YALE NATIONAL INITIATIVE
to strengthen teaching in public schools®

Curriculum Units by Fellows of the National Initiative
2017 Volume VI: Engineering of Global Health

Economics and Community Health - The Wealth-Health Paradigm

Curriculum Unit 17.06.03, published September 2017
by Michael A. Doody

Introduction and Rationale

When the 2014 West African Ebola virus outbreak occurred, I was a few short months into my teaching career. My ninth-grade students had many questions – some serious, some silly – about the outbreak. These included: What is it? How is it spread? Why is it such an issue there but not here? How can it be prevented in the future? I found myself wondering how to answer some of the more serious questions regarding what led to the outbreak in the first place. I did my best to regurgitate the information I read from the Centers for Disease Control and Prevention (CDC) and other sources like the *New York Times* and *Washington Post* to my students, but I did not arrive at a personally satisfactory answer until nearly two years later when I began teaching Advanced Placement Environmental Science (APES) to a few of those same students.

In this course, I present information on human population as a way of understanding many classic environmental pressures brought about by a growing population (natural resource consumption, pollution, ecosystem disturbance, etc.). I also present information on the varied quality of life experienced by the planet's more than seven billion people in order to set up a discussion of environmental justice further into the course, including the life expectancies and survivorship curves for populations in different parts of the globe. Life expectancy, in part, is controlled by access to clean water, food, shelter, education, and modern medicine.

During the past school year, while teaching the population chapter, I had an aha! moment that helped me arrive at a fundamental answer to the questions my ninth graders raised about why the Ebola outbreak seemed so out of control: individuals in the region of the world experiencing the outbreak did not have routine access to clean water, food, or modern medicine. This created a situation where, according to the World Health Organization (WHO), viral outbreaks are both more common and deadlier.[1] Moreover, I had a simple answer for those questions of how to prevent and/or control future outbreaks: "It's the economy, stupid!", as the famous political strategist James Carville so frequently shouted. As reported by the WHO, a confluence of economic restraints on hospitals and understanding of disease transmission by impacted communities paved the way for the outbreak and widespread hysteria that followed. As the world watched the crisis unfold, many world leaders and global institutions agreed that prevention and control of future outbreaks required "longer-term commitment to economic and technical support of…health care systems, roads, schools, and general development."[2] In this unit, I explore the relationship between economics and community health through the

lens of the Wealth-Health Paradigm – the phenomenon that countries with higher GDPs tend to have longer life expectancies and fewer deaths from communicable diseases.[3]

School Profile and Course Specifics

William Penn High School is a public high school in the Colonial School District in New Castle, DE. It is the only high school in the district and the largest high school in the state of Delaware, serving almost 2,100 students grades 9-12. The school district is mostly suburban, with small portions of the district being considered urban and some being considered rural. In total, the district serves over 10,000 students and expects to serve increasing numbers of students as New Castle experiences a reemergence of industry and jobs.

In 2012 the district redesigned the high school into three separate colleges focused on improving the college and career readiness of graduates. The three colleges are the STEM College, the Humanities College, and the Business College. Within each college there are specific pathways. In the STEM College, pathways include agriculture, architecture and interior design, construction, engineering, health services, information technology, mathematics, and science. The Humanities College offers pathways in behavioral science, communications, education, legal studies, international studies, and visual and performing arts. The Business College has pathways in Junior Air Force ROTC, business administration, culinary arts, financial services, and marketing. Students must choose a pathway upon entering high school and earn three consecutive credits in that pathway in order to graduate. To best suit our students' needs, students typically take classes with students enrolled in the same college. This fosters meaningful relationships between teachers and students and allows for targeted curriculum. This redesign has helped William Penn retain students who would otherwise attend one of the several vocational-technical or charter schools in the area. These pathways continue to grow and develop to meet the needs of our community.

Within the agriculture program, I have created a new environmental science program of study approved by the Delaware Department of Education. This program starts with students taking Introduction to Agriscience their first year; Natural Resources and Ecology their second year; Environmental Science Issues their third year; and finally APES their fourth and final year. I taught the first APES course in the most recent school year and will continue to teach the course under this new program. I used a mix of curricula in my first year teaching the course, ranging from the textbook and its resources to colleagues who teach the course elsewhere, to published units developed by Howard Hughes Medical Institute (HHMI) and other educational service providers. While these resources were helpful, I need to develop more personalized units moving forward to better meet the needs of my students, especially those who are part of the environmental pathway. Doing so will help create buzz about the course and program, insuring student interest and in enrollment for future years. I also aspire to appeal to students from other majors within the school. I would specifically like to tailor content to those in the health services field, which is the most popular program in the STEM College, if not the entire school. In addition, I would like to increase the cohesiveness of the AP and the recently-adopted Next Generation Science Standards (NGSS). This last objective is a challenge for all AP science course teachers since NGSS focuses considerably less on content in favor of process and experiential learning. While this is may be difficult to do in the demanding world of AP scores I firmly believe that this shift will create a better learning experience for students and ultimately improve their test performance.

Content Objectives

The “Economics and Community Health – The Wealth-Health Paradigm” unit focuses on the relationship between socio-economic factors and community health. It also provides a roadmap for teachers of similar content to incorporate data-driven lessons, integrated and experiential learning, and NGSS 3-D instruction into their curriculum. This newly developed unit serves as a much-needed improvement to the human population portion of my Advanced Placement Environmental Science (APES) course. It could also be revisited during the “Hazards to Human Health” unit since such hazards in developed regions are quite different than those in less developed regions. Currently in the population unit we discuss a wide range of topics pertaining to human population, ranging from population growth, environmental pressures, survivorship, causes of death, and the demographic transition that countries undergo as they industrialize and modernize their economies. In its current form, this unit requires a lot of reading and intake of information. In other words, students don’t *do* a whole lot, and with this unit, I change that. My overarching goal is for students to investigate the relationship between Gross Domestic Product (GDP) and cause of death data from the World Health Organization in order to develop a more in-depth understanding of how economic conditions are a major controller of community health.

There are several course objectives and aspects of the three-dimensional NGSS that I address in this unit. Specific to the course, students learn: (1) the Wealth-Health Paradigm can be explained by the phenomenon that, in general, people in less developed countries (low GDP) die from communicable diseases at young to middle age, while people in more developed countries (mid to high GDP) die from non-communicable diseases at middle to old age, (2) access to clean water, education, and healthcare in more developed countries alters survivorship and extends lifespans, and (3) advances in basic science and the tools developed by biomedical engineers (among others) have the potential to alter the Wealth-Health Paradigm by improving community health in less developed, low GDP countries.

Background Content

Student Background Knowledge

By this point in the course, students have completed related units on earth science and the living world (without specifics on humans). In the earth science unit students learn about plate tectonics and how incoming solar radiation, latitude, and global wind and ocean currents establish climatic regions across the globe. In the living world unit, students learn about classical principles such as biomes, ecosystem structure, energy and matter flow within ecosystems, ecosystem diversity, ecosystem change, and biogeochemical cycles. Ultimately the two units flow together because climatic regions determine the type of biome, and ultimately types of living organisms, in a given region.

Key Content

Basic Economic Principles and Classifications

Students need to understand the basic economic principle of Gross Domestic Product (GDP), as well as the

accepted classifications of More Developed Countries (MDCs) and Less Developed Countries (LDCs). Students take Economics as part of their tenth-grade social studies curriculum, and some may have more advanced knowledge through participation in AP Microeconomics or AP Macroeconomics. For these reasons, presentation of this information is for general review purposes. Nevertheless, it is absolutely critical for students to have a firm grasp of these principles before moving further into the unit.

GDP is defined in the course textbook as "the annual market value of all goods and services produced by all firms and organizations, foreign and domestic, operating within a country."[4] GDP can also be expressed per person, or "per capita" as way of normalizing the value for comparison between countries of vastly different population (such as the United States and Kiribati). Students should understand that high per capita GDPs are associated with advanced, modernized nations, while lower per capita GDPs are typically associated with less modernized nations. To that end, the terms MDC and LDC become valuable when differentiating between the level of advancement of a country and its economy. The same textbook defines MDCs as "industrialized nations with higher than average national income." Such countries include the United States, Canada, Japan, Australia, and most of Europe. LDCs are then loosely defined as all of the remaining countries of the world, each of which falls somewhere on the spectrum of middle-income, moderately developed countries (such as China and Mexico) to low-income, least developed countries (such as India and Nigeria).

These ambiguous definitions can be supplemented with Per Capita GDP data from the World Bank[5] in Table 1. Clearly these categories are broad given the range of per capita GDPs within each classification. Nevertheless, they provide a useful starting point for identifying key differences in the economies and quality of life across the world and serve as a critical resource for establishing connections between economics and community health.

Table 1: Per Capita GDPs and Classification of Selected Countries

Country	Classification	2016 Per Capita GDP (USD)
United States	MDC	$57,466
United Kingdom	MDC	$37,899
Mexico	LDC (middle-income)	$8,201
China	LDC (middle-income)	$8,123
Nigeria	LDC (low-income)	$2,178
India	LDC (low-income)	$1,079

Knowledge of basic geography can make these vague categories more meaningful in the lens of economics; by and large the Western world is developed with a moderate to high per capita GDP, whereas regions such as Sub-Saharan Africa, Southeast Asia, Latin America, and to some extent the former Soviet Socialist Republics in Eastern Europe have low per capita GDP as evidenced by the previously cited World Bank data. It is under this lens that students view the Wealth-Health Paradigm. Students also need to understand the role of climate in this pattern of GDP, with special attention given to the harsh climate of regions within Africa.

Population Ecology – Human Population Specific

As a fundamental principle of population ecology, a survivorship curve is a useful tool for analyzing the influence of the Wealth-Health Paradigm. Such curves show the percentage of individuals surviving to each successive age in a given population of a species. As shown in Figure 1, there are three classical types of curves.

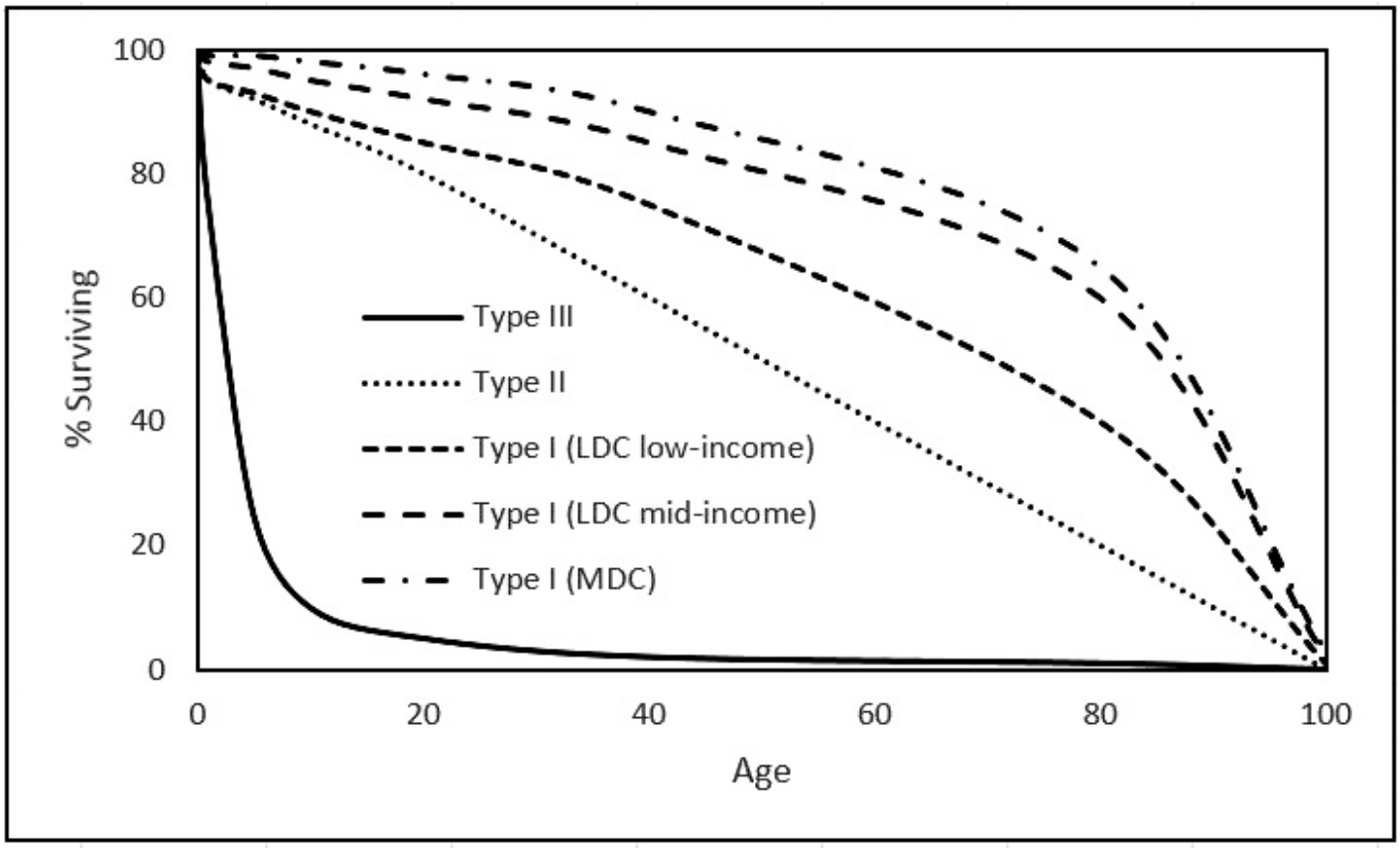

Figure 1: Sample Survivorship Curves

The Type I curve is characterized by high survivorship in early and middle life, followed by a steady decline to near zero in as age increases. Such a curve is typical in mammals, which produce few offspring but spend considerable time caring for them. The Type II curve is characterized by a relatively constant survivorship regardless of age, as is demonstrated by the linear shape in Figure 1. This type is typical of some bird and reptilian species. The Type III curve is characterized by very low survivorship in early life followed by only small declines in survivorship at middle and later stages of life (called a bottleneck in population ecology). This curve is highly typical of species that produce many offspring such as many types of insects and fish. In these species, very few of these offspring reach ages of maturity due (mostly) to predation.[6] For reasons explained below, survivorship in humans varies across populations. As shown in Figure 1, LDCs experience lower survivorship at all ages, and even within the broad classification of LDCs there is considerably variation. MDCs experience greater survivorship due to their access to high quality healthcare and access to public infrastructure that promotes health, as described below.

Causes of Death and the Wealth-Health Paradigm

Before discussing the cause of death data and Wealth-Health Paradigm, a few vocabulary terms of central importance to student understanding are introduced. Undernutrition is a chronic state of not receiving enough food,[7] and is the leading cause worldwide of morbidity and premature death.[8] Malnutrition is a serious condition arising from a lack of adequate nutrients and is a major contributor to high infant mortality rates in LDCs.[7] Communicable diseases, also called infectious diseases, are defined by the WHO as diseases caused by pathogenic microorganisms, such as bacteria, viruses, parasites, or fungi. Such diseases can be spread from person to person either directly or indirectly.[9] Examples of communicable diseases include Tuberculosis,

HIV/AIDS, Dengue Fever, and Influenza. Non-communicable diseases, also called chronic diseases, are defined by the WHO as diseases that are not passed from person to person and are of long duration and generally slow progression.[10] Examples of such diseases include diabetes, cancer, Alzheimer's, and heart disease. Although undernutrition is the leading cause of morbidity and premature death worldwide, this unit focuses on the two broad categories of disease. This is because it is well known that undernutrition weakens individuals and their immune system, making them more susceptible to disease.[11] Moreover, in areas where undernutrition is prevalent, so are deaths by communicable diseases, as explained below.

While the world has made great strides in reducing the number of premature deaths from communicable diseases,[12] the fact remains that individuals in low-income LDCs are much more likely to die from such diseases than individuals in even moderate-income LDCs (not to mention MDCs). It is also true that in moderate-income LDCs and nearly all MDCs, individuals are more likely to die from non-communicable diseases associated with the aging process or their lifestyle choices. This is evidenced by the following statement from a January 2017 state of global health report published by the WHO:

"More than half (52%) of all deaths in low-income countries in 2015 were caused by…communicable diseases, maternal causes, conditions arising during pregnancy and childbirth, and nutritional deficiencies. By contrast, less than 7% of deaths in high-income countries were due to such causes."[13]

This precise phenomenon is what I have been referring to as the Wealth-Health Paradigm. This can be defined as the pattern that individuals from poorer countries tend to die from infectious and contagious diseases amplified by a lack of access to clean water, adequate nutrition, education, and modern healthcare infrastructure, while wealthier individuals tend to die from chronic and often genetic diseases or complications attributed to lifestyle choices at considerably older ages. A robust example of this phenomenon is provided by Sepulveda and Murray in their report of the state of global health.[14] Of great interest to this unit is a graph depicting the burden of disease across various life stages and regions due to three specific cause categories: communicable, maternal, neonatal, and nutritional disease; non-communicable disease; and injuries. Individuals are far more likely to die due to communicable, maternal, neonatal, and nutritional disease at very young ages if they live in Sub-Saharan Africa or India than in High Income countries. A simplified version of this graph appears in Figure 2 below.

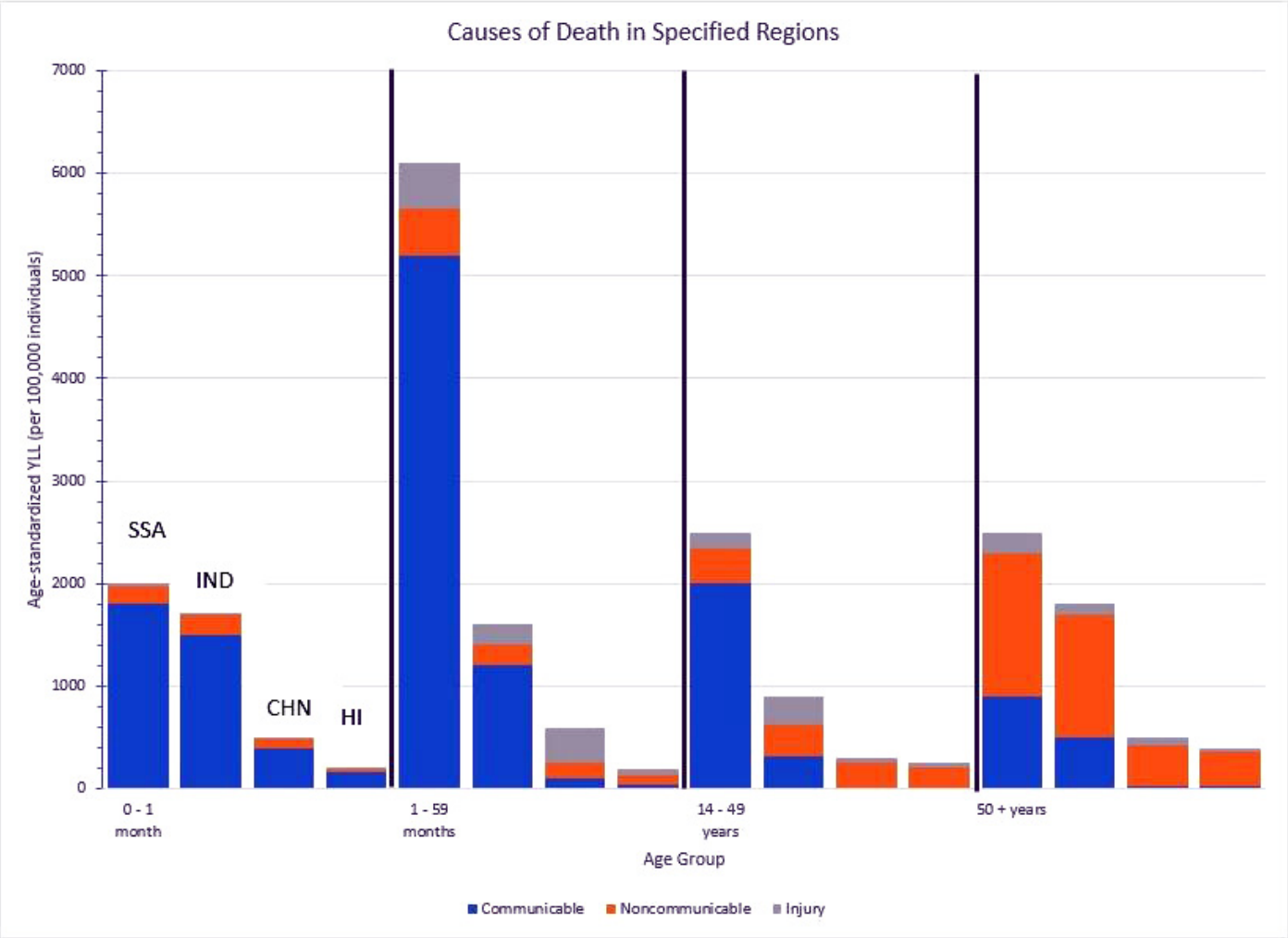

Figure 2: Simplified Cause of Death Graph from Sepulveda and Murray

In Figure 2, SSA represents Sub-Saharan Africa, IND represents India, CHI represents China, and HI represents High-Income. The magnitude of the differences is stark: approximately 2000 individuals per 100,000 die from a communicable, maternal, neonatal, or nutritional before reaching their first month in Sub-Saharan Africa. Only about 100 such deaths occur in High-Income countries. The same trend continues into the next age category where the difference is just as large. It is clear that surviving the first months and years of life in LDCs is not a guarantee. And even then, death from such diseases is still much more likely in such countries compared to higher income countries.

Conversely, deaths from non-communicable diseases represent a significantly higher percentage of deaths in MDCs (even while the total number may be higher in LDCs). In a related data table, the authors show that the percentage of number of years of potential life lost (YLL) due to non-communicable disease drastically increases with income. Specifically, low-income LDCs experience 20.7% YLL, moderate-income LDCs 34.0%, and MDCs 65.3%. This phenomenon is at least in part due to the aforementioned lack of deaths from communicable diseases. In other words, individuals in better-off countries live long enough for non-communicable diseases to manifest themselves because their income has (in large part) made communicable diseases non-fatal. Because individuals are living longer, they are experiencing prolonged exposures to risk factors that ultimately lead toward increased deaths from non-communicable diseases.

This phenomenon can be directly linked to the survivorship curves discussed above and shown in Figure 1. And while nearly all countries experience Type I survivorship, as per capita GDP increases, the curve shifts up and to the right. In practical terms, this means that more and more individuals survive at each age, and that the total life expectancy within that population increases.

The consistent message from the WHO and United Nations (UN) surrounding the relationship between living conditions and death from communicable diseases is not surprising: poor sanitation is a major threat to public health. It is also not surprising that unsanitary conditions are much more prevalent in LDCs. In a joint release in 2008, the two groups stated that "sanitation is a cornerstone of public health," that "improved sanitation contributed enormously to human health and well-being," and that "simple, achievable interventions can reduce the risk of contracting diarrheal [sic] disease by a third."[15] The group also published statistics that describe the enormity of the problem, including that 40% of the world's population lacks access to toilets and that children suffer a disproportionate number of deaths due to diseases associated with unsanitary conditions. Of the communicable diseases threatening individuals living in LDCs, polio, cholera, typhoid fever, infectious hepatitis, and diarrheal diseases are spread through contact with human excreta.[16]

This contact with human excreta is facilitated by a lack of proper sanitation in such countries. Such diseases were at some point commonplace in the major urban centers of what are now MDCs. For example, in the 1850s London experienced a severe outbreak of cholera. At this point the germ theory of disease had not yet been developed, and the prevailing theory of the day (that disease was spread through "noxious air") could not explain the pattern of the outbreak. John Snow, a member of the Royal College of Physicians and considered to be the Father of Epidemiology, was able to trace the outbreak to the use of a public water pump that drew in water contaminated with sewage. Ceasing use of this particular pump contributed to the decline of outbreak.[17] The critical aspect of this anecdote is that such outbreaks are no longer common in London (or really any other city of enormous wealth). Yet they are commonplace in urban centers and villages of LDCs worldwide. As discussed later, this offers a point of entry for engineers of all types seeking to limit the spread of communicable diseases. It should be noted that even in moderate-income LDCs and MDCs, unsanitary conditions are prevalent and do allow for transmission of such disease; it just so happens that health care infrastructure is better equipped to handle these diseases, ultimately reducing the number of individuals who experience fatal cases.

Demographic Transition

The demographic transition is defined as a particular phenomenon: as countries become industrialized and economically developed, their populations tend to grow more slowly.[18] As shown in Figure 3, this process takes place in four distinct stages.

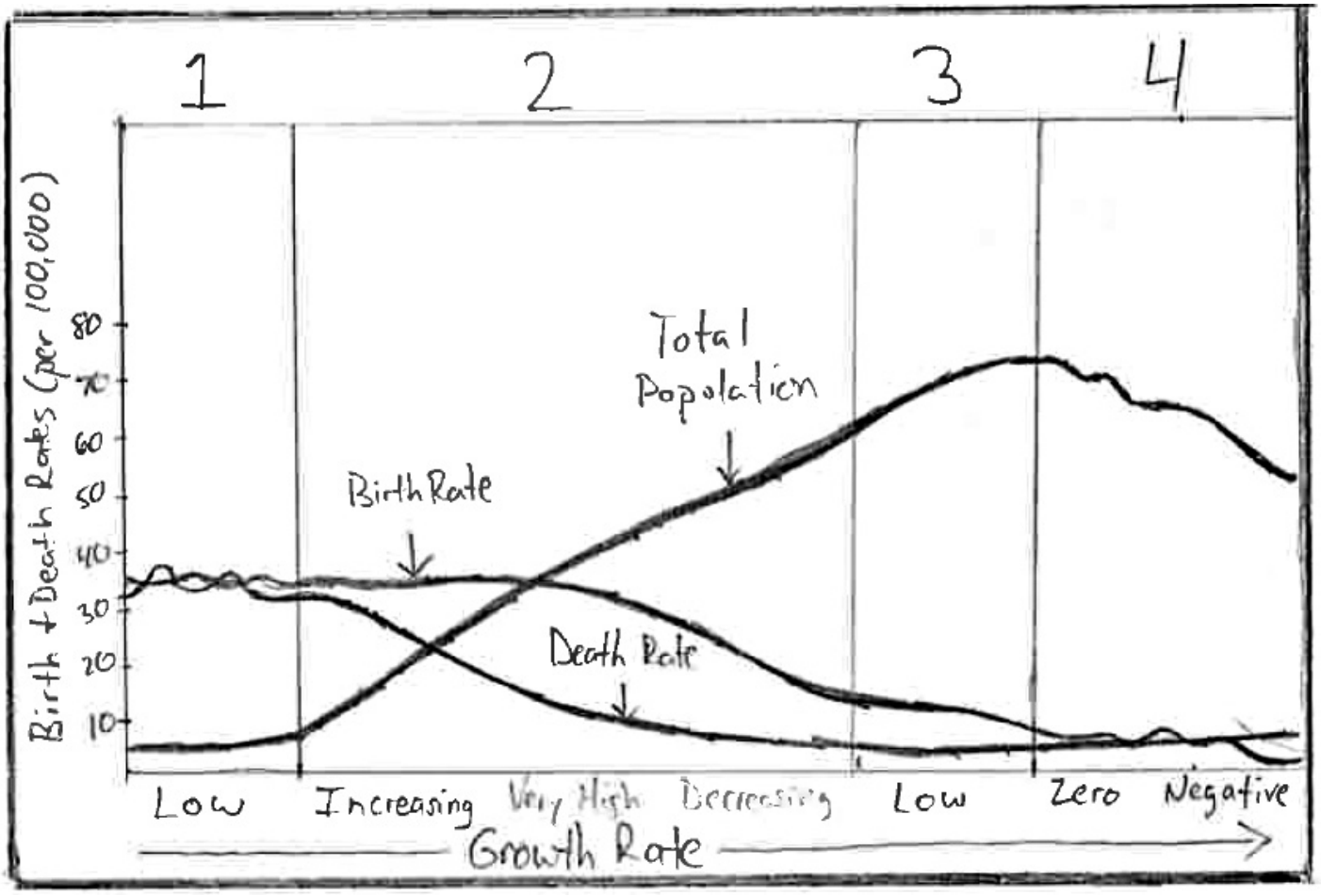

Figure 3: Demographic Transition

During, the preindustrial stage, the country experiences little to no growth due to nearly equal birth and death rates. The populations may also experience contraction for a variety of reasons, including epidemic, war, famine, etc. It is important to note that birth rates are high because of high infant and child mortality; because parents know it isn't likely that each child will survive, they have as many as possible (obviously this is a generalization and is not true of every family). As countries enter the transitional stage, death rates drop due to more favorable economic conditions. Such conditions lead to improved food production and health. However, growth rates accelerate because birth rates are still high. As countries move into a more industrial economy, birth rates begin to fall as families decrease the number of children they have. This is directly tied to the increased education of women and use of modern family planning and contraception. Death rates approach their minimum during this stage, and population growth begins to level off. Finally, in the post-industrial stage of the transition birth rates equal and may decrease below death rates. Populations stabilize or contract during this stage.

While demographers have long used this phenomenon to describe population changes, there is increasing concern that as industrialization occurs in LDCs, a lack of foreign aid and investment from MDCs may keep LDC populations stuck in Stage 2, leading to an explosion of population as families continue having many children even as death rates fall. This potential problem, though not central to the unit, is critical for students to understand as it speaks to the global nature of the issue of population growth and its impact on the planet. During last year's discussion of the demographic transition, students raised questions about why an industrializing or modernizing economy is a necessary precursor to dramatic decreases in death rates. The

answer is a difficult one and requires a discussion of morality, environmental justice, and economics. And while this issue is somewhat beyond the scope of this unit, the work of biomedical engineers offers a little hope to students seeking an answer to this question.

Role of Biomedical Engineers

Biomedical engineers can and have developed low-cost preventative, diagnostic, and treatment options that can fundamentally alter the Wealth-Health Paradigm. Vaccines are chief among these developments. They work by stimulating the immune system to enhance the body's natural defenses, and are classically defined as a preparation of all or part of an infectious agent that primes the immune system to recognize a disease *without causing the disease*. Vaccination, then, is the process of administering a vaccine to an individual or group.[19] For instance, the development and dissemination of vaccines has successfully eradicated Smallpox, even in LDCs.[20] Efforts are underway (with a great deal of success) to eradicate polio worldwide with a focus on countries such as India, Pakistan, and Somalia,[21] all of which are classified as LDCs. Vaccination against tuberculosis has greatly reduced incidences and deaths in many LDCs, as statistics from the WHO demonstrate.[22]

However, vaccines for some of the most prevalent diseases, such as HIV/AIDS,[23] diarrheal diseases,[24] and malaria,[25] have proven to be difficult to engineer. Therefore, biomedical engineering devices designed to diagnose and treat such diseases – along with education – are critical to stop their spread and minimize their impact on infected individuals. Examples of such diagnostics for HIV/AIDS include ELISA tests, viral load tests, and Western blot tests.[26] Each of these tests involve processes to which biomedical engineering has greatly contributed, ranging from identification of the molecular machinery responsible for virulence to discovering methods to synthesize large quantities of compounds used in the diagnostics.

Additional engineering innovations for ensuring access to clean water and sanitation have gone a long way towards reducing risk of death from communicable diseases.[27] As discussed above, the WHO and UN have consistently remarked that limiting the incidences of communicable diseases requires the expansion and improvement of sanitation in LDCs. Such innovations have provided a roadmap toward increased health and quality of life for individuals living in economies that lag behind in terms of modernization and output. Widespread vaccination programs, combined with increased and improved sanitary services would shift the survivorship curves of LDCs upwards and to the right, even without having to drastically alter the economies of such countries (not that improving the economies of these countries isn't or shouldn't be a goal of organizations like the UN or World Bank).

Strategies

This unit incorporates content from several disciplines including economics, demography and statistics, medical sciences, and engineering, and is anchored in the phenomenon of the Wealth-Health Paradigm, as described above. In order to satisfactorily integrate this content into meaningful lessons designed to improve student understanding of the wealth-health paradigm and its underlying causes, students engage in a number of NGSS Scientific and Engineering Practices (SEPs). To that end, students use numerous Learning Focused strategies (LFS) and higher order thinking (HOT) strategies.

NGSS SEPs

In order to instill in students as understanding that science is not merely a body of isolated facts but a systematic process for acquiring new knowledge, we as teachers must incorporate real aspects of the scientific process into the classroom. The National Research Council (NRC) lays out a framework for how to ensure that--under NGSS--students have authentic scientific experiences in their classrooms even as they learn the bodies of knowledge of the specific sciences. When implemented properly, this framework of SEPs "supports a better understanding of how scientific knowledge is produced and how engineering solutions are produced…help[ing] students become more critical consumers of scientific information."[28] This focus on process, according to the NRC, improves upon previous practices that reduced scientific procedures to isolated aims of instruction, rather than a vehicle for developing a meaningful understanding of the true scientific concept. Additionally, the process of discovering scientific truths allows students to engage in the types of critical thinking necessary to understand why the right is answer is right, and perhaps more importantly, why the wrong answer is wrong. This emphasis on argumentation from a strong evidence foundation supports student understanding of fundamentals of scientific truths instead of asking for rote memorization of facts.

The NRC developed eight explicit practices essential to K-12 science education. These practices can be found in the NRC framework document referenced above. In this unit, students explicitly engage in the following SEPs: asking questions and defining problems, analyzing and interpreting data, obtaining, evaluating and communicating information, and using mathematics and computational thinking. Because of the three-dimensional model espoused by NGSS (the other dimensions being Disciplinary Core Ideas, known as DCIs, and Crosscutting Concepts, known as CCCs), the above SEPs were chosen as the best vehicles to make use of the CCCs with the goal of satisfying the DCIs. Three-dimensional assessment tools are used in order accurately assess students mastery of content at the end of the unit. Specific CCCs and DCIs are presented in the Appendix entitled "Implementing District Standards."

Using LFS to Support SEPs

In order to satisfactorily carry out the SEPs, students are expected to complete all assigned readings and take guided reading notes. Prior to beginning the unit in the classroom setting, students use a strategy of close reading. Close reading is a strategy whereby students engage in a thoughtful critical analysis of a text by focusing on specific details or patterns. This allows them to develop a deeper, more precise understanding of the text. The benefit of having students employ this strategy is not limited to success on the unit; it also prepares them for the AP exam, on which they must critically evaluate text excerpts before crafting an answer to a free response question (FRQ). They then use a graphic organizer in order to create contextual meaning for the critical vocabulary of the unit. As part of the activation strategy for each day of unit, students are challenged to ask meaningful questions after engaging-in KWLs and Think-Pair-Shares. In a KWL, students create a chart with three columns: the first column is what they currently know, the second column is what they wonder, and the third and final column is what they want to learn. This strategy encourages students to take ownership of their learning and allows for differentiation and strategic grouping. In a Think-Pair-Share, students are given a statement, question, or graph and asked to think of a response. They then pair with a partner and discuss their response before sharing out with the entire group. This strategy allows time for students to process and distill information before sharing with the group, reducing the stigma of being wrong. It also encourages participation from all students instead of calling on the first few students to raise their hands. Both of these activating strategies support the SEPs identified above. Specifically, in the KWL, students engage in the practice of asking questions (this occurs in the wonder section). Because these questions help

students focus their attention to the most critical information, I guide them through this process. In the Think-Pair-Share students obtain, evaluate, and communicate information, and depending on the initial type of information (question, statement, or graph), they may be asked to analyze and interpret information.

Students analyze and interpret several maps in the beginning of the unit in connection with the activating described above. This is critical because the AP exam consistently asks students to analyze maps, graphs, or other visuals before answering series of multiple choice questions. Additionally, at least one FRQ requires analysis of visuals. The bulk of analysis and interpretation centers on cause of death data from the WHO and economic data from the World Bank, UN, and other available resources to discover the Wealth-Health Paradigm. This requires the use of HOT strategies such is identifying patterns, establishing connections between concepts, and using graphic organizers to categorize and establish relationships, such as that between GDP and mortality. To ensure that students truly understand the Wealth-Health Paradigm on a deep and meaningful level, they are grouped strategically so that they must share key findings in order to form a complete picture of the topic. This strategic grouping is often termed a Jigsaw, and is informed by the students' completion of the KWL during the activation strategy. In such a grouping strategy, students are part of two groups; their home group and their specialist group. Students in the home group may work on different aspects of the same problem, while they work with a separate, specialist group on the same aspect of the problem. After returning from the specialist group, the home group integrates the knowledge from all the specialists into a coherent understanding. This allows students to practice effective communication since they must share their acquired knowledge on several occasions. Furthermore, it allows for both depth and breadth of content knowledge without taking inordinate amounts of time.

Finally, when thinking about how biomedical engineers can help alter the Wealth-Health Paradigm, students need to think computationally by decomposing the problem, recognizing any emergent patterns, generalizing those patterns, and identifying/designing potential solutions for use. For example, students may consider whether a vaccine could be a more effective preventative measure for a certain disease impacting LDCs than potentially lower cost education and lifestyle modifications. I employ a Multiple Text Analysis (MTA) strategy during this portion of the unit in which students participate in a discussion board. Like the KWL, using the MTA in a discussion board setting serves multiple purposes: it trains students to integrate knowledge from several sources when crafting a response and building content knowledge, and prepares students for the increasing online nature of many college courses.

Throughout the unit students engage in distributive summarizing strategies as a way of monitoring their progress in the unit. Students also engage in several Think-Pair-Shares throughout the unit as frequent checks for understanding. In order to gather more formal assessments of student understanding, I also use the Think-Ink-Share strategy. This is a variation on the Think-Pair-Share where students have time to process information, then write a response, and share in small group settings before discussing with the class. Students also engage in Quick-Writes, a strategy where students develop thoughtful, written responses to open-ended questions in a given amount of time (typically 2-10 minutes). Like the Close Reading strategy, this allows students to practice skills critical for success in the high-stakes timed FRQ section of the AP exam. Each of these offers an opportunity for informal assessment of student progress and identification of any common misunderstandings needing correction while also moving students towards mastery of the unit.

Classroom Activities

Close Reading

Students are given the following purpose for reading: identify a relationship between causes of death and general sanitary conditions. This purpose guides students through the readings and primes them to receive the information. Prior to coming to class on the first day of the unit, students read the following short publications from the WHO and generate three questions about what they read: “The top 10 causes of death”, “Infectious diseases”, “Noncommunicable diseases”, and “Poor sanitation threatens public health.” In class, students use their questions to establish a K-W-L in order to flesh out common strands from the reading and create a focused set of learning objectives for the unit. Students then receive definitions of GDP, MDC, and LDC, along with Table 1 to assist in making sense of these definitions. They are given a map of GDP and use this information to predict categorical causes of death in select regions of the planet. Students then engage in a T-P-S exercise as an informal assessment of their understanding so far. It is at this point that students are introduced to the term “Wealth-Health” paradigm

Data Analysis

Following the informal assessment, students participate in a Jigsaw activity in which they examine cause of death data for specific countries (those countries listed in Table 1). In their home group, students make predictions about categorical causes of death in their specific country (this should be a continuation of the discussions had during the T-P-S). Then each student is assigned a specific cause of death category: communicable, non-communicable, and injury, mirroring the categories used in Figure 2. Students then move to their specialist groups; all students assigned communicable diseases work together, etc. They then access the WHO database (embedded in our online learning platform for ease of access) and examine data for the years 2000 and 2015. Students return to their home group and share out information regarding which categorical cause of death was most prevalent in their country, noting if their prior predictions agreed or disagreed with the data. Each country will then share out with the entire class.

Students then revisit the “The top 10 causes of death” and “Poor sanitation threatens public health” WHO articles to make connections across different media in a T-I-S summarizing activity. Having already read the chapters on population ecology and human population and completed activities on the shape of survivorship curves for different types of organisms in a previous unit, students use these readings and data to integrate information from the Close Read activity to generate, label, and explain three differently shaped curves for three select countries (different from those in Table 1).

Discussion Boards

Role of Biomedical Engineers

In order to connect the Wealth-Health Paradigm with the information presented in the text, students revisit the section on the demographic transition look more in depth at the causes of the transition and the role of biomedical engineers in this process. After examining Figure 3, students are asked the following questions and engage in Quick-Writes: How exactly does the death rate in industrializing countries fall so dramatically? What does an increase in public healthcare look like? Who is responsible for the development of technologies critical to adequate public healthcare? Ultimately students discuss their responses and come to a common understanding of the answers.

Using the course's online learning platform, students are then presented with information on the major contributions of biomedical engineers, with specific regard to limiting the spread of communicable diseases in regions of the world with low GDP. This reinforces the idea that death rates can be suppressed in such regions without major investments and increases in GDP, thus altering the Wealth-Health Paradigm. Students then participate in a discussion activity in which they present information on one of the following: vaccination, sanitation, and diagnostic devices. They then ask questions of their peers related to the other two and answer peer-submitted questions regarding their own.

Influence on Global Population

To consider the effect of the demographic transition on global population, students engage in a two-part discussion board activity in the course's online learning platform. In the first part, students consider that common demographic theory states that as countries industrialize, they go through a period of massive population growth because death rates plummet but birth rates remain relatively high. They then consider the following question: won't using BME technologies to reduce death rates in areas with high birth rates (for example central Africa) lead to dramatic increases in the already massive global population? After making their initial post, students then watch a short video clip entitled "Will saving poor children lead to overpopulation?"[29] by the late Swedish physician and statistician Hans Rosling. Once they have watched the video, students respond to a second prompt: what does Rosling say about the issue of "saving poor children"? Do you agree with his point of view? Defend your position. Finally, students respond to two others' answers with questions/comments/critiques.

Free Response Practice

Students are given a mock 10-point FRQ that integrates all of the above information, including analysis of data, explanation of the wealth-health paradigm, survivorship curve shifts, the demographic transition, and the role of biomedical engineers. After examining a modified version of the figure from Sepulveda and Murray described above, students will answer the following questions: (1) define communicable and noncommunicable diseases; (2) calculate the percentage of all age-standardized years of lost life due to communicable diseases for children aged 0 to 59 months for the Sub-Saharan Africa and High-Income regions; (3) describe the Wealth-Health Paradigm and identify TWO potential solutions to this problem; and (4) explain how changes in GDP can alter a population's survivorship curve.

Students have 22 minutes to answer the question. Once the question has been answered, students use a strict FRQ rubric and complete peer-review scoring. For question 1, students are awarded one point each for the correct definitions of the terms. For question 2, students are awarded two points each for the correct approximations of the percentages for each region (any answer within the range of 80-90% is acceptable for Sub-Saharan Africa, and an answer from 45-55% is acceptable for the High-Income region). Students must show work to earn any credit on this problem. For question 3, one point is awarded for a correct explanation of the Wealth-Health Paradigm, and one point each for identification of potential solutions, including specific biomedical engineering advances, raising the income of the region, increasing access to education, supplying clean water, and ensuring access to adequate nutrition. For question 4, students are awarded one point for correctly describing how increasing GDP can shift the survivorship curve up and to the right.

This scoring is a typical activity in an AP class and allows for peer-to-peer teaching, clarification and corrections of commonly-made mistakes, and self-assessment upon receiving their response back. These activities promote a growth-mindset for students and offer a low-stakes environment for assessment for two

reasons: first, ten points is comparatively small for an assessment great and 2) rubric scores are scaled for use as an assessment grade (greater than eight = A, between six and seven = B, between four and five = C, three = D, and less than three = F).

Resources for Teachers and Students

Miller, G Tyler and Scott E Spoolman. 2015. *Living in the Environment*.

This text forms the foundation of my APES course. Students read essentially the entire book throughout the course. Many of the definitions in this unit are pulled from this text in order to provide students with a sense of consitency. This text is also available in a non-AP edition for teachers of general environmental science.

National Research Council. 2012. *A framework for K-12 science education: practices, crosscutting concepts, and core ideas.*

This publication from the NRC offers valuable insight into the three dimensional approach to science education. The reasoning behind why this approach is critical to reinvigorating American science is excellent reading for all educators.

Rosling, Hans. 2015. *Will saving poor children lead to overpopulation?* http://www.gapminder.org/answers/will-saving-poor-children-lead-to-overpopulation/.

Students will view and discuss this video towards the end of the unit in order to give the unit a positive spin.

Saltzman, W Mark. 2015. *Biodmedical engineering: bridging the gap between medicine and technology.*

This text provides definitions and explanations for many concepts presented in the unit. The reading level is over most high school students' heads, but it is approachable for teachers wishing to incorporate more egineering into their courses.

Sepulveda, Jaime, and Christopher Murray. 2014. "The state of global health in 2014."

This paper is the basis of the unit. Figure 1 from this paper is used extensively in the unit and serves as a graph to be analyzed during the practice FRQ at the end of the unit.

World Bank Group. 2017. *GDP per capita (current US$).* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD?year_high_desc=true.

Information from this site provided the basis of Table 1. Students are referred to this site in order to get an idea of GDP differences by country.

World Health Organization. 2017. "Infectious Diseases." http://www.who.int/topics/infectious_diseases/en/.

Students read this article as part of their close read activity to form a foundational understanding for the unit.

World Health Organization. 2017. "Noncommunicable Diseases." http://www.who.int/topics/noncommunicable_diseases/en/.

Students read this article as part of their close read activity to form a foundational understnading for the unit.

World Health Organization. 2008. "Poor sanitation threatens public health." http://www.who.int/mediacentre/news/releases/2008/pr08/en/.

Students read this article as part of their close read activity and revisit throughout the unit as they build understanding. Students may also reference this article in summary activities and/or on the practice FRQ.

World Health Organization. 2017. "The top 10 causes of death." http://www.who.int/mediacentre/factsheets/fs310/en/.

Students read this article as part of their close read activity and revisit throughout the unit as they build understanding. Students may also reference this article in summary activities and/or on the practice FRQ.

Appendix A: Implementing District Standards

APES Standards

Topic III.A: Population biology concepts

Topics III.B: Human population

Next Generation Science Standards

HS-ESS3-1: Construct an explanation based on evidence for how the availability of resources influences human activity

HS-LS4-5: Evaluate the evidence supporting claims that changes in the environment result in changes in populations

Common Core State Standards

CCSS.ELA-LITERACY.RST.11-12.2: students determine the central ideas of a text and summarize complex concepts presented in the text

CCSS.ELA-LITERACY.RST.11-12.9: students synthesize information from a range of sources into a coherent understanding of a phenomenon

CCSS:ELA-LITERACY.WHST.11-12.1A: students present precise and knowledgeable claims, establish significance for their claims, distinguish their claim from alternative or opposing ones, and use logical sequencing to their argument in support of their claim

Bibliography

Campbell, Neil Al, and Jane B. Reece. 2005. *Biology.* San Francisco: Pearson.

Clarke, Tom. 2001. "Polio's last stand." *Nature* 409: 278-280.

Garrett, Laurie. 2014. "Ebola outbreak a cause for alarm or for calm?" *USA Today*, August 04: 8.

Gunn, S William A, and Michelle Masellis. 2007. *Concepts and Practice of Huminitarian Medicine.* New York, NY: Springer.

Kumar, Vinay, Abul K Abbas, Nelson Fausto, and Jon C Aster. 2009. *Robbins and Cotran Pathological Basis of Disease, EBook.* Philadelphia: Elsevier Health Sciences.

Malaria Vaccine Initiative. 2017. *Vaccine Development.* Accessed July 15, 2017. http://www.malariavaccine.org/malaria-and-vaccines/vaccine-development.

Mathers, Colin D, and Dejan Loncar. 2006. "Projections of global mortality and burden of disease from 2002 to 2030." *PLos Medicine* 3 (11): 2011-2030.

Miller, G Tyler, and Scott E Spoolman. 2015. *Living in the Environment.* 18th. Stamford, CT: Cengage Learning.

Naruto, James P. 2004. "Vaccines against diarrheal diseases." *Seminars in Pediatric Infectious Diseases* 15: 272-279.

National Research Council. 2012. *A framework for K-12 science education: practices, crosscutting concepts, and core ideas.* Washington, D.C.: The National Academies Press.

2015. *Will saving poor children lead to overpopulation?* Directed by Gapminder. Performed by Hans Rosling.

Saltzman, W Mark. 2015. *Biodmedical engineering: bridging the gap between medicine and technology.* 2nd. Cambridge: Cambridge University Press.

Sepulveda, Jaime, and Christopher Murray. 2014. "The state of global health in 2014." *Science* 345 (6202): 1275-1278.

UNICEF. 2003. "Common water and sanitation-relaed diseases." *Water, Sanitation and Hygiene.* June 17. Accessed July 16, 2017. https://www.unicef.org/wash/index_wes_related.html.

United Nations, Department of Economic and Social Affairs, Population Division. 2017. *World Population Prospects: the 2017 Revision, Key Findings and Advanced Tables.* Working Paper, New York: United Nations.

University of California San Francisco. 2017. *HIV Diagnosis.* Accessed July 15, 2017. https://www.ucsfhealth.org/conditions/hiv/diagnosis.html.

World Bank Group. 2017. *GDP per capita (current US$).* Accessed July 12, 2017. http://data.worldbank.org/indicator/NY.GDP.PCAP.CD?year_high_desc=true.

World Health Organization. 2017. "Infectious Diseases." *Health Topics.* Accessed July 15, 2017. http://www.who.int/topics/infectious_diseases/en/.

—. 2015. "Liberia: a country – and its capital – are overwhelmed with Ebola cases." *Emergencies preparedness, response.* January. Accessed July 11, 2017. http://www.who.int/csr/disease/ebola/one-year-report/liberia/en/.

—. 2017. "Malnutrition." *Media Centre.* May. Accessed July 14, 2017. http://www.who.int/mediacentre/factsheets/malnutrition/en/.

—. 2017. "Noncommunicable Diseases." *Health Topics.* Accessed July 15, 2017. http://www.who.int/topics/noncommunicable_diseases/en/.

—. 2008. "Poor sanitation threatens public health." *Media Centre.* March 20. Accessed July 16, 2017. http://www.who.int/mediacentre/news/releases/2008/pr08/en/.

—. 2017. "The top 10 causes of death." *World Health Organization Fact Sheets.* January. Accessed July 12, 2017. http://www.who.int/mediacentre/factsheets/fs310/en/.

—. 2017. "Tuberculosis." *Media Centre.* March. Accessed July 15, 2017. http://www.who.int/mediacentre/factsheets/fs104/en/.

Endnotes

1. World Health Organization 2015
2. Garrett 2014
3. United Nations, Department of Economic and Social Affairs, Population Division 2017
4. Miller and Spoolman 2015
5. World Bank Group 2017
6. Campbell and Reece 2005
7. Miller and Spoolman 2015
8. Kumar, et al. 2009
9. World Health Organization 2017
10. World Health Organization 2017
11. World Health Organization 2017
12. Mathers and Loncar 2006
13. World Health Organization 2017
14. Sepulveda and Murray 2014
15. World Health Organization 2008
16. UNICEF 2003
17. Gunn and Masellis 2007
18. Miller and Spoolman 2015
19. Saltzman 2015
20. Saltzman 2015
21. Clarke 2001
22. World Health Organization 2017
23. Saltzman 2015
24. Naruto 2004
25. Malaria Vaccine Initiative 2017
26. University of California San Francisco 2017
27. Saltzman 2015
28. National Research Council 2012
29. Rosling 2015