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The Changing Threat of Malaria and the Impact on Global Health

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Introduction

The first time I travelled to a tropical region I remember my doctor telling me I needed to take prophylactic drugs to protect me from the risk of contracting malaria. Following some clarification as to what prophylactics meant, I was prescribed a once a week medication to help prevent my contracting malaria

Looking to my own naiveté with regards to the real health scourge of malaria, I want my students to be aware of one of the largest health issues that faces humanity. They need to understand that malaria, in the age of climate change, is an evolving threat with serious implications for the entire globe (including the United States).

After completing this unit my students will understand how the transmission of malaria occurs and how it affects human health around the globe. My objectives will include students mastering the following concepts: 1) Cells are the foundation of life; 2) Observation and identification of different types of cells, including single-celled organisms; 3) Understanding and identifying *Plasmodium* in the zoonotic transmission of disease; 4) Recognizing climate change as a catalytic factor in the dynamics of zoonotic interactions; 5) Examining the future global implications of climate change on the transmission of malaria; 6) Creating an action plan to help increase awareness and reduce the incidence of malaria in lesser-developed countries.

Further, new technologies, specifically the potential for genetic modification of the mosquito and or *Plasmodium* genetics, bring about huge ethical questions. My students need to be aware of, and able to discuss and debate, this brave new world.

Ultimately it is my hope that students will appreciate the advantages they have living in a developed country and further will recognize the role they can and need to play in helping those less fortunate.

Content Objectives

For this unit, I want to focus on how the changes being wrought by climate change, increase the risk of malaria, and what their role is in bringing about a change in behavior in themselves, their families and communities. They will need to explain behaviors that minimize future risk and combat climate change.

California is implementing the Next Generation Science Standards. One of the many new features of these standards is Crosscutting Concepts, used to bridge scientific and engineering fields, and bringing relevance to the topics being taught. There are seven:

1. *Patterns. 2. Cause and effect: Mechanism and explanation. 3. Scale, proportion, and quantity. 4. Systems and system models. 5. Energy and matter: 6. Structure and function. 7. Stability and change.*

This unit touches on each of these concepts repeatedly and will engage students in real-world activities to better understand the ecology of the *Anopheles* mosquito, the vectors of transmission, the physiological aspects of malaria and prevention of malaria.

Background and Rationale

The famed cosmologist and T.V. star, Carl Sagan, wrote “a little mote of dust suspended in a sunbeam”,[1] in reference to a dull pixel in a satellite photo taken on February 14th , 1990. He called it the *Pale Blue Dot*, and it was the planet Earth. We all inhabit this one blue planet. We all are completely dependent on the numerous natural systems that have evolved over billions of years, resulting in the incredibly diverse and complex systems that allow for life not only to exist, but also to thrive. As of 2015, over 1.9 million species have been named, another 8.7 million (+/- 1.3 million) are species estimated yet to be discovered.[2]

Humans are but one species in this magnificent collection of DNA-based creatures, but stand out in our ability to shape, impact and alter our surroundings. For thousands of years, what might have been a major change in a local setting, a human-induced forest fire, for example, was minimized by the locality of the fire, and globally by our small population. As human populations have grown, this impact is no longer measured on a local, but rather on a global scale, leading Nobel Laureate Paul Crutzer to coin the term for a new geologic Era, the Anthropocene Era.[3] The suggested beginning of the Anthropocene Era, which is the era in which humans have the power for significant ecological change, is 1945 with the test of nuclear weapons. While the risk of total nuclear annihilation has been reduced, a new specter has arisen, that of climate change.

This unit will use the human tragedy of malaria to introduce students to the concepts of cells, human body systems, and disease transmission, which are all content standards for biology. Over the course of my unit, students will learn to interpret distribution maps, and predict future changes based on a warming planet. They will understand the nature of malaria, the lifecycle of the *Plasmodium* parasite, how the mosquito acts as an agent of transmission, and the affects malaria has on humans and the societies in affected areas.

Demographics

Calero High School is part of the larger East Side Union High School District, which has 11 major campuses (as defined by more than 1000 students) and over 25,000 students. 42% of our student body qualify for free and reduced lunch. Of the 165 students enrolled in Calero for the 2014-15 past academic year, 53 are in tenth grade, 67 are in eleventh grade, and 45 are in 12th grade. This ethnic distribution is 0.6% American Indian or Alaska Native; 3.8% Asian; 7% African American, not of Hispanic Origin; 75.3% Hispanic or Latino; 1.3% Pacific Islander; 8.2% White, not of Hispanic Origin; 3.8% Other. This ethnic mix does not represent the ethnic makeup of the city of San Jose or the rest of East Side Union district, but rather students who are traditionally underrepresented. With a student population of more than 90% with origins in developing countries, they have a personal interest in helping to understand and educate others about malaria

In my experience with at-risk students, integrated projects that tie different topics and standards together are more successful at capturing their attention and excitement. I believe this unit will engage them due to malaria's current relevance in the world, the unit's incorporation of many biology standards, and the variety of teaching modalities this unit requires. Rather than isolating standards and teaching them piecemeal, units such as this attempt to frame knowledge for students in a holistic, real-world, and multi-faceted manner.

Our students at Calero access all classes required to graduate and continue their studies at college and university levels. Most students come to Calero down in credits, and opportunities for recovery are integrated into our master schedule. Using technology as an integral 21st century skill, students have a regular class dedicated to online learning for credit recovery and grade enhancement. Working at the self-paced, A-G (the California university requirements) approved program our students recovered over 400 credit units last year. We are integrating Next Generation Science Standards along with Common Core in both Mathematics and English. In addition, our staff has committed to collaboration in Project Based Learning for several school-wide projects. As a staff at a new school we are committed to building community and finding new ways to encourage and motivate our students.

Content Objectives

The unit will be implemented at the beginning of the year when I start with the Requirements of Life and Cell Biology. This unit will provide a survey of the disease malaria and how it affects human health and physiology. *Plasmodium* and *Anopheles* will be covered as they pertain to how the parasite and vector affect humans at the cellular and organismal levels. Investigation and experimentation standards will be interspersed throughout the unit. Ecology and the Environment pertain to the habitat of requirements of the mosquito vector and correlate to the distribution of the disease. Evolution lends itself to this unit as life adapts to changing conditions and species evolve. We will focus on the mechanisms involved in climate change, ecological responses to climate change, the niche of the *Anopheles* mosquito. Many of my students have family members from other countries that are in these affected regions, including Central America, South America and Asia.

The scientific consensus is that the climate is changing, and it appears to be affecting ecosystems, there by

affecting rates of malaria.[4]

Microscopy

Since Robert Hooke first observed “little boxes” inside of a thin layer of cork, microscopes have literally opened up a whole new world to explore. The realm of microbiology is vast, and I want my students to have exposure to it from the beginning of the year when they start by looking at cells and microorganisms. These microscopy skills help to bridge the knowledge of cells as building blocks of life with the malaria parasite, a microorganism, with the effects of malaria on human physiology.

Characteristics of life

We will start off with one of the most basic questions of biology, but one that is very difficult to answer: What is life? There is no one answer that fully captures the essence of Life. However, one can use a list of six basic characteristics that all living things share.

Living things are made of cells and as the building blocks of life; every living thing is made of at least one cell. Cells can be broken down into two categories, prokaryotes and eukaryotes. Prokaryotes have no nucleus or membrane bound organelles. All prokaryotes are single-celled organisms. Conversely eukaryotes are more complex, with a nucleus and membrane bound organelles. They can be single celled organisms e.g. paramecium, or complex organisms that are multicellular such as ourselves, containing some 20-50 trillion cells.

Life uses energy. Living things must take in energy from their environment to power the reactions of life. The reciprocal pair of reactions of photosynthesis ($6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$) and respiration ($C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$) show the interconnectedness of this for autotrophs (including plants) and heterotrophs (including animals). For us the processes of consuming food and producing waste represents this interconnectedness.

Life is organized. Cell organelles combine to function together as an individual cell. These cells arrange themselves as tissues, and tissues work together as an organ. Multiple organs function together as organ systems, and lastly as a complete organism. The parts individually are not alive, but the parts are truly greater than the whole. Organization can also be thought of with a simpler example: For us skin is found on the outside of our bodies and our organs are on the inside, and it would be very disadvantageous the other way around.

Living things grow. From birth to death, there is a pattern that life is born, develops, matures and dies. For multicellular organisms the number of cells increases from conception until adulthood.

Life reproduces. For a species to not go extinct it must be able to reproduce. Species can reproduce asexually, that is by the single organism splitting or budding and producing clones of itself. Species can also reproduce

sexually, that is two individuals (male and female) combine to form a new individual with a new and different genome.

Life evolves. Species must adapt to changes in their environment; those that cannot will die off. As Darwin explained in *On the Origin of Species,* individuals of a given population are diverse, and those that have adaptations that provide an advantage will tend to survive longer and reproduce more. Those adaptations tend to be passed on to their offspring and over time species evolve. When conditions change and the adaptations no longer confirm an advantage those species die off. For example, dinosaurs were the dominant life forms for over 200 million years. 65 million years ago, they were unable to adapt fast enough to climatic changes due to volcanism or comets striking the Earth.

Cells and Microorganisms

Prokaryotes

Prokaryotic cells are the simplest form of life. Consisting of a single cell, bound by a cell membrane, they are microscopic and contain relatively few parts. They have no nucleus; rather their DNA is clumped up, and floating in the cytoplasm. Ribosomes are also floating in the cytoplasm. Most have flagella for movement. These organisms are found in almost every habitat on Earth, including very harsh environments such as hyper saline (halophiles) and extreme temperature (thermophiles). Locally we have salt ponds that are stained various hues of the rainbow as evaporating water changes the salinity and different species of these organisms can survive.

Eukaryotes

Eukaryotes are more complex cells that have both a nucleus and specialized membrane bound organelles. They can be found as single celled organisms or can join together to form the macroscopic flora and fauna found all around us. Different organelles each have their own functions to keep the cell alive. The nucleus is generally the largest and most obvious feature, responsible for the regulation of cell processes, and can be thought of as the brain of the cell. The DNA is enclosed by the nuclear membrane and is the site where transcription takes place. After the nucleus the mitochondria are one of the most noticeable organelles. These kidney bean shaped structures have a double membrane and are the powerhouse of the cell, converting the chemical energy of food into ATP for the cell's needs. Endoplasmic reticulum (the ER) act as conveyor belts moving cellular products around inside the cell. ER that has ribosomes found on it is called rough ER and is the site of protein manufacturing. The Golgi apparatus can be compared to UPS in that they process and package cell products. Lysosomes function as trashcans disposing of waste products. Animal cells tend to be round or blob-like where as plants have an additional structure in a cell wall for structure and support, generally giving a rectangular shape to the cell.

Some species of organisms (both prokaryotes and eukaryotes) can be parasitic, invading other cells or larger organisms to derive their nutrition from them.

Malaria

A worrisome change from the point of view of human health is the potential expanded range of the either the *Anopheles* mosquito or the *Plasmodium* parasite, the vector and infectious agent of human malarial transmission. Malaria is a deadly disease that leads to over one million deaths in the developing world annually. Areas currently free of malaria are at risk of becoming more hospitable to the *Anopheles* mosquito or more favorable to the *Plasmodium* parasite, which could lead to an increase in cases of malaria.

Warmer temperatures lead to longer seasons for mosquito breeding, and expanding ranges into areas that were previously too cold to allow for the mosquitoes to survive. Areas that receive more water also provide areas for mosquito breeding.[5]

Malaria is a global killer that affects between 200 and 300 million people every year,[6] the majority in poor and undeveloped countries in tropical regions. The disease is caused when a mosquito infected with parasitic protozoa of the genus *Plasmodium* bites a human and infects the bite victim. Over 1 million people die of malaria annually, due to lack of medical access to lifesaving medicines such as cholorquine and mefloquine. Both of these are orally administered medications that can be used prophylactically or for treatment.

Plasmodium is a single celled, eukaryotic microorganism with a complex lifecycle. It is an obligate parasite, which means it is only able to live inside of a vector and host organism, in this case the *Anopheles* mosquito and vertebrates. The genus *Plasmodia* comprises over 200 recognized species, of which approximately 100 species are pathogenic and cause some form of malaria.

The symptoms of malaria include fever, fatigue, nausea and respiratory distress. A worst-case scenario can lead to coma or death. Malaria is curable if it is properly diagnosed and treated with medication. Sadly these medicines are lacking throughout much of the developing world where malaria is found today. Malaria can be diagnosed through microscopic analysis of a blood smear by identifying the parasite in the blood cells or serum.

Due to a lack of adequate medical facilities and trained personnel, often the only recourse is to focus on the prevention of transmission through the use of bed nets to prevent mosquitos from biting, and pesticide spraying to kill the vector mosquitoes.

Malaria was once endemic to the United States; it was found all along the west coast, eastern seaboard and especially in the South, with thousands of cases reported annually well into the 20th century. In 1947 a government campaign was begun to eradicate the disease, and by 1951 it was declared successful.[7] This amazing endeavor was a result of attacking the disease on several fronts. Mosquito population reduction was performed by changing agricultural land use to minimize standing water, where the mosquito breeds. Pesticides such as DDT were used to kill adult mosquitos upon contact. Improved diagnosis and treatment with newly available drugs prevented the spread of the disease by killing the parasite and thereby reducing the chances for a mosquito to become infected with the parasite.

Most species of mosquitos in the United States were never implicated in malaria transmission, Texas leads the nation with 85 native species of mosquitos and Florida is second with 80. Four species of *Anopheles* mosquitos that were responsible for malaria transmission are still found in the United States. Between 1957 and 2014, there were 63 cases of local malaria transmission reported in the United States.[8] An infected person, infected

in an endemic area, brought the parasite back to the U.S. where local mosquitos were infected upon biting the affected person.

The cost of malaria can be measured in human life and suffering, as well as in the economic and societal costs to countries with endemic malaria. To this end, The Bill and Melinda Gates foundation has dedicated over $1.3 billion to combat this deadly disease. Their goal is nothing less than the complete global elimination of malaria.[9]

Malaria infection begins when an infected female *Anopheles* mosquito bites someone. The malaria infection cycle can be broken into three locations. The first location is in the infected person's liver. Once bitten by an infected mosquito, *Plasmodium* parasites, in the form of sporozoites, are injected into the bloodstream. Once in the host, they quickly migrate to the human liver. There, they multiple asexually within 1-2 weeks. This phase is asymptomatic. The next location is the bloodstream. In this phase of the lifecycle, the parasite is called merozoites. It is released by the liver in vesicles into the circulatory system that then migrate to the lung capillaries. Once lodged in the lungs, the vesicles disintegrate allowing the parasite to travel freely in the bloodstream where they invade red blood cells. Once inside the blood cells they again multiply asexually, leading the enlarged cells to burst, and releasing more parasites to repeat the cycle. Some of the merozoites will progress to the next phase called gametocytes, where they reproduce sexually. The gametocytes circulate in the bloodstream where they can reinfect a biting mosquito. The third location is inside of an *Anopheles* mosquito, where they continue their lifecycle into another phase called ookinetes. The ookinetes develop into sporozoites and then migrate to the mosquito salivary glands where they can infect a new victim starting the cycle anew.

The Mosquito

Mosquitos are small fly like insects that belong to the family Culicidae. Their lifecycle consists of four stages: 1. Eggs. 2. Larva. 3. Pupa. 4. Adults. These timeframe of these stages vary depending on individual species, temperature and moisture levels. It is the adult females that are the vector for malaria.

Mosquitos lay eggs on the surface of calm water, where they hatch after roughly 24 to 48 hours. Floating to the surface the larva breathe through air tubes that extend out of the water. They look like small hanging canes that wriggle when disturbed. After 7-10 days have passed the larva metamorphoses into the pupal stage. It is during this stage that the mosquito is developing the parts recognized in adults; the biting mouthparts, legs and wings. Finally after about a week the adult emerges at the waters surface where it needs to dry itself off before flying off.

Malaria is transmitted to humans by the bite of one of the many different species of mosquitos in the genus *Anopheles*, though only the female can transmit *Plasmodium*. While both sexes feed mainly on plant nectar, it is the female mosquitoes that also bite animals to obtain the protein in blood needed for egg production. Using a razor sharp, tube like structure called a proboscis, they pierce the skin and draw blood from a capillary. During this uptake, an infected mosquito transmits the parasite to the blood of the bite victim, which goes on to reproduce in the blood stream and leads to the disease symptoms.

We will grow mosquitos in class, allowing students to observe the lifecycle of the malarial vector. This will

provide them with a better understanding for possible ways to combat new malarial infections.

Local vector control agencies can provide mosquito eggs for raising in the classroom, an alternative is to collect larvae from local water sources and observe the pupae and adult forms only. I plan to use an aquarium with a screen top to prevent the adult mosquitos from escaping into the environment. Using small nets or a vacuum bug sucker the adults can be captured and placed in small jars with dry ice to stun them for observation under a dissecting scope.

Human Health and Implications

Malaria is found primarily in the human circulatory system. The circulatory system, then, is especially relevant to malaria as it is one of the three locations the parasite occurs and reproduces in humans. Each of us has roughly 60,000 miles of blood vessels, all tied together in a web of different sized tubes, that transport blood in a constantly flowing loop. There are three main types of blood vessels; arteries that carry blood away from the heart, veins that carry blood back to the heart and capillaries, the smallest vessels, which carry blood in close proximity to cells within the body tissues.

When an infected mosquito bites a person, the parasite is transmitted to the bloodstream, which is the starting point of a new malarial infection. This stage is the sporozoites, which migrate to the liver. In the liver they reproduce and are eventually re-released into the bloodstream as merozoites where they infect red blood cells. Reproducing again in red blood cells, they eventually rupture the cell causing a reaction in the blood from the toxic byproducts of cellular lysis. Lysis is the destruction of the cellular membrane precipitating death of the cell. Antibodies respond to this infection causing the symptoms of malaria.

Though some types of malaria are more resistant, cases that are diagnosed and treated early can be cured. Some statistics measure the lethality of this disease at 50% of all the people that have ever lived. Some 50 billion people have died from malaria over the course of our species' existence.[10]

With such a long interrelationship it is not surprising that humans have evolved some defense mechanisms against this plague. Sickle cell anemia is a recessive inherited disease that affects hemoglobin production and leaves cells a quarter-moon shaped sickle. Those afflicted with the condition suffer from a variety of conditions due to reduced oxygen carrying ability and difficulty of the oddly shaped blood cells' movement through the circulatory system. Lifespan is generally decades shorter, especially without ongoing medical treatment. So what is the connection with malaria? A heterozygous individual, that is one that has two different alleles for the sickle cell trait, has a slightly different hemoglobin molecules, not enough to affect their health, but when infected by *Plasmodium* their blood cells rupture before the parasite is able to reproduce. This effectively provides them with immunity to malaria and a survival advantage.

Scientific consensus around human induced climate change is such that all major scientific organizations are in agreement that human activities are impacting global climate by increasing the atmospheric levels of carbon dioxide.[11] The following paragraphs supply background information for the teacher.

The atmosphere is a soup of gases, primarily nitrogen (78%), oxygen (21%) and a longer list of minor gases (1%). One of these minor ingredients is carbon dioxide. CO_2 is a simple molecule. It exists as a gas at the standard temperature and pressure found on Earth's surface. As a gas, CO_2 is one turn in the carbon cycle, returning photosynthetic products back to the atmosphere after respiration, decomposition or combustion. But what makes this gas of special concern? We must first look at the nature of the carbon atom.

Carbon is a non-metal, with an atomic number of six and an atomic weight of 12 (rounded). The most common, and stable isotope ^{12}C contains six protons, six neutrons and six electrons swirling around in two orbitals. It is a quadravalent atom; meaning it needs to share four electrons to achieve stability. Being able to form four covalent bonds allows Carbon to create an endless variety of molecules. This factor is what makes it the critical element for our own biological chemistry. Carbon creates the complex structures that form our being, from the backbone of our DNA to the twisted proteins that comprise our bodies. One of the simplest forms in which we find carbon is in carbon dioxide. A single carbon atom bonds with two oxygen atoms, each doubled bonded, resulting in a molecule that looks similar to a Mickey Mouse head balloon.

Ignoring carbon dioxide for just a moment, let's shift our focus to energy. While we tend to think of planet Earth as a closed system this is not the case. In addition to intergalactic immigrants, such as comets, meteorites and falling dust, every day the Earth is bathed in electromagnetic energy emitted by the Sun. It is the primary energy source for all life on Earth, mainly comprised of visible light passing through the atmosphere and hitting the planet's surface where it is absorbed. Later on, it is radiated back into space as infrared radiation (IR). The longer wavelengths of IR light do not pass as easily through the atmosphere and some of them are reflected back towards the planet's surface where they continue to warm the planet. When the amount entering and leaving remain constant the planet's climate remains stable.

Carbon dioxide in the atmosphere is the main gas that acts to trap the IR radiation responsible for reflecting radiant heat back to the Earth, effectively trapping heat that would otherwise escape into space. This is known as the greenhouse effect. Like Goldilocks' porridge, our planet is found in a region of habitability where things are not too hot and not too cold. This is a good thing, for it keeps the planet in a temperature zone that allows for the existence of liquid water at the surface - a requirement for life. The planet Venus, however, is an example of the same effect out of control, with average surfaces temperatures on Venus over 860˚ F (460˚C). The Three Bears would complain about more than just chairs and mush if they lived on Venus. Currently, the concentration of CO_2 is at 402 parts per million (ppm) levels not seen on Earth for over 3 million years.[12]

Many human activities contribute to climate change, including the combustion of fossil fuels, clearing of forest habitats and industrial processes such as making steel or concrete. All of these activities release CO_2 into the atmosphere. Using the analogy of an additional blanket on a bed, more CO_2 in the atmosphere causes more heat to be trapped on Earth, causing an increase in the average global temperature.

Climate change contributes to changes in ecosystems. These different examples are all insect related

examples that have been recorded in the last ten years. First northbound songbird migrations in the northeastern United States are arriving earlier than previously recorded. This change is hypothesized to synchronize with earlier hatches of insects, a main food source for hatchlings.[13] A second example of insect populations potentially affected by climate change is the reduced range of honeybees in Europe and North America. The southern edge of their habitat has been shrinking, while their northern edge has not been expanding.[14]

It is common knowledge that California is in the middle of its 4th year of drought, now officially classified as a critical situation and a State of Emergency. What is not as well known is that while widespread and certainly damaging, these regional events are not sufficient as evidence for climate change. The drought however is an example of a high interest news event that can help my students both access this topic as well as discuss the kinds of changes they are observing that impact their own lives..

How will these changes affect mosquito habitat and range? Two specific example provide clues. Nairobi, the capitol city of Kenya was founded in part due to it's elevation of 1661m, high enough and cool enough to prevent the breeding of *Anopheles*.[15] How will this city be affected as climate changes and many places experience warming conditions? Will *Anopheles* now be able to survive where it has not been before?

Another example is the recent reemergence of malaria on the Korean Peninsula, which has been attributed to climate change, as warmer temperatures provide a longer season for the mosquitos to live.[16]

Remediation and Ethics

The range of malaria used to be much larger. Extensive campaigns to eradicate the disease, however, have resulted in the disease's confinement to developing countries. Due to the complex nature of malaria, ending the scourge of malaria will need to be accomplished in several different ways.

Malaria is generally curable in those affected, but limited access to medicines leaves the world's poor shutout. Killing the parasite *Plasmodium* would end the cycle of transmission, as would eliminating the mosquito that transmits the parasite. In spite of millions of people contracting and dying from this disease, major drug companies don't see enough return on their money and so do not invest in malaria research.

Many species of the *Anopheles* mosquito are more active at night, and sleeping people are more vulnerable to being bitten. Nets covering beds are one very effective way to prevent transmission and millions of nets have been distributed around the world. Even the NBA got in on the act, joining with the United Nations in a campaign called Nothing But Nets - helping to collect and distribute bed nets in Africa.[17]

DDT has been banned in the United States since 1972, due to the persistence of the molecule in the environment and the bioaccumulation in numerous species. Examples such as the Brown Pelican, Bald Eagle and Peregrine Falcon are three bird species hard hit due to the effects DDT had on reproduction. The chemical led to thinner egg shells resulting in eggs being crushed under incubating parents.

The connection to this unit is that DDT is still one of the most effective pesticides to kill mosquitos. While it is not being sprayed over larger areas, it is still in use inside households where it provides long-term protection.

Is this truly safe?

Yet as mentioned before eradication has and can be done. What responsibility, if any, does the developed world have to help eliminate this disease?

Classroom Activities

A first lesson will be microscope activities to examine microscopic organisms in local soil and water samples to begin their understanding of “invisible” life and introduce the concept of cells. They will learn how to prepare slides and use the appropriate tools to the microscope to make observations and record data. They will also use prepared slides of various tissues to make further observations and gain content knowledge.

We will have classroom hatching and development of mosquito larva for direct observation of life cycle and anatomy. They will be able to identify the basic anatomy and gender of the mosquitos raised. The mosquitos will be kept in small jars so that they will not be able to escape, and small enough to be able to put into a refrigerator to temporarily to immobilize them for observation. Local health departments as well as biological supply companies can be sources for mosquito larva, as well as water left outside the classroom for several days.

For the final project students will select a specific country or location and investigate the current threat from malaria. Using the content knowledge acquired in this unit they will use demographic information to develop an assessment of the risks presented to their location and explain potential impacts of climate change. They will suggest strategies to mitigate the risks. Finally we will have a Socratic Seminar discussing whether the developed world has a reason or responsibility to assist developing nations in combating malaria.

Teaching Strategies

Realia: Hands on activities are the bread and butter of a science classroom. They are important so that students can practice and gain new laboratory skills, and this is where many students actually engage in the material. The physical manipulation of “real things” allows them easier access to the curriculum. The microscope work and growing of mosquito larvae in class are the introductory activities designed to “hook” students from the beginning of the unit.

Microscopy: While working with the microscopes students will have to document their observations in their notebooks and through research compare the difference between the cells they observe and generalized cells. This work of matching what they see with the “official” diagram or photo of a cell forces them to really think about what it is that they are looking at. During these activities they must find and be able to show me different cell parts, and phases of the cell cycle. At times it is a struggle for them, but it makes their learning more personal when they are challenged and ultimately find success.

Collaboration: The final project requires them to work in pairs. For many students this will be their first time

working on a large research project with someone else. This again provides them with the challenge of communication, division of labor and meeting deadlines in a group. These are lifelong skills that they need to perfect to be successful in all other aspects of their life.

Appendix

This unit implements all five of our District's 5 C's, the academic standards our district has made a priority for all of our students. The 5 C's are: Communication, Collaboration, Creativity, Critical Thinking, and Civic Engagement.

Communication will be used between the students and in their mastery of the scientific skills and knowledge, as well as in their plans to disseminate knowledge they've gained to others.

Collaboration between me and my students, will take place, of course, as I teach them microscopy, breeding larva, zoonotic transmission of disease, and human circulatory reality. Collaboration will also be part of the teaching strategy, as students work in pairs to complete their final project.

Creativity will come into play, both in their breeding of mosquito larvae and in the choice and production of their final project.

Critical Thinking is required for the Socratic Seminar, and for synthesizing and reporting the information learned through microscopy and larval growth.

Civic Engagement is an umbrella under which all of the other C's come into focus. It is what the culminating activity will include, where students accept their responsibility to make the world better for the future. Civic Engagement, on a global scale, where students reduce their carbon footprint to lessen their contribution to global warming and share their knowledge about the transmission of malaria, to improve the quality of life for all of us, including their families and loved ones in less-developed countries.

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