



The Public Health Triad

Brian Szekely

Modification of natural habitats by humans is a leading cause of emerging zoonoses. The new “habitat” is used mostly by livestock that are in close proximity to wild species possibly harboring disease. Modification of rainforests to pasture thereby increases the chance for zoonotic disease transmission to occur. It is the proximity of humans to infected domesticated and/or wild animals that perpetuates the spread of the **pathogen**.¹

LEARNING OBJECTIVES

By the end of this chapter, the student will be able to:

- Explain the public health triad and discuss why and how we study it.
- Discuss how conservation biology is directly tied to public health.
- Demonstrate how we are contaminating the planet’s resources, and what can we do, if anything, to offset these actions.
- Discuss how we are altering infectious disease transmission.
- Define **biodiversity**, and discuss why it is so important to the future of the planet.

INTRODUCTION

This chapter serves as an introduction to the public health triad and the emerging field of **conservation medicine**. The public health triad involves studying the interactions among humans, animals, and the environment. Conservation medicine practitioners study these interactions in order to solve global and micro-scale health problems. The topic of

zoonoses—diseases transmitted between humans and animals—is one of high importance to the public health triad. Presently, zoonoses account for nearly 75% of emerging infectious diseases worldwide.²

Preventable human behavior has been attributed to some of these outbreaks and is discussed throughout the chapter. In addition, several current ecological problems are caused by some of the same human actions. An overview is provided on how we are misusing man-made products and natural resources shown by their local and global consequences. Human behavior can negatively affect the health of the environment and the animals that are sustained by that environment.

Additionally, human behavior can lead to *human*-related health problems, which is an obvious concern for the health and well-being of the planet. If the stewards of the planet are in trouble, what does that say for the planet as a whole? Other topics discussed include the need to decipher relationships between environmental issues and human and animal health in the hope to promote a sustainable future. Furthermore, the implications of biodiversity reduction and their associated loss of **biologically active substances** are explained.

BASIC SCIENCE FACTS/KEY CONCEPTS REVIEW

What Is The Public Health Triad?

The public health triad (or simply, the triad) describes the interactions among humans, animals, and the environment using health-related consequences. The triad attempts to fuse scientific disciplines to characterize public health issues, as all forms of life on earth are extremely interactive. To understand each role the triad plays in any given health problem, one must take a theoretical “step back” to gain the right perspective. Rarely is

only one aspect of the triad involved in a public health crisis; usually all three play a role. Confounding factors affect disease epidemics, extraordinary ecological phenomena, the extinction of an uncommon species, or the changing of our atmosphere. To study the triad translates to studying ALL of these factors to gain a more holistic approach to health research. The concept of the triad is a frame of mind more than anything else. By studying the interactions among the triad, we have the ability to show true causes and, therefore, uncover real solutions.

One example of how each member of the triad interacts is how the poor maintenance of livestock or agricultural fields by humans can aid in the spread of many animal and human diseases. Over the past several years, a number of different bacterial outbreaks have plagued vegetable growers in the western United States. Many believe that the contamination was due to the poor maintenance of livestock in the immediate or adjacent area.

Also, the overuse of petroleum products has led to the increase of carbon dioxide (CO₂; a greenhouse gas) in the atmosphere,³ which in turn enhances the greenhouse effect that is associated with global warming. Another instance is human's previous use of chlorofluorocarbons (CFCs), which were proven to be a cause of reducing ozone in the Earth's stratosphere. This reduction allowed more direct sunlight (UVB in particular) to enter the earth's atmosphere, and in turn could have made more people at risk for nonmelanoma skin cancer and plays a major role in malignant melanoma development.⁴ In addition, the hole in the ozone layer, concentrated mostly over the Antarctic, increases melting of the polar ice caps that alters weather patterns, increases flooding incidence, and destroys wildlife habitat.⁵ These human, animal, and environmental problems caused by human's use of a dangerous chemical made the international community pass the Montreal Protocol in 1989. The phasing out of several groups of halogenated hydrocarbons, including CFCs, was implemented.

The health of the planet and its resident can benefit if we humans strive to determine relationships among the fields of human, animal, and environmental health, rather than trying to separate them. All of the above examples illustrate a point. Human behavior (possibly preventable) has negatively affected the health of the triad. Each aspect of the triangle is inexplicitly linked to the other. What happens to one no doubt can affect the rest. That is the core concert of the triad (Figure 4-1).

One organization that sees the benefit of these three disciplines working together is the World Health Organization (WHO). WHO openly and strongly stresses the cooperation between human, veterinary, and environmental public health professionals and refers to the term "public health triad" throughout its Web site.

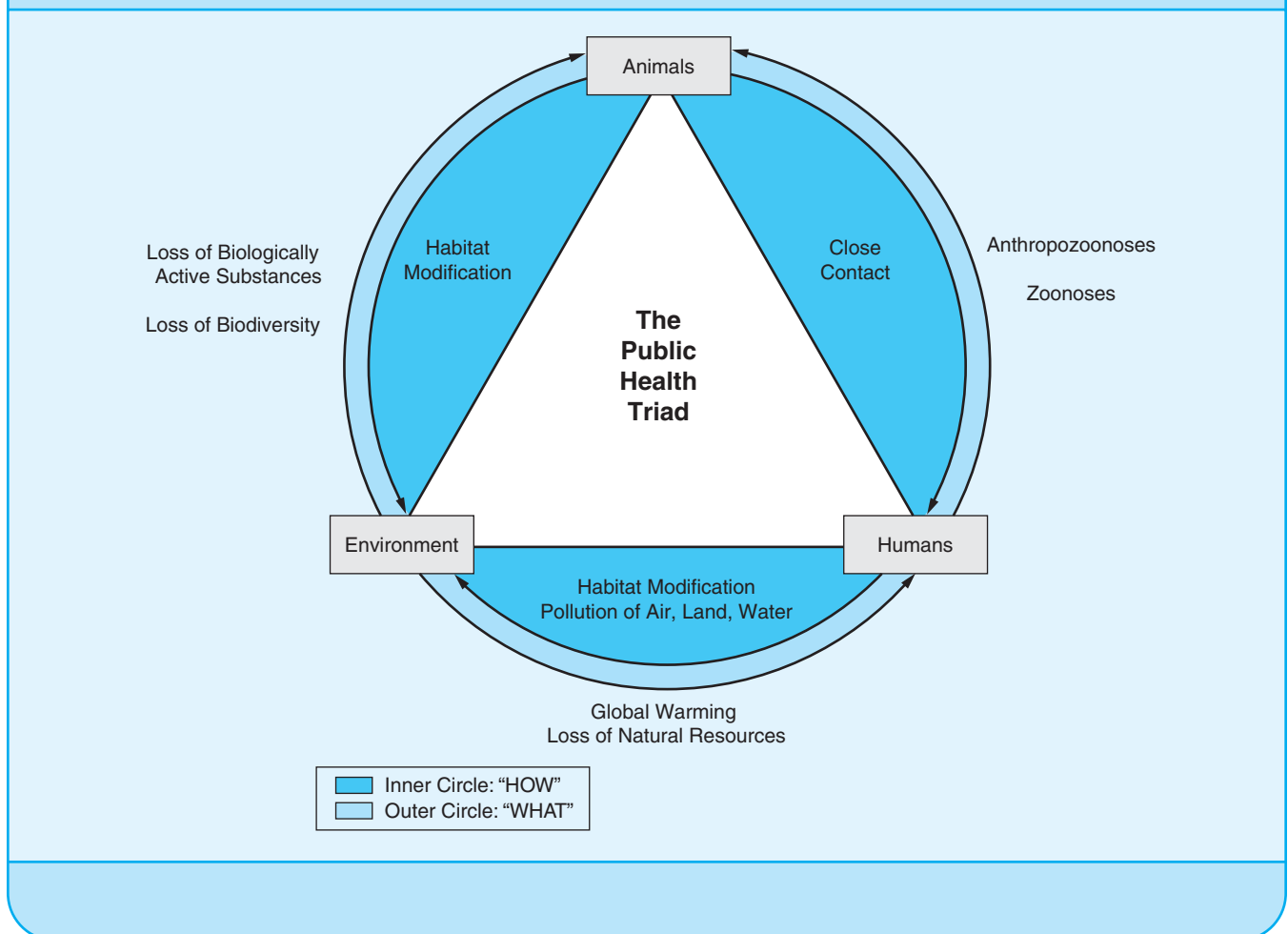
Established in 1948, WHO is the specialized agency for health under the United Nations. This organization deals with all aspects of health, including everything from emerging infectious diseases and nutrition, to biodiversity, alcoholism, and ethics. In addition to trying to link all aspects of the triad together, WHO recognizes that these links are much tighter in developing nations. Human populations in these areas work directly with animals for transportation, agriculture, and their own food supply much more often than in industrialized nations. Horses are used instead of cars, tractors are used for draught power, and their meats aren't cut and sealed in plastic wrap and waiting at the grocery store. The connections among humans, animals, and the environment are impacted to a greater extent by those relying on the rawest natural resources, of which most reside in underdeveloped or developing nations. One way that these close conditions can negatively affect public health is the increased incidence of zoonotic transmission.

Zoonoses

Many historical and current human diseases originated from animal hosts. A handful of these zoonoses and their hosts are: the plague (rodents), anthrax (cattle, sheep, goats, and other herbivores), epidemic typhus (rodents), tuberculosis (mainly cattle), Lyme disease (**vector borne** from rodents and deer), West Nile fever (vector borne from birds and some other small mammals), Ebola virus (undetermined animal reservoir), avian influenza (birds), severe acute respiratory syndrome (SARS; possibly several animal hosts including cats and ferrets but currently undetermined). The proximity of humans to animals harboring such diseases is a large factor for the emergence of these zoonoses. Humans who work with or live near animal species are at a much greater risk of contracting and perpetuating zoonoses as well as starting new epidemics. As humans expand their range into wild animal habitat, we are documenting the emergence of more zoonoses. We are also documenting the reemergence of zoonoses that were thought to have been controlled, such as bovine tuberculosis in Great Britain.¹

Bovine Tuberculosis in Great Britain

Bovine tuberculosis (bTB), caused by the bacteria *Mycobacterium bovis*, has the greatest host range out of all TB organisms, being able to infect all warm-blooded vertebrates.⁶ During the 1930s, a large portion of dairy cows were infected with *M. bovis* in Great Britain. This became a major public health concern because people drank the raw milk from infected cows, which increased the spread of the disease to include high density urban areas, Approximately 2,500 people

FIGURE 4-1 The Triad.

died per year from bTB during the 1930s in Great Britain.⁶ The disease was spread among cattle due to large numbers being closely confined and in poorly ventilated cowsheds, an ideal environment for this airborne disease. bTB is primarily transmitted through the exchange of respiratory secretions between infected and noninfected humans or animals. Over the subsequent 50 years, the voluntary and eventual compulsory testing and slaughter program helped to reduce the incidence of bTB and TB in humans to a very low level by 1980. However, there has been a rise in bTB incidence in the past 15 years and it is currently one of the most difficult animal health problems facing the farming industry in Great Britain. A long-term epidemiological study in Woodchester Park in southwest England shows the rise having been attributed to badgers, one of the natural reservoirs of the disease. Less than adequate cattle farming practices bring badgers into close contact with these domesticated species, increasing the risk of disease trans-

mission to cattle⁷ and ultimately to humans. Constant surveillance, routine testing, and effective barriers for badgers are some ways that can lessen the incidence rate of bTB. However, time and money are not always available to the farmer, and TB-infected badgers can contaminate cattle either by infecting their food supply or by direct contact.⁸ Therefore, many factors (cultural, financial, environmental, and biological) are affecting the rate of disease transmission of bTB in England. Public health officials are still figuring out the best course of action for curbing this **zoonosis**.

Human Immunodeficiency Virus (HIV) and Acquired Immune Deficiency Syndrome (AIDS)

One of the most devastating epidemics of the 21st century, HIV/AIDS has killed more than 25 million people since it was first recognized in 1981. HIV/AIDS infects children under the age of 15 EVERY MINUTE OF EVERY DAY, while over 90%

of the more than 5 million children who have been infected with HIV were born in Africa.⁹ Lack of education, resources, and the nonuse of prophylactics in many parts of Africa has led to the spread of the virus over the past 30 years. Some people believe that HIV/AIDS is not technically a zoonosis, due to the fact that the current primary mode of transmission is human-to-human. However, the disease has been attributed to the mishandling of contaminated animal products and therefore is relevant for our purposes of demonstrating relationships among the public health triad.

HIV is a retrovirus (which integrates itself into the host genome) that targets vital organs related to the immune system. The origin of HIV-1, the more common, virulent strain responsible for most AIDS cases, has been accredited to a subspecies of chimpanzee native to west equatorial Africa.¹⁰ It is still uncertain as to how the simian immunodeficiency virus (SIV) was actually transmitted to humans (which in turn became HIV), although many believe it was due to the bushmeat trade. It is believed that an infected chimpanzee killed by a human hunter who had an open wound when handling the carcass subsequently passed the virus to other humans. Incidence of HIV infection is still on the rise and much of the world is banding together to fight this horrible, debilitating disease, as there is still no cure. Many new treatments involving several forms of antiretroviral therapies are being developed, but have not been perfected yet for the masses due to large amounts of side effects as well as exorbitant prices.

Anthropozoonoses: Zoonoses Reversed

Additionally, anthropozoonotic transmission (human to animal) is a serious concern in zoos and national parks around the world. Certain “harmless” human sicknesses (such as the common cold) can be lethal in a novel host, a non-human primate for example. Tanzanian National Parks (TANAPA) require tourists and researchers to wear masks in Mahale National Park (and others) when viewing chimpanzees, specifically to cut down on possible diseases transmission from humans to the endangered population of wild chimpanzees of the region (Figure 4-2).

Zoonoses pose an obvious threat to both human and animal health. It is difficult to discuss the topic without taking the time to talk about its relation to the environment, specifically in the form of **habitat modification** (discussed below in the section entitled *Land*).

Pollution of Air, Water, and Land: How Humans Affect the Environment

Health of the triad is also linked to the changes in chemistry of earth’s air, water, and land. Many diseases and negative eco-

FIGURE 4-2 Acko’s Baby.



logical consequences are caused by humans spewing toxicants into the environment. The next section will address some of these problems for the triad, how they can be measured, and what humans have done to alleviate some of the problems that pollutants have caused to the triad.

Air

Air pollution has the ability to affect the triad on a global scale, as hazardous air pollutants have been seen traveling thousands of miles and having a severe impact on Earth’s atmosphere along the way. Pollution was first seen as a problem in the air within urban environments during the mid to late 1800s. Most of the pollutants at this time were soot consisting of sulfur dioxide (SO₂), volatile organic compounds (VOCs) such as benzene and toluene, and nitrogen oxides (NO_x), all from the burning of fossil fuels. By the mid 1900s, the effects of these pollutants were known to be lethal in urban centers where a large amount of factories produced such pollutants. To correct this problem in some areas, newer smokestacks were built taller and away from city centers. These actions helped the local residents of the city, but overall, the region was affected by an increase in acid rainfall as more of the pollutants were able to react with water, oxygen, and other chemicals naturally in the atmosphere. Pollution as well as the deposition of acidified rain can damage forests and lakes, which can increase the amount of fish kills in a particular area as well as have serious impacts on human health.

Air pollution is known to increase the risk of chronic respiratory disease and lung cancer, damage the liver and kidneys, generate reproductive complications, and can also exacerbate other existing health conditions for the triad. The Environmental Protection Agency (EPA) has estimated that with the full implementation of the Acid Rain Program (Title IV under the Clean Air Act) by 2010, the public health benefits will be valued at \$50 billion annually due to decreased mortality, hospital admissions, and emergency room visits alone.¹¹ The goal of the Acid Rain Program is to reduce annual SO₂ emissions 10 million tons below 1980 levels. This goal is to be carried out by the stricter regulations set on fossil fuel-fired power plants.

The most common chemicals found in the air today that are considered pollutants are still SO₂, VOCs, and NO_x; however, ground level ozone, carbon monoxide, and lead have been added in recent years.¹² Lately, more and more research is being published about the effect of increased CO₂ levels in the atmosphere, which contributes to global warming. Therefore, CO₂ has become a much more common air pollutant than in the past due to its higher-than-natural concentration in the atmosphere. Nearly all of these compounds are generated from the burning of fossil fuels from such activities as driving cars and trucks, electricity production from coal, manufacturing chemicals, and other large-scale industrial processes.

Air pollution in the United States is regulated by the EPA, and guidelines pertaining to air quality are outlined in the Clean Air Act. Under this law, first passed in 1970, the EPA set limits to how much of a pollutant can be in the air. Permits are now being issued to larger sources of air pollution that detail how much of and what type of pollutant may be expelled into the atmosphere based on how it affects humans, animals, and the environment. Economic incentives are being issued by the EPA for clearing the air of toxicants. One example of such an incentive is how gasoline refiners can receive credits if the gasoline they produce is cleaner than required. Those credits may then be used in place of paying a fine when their gasoline doesn't meet EPA's standards.¹³ However, industrialized cities are by no means the only areas feeling health effects from air pollution. Air pollution is affecting the triad on a *global* scale. Mean temperatures worldwide are rising, mainly due to air pollution caused by human actions (Figure 4-3).

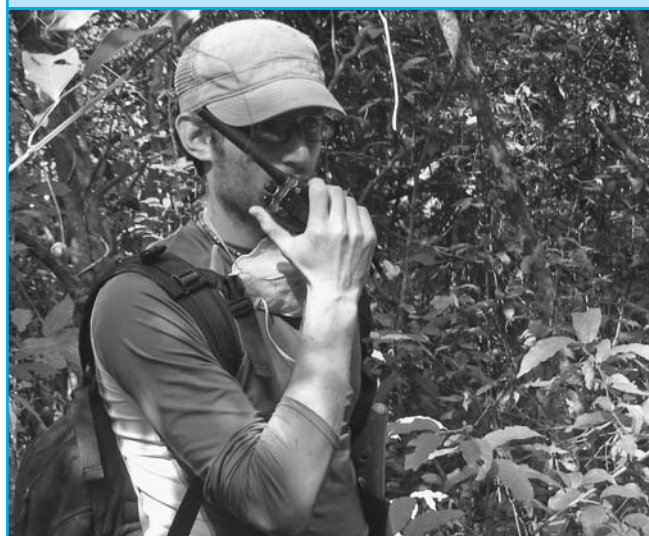
Global Warming: Human-Induced Air Pollution Has Its Consequences

Increased levels of greenhouse gases (CO₂, water vapor, methane, and ozone) in the air are caused by the combustion of fossil fuels and the changes of land use by humans.¹⁴ The “greenhouse effect” is a natural, essential process that warms

the earth enough to make it suitable for life. Without it, the Earth's surface would be approximately 33°C colder.¹⁵ It is the “enhanced greenhouse effect” that is contributing to the warming of the planet. More and more greenhouse gases are being expelled into the air due to the increased amount of carbon products that humans are using, which allows increased trapping of heat that is radiated from the earth's surface. The topic of whether global warming was even occurring has been debated since the 1970s. Within the past few years, more information has been brought into the public eye and to the desks of politicians (most scientists in the field have agreed with the theory for a number of years now). Finally, most of the world believes that global warming is occurring and that humans are playing an active role in the cause of this trend. It has been strongly speculated that due to human behaviors, increases in global mean temperature can influence disease transmission. Could driving to work every day be a biological basis for perpetuating disease?

Many disease-harboring parasites and vectors are affected by rainfall, humidity, and temperature. Temperature extremes may kill *Anopheles* mosquitoes (a species that carries malaria in Africa), but a slight increase in temperature from 19°C to 21°C shortens the interval between blood meals (the gonotrophic cycle). It can also increase their pace of development, thereby infecting more people at a faster rate.¹⁶ Malakooti's group have

FIGURE 4-3 Communicating with the Author's Laboratory: Bush2Base.



documented the emergence of epidemic malaria in a highland area of Kenya traditionally thought to be free of the disease due to its high altitude.¹⁶ Warmer mean temperatures have caused the expansion of the “mosquito line,” and these vectors are spreading disease at elevations they have never survived at in the past. Additionally, the rate of dengue virus replication in *Aedes aegypti* mosquitoes increases directly with temperature in the laboratory, and it was also found that epidemics of Saint Louis encephalitis virus and West Nile virus may be influenced by climatic factors.¹⁷ The chemistry of the atmosphere is changing in part due to human activity. Some consequences of the shift in chemistry are serious and already causing problems for the health of the planet. If we don’t have air in our lungs, in a sense, what do we have?

Water

Safe accessible water is a cornerstone for maintaining nearly all life on Earth. Potable drinking water is a necessity for the health and well-being of humans and animals. Water can be contaminated with a seemingly endless array of chemicals from a number of different sources, both natural and **anthropogenic**. The erosion of certain rock formations during natural flow and percolation of groundwater can lead to the buildup of minerals, some of which are radioactive. The prolonged exposure of drinking water contaminated with these minerals increases the risk of cancer to humans. The EPA also regulates water quality within the United States under the Clean Water Act (formerly known as the Federal Water Pollution Control Act Amendments of 1972). The Act allowed the EPA to set up standards for discharging any pollutant into waters of the United States. Point sources (PSs) such as industrial complexes, toxic waste sites, and manufacturing plants play a role in water contamination. The mishandling of harmful chemicals by both consumers and workers at the plants can aid this type of pollution. Some of the implications associated with the release of dangerous chemicals (VOCs, pesticides, and heavy metals) into the drinking water supply include chronic and acute health problems such as: cancer, damage to the immune system, liver and kidney disease, birth defects, and disorders of the nervous system. Non-point source (NPS) pollution comes from rainfall or snowmelt that travels over the ground and carries away pollutants for final deposition in lakes, ponds, rivers, wetlands, and underground sources of drinking water that can affect a large number of people simultaneously. NPS toxicants include: fertilizers, pesticides, oil and toxic chemicals from urban runoff, and improper management of animal by-products. Everything from cancer and birth defects to skeletal fluorosis has been attributed to contaminated waters. Nearly all of the water pollution discussed above is due to the poor containment of dangerous

chemicals by humans, thereby negatively affecting the triad once again.

Water can be contaminated with infectious disease particles also. Transmission of parasites such as *Cryptosporidium* as well as bacterial and viral infections (*Escherichia coli* and hepatitis A, respectively) can be spread by infected water. Waterborne infectious diseases are a major global problem, as it is estimated that nearly 1 million deaths worldwide are due to waterborne bacterial infections alone, caused by large poorly functioning municipal water distribution systems.¹⁸ The amount of fresh water available is dwindling as the human population grows. If we don’t find ways to use it more wisely, another one of life’s necessities will slowly vanish.

Land

Healthy plant growth and food production rely on the health of the soil in which the organism grows. Land contamination therefore has the ability to affect the food chain, which has an obvious application to public health. **Biomagnification**, the accumulation of a substance (in this case, a pollutant) up the food chain is one clear example of how higher trophic levels can be in serious danger. For example, land can be polluted with a hazardous chemical such as a harmful pesticide, which seeps into the soil and eventually resides in a plant to be eaten by a consumer, such as a cow. Granted, maybe only a trace amount of pollutant is within each blade of grass. But, if a cow eats nearly 40 pounds of grass a day, the concentration of pesticide within the cow will slowly rise, making it unfit to be eaten by humans. This is another case where humans are

Habitat Modification: Human Population Needs More Land. Who Suffers?

1. Can cause a loss of flood control as trees and other vegetation are uprooted.
2. Can cause a loss of beneficial species from which prescription drugs and vaccines are developed.
3. Can help to spread disease (zoonoses in particular) as more people are exposed to new arthropods harboring infections.
4. Slash and burn habitat modification can aid in the release of greenhouse gases that contribute to global warming.
5. Can cause ecological imbalances where there is a boom or bust of a certain species, which can negatively affect the food chain.

negatively affecting the environment. However, in this instance, a food-animal's health is put in jeopardy, which in turn could negatively affect the health of the humans who eat it. It comes full circle very quickly, and therefore affects us ALL. Additionally, the use of pesticides can have other affects on the triad. Certain pests may become resistant to pesticides. Consequently, the more robust species survive. After several instances of spraying ineffectively, a farmer may have to spray more often and in higher doses. But spraying massive amounts of pesticides on crops has its price. Some acute dangers to humans include headaches, dizziness, nausea, and fatigue. Long-term exposure through the food we eat can cause cancer, endocrine disruption, and multiple chemical sensitivity (MCS; a medical condition characterized by the body's inability to tolerate relatively low amounts of chemicals). Pesticides also can harm the environment. Beneficial insects, worms, and soil microorganisms may be killed from pesticides, in turn harming the plants that we are trying to protect in the first place. Essential plant nutrient concentration may be affected, causing too little or too much nutrient uptake by the plant roots.

Contamination of our air, water, and land is a considerable threat to the triad, causing acute health complications as well as diseases. It is imperative that we not lose sight of the larger goal to protect the planet by acting in a sustainable manner. Pollution is inevitable; however, the contents of the pollution and how we are disposing or recycling them make a large difference.

The term *habitat modification* is used instead of the word *deforestation* at times, but the term generally means the addition or subtraction of plants, animals, or man-made products to an ecosystem by humans. As human population is on the rise, the need for land is also growing. Cattle pasture remains the dominant land use once forests are cleared in the most heavily deforested state of Mato Grosso in Brazil.¹⁹ Rainforests that are modified to developed, agricultural or pasture land pose a twofold environmental complication: first, the loss of flood and erosion control can be significant, while the loss of plant and animal species affects the health of the ecosystem from the bottom up (in terms of the food chain, otherwise known as trophic levels). Second, if livestock is transported to the new pasture land, and wild animals also have a chance to fill a new niche in the recently cleared habitat, potential zoonoses threaten the local human population simply due to their close proximity to both wild and domestic animals.

Some land clearing practices are affecting the triad negatively, such as *slash and burn*, where forests are clear cut and burned, leaving fairly less fertile soil behind. This technique has been used for thousands of years. However, much more time between burnings was allotted in the past so the forest could recover properly. A farmer now may repeatedly slash

and burn, thereby leaving plots completely infertile. Much of the infertility comes from the loss of natural fertilizers. Under ideal conditions, decaying biomass such as animal waste, fruit, and leaves are quickly reabsorbed once returning to the forest floor. However, mismanaged farmland can lead to a loss of plant and animal species in the area, which translates to a loss of nutrients in the soil. The farmer then simply moves his garden plot to another area and starts again.

Many natural systems in these areas are becoming out of balance due to the loss of species caused by their destruction of habitat and food supply. This imbalance can cause droughts, floods, a boom or bust in a certain population of animals or plants, and the emergence of infectious diseases, all of which have a major effect on public health.

Increased Disease Occurrence

Infectious diseases can arise when rainforests and other habitats turn into pasture/cropland or are cut for the logging industry, for example, when loggers invade a particular forest and find themselves in close proximity to disease-causing agents. Mayaro and Oropouche virus infections in Brazilian woodcutters in recent years are due to exposure to new arthropods and the viruses they carry.²⁰ Mayaro and Oropouche viruses are nonfatal mosquito-borne diseases that are commonly mistaken for dengue fever. Large outbreaks have occurred throughout Amazonia, with more cases seen every year. While loggers are venturing into newly acquired forests, these workers may not be given the necessary education or equipment (mosquito nets, insect repellent, sufficient clothing) to ward off the arthropods and the emerging infectious diseases they carry. Consequently, after areas have been cleared, more land is available for domesticated or wild animals to spread disease and expand their range as discussed earlier. It is simply the closer proximity of wild and domestic animals that aid pathogens to "jump" species. A pathogen that has a regulated life cycle (typically low virulence) within one host may not be the same in another closely related host and might be lethal to the new host harboring such a novel pathogen. This poses problems for domestic animals as well as wildlife and of course humans.

Yellow Fever

Yellow hemorrhagic fever is caused by an arbovirus found in South America, Africa, and the Caribbean. It is transmitted between humans and some new world primates, with mosquitoes being the primary vector. In South America, sporadic infections occur almost exclusively in forestry and agricultural workers.²¹ Monkeys, infected by mosquitoes carrying the disease, pass the virus on to other mosquitoes, which in turn can

infect humans entering tropical forests. Urban yellow fever results when travelers and workers from rural and forested areas harboring the disease venture into major cities. Therefore, an increase in workers entering tropical forests (for deforestation activities or otherwise) provides an increased chance for urban yellow fever epidemics to occur once the workers return to their city centers. Also, varying cultural and political facets prolong the problem, as many high-risk undeveloped and developing countries are ill-equipped to distribute vaccinations and educate the public.

Reduction in Biodiversity: Humans May Be the Cause of Species Loss

The last great extinction event took place 65 million years ago at the end of the Cretaceous period with the demise of the dinosaurs and the subsequent radiation of small mammals. An extinction event describes the rapid loss (a relative term here, as some extinction events lasted more than 10 million years) of a large number of species. Using the fossil record to determine such extinction events, the remains of a certain taxonomic class (mammals, reptiles, fish, etc.) are no longer present and are therefore considered to have gone extinct. The largest of such extinction events (The Late Devonian extinction) occurred 360 million years ago, with nearly 70% of all species going extinct.

Some biologists refer to the present time period as “the sixth extinction” as more species are being recorded to have gone extinct every year. Humans are continuing to destroy other species at an astonishingly faster rate than the previous five extinction events.²² Evolutionary and geological scientists have described human activity to result in species extinction rates to be anywhere from 100 to 10,000 times the pre-human rate, although these numbers are still highly debated. The loss of biodiversity is largely due to the decline of sustainable habitat from human encroachment (increase in pasture, agricultural, and developed land to support the growing human population).

Humid tropical forests are the location of almost half of all species in the world.^{23–25} The largest area of such forests is in the Amazon rainforest of Brazil. Between 1990 and 2005, 42 million hectares (approximately the size of California) of forest were cleared. Scientists are now gathering and analyzing current rates of deforestation, which appear to be slowing down due to the increased awareness of the effects of deforestation.²⁶ This corresponds to nearly a 20% reduction of the Amazon rainforest since 1970, when scientific land destruction research in Brazil first began. Many highly specific arthropod species are only found on several hectares of forest and nowhere else in the world. If their habitat is destroyed or modified, these species could be lost forever. Humans are squander-

ing the opportunity to learn from and develop the species we are eradicating through habitat modification.

Loss of biodiversity negatively affects both our physical health and our ability to enjoy the natural world. Although not all humans are emotionally enriched by spending time close to nature, many people enjoy hunting, gardening, fishing, and camping. Whether or not someone enjoys being outdoors, there are large consequences to our *physical* health by the reduction in biodiversity. We risk the loss of biologically active substances (BAS) that are used to treat diseases in animals and humans, as well as other environmental health crises.

Loss of Prescription Medication and Vaccines

BAS affects the metabolic activity of living cells and therefore is extremely valuable to medical and pharmaceutical sciences. Over the past several millions of years, species have developed highly specific BASs that are of great use to humans to directly fight disease or gain knowledge through medical models to combat disease. It is no wonder that natural products have been the ultimate source of medicines for thousands of years, but you may not know that they are still the primary source for which new prescription drugs are designed.²⁷ With each species that goes extinct, we are risking the loss of cures for such diseases as AIDS, cancer, human to human avian flu (if it ever mutates), and many more.

The top two selling prescription drugs for the year 2005 in the United States are the cholesterol-lowering drugs atorvastatin and simvastatin, both of which are synthetically modified versions of a fungal-derived chemical.²⁸ Additionally, aspirin, codeine, morphine, colchicine (anti-tumor), (l)-dopa, vincristine (anti-tumor), quinine (anti-malarial) as well as approximately **75% of the top 20 hospital drugs** (mostly antibiotics) and approximately **20% of the top 100 most widely prescribed drugs** are derived from natural sources.^{29,30}

Taxol

Taxol is a cancer fighting compound that works in a significantly different way from other chemotherapeutic techniques, in that it prevents cell division specifically by inhibiting disassembly of the mitotic spindle.³¹ Taxol is extracted from the Pacific yew, once discarded as a trash tree during logging of old growth forests in the Pacific Northwest.²² In early clinical trials, taxol was able to induce remission in cases of advanced ovarian cancer that were unresponsive to other treatments.³² After recognition of the importance of the Pacific yew, many environmental campaigns used the tree to save ancient forests in Washington state, Oregon, and northern California. The possible cure for ovarian and breast cancer was overlooked for many years. Now, the Pacific yew is not only able to help save

CASE STUDY

Love Canal

Love Canal, located in Niagara Falls, New York, was named after William T. Love, who had a vision of creating a modern community. He thought that by creating a canal between the upper and lower Niagara Rivers, power could be generated to run the industry and homes in the immediate area. Alternating current was the invention that allowed electricity to travel large distances, but by 1910, Love's vision faded away. A partially built canal was all that could be seen in the area. The site was sold to the City of Niagara Falls in 1920 to be used as a municipal waste disposal site. Love Canal was such a fitting place as there was an unpopulated surrounding area and a large hole existed already. In 1942, Hooker Chemical and Plastics (HCP) expanded use of the site and buried more than 20,000 tons of chemicals over the following 10 years.³³ The site was reportedly covered with several feet of dirt in 1953 and subsequently sold to the Board of Education for one dollar. The deed spoke of a "warning" of the chemical wastes under the site; however, the Board of Education and the local residents were not fully aware of the consequences they could face in the future. Some also believe that other options should have been entertained by the Board of Education and the town before building a school on a known chemical waste disposal site.

From the mid 1950s through the 1970s, residents of Niagara Falls complained of unfamiliar odors and actual substances coming from the ground, which were covered with earth and clay by city workers. More and more complaints were being filed every year, and cancer and birth defects began to be more prevalent within the community. In 1978, President Carter declared a federal emergency and permanently relocated 239 families who lived in the first two rows of homes that surrounded the landfill. Several other evacuations occurred throughout the following two years. Blood tests conducted by the EPA in 1979 concluded that the residents of Niagara Falls had chromosomal damage and were at risk for genetic disorders, cancer, and reproductive complications, in part due to the chemical dioxin from the hazardous waste. The unmistakable and serious health effects associated with the mishandling of toxic waste prompted President Carter to sign the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980. One of the first impacts of CERCLA was the prompt relocation of all residents who wished to be relocated out of the small Niagara Falls community. A large impact that CERCLA had on the nation was the charging of very high taxes on the chemical and petroleum industries to create a "Superfund," the act's more commonly used name. Superfund would be used to clean up the nation's poorly maintained hazardous waste sites that posed a current or future threat to human health, animals, or the environment. Nearly \$1.6 billion was collected in only 5 years under Superfund, for use in cleaning up Love Canal among several other sites.³⁴ New sites are found every year, and superfund is now beginning to struggle as more and more serious risk sites are found, which are called National Priorities List (NPL) sites. Most cleanup processes are anything but fleeting, and as each site requires long-term monitoring, more money is needed all the time. Currently, the EPA has more proposed NPL and other sites than there are funds available to start work.

Human's mishandling of hazardous chemicals at Love Canal caused severe public health concerns and made the public aware some of the dangers associated with less than adequate disposal practices. Despite that the story of Love Canal examined environmental contamination as a serious public health problem in the United States, dangerous chemicals and other hazardous materials are still being deposited into the environment irresponsibly. Some offenders continually fail to see connections between polluting the environment and the associated health risks. Humans are surely part of the problem, but we also are the only ones that can actually be a part of the solution. Sadly, many people know the risks associated with polluting the earth but either do not care or do not want to pay the costs associated with disposing various materials according to law. Others simply are not aware of the "big picture" of how pollution can be a serious problem for the triad, which unknowingly includes the polluters themselves and generations to come.

cancer patients, but it is also used to help save old growth forests, which are a much-needed natural resource. Old growth forests tend to be an extremely biodiverse area that in turn could host many more beneficial substances like taxol. Pharmaceutical companies, non-profit organizations, and many scientific researchers are continuing to scour the earth for

more BASs, as the need for newer drugs, vaccines, and medical models is ever-growing.

CONCLUSION

Ultimately, the need for more interactions to be described among humans, animals, and the environment is great. Knowing

the effects of altering earth's atmosphere, waterways, and land is inherent to our future as a species and—more importantly—of the planet. Is there a “point of no return” with regards to deforestation, and, if so, have we already passed that point? Can we reverse global warming? Why do zoonoses account for nearly 75% of emerging infectious diseases? Should air pollution standards be raised in certain areas? Researching these and other interactions among the triad will enable us to preemptively strike against threats to public health such as environmental contamination and the spread of disease. Additionally, the research of vital biochemical pathways can be performed that may lead to new vaccines and prescription drugs.

Throughout the chapter, we have demonstrated that some ecological and disease-related problems are caused by humans. A portion of these problems can be solved by knowing the consequences of our actions to us and the rest of the triad. William Karesh, in an interview with National Geographic, summed up the public health triad succinctly: “It’s not about wildlife health or about human health or about livestock health. There’s really just one health—the health and balance of ecosystems throughout the planet.”³³ Therefore, the more connections we can describe, the more preventative measures can be taken to protect public health.

Environmental causes of health problems include both natural and anthropogenic forces. Most of these causes are understudied, complex, and found all over the globe. Conservation medicine practitioners form interdisciplinary panels to study these environmentally related health problems. Teams are formed by vastly diverse types of researchers including: epidemiologists, microbiologists, environmental engineers, anthropologists, veterinarians, and public health scientists. The goals of the teams are twofold: to improve overall ecosystem health and tackle the social and environmental problems that are causing disease or other complications for the triad. The Consortium for Conservation Medicine is a unique collaborative institution that strives to understand the link between anthropogenic environmental change, the health of all species, and the conservation of biodiversity.³⁵ Several schools of public health, including Johns Hopkins

University and the University of Pittsburg, as well as the United States Geological Survey National Wildlife Center, are key partners in CCM. This is one of many organizations dedicated to conservation medicine and the public health triad.

As several billion more people will populate the earth this century, more land will be deforested, more raw materials consumed, more pollutants created, and more stresses will be put on the environment. Demands for clean air, water, and useable land will increase during this time as well. A change of thought must be embraced within the global community. Although people believe that we are the most important species, we are merely one among millions, and our health and welfare depend on the strength of our environment and all the species it contains.

KEY TERMS

Anthropogenic: Ideas, actions, products, or effects that are caused or produced by humans.

Anthropozoonosis (pl. anthropozoonoses): Infectious diseases that can be transmitted from humans to animals.

Biodiversity: The number, variety, and range of different organisms (and their genes) located within an ecosystem.

Biomagnification: The accumulation of an element or compound up the food chain

Biologically Active Substance (BAS): A substance that has the ability to alter a biological function of an organism.


Conservation Medicine: A dynamic biological discipline that describes the relationships among human-induced environmental impact, public health, and the conservation of endangered species or ecosystems.

Habitat Modification: The addition or subtraction of plants, animals, or man-made products to an ecosystem that is performed by humans.

Pathogen: An infectious biological agent that causes disease.

Vector Borne Diseases: Infectious diseases, both bacterial and viral that are transmitted via an arthropod.

Zoonosis (pl. zoonoses): Infectious diseases that can be transmitted from animals to humans.



Questions for Further Research, Study, Reflection, and Discussion

For the Individual Student

In order to answer these questions, it may be necessary to research the primary literature.

List 4 problems associated with habitat modification.

- What is non-point source (NPS) pollution? How can it affect public health?
- What is WHO, and what is its purpose?
- What percent of emerging infectious diseases are zoonotic? Name some of the reasons why that percentage is so high.
- What is the CCM? What are their conservation goals, and how are they achieved?
- How are slash and burn farming techniques bad for the triad?

For Small Group Discussion

- Should Superfund have been passed earlier than 1980? If so, then why and when?
- Who are all the parties to blame for Love Canal, and why?
- Under Superfund, chemical and petroleum industries were taxed very heavily. Should any other industry or group be taxed with such harshness? If so, then why?

For Entire Class Discussion

- Why is biodiversity important to our physical and mental health?
- First, what defines a species? Next, what species are most important for the health and well-being of the planet? Should ALL species on the planet be

conserved if they are all potentially useful? Which ones could we do without?

- What is the biggest environmental threat that leads to an increase in disease occurrence? Nuclear waste, air pollution, industrialization, urbanization, land modification, poor farming practices? Think of more causes and write them down. Split into a group of five to six, and have each person research one threat outside of class. Make your case to the rest of the group about why your threat is the most severe.

EXERCISES/ACTIVITIES

- Go to your local zoo. If there is no zoo in the area, you may go to a zoo's Web site, although this is not preferred.
- Find at least three animals at the zoo that are endangered or threatened. Write down why each species is at risk for extinction. There should be a placard with this information near each exhibit.
- Once you've fully enjoyed your visit to the zoo, now it's time to do some research. Determine the niche of each species (how it interacts with the other species in its environment). Is it a top predator, a scavenger, a bottom-feeder? What purpose does it serve for the surrounding environment? Determine if the animal has a mutually beneficial species associated with it. For example, several bird species will perch themselves on large mammals like buffalo, which are a source of ticks and other arthropods. The birds get a meal, while the large mammals get groomed and subsequently have fewer disease outbreaks.
- Now, focus on one species in particular. List as many effects as possible that would arise from that animal's extinction. Are any biological active substances associated with the animal or animals similar to it? Does another species rely on it for survival? Try to think from as many different angles as possible. What might happen to the triad and why?
- Write a one page summary of what would happen to the world if your species went extinct.

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