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Evolution of a transdisciplinary "One Medicine–One Health" approach to global health education at the University of California, Davis

Patricia A. Conrad [a,*], Jonna A. Mazet [b], Deana Clifford [b], Cheryl Scott [c], Michael Wilkes [d]

[a] Department of Pathology, Microbiology and Immunology, School of Veterinary Medicine, University of California, One Shields Avenue, Davis, CA 95616, United States
[b] Wildlife Health Center, School of Veterinary Medicine, One Shields Ave., Davis, CA 95616, United States
[c] Calvin Schwabe One Health Project, School of Veterinary Medicine, University of California, One Shields Avenue, Davis, CA 95616, United States
[d] Office of the Dean, School of Medicine, University of California, One Shields Avenue, Davis, CA 95616, United States

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ABSTRACT

In today's world health events in one nation or geographic area often have repercussions for the health and well-being of populations beyond that region; sometimes even globally. In recent years many factors, most notably concern about emerging infectious diseases, have contributed to an increasing appreciation of the interdependency of human, animal and ecosystem health worldwide. Integrated global approaches to improve the health of humans, animals and their shared environments are proving to be in the best interest of many countries. A special symposium and award were established in memoriam to the internationally renowned epidemiologist, Dr. Calvin W. Schwabe, who (while at the University of California, Davis) was a significant advocate of the "One Medicine" approach to public health, calling upon all health professionals, including veterinarians, to work collaboratively and comparatively to improve human health. This paper discusses the evolution of the "One Medicine" concept into a global "One Health" approach to research, training capacity and service infrastructure, focused not only on disease, but also on health at the individual, population, and ecosystem levels. Projects involving UCD faculty which attempt to integrate a One Health approach include the Health for Animals and Livelihood Improvement (HALI) Project in Tanzania, Envirovet Summer Institute, Avian Flu School and Newcastle Immunization Program in Africa, a web-based virtual global health training program, and the Calvin Schwabe One Health Project.

1. Why focus on global health education?

The world has become a global community, made up of villages as small as a group of bandas in rural Tanzania and as large as the 13 million people in Mumbai, India. The smoke from one village blows over the hills, pastures, and oceans only to be inhaled in distant villages. Health issues are no different. What happens in one nation or geographic area has repercussions for the health and well being of that region and potentially the whole global community. In veterinary medicine this concept is of critical importance in addressing transboundary diseases such as brucellosis, tuberculosis and foot-and-mouth disease. Infections with pandemic potential zoonotic diseases (SARS—severe acute respiratory syndrome, avian influenza, West Nile encephalitis, Lyme disease, echinococosis, anthrax), water toxicity due to pathogens, pesticides and chemicals, and more insidious infections such as human immunodeficiency viruses (HIV) and multi-drug resistant tuberculosis are examples of how health issues quickly become worldwide concerns.

The developed and the developing world share concerns about factors, including malnutrition, migration, access to health care, environmental illness, urbanization,

* Corresponding author.
E-mail address: paconrad@ucdavis.edu (P.A. Conrad).

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and infectious diseases, that affect human health. Developing nations continue to struggle with problems related to rapid population growth, sanitation, adequate safe water, lack of sustainable agriculture and livestock, as well as access to quality health care. At the same time, the health problems in developed nations have shifted to chronic degenerative illnesses, escalating health care costs, and the use and misuse of technology.

Global environmental changes, population growth and increasing international trade, have resulted in expansive, often rapid movement of people, pathogens, animal (livestock and wildlife) products and produce worldwide (Slingenbergh et al., 2004; Bender et al., 2006; Chomel, 2008). Such movement creates enormous challenges for tracking and controlling pathogens (foot-and-mouth disease and avian influenza viruses) and toxins (melamine and ethylene glycol) that threaten both human and animal health. Most countries, including the USA, are inadequately equipped to deal with diseases involving the human–animal interface and environmental change. The impact of these health problems on the world's poorest communities is even more profound, and many have just begun to be recognized.

A global perspective and approach to improve the health of humans, animals and the ecosystems in which they live is in the best interest of all countries. Health is an imperative for economic strength and prosperity. Improved health increases productivity, reduces the need for foreign aid, and creates greater demand for goods and services, thereby stimulating the global economy. By improving health and reducing human suffering we also contribute to political stability, making the world more secure.

Now more than ever, transdisciplinary approaches are needed to solve these complex health problems at the human–animal–environmental interface. Facilitating the involvement of our global community, including universities, industry, governments, non-governmental organizations (NGOs) and citizens, is the only approach that holds promise to improve global health. As a first step, universities need to provide relevant training to prepare students and faculty for successful participation in the sensible resolution of pressing global health problems.

2. The "One Medicine" concept

The connection between human and animal health is not a new observation. In the 19th century Robert Virchow, the German physician and pathologist acknowledged that "between animal and human medicine there is no dividing line, nor should there be. The object is different, but the experience obtained constitutes the basis of all medicine" (Kahn et al., 2007). Early in his medical career, Virchow's experimental studies on *Trichinella spiralis*, a helminth parasite of pigs, as well as bovine cysticercosis and tuberculosis lead him to coin the term "zoonosis" to describe pathogens such as these which are transmitted from animals to humans (Saunders, 2000). In 1873 a young Canadian physician – Sir William Osler – went to study with Virchow in Germany and upon his return he was the first to establish the field of veterinary pathology as an academic discipline in a North American school of veterinary medicine. Osler was also the first to use the term "One Medicine" in the English language literature (Cardiff et al., 2008; Saunders, 1987).

There are several notable examples of successful collaborations involving veterinary and medical scientists over the past 150 years that resulted in significant discoveries benefiting both human and animal health. In 1893, Theobald Smith and F.L. Kilbourne were the first to discover that arthropods could serve as vectors for pathogen transmission. They showed that *Boophilus* ticks transmitted the intra-erythrocytic protozoal parasite *Babesia bigemina*, which caused the severe, often fatal cattle disease known as redwater. Subsequently, their work lead to the discovery by Walter Reed that mosquitoes vector the virus responsible for yellow fever in humans (Wilkinson, 1992). Another example of zoonotic disease discovery is Edward Jenner's famous observations on the exposure of milk maids to cowpox and their resistance to smallpox resulting in the first human smallpox vaccine (Baxby, 1996). Similarly, Jenner's use of the first inactivated vaccine for hog cholera in pigs laid the foundation for the production of human typhus and polio vaccines (Kahn, 2006). A more recent example of successful collaborative discovery is that of physician Rolf Zinkernagel and veterinarian Peter Doherty who were awarded the Nobel Prize in 1996 for their pioneering work showing how the immune system distinguishes normal cells from virus-infected cells (Zinkernagel and Doherty, 1974).

The Schwabe symposium at the Conference of Research Workers in Animal Disease, where this paper was presented in December 2008, was originally established in honor of another renowned scientist and advocate of comparative, collaborative medicine, Calvin W. Schwabe. Dr. Schwabe, the late veterinary epidemiologist and parasitologist organized and chaired the Department of Epidemiology and Preventive Medicine in the School of Veterinary Medicine at the University of California, Davis. During the second half of the 20th century Dr. Schwabe reintroduced the "One Medicine" concept in his book *Veterinary Medicine and Human Health* and is credited with renewing recognition that the "cumulative effect of all practitioners of medicine is aimed at quality of human life and survival" (Schwabe, 1984). Schwabe's presciently contended words that "the critical needs of man include the combating of diseases, ensuring enough food, adequate environmental quality, and a society in which humane values prevail" (Schwabe, 1984) are even more profound today. His vision that human and veterinary medical practitioners are obliged to work together in sharing information to ensure the physical, mental, social, economic and inner health for all life, have never been more important than it is now in our changing global environment.

3. A trandisciplinary "One Health" approach to combat emerging diseases

Many factors have contributed to an increasing appreciation of the interdependency of human, animal and ecosystem health. Arguably, the most notable is the

intensive public interest focused on emerging infectious diseases in the past 20 years. Human infections with zoonotic pathogens such as Ebola and HIV which were originally derived from primates; Rift Valley fever virus and *Mycobacterium bovis* (one cause of human tuberculosis) from livestock and wildlife; hantavirus, *Yersinia pestis* (cause of plague) and *Borrelia burgdorferi* (cause of Lyme disease) transmitted from wild rodents; Hendra, Nipah and rabies viruses from bats and domestic animals; and most recently, avian influenza virus H5N1 and mosquito-vectored encephalitis viruses such as West Nile virus from birds are of great concern to both public and animal health professionals, scientists and policy makers (Bengis et al., 2004; Brown, 2004; King et al., 2004; Torres-Vélez and Brown, 2004; Kahn, 2006). There is also an increasing awareness that a variety of protozoal parasites (*Cryptosporidium*, *Giardia, Toxoplasma*, *Entamoeba histolytica*), bacteria (*Salmonella*, *Vibrio cholera*, *Listeria*, *Escherichia coli* 0157:H7) and viruses (Hepatitis E virus, Coxsachievirus B5, Norovirus) derived from wildlife and/or domestic animals are transmitted to humans via food or water (Schlundt et al., 2004; Dubey and Jones, 2008). In addition, bovine spongiform encephalitis (BSE), referred to as Mad Cow Disease, attracted global attention when it was first discovered in 1986 and soon thereafter was recognized as a zoonotic prion disease, when evidence emerged that the human variant Creutzfeldt-Jakob disease (vCJD) epidemic in the United Kingdom was associated with the consumption of BSE-infected beef. Human diseases caused by these zoonotic agents and others have focused faculty and student research interests on the interrelated factors of land and water use change, natural resource management (including wildlife conservation and livestock production), and human population behaviors that may alter the emergence and spread of zoonotic disease agents.

Animal and human health specialists are particularly interested in the interface of humans, wildlife and domestic animals in shared ecosystems because zoonotic agents are the most significant pathogens associated with emerging infectious diseases. Zoonotic pathogens account for 61% of the infectious organisms that cause illness in people, and are twice as likely to be associated with emerging diseases as pathogens that are not zoonotic (Taylor et al., 2001). Thus, domestic animals, wildlife and arthropod vectors are an important part of the public health picture, being integral to the ecology of many of the infectious diseases currently important to society. In addition to infectious disease, the veterinary and public health professions are called upon to solve environmental (ecosystem) health problems involving the management of agricultural byproducts, environmental contaminants, and air and water quality. The rapidly increasing human population, along with the industry, agriculture, and commerce needed to sustain it, has dramatically expanded the rural–urban interface, accelerating the movement of pathogens and pollutants among people and animals. In addition, the influx of human-generated toxins and chemicals seriously erodes the health and vitality of animal populations and communities. The challenge of sustaining healthy ecosystems defies simple solutions and narrow approaches. Pathogens, toxins, and environmental change are taking an increasing toll on the health of ecosystems. Although the problems are complex, they all point to one conclusion.

We must develop the research, and service capacity and infrastructure to prevent and respond to these rapidly expanding problems, focusing not only on disease, but also on the promotion of health at individual, population, and ecosystem levels.

In 2007 the American Medical Association (AMA) House of Delegates approved a "One Health" resolution that promotes the partnership between human and veterinary medicine and the American Veterinary Medical Association (AVMA) convened the One Health Initiative Task Force. The document produced by the Task Force, entitled "One Health: A New Professional Imperative" (http://www.avma.org/onehealth/onehealth_final.pdf) describes a holistic, collaborative approach to animal and human health (Blackwell and Leap, 2008; Pappaioanou and Spencer, 2008). This approach comprises integrated research, education, and public health prevention, preparedness, and response for achieving improved animal and human health specialists. The initiative recommends the development of centers of excellence, innovative ways to collaborate on research, joint outreach and education for veterinary and human medical professionals, and new directions toward professional opportunities.

Since 2006 there has been a plethora of publications reporting efforts to improve the linkage between veterinary medicine and public health (Hird et al., 2008; Hoet et al., 2008; Howell et al., 2008; King, 2008; Lindenmayer and Schlaff, 2008) as well as to initiate and/or strengthen global health programs in medical (Harden, 2006; Panosian and Coates, 2006; Stapleton et al., 2006; Haq et al., 2008; Hotez, 2008; Koplan and Baggett, 2008; Lorntz et al., 2008; Macfarlane et al., 2008; Quinn, 2008; Saba and Brewer, 2008; Vermund et al., 2008) and veterinary schools (Marshall et al., 2006; Hoet et al., 2008; Hueston, 2008) throughout the USA, Canada and Europe. Reports of efforts to encourage medical educators and students to consider a "One Health" approach to solving global health problems are more limited (AVMA, 2008). In addition to the MPVM program described by Hird et al. (2008), we highlight below several examples of collaborative programs that are currently being supported by faculty and students at the University of California, Davis to encourage a more global "One Health" approach to understanding and solving challenging health problems that arise at the human–animal–environmental interface.

4. Research: Health for Animals and Livelihood Improvement (HALI) Project

Nowhere is the intimate linkage of human and animal health more evident than in the developing world where availability of natural resources determines daily workloads and livelihoods. Water resources are perhaps the most important, as humans and animals depend on clean water for health and survival, and sources of clean water are dwindling due to demands from agriculture and global climate change. As water becomes more and more scarce, animals and people are forced into smaller and smaller

workable areas. Contact among infected animals and people then increases, facilitating infection transmission. When this situation is complicated by co-infection with HIV/AIDS, the results can be catastrophic to families and whole communities due to the increased susceptibility of immunosuppressed individuals to severe disease caused by pathogens such as *M. bovis* and *Cryptospridium* spp., which are better controlled by those with a healthier immune response.

The Health for Animals and Livelihood Improvement (HALI) Project in the Rungwa–Ruaha Ecosystem in the United Republic of Tanzania is a research and capacity building program exploring the impacts of zoonotic disease caused by restricted water flow, degraded water quality, and increased interactions between livestock and wildlife. It is likely that the requisite sharing of diminishing water sources in rural Tanzania is increasing infection transmission and illness in livestock, wildlife, and people; reducing livestock productivity; and even impacting non-agricultural means of livelihood improvement, such as wildlife tourism. By determining zoonotic disease presence and prevalence in domestic animal and wildlife populations in areas of ample available water as compared to areas of water restriction, Tanzanian scientists are collecting critical data, necessary to develop socioeconomic and health models of zoonotic disease impacts. Detailed analyses of these models allow for the development of targeted management recommendations to improve wildlife conservation, water management, public health policy, and agricultural development. The HALI Project is led by Sokoine University of Agriculture, UC Davis Wildlife Health Center, Wildlife Conservation Society and the University of Vermont, with intellectual and financial support from the Global Livestock Collaborative Research Support Program of the United States Agency for International Development. Collaborative support is also provided to this project by the National Institute of Medical Research in Tanzania with medical researchers involved in the socioeconomic health surveys being conducted at the village level as well as in the investigation of tuberculosis transmission to humans. Although HALI is in its initial phases, bovine tuberculosis (*M. bovis*) has already been identified in cattle from which people are consuming raw products and from wildlife that share common water sources and habitat, as well as range into the national park, potentially exposing wildlife, one of Tanzania's most valuable resources, to this population-limiting disease.

5. Training capacity: Envirovet Summer Institute

Founded in 1991, by Dr. Val Beasley of the University of Illinois, College of Veterinary Medicine, the Envirovet Summer Institute has trained over 400 veterinarians, veterinary students and wildlife biologists from 44 nations in the science and policy of ecosystem health (Beasley, 1993). The intensive Summer Institute builds expertise to protect biodiversity and health with a focus on emerging and infectious diseases, chemical contaminants, climate change, and habitat degradation. Envirovet's main objective is to create an international cadre of scientists with the unique perspectives, knowledge, skills, and expertise to address complex issues in ecosystem health, conservation and emerging infectious diseases. The diverse faculty comes from around the globe, with the terrestrial ecosystem health and developing country instruction being led by UC Davis faculty, Drs. Kirsten Gilardi and Deana Clifford. Envirovet 2008 provided seven weeks of lecture, laboratory, and field experiences to 31 (11 male; 20 female) participants from eight countries (Canada, India, Nigeria, Uganda, Sri Lanka, Tanzania, Mexico and the USA) in the areas of terrestrial and aquatic wildlife and ecosystem health, addressing both developed and developing country issues. Each participant engaged in comprehensive classroom, laboratory, and field interactions, totaling 60–70 h per week. Participants were linked to cutting-edge leaders in a wide variety of relevant disciplines. A strong emphasis was placed on collaborations to address health problems at the animal (livestock and wildlife) and human interface which occurred both in natural areas and areas devoted to agriculture, forestry, mining, urban development, and other forms of human enterprise.

Envirovet 2008 was organized into three sessions. Session I, held at White Oak Conservation Center near Jacksonville Florida, focused on wildlife and ecosystem health as over-arching frameworks for environmental problem solving. Session II held at Harbor Branch Oceanographic Institute in Ft. Pierce, Florida introduced students to aquatic (marine and freshwater) animal and ecosystem health, starting with a primer on aquatic ecology, and on the utilization of aquatic biodiversity as an early warning system for environmental contamination. Section III took place in Tanzania, taking advantage of the HALI research activities and a well-developed network of local partnerships forged from the project's commitment to training and capacity building. The overall goals of the Envirovet Tanzania session were to:

- Produce globally aware wildlife and ecosystem health professionals able to solve problems in diverse cultural contexts.
- Develop the participants' understanding of conditions and constraints relevant to addressing health and conservation issues in developing countries.
- Allow participants to develop a professional network of colleagues and exchange ideas and propose solutions in a supportive environment.

In Tanzania, Envirovet students first explored health and conservation at the wildlife–livestock interface, learning from case studies presented by researchers who were actively working to mitigate these problems. They participated in field excursions to sites of wildlife–human conflict, witnessed the impact of irrigation and water diversion schemes and had the opportunity to talk with pastoralists living near a wildlife protected area. Students also directly participated in HALI project research activities which included testing cattle for bovine tuberculosis and sampling of water for fecally transmitted protozoal and bacterial pathogens to evaluate the prevalence of zoonotic disease at the interface between wildlife, livestock and

human populations. At Sokoine University of Agriculture, students learned how to properly handle, test and necropsy chickens in case of a suspected outbreak of highly pathogenic avian influenza. They received lectures from Tanzanian scientists involved in a recent Rift Valley fever outbreak as well as those working with medical researchers to access the impact of bovine tuberculosis transmission to human populations and evaluate the use of rats to diagnose human tuberculosis from bronchial swabs. Current research and innovative methods being developed in Tanzania for diagnosis and surveillance were emphasized in lectures, laboratories and discussions. Pollution problems and the latest research in freshwater and marine ecosystems were highlighted through discussions and field exercises at the Sokoine University, as well as at the Institute for Marine Sciences on Zanzibar. In addition, coral health and innovations in mariculture were discussed in lecture and field visits to relevant sites on the island.

6. Virtual global health training

As valuable as international experience is, many students interested in global health are not fortunate enough to travel to other countries during their training. Therefore, technology may have to be employed in an attempt to simulate these experiences. The article's first author (PC) was fortunate to work with Dave Hird, the 2008 recipient of the Calvin W. Schwabe Award, to develop a computerized case-based CD-ROM (CD) designed to give veterinary students an opportunity to "virtually" work along-side veterinarians as they tried to solve challenging health problems relating to tuberculosis in South African wildlife, bovine abortion in Mexico and neurologic disease caused by plant toxins in Rapa Nui, Chile. Each of the three case modules presented, in a highly interactive format, a problem or mystery that must be solved by the learner. As well as acquiring information by video clips and text about the specific health problem, learners obtained information about the different countries, language and social customs, wildlife and livestock management practices, diagnostic methods, related disease control issues, economic factors, human health risks and the opinions of local experts. After assimilating this information, the learner was required to define the problem and formulate an action plan to confirm the diagnosis or make appropriate health recommendations. The computerized program invoked three adult education principles; active learning, learner-centered education and experiential learning and thereby served as an efficient learning tool and template for developing other case-based, problem solving computerized programs. Individual cases or their component parts, such as videos and animations, developed for this program are freely available and have been used by others in courses offered online and in the classroom as well as for auto-tutorial instruction. The program is accessible on the Web at: http://calf.vetmed.ucdavis.edu/html/International_web/international_menu.html.

A broadband Internet connection is recommended since the modules make extensive use of embedded video and audio clips.

7. Research, training and service: Avian Flu School and newcastle immunization in Africa

The avian influenza group at UC Davis is focused on a 'One Health' approach to research, public health investigations, training and outreach. The group includes poultry pathologists, veterinary epidemiologists, public health physicians, avian flu specialists, a respiratory pathogen research scientist, and extension specialists to develop methods and protocols to manage live bird markets, poultry farms, and wildlife–human interfaces to prevent outbreaks of highly pathogenic avian influenza (HPAI). The interdisciplinary, international team designed a training of trainers program that strengthened the critical links between animal and human components to preventing HPAI. The team determined that HPAI prevention efforts would be more successful if they involved strategies that would also reduce Newcastle disease and other diseases that plague poultry in developing countries.

The full AFS curriculum is designed as a four- to six-day course for training instructors regarding critical information for H5N1 HPAI emergency management and communications, surveillance in domestic and wild birds, public health and worker safety, outbreak prevention and response, and practical skills (using personal protective equipment, packaging diagnostic samples, and swabbing, bleeding, and vaccinating a chicken). The AFS course is designed to be adaptable to different countries and environmental conditions. AFS curriculum has been utilized in courses in over 15 countries by the staff that includes both MD and DVM trained specialists working together.

The AFS team, working with the Department of Veterinary Medicine and Public Health at Sokoine University of Agriculture, the Tanzania Wildlife Conservation Society, and the Tanzania Veterinary Investigation Centres, is also implementing a Newcastle Vaccination and Avian Flu Control Project at the village level funded by the Global Livestock Collaborative Research Support Program. Poultry is a vital resource for rural families and communities across Africa, particularly for the poor. Improving poultry health and production at the village level has tremendous potential to improve the livelihoods and the health of some of the poorest and most undernourished people on earth. In general, women and children raise chickens, ducks, guinea fowl and other poultry for the family and market, putting them at greatest risk for acquiring zoonotic infections, like influenza. In addition, poor poultry production has limited the contribution of domestic fowl to rural livelihoods. This project aims to both assess and improve biosecurity practices at the village or community level through education, outreach and vaccination of chickens for Newcastle disease. Data collection at the rural village level is assessing changes in poultry health and productivity and biosecurity practices. Already, dramatic increases in poultry production have been achieved through the very inexpensive vaccination for Newcastle disease; families who rarely ate eggs or chicken before, opting to sell the few eggs they produced, now have animal protein in their diets with plenty of eggs remaining to sell at market. This project aims to develop a model

village and market to demonstrate the potential for sustainable Newcastle disease vaccination programs, improving health and livelihoods while creating awareness about transmission of diseases like highly pathogenic avian influenza.

8. Calvin Schwabe One Health Project: preparing veterinarians for global challenges

The Calvin Schwabe One Health Project was recently established at UC Davis as a Center of Excellence in response to the AVMA's national One Health Initiative. The project's over arching goal is to provide focused educational opportunities and career transitioning experiences for a new 'cadre' of veterinary medical students, who are prepared to work with human health specialists on global health problems that affect both humans and animals. UC Davis is particularly well suited to support this transdisciplinary research and training project, with schools of veterinary and human medicine as well as management and education, colleges of agriculture and natural resources, letters and science and engineering, the Watershed Institute and the John Muir Institute for the Environment all on one campus, which provides for greater collaborative opportunities and potential linkages with the project. By creating opportunities to support increased communication, interaction and collaboration, the project aims to synergize the critical and innovative thinking of individuals from diverse disciplines and focus their attention on solving challenging global health problems. Within the School of Veterinary Medicine, the project strives to;

- Expand the scope of the core veterinary knowledge base to include information about food safety, water quality, emerging infectious and zoonotic disease transmission, ecosystem health, population and disease epidemiology, disease and emergency surveillance and preparedness, public health and public policy, biodiversity and sustainability, wildlife health and protection, and medical/human ethics.
- Promote the integration of the "One Health" concept into the Masters of Public Health, Masters of Preventive Veterinary Medicine, and PhD programs offered at UC Davis.
- Secure externships, internships, scholarships, fellowships and graduate-level research and educational opportunities which will assist students transitioning into "One Health" careers.

9. Fundamentals of transdisciplinary "One Health" global education

As evidenced above, Osler and Schwabe's vision of 'One Medicine' has evolved into a broader vision of 'One Health' with the focus on health (prevention of disease, nutrition, safety, security, environmental resources, etc.) in addition to the original concepts of infectious diseases and disease processes shared by humans and animals (Kahn et al., 2007). The newly formed University of California Global Health Institute will include a One Health Center of Expertise (co-lead by faculty at the Davis and Riverside campuses). The mission of the Center is to train global health leaders in a transdisciplinary, action-oriented approach to solving problems that affect human, animal (both domestic and wildlife) and ecosystem health globally with a particular focus on those affecting underserved populations of the world. Today's 'One Health' professional is likely to find this perspective and skill set applicable at every level of the private or public health sector as well as in academia. 'One Health' concepts must be integrated into our global health and veterinary curricula to ensure that our graduates, both academic and professional, are prepared to excel in this new and complex global community in which the health of domestic animals, wildlife, people and the environment are interdependent.

Conflict of interest

Drs. Patricia Ann Conrad, Jonna Mazet, Deana Clifford, Cheryl Scott and Michael Wilkes do not have a financial or personal relationship with other people or organizations that could inappropriately influence or bias the paper entitled "Vision for a Transdisciplinary "One Medicine" Approach to Global Health Education".

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