.int/gho/interactive_charts/mdg5_mm/atlas.html

Infant mortality rates:

http://gamapserver.who.int/gho/interactive_charts/MDG4/atlas.html?indicator=i1

Day Fourteen - Day Fifteen

Topic:Global Burden of Disease

Essential Questions: Why is there a difference in the global burdens of disease statistics? Why are communicable diseases the leading cause of mortality in developing countries? Why are there higher incidences of non-communicable diseases in developed countries?

Objective: To analyze global burden of disease data in developing and developed countries.

Standards: **CCSS.ELA-Literacy.RST.9-10.1** & **CCSS.ELA-Literacy.RST.11-12.8**

Strategies: To further understand global health, the class will explore the causes of mortality throughout the world. While there are many distinct causes of death, analysis categorize them into three categories: communicable / non-communicable diseases and injuries. This lesson will once again use data from the WHO repository, which presents age standardized mortality rates in the three categories mentioned above. The class will first examine these graphs to determine if which causes are more prevalent in given regions or countries. The class will also examine statistics from the *Global Burden of Disease*, article that provides a more detailed examination of the diseases in the three categories.

Direct Instruction: I will review the mortality data from the previous class and explain the difference between the three descriptors used to categorize the causes of mortality.

(Lozana, Naghavi and Foreman)

Classroom Activity: The class will explore the WHO data: Age standardized mortality rates and explore the relationship between the three causes of death and regions / countries (and degree of economic development).

EXTENSION: What kind of communicable diseases are more prevalent in developing countries? What role does the environment (water treatment facilities) play in the transmission of communicable diseases?

Materials: WHO graph: Age standardized mortality rates at:

http://gamapserver.who.int/gho/interactive_charts/mbd/as_death_rates/atlas.html

Global Deaths for 235 Causes data from: *Global Burden of Disease (Lozana, Naghavi and Foreman)*

Day Sixteen - Day Seventeen

Topic: Water Quality, Sanitation, and Hygiene

Essential Questions: Why are communicable diseases so prevalent in developing nations? How do sanitation, hygiene, and water quality affect health? What environmental factors contribute to poor water quality

Objective: To evaluate the effect that sanitation, hygiene, and water quality have health

Standards: **CCSS.ELA-Literacy.RST.9-10.1** & **CCSS.ELA-Literacy.RST.11-12.8**

Strategies: Selective Infectious Diseases: The analysis of this data set will reference the water borne pathogens studied during the first phase of this unit. Given that infectious diseases are more prevalent in developing nations, we will have the opportunity to discuss why wastewater treatment, hygiene, and sanitation are so ineffective in developing nations.

Direct Instruction: I will review lessons from our environmental science curriculum on water pollution, and water treatment before the examination of the data. The class will also review notes from their exploration of water borne infectious diseases (day four of this unit). We will list the diseases that result from contaminated water sources.

Classroom Activity: The class will then analyze data from the WHO website on the effects of inadequate sanitation, hygiene, and water quality on health in low and middle-income countries. The interactive graphs present the data by country and region in terms of Disability Adjusted Life Years and Mortality. Before completing our analysis, I will show the class a brief video on water quality in developing nations. The video examines the effects that poor water quality has on the lives of poor residents in developing nations, and suggests actions that should be taken to provide clean water to all citizens. The class will complete a video viewing guide as part of the lesson.

EXTENSION: The video mentions the Millennium Goals for Public Health. What are these goals? How have they affected the state of global health in the past 15 years?

Materials: PHE: water, sanitation, and hygiene graph at:

http://gamapserver.who.int/gho/interactive_charts/phe/wsh_mbd/atlas.html

You tube Video: at: https://www.youtube.com/watch?v=3JY8MFTXrM.

Day Eighteen: End of Unit

Topic:The State of Global Health

Essential Questions: How has global health changed since the establishment of the millennium goals? Is the world doing all that it can do to improve the health of children, women, and other vulnerable populations?

Objective: To propose responsible action that protects the environment and our health.

Standards: **CCSS.ELA-Literacy.RST.9-10.1** & **CCSS.ELA-Literacy.RST.11-12.8**

Strategies: At this point students should be aware of the ways in which environmental factors affect health in our nation and throughout the developing world. The first question that we should address is what is our responsibility to the nations with limited resources and poor health. We will explore the Millennium Goals outlined in the WHO report. The eight goals were established in 2000 by the United Nations. The class will review the progress (and setbacks) that has occurred in the ensuing 15 years.

Classroom Activity This class will be a collaborative discussion. Each of the four student groups will address two goals. They will list the criteria for each goal, the progress that has occurred, and what obstacles exist. The class will engage in a discussion on the state of global health once each group has completed their evaluation

EXTENSION: Write a reflective essay that summarizes what you have learned about global health. The essay may address issues of health in developing nations, or issues of health in this country.

Materials: WHO Millennium Goals at: http://www.who.int/topics/millennium_development_goals/en/

Appendix A

HEALTH QUESTIONNAIRE

1. What is health?
2. How do you know that you are healthy?
3. What should you do to maintain your health?
4. Is it possible to feel healthy and still be ill?
5. What is homeostasis?
    - How does our body maintain homeostasis?

6. What does homeostasis have to do with health?
7. How much does the environment affect your health?
8. Is this effect the same for all people?
    - Explain your answer.
9. Describe the ways in which you maintain your health?
10. Describe the ways in which you do not keep yourself healthy?
11. What is a healthy lifestyle?
12. How does your lifestyle (personal decisions) affect your health?
13. Do all people in our society have the same ability to maintain their health?
14. Do some people have a predisposition to disease?
15. How much does your family (your genes) have to do with your health?
16. What is a person's genotype?
    - Explain your answer.
17. Do all people in the world have the same ability to maintain their health?
    - Explain your answer.
18. What is a disease?
19. What causes diseases?
20. Does the type and incidence of disease vary?

Disease Discussion Focus Questions

1. What is a disease?
2. What do you think causes disease?
3. What role does the environment have on diseases?
4. Do diseases change over time? Or are they always the same?
5. Which disease causes the most deaths worldwide?
6. Which disease do you consider to be the most dangerous?
7. Which disease is historically the most lethal?
8. What new (emerging) diseases are you aware of?
9. In you group list the ten most dangerous diseases.
10. Which of these diseases are communicable?
11. Which are non communicable?
12. In what parts of the world are communicable diseases most prevalent?
13. Can you propose a reason?
14. In which parts of the world are communicable diseases almost non-existent?
15. Can you propose a reason?

Video viewing questions

As you watch name the historical diseases and their dates:

1. What disease was prevalent in the 18th /19th century
2. What disease was prevalent in 1918?
3. What was the leading cause of death for soldiers in the First World War?
4. Where are infectious diseases still a problem?
5. Why is this so? What are the environmental reasons?
6. Name the emerging diseases.
7. Are we at risk in this country?

8. Can emerging infectious diseases threaten us?

Bacterial Lab Procedure and analysis questions located at:

https://science.education.nih.gov/supplements/nih1/Diseases/guide/pdfs/ACT3M.pdf

Genetics of Cancer Video Viewing Guide

1. How was the study conducted? How large was the sample?
2. How did researchers determine the number of cancer causing genes?
3. What is a silent mutation?
4. How many cancer-causing genes are estimated as of 2013?
5. Do we expect the number to change?
6. How many of these genes are oncogenes?
7. How many are tumor suppressor genes?
8. What is the difference between a proto-oncogene and an oncogene?
9. What is the difference between a proto-oncogene and a tumor suppressor gene?
10. What are the three areas of cellular functions that these cancerous genes affect?

Appendix B

COMMON CORE SCIENCE LITERACY STANDARDS:

Source: http://www.corestandards.org

CCSS.ELA-Literacy.RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of process, phenomenon, or concept, resolving conflicting information when possible. Throughout this unit, students will use information from their environmental science, biology, and their chemistry classes. The learning activities for the first phase of this unit will require them to access prior knowledge and use it in their analysis of issues pertaining to global health. (Days 1-11)

CCSS.ELA-Literacy.RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

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

The second phase of this unit relies on the extensive analysis of global health data. Throughout this part of the unit students will need to evaluate data, determine patterns, and propose explanations to their observations. These standards are relevant to these lessons, as each day's work will require to them to evaluate statistical data and then use pertinent information to justify their analyses. (Days 12-18)

NEXT GENERATION SCIENCE STANDARDS:

Source: http://www.nextgenscience.org/msls3-heredity-inheritance-variation-traits

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

This standard focuses on the role that environmental factors have on internal processes of growth and development. It is a central guiding principal in this lesson and throughout the unit as health is determined by the interaction with the external environment. (Day 1)

HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multi-cellular organisms.

This standard focuses on the interconnectedness of systems within the body. It is appropriate to this first lesson as homeostasis depends upon the interaction of many bodily systems that interact to maintain a consistent internal environment. (Day 2)

HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.

DNA replication and protein synthesis depend on the coordinated action of various cellular components. This standard supports this lesson's learning goals as it focuses on the ways in the genetic code directs protein synthesis (Day 3)

It also focuses on the manner in which bacteria alter their genetic code to survive environmental pressures (lethal antibiotics). This standard is pertinent to this laboratory activity as it addresses the manner in which organisms alter their structure to benefit their function. (Day 3,6, 9, &11

HS-LS4-4 Construct an explanation based for how natural selection leads to adaptations of populations.

Our genotype, many of our bodily systems (specifically our immune system) have evolved in response to adaptive pressures from pathogens and toxins. This standard focuses on the fact that a species' survival depends on its ability to successfully adapt to environmental factors (Day 4, 5, 7 & 8)

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