Chapter 10
One Health and Food Safety

Peter R. Wielinga and Jørgen Schlundt

Abstract Many, if not most, of all important zoonoses relate in some way to animals in the food production chain. Therefore food becomes an important vehicle for many zoonotic pathogens. One of the major issues in food safety over the latest decades has been the lack of cross-sectoral collaboration across the food production chain. Major food safety events have been significantly affected by the lack of collaboration between the animal health, the food control, and the human health sector.

One Health formulates clearly both the need for, and the benefit of cross-sectoral collaboration. Here we will focus on the human health risk related to zoonotic microorganisms present both in food animals and food derived from these animals, and typically transmitted to humans through food. Some diseases have global epidemic—or pandemic—potential, resulting in dramatic action from international organizations and national agricultural- and health authorities in most countries, for instance as was the case with avian influenza. Other diseases relate to the industrialized food production chain and have been—in some settings—dealt with efficiently through farm-to-fork preventive action in the animal sector, e.g. *Salmonella*.

Finally, an important group of zoonotic diseases are 'neglected diseases' in poor settings, while they have been basically eradicated in affluent economies through vaccination and culling policies in the animal sector, e.g. *Brucella*. Here we will discuss these three different foodborne disease categories, paying extra attention to the important problem of antimicrobial resistance (AMR). In addition, we present some of the One Health inspired solutions that may help reduce the threat of several of the foodborne diseases discussed.

Keywords Antimicrobial resistance • Farm-to-fork • Food safety • Foodborne zoonoses • One health

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10.1 Introduction

People in ancient times already understood they could get sick from consumption of infected meat. By keeping their animals healthy, and by using dedicated methods of food preparation and conservation, ancient farmers learned how to improve health and prevent disease. Probably the oldest written document about it is '*On Airs, Waters, and Places*', written by Hippocrates,[1] which describes how human health is influenced by its interaction with the environment. Since then, our health situation has improved by applying these simple rules of thumb, and even more through improved technologies such as good animal management, hygiene and biosecurity, vaccination programs and prudent animal drug treatment. Nowadays, some of the most feared zoonotic diseases such as anthrax or brucellosis are absent in many countries. However, there are still many important diseases that threaten human health and which have animals as their reservoir. These animal reservoirs range from wildlife to domestic animals, both in companionship and agricultural settings. By the obvious close contact and the sheer number of animals needed for consumption, the animals produced for food form the largest reservoir and production grounds for emerging zoonotic pathogens.

Actions of authorities to protect society from zoonotic diseases differ significantly according to socio-economic status and the zoonotic pathogen in question. Basically, zoonotic diseases related to food animals can be separated into three groups. In the first group are diseases with a potential for global spread and with a dramatic public relations potential, often these diseases have a significant human reservoir showing human-human transmission, e.g. SARS, avian influenza and certain types of AMR bacteria. The second group is constituted by persistent zoonotic diseases related to the industrialized food production chain, such as *Salmonella* and *Campylobacter,* which are broadly distributed in the farm-to-fork chain. These human pathogens are often non-pathogenic in animals and seem to be distributed in all countries, both rich and poor. In the third group are the 'neglected zoonotic diseases'. They are zoonotic diseases which have been eradicated (or drastically reduced) in affluent economies through vaccination and culling policies, and through introduction of hygienic and animal biosafety management practices. However, in many poor settings these diseases are 'neglected diseases' and receive very little attention from national authorities or even international organizations. This group includes *Brucella*, bovine TB (tuberculosis), i.e. Mycobacterium bovis, and many parasitic diseases, e.g. leishmaniasis and cysticercosis. In addition to these traditional infectious diseases there is a new threat of antimicrobial resistant (AMR) bacteria. Caused by the use of antimicrobials both in human and veterinary medicine this problem has emerged and is now to be recognized as one of the most important threats to human health.

Although in the detail the control of these groups of diseases differ, they are all most efficiently prevented by a One Health approach which considers the full

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[1] http://classics.mit.edu/Hippocrates/airwatpl.mb.txt.

farm-to-fork chain. Such preventive and holistic approaches may reduce both the disease burden to human health and the economic burden to developing economies, and therefore represent a significant *potential for improvement* related to food safety as seen in a One Health perspective.

10.2 Transmission Routes

Through food and feed, direct contact, and via the environment, the human- and the animal microbial flora are in contact with each other. Figure 10.1 outlines the most important routes of transmission for infectious diseases between humans and animals. Via these routes infectious diseases from (food-)animals may enter the human reservoir and vice versa. The foodborne transmission route is probably the most important gateway for this contact, and the vast majority of human infections with enteric zoonotic bacterial pathogens, such as *Salmonella enterica*, *Campylobacter coli/jejuni*, and *Yersinia enterocolitica*, occur through this route. For other diseases there is evidence that transmission also occurs via direct contact between (food) animal and humans, e.g. live-stock associated methicillin resistant *Staphylococcus aureus* (MRSA) (Graveland et al. 2011). Next, there is transmission via the environment (e.g. surface water or water used to irrigate plants) mainly as a result of spreading of manure into the environment (Spencer and Guan 2004; Hutchison et al. 2005). And though much less frequently reported, there may be transmission of pathogens from humans to animals, which most probably was the
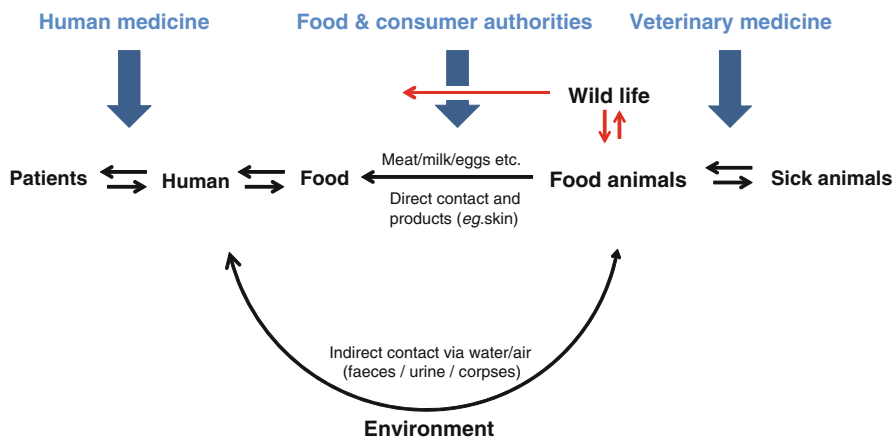
Fig. 10.1 Schematic presentation of important microbial transmission routes via which the human and (food) animals are in contact with each other. In *blue* control mechanisms are shown, and in *red* some of the transmission routes that are more difficult to control. Via the environment transmission may take place of microorganisms present in excretion products, and in diseased animals and people. In addition, wildlife constitutes a risk, as it holds a broad spectrum of diseases, including many highly pathogenic diseases

case for the *Staphylococcus aureus* CC398 (Price et al. 2012). In many developing countries, wildlife forms an additional important reservoir for foodborne pathogens, not only through consumption of wildlife. Because of often lower bio-safety levels in these countries, direct contact between humans and food animals is generally more frequent, and diseases from the wildlife community may cross over more easily to domestic animals. For instance, the general understanding now is that the SARS epidemic in 2003 originated in direct human contact with and/or consumption of wildlife, or indirectly through contact between wildlife and domestic animals (Guan et al. 2003; Shi and Hu 2008).

Wildlife holds a broad spectrum of diseases including some of the most feared, such as Ebola, rabies and anthrax and, and in contrast to other food sources, much of the consumption of wildlife goes undetected by food controlling agencies. For these reasons, and because of the global trade in wildlife derived food and other items (Pavlin et al. 2009), consumption of wildlife animals, and the spillover of infectious diseases from wildlife to food/production animals, should not be overlooked.

10.3   Food Animal Zoonoses in General

The spread of foodborne zoonoses through the food production chain is often referred to as the 'farm-to-fork' (or 'farm-to-table' or 'boat-to-throat') chain. It should be noted that risk mitigation solutions under this framework typically have focused on a consideration of the full food production continuum, involving all relevant stakeholders, i.e. a typical One Health framework invented before the One Health paradigm was defined. Figure 10.2 tries to capture a generalized picture of a farm-to-fork chain, starting with animal feed and ending in human consumption of animal food products.

Although a number of very important zoonoses are related to wildlife—and in some cases directly transmitted from wildlife animals—the vast majority of zoonotic disease cases in the world relate to animals that are bred for food purposes. Such zoonotic pathogens include bacteria such as *Brucella*, *Salmonella*, *Campylobacter*, verotoxigenic *Escherichia coli* and *Leptospira*; parasites, such as *Taenia*, *Echinococcus* and *Trichinella*; and viruses, such as Influenza A H5N1 (Avian influenza) and Rift Valley Fever virus. Next to these infectious diseases, derived agents such as (microbial) toxins and prions (Prusiner 1997) form another important zoonotic subgroup.

Diseases originating on the farm can in many cases most efficiently be dealt with on the farm itself, thereby eliminating more complex measures or cross-contamination down the farm-to-fork chain. For example, brucellosis in animals (mainly cattle, sheep and goats) has been eliminated in many countries, thereby virtually eliminating the human disease burden (Godfroid and Käsbohrer 2002). Also, some of the main parasites can be effectively controlled at the farm level, and this could work for both *Taenia solium* in pigs (defined by WHO/FAO/OIE as a 'potentially eradicable parasite'), as well as, *Trichinella spiralis* which is found in
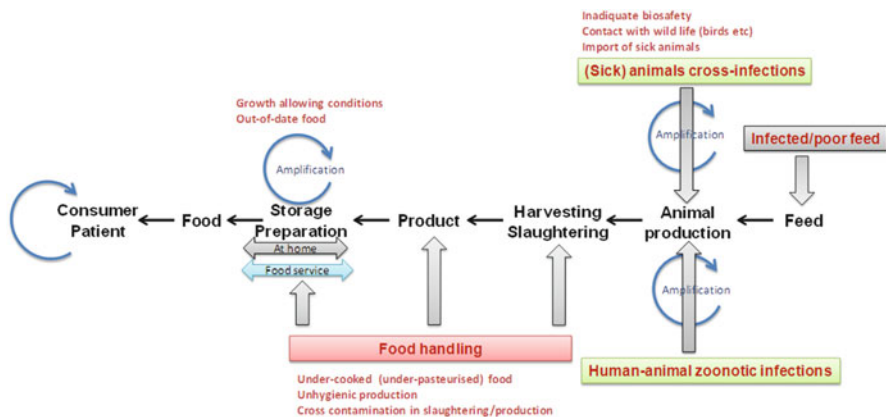
Fig. 10.2 Farm-to-fork scheme showing how infectious diseases may travel through the food chain. Along the chain we have indicated some of the most prevalent causes of infectious disease introduction

many wild animals and importantly in pigs for human consumption. Both parasites have essentially been eliminated from farmed pigs in most northern European countries (WHO/FAO/OIE 2005; Gottstein et al. 2009). However, both diseases still form a serious 'neglected diseases' threat in settings where there is potential for contact between wild and domestic animals.

10.3.1   Zoonoses with a Dramatic Public Relations Impact and Potential for Global Spread

It was primarily the outbreaks of SARS and zoonotic influenza, AMR (dealt with separately) and BSE (Bovine Spongiform Encephalopathy) which alerted the world to the need for a One Health approach. Outbreaks of viral diseases in humans, originating in or spreading through farm animals (avian flu—H5N1 and swine flu—H1N1) have caused major global alerts in the last decade. These influenza outbreaks spread very quickly, either in the animal population (H5N1) or directly in the human population (H1N1), and formed a global threat for human health. H1N1 was therefore characterized by the World Health Organization (WHO) as a pandemic. Although in total the human disease burden related to the endemic bacterial zoonoses is probably many fold higher than these influenza outbreaks, it is basically these relatively few but fast spreading outbreaks that have put One Health on the global agenda. In addition, the failure to predict, monitor and control the spread of these diseases in animals presented regulators and politicians with a wake-up call, and made them demand (better) cross-sectoral collaboration between the animal and human health sectors.

Prions, non-living infectious agents, have been a significant burden of disease in animal and man. The most well-known zoonotic prion disease is probably the one causing Bovine Spongiform Encephalopathy (BSE) in cows, and new variant Creutzfeldt-Jakob disease in humans, as represented by the massive outbreak of 'Mad Cow Disease' in the UK in the 1980s and 1990s. This agent, a mutant protein, which mainly sits in the brain, got into the (beef) food chain by the feeding of ruminant derived meat and bone meal to ruminants. Prions (Prusiner 1997), Scrapie (the disease in goats), spongiform encephalopathy of Rocky Mountain elk, transmissible mink encephalopathy, kuru and Creutzfeldt–Jakob disease were known before the large outbreak of bovine spongiform encephalopathy in the UK. It, however, took some time and great efforts, and an early One Health approach, to establish the links between the different animal diseases and the human disease (Hill et al. 1997; Prusiner 1998; Ghani et al. 1998). This insight created a background to efficiently stop the spread of this prion disease, by banning the use of animals in animal feed, and seeing a subsequent decrease of the disease in humans (Hoinville 1994).

In the Western world prion diseases have attracted much attention, and their control has resulted in a large economic burden to society. In developing countries, often with less strict rules about the re-use of dead animals, and more direct contact with wildlife, prion diseases may still be endemic though unrecognized.

10.3.2   Endemic Zoonoses Related to Industrialized Food Production

In contrast to the dramatic outbreaks discussed above, many food-related zoonoses are endemic in farm animals and some of the most important of these do actually cause disease in the animals. It should be realized that most countries—including most developing countries—produce large amounts of food animals, and most of the production takes place in some sort of industrialized setting. Such settings are invariably linked to a number of important zoonotic pathogens. Table 10.1 shows three lists of the most important food pathogens, as reported in studies published by the CDC in the USA and by RIVM (Havelaar et al. 2012) in the Netherlands, as well as a list of pathogens recognized by ECDC as focus organisms for the EU.

Although widespread, these pathogens are often not recognized as important human pathogens because of their often mild disease syndromes in healthy persons (e.g. limited to diarrhea and vomiting) and because of the complexity of source attribution. However, they do form a serious threat to the vulnerable segments of our societies (i.e. the young, the elderly, the immune-compromised and recovering patients), and some patients may develop long-lasting chronic disorders (e.g. arthritis and neurological disorders) (McKenna 2012). These facts, together with the sheer number of infections they cause, results in a substantial total burden of disease for these pathogens as expressed in Disability-Adjusted Life Years

Table 10.1 The most important foodborne infections as experienced in the US, EU and the Netherlands

Ranking of the top five foodborne diseases in the USA, ranked according to incidence (regular), hospitalizations (*italic*) deaths (**bold**) (CDC 2011)	Ranking of top 14 foodborne pathogens and toxins in the Netherlands, ranked according to their burden of disease in DALYs[a] (Havelaar et al. 2012)	Focus panel of food- and waterborne diseases in the EU, without ranking (ECDC 2010)
Norovirus 1, *2*, **4**	*Norovirus 4*	
Salmonella (nontyphoidal) *2*, *1*, **1**	*Salmonella* spp. *5*	Salmonellosis
Clostridium perfringens 3,..,..	*perfringens* toxin *7*	
Campylobacter spp. 4, *3*, **5**	*Campylobacter* spp. *2*	Campylobacteriosis
Staphylococcus aureus 5, ..,..	*Staphylococcus aureus* toxin *6*	
Toxoplasma gondii .., *4*, **2**	*Toxoplasma gondii 1*	Toxoplasmosis
E. coli (STEC) O157 .., *5*, ..	STEC O157 *10*	Infection with VTEC/STEC
Listeria monocytogenes ..,.., **3**	*Listeria monocytogenes 11*	Listeriosis
	Cryptosporidium spp. *13*	Cryptosporidiosis
	Giardia spp. *8*	Giardiasis
	HepA *9*	*Hepatitis* A
	HepE *12*	
	Rotavirus 3	
	Bacillus cereus toxin *12*	
		Shigellosis
		Variant Creutzfeldt–Jakob disease

[a]Disability-adjusted life years (DALYs), are a combined estimate of the burden of disease due to both death and morbidity. One DALY can be thought of as 1 year of healthy life lost and is often expressed in years of life lost on the population level, and can be thought of as a measure of the gap between current health status and an ideal situation where each individual in the population lives to old age, free from disease and disability (Murray 1994)

For the list of the CDC and the Netherlands the ranking in terms of incidence, hospitalizations, deaths or DALY is given. The list from ECDC was generated by expert consultation and for use as an EU focus list in future disease burden studies

(DALYs) (see Murray 1994). For instance, the study of Havelaar et al. (2012) showed that the total burden of the 14 diseases he studied was 13,500 DALYs, for a total of 1.8 million cases and 233 deaths caused by these diseases (in 16 million people). Source attribution estimates showed that one-third could be attributed to foodborne transmission. Similarly large numbers were reported for the USA (CDC 2011), where surveillance studies of 31 known pathogens gave an estimated total of 9.4 million illnesses, 55,961 hospitalization and 1,351 deaths attributed to foodborne diseases (in 315 million people). Importantly, the latter report also showed that the 31 pathogens studied make up only 44 % of the foodborne diseases, and the majority of 56 % is caused by unknown agents. This situation is probably not unique for the USA, and thus indicates that there is still much health to be gained from improved food safety. Table 10.1 shows that an almost identical list of

important foodborne pathogens are found in Europe, and that *Toxoplasma gondii*, *Listeria monocytogenes*, *Campylobacter*, rotaviruses, noroviruses and *Salmonella*, should probably form the key targets for interventions. Except for norovirus, these pathogens have been shown to be zoonotic, and find their way to humans via food and the environment (Fig. 10.1). A One Health approach ensuring efficient cross-sectoral collaboration and data-sharing, could lay the foundation for a realistic description of the situation, and could help implement sensible cross-sector solutions.

Building on the idea of One Health to control these diseases, there are several countries (especially in northern Europe and North America) that have instituted cross-sectoral data collection and collaboration. This is typically done through the construction of zoonosis centers or their equivalents. These centers aim to stimulate and facilitate the collaboration between human, veterinary and food institutes. Some examples of such specialized centers are the US National Center for Emerging and Zoonotic Infectious Diseases (http://www.cdc.gov/ncezid), the British National Centre for Zoonosis Research (http://www.zoonosis.ac.uk/zoonosis) and Danish Zoonosis Centre which is part of the Danish National Food Institute (http://www.food.dtu.dk/English/Research/Research_Groups/Zoonosis_Centre.aspx). Two clear examples of what such centers can accomplish are: the reduction of *Salmonella* in food animals in Denmark, and the Danish integrated approach to combat AMR (described below in a separate section). In the Danish *Salmonella* reduction program, data sharing across animal, food and human health sectors has enabled science-based solutions, and has most noticeably resulted in significant reductions in human salmonellosis through lowering *Salmonella* prevalence in animals (Wegener et al. 2003). In relation to laying hens the program started with a simple and inexpensive serological surveillance of egg producers. Flocks found positive were either culled and repopulated, or used to produce heat-processed eggs, Danish eggs are now considered free of *Salmonella*. Next to this arm, a program of surveillance and eradication of infected broiler flocks was setup. The effect of the whole program was measured in term of cases of human salmonellosis, which were found to be significantly reduced as the project progressed in time.

The construction and solutions of this program clearly followed One Health principles. Food, veterinary and human health sciences worked together, using similar detection and (geno)typing techniques, which enabled comparison and sharing of data. This top-down selection of *Salmonella*-free poultry could work in other countries with industrialized food animal production as well. In other countries—including most likely most developing countries, *Salmonella*-positive animals have been imported from big producers in industrialized countries.

One such documented example was the import into Zimbabwe of *Salmonella enteritidis* via live animals. *Salmonella* entered the country through import of infected poultry in the commercial national production system around 1993, and thereafter spread quickly to the communal sector (small-scale farming), as well as to the human population (Matope et al. 1998). The most likely reason for the spread within Zimbabwe was that old animals from the commercial sector were sold to

small-scale communal production systems. As the trade of live animals is done on a global level and does not take into account whether the traded animals carry any of the diseases from Table 10.1, reducing the prevalence in the commercial sector in producing countries, may also lower the global spread and human disease burden in the rest of the world.

10.3.3 Neglected Zoonoses Related to Poverty

The spectrum of neglected diseases is broad and includes diseases caused by bacteria, viruses and parasites. Many are found world-wide but their prevalence in the human and animal populations varies according to the local agricultural, demographic and geographic conditions and tradition. For many of the neglected diseases solutions to dramatically decrease the disease burden are well-known, but action is lagging, this is the case for example for many of the parasitic zoonoses. This is the reason why the WHO refers to these diseases as 'Neglected Diseases' (WHO 2006; Molyneux et al. 2011). Neglected diseases may be categorized into two (strongly overlapping) categories. In the first category are the neglected tropical diseases which include Chagas disease, trypanosomiasis, leprosy, rabies, schistosomiasis and others, many of which are zoonotic and parasitic diseases.[2] The second category are the neglected zoonotic diseases, covering many of the diseases above and also some bacterial diseases such as anthrax, bovine tuberculosis (TB), brucellosis, and also cysticercosis and echinococcosis.[3]

Many of the neglected diseases are carried by wildlife and in poor and rural settings by livestock (e.g. brucellosis, anthrax, leptospirosis, Q-fever and bovine TB). In addition, many are food- and waterborne (e.g. brucellosis, cysticercosis/taeniasis and echinococcosis). In particular, the prevalence of bovine TB appears to be increasing in many poor settings and has been linked to HIV infections as an important factor for progression of a TB infection to an active TB disease (LoBue et al. 2010). Brucellosis and bovine TB in cattle cause lowered productivity in the animal population, but seldom death, and both have largely been eradicated from the bovine population in the developed world by test-and-slaughter programs, which in effect has eliminated the human health problem (Godfroid and Käsbohrer 2002).

Some of the parasitic diseases (e.g. schistosomiasis, cysticercosis, trematodiasis and echinococcosis) have high mortality rates and long-term sequelae including cancer and neurological disorders. Cysticercosis is emerging as a serious public health and agricultural problem in poor settings (García et al. 2003). Humans acquire *Taenia solium* tapeworms when eating raw or undercooked pork contaminated with cysticerci. The route of transmission is, pigs infected through *Taenia*

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[2] http://www.who.int/neglected_diseases/diseases/en/.

[3] http://www.who.int/neglected_diseases/zoonoses/en/.

eggs shed in human faeces, and the disease is thus strongly associated with pigs raised under poor hygienic conditions. This means that the cycle of infection can be relatively easily broken by introducing efficient animal management, as has been done in most developed countries.

Given that 70 % of the rural population in poor countries is dependent on livestock as working animals to survive (FAO 2002), the effect of these animals carrying a zoonotic disease can be dramatic, both relative to human health directly, but also as it affects the potential to earn an income. This also affects the potential mitigation action; for instance the large-scale culling of animals, which can be a viable solution in rich countries, might be problematic in the poorest countries. Such solutions would not only mean loss of food, but also a serious socio-economic disruption, in some cases leading to national instability.

10.4 AMR in Food Animals

Some of the recent serious outbreaks of antibiotic resistant (AMR) foodborne disease, such as EHEC in Germany (Mellmann et al. 2011), have shown us a new problem. There seems to be a global trend with the prevalence of AMR rising (WHO 2001; DANMAP 2010; ECDC 2010; Aarestrup 2012). Especially dangerous is the emergence of resistance against antimicrobials that are considered critically important in human medicine, and in multidrug resistant (MDR) infections (Potron et al. 2011; Kumarasamy et al. 2010).

In the early 1940s antibiotics were first introduced to control bacterial infections in humans. The success in humans led to their introduction in veterinary medicine in the 1950s, where they were used in both production and companion animals. Nowadays, antibiotics are also used with intensive fish farming and to control some infectious diseases in plants. Their use is thus widespread. Antibiotics in animals are mainly used in three ways: (1) for therapy of individual cases, (2) for disease prevention (prophylaxis) treating groups of animals, and (3) as antibiotic growth promoters (AGP) treating groups of healthy animals with sub-therapeutic concentrations to promote animal growth. When first introduced, the use of antibiotics led to improved animal health, and subsequently higher levels of both food safety and food security. All use, but in particular the use as AGP, resulted in a dramatic rise in the use of antibiotics, and for instance, between 1951 and 1978 the use in the United States alone went from 110 to 5,580 t (WHO 2011).

However, the use of antibiotics in animals has over the years also resulted in a selective pressure for AMR microorganisms, contributing significantly to the human health problem of AMR bacteria. Notably a number of bacterial strains that were previously susceptible to antibiotics are now in very high frequencies becoming resistant to various antibiotics, some of which are very important as last resort treatment potential for humans (Bonten et al. 2001). In particular the use as AGP is questionable, as the concentrations used are sub-therapeutic which result in the selection for resistance but do not efficiently kill microorganisms. Nowadays

there are serious efforts by national authorities and some international organizations to reduce the antibiotic overuse in animals (Food Agricultural Organization of the United Nations (FAO)/World Organization for Animal Health (OIE)/WHO 2003; WHO 2011; U.S. Food and Drug Administration (FDA) (2012)), especially—but not only—through abolishing their use as AGP. However, there seem to be major problems in ensuring cross-sectoral understanding, since the veterinary and medical professions are still in debate about how the AMR problem has emerged (Phillips et al. 2004; Karp and Engberg 2004; Smith et al. 2005; Price et al. 2012). To achieve a science-based understanding of the problem, data on AMR from both the animal and the human side should be compared, and both risk assessments and source attributions performed in an integrated way. In other words, a One Health approach in which human and animal health sectors, including food and environmental sectors, work together, may help to deliver answers needed and suggest ways to reduce problems in both human and animal reservoirs (Figs. 10.1 and 10.2).

10.5   Global One Health Efforts

In addition to the factors described above, food production and food trade are now more and more global, and thus some of the food related problems are also global food problems. On the positive side, globalization has helped with some of the important global food issues: it raised food security, made our food more varied and tastier, and even including transport costs in the equation, still has global financial advantages. However, together with the food also the foodborne diseases now travel the globe. And if we do not stay on top of the problem, disease outbreaks might affect large parts of the global food sector negatively, in the end leading to negative health—but will also have financial and socio-economical consequences. A more holistic and pro-active approach to food safety may help prevent future food disasters and build healthy economies.

10.5.1   Global Initiatives to Contain Foodborne Zoonoses

One Health approaches to combat zoonotic foodborne diseases need to consider at least three levels, the international level, national level and the farm level where the actual production takes place. To facilitate the work at all these levels, many countries have established specialized zoonosis centers. These centers focus their work on zoonotic diseases and promote collaboration between different sectors, and between different countries. They examine the prevalence of zoonotic diseases in humans and (food-)animals, their routes of transmission, the risk associated with their presence in our food chain, and the relation between human disease and zoonotic transmission. In addition, as our food production system has become increasingly dependent on global trade, the approaches taken by these zoonoses

centers (should) also include a global angle. National zoonosis centers may also help tackle the global problems associated with zoonotic diseases.

However, at the moment most of this work is done by international and global organization, such as the WHO, OIE, and FAO. These three international organizations have recognized that combating zoonoses is best achieved via a One Health approach, as stated in their seminal paper 'A Tripartite Concept Note' (FAO/OIE/WHO 2011), in which they express the need to collaborate for a common vision. Given the impact zoonotic diseases have in socio-economical terms and on the vulnerable sectors in our societies, a One Health vision is also endorsed by the World Bank and the United Nations Children's Fund (UNICEF) (World Bank/WHO/UNICEF/OIE/FAO/UNSIC 2008). In their common vision, they say that a One Health approach may lead to novel and improved solutions, including solutions that have not been considered before because of the high costs involved.

For instance, while in some cases vaccination is the ultimate tool to prevent disease, it is not always considered because the costs of mass vaccination are higher than the public health benefit savings, or because of global trade regulations. Under a One Health approach sharing of costs, as well as other mitigation strategies could likely enable novel ways of reaching sensible solutions (Narrod et al. 2012).

For global infectious disease safety national authorities report to WHO important outbreaks of human disease which have the potential of cross-border spread, under the auspices of the International Health Regulations (IHR) (WHO 2005). These regulations also cover foodborne diseases associated with globally traded food. However, given the major impact that such announcements may have on global food trade, such as was the case with BSE in the UK or the more recent trade barriers put up after the EHEC outbreak in Germany, national authorities may have become more careful and restricted in what they report.

A global One Health approach which both considers human health aspects and socio-economic consequences would therefore be a welcome improvement to the IHR of 2005. Next to WHO, other organizations are active in reporting global infectious disease outbreaks, most notably ProMED-mail (http://www.promedmail. org), which is an internet based Program for Monitoring Emerging Diseases worldwide, set up by the International Society for Infectious Diseases. The program is dedicated to rapid global dissemination of information on outbreaks of infectious diseases and acute exposures to toxins that affect human health, including those in animals and in plants grown for food or animal feed, and thereby supports the One Health principles.

Many of the (international) organizations and governing bodies named above have generated guidelines to control – and disseminate information about—food related zoonoses, such as for instance WHO's Global Foodborne Infections Network (GFN) (www.who.int/gfn), the European Food Safety Authority (EFSA) (www.efsa.europa.eu/en/topics/topic/zoonoticdiseases), Foodnet from the US Centers for Disease Control and Prevention (www.cdc.gov/foodnet) and others.

The goal of these networks is essentially the same: *To help capacity-building and promote integrated, laboratory based surveillance and intersectional collaboration among human health, veterinary and food-related disciplines to reduce the risk of foodborne infections.*

10.5.2   Efforts to Contain AMR Zoonoses

The emergence of AMR in food animals is a serious threat for modern human medicine. The risks exist that both (i) the overuse by mass prophylaxis and AGP in animals, and (ii) the misuse of human critically important antibiotics in animals, will lead to the emergence of new AMR organisms which may spread to the human reservoir, and via global food trade spread around the world. In the most critical scenario this will make our arsenal of antibiotics unfit to treat previously treatable infectious disease, and it might take us back to a situation as before World War II, when antibiotics were not yet used in human medicine.

One Health principles may help mitigate this risk and deal with the AMR problem in an efficient way. Collaboration between the FAO/WHO Codex Alimentarius Commission and the OIE have generated important guidance on how an integrated approach and the prudent use of antimicrobials may reduce the emergence of AMR in (food-)animals and subsequently in humans.[4] Previous to this, in 2000 the WHO published the 'Global Principles for the Containment of Antimicrobial Resistance in Animals Intended for Food' (WHO 2000) which all countries should follow to reduce the risk of AMR. The three major principles are:

- Use of antimicrobials for prevention of disease can only be justified where it can be shown that a particular disease is present on the premises or is likely to occur. The routine prophylactic use of antimicrobials should never be a substitute for good animal health management.
- Prophylactic use of antimicrobials in control programs should be regularly assessed for effectiveness and whether use can be reduced or stopped. Efforts to prevent disease should continuously be in place aiming at reducing the need for the prophylactic use of antimicrobials.
- Use of antimicrobial growth promoters that belong to classes of antimicrobial agents used (or submitted for approval) in humans and animals should be terminated or rapidly phased-out in the absence of risk-based evaluations.

These Global Principles have been supplemented with, (1) guidance on the prudent use of antibiotics from the Codex Alimentarius Commission together with OIE, and (2) six priority recommendations from WHO to reduce the overuse of antibiotics in food animals for the protection of human health (WHO 2001), being:

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[4] See: www.codexalimentarius.org; www.who.int/foodborne_disease/resistance; www.oie.int/our-scientific-expertise/veterinary-products/antimicrobials.

(1) Require obligatory prescriptions for all antibiotics used for disease control in (food) animals;
(2) In the absence of a public health safety evaluation, terminate or rapidly phase out the use of antibiotics for growth promotion if they are also used for treatment of humans;
(3) Create national systems to monitor antibiotic use in food-animals;
(4) Introduce pre-licensing safety evaluation of antibiotics [intended for use in food animals] with consideration of potential resistance to human drugs;
(5) Monitor resistance to identify emerging health problems and take timely corrective actions to protect human health;
(6) Develop guidelines for veterinarians to reduce overuse and misuse of antibiotics in food animals.

A recent publication (WHO 2011) covers the broader scope of AMR in relation to both animals and humans. Thus, a 'One Health' approach has explicitly been proposed by these international organizations to mitigate the risk of AMR.

Since the occurrence of AMR in the food production sector, different programs to contain zoonoses and AMR zoonoses have been developed following these Principles and Guidelines. The Danish program to contain AMR zoonoses, DANMAP, has in particular gained international attention and has been analyzed in different publications (WHO 2003; Hammerum et al. 2007; Aarestrup et al. 2010). The reason for this was the early One Health approach that the Danish government and stakeholders proposed to combat AMR. In 1995, after publication of the finding that 80 % of *Enterococci* in all industrial produced chickens in Denmark were highly resistant to vancomycin (a last resort drug for human therapy) the government decided that actions had to be taken (Wegener et al. 2003) and set up the Danish Integrated Antimicrobial Resistance Monitoring and Research Program (DANMAP). Figure 10.3 shows the organization of DANMAP and how the animal health, food safety and public health sectors work together.

The objectives of DANMAP are: (1) to quantitatively monitor the consumption of antimicrobials used in (food) animals and humans, (2) to quantitatively monitor the occurrence of AMR in (zoonotic) bacteria in animals, food and humans, (3) to study and describe the associations between antimicrobial consumption and antimicrobial resistance, and (4) to identify routes of transmission and areas for further research. Next to this an automated/ICT program, called Vetstat, was introduced to collect quantitative data on all prescribed medicine for animals from veterinarians, pharmacies and feed mills (Stege et al. 2003).

Vetstat data on drug usage proved important for understanding the different aspects of the antibiotic usage problem, and to provide tools to control the use. For instance, with the information from Vetstat it has been possible for the Danish Veterinary and Food Authority (DVFA) to introduce "The Yellow Card Initiative" (DVFA 2012). This initiative works similarly to that in football, and farmers and veterinarians get a yellow card when their antimicrobial use is excessive as compared to similar farms. Only by reducing the antibiotic use, which may be done for instance by adopting management practices from low users, the card can be
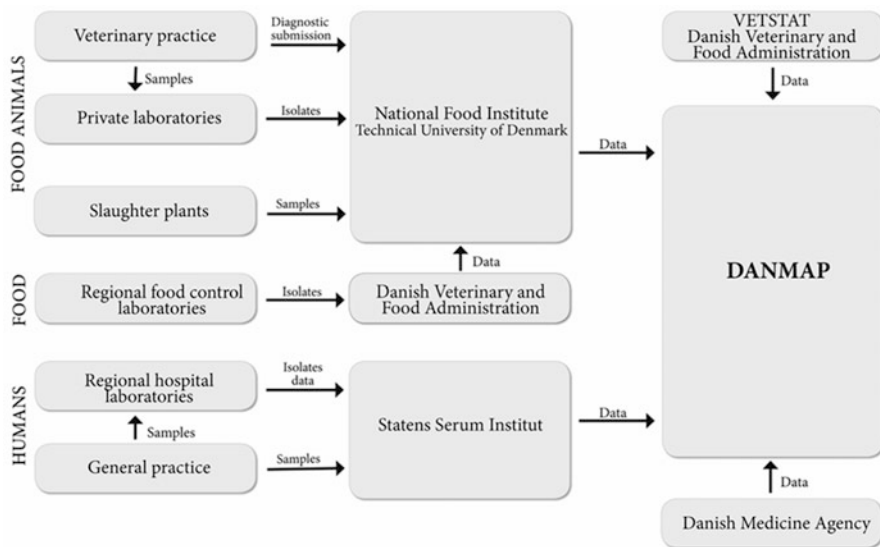
Fig. 10.3 Organization of DANMAP showing the different collaborating institutes and agencies, and how human, animal and food information is brought together (taken from: www.danmap.org)

retracted. This has not only worked as a stick, it also gives the farmers a sense of how they are doing compared to their colleagues. In the European Union several countries have now also started to collect antibiotic usage data and to compare antibiotic use at country level (EMA 2011).

10.5.3 Global Microbial Identifier

Surveillance of foodborne infections, and infectious diseases in general, is important to understand the transmission of infectious diseases and identify risks. To do this efficiently data collection should be done in a harmonized way, so data can be compared and integrated. Until now, this has been difficult because different human medical, veterinary medical, food and environmental laboratories have been using different techniques for surveillance, making it often almost impossible to compare data.

With the introduction of whole genome sequencing (WGS) this problem may be solved. Its unbiased way of detecting DNA and its single platform (the DNA code) for comparing genomic information gives WGS the potential to take disease diagnostics to a new level. Some early uses showing the value of WGS for diagnostic and epidemiological purposes were the tracking of the massive cholera outbreak in Haiti in 2011 (Hendriksen et al. 2011) and by the EHEC outbreak that was first detected in Germany and later also found in other countries and which could be traced back to Egyptian imported fenugreek seed using WGS (Mellman et al. 2011).

Following up on these successes, an international group of scientists with representatives from OIE, WHO, EC, USFDA, US CDC, ECDC, universities and public health institutes, came together in Brussels, September 2011, to further discuss the possibilities of using WGS on a larger scale. Their simple conclusion was that the technology to use WGS for diagnostic purposes is available, and its potential high, however, to make efficient use of the data, a global genomic database is needed (Kupferschmidt 2011; Aarestrup et al. 2012). Such a database should be open to, and supported by, scientists from all fields: human health, animal health, environmental health and food safety, and should include genomic data for all types of microorganisms as well as meta-data to trace back the source of the microorganism.

Building such a database depends on a global One Health approach, and in a One Health manner both human health as well as other sectors will benefit from it. An important aspect of pursuing this initiative is that it will not only be beneficial for the developed world, but it may especially be beneficial for developing countries. For them genomic identification will mean a giant leap forward as they do not need to implement the wide variety of specialized methods that are nowadays used in the developed world. If set up in a sensible, inclusive, open-source framework WGS analysis will provide the world with a strong weapon in the fight to combat infectious diseases in all sectors.

10.6 Discussion

One health approaches may be synergistic in controlling foodborne zoonotic diseases to support both sufficient food safety, and sustainable food security. Clearly, because of the unique situation of transmissibility between humans and animals, zoonoses control relies on the control of the microorganisms in (1) animals, (2) the food chain and in (3) humans. In addition, as zoonoses originate in animals before being transmitted to humans, the most effective interventions may be achieved at the source, i.e. at the farm. To be most effective, approaches to reduce the risk of foodborne zoonoses should include all stakeholders from the human as well as the animal health side. At the transmission level, it will be of major importance to involve food and consumers authorities and related stakeholders (e.g. environmental specialist), to make sure the spillover from the animal reservoir is kept as low as possible.

The exact solution will differ per country and type of disease (e.g. in many developing countries neglected diseases may still be of importance). Given that 70 % of the rural population in poor countries is still dependent on livestock as working animals to survive, the effect of these animals carrying a zoonosis will work out differently than in the industrialized settings. A number of the most important zoonoses relate directly to food production systems in poor settings which could be reduced dramatically through well-known interventions, such as has been the case for *Brucella*, bovine TB and cysticercosis.

Furthermore, it is important to realize that much of the One Health efforts until now have focused on zoonotic pathogens with a potential for dramatic global spread (such as avian influenza and BSE). However, major health gains can be obtained with the endemic zoonotic pathogens. For instance *Salmonella* causes a dramatic global disease burden because of the sheer number of cases and the global spread via food and live animal trade. For *Salmonella* there are efficient methods to reduce the prevalence in food animals.

One Health approaches in the food sector are complex and involve both public and commercial stakeholders, which may put limitations on what can be done. On the one hand food should be nutritious and adding to one's health. On the other hand most food is commercially produced and traded. As food is a commercial product, one of the ways to make food producers (the supply-side) produce more healthy food, is if the public demands this (the supply–demand balance). Therefore, educating the public to buy healthier food may be a way to make food manufacturers produce healthier food. Next, there are other stakeholders and fields of science (e.g. industrial sciences or logistics) and policy (e.g. economics) that contribute to the food chain, but which may focus on other aspects than healthy food alone, and their conclusions may conflict with the food safety principles (e.g. the use of AGP to improve animal growth).

Clearly food safety is a complex issue, and integration of all its problems and data is difficult and should best be limited to its essential components. For this reason, countries should learn from experiences abroad that have documented success. There are many examples of One Health approaches that have helped lower the risk of zoonotic foodborne disease. Key to all approaches has been surveillance of the farm-to-fork chain.

Surveillance should be done at relevant levels of the chain, at the farm level by the veterinary system, and at the food production stage by food-scientist. Findings should be shared and compared with the findings in human medicine, to be able to make decisions about potential risks for human health. Thus the animal, food and human sectors need working together, to collect and to share data in such a way that they may be compared. As there are still many different techniques used in all three fields, it is still difficult to compare data. An important development in infectious disease diagnostics will be the introduction of WGS techniques, and the construction of a global, open-access genomic database for microorganisms. In a One Health manner, the latter would take diagnostics to a new level, and will greatly improve human, animal and food safety.

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