ABSTRACT

The Status of One Health Education Among Undergraduate Pre-Health Students

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One Health is collaborative, multidisciplinary approach to solving and studying health issues, from the local to global level, with special consideration given to the interdependency of human, animal, and environmental health. This thesis first dives into the history of One health and all the collaborative interactions between human and animal medicine. Then it will explore the data from a survey of Pre-Health students at Baylor University. In this survey, it was found that only 5.8% of students had heard of One Health and that these students seemed more knowledgeable about zoonotic disease. The vast majority of students agreed that One Health concepts would be useful to know in their future careers and expressed a desire to learn more about them. Lastly, this thesis argues the all healthcare professionals should be familiar with One Health concepts because they help provide a broader context for understanding human health, help impart knowledge about zoonotic diseases and how they can affect their patients, and it teaches how to think and work cooperatively with their colleagues and professionals in other fields. Also, undergraduate education is the best place to introduce One Health to students because of the natural collaborative and multidisciplinary environment in college.

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The Status of One Health Education Among Undergraduate Pre-Health Students

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CHAPTER ONE

History and Definition of One Health

Introduction

The connections between humans, animals, and the environments they share have long been acknowledged by humanity. The health of humans is closely linked to the health of animals we come in contact with, as well as the health of the environment we live in. Respect for our land and our careful raising of our animals has been part of the cultural and, sometimes, spiritual beliefs of civilizations throughout our history (Evans & Leighton, 2014). Although they did not have a term such as "One Health" to help define the concepts they discovered, humans have used these concepts to shape human behavior and societal practices, nonetheless. Because of this, the history of One Health and the application of its concepts goes back much farther than the first coining of the term. To fully understand the development of the broad, complex idea of One Health, it is necessary to track its progression from ancient times to modern times. This chapter will aim to display the rich history of One Health, highlighting important moments and influential people. After tracking the progress of One Health through, a comprehensive definition will be developed.

Early History

About 11,000 years ago, human civilization experienced a significant shift towards agriculture. With a stable food supply, there was no reason to live a migratory,

hunter/gatherer lifestyle. This marked the start of the development of large cities where vast populations lived together with other humans in closer quarters than ever before. As early as 3500 B.C.E. Egyptian hieroglyphs show the domestication of animals (Fox, 2014). With the rise of animal domestication, humans were now also keeping livestock, meaning farmers now had closer and more frequent contact with animals than their ancestors before them. This new human-animal dynamic created the perfect setting for animal pathogens to transfer to humans and evolve to become capable of infecting large populations of people (Wolfe et al., 2012).

Ancient civilizations were very much aware of how connected their own health was to the health of their domesticated animals. Aristotle studied the comparison between human and animal anatomy with Hippocrates following suit after him (Fox, 2014). Hippocrates wrote in Airs, Waters, and Places that climate and environmental conditions have an effect on human health while also hypothesizing that the "bad air" that makes humans sick could similarly make animals sick (Capua & Cattoli, 2018).

Egyptians took One Health approaches to human medicine by comparing animal and human health. The Papyrus of Kahun, from Egypt around 1900 B.C.E., is regarded as one of the first medical and veterinary texts. It is the first written document that lists three veterinary diseases, their probable causes, and treatment options (Lord, n.d.). Even though these diagnoses and treatments were likely not very effective, the documentation of established veterinary practices in the Papyrus of Kahun shows a desire from the Egyptians to keep their animals healthy. The treatment of sick livestock could be to keep them alive for more food supply, but it also has a definite One Health aspect to it. There is evidence that ancient priests who cared for both sick humans and sick animals learned

much about animal anatomy and physiology from sacrificial killings (Fox, 2014). Humans were thinking about and acknowledging the relationship between themselves and the animals they interacted with.

There is a clearer One Health link in early approaches to preventing rabies infections. Because there are obvious signs of transmission of rabies from a rabid dog to humans that it bites, it makes sense that the connection was made between rabid animals and rabies. The Persian Avesta written around 200-400 C.E. says that rabies could be prevented by stopping bites from rabid dogs. Earlier, around 60 C.E., it was suggested that cutting off the tails of puppies at forty days old would prevent them from getting rabies if they are bitten. We know now that this strategy would not work but attempting to prevent diseases in animals in order to ultimately prevent diseases in humans is a distinct One Health concept. It was used in this scenario to help prevent the spread of rabies in a time before much was understood about viruses and infection (Tarantola, 2017).

18th to 20th Century History

There seems to be a lull in the development of One Health concepts until the early 18th century during the spread of rinderpest among cattle in Europe. Rinderpest was plaguing cattle herds across Europe and severely damaging economies, so Pope Clement sent his personal physician, Giovani Lancasi, to help investigate and resolve the rinderpest epidemic. Lancasi's proposal was to keep herds separated from each other. This quarantine measure was unique at the time because the idea of a contagious disease was not yet known, but it was highly effective in containing rinderpest. The rinderpest epidemic which caused mass casualties of cattle around Europe sparked a vested interest

in veterinary medicine and disease research. Ultimately, the epidemic was the reason that the first school of veterinary medicine was created in 1761 in Lyon, France (Cowen et al., 2016). This school, founded by Claude Bourgelat, taught students about animal health and its effect on human health (Evans & Leighton, 2014). Governments from around Europe sent their physicians to the Veterinary School in Lyon because they thought that the risk of another epidemic like rinderpest was too dangerous. The students took their new knowledge about animal diseases back to their own countries and implemented animal disease investigation programs which led to great progress in developing the body of knowledge about animal disease in the scientific community (Cowen et al., 2016). Having human physicians train in veterinary medicine was a significant milestone in the 18th century, leading doctors to build their own bridges between human and animal medicine.

One of the most important developments in One Health came from Edward Jenner in the late 18th century. Jenner was a natural scientist from rural England, where he had plenty of contact with farmers and others in the dairy industry. He heard a woman talking one day about how she believed she would never get smallpox because she had been exposed to cowpox before. Thinking this was an interesting connection the milkmaid had made, Jenner decided to test this experimentally. On May 14, 1796 Jenner gave the first ever vaccine to a young boy. The vaccine was comprised of pus from a lesion on a milkmaid infected with cowpox injected into the boy. The creation of this vaccine required incredible insight from Jenner who had to make the connection between the cowpox and smallpox infections and devise a way to transfer the immunity from one human to another. However, Jenner was not new to One Health concepts as the pupil of

John Hunter, regarded as the Father of Modern Surgery. Under Hunter, Jenner studied comparative anatomy and was trained as a surgeon with a One Health orientation. Hunter was interested in animal medicine and anatomy and thought that much could be learned through comparison of human and animal anatomy (Cowen et al., 2016).

Another figure important to the development of One Health from the 19th century was the physician, Rudolf Virchow. Virchow was a physician and pathologist, often referred to as the father of comparative medicine, cellular biology, and veterinary pathology. He created the new field of cellular pathology, the study of disease processes on the cellular scale. Looking at disease microscopically provided fresh perspectives into how disease could be diagnosed as well as the discoveries of things like leukemia and the existence of myelin (Schultz, 2008). After studying *Trichinellas* spiralis, a roundworm found in pigs, Virchow became interested in the connection between human and animal medicine due to similarities in disease processes in humans and animals (Gyles, 2016) (Zinsstag et al., 2011). He believed that human and animal disease were two sides of the same coin. They were different in detail but still similar on a deeper level. We can see this view summarized when he said, "between animal and human medicine there are no dividing lines – nor should there be. The object is different but the experience obtained constitutes the basis of all medicine." Most notably, Virchow is known for his coining of the term "zoonosis" in 1855 which is the modern word for the transmission of disease between animals and humans (*Zoonotic Diseases and the Possibilities with EBV Monitoring | Wilson Center*, n.d.).

In addition to his medical achievements, Virchow was also a champion of public health. He believed that health outcomes could improve if social and economic

conditions improved. When a typhus epidemic broke out, he was part of a commission to investigate, and his report detailed that the best remedy would be improving social conditions that were conducive to the spread of the disease (Schultz, 2008). He recommended providing the affected area with better infrastructure, better education, and more freedom (Capua & Cattoli, 2018).

Virchow's legacy was passed on through Sir William Osler, a Canadian physician with many accolades to his name. Osler revolutionized medical education in North America and became known as the father of modern medicine. He helped found Johns Hopkins School of Medicine, and he established a new medical curriculum that gave medical students real clinical experience before graduation. Before this, he also made progress in the One Health field. After studying under Virchow, Osler moved back to Canada and held positions at McGill University medical school and Montreal Veterinary College where he implemented the ideas of comparative medicine and comparative physiology. At the veterinary school, he taught parasitology and physiology before creating a veterinary pathology curriculum using the autopsy techniques he learned from Virchow. He researched several veterinary diseases such as dog bronchitis, hog cholera (swine fever), and Pictou cattle disease among others. He only kept his veterinary faculty position from 1876 to 1884, but still achieved great strides in veterinary medicine (Kahn et al., 2007).

Throughout the 19th century, there was an extremely high amount of cooperation and collaboration between doctors and veterinarians. In a time riddled with sickness, efforts were made by both parties to investigate the true nature of these diseases. Doctors focused on analogous diseases found in animals, to learn more about pathological

processes in human diseases. One important reason for this was that the prevailing theory of the time was that epidemics were caused by something "bad" in the air, so it was likely that these diseases affected animals and humans similarly. Animals were used for experiments and studied to find how structure, function, and habits affected disease expression (Woods & Bresalier, 2014). In these investigations by doctors, the knowledge of veterinarians was heavily relied on. Doctors required their expertise in veterinary disease and their clinical experience from their years of veterinary practice in order to find connections between human and animal disease (Woods & Bresalier, 2014).

There was a shift in the medical community's attention in the late 19th century. Zoonotic disease became the primary focus and became a topic of division among doctors and veterinarians after so many years of cooperation. In Britain, the government took charge of human and animal health issues. They hired veterinarians to control contagious animal diseases in order to help their trade and agricultural economy. They hired public health doctors to ensure sanitary conditions of livestock to ensure consumers did not consume contaminated or rotten food (Woods & Bresalier, 2014). This placed the issue of zoonotic disease into the jurisdictions of both doctors and veterinarians, leaving no clear answer as to who was ultimately responsible. Doctors and vets began quarrelling rather than working together. Doctors began questioning veterinarians' knowledge about their own field and vets began questioning the work of public health doctors as well. The previous era of cooperation and collaboration between veterinary medicine and human medicine was over, marking a temporary cease in One Health progress (Woods & Bresalier, 2014).

The industrial revolution in the early 20th century was another reason for a waning in the One Health movement. The growing popularity of railroads as the primary means of long-distance transport decommissioned the horses and oxen that were the focus of veterinary study. The first cars were beginning to take the place of the horse and carriage. The need for veterinarians and animal medicine research in the past had been to keep the animals that society depended on healthy. Suddenly the profession had much less of a purpose in society (Cardiff et al., 2008).

One Health history experienced another lull in development until the work of two important figures revived the emphasis of One Health in the mid 20th century. The first is James Steele, an ambitious man who pushed for the integration of his two fields of study, veterinary medicine and public health. After joining the United States Public Health Service (USPHS) in the middle of World War 2, he pushed for the formation of a new branch of the USPHS that focused on zoonotic disease. He created the new Veterinary Corps of the USPHS which was the first organization of its kind. Steele then went to work for Dr. Joseph W. Mountin at the newly formed CDC and created the Veterinary Public Health Division (*History | One Health | CDC*, 2020). Their first project was to build rabies programs in several states, sending Veterinary Officers to handle rabies crises using epidemiological principles. It was a highly effective initiative, prompting states to create their own funding for similar programs (Cowen et al., 2016).

The early success of the USPHS veterinary public health program led to more confidence from the CDC, a relatively new organization and a similar program was created there. Steel began to work at the CDC under Dr. Alex Langmuir, a well-respected physician who was the director of the Division of Epidemiology. Under Langmuir's

mentorship, Steele made many new connections and relationships with important people from the CDC and the NIH. He used these connections to promote his ideas about veterinary public health and start even more important programs. He helped form the public health section of the American Veterinary Medical Association (AMVA) as well as the AMVA specialty board on Veterinary Public Health. Steele gave lectures at universities and veterinary schools all across the world, spoke at World Veterinary Association meetings, and chaired conferences of the WHO/FAO Expert Committee on Zoonosis (Cowen et al., 2016). It is said that the Veterinary Public Health unit of the WHO was created because of his work (Evans & Leighton, 2014).

The second man to help revitalize One Health in the medical world was Calvin Schwabe. Schwabe was a veterinarian who had a background in parasitology and zoology. His career started when he became the founding chair of the Department of Epidemiology and Biostatistics at the School of Medicine and School of Public Health at the American University of Beirut. During this time, he researched many parasitic diseases and directed some WHO programs on parasites. Like Steele, he attended WHO Expert Committees on Veterinary Public Health. He took a job as the founding chair of the Department of Epidemiology and Preventative Medicine at UC Davis Veterinary School and as professor of Epidemiology and Parasitology at the School of Medicine at UC San Francisco. Here he came to be considered the founder of veterinary epidemiology when he was the first to employ human disease tracking techniques with animal diseases (Atlas, 2013).

Schwabe's greatest contribution to One Health history was likely his writing. He was particularly interested in the intersection between human health and veterinary

medicine in history, and he decided to write the first textbook on the subject. In 1964, Schwabe published the first edition of "Veterinary Medicine and Human Health". The book explores the history of the connection between the two titular topics and analyzes the ways they have interacted throughout history. It also looks at the dynamic ways that veterinary medicine contributes to human health in the modern age. Most importantly, the book coins the term "One Medicine" which is the direct predecessor to the One Health term used today. One Medicine refers to a two-part system comprised of the integration of human health and animal health, whereas One Health is an evolution of the term adding environmental health into the mix. Through his writings and teachings, Schwabe very effectively shared his views on the multifaceted role that veterinary medicine plays in public health. Because most human diseases are derived from animals, Schwabe advocated that the field of veterinary medicine is an essential part of the public health fight against more than just zoonotic disease (Calvin W. Schwabe, 1984).

Modern History

The One Health movement continued its momentum right into the 21st century and hit a huge spike in 2004. Robert Cook, William Karesh, and Steven Osofsky of the Wildlife Conservations Society put together a conference that would establish a place for One Health for many years to come (Gibbs, 2014). International experts in several disciplines were invited to New York to discuss and respond to the dangers of emerging diseases. It was here that the term "One World – One Health" was first used, cementing the use of One Health as the term we know today. At the conference, there were twelve principles or recommendations for "establishing a more holistic approach to preventing epidemic disease and for maintaining ecosystem integrity for the benefit of humans, their

domesticated animals, and the fundamental biodiversity that supports us all." The recommendations are as follows:

> 1. Recognize the essential link between human, domestic animal and wildlife health and the threat disease poses to people, their food supplies and economies, and the biodiversity essential to maintaining the healthy environments and functioning ecosystems we all require.
>
> 2. Recognize that decisions regarding land and water use have real implications for health. Alterations in the resilience of ecosystems and shifts in patterns of disease emergence and spread manifest themselves when we fail to recognize this relationship.
>
> 3. Include wildlife health science as an essential component of global disease prevention, surveillance, monitoring, control and mitigation.
>
> 4. Recognize that human health programs can greatly contribute to conservation efforts.
>
> 5. Devise adaptive, holistic and forward-looking approaches to the prevention, surveillance, monitoring, control and mitigation of emerging and resurging diseases that take the complex interconnections among species into full account.
>
> 6. Seek opportunities to fully integrate biodiversity conservation perspectives and human needs (including those related to domestic animal health) when developing solutions to infectious disease threats.
>
> 7. Reduce the demand for and better regulate the international live wildlife and bushmeat trade not only to protect wildlife populations but to lessen the risks of disease movement, cross-species transmission, and the development of novel pathogen-host relationships. The costs of this worldwide trade in terms of impacts on public health, agriculture and conservation are enormous, and the global community must address this trade as the real threat it is to global socioeconomic security.
>
> 8. Restrict the mass culling of free-ranging wildlife species for disease control to situations where there is a multidisciplinary, international scientific consensus that a wildlife population poses an urgent, significant threat to human health, food security, or wildlife health more broadly.
>
> 9. Increase investment in the global human and animal health infrastructure commensurate with the serious nature of emerging and resurging disease threats to people, domestic animals and wildlife. Enhanced capacity for global human and animal health surveillance and for clear, timely information-sharing (that takes language barriers into account) can only help improve coordination of

responses among governmental and nongovernmental agencies, public and animal health institutions, vaccine / pharmaceutical manufacturers, and other stakeholders.

10. Form collaborative relationships among governments, local people, and the private and public (i.e.- non-profit) sectors to meet the challenges of global health and biodiversity conservation.

11. Provide adequate resources and support for global wildlife health surveillance networks that exchange disease information with the public health and agricultural animal health communities as part of early warning systems for the emergence and resurgence of disease threats.

12. Invest in educating and raising awareness among the world's people and in influencing the policy process to increase recognition that we must better understand the relationships between health and ecosystem integrity to succeed in improving prospects for a healthier planet.

These recommendations became known as the Manhattan Principles (One World - One Health, n.d.). During a time plagued by emerging disease and fear of a possible global pandemic, the Manhattan Principles served as a catalyst for a wave of collaboration and clearly marked a direction for One Health efforts and research.

The CDC One Health office was established in 2009 (*History | One Health | CDC*, 2020). This was followed by a tripartite agreement made in 2010 between the WHO, FAO, and OIE to address the health risks existing at the human-animal-environment interface. These three organizations recognized the need for an international collaborative framework for combating problems concerning animal disease and zoonosis (*WHO | The FAO-OIE-WHO Collaboration*, n.d.).

The arrival of COVID-19 tested these partnerships and frameworks that were put in place, and they could not stand to the task. Granted, COVID-19 is unlike anything seen before and pandemic mitigation measures only work if they are effectively implemented and enforced by governments, but, ultimately, the world was not prepared for the

pandemic that was feared in the early 2000s despite the One Health movement. The One Health approach is arguably the world's best weapon in preventing devastation from emerging disease, yet students entering the health field are not aware of One Health and its important initiative. Hopefully, the lessons learned from the COVID-19 pandemic will reinvigorate recognition of One Health and bring about significant increase in research and emphasis.

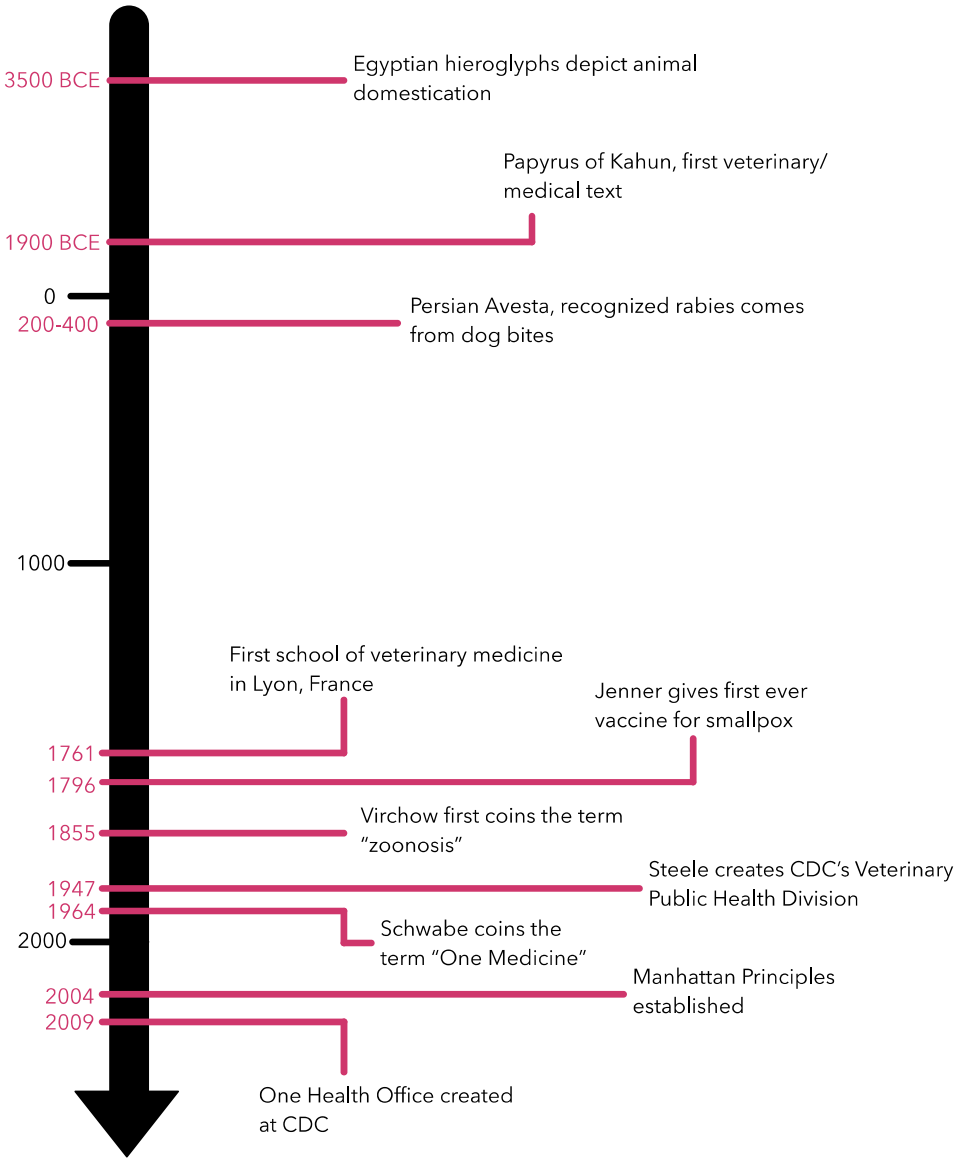

Figure 1. Timeline of the history of One Health from ancient times to the modern era.

Definition of One Health

Keeping a historical context in mind, developing a comprehensive and accurate definition of One Health is a difficult task. A definition should be focused and succinct, yet One Health is a concept that is far-reaching and sweeping. We will explore other prominent definitions before synthesizing our own.

The World Health Organization defines One Health as "an approach to designing and implementing programmes, policies, legislation and research in which multiple sectors communicate and work together to achieve better public health outcomes" (World Health Organization, n.d.). This definition focuses on the implementation of One Health ideas and how they can effect real change. However, it does not give much insight into what kind of ideas One Health can encompass.

The CDC defines One Health as "a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment" (Centers for Disease Control and Prevention, 2020). This definition does a great job looking at the scale of One Health ideas from the local to the global level. It also acknowledges the collaboration between multiple disciplines that is needed for a One Health effort.

The FAO's One Health Initiative defines One Health as "a worldwide strategy for expanding interdisciplinary collaborations and communications in all aspects of health care for humans, animals and the environment" (One Health Initiative, n.d.). This definition also acknowledges the multidisciplinary collaborations, but it states that these

collaborations are the goal of the One Health "strategy" which is different than the other definitions.

Considering the previous definitions, a proper definition of One Health needs to address the collaboration across different fields, the scope and scale of One Health, and the purpose of studying or promoting it. One Health is an elastic word meaning the definition can be tweaked and altered to fit a particular person's or organization's mission. For the purposes of this thesis the definition of One Health is as follows: One Health is collaborative, multidisciplinary approach to solving and studying health issues, from the local to global level, with special consideration given to the interdependency of human, animal, and environmental health.

More information on One Health can be found at the following websites:

- https://www.cdc.gov/onehealth/index.html
- https://www.who.int/news-room/q-a-detail/one-health
- https://www.avma.org/resources-tools/one-health
- http://www.fao.org/one-health/en/
- https://onehealthinitiative.com/
- https://www.oie.int/en/for-the-media/onehealth/

CHAPTER TWO

Survey of Pre-Health Students at Baylor University

Introduction

Health professionals of the past have understood the connection between animal health and human health. As chapter 1 discussed, the distinction between human medicine and veterinary medicine has always been blurred, with knowledge from one contributing to the progress of knowledge of the other. Just a few centuries ago, medical doctors were trained in comparative anatomy and physiology, in which they learned the similarities and differences between the human body and the bodies of livestock and other domesticated animals. This gave physicians and veterinarians alike a more complete outlook on health. Even though they did not have a name for it back then, these doctors were learning and developing One Health ideas.

As medical knowledge and technology improved over the years, it was believed that there was no longer much of a need to be knowledgeable in both human and veterinary medicine. They became different fields and different occupations with different training and education. The purpose of this study is to look at today's undergraduate medical education to determine the extent One Health is still prevalent in Pre-Health curriculums. The last chapter will detail why One Health education for future health professionals during their undergraduate years is important.

A survey was given to students at Baylor University with the purpose of determining undergraduate Pre-Health student familiarity with the field of One Health

and its concepts. The survey was emailed to specific professors with a high proportion of Pre-Health students in their classes to distribute to their students. All participation was voluntary, and no compensation was given for completion. The survey recorded Baylor ID number, grade/classification, major, pre-health designation, One Health familiarity, context in which familiarity was gained, and estimated level of familiarity. The survey then asked questions to assess students' understanding of zoonotic disease and their opinions on the importance of One Health and topics in One Health research. This protocol was approved by Internal Review Board at Baylor University.

Results

There were 234 total student responses to the distributed survey. 52 of the surveys were not used because they had <80% completion and 9 more not used because they did not indicate that they were pre-health students. This left 173 surveys to be used for analysis.

Of the survey participants, 106 were Freshman (61.3%), 27 were Sophomores (15.6%), 27 were Juniors (15.6%), and 13 were Seniors (7.5%). 123 were designated as Pre-Medicine (71.1%), 7 as Pre-Dentistry (4.0%), 7 as Pre-Physician's Assistant (4.0%), and 6 as Pre-Physical Therapy (3.5%). The rest were undecided, Pre-Pharmacy, Pre-Veterinary Medicine, or Pre-Dietetics.

Only 10 participants indicated that they had previously heard of One Health. This is only 5.8% of the students sampled. These 10 will, from here on, be referenced as the "OH cohort". All of the individuals in the OH cohort are Pre-Medicine students, and most are upperclassmen. There is 1 Freshman, 2 Sophomores, 6 Juniors, and 1 Senior. When

asked to rate their own level of understanding of One Health on a scale from 1, meaning little to no understanding, to 10, meaning expert in the field, the average rating from the OH cohort was 4.1. Only 3 individuals rated their understanding at a level 5 or greater. 6 of the students reported learning about One Health in one of their classes while the other 4 reported hearing about health in an academic setting outside of class (journal article/presentation).

All participants were asked whether diseases could be transmitted from animals to humans and vice versa (2 separate questions) in order to test their understanding of the basics of zoonotic disease. If the participants responded "Yes" to each of the questions, they were asked to give an example of such diseases. 100% of the OH cohort knew that diseases could be transmitted from animals to humans, and all but one were able to give an example. Only 155 out of 163 non-OH cohort participants responded "Yes" (95.1%), while 7 responded "Unsure" (4.3%) and one responded "No" (0.6%). Of the 155 who responded "Yes", 17 non-OH cohort participants were unable to give an example (or gave an incorrect example). Next, the question was changed to ask whether diseases could be transmitted from humans to animals. In the OH cohort, 9 responded "Yes"(90%) and one was "Unsure" (10%). Of the 9 participants who responded "Yes", 3 were unable to give an example (or gave an incorrect example). In the non-OH cohort, 84 responded "Yes"(51.5%), 75 said responded "Unsure" (46.0%), and 4 responded "No" (2.5%). Of the 84 "Yes" responses, 32 were unable to give an example (or gave an incorrect example). From these results, we can see that the OH cohort seems to know more about zoonotic disease and be better at providing examples.

Table 1. Comparison of responses from OH cohort and Non-OH Cohort to questions about zoonotic disease.

Can animals transmit diseases to humans?				
OH Cohort	No (%)	Unsure (%)	Yes (%)	Example? (%)
	0	0	10 (100)	9 (90)
Non-OH Cohort	No	Unsure	Yes	Example?
	1 (0.6)	7 (4.3)	155 (95.1)	138 (84.7)

Can humans transmit diseases to animals?				
OH Cohort	No (%)	Unsure (%)	Yes (%)	Example? (%)
	0	1 (10)	9 (90)	6 (60)
Non-OH Cohort	No	Unsure	Yes	Example?
	4 (2.5)	75 (46.0)	84 (51.5)	52 (31.9)

Next, all participants were given a definition of One Health from the CDC and asked whether they agreed with a series of statements about One Health and their educational and career goals. They were given choices ranging from “Strongly Agree” to “Strongly Disagree”. To quantify the responses, a number value was assigned to each of the agreement options (“Strongly Agree” = 3, “Agree” = 2, Somewhat Agree” = 1, “Neither Agree nor Disagree” = 0, “Somewhat Disagree” = -1, “Disagree” = -2, “Strongly Disagree” = -3.)

When given the statement “An understanding of One Health concepts would be helpful in my future career”, the OH cohort had an average agreement response of 2.55 (standard deviation = 0.83). The non-OH cohort had an average response of 2.165 (standard deviation = 0.80). Average agreement response of all survey participants combined was 2.189. The most frequent responses were “Agree” at 46.3% and “Strongly Agree” at 36.2%.

When given the statement “An understanding of One Health concepts is important for physicians and other healthcare providers”, the OH cohort had an average agreement response of 2.33 (standard deviation = 0.5). The non-OH cohort had an average response of 2.355 (standard deviation = 0.64). Average agreement response of all survey participants combined was 2.354. The most frequent responses were “Agree” at 45.6% and “Strongly Agree” at 42.5%.

When given the statement “An understanding of One Health concepts is important for veterinarians”, the OH cohort had an average agreement response of 2.66 (standard deviation = 0.71). The non-OH cohort had an average response of 2.59 (standard deviation = 0.64). Average agreement response of all survey participants combined was 2.599. The most frequent responses were “Agree” at 23.3% and “Strongly Agree” at 66.0%.

When given the statement “I am interested in learning more about One Health”, the OH cohort had an average agreement response of 2.33 (standard deviation = 0.5). The non-OH cohort had an average response of 1.765 (standard deviation = 1.07). Average agreement response of all survey participants combined was 1.801. The most frequent responses were “Agree” at 38.1% and “Somewhat Agree” at 25.0%.

When given the statement “I wish I had learned more about One Health in my undergraduate education”, the OH cohort had an average agreement response of 2.25 (standard deviation = 0.71). The non-OH cohort had an average response of 1.69

(standard deviation = 1.09). Average agreement response of all survey participants combined was 1.727. The most frequent responses were “Agree” at 46.3% and “Somewhat Agree” and “Neither Agree nor Disagree” both at 21.2%.

Table 2. Frequency of different agreement levels to statements about importance and student interest in One Health.

	Disagree (%)	Somewhat Disagree (%)	Neither Agree nor Disagree (%)	Somewhat Agree (%)	Agree (%)	Strongly Agree (%)
An understanding of One Health concepts would be helpful in my future career	1 (0.6)	2 (1.3)	5 (3.1)	20 (12.5)	74 (46.3)	58 (36.2)
An understanding of One Health concepts is important for physicians and other healthcare providers	0	0	6 (3.8)	13 (8.1)	73 (45.6)	68 (42.5)
An understanding of One Health concepts is important for veterinarians	0	0	5 (3.2)	12 (7.5)	37 (23.3)	105 (66.0)
I am interested in learning more about One Health	3 (1.9)	4 (2.5)	14 (8.7)	40 (25.0)	61 (38.1)	38 (23.8)
I wish I had learned more about One Health in my undergraduate education	2 (1.3)	6 (3.8)	34 (21.2)	34 (21.2)	55 (34.4)	29 (18.1)

The respondents were also asked their opinion on how important a series of activities are to preventing future pandemics (Dobson et al., 2020). They were given choices ranging from “Extremely important” to “Not at all important”. Again, a number

value was assigned to each of the choices. ("Extremely Important" = 4, "Very Important" = 3, "Moderately Important" = 2, "Slightly Important" = 1, "Not at all Important" = 0)

When asked to rate how important it is to "Reduce deforestation to limit the loss of wildlife habitats", the OH cohort gave an average importance response of 3.22 (standard deviation = 0.97). The non-OH cohort had an average response of 2.97 (standard deviation = 1.09). Average importance response of all survey participants combined was 2.993. The most frequent responses were "Extremely Important" at 43.7% and "Very Important" and "Moderately Important" at 22.5%.

When asked to rate how important it is to "Control the trade of bushmeat which could lead to transmission of zoonotic disease", the OH cohort gave an average importance response of 3.55 (standard deviation = 0.53). The non-OH cohort had an average response of 3.188 (standard deviation = 0.81). Average importance response of all survey participants combined was 3.209. The most frequent responses were "Extremely Important" at 43.1% and "Very Important" at 22.5%.

When asked to rate how important it is to "Test humans and livestock for known pathogens in regions of high disease emergence risk", the OH cohort gave an average importance response of 3.55 (standard deviation = 0.73). The non-OH cohort had an average response of 3.458 (standard deviation = 0.79). Average importance response of all survey participants combined was 3.464. The most frequent responses were "Extremely Important" at 59.4% and "Very Important" at 30.6%.

Table 3. Frequency of different importance ratings on activities to prevent pandemics.

	Not at all Important (%)	Slightly Important (%)	Moderately Important (%)	Very Important (%)	Extremely Important (%)
Reduce deforestation to limit the loss of wildlife habitats.	2 (1.3)	16 (10.0)	36 (22.5)	36 (22.5)	70 (43.7)
Control the trade of bushmeat which could lead to transmission of zoonotic disease	0	3 (1.9)	29 (18.1)	59 (36.9)	69 (43.1)
Test humans and livestock for known pathogens in regions of high disease emergence risk	1 (0.6)	4 (2.5)	11 (6.9)	49 (30.6)	95 (59.4)

Discussion

It was not surprising that only 10 students surveyed had heard of One Health as it is not something that comes up in the core Pre-Health curriculum. In fact, only 6 of the OH-cohort had heard about it in a classroom setting. It was expected that more upperclassmen had heard of One Health because they have taken more classes outside of the General Chemistry and General Biology classes. Because of the small sample size and the high percentage of participants that were underclassmen, it is possible that the survey underestimates the true percentage of Pre-Health students who have heard of One Health. Many of the participants have simply not had much time to be exposed to the

field. It may be appropriate to target upperclassmen, or even graduating seniors, to obtain a better sense of how prevalent One Health is in Pre-Health curriculums. The individuals in the OH cohort had varied levels of understanding of One Health. It is important to note that these values were self-reported, so each person's interpretation of their expertise may not be the same. Those who heard about it in class tend to rate their level of understanding higher than those who heard about it in an academic setting. One participant stated they learned about One Health in a "Summer Institute of Tropical Medicine" and rated their understanding at a 5.

In the questions about zoonotic disease, the OH cohort seemed to respond correctly more than others. This should be expected because a large proportion of the field of One Health is centered on zoonotic disease. They were all aware of animal to human transmission of disease as well as human to animal transmission, except for one who said they were unsure about human to animal transmission. This individual rated their level of understanding at a 3. The non-OH cohort participants seemed to be less aware that animals could transmit diseases to humans and seemed even less aware that humans could transmit diseases to animals. It is important to note that the ongoing COVID-19 pandemic has positioned a zoonotic disease into forefront of mass media, which may have skewed the results of this question. People who may not have learned about zoonotic diseases under normal circumstances would have very likely encountered the concept during the last year.

The survey participants, regardless of OH familiarity, indicated that they strongly believe an understanding of One Health concepts would be important in their own future careers and for healthcare providers. The average agreement ratings for these statements

were 2.189 and 2.354, respectively, meaning they fell between “Strongly agree” and “Agree”. The same can be said about their agreement with the statement that One Health concepts would be helpful for veterinarians. The average agreement rating was even higher for this statement at 2.599. Both groups indicated that they would be interested in learning more about One Health, but it seems from the difference in average agreement between the OH cohort and the other participants (2.25 and 1.69, respectively) that those familiar with One Health are more likely to wish they had learned more. The difference in average agreement for these last two statements suggests that students develop a stronger interest in One Health after being exposed to the field. However, this stronger interest may just be due to the OH cohort’s general interest in public/global health ideas. These students are possibly interested in public/global health which might be what led them to hear of One Health in the first place. This would require more data to determine the cause of these findings.

Of the three activities to prevent future pandemics given to participants, testing humans and livestock for pathogens in regions with high disease emergence risk had the highest average importance rating with 3.464, which lies in between “Extremely important” and “Very important”. This is reasonable because this is the most direct of the three activities. The other two activities, which are less direct and less obvious strategies to prevent pandemics also received high average importance ratings, but it is not surprising that limiting deforestation received the lowest of the three. This was the only choice where the language of the statement did not give a connection to preventing disease, leaving the survey participants to make the connection to pandemic prevention themselves. It is also likely that some participants responded with importance ratings

higher than what they actually thought. The context of the survey may have led the participants to believe that the given activities were important even if they did not know why.

Because of the small sample size of Pre-Health students that responded to the survey, only descriptive statistics could be used to analyze these data. With more responses, a more sophisticated statistical analysis could have been performed to find if the differences in responses from the OH cohort and others were statistically significant. Instead, we can only look at the raw form of the data and draw what conclusions we can from this.

Conclusion

This survey has shown that most students at Baylor University have not heard of One Health in their undergraduate Pre-Health curriculums. Very few were familiar with One Health and even less have been exposed to the field in a formal classroom setting. It can be suggested from these data that students with a knowledge of One Health are more likely to be knowledgeable about zoonotic diseases. It was surprising to find that many students were not aware that humans could transmit diseases to animals. This is a large focus of One Health research and would most likely be included in any One Health curriculum at the undergraduate level. The survey also showed that Pre-Health students are interested in One Health and understand it importance. Survey participants expressed a desire to learn more about One Health and said that they wished they had learned about it more. They also expressed their belief that an understanding of One Health would be helpful in their future careers. Their overall positive reaction to One Health strategies for preventing pandemics exhibited that they are able to make One Health connections to

relevant public health problems, even if they are not obvious, and recognize their importance. Ultimately this survey revealed Baylor students' lack of education on One Health and their limited knowledge of One Health concepts, but also their desire to learn more about a topic they find important and useful.

The lack of familiarity with One Health among Baylor Pre-Health students at Baylor is due to the lack of opportunities available to come across it in the curriculum. There are a limited number of ways that students may be exposed to One Health. There is a course in the Biology department titled "One Health & COVID-19" that seems to be the only course offered to Baylor students with a One Health focus. There are is also a study abroad opportunity, with the same professor of the One Health class, where students travel to Thailand to participate in One Health research. Other than these two, there were no opportunities to learn about One Health that were found.

In the next chapter, it will be argued that One Health needs to be included in undergraduate Pre-Health education. At Baylor, a One Health program could take many forms. A One Health department or One Health major could be long term goals, but smaller steps would need to be taken to set the foundation. First, Baylor would need to hire more experts in One Health who are qualified to teach One Health courses. One professor is not enough to expand One Health at Baylor. The next step would likely be to offer more One Health courses to students and advertise these classes to Pre-Health students. Also, One Health experts could be invited to give lectures about their research and hold panels that spark conversations about One Health issues. Growing the general awareness in the Pre-Health community would generate interest among the students and prompt more growth in a potential One Health program.

CHAPTER THREE

One Health in Undergraduate Medical Education

Introduction

The modern world is defined by rapidly advancing technology and globalization. The world has never been more connected than it is today, with people and information traveling across the world with ease. But there are consequences to this surge of globalization. A species of insect native to Asia is just a plane ride away from dismantling fragile food webs and ecosystems in North America. A new infectious disease in Europe is also just a plane ride away from spreading amongst the people in Africa. As the world expands and humanity connects all corners of the world, it has never been more important to take a broader, birds-eye view at health.

The COVID-19 pandemic is a prime example of the need for One Health. While the origins of the SARS-CoV-2 are still unknown, the leading theory says it originated in a bat, passed through an intermediary animal, then finally was consumed by humans, likely in some kind of meat at the Huanan Seafood Market in Wuhan, China (Mallapaty, 2021). There is no proof of natural animal to human transmission but it is still highly probable that the virus originated in animals (Haider et al., 2020). At the time of writing this, there have been 125 million confirmed cases of COVID-19 and it has caused over 2.7 million deaths worldwide (*WHO Coronavirus (COVID-19) Dashboard*, n.d.). It does not need to be said that this pandemic has had momentous effects on our world and will

have lasting impacts on our society in the future. The zoonotic origin of COVID-19 is not surprising. The CDC says the 3 out 4 emerging infectious disease come from animals (*Zoonotic Diseases | One Health | CDC*, 2020), which means that taking a One Health approach to preventing future pandemics has never been more urgent.

A One Health approach to the problem of emerging diseases leads to strategies that could hinder their spread. Such strategies that have been proposed (mentioned in the survey in Chapter 2) include reducing deforestation, regulating bushmeat trade, and monitoring livestock and people in areas of high disease emergence risk (Dobson et al., 2020). These strategies require a broader perspective on infectious disease because they do not only focus on reducing or preparing for human to human transmission, but instead focus on the initial transmission from animal to human. A One Health approach that aims to reduce the chances of zoonotic disease transmission to humans should be pursued. These steps would require large amounts of money, but these costs are just a fraction of the cost of another pandemic (Dobson et al., 2020).

To be able to gain funding and implement One Health projects such as the ones above, One Health first needs to become a larger part of the medical conversation. There needs to be more people who are familiar with One Health to have a seat at the table, so that they can promote strategies and actions that fully consider the connection of human health with animal health and the environment. For this to happen, One Health needs to be more ubiquitous in medical education. This chapter will aim to explain two things: why One Health should be a staple in medical curriculums and why students would benefit from starting to learn about One Health in their undergraduate years. All healthcare professionals should be familiar with One Health concepts because they help

provide a broader context for understanding human health, help impart knowledge about zoonotic diseases and how they can affect their patients, and it teaches how to think and work cooperatively with their colleagues and professionals in other fields.

One Health in Medical Education

There are numerous benefits to training future doctors and other healthcare professionals in One Health concepts. First, One Health training gives physicians the ability to see the bigger picture when treating their patients. Humans are interacting with other humans, their pets and other animals, and their environment all the time. When doctors assess their patients, it is important for them to recognize that each patient is coming from a unique environment that may be affecting their health. They also should be equipped with the knowledge and perspective needed to account for these interactions with their environment.

Recently, medical schools across the country have been updating their curriculums by transitioning to a systems-based approach to medicine. Rather than learning all of physiology, pathology, and pharmacology in distinct units, the new curriculums focus on one organ system at a time. For example, students learn the physiology of the heart while they are learning the pathology and pharmacology of the heart. This helps students keep everything they are learning in context, so they can make connections between what they are learning and see the bigger picture (Dubin, 2016). In addition to a systems-based curriculum, a biopsychosocial model of human health developed by Engel (Engel, 1977) has been proposed looks past the "biomedical" model to account for the patients' interactions with their families and communities and how that affects their care. The AAMC has acknowledged this need to add psychosocial concepts

to medical training (Behavioral & Panel, 2011), so in 2015 they created a new section on the Medical College Admissions Test (MCAT) called the "Psychological, Social, and Biological Foundations of Behavior" (Kaplan et al., 2012). As has been shown, medical education is already making strides towards systems-based approaches, so it is logical to expand this mindset to include systems outside of human-to-human interaction. Introducing One health concepts would incorporate an even larger system that includes patients' interaction with their environment and their local ecosystem of living organisms. Doctors with an extensive knowledge of human health from the molecular level up to the global level would be most well-equipped to treat their patients with the best care possible.

Another benefit to introducing One Health the medical education is that it can give doctors, especially those in primary care, the ability to detect and address medical problems stemming from environmental health issues and zoonotic disease. In a survey of Texas primary care physicians, it was found that 86.1% of respondents had never had training in how to deal with environmental health issues (Hamilton et al., 2005). In another study of zoonotic disease outbreaks around the country from 1998 to 2008, it was found that clinicians/practitioners were only responsible for detecting about 18.8% percent of outbreaks (Allen, 2015). These studies show the need for education and training for doctors in dealing with environmental exposure risks and in zoonotic disease detection. Primary care physicians are the first line of detection for these types of cases and need to know how to identify them and how to address them.

But what would this look like in the day-to-day lives for doctors? The vast majority of physicians do not go on to work in public health so the training should be

focused on the clinical applications of a One Health framework. One example of how this One Health training could improve medical practice is in history-taking. Taking a more comprehensive history from a patient including environmental and animal/pet exposures would allow the physician to catch things that would be missed otherwise. Asking these types of questions also helps the doctor keep the world outside of the patient's body in mind. Certain symptoms or health problems may be due to social or psychological stressors rather than biomedical issues, and a One Health adapted history would reveal this sort of information.

Specifically, asking patients about pets is a great gateway into learning about a patient's home environment and animal contact history. A pet history could give insights into possible zoonotic diseases the patient may be exposed to at home as well as uncover relevant environmental issues. Zoonotic diseases that are often transmitted from pets include ringworm (dermatophytosis), toxocariasis, Salmonella, and avian psittacosis (Hodgson et al., 2015). Individuals are especially at risk for contracting zoonotic disease from pets if they are immunocompromised (Grant & Olsen, 1999), so it is important to gather this information in a patient history so that physicians can better protect their vulnerable patients.

There are additional benefits to asking about a patient's pets. It can improve the doctor-patient relationship because it causes the patient to feel more welcomed and cared for by the doctor. Pets are often loved as if they are truly a part of the family, so talking about them can help relax a nervous patient. This can lead to more open sharing by the patient and increased trust in the doctor-patient relationship (Hodgson et al., 2015). Talking about a patient's pet can also reveal more information about their home life and

what kind of environment they live in. Many times, pets will exhibit health problems due to environmental health hazards before their human caretakers. In an example from Rabinowitz, pets will show signs of heat stress before their humans because of their inefficient sweating and their limited ability to move to a cooler environment. If a patient shares that their pet is not doing well, this can give clues to clinicians about what environmental factors may be causing their patients symptoms (Rabinowitz et al., 2017).

Another benefit of adding One Health to medical education is that it promotes the collaboration between human health and animal health professionals. Just like in the times of Virchow, human and veterinary medicine can mutually benefit from sharing information and working together on issues that affect both of their respective fields. In medicine, if a case is near the edge of the scope of a physician's expertise, the physician will consult or refer to a colleague who is more knowledgeable about the case at hand. Doctors from different specialties frequently work together on patients to give them the best care possible. This culture of teamwork in medicine can and should extend outside of human medicine to include veterinarians when possible. In terms of biomedical research, there are areas that can improve with coordination and information sharing. In cancer research, in particular, there have been numerous proposed benefits from collaboration between pet cancer researchers and human cancer researchers. Teaching a One Health model of collaboration between primary care physicians and veterinarians can also be used in clinical situations on the individual level to help prevent zoonotic disease transmission.

Animals can play a significant role in uncovering the mysteries of human health. Many of the health problems in animals and humans overlap due to our similar anatomy

and physiology, so despite their intended subjects being of a different species, veterinarian scientists and medical scientists work on many of the same problems. These veterinarian scientists have a background in animal disease and comparative medicine that is essential in a One Health approach to biomedical research. Their unique, multi-species education gives them a unique perspective on these overlapping issues in health (*One Health: Integrating the Veterinarian-Scientist into the Biomedical Research Enterprise | Office of Research Infrastructure Programs (ORIP) – DPCPSI – NIH*, n.d.). Teaching future doctors about the importance of listening to and collaborating with these veterinarian scientists can greatly benefit the scientific community because animal studies can expand the base of knowledge in certain areas of research.

For example, studying cancer in dogs and cats can provide insights into cancer in humans. Larger pets like cats and dogs have much more similarity to humans anatomically and physiologically than smaller animal models which makes data gathered from them more relevant. Pet cancers also develop more frequently and quickly which makes gathering information about it quicker than studying human cancers. Dogs have been shown to have different susceptibilities to cancer based on their breed, just like how humans can have susceptibilities in their family history. The genetic causes of these susceptibilities in one species can be studied to help answer some questions about cancer in the other species. Another way to use pets in cancer research is in drug development. It has also been proposed that conducting clinical trials for cancer drugs in humans and pets simultaneously can add an extra dimension to the evaluation of the effectiveness of the drugs. Concurrent comparative studies in pets can be used to help assess the pharmacokinetics and pharmacodynamics of the drugs as well as the dosage, schedule,

and regimen (*Read "The Role of Clinical Studies for Pets with Naturally Occurring Tumors in Translational Cancer Research*, n.d.).

Collaboration between physicians and veterinarians on a local, community level can help to stop the spread of zoonotic disease. In a clinical setting, it has been found by that physicians are not usually comfortable with talking with their patients about animals and transmission of zoonotic disease. Physicians believe that veterinarians should have a bigger role in informing patients about zoonotic disease. However, when it comes to these questions, patients do not view veterinarians as someone they could ask about zoonotic disease. In fact, most veterinarians do not ask about the pet owner's health in their visits (Grant & Olsen, 1999). This is concerning because this leaves many patients' important questions about zoonotic disease unanswered. This can be especially dangerous for immunocompromised individuals who have close relationships with their pets as a part of their support systems. These individuals would be much safer if both their physician and their veterinarian were informed and working together on their zoonotic disease risk.

These forms of collaboration between doctors and veterinarians should be an integral part to the One Health curriculum in medical education. At its core, One Health is a collaborative effort from many different areas of expertise. Students should be taught how to think synergistically with others to promote this collaboration in the future.

One Health in Undergraduate Education

Why in particular should pre-health students be exposed to One Health concepts in their undergraduate education in particular? This is an interesting question because it seems obvious to train doctors to be competent in One Health in medical school.

However, other than the fact that medical school curriculums are expecting students to learn an already immense amount of information, there are a few reasons why introducing One Health into students' medical education earlier will benefit the students and make them better One Health advocates in the future. College is the best place for students to begin their One Health education because it is inherently a place of multidisciplinary study where students live and study with students of from other areas of academics. It also allows for the addition of a One Health perspective before students begin to specialize their interests where they think One Health may not be applicable.

The multidisciplinary and collaborative nature of One Health fits very well with the undergraduate curriculum. Students on college campuses are taking classes across many different subject areas, learning and synthesizing all different kinds of information at once. Many colleges and universities have core parts of their curriculums that require all students to take basic level courses in a variety of subjects like the sciences, English, mathematics, foreign languages, arts, political science, history, etc. no matter what their degree path is. This kind of curriculum would mix well with an introduction to One Health where students would be taught the value of multidisciplinary thinking for solving problems. Students could apply their own experience learning about many different subjects and think about how they could fit in the One Heath framework.

The college environment also fosters collaboration amongst students. Students are surrounded by other students who are studying different subjects and on different career paths than them. You can have a chemistry major sitting next to an economics major in an introduction to business course. You can have an environmental science major living in the same dorm as a pre-law student. College students are naturally introduced to others

who are studying to be experts in another field than they are. Through a One Health perspective, pre-health students could learn to utilize these relationships and friendships to work together on group projects and other group assignments. The diversity of subjects of study at an undergraduate institution is greater than any graduate institution that a pre-health student may go to, so students have a prime opportunity to learn the One Health skills of collaboration and interdisciplinary thinking.

Another reason to introduce One Health into undergraduate pre-health education is that is a time when future health professionals are not cemented in what they want to do with their careers. This has two effects: it can attract more students to study One Health and it can reach students before they specialize in areas where One Health concepts are not as important. By being exposed to it early, students who have particular interest in One Health have the opportunity to plan their careers in a manner where One Health can be a focus of what they do. If they do not hear of One Health early enough, they may commit to other areas of research or medical practice. It is clear from Chapter 2 that many pre-health students have never heard of One Health and each one of these students with the right education could go on to make major contributions to the field. Also, students who may not hear about One Health until medical school may have already chosen a specialty which may not be as applicable to One Health concepts as others. These individuals might be disinterested if they know they should focus on topics more relevant to their future careers. If One Health is introduced in undergrad where most do not know what they want to do, it remains relevant for all pre-health students.

In a rapidly globalizing world, where humans are more connected than ever before, it is essential to introduce a broader framework for understanding health to our

future medical professionals. One Health, which recognizes and utilizes human, animal, and environmental health and all the connections between them, is the answer to providing our future doctors with the tools they need to tackle the complex health problems of tomorrow. An education in One Health concepts should be in every doctor's medical training as it provides a larger context of their patients' health, teaches valuable information about zoonotic disease, and promotes collaboration with other fields of health. Further, these One Health concepts would best be introduced in students' undergraduate education because the university environment perfectly fosters the interdisciplinary and collaborative thinking that is fundamental to One Health.

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