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Curriculum Units by Fellows of the National Initiative
2020 Volume V: Caretakers versus Exploiters: Impacting Biodiversity in the Age of Humans

Strands of One Braided Cord: How Humans Are Impacting Biodiversity Through the Spread of Disease

Curriculum Unit 20.05.02, published September 2020
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Introduction

During the writing of this unit, we are all sitting at home in a global wide lockdown due to the SARS-Cov2 pandemic. At the time of writing on July 7th , 2020, America was 10th in global ranking in both number of cases (2,888,461) and deaths (127,498). In a time where the spread of misinformation is abhorrently high and far reaching thanks to social media and the lack of leadership at government levels, it is of utmost importance to increase the scientific knowledge of our students, or at the very least, their belief in science. We need students to see more aspects of the human impact to biodiversity and not just us as the main source of climate change. Therefore, there is no doubt in my mind that humans are changing the Earth at an unprecedented rate and many scientists agree. "75% the planet's land surface is experiencing measurable human pressures." [1] Since the dawn of humans, we have spread out and taken over various regions, eliminating animals, people, and plants. "Since humans appeared on Earth, 77% of all wilderness has been destroyed, 10% of that loss has occurred since 1990." [2] "The human-mediated translocation of species poses a distinct threat to nature, human health, and economy." [3] As our technology has improved over time, so has our ability to transfer people, plants, and animals. In fact, the website Amphibia Web states "50,000 frogs per year are accidentally carried in produce." [4]

From this unit, students will learn background knowledge on the spread of the chytrid fungus *Batrachochytrium dendrobatidis* (Bd) and look at scientific research on SARS and SARS-Cov2 viruses with the hope that they will be able to synthesize the information and then apply that knowledge to a different scenario in order to make a prediction on how the environment could change as a result of human interaction.

Rationale

Most people today could probably provide at least one example of how humans are changing the Earth. Their example would most likely, if I had to guess, be global warming or climate change. But what about the other changes humans have caused? This unit will discuss the role of global trade, climate change, and the human

impact on frogs and the spread of pandemic level viruses.

Frogs were selected because they face a pandemic of their own, that of the chytrid fungus. In addition to this reason, frog life cycles were studied in the previous grades and therefore my students are familiar with frogs. Also, frogs are readily available to have in classrooms as pets for observation purposes or even potentially as part of an experiment detailed in the Classroom Activities section. Amphibians are also one of the most commonly endangered living organisms on our planet. According to the United Nations Report from 2019, "more than 40% of amphibian species may be threatened." [5]

The student population at Hearne Elementary in Hearne, Texas is predominantly Black (46.6%) and Hispanic (43.1%). People of color have taken the brunt force of Covid-19 (possibly due to systematic racism and pre-existing conditions in people of certain ethnicities), therefore it is of great importance that my students understand how a virus (especially one affecting humans), or a fungus can spread and how to prevent that spread in their own community. In addition, I have learned through my own teaching that the more relatable a unit or topic is the more likely I'll have student buy-in and engagement. Hopefully by discussing a topic they all have experienced first-hand; my students will be fully engaged. I also hope to present information in order to quell any misinformation they may have acquired in the six months since I have seen them in person. In addition, having background knowledge on how humans impact the environment will help them when it comes to our state standardized test as well. The Texas state standard is TEK 5.9C and states students will be able to predict the effects of changes in ecosystems caused by living organisms, including humans, such as the overpopulation of grazers or the building of highways. My goal for my students, is that after they have seen how humans can affect ecosystems that they then can make predictions based on other scenarios. This is often what the questions from the state test asks them to do.

Essentially though, the best rationale for this unit comes from Martin Luther King Jr., "It really boils down to all life is interrelated. We are all caught in an inescapable network of mutuality, tied into a single garment of destiny. Whatever affects one destiny, affects all indirectly." [6]

Learning Objectives

Thanks to the "Save The Turtle" movement and Greta Thunberg's #schoolstrike4climate my students are very aware of the human impact on the environment. They want to make changes and even suggest content for me to research on my own. However, they do not know the entire extent, as even scientists are still discovering the extent to how humans are changing the world. One of the struggles I see in my classroom is students have difficulty looking at different scenarios and predicting what the outcome would be. For example, one of the standards asks students to predict changes in an environment. This is a higher order thinking skill that relies on having prior experiences to draw from in order to make an assumption about the possibilities of what could happen. Although the specific standard asks students to assess animal overpopulation and humans building bridges, examining the impact that humans have on our own health is a more essential skill in my opinion. Especially in the time of Covid-19.

The target grade for this unit would be fifth grade, however the subject matter covered could potentially teach 6-12th as well. In this unit the students will analyze how humans and disease are tied together. Students will complete several activities to advance their knowledge, including inferring the relationship between humans,

frogs, fungi, and viruses, immersing themselves in a sort of role-play in which they analyze data from the SARS 2003 epidemic and SARS-CoV2 pandemic and the spread of chytrid fungus, and engage in scientific debate while making a prediction on a possible emerging pandemic with bananas. The student will be able to form opinions on the role of humans in the environment, provide examples of human impact on environment, and develop an argument analyzing the potential for a future outbreak. I will also keep Social Emotional Learning in mind during the lesson and also recognize that SARS-CoV2 could have potentially been traumatic in more ways than one. It's important to focus on the facts and not opinions during the lesson.

Content Background

This unit is broken down into four or five concepts. The first is the impact that humans have on their environment. The majority of this section comes from the seminar. Next is an overview of the chytrid fungus. A fungus is defined by the Oxford English Dictionary as "any of the organisms of which these are the fruiting bodies (reproductive structures); (more generally) any member of the large biological group (now a kingdom) comprising eukaryotic organisms, including yeasts and molds as well as mushrooms, which typically have vegetative forms consisting of single cells or of simple multicellular filaments which lack photosynthetic pigments and have chitinous cell walls, and which reproduce by means of sexual and asexual spores." Then there is the discussion of SARS outbreak from 2003 and SARS-Cov2 viruses. A virus is defined by the Oxford English Dictionary as "an infectious, often pathogenic agent or biological entity which is typically smaller than a bacterium, which is able to function only within the living cells of a host animal, plant, or microorganism, and which consists of a nucleic acid molecule (either DNA or RNA) surrounded by a protein coat, often with an outer lipid membrane." Finally, there is a discussion on the connection between chytrid, humans, and the SARS viruses.

Human Impact on Environment

This section will examine climate change, globalization, and their impacts on emerging diseases, and changes to the livestock sector. Starting with climate change, a long-term change in average weather patterns that define local, regional, and global patterns, we can say climate change is a trickle-down effect. One of those trickle-down effects is that species range distributions are changing. When a species can no longer tolerate its local environment, individuals will naturally move to a more suitable environment, if possible. Many species are moving north. For example, the invasive mosquito that can transmit West Nile Virus has in recent years moved further and further north into new territories. This is just one of the ways that climate-driven changes in species distributions or range shifts affect human well-being directly through emerging diseases. For the next several decades, the climate will continue to change despite the agreements to curb greenhouse gas emissions[7] . Anthropogenic (human-caused) climate change has been set in motion for centuries and will continue to affect future generations for centuries. To say that climate change and the spread of disease go hand in hand and will continue to affect future generations for quite some time would not be a stretch. A recent report from the UN in which the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Chair, Sir Robert Watson states "The health of ecosystems on which we and all other species depend is deteriorating more rapidly than ever. We are eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide." [8] The report continues to state data including that since 1980 "greenhouse gas emissions have doubled, raising average global temperatures

by at least 0.7 degrees Celsius” [9] This may not seem like much of a change, but it’s been enough of a change to impact “nature from the level of ecosystems to that of genetics”. If you’ll recall, mosquitoes have started to move north trying to find a more suitable climate to live in. It’s also important to note that although there has been some progress to conserve nature, it hasn’t been enough. The UN Report states, “Despite progress to conserve nature and implement policies, global goals for conserving and sustainability using nature and achieving sustainability cannot be met by current trajectories, and goals for 2030”. [10] Even with this bleak outlook, scientists realize that a pattern emerges showing global interconnectivity and that we need to understand the history of the global interconnection and economic indirect drivers. [11] While the relation between human activity and climate change explains the SARS 2003 epidemic and SARS-CoV2 as “diverse environmental factors, such as ambient climate and the presence or absence of overcrowding…. influences a pathogen’s chances of flourishing and causing disease” [12] , scientists do not believe that it can explain how a fungus affecting amphibians can spread. For this we really need to examine global trade, or else go back to that idea of global interconnectivity. In 2012, news of the global bullfrog trade spreading a deadly amphibian fungus worldwide began to spread thanks to a study from the University of Michigan. The researchers, Timothy James and colleagues, analyzed bullfrogs raised in Taiwan, Brazil, and Ecuador whose legs are sold as food in Asian food shops. They found that 41 percent of the frogs sold at markets in Asia were infected with the chytrid fungus. [13] James and his colleagues also studied four previously unknown chytrid strains and determined that they were related and named them Bd-Brazil. Bd-Brazil was present in bullfrogs in Japan. The data suggest that the Bd-Brazil strain probably originated in Brazil among native frogs and then spread to a bullfrog farm in Brazil where it then spread around the globe when the frogs were shipped out of country. [14] This also relates to how scientists think SARS originally came to humans (which will be discussed further down). It is also important to note that the North American bullfrog, a carnivorous species, is resistant to the chytrid fungus. This means the bullfrog is an excellent carrier of the disease but not a victim. Since bullfrogs have very thick legs, they are also commonly used for food.

Another important topic to look at for the spread of emerging diseases is how raising livestock has changed. During the past two decades we have seen a change in the livestock sector. One change includes a rise in demand for livestock and their products or by-products. As a demand for frog legs or unique cuisine has increased, we have seen a change. The result to this change is that certain humans are interacting with animals more often than they used to. As humans raise livestock, convert land for food, or send animal produce around the world, some people will encounter animals more often. This raises their chances of being exposed to zoonotic viruses and then spreading that virus in their communities. “An unintended consequence has been the emergence and spread of transboundary animal diseases, and more specifically the resurgence of zoonotic diseases.” [15] Some of these emerging diseases include avian influenza, severe acute respiratory syndrome (SARS), and West Nile virus. Looking back at the history of SARS it’s important to understand the concept of the Era of Wild Flavor. [16] In China, several species most Americans would consider inedible make their way to the table. Some examples of this include snakes, civet cats, and bamboo rats. During the 2003 epidemic of SARS, scientists linked the civet cat to the spread. At the time they thought the civet cat was the reservoir host for SARS (they were initially wrong), but this initial theory proved deadly to the civet cat with at least 1,000 eradicated in 2004 when a re-emergence of SARS occurred in China. [17] Another change in China was the banning of 53 other Wild Flavor species from being sold in markets around China.

Although these particular diseases, SARS, West Nile fever, and avian influenza, have received a lot of media attention, especially SARS at the time of this writing, humans overall seem to be too optimistic about emerging diseases. In 1948, the U.S. Secretary of State George Marshall said, “the conquest of all infectious

diseases was imminent" [18] The United States has seen a similar response from President Trump concerning the SARS pandemic in 2020 stating "it's going to disappear" in February of 2020 (Washington Post). I believe it's important that not only ourselves as educators, but our students understand how deadly this thinking can be. Global trade and global demand for trading of products is not going to decrease anytime soon. We need to understand that "nearly two-thirds of EIDS (emerging infectious diseases) are zoonotic and three-quarters of those originate in wildlife. [19] Without transformative system-wide change, the climate will continue to change, living organisms will continue to redistribute, and human health will continue to be affected by zoonotic emerging diseases. Without these types of drastic changes "negative trends in nature will continue to 2050 and beyond…. due to the exploitation of organisms and climate change." [20]

Chytrid Fungus

In the late 1900's and early 2000's frogs began declining rapidly. Researchers were noting that in areas once abundant with frogs (you'd have to watch your step, or you would squish a frog) were now showing a decline in frogs. The frogs seemed to be dying at an alarming rate in large groups, with some places coated in little dead frog bodies. The first clue to the killer came from the National Zoo in Washington D.C. The zoo had been successfully breeding and raising a species of frog native to Suriname when "from one day to the next, the zoo's tank-bred frogs started dropping." [21] This frog was in the *Atelopus* genus. A veterinary pathologist at the zoo decided to swab the bodies and scan them under a microscope. By doing so they uncovered something capable of causing so much damage in a short amount of time. They discovered a "fungus belonging to a group known as chytrids." [22]*Batrachochytrium dendrobatidis* (Bd) as it is known scientifically, "interferes with frogs' ability to take up critical electrolytes through their skin" [23] which in turn leads to paralysis and eventually a heart attack. Chytrid has hit the "*Atelopus* genus harder than most." [24] It's no wonder that news articles, like one from The Atlantic, say that Bd "has condemned more species to extinction than any other pathogen." [25]

We now need to understand how frogs and humans relate to each other. Students learn from an early age that organisms interact with both biotic (living) and abiotic (nonliving) parts of their ecosystems. Throughout time, we have seen several species that through interacting with their own environment have developed some sort of fungal infection. A more widely known infection (at least widely known in China) is that of the caterpillar fungus. Used in China as traditional medicine in a tea, the caterpillar fungi have been used so frequently (at least in China) that the fungus is now endangered. [26] This fungus is another example of a fungus acquired through interaction with the hosts environment. The fungus is typically found in the soil where the caterpillar lives. The caterpillar and the frog are not alone. "The animal kingdom is widely colonized and often infected by fungi; it is safe to say that no fungus-free animal exists." [27] Even humans can have fungal infections. Amphibians, of course, are no exception to the rule when it comes to acquiring fungal infections. Amphibians, unfortunately, seem to have also been hit the hardest by not only disease such as the one caused by chytrid, but other factors also have increased their extinction rate. Chytrid has been "documented throughout the Americas, including Mexico and the U.S., Europe, and most recently in Southeast Asia." [28] Chytrid has been documented in Texas although the extent of its distribution is not known at this time.[29]

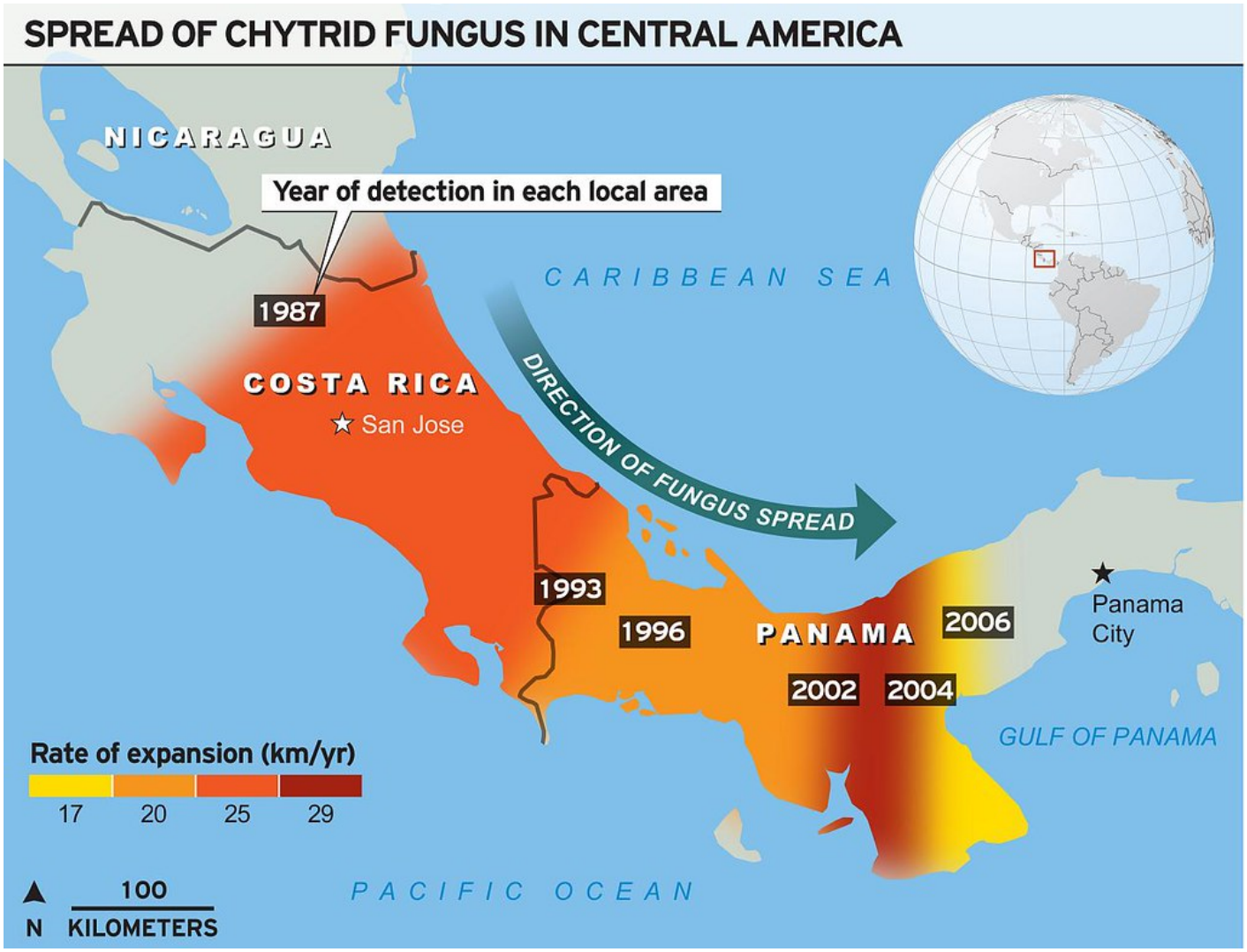

Figure 1. This photo shows the spread of chytrid fungus throughout Central America.[30]

Panamanian golden frog

Panamanian golden frogs are a typical small frog. Panamanian golden frogs lay around 200 to 620 eggs per clutch and take about 2 years to reach maturity. When fully grown females can be 1.7 to 2.5 inches and males' range in size from 1.4 to 1.9 inches. Panamanian golden frogs lived in wet rain forests and dry cloud forests. [31] The frogs could normally be found in streams. Like many frogs, their diet consists of small insects. Like their distant relatives, the poison frogs from South America, their bright color lets predators know that they are toxic as well. Although they are revered as a symbol of good luck in their native country of Panama, the Panamanian golden frog (*Atelopus zeteki*) has not had any good luck of its' own. As a member of the *Atelopus* genus the Panamanian golden frog has been a victim of the chytrid fungus and is believed to be extinct in the wild according to the San Diego Zoo website.[32] Panamanian golden frogs can be found at several zoos including the San Diego Zoo and the Houston Zoo. In a short ten years, Panamanian golden frogs have declined more than 80% because of the chytrid fungus.[33] Projects such as the Smithsonian Tropical Research Institute were created to combat the extinction of the Panamanian golden frog as well as conserve it.

In our seminar, we discussed five ways humans impact the environment. Those five ways include climate change, changes in land and sea use, direct exploitation of organisms, pollution, and invasive alien species.

While research is currently showing that chytrid fungus may or may not be being spread because of climate change, it is important to understand that the spread of invasive alien species could be the cause or correlation of the rise in amphibian deaths due to chytrid. Trade routes and globalization have caused species re-distribution since the long-ago trade routes like the Silk Road. To reiterate an earlier point, thousands of frogs a year are transferred in produce from country to country unintentionally. A review of the trade in CITES-listed species between 1976 and 2007 in a 2014 study examined why frogs were transferred around the globe. Part of the study looked at the trade of live animals. 18 different genera were reported with a total of 482,292 individuals traded between 1976 and 2007. 48% of these were a part of wild populations. Over 85% of the total number of frogs were traded for commercial activity. [34]

Figure 2 shows a female Panamanian golden frog.[35]

Coronaviruses

Coronaviruses are aptly named from the "crown the virus looks like it's wearing."[36] Human coronaviruses cause up to 30% of common colds, rarely causing lower respiratory tract disease in humans (Holmes, 2003)." "Coronaviruses are enveloped, single-stranded, positive-sense RNA virus that infect and cause disease in a variety of species including bats, birds, cats, dogs, pigs, mice, horses, whales, and humans. Coronaviral infections may range from mild to severe and can result in respiratory, enteric, hepatic, or neurological diseases in their carriers."[37] Research during the 2003 outbreak of SARS, Severe Acute Respiratory Syndrome, came to the conclusion that "the SARS-associated coronavirus is neither a mutant of any known coronavirus nor a recombinant of known coronaviruses. It is a "previously unknown coronavirus, probably from a

nonhuman host, that somehow acquired the ability to infect humans." [38] The study by Holmes also addresses an interesting point "if there is no animal reservoir, there will be a better chance of eliminating the virus from humans". [39] A few coronaviruses have started epidemics or pandemics. In 2003 there was the SARS epidemic. In 2012 there was MERS (Middle Eastern Respiratory Syndrome) epidemic first reported in Saudi Arabia, and the SARS-CoV2 pandemic in 2020. Research would be conducted, and these outbreaks would be designated epizootic in nature. Research by Guan Yi, which would be published in the *South China Morning Post*, would link civet cats to the SARS outbreak. Over time data would change though. Originally, the data suggested that the civet cat was the reservoir species, but further research would link the genus *Rhinolophus*, or horseshoe bats, to the SARS 2003 outbreak.

SARS 2003 Epidemic

In 2003 a mysterious pneumonia began affecting people in southern Asia. Over the next six months it would spread to North America, South America, and Europe before the World Health Organization (WHO) declared it contained in July 2003. First defined as an atypical pneumonia, scientists today know SARS as a viral respiratory illness caused by coronaviruses. SARS can start out feeling like the typical flu or cold but after a week of fever and coughing, sufferers become increasingly short of breath as the virus attacks the linings of the lungs, causing the air sacs to become filled with fluid. SARS would cause an epidemic which is described by the Center for Disease Control (CDC) as an increase, often sudden, in the number of cases of a disease above what is normally expected in that population in that area. Interestingly, it should be noted that the WHO never formerly classified SARS as a pandemic, but it is often referred to as one.

First reported in November 2002, doctors called the unknown virus at the time an atypical pneumonia. Because of rocky relationships between Hong Kong and the province of Guangdong a lack of communication would help spread the disease. David Quammen notes in his book *Spillover*, "more than a quarter million people" cross the border between Guangdong and Hong Kong but "there's not much direct contact between Hong Kong officialdom and Guangdong's provincial capital." [40] Because of the lack of communication between the government officials, there would also be a lack of communication in the medical and science fields. Some weeks later the WHO would issue a global alert. Then about a month later, a local seafood merchant would become ill with SARS as well. He would end up at two hospitals, further spreading SARS, but would ultimately survive and unfortunately be known as the "Poison King" because of his role as a "superspreader". A superspreader is "a patient who, for one reason or another, directly infects far more people than does the typical infected patient." [41] This means that instead of infecting the 2.9 people that Donnelly et al. would later calculate, they infected so much more. One of the Poison King's doctors (one of the many people he infected; in total it is suspected he infected about 94 people) would also become infected while treating him. The 2003 SARS epidemic would then go global in a hotel room in Hong Kong on February 21, 2003. From the hotel, at least 17 people were infected who would later go on to establish major epidemics in Singapore, Hanoi, Toronto, and Hong Kong. "To say that 'SARS got on a plane', of course, is to commit metonymy and personification, both of which are forbidden to the authors of science journal articles." [42] What really happened was several people infected from a man at a hotel boarded a plane and went back to their respective homes. No one is really sure what happened at the hotel that triggered the spread though. Did the man cough, sneeze, or vomit in the hallway? We will probably never know as there are varying accounts and no actual footage to prove what happened. Whatever happened, people at the hotel staying on the ninth floor interacted with the SARS virus unknowingly. But what we do know however, is that scientists believe that the doctor in that hotel was also a "superspreader" just like the "Poison King" was and there would be other superspreading events, such as one in Canada, as SARS "traveled" from China to Canada, Taiwan, Singapore,

and Vietnam. In the end, 8,098 people became sick from SARS and 774 would die before the virus was under control.

Figure 3: Spread of SARS in 2003 out of China from the hotel room in Hong Kong. [43]

SARS-Cov2 Pandemic

At the time of writing this curriculum unit, information about SARS-CoV2 is still emerging. Information is subject to change but is current as of July 2020. SARS-CoV2 is a coronavirus. Coronaviruses can cause the human cold but can also cause more serious respiratory illnesses. Occasionally some coronaviruses jump from animals to humans. According to the Imperial College of London's' Report, *Phylogenetic Analysis of SARS-Cov2*, SARS-Cov2 jumped from an animal to humans in China in "early December and has an epidemic doubling time of approximately seven days." [44] It is estimated from the Imperial College of London that "the time of most recent common ancestor was December 5th , 2019." [45] This roughly means that on about December 5th , 2019 the virus spread from an animal reservoir host to an unknowing human. This human would set off a chain of events spreading the virus from China to every continent except Antarctica. Even cruise ships would be affected having to dock and wait weeks before they could let passengers off and send them home to their respective countries.

What is known currently is that SARS-CoV2 can be spread "from person to person through large droplets from when you cough or sneeze." [46] The droplets can land on surfaces or stay in the air. Since the virus is novel, meaning new, it is unsure how long exactly droplets containing the virus can live on surfaces or hang in the air, although there are estimates. SARS-CoV2 causes the disease Covid-19 which can cause a slew of symptoms. Some symptoms according to Harvard Health are high fever, severe cough, gastrointestinal symptoms, loss of smell and taste, and fatigue. In serious cases it can cause pneumonia and cytokine storms (when your body releases cytokines out of proportion to what is needed which in turns attacks the body's own tissue). In children symptoms known as "Covid toes" (a red rash on feet) and MIS-C, multisystem inflammatory syndrome.

In the United States, the first cases of SARS-CoV2 nontravel-related were confirmed on February 26th in California and February 28th in Washington. (CDC) The data suggest that virus was "imported directly or indirectly from China and began circulating in the United States between January 18th and February 9th, followed by several SARS-CoV2 importations from Europe." CDC Several deaths in early February also suggest that community transmission had "begun before the detection of the first two nontravel-related cases" on the 26th and 28th of February. CDC

At the time of writing this section on July 22, 2020 worldwide cases totaled 15.1 million with 3,873,191 of those cases in the United States alone.

What Is the Common Link Between Coronaviruses and Chytrid?

The common link between coronaviruses and chytrid spreading around the world is humans. We have spread chytrid and coronaviruses through trade, global travel, lack of biosecurity protocols, lack of communication between governments, increasing temperatures globally, and overcrowding. While SARS was deemed an epidemic, Bd and SARS-Cov2 were both declared pandemics. In a pandemic, "there's an outbreak stage, but then frequently, there's a drop-off in terms of the severity of disease within a population." [47] While the outbreak stage of Bd may have started in 1938 and continues to this day, SARS-Cov2 is still in the outbreak stage as cases continue to climb globally. SARS outbreak was much shorter as the first case appeared in November 2002 and by July 2003, the WHO declared the epidemic over.

A few theories do surround the spread of chytrid, however. There are two theories for the spread of Bd the first being the "Out of Africa" and the second being "Frog-Leg Soup". In the 1960's the African Dwarf frog

native to Africa was used for pregnancy tests. Apparently, urine can be placed on the frog and if a person is pregnant, the frog will lay eggs within hours. As a result, the frog began being sold internationally for medical use. It is interesting to note that the African Dwarf frogs seem to be immune to the fungus nowadays though. [48] The other theory, "Frog-Leg Soup" is from humans' voracious appetite for frog legs. [49] The American Bullfrog is a rather meaty frog and has been used for decades as frog legs being sold to countries around the world. As noted earlier, bullfrogs have been known to be raised on farms in Brazil and sold to China. From there China creates their own farms by breeding pairs of frogs. Again, though we see an interesting note, that the American Bullfrog also does not seem to be affected by the fungus, but populations of the frog have trace amounts of fungus on them. These data imply that the fungus can only be carried by these species instead of killing the species.

SARS 2003 and SARS-CoV 2 quite possibly came to us from wild animals thrust into contact with humans as we encroach on their increasingly endangered habitat. It also may have come from humans need to eat and desire for whatever they can get their hands on. These pathogens could evolve as we began to butcher and eat the meat of animals and raising them alongside us on farms. [50] SARS 2003 most likely came to humans from civets that were butchered and sold in wet markets in South East Asia. Although scientists agree for the most part that the SARS outbreak of 2003 started in civets, they are only an intermediate host. This means that they are not the original source of the virus, but instead an animal that the virus jumped to from another animal. The true outbreak source of SARS 2003 was possibly the horseshoe bat. The spread of SARS-CoV2 began in Wuhan China at a wet market (where live animals are sold) jumped from a species to humans, and then spread to Europe and North America around the month of February. As stated earlier, the possible reservoir host was again possibly a bat, the fruit bat.

Transportation such as planes and cruise ships have also made it easier for SARS-CoV, or any pathogen, to spread from place to place as well. Nathan Wolfe from Stanford University stated, "we live in an 'age of pandemics', with flights connecting every major city, microbes can move faster than ever before". Travel isn't the only problem though. As our populations have grown and our cities have seen an increase in population density as well, we have given microbes a location where there are plenty of hosts to infect. An analogy of an all you can eat buffet where we are the food and the virus is the consumer is not too far off.

I think it is also important to look at the global coordinated strategies, or lack thereof. According to a study published in the Proceedings of the National Academy of Sciences of the United States of America in 2014, strategies to combat pandemics are "." [51] Instead of spending money preventing pandemics, the United States tends to spend money on treating and ending a pandemic. The 2014 study also looked at mitigation strategies and determined that to reduce the annual rise of emerging infectious diseases events by 50% within the next 27 years would cost $343.7 billion. [52] If implemented today it would cost $360.3 billion over the next 100 years. The study then determined "pandemic prevention policies need to be enacted urgently to be optimally effective and that strategies to mitigate pandemics by reducing the impact of their underlying drivers are likely to be more effective than business as usual." [53] It is important for countries to have a plan that can be easily and readily enacted upon in the event of a pandemic, because another one will happen sooner rather than later, but it may be even more important to create policies preventing pandemics from occurring in the first place.

Strategies

In my classroom I use technology paired with strategies for English Language Learners (ELL's). In this unit, students will have numerous opportunities to talk using academic language through student discussions and explain their thinking orally and in writing. Best practice strategies to increase interaction with ELL's for this unit could also be pairing ELL's with fluent English speakers, partner reading, and working in pairs. I also use inquiry-based problem solving and the 5E model. Inquiry-based problem solving is where students are provided with opportunities to investigate a problem, search for a possible solution, make observations, ask questions, test out ideas, and think creatively using their intuition. The 5E model is traditionally linked with inquiry-based learning as it provides students with many of those opportunities. The 5E model is a model of learning in five stages in which collaboration is promoted through active learning where students work together to solve problems, ask questions, observe, analyze, and draw conclusions.

Classroom Activities

Classroom activities in this section will be broken down by the 5E model (engage, explore, explain, extend, and evaluate). The ideal unit would take five days (one day per each section). However, teachers should feel free to adjust to their classrooms needs. One example would be combining engage and explore in the same day as the engage activity should not take very long at all.

Engage

For the engage portion of the unit, students will examine three images individually and then analyze how they could all be connected. I will provide estimates of how long the activity should take, but feel free to adjust to the needs of your class. The three images are below and consist of a frog, people, and a coronavirus. In pairs/groups students will discuss what the first image is for two minutes. Then they will discuss the second image, and finally the third. After the three images have been looked at students will discuss for around four minutes how all three images are related.

Due to potentially having classes online, this lesson can be done in Zoom using the breakout feature. I suggest showing the students the three images and then sending them to breakout groups with the prompt sent out as a reminder. Another option is to have the three pictures presented on FlipGrid with students creating a personal response to what they think these three images represent and how they are related. A final step would be then to reply to a few classmates on what they posted. How to do that can be found here https://www.vanderbilt.edu/brightspace/how-to-use-breakout-rooms-in-zoom/#Step7

Explore

In the explore portion of the 5E model students have not yet been taught scientific vocabulary for the unit, they are just exploring and creating a hypothesis through carefully constructed questions. For this unit students will observe a set of objects at an observation station and will be given a real-world problem in which they will consider everything they know already and try and come up with a solution to the problem. The teacher should ask open-ended questions to help the students see all sides of the issue. Examples of open-

ended questions for inquiry-based lessons are provided in the appendix. Students will have two scenarios to examine at the observation station. For the first scenario students will pretend they are herpetologists studying frogs in El Valle De Anton in central Panama. The teacher might want to provide a notebook or a piece of paper so students can write their ideas down. The golden frog was endemic to Panama and individuals were often found in abundance dating back to around 2004. However, they began to mysteriously disappear. At a table, students will find some toy frogs or a photo of the frogs which can be found on pexels.com and clues as to how the frogs died out. Students should write down their observations. Sentence stems should be provided for ESL students. An example sentence stem could be "I observed that…." At the second station students will read over information on how they can be Health Ambassadors to our communities. It's important for this second scenario that the students look at facts on ways to prevent illness, keeping themselves and others healthy in their classroom community, and how to clean commonly touched areas, especially when returning to the classroom post pandemic. A response sheet will be filled out as they go in which they answer higher order thinking questions for this scenario. If you are teaching online, you can easily create a HyperDoc version of the observation station for both scenarios to share with your students on your Learning Management System.

An alternative activity for the explore portion (depending on your schools funding and impact of the pandemic in your state) could be to purchase a pet frog from a local pet store. Places such as PetSmart sell dwarf African frogs for around $5 as well as other breeds with prices around $40. Studies show that even local pet stores selling amphibians carry species currently infected with the chytrid fungus. A testing kit can be ordered from this website. This experiment could be teacher led or, again depending on funding and current pandemic levels, student led. You will need gloves, frogs (possibly one for each group, one per pair, or one for the whole class), and the same amount of testing kits as there are frogs. Directions are included in the testing kits, but essentially you take a cotton swab and swipe its belly (while wearing PPE). Students could predict which frogs will be positive and negative. Teachers can encourage the students to write their hypothesis down in a notebook and then share with a friend or the class.

Explain

This lesson is a teacher-directed lesson. Teachers will provide the students with background knowledge from the content background section explaining how emerging diseases in humans and animals have spread because of human interactions with the environment. I have created a PowerPoint that teachers can use for this lesson. The lesson should cover vocabulary words and concepts students need to know. Some examples of vocabulary words would be pandemic, epidemic, chytrid fungus, coronavirus, and SARS.

Extend

Students will read different articles in the extend lesson. Articles come from NewsELA and can be adjusted to student reading levels. The articles are "The impact of globalization on the physical and human characteristics of communities", "The link between the coronavirus and wildlife", and "Earth's frogs are in danger, scientist learns reasons hard to figure out". Students can be paired to read through the articles together. After the articles are read, students should complete a student response page. On the student response page students should have sentence stems available to them such as "I noticed", "I wonder", "The author wants the reader to think" or "I would like to know", in order to create a few sentences or a paragraph (up to teacher discretion) in which the student develops thoughts on the articles read. I have included a sample student article response page in the appendix. If three articles are too many, you can encourage students to choose 2 out of 3 articles to write about. Another option would be to have students pick one article, write about it, and share their

response with a student who wrote about a different article.

Evaluate

Students will develop an argument in this lesson. Students will be presented with the NewsELA article “New disease can destroy banana plants around the world”. Students should debate if they believe that humans caused the fungus to spread and predict the results of bananas contracting “Fusarium wilt”. Students will need to tie in there learning by citing information from previous lessons on how humans assisted in the spread of the frog pandemic and the SARS epidemic/pandemic. Students will be expected to write their thinking down and then present their argument in FlipGrid. Additionally, students will respond to one other classmate and state whether they agree or disagree with the student and why. If in person, students could present their opinion to small groups or the whole class by volunteer.

Appendix on Implementing District Standards

In order to satisfy the aforementioned learning objectives, I use the 5E model and Texas Essential Knowledge and Skills Standards: The student uses critical thinking and scientific problem solving to make informed decisions, analyze, evaluate, and critique scientific explanations by using evidence, logical reasoning, and experimental and observational testing, and connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists. These skills correlate to the following Science and Engineering Practices from the Next Generation Science Standards: Science explanations describe the mechanisms for natural events, engaging in argument for evidence, changes in biodiversity can influence humans resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on for example water purification and recycling, MS-ESS3-3 apply scientific principles to design a method for monitoring and minimizing a human impact on the environment, and obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment. As well as the following Crosscutting Concept: Cause and effect relationships are routinely identified and used to explain change.

Although this unit is targeted towards fifth grade, this unit can lay the groundwork for higher grade levels depending on the depth and terminology the teacher expresses to the students.

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