# Bridging the Gap Between Animal and Human Medicine:

# Implementing the One Health Initiative to Improve the Health of All Species

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Abstract

Professional segregation between animal and human medicine is common. Clinical data is not shared between human and animal health providers, and disease surveillance for humans and animals are performed and reported to separate agencies and departments. The One Health Initiative (OHI) seeks to promote and improve the health and well being of all species by improving cooperation between physicians, veterinarians, and other scientific health and environmental professionals. It is evident that the health of non-human animal species and humans are inextricably linked. Veterinary professionals have adopted the OHI with great enthusiasm, but One Health does not seem to have been accepted nearly as widely among medical and health care professionals. As a consequence, Google Scholar, PubMed, and the website of the One Health Initiative were utilized to access relevant databases that would provide the references and supportive materials for this paper, which supports the implementation of the OHI across all disciplines. Although the various professionals have different roles, they share an underlying common interest, and they often share similar challenges. Professionals within animal, human, and environmental health need to unify their efforts in managing the health of all species. This can be achieved by continual collegiate and/or self-education, keeping up to date with recent publications in other fields' journals, educating the general public about One Health, and by setting up and attending One Health conferences at the global, national, and local levels.

## My Journey

Before entering the nursing field, I worked in wildlife biology and environmental science. Anytime I had an interaction with a wild animal, I had to be cautious about the individual going into cardiac arrest. Any interaction needed to occur quickly and without any eye contact, as this would induce a predator-prey response in the animal, causing the animal to experience undue stress. I decided to enter nursing once I realized my passion for delivering care, but understanding that I also needed to be able to communicate with my patients and reassure them of their safety and my intent.

It was only when I started taking my nursing prerequisite classes that I noticed the similarities between animal and human medicine, and the connections between our health and the health of the environment. Although there are obvious differences in the outward appearances of our bodies and the bodies of an array of other animal species, there are overwhelming similarities across animal species in the pathophysiology of diseases, in common behaviors, and in internal anatomy and physiology. At one point I worked closely with marine biologists identifying infectious diseases in marine mammals and the water sources. I quickly realized that many of these diseases were zoonotic in nature, and could be passed to humans or passed back terrestrially into the local wildlife. The environment, animals, and human health were no longer distinct from one another in my mind, but became inextricably linked. When conducting additional research, I came across the One Health Initiative and realized that there are more people than myself who also recognize the link between fields. It became my mission to continue to bring light to the concept of One Health, and to continue to use my prior background in animal and environmental health to provide better care to my patients as a nurse.

Bridging the Gap Between Animal and Human Medicine:

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## Introduction: Segregation of Human and Animal Medicine

Professional segregation between animal and human medicine is common, as human health professionals often adopt an " us versus them" approach, considering animals only when they pose a direct risk to human health (Rabinowitz, Scotch, & Conti, 2010). Clinical data is not shared between human and animal health providers, and disease surveillance for humans and animals are performed and reported to separate agencies and departments (Rabinowitz et al., 2010). To address this challenge, it is imperative to implement the One Health Initiative in order to bridge the gap between these fields. For the purposes of this paper, when the term "animal" is used, it refers to all non-human animal species.

### The "One Health Initiative"

The mission statement of the "One Health Initiative" (OHI) is to "[recognize] that human health, animal health, and ecosystem health are inextricably linked. One Health seeks to promote, improve, and defend the health and well-being of all species by enhancing cooperation between physicians, veterinarians, other scientific health and environmental professionals and by promoting strengths in leadership and management to achieve these goals" (One Health Initiative, n.d.). Along with incorporating animal and human health, an evolution occurred to also include environmental factors, as this inter-relationship among humans, animals, and the environment are critical to the health of all species (Gyles, 2016).

Although One Health can be applied to a wide range of health issues, a major area of concern that One Health addresses is the emergence of zoonotic diseases that could easily turn pandemic. Essentially, One Health was born and fueled by fear, as anxiety rose worldwide in

2004 concerning HPAI H5N1, or the "bird flu" (Gibbs, 2014). International agencies (i.e. World Health Organization, World Organisation for Animal Health, Food and Agriculture Organization, and the World Bank) and political actors (i.e. European Union, USA, and the United Nations) recognized that interdisciplinary collaboration was required in order to prevent and control these zoonotic diseases (Gibbs, 2014). Interdisciplinary collaboration amongst scientists included cooperation between physicians, veterinarians, wildlife specialists, environmentalists, anthropologists, economists, sociologists, and more (Gibbs, 2014). Although zoonotic diseases are a major focus of One Health, the scope of One Health also focuses on comparative/translational medicine, environmental health, food security and safety, and more. Veterinary professionals have adopted the OHI with great enthusiasm, as have international agencies such as the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the World Organisation for Animal Health (OIE) (Gibbs, 2014). However, One Health does not seem to be accepted nearly as widely among medical and health care professionals.

Due to the barriers in communication and lack of collaboration between fields, it is imperative to implement the OHI. This paper will outline not only the importance of implementing the OHI for zoonotic diseases, but also other major health concerns seen in today's society. Emphasis will also be placed on why and how interdisciplinary collaboration could benefit all healthcare fields, as well as showing how these fields are inextricably linked in relation to the health and well-being of all species and the ecosystems we share.

## Methods

Google Scholar and PubMed were utilized to access relevant databases that would provide the references and supportive materials for this paper. The majority of the studies selected for this paper were published within the past ten years, were written in the English language, and were research-based and peer-reviewed. Since there were multiple relevant studies that were conducted internationally, the criterion for the study being conducted in the United States was eliminated in order to expand on the number of pertinent articles retrieved. In order to identify relevant articles pertaining to this study, the abstracts of the articles were read to determine applicability of the studies to the topic of interest. The website of the One Health Initiative was also used as a major resource because it provides quick links to related publications within One Health Journals and a newsletter, which both contain specific information pertinent to this research paper.

## Importance of Implementing the "One Health Initiative"

### Zoonotic Diseases and One Health

As previously mentioned, One Health was originally focused on emerging zoonotic diseases that were at high risk of becoming pandemic. Zoonotic diseases are diseases that can be transmitted between human and animal species. These diseases can be bacterial, fungal, viral, or parasitic in nature, and have been a concern since the domestication of animals 10,000 years ago (Centers for Disease Control and Prevention, 2014; Gebreyes et al., 2014). A domesticated animal simply refers to an animal that has been tamed and kept by humans. The term "zoonosis" was devised in 1855 by Rudolf Virchow, a German physician and pathologist, who argued that there should be no dividing line between human and animal medicine (Brown, 2003; Gyles, 2016). Although zoonotic diseases are increasing worldwide, research within the biological, environmental, and life sciences fields continue to be conducted separately (Goodwin et al., 2012).

**Zoonotic disease transmission into the human population.** According to Goodwin et al. (2012), the two drivers of zoonotic disease transmission into the human population are: (1) the occurrence of the disease in animals which may change due to population dynamics of hosts or vectors and alteration of habitats, and (2) the variations in the human population's composition or behavior, which alters their susceptibility to the disease. Goodwin et al. (2012) also identified three factors that can determine the rate at which new infections spread within a population: (1) the contact rate between human and animal individuals; (2) the proportion of contact between the infected and the susceptible; and (3) the human probability of infection once contact has occurred. Appendix A outlines some specific zoonotic diseases that a wide variety of animals may harbor, along with their various transmission routes.

Expanding human populations, global land-use change, and the introduction of human commensal vectors place pressures on zoonotic pathogens, causing them to evolve and take advantage of new environments (Kilpatrick & Randolph, 2012). These introduced and newly evolved pathogens can cause volatile epidemics where a large proportion of the population at-risk will become infected within the first few years after introduction of the pathogen (Kilpatrick & Randolph, 2012). In other words, if there is a host population that is immunologically naive to the introduced pathogen, and there are high vector populations of this pathogen, then reproduction of the pathogen will be at its greatest potential (Kilpatrick & Randolph, 2012).

**Increase in endemic pathogens.** Land use change usually causes a gradual rise in endemic pathogens and can alter the interactions and abundance of insect vectors, susceptible people, and wildlife and domestic hosts (Kilpatrick & Randolph, 2012). For example, deforestation in the Amazon River Basin and in East Africa increases standing bodies of water and sunlight exposure, which enhances the success of mosquito breeding rates, leading to increased risk of malaria among the residing human population (Kilpatrick & Randolph, 2012).

Socioeconomic conditions can also cause increases in the incidence of various endemic pathogens (Kilpatrick & Randolph, 2012). For example, hardships that are endured through civil conflicts, loss of housing through natural disasters, and the use of natural resources driven by economic transitions can lead to increased pathogen transmission (Kilpatrick & Randolph, 2012). Seasonal and weather factors can also contribute to poor sanitation and inhospitable housing conditions, which can introduce infected animals, contaminated water, and contaminated air into these human environments (Goodwin et al., 2012).

**Implementing One Health to address the rise in tick-borne illnesses.** Ticks were the first arthropods to be established as a vector pathogen, and are still recognized today as one of the main vectors of diseases to humans and animals (Dantas-Torres, Chomel, & Otranto, 2012). Tick-borne illnesses are commonly seen in both veterinary and medical settings, and incidence rates are increasing worldwide (Dantas-Torres et al., 2012). For example, the most commonly reported vector-borne disease in the country, Lyme disease, is expanding with historically high significance (Rubin, 2017). Between 2008 and 2015 there were 275,589 cases of Lyme disease reported in the United States, and it is estimated that the actual incidences could be higher than reported (Rubin, 2017).

Common tick-borne diseases include Lyme disease, babesiosis, Rocky Mountain spotted fever, as well as many others. A list of common hard and soft tick-borne diseases can be found in Appendix B. However, new species, strains, and genetic variants of pathogens are continuously being detected in ticks across the world (Dantas-Torres et al., 2012). Some of these new species and variants have been detected decades before their emergence in humans, and others are infecting humans and animals in new geographical areas (Dantas-Torres et al., 2012). Different species of ticks are also associated with different pathogens, and some tick species can harbor more than one zoonotic disease. For example, *Ixodes scapularis,* or the deer tick, can transmit Lyme disease. *Amblyomma americanum,* or The Lone Star Tick, can transmit *Borrelia lonestari, Ehrlichia chafffeensis, Francisella tularensis, Rickettsia parkeri,* and *Rickettsia rickettsia.* Therefore, not only do veterinarians and physicians need to have access to resources to identify a particular tick species if present on the individual, but also recognize the potential diseases that the particular species can harbor. The various pathogens that can be found in certain tick species and tick families are listed in Appendix B.

Despite the growing risk of diseases, veterinarians and physicians are rarely knowledgeable on tick identification, which is why they should seek out an expert's opinion and/or keep updated on recent tick infestations in order to promptly administer the proper treatment (Dantas-Torres et al., 2012). For example, when veterinarians recognize an epidemic of Rocky Mountain spotted fever in dogs, physicians should be notified and educated about symptoms that can arise in humans, as dog owners (or anyone else exposed to an animal) may seek healthcare with symptoms that can be easily misdiagnosed. This is especially true since many humans may not recall being bitten by a tick, but can recall being around a tick-infested animal (Dantas-Torres et al., 2012).

Due to the marked increase in tick-borne illnesses in animals and in humans, it is imperative to implement an interspecies comprehensive approach in order to better manage the existing and emerging tick-borne diseases. In addition, studies need to be conducted on the epidemiology, diagnosis of, and ecology of these emerging diseases. Filling these gaps in communication can accelerate diagnoses, hasten treatment decisions, and implement more productive preventive measures (Dantas-Torres et al., 2012). Therefore, it is crucial to be in continual communication between not only veterinary and medical professionals, but epidemiologists and environmental scientists as well.

**Climate Change**

Despite some resistance, an overwhelming consensus that climate change is occurring and human activities are the primary cause has developed (Black & Butler, 2014). Climate change can include natural climate variability that occurs over an extended period of time, as well as the change that occurs from external anthropogenic origins, such as greenhouse gas emissions. The natural climate variability, also known as internal variability, is the expected adaptability in climate that includes natural processes from the atmosphere, the ocean, and the coupled ocean-atmosphere system across several hundred to a thousand years (Deser, Phillips, Bourdette, & Teng, 2012). However in this paper, climate change will be referred to as the change of the climate attributed to human activity, which is accelerating the natural climate variability that occurs over time (Black & Butler, 2014). Climate change has been linked to an increase in frequency and intensity of extreme weather events such as droughts, floods, and heat waves (Black & Butler, 2014). Climate change has also contributed to high rates of terrestrial and marine biodiversity loss; increased interference within the nitrogen and phosphorus cycles; decreased global freshwater accessibility; led to changes in land use; increased ocean acidification; as well as many other impacts (Black & Butler, 2014). The big question that is rarely addressed is, how does this affect human health?

**Climate change, zoonotic diseases, and food security.** For the first time, humans have collectively overloaded Earth's capacity to supply, absorb, replenish, and stabilize (Black & Butler, 2014). In addition to emerging infectious diseases and conventional/translational medicine, One Health also focuses on food security and food safety (Black & Butler, 2014). Identified drivers of emerging infectious diseases are the same as those underpinning food security and food safety (Black & Butler, 2014). One of the key drivers is climate change.

Climate change is already altering the distribution and frequency of a wide range of diseases, as it increases the incidence of host-pathogen-vector interactions (Black & Butler, 2014). Animals that harbor certain diseases, both aquatic and terrestrial, are now moving and changing in response to climate change. Some pathogens can complete their life cycles more quickly due to increased temperatures and exposures to new, susceptible hosts. As discussed in the zoonotic disease section, flooding and standing bodies of water can increase not only the risk of mosquito-borne diseases, but other tick-borne diseases and bacterial pathogens that can cause zoonotic gastrointestinal diseases (Black & Butler, 2014). Foodborne zoonoses are highly likely to be sensitive to any climate change (Black & Butler, 2014). Risks of infection with common foodborne pathogens, such as campylobacter and salmonella, are increased and strongly correlated with climate change (Black & Butler, 2014). Significantly, many of these foodborne pathogens are associated with poultry and pigs, and the global production of poultry and pigs is expected to continue to rise (Black & Butler, 2014).

Addressing the challenges that result in anthropogenic climate change is complex and requires a multidisciplinary approach, which should also include policy and decision-makers to assure implementation of One Health recommendations (Black & Butler, 2014). The latter two need to be included since decision-makers base their policy decisions on interdisciplinary, objective scientific data (Cardona et al., 2015). Those addressing these issues need to take a systemic approach, rather than focusing on single determinants (Black & Butler, 2014). Overall, those that practice One Health need to reconsider how humans plan, move, produce, and consume (Black & Butler, 2014).

**“Resistance Anywhere is Resistance Everywhere.”**

It is estimated that annually there are 700,000 human deaths attributable to drug-resistant microbial infections, which is expected to increase significantly (Robinson et al., 2016). Antimicrobial resistance is often focused on human health outcomes, without considering impacts that occur in animals and the environment. Antimicrobial resistance is a global problem, with resistant pathogens existing in humans, animals, food, and the environment (Queenan, Häsler, & Rushton, 2016). Globalization of the food system (e.g. movement of livestock and agricultural produce) as well as increases in human travel have contributed to the spread and mixing of antimicrobial resistant genes (Robinson et al., 2016). Based on these factors, the World Health Organization has called for local, national, and global surveillance systems to be established to identify and reduce the rates of antimicrobial resistance (Queenan et al., 2016). However, the lack of integration and communication between the fields where antimicrobial resistance is found will lead to gaps in promoting antimicrobial stewardship (Queenan et al., 2016). Good stewardship, which means to optimize the use of antibiotics while minimizing developmental resistance and adverse effects, is the most critical challenge facing human and animal medicine (Prescott, 2014).

Medical professionals may blame the agricultural industry for the use of antibiotics in their livestock animals, but the agricultural industry claims this resistance is due to the over-prescription and abuse of antibiotics by physicians and veterinarians. Sometimes antibiotics are the only resource farmers can use to tackle endemic bacterial infections found in their animals (Robinson et al., 2016). Just as in the medical field, animals can be overexposed to antibiotics, not enough, or are exposed unwisely (Robinson et al., 2016). Antimicrobial resistance is an ecological problem, and should be addressed in humans, animals, plants, food hygiene, and environmental science (Queenan et al., 2016). Therefore, it is essential to stop placing blame for antibiotic resistance, and begin taking action in an integrated and unified effort to address this global issue. As Prescott (2014) stated, “resistance anywhere is resistance everywhere.”

**Sentinel Species**

Many have heard of the caged canaries that warned coal miners when there were toxic gas risks, such as carbon monoxide and methane (Rabinowitz et al., 2010). These canaries were known to be a “sentinel species.” Animals can provide sentinel warnings to humans by indicating the presence of environmental toxins as well as zoonotic infectious diseases in the community (Rabinowitz et al., 2010). Because animals suffer from a similar spectrum of diseases as humans do, they are sensitive indicators of, and early warning systems for, environmental hazards (Reif, 2011). However, the reverse is also possible. Sometimes humans serve as a sentinel species for animals as well. Humans often receive more medical care, which can lead to earlier diagnoses of a potential environmental disease agent before animal health providers consider testing their patients (Rabinowitz et al., 2010).

**Aquatic animals as sentinels.** Ocean health is inextricably linked to human health on a global scale (Bossart, 2011). Due to marine mammals’ relatively long lifespans, they experience chronic diseases, abnormalities in growth/development, reproductive failures, cancers, and more that are also commonly seen in humans (Reif, 2011). Since many marine mammals share the coastal environment with humans and consume similar foods, they can serve as effective sentinels for emerging and reemerging infectious diseases, neoplastic diseases, and environmental distresses (Bossart, 2011). They are also highly susceptible to anthropogenic contaminants, or contaminants originating from human activity. The blubber and tissues of marine mammals can show levels of heavy metals, chlorinated pesticides (e.g. DDT), polychlorinated biphenyls (PCBs), and other chemicals and toxins due to biomagnification, which results from being at the top of the food chain (Reif, 2011).

Marine mammals are not the only aquatic sentinels. For example, in the 1950s sediments, shellfish, and fish in Minamata Bay were found to have high levels of mercuric chloride due to wastewater discharge from a chemical plant (Harada, 1995; Reif, 2011). In 1950, city cats around the waters were making noises and looked as if they were dancing due to jerks and convulsions caused by mercury poisoning, which eventually led to death due to consumption of the contaminated marine products. Along with the dancing cats, seabirds were losing their ability to fly, dead fish were seen floating on the surface of Minamata Bay, and rats were dying off (Kessler, 2013). In 1956, physicians encountered a young female resident of Minamata, Japan that presented with the same neurobehavioral symptoms as the dancing cats, and was the first to be diagnosed as having “Minamata disease” (Harada, 1995; Reif, 2011). It wasn’t until that particular patient that physicians realized many other local residents that presented with similar symptoms in the past were misdiagnosed and actually had Minamata disease. These ataxic “dancing cats of Minamata” were warning signs that a human epidemic would occur, and if not ignored, the epidemic could have possibly been averted if the connection between human and animal health had been identified promptly (Reif, 2011). A number of scientists in different disciplines were required in order to identify the causal agent and finally recommend action to prevent further poisonings and death (Tsuchiya, 1992). However, despite interdisciplinary collaboration between scientists, their recommendations could not be initiated without the support of the government. Despite the recommendations and continual diagnoses of Minamata disease in the locals, the government did nothing to stop the wastewater dumping, nor did they discourage people from eating the contaminated marine products (Kessler, 2013). It wasn't until 1968 when the chemical plant stopped using mercury on its own that the government officially recognized the plant's role in Minamata disease (Kessler, 2013). This is another reason why it is essential to not only include environmental scientists and professionals in human and animal medicine in One Health, but also policy and decision-makers within the government.

**Sexually Transmitted Infections and One Health**

Usually people think of koalas as being cute, innocent, fluffy animals. The thought of any perceived animal that is "innocent-looking" or "cute" having a sexual transmitted infection (STI) just seems counterintuitive. However, the bacterial pathogen, *Chlamydia*, is a significant threat to the survival of koalas and is one of many drivers that have placed these cute, fluffy animals near extinction in some areas (Desclozeaux et al., 2017). It is important to remember that animals do not have the option of "safe sex," leaving unprotected sex as the only possibility.

Craig et al. (2011) projected that within five to six years the current population decline among koalas due to *Chlamydia* could be reversed using a realistic vaccine-dosing schedule where female koalas ages one to two years are targeted. Desclozeaux et al. (2017) tested two different single-dose vaccines on the immune response of koalas, which showed an elicited systemic and mucosal humoral response in more than 90% of the vaccinated koalas, as well as a cell-mediated response (Desclozeaux et al., 2017). One vaccine even showed clearance of infection in all infected koalas (Desclozeaux et al., 2017).

So, why should human beings care? Despite human's ability to practice safe sex, *Chlamydia* is still the most commonly reported sexually transmitted infection in the United States, and it can lead to serious and potentially permanent damage to a woman's reproductive system (Centers for Disease Control and Prevention, 2017). Currently, there is no approved vaccine for human use. If communication occurs across human and animal medicine and research is performed collaboratively, advancements in vaccines may occur at a more expedited rate, and the pervasiveness of this STI could be better addressed in not only humans, but all other species as well.

*Chlamydia* is not the only STI of concern across species. Pathogens are always looking for new paths, which means both humans and other animals are at risk (Natterson –Horowitz & Bowers, 2012). Rabbit syphilis once spread to human trappers in East Yorkshire, England despite the absence of sexual contact between the two species (Natterson –Horowitz & Bowers, 2012). The syphilis pathogen jumped from the rabbits to the trappers through cuts in the handlers' hands, which led to the development of hand sores (Natterson –Horowitz & Bowers, 2012). It is not unusual for pathogens to have two different paths of entry, both oral and sexual (Natterson –Horowitz & Bowers, 2012). Another pathogen of interest is *Brucella spp.* Humans typically acquire brucellosis after consuming infected unpasteurized dairy or undercooked meat. However, the pathogen *Brucella spp.,* is usually transmitted sexually within species and is known to cause spontaneous, late-term miscarriages in females, as well as swollen, bleeding testicles in males (Natterson –Horowitz & Bowers, 2012). Although originally thought of as a terrestrial pathogen, *Brucella spp.* can now be found in both terrestrial and marine vertebrates and is among the most prevalent zoonotic diseases (Foster et al., 2009; Sohn et al., 2003). The question of how *Brucella spp.* crossed the terrestrial-aquatic barrier is still unknown. However, we do know that there are cases of humans contracting marine species of *Brucella* as well.

Interdisciplinary collaboration in STI studies reminds us that pathogens are constantly evolving and can take multiple pathways to infect a host. A species suited to one region of the body can change over time, and can also adapt to new ecologies to live and thrive (Natterson – Horowitz & Bowers, 2012). Terrestrial infection today could mean marine infection tomorrow. Or, gut infection today, could be genital infection tomorrow (Natterson –Horowitz & Bowers, 2012).

**Cancer and The One Health Initiative**

Cancer strikes across all ecosystems and all throughout the animal kingdom (Natterson – Horowitz & Bowers, 2012). Cats can present with fever and jaundice, leading veterinarians to check for leukemia or lymphoma (Natterson –Horowitz & Bowers, 2012). Or, they may present with a lump in their breast, which can be an aggressive form of breast cancer also diagnosed in human women (Natterson –Horowitz & Bowers, 2012). Rabbits have a high risk of uterine cancer, parakeets develop reproductive tumors, reptiles are diagnosed with leukemia and lymphoma, and light-colored horses are monitored for skin cancer (Natterson –Horowitz & Bowers, 2012). Even insects can develop cancer and plants can grow tumors called “galls” (Natterson –Horowitz & Bowers, 2012). Compared to humans, cancer has a relatively short latent period in animals, which provides an advantage in studying spontaneous diseases in animals (Reif, 2011). An example that will be discussed in further detail will be osteosarcoma in dogs.

**Osteosarcoma in dogs**. Many canine neoplasms resemble the same biological behavior, pathologic features, proportional morbidity, and recognized risk factors as human neoplasms

(Reif, 2011). Although Osteosarcoma (OSA) is the most common type of bone cancer, it is still rare in humans. Among dogs, rates of OSA are 27 times higher than in humans, yet the prognosis is grim in both species (Simpson, Dunning, Brot, Grau-Roma, Mongan, & Rutland, 2017). Second to cardiovascular disease, cancer is the leading cause of non-communicable morbidity and mortality in adult humans, and the number one cause in dogs (Simpson et al., 2017). Although cancer is more common in adults, OSA is most common in the young (<20 years old) and in those >60 years old (Simpson et al., 2017). Despite improvements in five-year survival rates for other types of cancer, OSA has not shown comparable advances, which suggests the need to further develop treatments that would improve the morbidity and mortality rates (Simpson et al., 2017). Comparing the two species can provide valuable insight into the origin and progression of OSA, as many similarities between the disease in both species exist (Simpson et al., 2017).

**Comparative oncology.** Cancer is not unique to humans. Animals will also develop cancer through genetic mutations such as BRCA1, viral infections, and external factors such as ultraviolet or chemical exposures. Therefore, comparative oncology should be implemented to improve the health of both animal and humans. For example, limb-sparing techniques that are used in humans were originally pioneered in dogs by a veterinary oncologist, Stephen Withrow, who worked collaboratively with medical physicians (Natterson –Horowitz & Bowers, 2012). Comparative oncology does not mean experimenting on animals in labs, but is about observing cancer while caring for our companion animals who also develop spontaneous cancers and are under treatment from a veterinarian (Natterson –Horowitz & Bowers, 2012).

**Takotsubo Syndrome**

It has been widely known that wildlife can experience sudden stress-induced death when confronted with predatory stress or capture (Blumstein et al., 2015). There are different sub-types of capture myopathy, with peracute capture myopathy occurring soon after exposure to a stressor (Blumstein et al., 2015). Animals can experience rhabdomyolysis, muscular necrosis, ataxia, paralysis, and fatal metabolic distress during predatory pursuit, capture, holding/handling, and manipulation (Blumstein et al, 2015). This sub-type shares many features with Takotsubo Syndrome in humans, which is also known as Broken-Heart Syndrome (Blumstein et al., 2015). Therefore, capture myopathy in wild animals can be a model for human stress cardiomyopathy patients (Blumstein et al., 2015).

In the 1990s a team of Japanese cardiologists noticed that some patients that came into the emergency room presented with non-normal hearts and severe, crushing chest pain following emotional distress (Natterson-Horowitz & Bowers, 2012). Despite an initial EKG showing that the patients were having a heart attack, further tests showed healthy, "clean" hearts with no evidence of coronary artery disease or blockage (Natterson-Horowitz & Bowers, 2012). The only abnormal finding was that the bottom of the heart had a bulge and was shaped like a light bulb, or the *takotsubo* pot that Japanese fishermen used to catch octopuses (Natterson-Horowitz & Bowers, 2012). So, Takotsubo cardiomyopathy became a "new finding" which showed evidence that severe stress could alter the heart's chemistry, shape, and how it pumped (Natterson-Horowitz & Bowers, 2012). Both syndromes can be triggered by emotional and physical stress, and both present with an increase in catecholamines and creatinine kinase levels (Blumstein et al., 2015). However, capture myopathy had been first noticed a hundred plus years ago by human hunters and continues to be acknowledged in animals in every level of the food chain (Natterson-Horowitz & Bowers, 2012).

## Steps to Advance The One Health Initiative

### Education and One Health

Although the idea behind the movement of One Health dates back to Rudolf Virchow, it has just recently gained increased interest. In order for One Health to be successful, there needs to be an educated workforce that is trained in its principles and applications (Gibbs, 2014). Education can involve those already working in their professional disciplines, as well as students working towards their degree in one of these disciplines (Gibbs, 2014). Although public health courses are offered in colleges and universities, courses should be offered specifically focusing on One Health. A graduate level course, "Philosophy to the Practical Integration of Human, Animal and Environmental Health," was offered in Spring of 2017 to UNC, Duke, and North Carolina State University undergraduate students from a variety of disciplines. Some schools, like The University of Florida, also offer certificate training programs for professionals interested in One Health, and PhD degrees specific in One Health (Gibbs, 2014). Several schools have also developed "One Health" clubs. As previously mentioned, the vast majority of these educational recommendations occur in the veterinary school or curriculum, rather than on the medical and nursing side. Despite recent headway in implementing One Health in education and training, the United States still has a shortage of paraprofessionals trained in the One Health approach who can also provide support to professionals in human, environmental, and animal medicine (Gibbs, 2014). If the importance of One Health can be instilled in students before they enter their professional field, they will be more likely to continue with interdisciplinary collaboration or conference participation related to One Health in the future.

**One Health Conferences**

One Health conferences should be held globally, nationally, and locally where veterinarians, physicians, and environmental scientists can sit at the same table to discuss recent findings and provide recommendations based on their practice. On a smaller scale or in the local area, colleges and universities could hold annual conferences where their students across disciplines come together to discuss what they have learned. It is also recommended that professionals periodically read journal articles in the other's respective fields. For example, the *Veterinary Record* publishes a series of articles to help encourage the process and acceptance of One Health and build on the momentum that the initiative has received so far.

**The General Public and One Health**

Awareness of One Health should also be introduced to the general public. When avian influenza was a concern in 2004, there was immense interest in the media outlets (Gibbs, 2014). Although the media still report on newly emerging zoonotic diseases, there is little interest or reports on One Health (Gibbs, 2014). Studies should be conducted on the awareness of the general public on One Health. Richard Brodie (1996), as cited by Gibbs (2014), identified four stages through which a new paradigm must progress in order to gain widespread acceptance: 1) complacency/marginalization; 2) ridicule; 3) criticism; and 4) acceptance. If one accepts that One Health is a new paradigm, then the attitudes would be considered in the third stage, criticism (Gibbs, 2014). Although it should be encouraging that One Health is one step away from acceptance, it is uncertain whether One Health is a true paradigm or just a short-lived response to the fear of 21st century infectious diseases, such as avian influenza (Gibbs, 2014).

**Nursing and One Health**

Although most studies in One Health address the participation of medical physicians, it is just as imperative for nurses to practice One Health, despite the fact that there were no studies found specifically addressing how and why nurses should practice and participate in the OHI. As the most trusted profession, patients rely on nurses to be their advocates and often times nurses are the first and last healthcare professional the patients encounter. This provides more time for patient interaction and the opportunity to identify certain presenting symptoms, changes in baseline, and more abnormalities that may warrant the physician's attention. Keeping up to date on public and environmental health concerns, as well as emerging zoonotic diseases, could allow for a more prompt diagnosis and hasten appropriate treatment plans.

Nurses can also enhance their leadership skills by practicing and advocating for One Health by utilizing outsight, which is the process of looking outside yourself and your familiar world for inspiration (Kouzes & Posner, 2014). By practicing outsight and being engaged in One Health, nurses can more easily see opportunities for change and can become more aware and knowledgeable about what is going on around them and with their patients (Kouzes & Posner, 2014).

## Conclusion

It is evident that the health of non-human animal species and humans are inextricably linked. Although the various professionals have different roles, there is an underlying common interest and they often share similar challenges. Professionals within animal, human, and environmental health need to unify their efforts in managing the health of all species. This can be achieved by continual collegiate and/or self-education, keeping up to date with recent publications in other fields' journals, educating the general public about One Health, and by setting up and attending One Health conferences at the global, national, and local levels. “It is not the strongest of the species who survive, nor the most intelligent; rather it is the most responsive to change (attributed to Charles Darwin). One Health is that response!” (Gibbs, 2014, p. 91).

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# Appendix A

## Potential Disease Reservoirs and Possible Animal to Human Transmission Routes for Zoonotic Diseases

| Reservoir species | | Zoonotic disease examples |
|---|---|---|
| Companion animals | Cats | Toxoplasmosis, Q fever, variant Creutzfeldt-Jakob disease, Capnocytophaga canimorsus, Plague, Bartonellosis |
| | Dogs | Q fever, Rabies, Leptospirosis, Capnocytophaga canimorsus |
| | Horses | Tuberculosis |
| Livestock | Cattle | Q fever, Creutzfeldt-Jacob disease, Crimean-Congo haemorrhagic fever, Tuberculosis, Leptospirosis, Rift Valley fever, Tuberculosis, Brucellosis |
| | Pigs | Toxoplasmosis, Japanese encephalitis, Campylobacteriosis, Tuberculosis, Streptococcosis, Tularaemia, Brucellosis, Leptospirosis, zoonotic influenza |
| | Sheep/goats | Toxoplasmosis, Q fever, Rift Valley fever, Tularaemia, Brucellosis |
| | Deer | Q fever, Tuberculosis, Human granulocytotropic anaplasmosis, Leptospirosis |
| Poultry | Poultry/fowl | Campylobacteriosis, Chlamydiosis, Salmonellosis, influenza |
| Wild mammals | Badger, | Tuberculosis |
| | Raccoons/skunks | Rabies |
| | Bats | Rabies, Ebola, SARS, Nipah virus |
| | Wild boar | Toxoplasmosis, Tuberculosis, Streptococcosis |
| | Wild deer | Q fever, Tuberculosis, Human granulocytotropic anaplasmosis |
| | Foxes | Q fever, Tularaemia, Echinococcosus, Rabies |
| | Rabbits/hares | Q fever, Tularaemia |
| | Rodents | Toxoplasmosis, Q fever, Leptospirosis, Dobrava-Belgrade virus, Tularaemia, Plague, Monkeypox |
| | Ground squirrels | Plague |
| Wild birds | Birds including waterfowl | Influenza, Japanese encephalitis, Q fever, West Nile fever, Eastern equine encephalitis, Chlamydiosis |
| Aquatic | Fish | Leptospirosis |
| Arthropod | Insects and arachnids | Campylobacteriosis |

We exclude vector species which cannot sustain the pathogen in the absence of other hosts.

| Transmission route | Zoonotic disease examples |
|---|---|
| Airborne/respiratory | Influenza, Q fever, Tuberculosis |
| Physical contact | Influenza, Q fever |
| Bite | Rabies, Capnocytophaga canimorsus, Pasturellosis |
| Faecal matter | Influenza, Toxoplasmosis, Salmonellosis, E. coli |
| Infected carcases (handling) | Ebola, Crimean-Congo haemorrhagic fever, Streptococcosis |
| Food | Toxoplasmosis, Campylobacteriosis |
| Water | Leptospirosis, Tularaemia |
| Arthropod vector (flea, midge, mosquito, tick) | Q fever, Crimean-Congo haemorrhagic fever, Lyme disease, West Nile Virus |

Goodwin, R., Schley, D., Lai, K., Ceddia, G.M., Barnett, J., & Cook, N. (2012). Interdisciplinary approaches to zoonotic disease. *Infectious Disease Reports, 4*(37), 146-151. doi:10.4081/idr.2012.e37

# Appendix B

## Ticks Frequently Found Attached to Humans and Animals and Their Main Associated Pathogens

| Tick families and species | Associated pathogens | Refs |
|---|---|---|
| **Argasidae (soft ticks)** | | |
| *Argas monolakensis* | Mono Lake virus | [1] |
| *Argas reflexus* | *Aegyptianella pullorum*[b] | [1] |
| *Ornithodoros asperus* | *Borrelia caucasica* | [1] |
| *Ornithodoros capensis* | SOLV | [27] |
| *Ornithodoros coriaceus* | *Borrelia coraciae* | [27] |
| *Ornithodoros erraticus* | *B. crocidurae*, *Borrelia hispanica*, ASFV[b] | [1,27,70] |
| *Ornithodoros hermsi* | *Borrelia hermsi* | [1] |
| *Ornithodoros maritimus* | SOLV | [27] |
| *Ornithodoros moubata* | ASFV[b], *Borrelia duttonii* | [1,70] |
| *Ornithodoros sonrai* | *B. crocidurae* | [66] |
| *Ornithodoros tartakovskyi* | *Borrelia tatyschewii* | [1] |
| *Ornithodoros tholozani* | *Borrelia persica* | [1] |
| *Ornithodoros turicata* | *Borrelia turicatae* | [1] |
| *Ornithodoros savignyi* | AHFV[b] | [30] |
| **Ixodidae (hard ticks)** | | |
| *Amblyomma americanum* | *Borrelia lonestari*, *Ehrlichia chaffeensis*, *Francisella tularensis*, *Rickettsia parkeri*, *Rickettsia rickettsii* | [1,27,67,71,72] |
| *Amblyomma aureolatum* | *R. rickettsii* | [36] |
| *Amblyomma cajennense* | *Candidatus* 'R. amblyommii'[b], *Rickettsia honei*, *R. rickettsii* | [1,36,73] |
| *Amblyomma coelebs* | *Candidatus* 'R. amblyommii'[b] | [36] |
| *Amblyomma hebraeum* | *Ehrlichia ruminantium*[a], *Rickettsia africae*, *Theileria mutans*[b] | [1] |
| *Amblyomma maculatum* | *E. ruminantium*[b], *Hepatozoon americanum*[b], *R. parkeri* | [1,36] |
| *Amblyomma neumanni* | *Candidatus* 'R. amblyommii'[b] | [36] |
| *Amblyomma ovale* | *Hepatozoon canis*[b] | [74] |
| *Amblyomma triste* | *R. parkeri* | [36] |
| *Amblyomma variegatum* | *E. ruminantium*[b], *R. africae*, *T. mutans*[b], THOV, BHAV, CCHFV | [1,27,70,75] |
| *Dermacentor andersoni* | *Anaplasma marginale*[b], *F. tularensis*, *R. rickettsii*, CTFV, POWV | [1,68] |
| *Dermacentor auratus* | *Rickettsia sibirica* | [73] |
| *Dermacentor marginatus* | *Babesia canis*[b], *Coxiella burnetii*, *F. tularensis*, *R. sibirica*, *Rickettsia slovaka*, BHAV, OHFV | [1,68,70,73,75] |
| *Dermacentor nuttalli* | *R. sibirica* | [1] |
| *Dermacentor reticulatus* | *A. marginale*[b], *Babesia caballi*[b], *B. canis*[b], *C. burnetii*, *F. tularensis*, *Rickettsia helvetica*, *R. sibirica*, *R. slovaka*, OHFV | [1,68,70,73,76,77] |
| *Dermacentor silvarum* | *Rickettsia heilongjiangensis*, *R. sibirica* | [73] |
| *Dermacentor variabilis* | *A. marginale*[b], *F. tularensis*, *R. rickettsii* | [1,27] |
| *Haemaphysalis concinna* | *Anaplasma phagocytophilum*, *F. tularensis*, *R. sibirica*, TBEV | [1,69,78] |
| *Haemaphysalis flava* | *Rickettsia japonica* | [1] |
| *Haemaphysalis longicornis* | *Babesia gibsoni*[b], *Babesia ovata*[b], *Theileria buffeli*[b], *R. japonica*, POWV | [1,13] |
| *Haemaphysalis punctata* | *A. phagocytophilum*, *Babesia major*[b], *Babesia motasi*[b], *C. burnetii*, *T. buffeli*, BHAV, CCHFV, TBEV | [1,27,70,75,78] |
| *Haemaphysalis spinigera* | KFDV | [1,70] |
| *Haemaphysalis turturis* | KFDV | [1] |
| *Hyalomma anatolicum* | *Theileria annulata*[b], *Theileria lestoquardi*[b], CCHFV | [1,70] |
| *Hyalomma asiaticum* | *T. annulata*[b], *R. sibirica* subsp. *mongolitimonae*, BHAV | [1,73,75] |
| *Hyalomma marginatum* | *Rickettsia aeschlimannii*, *T. annulata*[b], BHAV, CCHFV | [1,70,75] |
| *Rhipicephalus sanguineus* | *Babesia vogeli*[b], *Ehrlichia canis*, *H. canis*[b], *Rickettsia conorii*, *Rickettsia massiliae*, *R. rickettsii* | [1,12,27,38] |
| *Rhipicephalus turanicus* | *R. conorii*, *R. massiliae* | [27] |

[a]Only the most representative tick species are included and the list of associated pathogens may actually be longer; for example, many of these ticks have been found carrying genetic material of *Rickettsia* species or strains of unknown pathogenicity [73].

[b]Unknown pathogenicity for humans, although there might be evidence suggesting that some of these microorganisms are pathogenic.Abbreviations: AHFV, Alkhurma hemorrhagic fever virus; ASFV, African swine fever virus; BHAV, Bhanja virus; CCHFV; Crimean–Congo hemorrhagic fever virus; CTFV; Colorado tick fever virus; KFDV; Kyasanur forest disease virus; LIV; Louping ill virus; OHFV; Omsk hemorrhagic fever virus; POWV; Powassan encephalitis virus; SOLV; Soldado virus; TBEV; tick-borne encephalitis virus; THOV; Thogoto virus.

Dantas-Torres, F., Chomel, B.B., & Otranto, D. (2012). Ticks and tick-borne diseases: A One Health perspective. *Trends in Parasitology, 28*(10), 437-446. doi:10.1016/j.pt.2012.07.003