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Perspectives on advancing preventative medicine through vaccinology at the comparative veterinary, human and conservation medicine interface: Not missing the opportunities

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ABSTRACT

Vaccination has historically and remains one of the most cost-effective and safest forms of medicine today. Along with basic understanding of germ theory and sanitation, vaccination, over the past 50 years, has transformed lives and economies in both rich and poor countries by its direct impact on human and animal life—resulting in the eradication of small pox, huge reductions in the burden of previously common human and animal diseases such as polio, typhoid, measles in human medicine and contagious bovine pleuropneumonia, foot-and-mouth disease, screwworm and hog cholera and the verge of eradicating brucellosis, tuberculosis, and pseudorabies in veterinary medicine. In addition vaccination along with other animal production changes has provided the ability to produce otherwise unaffordable animal protein and animal health worldwide. The landscape however on which vaccinology was discovered and applied over the past 200 years, even in the past 10 years has and is undergoing continuous change. For vaccination as a public health tool to have its greatest impacts in human and veterinary medicine, these great medical sciences will have to come together, policy-relevant science for sustainable conservation in developing and developed countries needs to become the norm and address poverty (including lack of basic health care) in communities affected by conservation, and to consider costs and benefits (perceived or not) affecting the well-being of all stakeholders, from the local to the multinational. The need to return to and/or develop new education-based models for turning the tide from the heavily return-on-investment therapeutic era of the last century into one where the investment into the preventative sciences and medicine lead to sustainable cultural and cost-effective public health and economic changes of the future is never more evident than today. The new complex problems of the new millennium will require new educational models that train para- and professional people for thinking and solving complex inter-related biological, ecological, public-, political/economic problems. The single profession that is best positioned to impact vaccinology is Veterinary Medicine. It's melding with human medicine and their role in future comparative and conservation-based programs will be critical to the successful application of vaccines into the 21st century.

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1. Introductory backdrop

The new millennium did not bring the anticipated global Internet technology shutdown however, it has brought with and heralded a time of significant change, opportunity and challenges. I and my co-authors goal in this overview are to celebrate, provocate, instigate innovate and activate those in society who are in interested to contributing to the betterment of human and animal health through vaccination. For vaccination to have its greatest chance of working policy-relevant science for sustainable conservation in developing countries needs to address poverty (including lack of basic health care) in communities affected by conservation, and to consider costs and benefits (perceived or not) affecting the well-being of all stakeholders, from the local to the multinational. The need to return to and/or develop new education-based models for turning the tide from the heavily return-on-investment therapeutic era of the last century into one where the investment into the pre-

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ventative sciences and medicine lead to sustainable cultural public health and economic changes of the future is never more evident than today. If the article gets the attention of researchers, educators/teachers, funders, policy makers, economists and the general public in both developed and developing countries to become involved in finding collaborative solutions to the conservation crisis than we will consider it a success.

2. The celebration

2.1. Human medicine

Vaccination has and remains one of the most cost-effective and safest forms of medicine toward improving health today. Along with basic understanding of germ theory and sanitation, vaccination, over the past 50 years, has transformed lives in both rich and poor countries—resulting in the eradication of smallpox and huge reductions in the burden of previously common diseases such as polio, typhoid and measles. Immunization is particularly well suited to all countries including those with weak health systems, because it requires relatively less training and equipment and does not depend on skilled diagnosis, long-term drug regimens or extensive medical care. Immunization and sanitation remain as the most important public health modality responsible for improving the GNP of developing countries through additional gains in healthier children who are better educated and grow up to impact on their productivity. Like schoolchildren, healthier workers have better attendance rates and are more energetic and mentally robust. Workers in healthy communities, moreover, need to take less time off to care for sick relatives. Body size, which is greatly influenced by one's health during childhood, has been found to have large impacts on long-term productivity. Recent economists [1] have calculated that a 1-year increase in life expectancy improves labor productivity by 4%.

Despite the weakness of health systems in many developing countries, three-quarters of the world's children now receive a standard package of childhood vaccines through the WHO/UNICEF Expanded Program on Immunization to protect them against diphtheria, tetanus, pertussis, polio, measles and neonatal tuberculosis [2]. These vaccines currently save an estimated 3 million lives a year – almost 10,000 lives a day – and protect millions more from illness and permanent disability, thus providing as mentioned above a healthier cohort of people to contribute to the economic development of the nation. The full package of basic vaccines (diphtheria, tetanus, pertussis, polio, measles and neonatal tuberculosis) costs less than $20 per year of life saved in poor countries. "life-years" and "year of life" consistently refer to disability-adjusted life-years (DALYs). Interventions are generally considered extremely cost-effective if the cost per year of life is less than $100. By comparison, antiretroviral treatment for HIV/AIDS—an intervention that donors widely support in the developing world costs up to five times as much at $350 to $500 per life-year saved; by way of comparison, in the US and the UK medical interventions are considered cost effective at $50,000 to $100,000 per life-year saved [1,3–5].

The week during the conference in Amsterdam it was reported that "Vaccine-preventable deaths reach new low in U.S." as reported in a federal report released Tuesday, November 13, 2007 in the Health Day News. Within that same month, it was reported in the Herald Tribune that a vaccination program, called the Measles Initiative, that was founded in 2001 by a consortium of health groups including the WHO, UNICEF, the Centers for Disease Control and the American Red Cross resulted in death rates from measles in Africa dropping by more than 90% between 2000 and 2006. The drop from 396,000 deaths in 2000 to 36,000 in 2006—achieved a World Health Organization goal 4 years ahead of schedule. In 2005, the WHO's Global Health Assembly had set a target of reducing global measles deaths by 90% by 2010. Showing what collaboration form multiple agencies and governments can do through funding – as well as technical support – from groups including the GAVI Alliance and the Bill and Melinda Gates Foundation. From 2000 to 2006, the Measles Initiative spent $475 million to help 46 governments vaccinate close to five million children at ~$1/dose or $95/child total. Since World War II, vaccination has had a major impact on global health, as the following list of successes shows [1]:

- Smallpox, which had killed 2 million people per year until the late 1960s, was wiped out by 1979 after a massive worldwide immunization campaign.
- The number of polio cases fell from over 300,000 per year in the 1980s to just 2000 in 2002.
- Two-thirds of developing countries have eradicated neonatal tetanus.
- Since the launch of the World Health Organization's Expanded Program on Immunization (EPI) in 1974, the number of reported measles deaths has dropped from 6 million to less than 1 million per year.
- Whooping cough cases have fallen from 3 million per year to less than a quarter of a million.
- Diphtheria cases have declined from 80,000 in 1975 to less than 10,000 today.
- The haemophilus influenzae B (Hib) vaccine has reduced the incidence of Hib meningitis in Europe by 90% in 10 years.

2.2. Veterinary medicine—bridging agriculture and medicine

People readily associate the role of veterinarians with private veterinary practice focused on pets and farm animals, but the true dimensions and contributions of veterinary medicine are much broader and reflect expanding societal needs and contemporary challenges to animal and human health and to the environment [6]. Veterinary medicine has responsibilities in biomedical research; ecosystem management; public health; food and agricultural systems; and care of companion animals, wildlife, exotic animals, and food animals. The expanding role of veterinarians at CDC reflects an appreciation for this variety of contributions. Veterinarians' educational background in basic biomedical and clinical sciences compare with that of physicians. However, unlike their counterparts in human medicine, veterinarians must be familiar with multiple species, and their training emphasizes comparative medicine. Veterinarians are competent in preventive medicine, population health, parsitology, zoonoses, and epidemiology, which serve them well for careers in public health. The history and tradition of the profession always have focused on protecting and improving both animal health and human health [7].

Since 1892, a total of 14 diseases have been eliminated from equine, poultry, and livestock populations in the United States [8]. The elimination of these livestock diseases, along with outstanding research in animal health, is key to the remarkable gains in the efficiency of U.S. animal production [7]. Partly as a consequence, U.S. residents spend only approximately 10% of their disposable income on food, whereas residents in other countries pay three or four times more [9]. Although this achievement is recognized to have added billions of dollars to other parts of the U.S. economy, its success in allowing the U.S. public access to a nutritious, affordable, and sustainable food supply – also important for the public's health and well-being – is far less appreciated. The success of the national brucellosis and tuberculosis elimination campaigns has benefited not only the U.S. livestock industries but also human health by substantially reducing these zoonotic threats in animals. Additional public health contributions can be attributed to the Food Safety and Inspection Service of the U.S. Department of Agriculture (USDA),

which has substantially reduced the burden of food-borne illnesses, improved food safety, and eliminated other zoonotic threats. Over the years, CDC has worked closely with USDA and the Food and Drug Administration to improve the safety of U.S. foods and reduce antimicrobial resistance in pathogens that infect both humans and animals.

Veterinary scientist and veterinarians within the Health and Human Services serve in many critical capacities. Veterinary officers in the Commissioned Corps work throughout the U.S. Department of Health and Human Services and in other Federal agencies. Most veterinary officers are assigned to the CDC, NIH, FDA, USDA, EPA, OGHA, NDMS and State Department. Other veterinarians and veterinary scientists function as medical research scientists Post-doctoral NIH/NCI fellows, principal investigators, some specializing in lab animal medicine and providing critical lab animal health infrastructure and support, design of animal models for human disease in most of the HHS institutes. Some are part of the HHS National Disaster Medical Services and were deployed as the veterinary medical assistant teams (V-MATS) and supported the search and rescue in the World trade disaster. Additionally, since 1986, the AVMA and the College of American Pathologists have been working together to create a standard nomenclature that would allow veterinarians, physicians, and other medical professionals to create electronic medical records that use a common language. The Systematized Nomenclature of Medicine, SNOMED, was initially created by the college for human medicine but has since – through the partnership with AVMA – expanded to include veterinary terms. On July 1, 2003, the Department of Health and Human Services announced it would make SNOMED available nationally at no charge, a step toward instituting a standardized electronic medical records system. The HHS signed a 5-year, $32.4 million contract with the college to license SNOMED and make it available nationally. The National Library of Medicine is administering the program. Prior to the HHS's agreement with the AVMA, practitioners in areas of practice nationally on the front line of surveillance would have had to pay a $2000 to $3000 annual registration fee to access SNOMED.

The CDC has expanded the role, scope, and influence of veterinarians and veterinary scientists and epidemiologists in public health since its inception in 1946 [10]. Early in the history of CDC, veterinarians in the U.S. Public Health Service and the CDC Veterinary Public Health Division helped reduce zoonotic diseases, especially rabies and food-borne illnesses [11]. Today, 89 veterinarians serve throughout CDC in positions that address not only infectious diseases but also the entire spectrum of public health challenges: environmental health, chronic diseases, human immunodeficiency virus infection and acquired immunodeficiency syndrome, injuries, immunizations, laboratory animal medicine, global health, migration and quarantine, health education, and bioterrorism. Veterinarians contribute as epidemiologists, laboratory scientists, policymakers, researchers, and surveillance experts and in environmental and disease prevention and control programs both domestically and globally. At CDC, 228 veterinarians have participated in the Epidemic Intelligence Service since 1951 [12]. Forty-one states now have State Veterinary Public Health officials. In 2005, almost 300 students and faculty attended the first veterinary student day at CDC; in April 2007, CDC will co-host an inaugural conference with the Association of Schools of Public Health and Association of American Veterinary Medical Colleges. In addition, CDC has been recognized as a World Association for Animal Health Collaborating Center for Emerging and Re-Emerging Zoonoses. The CDC publication, *Emerging Infectious Diseases*, has highlighted zoonotic diseases in nearly every issue to zoonotic diseases and has devoted an annual issue in each of the previous 2 years. The CDC has provided an important scientific forum for zoonotic disease research and programs both domestically and globally and should serve as a template for the NIH, as will be discussed later in this paper (Section 5.1), for moving these highly trained and broad-based medical skill set professionals from a more decentralized setting into a central institute at the NIH.

3. The new reality

3.1. Preventative medicine—human health

Benjamin Franklin's famous quote, "An ounce of prevention is worth a pound of cure" was actually fire-fighting advice—he founded the first fire fighting organization in Philadelphia, its obvious application to medicine, although obvious, has not been a mainstay of heavily invested research and development in human health practices.

Many of the leading causes of death and disability in the United States can be prevented [13]. Primary prevention can prevent or arrest the disease process in its earliest stages by promoting healthier lifestyles or immunizing against infectious disease [72]. Secondary prevention, by detecting and treating asymptomatic risk factors or early asymptomatic disease, can substantially reduce subsequent morbidity or mortality. The human and veterinary clinician plays a pivotal role in both primary and secondary prevention. Health professionals deliver vaccinations, screen for modifiable risk factors such as high blood pressure and high cholesterol, counsel patients about smoking and other behavioral risk factors, provide screening tests for early detection of cancer and other chronic conditions, and advise patients about the benefits and risks of preventive therapies such as postmenopausal hormone replacement therapy.

The preventative health care landscape has changed in some regards in the 17 years since the U.S. Preventive Services Task Force (USPSTF/Task Force) was first established in 1984 to provide advice about prevention for health professionals. Prevention became more of an integral component of primary health care [14]. Delivery of clinical preventive services such as immunizations, mammograms, and cholesterol screening has risen steadily over the past two decades (National Center for Health Statistics [15]). Roughly 90% of employers now include well-child visits, childhood immunizations, screening tests, and adult physical examinations among covered health benefits, compared to less than half that did so in 1988 [16]. Interest in prevention grew significantly among the public, clinicians, educators, employers, and policymakers [17] and health plans and individual clinicians were increasingly being held more accountable for the quality of the preventive care they provide to their patients [18].

3.2. So what happened?

At the close of the 20th century, health care costs in the United States continued to rise steadily, accounting for 13.5% of the gross domestic product in 1998 [19], and debate on health care funding for the aging American population intensified.

No doubt fueled by the incredibly imbalanced historic spending in preventative healthcare of 3 cents for every 97 cents spent for curative treatment [20]. Numbers are harder to come by for recent years, but given the spiraling costs of treatment since 1988 it is likely that this ratio has gone down considerably since then—possibly grossly estimated to be closer to 1:99 today. In this environment, preventive services often compete with one another and with diagnostic- and treatment-oriented care for increasingly constrained resources [21]. While preventive services are often believed to save costs, delivery of most preventive services, with few exceptions (e.g. some immunizations), incurs net costs [22].

Evidence that US society clearly favors the cure (or treat) approach to disease over prevention can be shown in the following ways. First, though there is a shortage of preventive medicine specialists (public health, general preventive medicine, occupational medicine, and aerospace medicine physicians), in the US the number of residents in training in 2004 was less than 0.4% of all residents, not sufficient for replacement or to fill the expanding demand for the specialty's skills and talents [23,70]. Second, preventive medicine residencies and subspecialties in human and veterinary medicine are generally found in only graduate medical education programs not financed by CMS or mainstream academic training programs. Third, we believe that our preventive acts are only statistical, whereas our curative acts are certain. This mistaken belief perhaps derives from our sense that we have more control over cure outcomes than prevention outcomes—we think that we do cure, whereas we only facilitate prevention. This notion of doing vs. facilitating is an important one, because if we believe that our curative actions are more effective than our preventive ones then we will more likely act toward the more effective. The editor of the *British Medical Journal*, Fiona Godlee, expressed this well when she states, "Because it is acted on healthy people, preventive medicine needs even stronger supporting evidence on benefits and harms than therapeutic interventions" [24].

Thus substantial gaps in the delivery of effective preventive care in the United States remained, however, because clinicians continued to face many of the same barriers that originally spurred the formation of the first USPSTF. Identifying effective interventions were and are difficult in prevention, where prospective controlled trials are often difficult to conduct. These studies come from the field of epidemiology which has changed remarkably during its growth in the past quarter century. One of those changes has been a mixed blessing of ever-increasing specialization among its practitioners at the cost of the generalist. This phenomenon has shaped the field and a partial explanation for this trend is found in the decline in the availability of training funds not focused on specific and general disease areas. Without returning to the training of general conservation-medicine based epidemiologists, the needed trend associations and study designs that are needed to show the economic and public health returns related to preventative practices field will not be realized and in addition lose some of its ability to quickly respond to new and expected emerging public health challenges. Conflicting recommendations from different organizations, further exacerbated by the advocacy positions of some groups, leave many clinicians uncertain about what to do. Clinicians facing increasing time pressures in practice may question the value of some routine preventive interventions, as may employers and other payers struggling with accelerating health care costs. Although more prevention information is reaching the public, the messages conveyed are often inconsistent and increasingly colored by commercial self-interest. Clinicians may feel compelled to provide unproven or ineffective services because patients demand them or they fear being sued, but patients may find that insurance coverage for individual preventive services, especially new technologies, is inconsistent. The importance of clarifying what we know and do not know about the effectiveness of specific preventive services is as important in 2001 as it was in 1984. Although the USPSTF was disbanded in 1989 with the release of the Guide, the need to keep pace with the rapid growth in scientific evidence led to convening a second panel in 1990. The second USPSTF was smaller, with only 10 members, eight of whom were primary care physicians. It refined the previous group's methods for reviewing evidence and making recommendations, and expanded the scope of topics. It adopted policies for disclosure of conflicts arising from financial interests, funding sources, or other affiliations.

The work of the second USPSTF was marked by strengthened ties with both federal and nongovernmental partners, including primary care subspecialty societies. The work of the second USPSTF culminated in the publication of the second edition of the Guide in 1996, which covered over 200 interventions in 70 areas. By the time the second edition of the Guide appeared, the environment for preventive medicine and evidence-based medicine had changed dramatically. Managed care organizations, which had emerged as a dominant paradigm for delivering and paying for health care, included some preventive care among basic covered services more commonly than had traditional fee-for-service insurance. At the same time, the heightened competition spurred by managed care brought increased attention to costs and value of treatments with less attention given to prevention. The Guide was frequently cited by health plans and systems of care in defending their health maintenance programs and benefits packages, and its recommendations informed many of the Health Plan Employer Data and Information Set (HEDIS) quality measures developed by the National Committee on Quality Assurance for evaluating health plan performance but not integrated into cost saving practices by the insurance companies.

3.3. Human vaccination

The rapid progress towards universal vaccination coverage in the 1970s and 1980s has slowed in recent years. UNICEF funding for vaccination fell from $182 million to $51.4 million between 1990 and 1998 [25,63]. Global coverage of the diphtheria, tetanus, and pertussis (DTP3) vaccine has been at around 74% since 1990 [26]. Fifty-seven developing countries have yet to eliminate neonatal tetanus, and 200,000 babies died of the disease in 2000. Ten developing countries reported cases of polio in June 2005, despite the massive (and largely successful) global effort to eradicate the virus [27,50,51]. Sixty-two percent of countries, meanwhile, had still not achieved full routine immunization coverage in 2003, with GAVI estimating that at least 9.2 million additional infants need to be reached to achieve full coverage. There are several factors behind this loss of momentum. Although dramatic progress has been made in increasing worldwide vaccination coverage from below 5% to above 70%, the task has inevitably become harder now that the easiest-to-reach populations have been vaccinated. Because these communities are more elusive, the average cost per vaccination has increased, and it may be that other apparently cheaper health interventions have become more attractive.

There are many practical problems impeding vaccine delivery. Delivering vaccines to patients requires functioning freezers and reliable transport to move the vaccines from port to clinic; clinics refrigerators (which in turn require a constant supply of energy); good roads and with access to people who need to be immunized; parents who know the value of vaccination; trained medical staff to deliver the dose; and sterile syringes. Only 16% of vaccine-importing countries could guarantee vaccine safety and quality [28], while a further study of 19 developing countries found that at least half of injections were unsafe [64,73–76]. The third factor behind the lack of progress in recent years is political. Political disruptions have affected coverage in some areas. In Somalia and Congo, for example, where vaccination rates have fallen rapidly in the past decade, war and social breakdown have impeded public health campaigns, despite "vaccination days" in Congo that temporarily halted fighting. Gauri et al. have found that the quality of institutions and governance are positively correlated with vaccination coverage [29,62].

Politics in the developed world have also played a part. According to a report by the US Institute of Medicine, in 1982 the US vaccine industry was forced to stop offering low-price vaccines to develop-

ing countries following congressional hearings that "savaged" the industry for "allegedly subsidizing vaccines for the poor children of the world by charging high costs to US families and taxpayers". As the Institute of Medicine points out, this move was based on a flawed premise, as the US vaccines would have been developed anyway to protect American children and travelers.

Public perceptions of vaccination change—as coverage spreads through a community and it reaches a point at which those who are unvaccinated are highly unlikely to catch a disease because herd immunity has set in. At this juncture, it may be more rational for an individual to refuse vaccination in order to avoid any risk of side effects. With the oral polio vaccine, for example, there is a one in a million chance of paralysis, and in societies where mass vaccination has eliminated the disease, the risk of paralysis is greater than that of catching polio itself. What had once been a public and private good is now a public good but a private risk. As more and more people choose to avoid this risk, of course, overall coverage rates decline, and the community is once again exposed to the threat of the disease. Public perceptions have been influenced by vaccine scares. Controversy and the attendant bad publicity about the safety of vaccines have been abetted by incidents such as the withdrawal of half the US supply of flu vaccines in 2004 due to contamination at the manufacturer [60]. In addition, alarms over the safety of vaccines such as that for measles, mumps and rubella (MMR), which some believe to cause autism, have further fanned the anti-vaccine movement's flames [59]. In the US, disputes continue to rage about the scientific basis of such claims, but the preponderance of the evidence, according to the US Centers for Disease Control (CDC), says that the MMR vaccine is safe [30]. In response to these types of controversies in the US, the Institute of Medicine has called for independent oversight of vaccine safety studies to ensure the fairness and openness of the Vaccine Safety Datalink program, which is overseen by the CDC.

As one can see there are many complex factors that have to be considered when bringing vaccination programs into existence.

3.4. Veterinary vaccination

The impact of vaccination of animal diseases on agriculture is typically assessed in quantitative terms—lost revenues; costs of eradication, decontamination, and restocking; and the numbers of affected farms, animals and humans. This approach can be applied universally to all outbreaks in all countries because it normally reflects the hard data supplied by large commercial operations and the estimates by relevant governmental agencies of small farmer impact [31]. When used exclusively, however, it fails as a barometer, because it does not and cannot factor in the multi-dimensional character of major disease events—and the accompanying societal effects that often get lost when it comes to assessing the damage in developing countries. The quantitative approach must also be interpreted, and cannot be used "as is" for comparing impacts in developed and developing countries. Further, while export trade losses in a developing country may be small in terms of the dollar amount, the impact upon its pre-epidemic market share is inevitably greater and more persistent. Other impacts such as effects on human health and community stability tend to be more visible and last longer in developing countries, particularly at the village level where animal are husbanded primarily for the benefit of the immediate family, and often in impoverished circumstances [31].

The consequences of animal diseases in domesticated birds and livestock can be complex and generally go well beyond the immediate effects on affected producers. These diseases have numerous impacts, including:

- Productivity losses for the livestock sector (e.g. production losses, cost of treatment, market disturbances).
- Loss of income from activities using animal resources (in such sectors as agriculture; energy; transportation; tourism).
- Loss of well-being of human beings (morbidity and even mortality rates; food safety and quality).
- Prevention or control costs (production costs; public expenditure).
- Suboptimal use of production potential (animal species, genetics, livestock practices).

The most direct economic impact of animal diseases is loss of production and/or productivity, and ensuing income losses for farmers [55]. However, if the economy depends on one or some of the vulnerable products, the impacts can be serious, and local food security can be threatened. The economic impact also depends on response strategies adopted by farmers and possible market adjustments. If the farm economy is diversified or if there are other opportunities to generate income, the impacts can be mitigated. The economic impact also depends on response strategies adopted by farmers and possible market adjustments. The loss of the farmer's "well-being" will generally be lower than the value of the lost product, except where the farmer has few alternatives or is wholly dependent on the affected product, which is quite often the case in developing countries. Direct losses are the result of the disease itself (they may be very high when mortality rates are between 50 and 100%), or from animal health measures (stamping-out policies) [31,32]. In Vietnam, one of the countries most seriously affected by the avian flu, almost 44 million birds – 17% of the country's poultry population – had to be destroyed at an estimated cost of US $120 million (0.3% of GNP) [33]. The smaller scale producers lost the least in absolute terms, but the most in relative terms, as the outbreak resulted in losses equivalent to upwards of 50 times their daily income (from US $2 a day or less). In Africa, abortions caused by the Rift Valley fever virus not only affect birth rates, but also push human consumption of milk downward in the year following an outbreak [34]. In the dairy farming sector in Kenya, it is estimated that losses in milk production accounted for 30% of all losses caused by an outbreak of foot-and-mouth disease in the 1980s. Direct costs are generally well below the indirect costs of animal diseases and are directly linked to the rapid containment of outbreaks: case studies have shown that early detection and the implementation of appropriate measures in the event of an outbreak are essential to help minimize direct losses as much as possible. Conversely, inappropriate control and eradication measures are at the root of such endemic situations, which are much more difficult, and infinitely more costly, to keep under control or eradicate.

3.4.1. Ripple effects

The livestock sector plays a significant role in the economic development of many countries and vaccination can serve as one of the most important means of assuring its health. As such the cost of not developing new and important or properly applied vaccines can have tremendous economic consequences. The production of meat and other animal-based food items generates income, jobs, and foreign exchange for all stakeholders in the animal industries. Consequently, an epizootic which could have been otherwise mitigated by vaccination can affect the industry's upstream (inputs, genetic resources) and downstream activities (slaughterhouses, butchering operations, processing, marketing) in terms of jobs, income for the stakeholders in the industry, or market access. A survey by the Food and Agriculture Organization of the United Nations (FA0) on avian flu revealed that in the most seriously affected regions of Indonesia, 20% of permanent workers at industrial or commercial farms lost

their jobs [33]. Similarly, an outbreak of contagious bovine pleuropneumonia in Botswana led to the destruction of more than 300,000 animals in the most seriously affected province, and the immediate closure of the export slaughterhouse, which employed 200 persons. Owing to the catalyst role of livestock raising in the rural economy as a whole, the costs of the indirect effects of these measures were later estimated to be seven times higher than the costs caused by direct losses [32].

In Vietnam, 60% of the poorest segment of the population, for which poultry farming accounts for 6–7% of household income, is particularly vulnerable to income losses caused by avian flu. The FAO and World Organization for Animal Health (OIE) estimate that between one-third and one-half of the populations living in the most seriously affected areas of Southeast Asia depend on poultry farming for at least a part of their income [32,35]. In France, the leading European poultry producer, it is estimated that farmers affected by the crisis lost 40% of their income in 3 months (between January and March 2006). The effects of the production losses are also linked to price variations, which are caused by supply and demand (im)balances. Depending on the market, prices can rise sharply (consumer product on the domestic market) or plummet (product banned for export but cleared for consumption on the domestic market, product deemed too dangerous for human consumption or perceived as such). In Brazil, where 30% of products are exported, the price of a day-old chick, an early indicator of a possible change in production, reportedly fell by 50%. And even in cases where the country is not infected, market uncertainties and the fall in prices prompted the largest producers to cut back production by 15% this year. Loss of access to, or the opportunity to access, regional and international markets generally have more significant economic implications than just production losses. In 1997/1998, the Rift Valley fever outbreaks in East Africa seriously affected pastoral economies in Somalia, with a decline of more than 75% in exports (which generate more than 90% of foreign exchange in "Somali land"), following an embargo declared by Saudi Arabia on all animal products from the Horn of Africa [32,36].

Conversely, the World Bank has reported that eradication of certain major diseases to facilitate access to "high value" export markets can provide considerable benefits. Loss of access to, or the opportunity to access, regional and international markets generally have more significant economic implications than just production losses. Uruguay is a good example of a country that gained access to a lucrative market after eradicating foot-and-mouth disease. Beef exports increased in volume by more than 100% and in value by 52% after the OIE declared Uruguay to be officially foot-and-mouth disease-free without vaccination in 1996. Access to the U.S. market (where prices are double those of the domestic market) provides Uruguay with additional revenue to the tune of US $20 million each year. A medium-term analysis showed that access to "Pacific Rim" markets would generate additional revenue of US $90 million each year, and yet, before the disease was eradicated, Uruguay had been spending (only) US$8 million to US $9 million each year on vaccines to combat foot-and-mouth disease. In this case, control costs would account for less than 10% of the revenue generated by exports alone [32].

3.4.2. Spillover effects

Animal diseases that could be controlled by vaccination can have major effects on food availability and quality for poor communities. It is well known that agriculture plays an important role in the generation of income and jobs in other sectors but the closeness of this interdependence became particularly obvious during recent epizootics. For pastoral societies, animal husbandry contributes directly and indirectly to food security and to nutrition as a source of quality proteins, vitamins and trace elements, traction, and commercially tradable products [68,69]. Certain diseases could have significant repercussions on food supply and the nutrition of poor communities that do not have readily available substitute products, which could therefore lead to famine (rinderpest for example). Poultry meat is the primary animal protein in Africa (which has little to begin with) and the indispensable source of discretionary income for the survival of millions of small farmers. The high mortality rates as a result of avian flu, which is extremely pathogenic, and the sanitary slaughter of poultry would therefore have a negative impact on the food available to the entire population, as well as on rural revenue.

Furthermore, developing or transition countries which generally have poor public health systems are particularly at risk from zoonoses making vaccination against these diseases particularly important to target. In 1977/1978 a major Rift Valley fever epidemic in Egypt resulted in 200,000 human cases and 600 fatalities [32,36]. Twenty years later, a new epidemic affected over 500,000 persons in East Africa, and 500 persons succumbed to the hemorrhagic form of the disease. But zoonoses also affected industrialized countries with high health standards as was the case with the bovine spongiform encephalopathy crisis in Europe [65]. Food-borne diseases (over 200 have been classified) are a major source of acute gastroenteritis (which costs the Netherlands US $27 million per year) and the cause of major morbidity with fatalities among children in the Third World [32]. In the specific case of a pandemic, most of the economic loss is caused by the increase in morbidities and fatalities in the human population and its repercussions on the world economy. The most recent estimates suggest that the "Spanish" influenza in 1918 caused the death of 50 million persons, that is, 2.5% of the population at the time. The most obvious economic losses were the reduction in quantity and productivity of the workforce, and according to the experts, in the case of a pandemic could represent 10 times more than all the other losses combined [33]. Another category of economic impact is linked to individual strategies to avoid contamination—or to survive possible contamination. The example of the severe acute respiratory syndrome (SARS) clearly shows the sharp drop in demand in the services sector (tourism, public transport, retail trade, hospitality and food services) resulting from the combined efforts of individuals to avoid any close contact [37]. Based on the experience with severe acute respiratory syndrome in South-East Asia, the World Bank thinks that an avian flu pandemic could result in a 2% loss of the world's gross domestic product and cost the world economy US $800 billion in the space of 1 year. The losses are difficult to calculate and would undoubtedly be much more significant in light of the extremely high mortality rates in developing countries which do not have good health care systems. The impact of animal diseases on the tourism and leisure sectors could also be quite significant. The negative effect of foot-and-mouth disease in the United Kingdom on these two sectors amounted to US $49 billion because of restrictions on access to rural areas and represented more than half of the total cost of the disease [32].

The Federation of American Scientists' Animal Health/Emerging Animal Diseases (AHEAD) project proposed a major program in sub-Saharan Africa to detect and document the extent of infectious diseases shared by farm and wild animals, and to supply treatment, prevention and control services to remote communities that have previously been neglected by other programs, both national and international. This program, International Lookout for Infectious Animal Disease (ILIAD), was implemented in South Africa [38]. At the core of ILIAD is the need for a permanent and sustainable regional program of *in situ* surveillance designed to detect, monitor, treat, prevent and control infectious diseases with the goals of increasing livestock production in remote farming communities, protecting the health of wild species, building indigenous

physical and professional resources, and introducing communications and epidemiology information technologies. Transmission of infectious diseases is rampant in remote communities in the sub-Saharan region, just as they once were in the United States and as they always are wherever poverty and farming co-exist. Diseases shared by wild, farmed and captive/bred animals, and by animals and humans, suppress food production, frustrate species preservation efforts and greatly affect public health. Detection, prevention and control of these diseases are an essential element in expanding trade, improving nutrition, exploiting ecotourism and ensuring food security.

ILIAD is structured in the investor mode—an international consortium of donor groups providing short-term developmental assistance with program direction and oversight provided by veterinary diagnostic, public policy and epidemiology experts representing the Sub-Saharan Africa Partnership members—the renowned Onderstepoort Veterinary and Exotic Disease Institutes (OVI) and Tuskegee University (TU), and FAS-AHEAD. Given positive assessments of the benefits of the program after 3 years, national or provincial institutions will integrate some or all of the activities into their official veterinary and agricultural activities.

3.4.3. Long-term effects

It is difficult to calculate the cost of the public's loss of confidence in animal industries in their countries, or of an importer country towards the Veterinary Services of the exporter country. Animal diseases can have major effects on food availability and quality for poor communities. Consumers' obsessive fear of bovine spongiform encephalopathy (mad cow disease), fed by the media and which a good communication strategy could have prevented, would have tremendous social repercussions on a Europe still reeling from long term economic repercussions. In Italy, the baseless perception of a food risk related to avian flu coupled with low confidence in public health services eventually resulted in a 70% reduction in the consumption of poultry and eggs. The loss of confidence by an importer country can trigger a lasting embargo and major economic and social repercussions (Arabian Peninsula embargo on the Horn of Africa, affected by the Rift Valley fever virus). Loss of access to, or the opportunity to access, regional and international markets generally have more significant economic implications than just production losses. Animal diseases might also have indirect long-term impacts, affecting deferred productivity. This is the case for example of the reduction in the fertility rate of long-cycle species, the effects of which span periods of 10–20 years [32].

In short, the long-term costs of a slow response are rarely taken into account. Economic analyses focus primarily on the effects of the outbreaks and rarely take into account the long-term effects of an endemic situation (characterized by less virulent outbreaks which recur for several years). This is the case of classic swine fever in Haiti where recurrent outbreaks reduced the usage rate by 10%, which for pig farmers meant a loss of revenue of US $2.7 million per year [31–33]. With major crisis, long-term impacts would make themselves felt, since the additional costs of financing prevention and control measures would lead to an equivalent reduction in savings and investments. For example, the analysis of the global impact of the avian flu crisis in Europe was complicated by outbreaks of foot-and-mouth disease in Brazil, the largest global exporter of beef and poultry. It is therefore easy to imagine what the combination of these two events would mean in terms of the upward push of prices of all meats, similar to what occurred in 2004 with North American beef and bovine spongiform encephalopathy. The European Union, a net importer of beef, especially from Brazil, would see an increase in the price of beef in its internal markets stemming from the embargo imposed on Brazilian beef because of the foot-and-mouth disease.

It must be pointed out that the crises could have a cumulative impact, particularly since they are amplified by the effects of globalization The following example therefore illustrates the ripple, spillover and remote effects: in the United States, where 62% of oleaginous and cereal production is geared towards animal production. An epizootic which reduces animal production by 10% would have the immediate consequence of the loss of 418,000 jobs, a surplus of 18.4 ton in cereals and oleaginous products, a 10% reduction in world trade and, crises in other producing countries.

4. Ecological–microbiological soup

In 1900, nearly 800 Americans out of every 100,000 died each year of infectious disease. Laurie Garrett, author of "The Coming plague: newly emerging diseases in a world out of balance", writes that in the postwar environment, powerful medical weaponry (antibiotics, vaccines, water treatment, anti-malaria drugs) gave scientists confidence that they could significantly control and/or eradicate infectious disease from viral, bacterial or parasitical sources. In the late 1960s, the Surgeon General of the USA, William H. Stewart, said that ". . .it was time to close the book on infectious diseases and pay more attention to chronic ailments such as cancer and heart disease." A measure of that success came towards the end of the 1970s, when the world realized that smallpox had become the first disease to be eradicated from the human species. Such halcyon days from the 1960s to the early 1980s are but a memory. By 1980, the numbers were down to 36 per 100,000. The "Health for All" accord, signed in 1978, set a goal of the year 2000 for eliminating many international scourges. But amid all this optimism, the numbers started rising. In 1995, 63 people per 100,000 died and we know the rest of the story, . . . or do we? The grandiose optimism rested on two false assumptions; that microbes were biologically stationary targets, that for the most part human and other animal diseases were for the most part limited to those species and geographically sequestered. Scientists have witnessed an alarming mechanism of microbial adaptation and change, anything but stationary, microbes and the insects, rodents and other animals that transmit them are in a constant state of biological, ecological flux and evolution [52].

According to the U.K. Centre for Tropical Veterinary Medicine, 60–70% of all the 1415 known species of infectious organisms that affect human health (causing a quarter of the world's deaths) can be transmitted by animals. Approximately 175 of these infectious organisms are linked to diseases that have only recently emerged, or have increased in severity (and geographic distribution) in recent years. WHO averages 200 outbreak investigations every year, and around 50 will require an international response. More than 30 new and highly infectious diseases have been identified in the last 20 years. Furthermore, 20 known strains of diseases such as tuberculosis, many species of gram positive and negative bacteria as well as many parasites, e.g. malaria, food animal coccidia have developed resistance to various classes of antibiotics, while old diseases have reappeared, such as cholera (in Angola, with 1298 deaths), yellow fever (new cases recently reported in Guinea, Sudan, Mali, and Senegal), plague, dengue fever, meningitis, hemorrhagic fever, measles, mumps, rubella and diphtheria. There are 63 emerging diseases just among marine life, reports the book Conservation Medicine, and these include tuberculosis in fur seals and chlamydiosis in sea turtles.

More staggering than these cited numbers in living animals including humans are those coming out of the microbial genetic sequencing and diversity studies involving the oceans. Recent data in this field suggest that the oceans of the world contains approximately 10 (31) phage particles or virions (cf. 22 million metric

tons), much of it turning over once per day and most likely be a regular source for current and future zoonotic and human infections. This vast mutation engine, even if one assumes a minimal mutation rate, generates the equivalent of hundreds of new complete human genomes per day. A 200-L sample of surface seawater was concentrated; $\sim 2 \times 10$ (12) viral particles, the DNA once randomly sheared and cloned yielded 1,934 fragments for sequencing. Data analysis showed that most of the sequences were from previously unknown viruses. Approximately 3.5% of the total sequence samples overlapped, suggesting that the marine viral community was highly diverse. A unique mathematical analysis further suggested that approximately 10 (4) different new viral types may be present. It is obvious from this most recent description that complex and confounding zoonotic interactions can be expected to occur as ecosystems become concentrated and/or diluted during the upcoming environmental and ecological change. This will require a new breed of medical scientists that have foregone the days of super- and sub-specialization and are now grounded in both depth and broad general eco- and bio-medical systems training.

5. Comparative and conservation medicine

5.1. One medicine

Few people recognize the broad range of clinical and basic veterinary research and its many important contributions to society in the realms of public health and food safety, vaccination, fertility, drug and vaccine development, surgical techniques and biodegradable materials, space medicine, animal health and welfare, and comparative medicine [66]. Opportunities in veterinary research include comparative studies with animals that shed light on human health problems; the development of tools to better detect, prevent, and control zoonotic diseases (that spread from animals to humans); the establishment of scientifically based policies for the humane treatment of animals; and the development of measures to secure and protect the nation's food supply and farm-animal economy from a potential act of bioterrorism [67,71].

The new complex problems of the new millennium will require new educational models that train para- and professional people for thinking and solving complex inter-related biological, ecological, public-economic problems. The single profession that is most centered on the new paradigm is Veterinary Medicine. The three major disciplines within veterinary medicine and research – public health, comparative clinical and basic medicine, and animal health – are closely intertwined [49,61]. For example, research in comparative medicine contributes to animal health through the development of preventive medicine and treatment. The study of wildlife diseases contributes not only to wildlife health and conservation, but also to public health because many animal diseases can spread to humans. Therefore, collaborative and interdisciplinary research is crucial in translating scientific advances from one traditional discipline to another.

However, interdisciplinary research is in many cases hampered by administrative, funding, and cultural barriers between institutions. Furthermore, agencies that support veterinary research have specific missions. Funding to support proposed interdisciplinary research can be difficult to obtain when it is partially related to the mission of several agencies but does not perfectly fit the mission of any one agency. The future requires the veterinary research community to encourage research funders to develop a long-term interagency strategy for veterinary research [53,54,57]. In 1858, Rudolph Virchow, the father of comparative medicine, stated, "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" [39]. Sir William Osler (1849–1919), considered the best-known physician in the English-speaking world at the turn of the century, called the "most influential physician in history" is quoted as saying "Veterinary medicine and human medicine complement each other and should be considered as one medicine." Dr. Calvin Schwabe, a retired UC Davis professor of veterinary medicine who pioneered the use of human disease tracking techniques in the study of animal illnesses, a global authority on animal diseases that are communicable to human beings and was an early visionary in a field that today is marked by the emergence of pathogens such as avian influenza, mad cow disease and SARS. In 1966, Dr. Schwabe established the Department of Epidemiology and Preventive Medicine at the UC Davis School of Veterinary Medicine—the first of its kind in the world at a vet school. The author of more than 200 publications, he promoted the concept of "One Medicine," which attempts to bring the fields of human and animal health care together. To this goal in June of 2007 The American Veterinary Medical Association (AVMA) announced that in partnership with the American Medical Association (AMA) there was an adopted resolution calling for collaboration on a One Health Initiative. The two national, medical organizations will work collaboratively on areas of mutual medical interest, such as pandemic influenza, bioterrorism risks, biomedical research and will be charged with developing strategies to promote collaboration among the various health science associations, colleges, government agencies and industries. A quote from a AMA Board Member, Duane M. Cady, MD "New infections continue to emerge and with threats of cross-species disease transmission and pandemic in our global health environment, the time has come for the human and veterinary medical professions to work closer together for the greater protection of the public health in the 21st Century," The AVMA policies supporting the concept of "One Health" include:

- National Research Council's Recommendations in "Animal Health in the Crossroads".
- Participation in development of the objectives for the Healthy People 2020 program.
- Nomination to the HHS Secretary's Advisory Committee on National Health Promotion and Disease Prevention Objectives for 2020.
- Healthy Animal 2010 Vision.
- Research for Healthy Animals 2010.
- Training in Foreign and Emerging Animal Diseases.
- Comparative Medicine and Translational Research.

Furthermore to strengthen this initiative and give it a renewable funding foundation, it would be recommended to move toward, the creation of: (1) a specific focus at the National Institutes of Health (NIH) on integrated veterinary research via the Roadmap initiative-more specifically to create or combine existing potions of Institutes into an Institute of Comparative Medicine (ICM); (2) a joint interagency collaborative programs could also be established to enhance interdisciplinary collaborative research and have either re-routed an/or new congressionally supported intra-mural and extra-mural funding program; and (3) while working out and introducing the legislative changes for the ICM the NIH should create a veterinary liaison with all the current Institutes like the veterinary-medicine and public-health liaison at the Centers for Disease Control and Prevention (CDC) in which a veterinarian, Dr. Lonnie J. King, was selected to head up the agency's National Center for Zoonotic, Vector-Borne, and Enteric Diseases—a relatively recent creation, the center is dedicated to understanding infectious disease ecology and will help to ensure integration of veterinary and human medical research.

5.2. Shortages

The American Veterinary Medical Association, with information provided by many other organizations and institutions, conservatively estimates a current deficit of 1500 public health veterinarians (e.g. USDA Food Safety and Animal Disease Control, Homeland Security, research on domestic and foreign animal diseases, wildlife disease control, laboratory animal care and research) and is expected to increase possibly to 15,000 by 2025 as the human population increases without intervention. Comparably The Health Resources and Services Administration (HRSA) in the U.S. Department of Health and Human Services (DHHS) released a report in 2006, projecting a shortfall of approximately 55,000 physicians in 2020 [56]. If current trends continue, the full time equivalent (FTE) physician supply is projected to grow to 866,400 by 2020, while demand for physicians will increase to 921,500 due to the growth and aging of the U.S. Population (Physician Workforce Policy Guidelines, 2005). The report projects shortages will be in greatest in non-primary care specialties. It has been over 30 years since the federal government has allocated funds to increase the number of veterinarians and physicians that graduate each year. To begin to alleviate this problem The Veterinary Workforce Expansion Act (S. 914/H.R. 2206), which is currently being considered by the United States House of Representatives and Senate would provide an average of $150 million per year for the next 10 years in the form of competitive grants to help increase the number of veterinarians entering public practice. If passed and funded, this bill would allow the nation's veterinary schools and other institutions training public health veterinarians to apply for competitive grants to increase capacity in the form of classrooms, teaching laboratories, research facilities, and administrative space. This bill would be vital to the nation's ability to protect human and animal health, as veterinarians are often the first line of defense for both. The text of the bill can be found at: http://thomas.loc.gov by searching by the bill numbers listed above. A list of co-sponsors to the bill can also be found via that site by selecting the link entitled "Bill Summary & Status".

6. Ecological health in practice

Over the past century, humanity has had a devastating impact on the earth's wildlife and ecosystems. We are in fact living through the largest mass extinction since the end of the dinosaurs 65 million years ago. Unless effective solutions are found, this new century will see the demise of countless more species and pristine ecosystems, particularly in the tropics. The global society, and what surrounds and influences it, are in profound change. These changes will have very significant impacts on future veterinary medicine and veterinary medical education. There are major demographic, political, environmental, disease, technological, and economic influences, all forcing changes onto society. A few examples illustrate the point [40].

- At 19:16 GMT, 25 February 2006, the global population passed 6.5 billion people (World Population Clock of the U.S. Census Bureau).
- Worldwide, the amount of forest is shrinking by the size of a soccer field every 2 s.
- The consumption of water is rising twice as fast as population growth.
- In the past 25 years, 38 new pathogens have emerged—75% originated as animal diseases (Mark Woolhouse, University of Edinburgh).
- With an annual increase of 76 million people, the world population is expected to reach 9.1 billion in 2050.
- With immigration into North America accelerating, combined with a declining birth rate, the ethnic diversity in society will continue to increase, with the associated impact on values.
- In 2007, for the first time in history, urban people will outnumber rural people.
- Political destabilization, inflamed by bio-terrorism and religious fanaticism, is expected to increase.
- Changes in the atmosphere are causing powerful shifts in the environment (melting of the ice caps, rising sea levels) and in the climate (hurricanes, flooding).
- Global water shortages, especially in heavily populated areas, will soon approach critical levels.
- The emergence of new diseases is occurring about every 8 months and the threat of new zoonotic diseases is very real. Of the more than 1400 pathogens causing human disease, 800 have crossed the species barrier from animals.
- The speed of global travel and of disease transmission are surpassing control measures. The rate of habitat change leads to unprecedented disease exposures.
- Information technology has flattened the globe for access to information and service (http://www.jvmeonline.org/cgi/content/full/34/1/1#B4#B4).
- Consumer spending power in emerging economies will go from $4 trillion to $9 trillion by 2015, but the gap between rich and poor is increasing.

How will these changes alter the needs of society? How must academic veterinary medicine adapt to prepare veterinarians to respond to these new needs? Clearly, humanity has yet to find a way to live on planet earth in a potentially sustaining manner where by stabilizing flora and fauna remain intact to promote healthy ecosystems diversity for all species including our very own-humans. For example, it is estimated that the equivalent of six earths would be needed to sustain the current world's population if people everywhere consumed natural resources at the rate we do in the United States. It is interesting to think that vaccination directly or indirectly impacts six of the seven United Nations Millennium Goals. Understanding and coping effectively with an emerging crisis may sometimes require the birth of action-oriented "crisis disciplines." Conservation Medicine: Ecological Health in Practice brings together an impressive group of experts from diverse specialties medicine, veterinary science, conservation biology, epidemiology, parasitology, public health, and others) to examine the links among human health, wildlife health, and ecosystem health and begin to address questions like:

- how factors such as climate change, endocrine disruptors, and toxic microalgae affect wildlife and human health;
- the importance of biodiversity for human health (as medical models, sources of medicines, factors in the ecology of infectious diseases, and indicators of environmental quality), with a review of 769 biodiversity-related biomedical research projects funded by the National Institutes of Health from 1995 to 1997;
- how the health of rainforest-dwelling peoples depends on such diverse factors as forest integrity, floods, seasonality, community organization, education, gender dynamics, national budgets, and global markets;
- how wildlife health relates to environmental security;
- the health hazards of ecotourism;
- the causes and impacts of emerging infectious diseases of humans and wildlife;
- how the health of terrestrial and marine animals and ecosystems are monitored, and descriptions of innovations using stool DNA and retrovirus evolution as markers of animal population

dynamics, stool hormones to indicate species stress, and animal behaviors as proxies for the health of ecosystems;
- how habitat fragmentation and reduced biodiversity can increase the risk of Lyme disease infection;
- how land use changes such as deforestation and water projects influence the ecology of malaria and other vector-borne infections;
- how ecological health and wildlife disease are managed in national parks;
- the role of zoos in the recovery and conservation of endangered species;
- how reducing the burden of infectious disease among park workers in Africa could prevent a devastating epidemic among the world's 650 remaining mountain gorillas;
- how efforts to control livestock diseases are affecting wildlife health and ecosystems in Botswana;
- teaching ecosystem health in an undergraduate medical curriculum.

7. Additional opportunities

7.1. Bringing together of OIE and WHO/PAHO

More than one billion poor people in Asia and Africa are closely linked with animals for their livelihoods and they pay a really high tribute to different animal diseases—one can easily demonstrate that improving animal-health mechanisms at the national and local level, and decreasing this weight of animal diseases, will lead very quickly to the alleviation of poverty for this class of people. The World Organization of Animal Health (OIE) brings together chief veterinary officers from 172 countries in an effort to create global standards of animal health and animal welfare robust enough to withstand the daunting challenges of worldwide commerce. With an annual budget of around $20 million, it is a significantly smaller organization that its human-health counterpart, the World Health Organization, which has some $2 billion a year expenditure on its programs. Last year, over 21 billion food animals were produced worldwide to help feed a population of 6 billion people, resulting in trillions of pounds of animal products distributed worldwide and projections for 2020 show that demand for animal products will increase by 50%, especially in developing countries. This poses unprecedented risks for human safety and will require a closer linking of the two agencies. Along with those core concerns, OIE also addresses farming practices, analyzes import risks, and mediates bilateral trade disputes among its member countries. Among its most important achievements in recent years, has been the eradication of rhinderpest, a centuries-old intestinal disease also known as "cattle plague in some countires." In the early 1980s, rhinderpest wiped out upwards of $500 million worth of African livestock, contributing to widespread human famine.

7.2. Leadership and politics

In general professional students of veterinary and human medicine are exposed more likely to a more scientifically exposed than a politically exposed culture. Animal and human health policies must be science-based the rallying cry that is heard from animal and human health professionals around the world. The second verse of this mantra is often 'science, not politics', as if science is unquestionably 'good' and politics 'evil'. Antipathy toward politics is worn as a badge of honor. The crowning moment frequently comes with the proclamation, 'I am a scientist, I want nothing to do with politics.'

The phrase 'science-based' infers that the underlying justification of animal/human health policy is derived from knowledge gathered through the systematic observation of, or experimentation with, phenomena. Scientific knowledge implies the compilation and analysis of data by individuals with advanced education in specific disciplines. Scientists seek facts, the fundamental truths which explain the world around us. At face value, the 'science, not politics' paradigm has a great deal of appeal. However, the very notion of fundamental truth is illusory, as scientific knowledge changes frequently with new observations and experiments. Furthermore, conjecture and refutation characterize the scientific method, with disagreement and debate the recognized features of scholarly pursuit. Scientists often reach conflicting interpretations of observational and experimental data. Consequently, individual scientists may champion different, even diametrically opposed, sets of ideas and principles, so that any number of alternatives may be justified as 'science-based'. Finally, animal health professionals typically consider only the biological and physical sciences as 'true sciences', dismissing the social sciences.

Politics reflect the human need for organization of authority, whether in public or private life. Politics exist whenever two or more people come together. The terms 'office politics' and 'family politics' are recognized as clearly as the collective activities surrounding local or national governance. Politics exist even in science, affecting scientific organizations, refereed publications and academe. Indeed, politics are inescapable. All public courses of animal/human health action adopted by governments emerge from the interplay of science and politics. The policy-making process is governed by rules and regulations, affected by the organizational culture of the government agencies involved, and constrained by legal authorities, political correctness and resource availability. The animal/human health policy-making process involves consideration of current biological and physical scientific knowledge. Policy decisions also consider social science factors including ideologies, economics and public opinion. Hence the etiology of animal/human health policy is multifactorial. The current older traditional schools of veterinary and human medicine and future schools of "One Medicine" will need to include leadership, economics and local, state, national and international governances courses and better training in mechanisms of public policies and rule making.

7.3. Applied epidemiology involves policy analysis

Epidemiologists accept the concept of multifactorial etiology as a basic tenet. We discuss disease in terms of agent, host and environment interactions. The practice of applied epidemiology demands a breadth of knowledge and the ability to work in interdisciplinary teams. The more complex the problem, the greater the demand for additional knowledge and insights. Veterinary and human epidemiologists study risk factors for disease in animal/human populations and develop strategies for health promotion and disease control [58]. Unfortunately these are done frequently in a vacuum when in fact the two are inter-related and contributing to the observed and at the time undiagnosed disease spectrum However, animal/human health problems cannot be resolved by consideration of biological and physical factors alone. The veterinary and human (someday to become one and the same) epidemiologist working with field problems soon recognizes the critical role played by people in animal/human health issues. Applying epidemiological principles to animal/human disease prevention requires consideration of social issues such as attitudes toward animals, cultural and religious mores, and individuals' willingness and capability to implement the prevention strategies. Implementing prevention on a national scale brings additional factors into the equation such as availability of resources, adequacy of veterinary services, and animal health infrastructure, among others. Therefore, animal health policy development and imple-

mentation require attention to macroepidemiology, the study of all of the economic, social and political inputs which affect the distribution and impact of animal or human disease at the national level [41,77].

8. Conclusions

The low hanging fruit of yesterdays fields of microbiology, zoonotic and emerging infectious diseases, immunology, antibiotic sensitivity, vaccine development, oncology, anti-viral drugs, public health, ecology, environment, human and animal health, to name a few have been picked. Today comparative and interdisciplinary research is critical to translating scientific advances from one discipline or species to another and providing new insights into human health problems. Scientific fields such as laboratory animal medicine, pathology, immunology, biophysics, mathematics, bioinformatics, genetics, molecular biology and toxicology, when combined with veterinary medicine, have proven especially relevant to success in biomedical research.

Veterinarians also have contributed to public health through the care of companion animals. Fifty-seven percent of all U.S. households own a dog, cat, or both. In addition, millions of exotic animals, birds, and reptiles are kept as pets [42]. Although pets enrich the lives of humans, they also potentially can threaten public health. Veterinarians help educate the public about prevention of zoonoses; vaccinate large numbers of pets for zoonotic diseases, such as rabies and leptospirosis; and reduce the level of ecoparasites that can transmit human diseases and intestinal worms, such as roundworms and hookworms, which can cause serious health problems in humans. The 60,000 private-practice veterinarians in the United States form a valuable front line for detecting adverse health events, reducing zoonotic diseases, and delivering public health education. Because veterinarians work at the interface of human, animal, and environmental health, they are uniquely positioned to view this dynamic through the lens of public health impact. Significant changes in land use, expansion of large and intensified animal-production units, and microbial and chemical pollution of land and water sources have created new threats to the health of both animals and humans [43]. Because animals share human environment, food, and water, they are effective sentinels for environmental, human, and public health problems, including bioterrorism.

Concerns are increasing about antimicrobial resistance of pathogens, waste and nutrient management, and potential runoffs into streams, rivers, and oceans. Food animal and wildlife populations are inextricably linked to some environmental problems. Together these have led to creation of a new scientific discipline called conservation medicine and ecosystem health, and veterinarians are assuming a leadership role in the field [44].

Several decades ago, special factors came together to create a new epidemiologic era characterized by increases in emerging and reemerging zoonoses [45]. Humans, animals, and animal products now move rapidly around the world, and pathogens are adapting, finding new niches, and jumping across species into new hosts. In 2005, approximately 21 billion food animals were produced to help feed a world population of 6.5 billion persons; the United Nations' Food and Agriculture Organization estimates that demand for animal protein will increase by 50% by 2020, especially in developing countries [46]. The lessons learned from severe acute respiratory syndrome, West Nile virus, monkeypox, and avian influenza are reminders of the need to view diseases globally; integrate animal and public health surveillance, epidemiology, and laboratory systems; and create new strategic partnerships among animal, human, and public health professions [47,48]. Veterinarians are essential to the detection and diagnosis of and response to these threats and are integral to first-line defense and surveillance for bioterrorism agents.

The convergence of human and animal health drove creation of the newly proposed National Center for Zoonotic, Vector-Borne, and Enteric Diseases. Plans are being completed to establish several multidisciplinary state-level zoonosis research and development centers. The veterinary profession has recently gained a important foothold on the Health and Human Services government research institutes at the CDC and evolved in prominence as a member of the health professions and has established its importance and usefulness to human and public health. It is hoped and expected that with the developing visions and challenges outlined in this overview we will see the continued melding of veterinary and human medicine to create new educational programs and tools for developing future leaders for solving globally some of the most challenging public and animal health, ecosystem, and conservation problems of the 21st century.

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