

REVIEW ARTICLE

One Health training and research activities in Western Europe

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Introduction: The increase in emerging human infectious diseases that have a zoonotic origin and the increasing resistance of microorganisms to antimicrobial drugs have shown the need for collaborations between the human, animal and environmental health sectors. The One Health concept increasingly receives recognition from policy makers and researchers all over the world. This overview compiled research and education activities in the area of One Health in Western Europe (Austria, Belgium, France, Germany, Italy, Iceland, Ireland, Liechtenstein, Luxembourg, Monaco, the Netherlands, Portugal, Scandinavia, Spain, Switzerland, and the United Kingdom (UK), with a focus on infectious diseases. It can serve as a starting point for future initiatives and collaborations.

Material and methods: A literature search for ‘One Health’ was performed using National Center for Biotechnology Information and Google. Moreover, information from global and European policy documents was collected and a questionnaire was designed to gather current One Health research and training activities in Western Europe.

Results: This overview shows that there is considerable recognition for One Health in Europe, although most educational initiatives are recent. In Europe, the One Health approach is currently mainly advocated in relation to antimicrobial resistance (AMR). Many countries have incorporated the One Health approach in their policy to fight AMR, and funding possibilities for AMR research increased significantly. The number of national and international multidisciplinary research networks in the area of zoonotic diseases and One Health is increasing.

Discussion: Although One Health has gained recognition in Europe, often a One Health approach to research and education in the area of zoonotic diseases and AMR is not implemented. In many countries, collaboration between sectors is still lacking, and One Health activities are predominantly initiated by the veterinary sector. To facilitate the multidisciplinary approach that is needed to fight zoonotic diseases and AMR, exploring current barriers for collaboration is needed. Targeted funding can help address these boundaries and facilitate multidisciplinary research and training to fight both zoonotic diseases and AMR in Europe.

Keywords: *one medicine; ecohealth; zoonoses; antimicrobial resistance; global health; multidisciplinary research; multidisciplinary collaboration; ecosystem health; comparative medicine*

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The similarities between human and animal diseases and the relations between animals and humans being in contact with them have already been recognized in ancient times. In the 20th century, human and veterinary medicine diverged. In the same period the knowledge on infectious diseases and antibiotics increased immensely. In the second half of the 20th century, the understanding increased that collaborations between the human health sector and the veterinary sector are needed to prevent and control zoonotic diseases and antimicrobial resistance (AMR). In 1952, the Food and

Agricultural Organization (FAO) and the World Health Organization (WHO) already published a joint report on ‘advances in the control of zoonoses’ (1). In 1969, the Swann report was already published, recommending a joint strategy for antibiotic use in humans, animals, and horticulture and discouraging the use of antibiotics used in human medicine as growth promoters (2).

Calvin Schwabe first introduced the term ‘One Medicine’ in 1984, recognizing that human and veterinary medicine should be seen as one discipline (3). Toward the end of the 20th century, the concept of ecosystem health was

introduced, extending the integration and collaboration of human and animal medicine to the environment (4). This was also illustrated by the publication of the ‘Manhattan Principles’ that were formulated to ‘guide the international implementation of a holistic approach to prevent epidemic disease while maintaining ecosystem integrity’ (5). Later, the term ‘One Health’ was introduced, describing such a holistic approach, to improve human, animal, and environment health through multidisciplinary collaborations and communications (6, 7). In 2008, the FAO, World Organisation for Animal Health (OIE), WHO, World Bank, United Nations Children’s Fund and United Nations System Influenza Coordination published a strategic framework for the reduction of risks of infectious diseases at the animal–human–ecosystems interface, thereby endorsing and promoting the One Health approach (8). Since 2008, a large number of national and international institutes have endorsed and implemented the One Health approach.

In Europe, the One Health approach was formally recognised when the European Commission made a formal statement on the One Health approach at the International Ministerial Conference on Avian and Pandemic Influenza of Sharm-El-Sheik in 2008 (9). Also in 2008, the European Commission’s Directorate General for Health and Consumers and the Federation of Veterinarians of Europe (FVE) launched a campaign called ‘One Health’ to promote the role of Member States and the European Union (EU) in the protection of farmed and domestic animals and consumers in the EU by means of biosecurity measures (10). The FVE has published several other position papers and organized activities in the area of One Health since then (11).

Currently, One Health in Europe is often mentioned in relation to AMR. The Council conclusions on AMR in 2012 clearly stated that a One Health perspective on AMR is needed. The recent EU ministerial One Health conference on the same subject also concluded that there was a clear need for a One Health approach to fight AMR (12). In 2015, the FVE and the Standing Committee of European Doctors signed a memorandum of understanding in the field of One Health with AMR as the main topic (13). The One Health approach to fight AMR is also promoted on a global level, as illustrated by the WHO global action plan (14).

To support the call for the application of a One Health approach to AMR and infectious diseases, research on the human–animal–environment interface is important. Moreover, to promote the One Health concept and facilitate the application of such a concept among different stakeholders, training and extension activities are essential.

This overview compiles research and education activities in the area of One Health in Western Europe, with a focus on infectious diseases. It can serve as a starting point for future initiatives and collaborations.

Methods

This review describes One Health research and extension activities in Western Europe, including Austria, Belgium, France, Germany, Italy, Iceland, Ireland, Liechtenstein, Luxembourg, Monaco, the Netherlands, Portugal, Scandinavia, Spain, Switzerland and the UK. Activities were only included if the term ‘One Health’ was specifically mentioned in the description of the activity.

First, a search for the term ‘One Health’ was performed on August 24, 2016, in the National Center for Biotechnology Information PubMed database. Publications that use ‘One’ as a numeral rather than referring to the concept ‘One Health’ in relation to human, animal, and ecosystem health were removed. Also, articles that only used the term ‘One Health’ as a key word or in the name of an institute were removed: only those articles that used the term ‘One Health’ in their title or abstract were selected. Articles that did not have a first or last author from a Western European country, as well as congress reports, news reports, editorials and articles by authors that did not represent non-governmental organizations (NGOs), governmental organizations or research institutes, were removed. The remaining articles were used for the bibliographic analysis and overview. Information on European research projects was extracted from Community Research and Development Information Service, the public database on all EU-funded research projects and their results (15).

Background information on the One Health initiative and European One Health initiatives were also obtained from One Health policy documents published by international organizations and governments.

In addition, a short questionnaire was composed to identify One Health research programs and funding, One Health education, and government support for the One Health approach. The questionnaires were placed on international One Health web sites and were sent to delegates of the FVE, national representatives of the International Veterinary Students’ Association (IVSA), international organizations such as the WHO, the FAO, the European Centre for Disease Prevention and Control (ECDC), the European Food Safety Authority (EFSA) and many more. Finally, a Google search was executed using the search term ‘One Health’ combined with each included Western European country and ‘One Health’ combined with ‘research’, ‘funding’, ‘education’, and ‘training’. Only the first 100 search results per country were analyzed.

Results

One Health research

Results of PubMed search

Searching for the term ‘One Health’ in PubMed generated 2,214 results. After selecting articles that refer to the One Health concept or approach in their title or abstract,

637 publications were left. Of those, 184 were scientific publications of first and last authors that represented NGOs, governmental organizations or research institutes from Western Europe (Fig. 1a). The first Western European article from our search results that referred to 'One Health' was published in 2008. After 2012, the number of publications that mentioned the One Health approach or One Health concept showed a major increase (Fig. 1b).

The first publications that talked about One Health in their title or abstract were published by US institutes and organizations, followed by European institutes. On a global level, almost half of the total number of scientific publications on One Health are authored by North American institutes, followed by European scientific institutes that make up for one-third of the total number of publications. Although earlier literature mainly came from North America and Europe, authorships of more recent articles show that One Health is under the attention of an increasing number of countries. The large majority of European One Health scientific publications come from institutes in Western Europe, compared to Eastern Europe (Albania, Baltic states, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Greece, Hungary, Macedonia, Malta, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia and Ukraine).

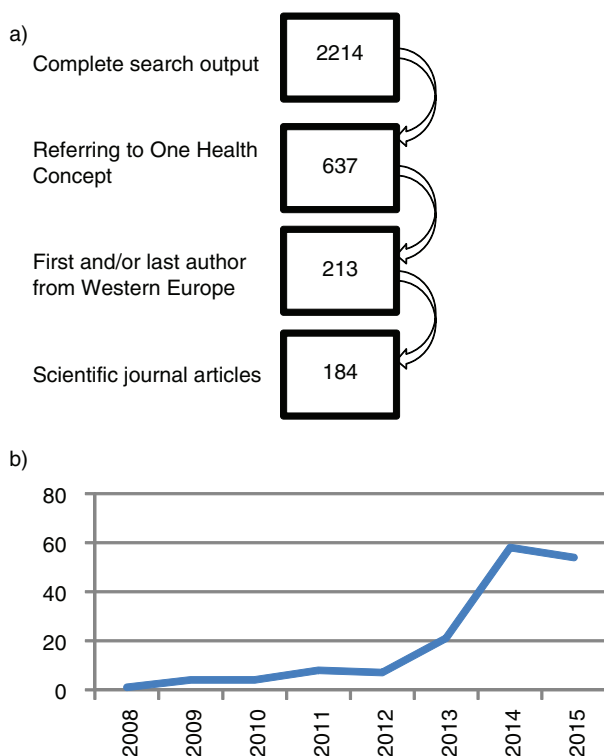


Fig. 1. Search strategy for the overview of One Health research publications, Western Europe, with a) breakdown of search strategy and b) number of publications with first or last authors from Europe per year.

A total of 39 institutes based in Western European countries published two or more articles that mentioned the One Health concept in their title or abstract. The 10 institutes with the highest number of publications mentioning 'One Health' were included in Table 1. Interestingly, five out of 10 institutes are based in the UK.

Funded research projects

Horizon 2020 (2014–2020) and the Seventh Framework Programme (2007–2013), the EU Research and Innovation programs, fund many research projects in the area of One Health, zoonotic diseases, and AMR. The research projects that are funded can either be collaborations within the EU or collaborations between institutes from the EU and organizations outside of the EU (third countries) (Table 2).

The Med-Vet-Net European Network of Excellence (NoE) for zoonoses research was initially funded by the EU Sixth Framework Programme (2004–2009). After 2009, the network of eight veterinary and seven public health institutes from 10 European countries continued independently (16). Amongst other things, The network organizes scientific meetings and training courses, launches calls for One Health collaborative projects and promotes multidisciplinary collaborations in One Health research.

The Network for Evaluation of One Health (NEOH) is funded by Cooperation in Science and Technology (COST), a European framework that supports transnational cooperation between researchers, engineers, and scholars in Europe. NEOH aims to develop and apply a science-based evaluation protocol to enable future quantitative evaluations of One Health activities (17).

Regional and national initiatives

Antimicrobial resistance. In 2015, a declaration on AMR through a One Health perspective was launched by the Nordic Council, the interparliamentary body in the Nordic region (Denmark, Finland, Iceland, Norway and Sweden), urging the European Parliament to implement a One Health approach in the fight against AMR (18). Under the presidency of the Netherlands, the Ministerial Conference on AMR emphasized the need for a One Health approach to combat AMR in 2016 (9). Many countries, such as the UK, France and the Netherlands, incorporated the One Health approach in their strategy to fight AMR (19–21). This is also illustrated by joint reporting of antibiotic use and AMR in the human and veterinary health sectors in many European countries (21–25). EU Member States report data on AMR in zoonotic bacteria to the European Commission, the EFSA and the ECDC. In 2015, the ECDC, EFSA and European Medicines Agency for the first time published a joint report on the analysis of antibiotics consumption and AMR in bacteria from humans and food-producing animals (26).

Table 1. Overview of 10 European institutes with most publications that include the term ‘One Health’ in their title or abstract

Country	Research institute	One Health topics
Belgium	Institute of Tropical Medicine	Advocating the One Health approach and performing research of tropical zoonoses such as <i>Taenia solium</i> taeniosis.
Denmark	University of Copenhagen	Research of zoonoses, such as parasitic and neglected zoonoses. Some publications on comparative medicine.
Germany	Freie Universität Berlin	Publications on antimicrobial resistance (AMR) and zoonoses in the food chain such as <i>Vibrio</i> and <i>Campylobacter</i> .
France	OIE	Advocating the One Health approach in general and in relation to rabies and Rift Valley fever.
Switzerland	Swiss Tropical and Public Health Institute	Advocating the One Health approach and One Health surveillance of zoonoses. Research of tropical zoonoses and economic analyses of zoonoses and the One Health approach.
UK	The Royal Veterinary College	Research of zoonoses such as influenza and rabies, assessing (economical) impact of zoonoses and the One Health approach and zoonotic disease risk management. Publications on comparative medicine.
	London School of Hygiene and Tropical Medicine	Research of zoonotic diseases, such as emerging zoonoses and neglected zoonoses. Research of AMR.
	University of Liverpool	Research on zoonoses such as Japanese Encephalitis Virus (JEV) and rabies.
	University of Cambridge	Advocating the One Health approach in education and research on zoonoses (such as <i>Leishmania</i>) and AMR.
	University of Edinburgh	Advocating the One Health concept and research of (neglected) zoonoses and AMR.

A large number of EU Member States are participating in the EU Joint Programming Initiative on AMR. This initiative coordinates and pools EU national research funds and efforts to maximize research output in the area of AMR. The web site also contains a searchable database and a mapping report of national and European research funding in the field of AMR (27).

Zoonotic diseases. Data from monitoring of zoonoses and zoonotic agents in animals of EU countries are reported to EFSA and the OIE (28). Data from human monitoring are submitted via the European Surveillance System, hosted at ECDC. The results are published in the EU summary report on trends and sources of zoonoses, zoonotic agents, and food-borne outbreaks of the EFSA and the ECDC and the OIE World Animal Health Information Database (WAHIS Interface) (29). Many countries also publish a national zoonotic disease report. All Scandinavian countries, for example, have zoonoses centers that are also involved in research activities and information provision for professionals and the public (30). Other countries, such as the Netherlands, Germany, Belgium and the UK, also publish yearly zoonotic disease reports (31–34). The UK and the Netherlands have also established a specific multidisciplinary and multiagency group that assesses emerging infection risks to human health: the UK the Human Animal Infections and Risk Surveillance group and the Dutch Signalling Forum Zoonoses (35, 36).

In recent years, several national One Health research networks have been founded in Europe. They are listed in Table 3.

A 90 million Euro Co-fund Joint Programming Initiative for One Health is planned for 2016–2017 to create a joint European program to deal with One Health in relation to (emerging) zoonoses (37). Other institutes, such as the Wellcome Trust, also provide funding for zoonotic disease research (38). In addition, most Western European countries have national funds for zoonotic disease research.

One Health training opportunities

University training

Universities from Denmark, France, the Netherlands, Spain and the UK offer minor and master’s programs in One Health. The One Health master of the Royal (Dick) School of Veterinary Sciences in Edinburgh is the only online master’s program. The University of Copenhagen also offers a summer course on One Health, which is open to all international master’s students, PhD students and postgraduates (39) (Table 4).

The University of Basel recently launched a new 30-h online One Health course for non-professionals as well as professionals in the field of human, animal and environmental health (40).

In addition to the listed courses, many other veterinary faculties offer courses on zoonotic diseases. In general, human medical education pays less attention to zoonotic diseases in their curriculum.

In recent years, students have also taken up an active role in One Health. Some countries have One Health student associations or veterinary public health associations and networks, such as the Netherlands (Hygieia), the UK (One Health Bristol) and Ireland (University College Dublin One Health Society) (41, 42). Moreover, the IVSA recently

Table 2. Selection of Horizon 2020 (2014–2020) and Seventh Framework Programme (2007–2013) funded research programs in the area of One Health

Name of the project	Summary	Web site
Anticipating the Global Onset of Novel Epidemics (ANTIGONE)	<i>Identify the key factors that contribute to the emergence of pathogens with human pandemic potential from pathogens with a zoonotic background.</i>	www.antigonefp7.eu/
Companion Animals Multisectorial Interprofessional Interdisciplinary Strategic Think tank on Zoonoses (CALLISTO)	<i>Provide an overview of the current situation with regard to the role of companion animals as a source of infectious diseases for people and food animals to identify knowledge and technology gaps and propose preventive actions.</i>	www.callistoproject.eu/
Collaborative Management Platform for Detection and Analyses of (Re-) emerging and Foodborne Outbreaks in Europe (COMPARE)	<i>Develop an enabling analytical framework and globally linked data and information sharing platform for the rapid identification, containment, and mitigation of infectious disease outbreaks in humans and animals using new genome technology.</i>	www.compare-europe.eu/
Biology and Control of Vector-borne Infections in Europe (EDENEXT)	<i>Study the biological, ecological, and epidemiological components of vector-borne disease introduction, emergence, and spread, and the creation of new tools to control them.</i>	www.edenext.eu/
Epigenesis	<i>One Health approach to integrate Guadeloupe research on vector-borne and emerging diseases in the European Research Area: from characterization of emergence mechanisms to innovative approaches for prediction and control.</i>	www.epigenesis.cirad.fr/
Ecology from Farm to Fork of Microbial Drug Resistance and Transmission (EFFORT)	<i>Study the complex ecology of antimicrobial resistance (AMR) and the complex interactions between bacterial communities, commensals, and pathogens in animals, the food chain, and the environment.</i>	www.effort-against-amr.eu
Integrated Control of Neglected Zoonoses (ICONZ)	<i>Improve human health and animal production in developing countries through integrated control of neglected zoonoses in animals, based on scientific innovation and public engagement.</i>	www.iconzafrica.org
Joint Programming Initiative on Antimicrobial Resistance (JPI AMR)	<i>The primary aim of the third joint call of JPI AMR is to combine the resources, infrastructures, and research strengths of multiple countries in order to address transmission of AMR following a 'One Health Approach'.</i>	www.jpiamr.eu/
Linking Epidemiology and Laboratory Research on Transboundary Animal Diseases and Zoonoses in EU and China (LinkTADs)	<i>Coordinate research between the EU and China in the area of transboundary animal diseases and zoonoses.</i>	www.linktads.com
PREDEMICS	<i>Providing preparedness, prediction, and prevention of merging zoonotic viruses with pandemic potential using multidisciplinary approaches.</i>	www.predemics.biomedtrain.eu/
Training and Research Aimed at Novel Antibacterial Solutions in Animals and People (TRAIN ASAP)	<i>Develop novel antibacterial solutions for humans and animals.</i>	www.train-asap.eu/
Zoonoses Anticipation and Preparedness Initiative (ZAPI)	<i>Develop platforms for the rapid identification and production of viral domains that can be used as veterinary vaccines and develop platforms for the rapid development, selection, and production of protective antibodies to protect the human population.</i>	www.cordis.europa.eu/project/rcn/203726_en.html

launched the standing committee on One Health and a network of local veterinary public health officers (43).

Training courses and extension activities

Several European funded research projects include extension activities. For example, the Anticipating the

Global Onset of Novel Epidemics (ANTIGONE) project organizes a yearly One Health workshop and the One Health for Next Generations (OH-NEXTGEN) project developed One Health course materials and workshops aimed at researchers in the Sahel and Maghreb (44, 45). The Southeast Asia and European scientific collaboration

Table 3. Selection of One Health research networks in Western Europe

Name of the project	Summary	Web site
One Health Sweden	<i>Multidisciplinary network of researchers with interest in zoonotic infections and antibiotic resistance (AMR), mainly from universities and governmental organizations in Sweden. Recently, researchers from other Nordic countries also joined. Stimulates multidisciplinary partnerships by providing biological samples to collaborative projects for detection and characterization of viruses and bacteria with emerging potential and by educational activities for students and researchers.</i>	www.onehealth.se
National Consortium for Zoonoses Research (NCZR)	<i>The UK Consortium aims to encourage interdisciplinary and interinstitutional research into zoonoses.</i>	www.zoonosis.ac.uk
Netherlands' Centre for One Health (NCOH)	<i>Partnership of academic research institutes in the Netherlands to collaborate on research on the interactions and connections between human, veterinary, wildlife, and environmental health.</i>	www.ncoh.nl
Strategic Network on Neglected Diseases and Zoonoses (SNNDZ)	<i>Research collaboration initiated by the Institute of Tropical Medicine in Antwerp, Belgium (ITM). The Network aims to stimulate and support collaborations between ITM and partners from Asia, Africa, and Latin America.</i>	www.snndz.net/
German Research Platform for Zoonoses	<i>Network for German researchers in the field of zoonoses that aims to increase research activities in the field of zoonoses research and promote 'broad horizontal cross-linking of human and veterinary medicine'. Within this network, 11 smaller networks in the area of specific zoonotic diseases have been established.</i>	www.zoonosen.net/

project (SEA-EU-NET) project also organized workshops in the area of One Health (46). The NEOH, under the COST framework, organized several workshops, such as the European One Health/EcoHealth workshop in 2016 (47).

Notably, One Health Sweden developed an educational strategy program targeting secondary schools and high schools. All materials can be found on their web site. 40,000 copies of their One Health educational materials

have been distributed to all Swedish schools. The course package is called 'Infectious diseases in a changing world'.

Moreover, in recent years, many conferences in the area of One Health and zoonoses have been organized in Europe. Some of them, such as the One Health congress in Amsterdam (the Netherlands) in 2015 and the One Health summit in Davos (Switzerland), attract scientists and policy

Table 4. Overview of European university training on 'One Health'

Country	Institute	Type of training	BSc	MSc	Postgraduate	Credits
Denmark	Veterinary Faculty, Copenhagen	One Health track (minor)		X		21.5 ECTS
France	Nantes-Atlantic National College of Veterinary Medicine, Food Science and Engineering, in partnership with the University of Nantes' Department of Medicine and the University of Angers' Department of Medicine	Master 'Manimal'			X	60 ECTS
Netherlands	Veterinary Faculty, Utrecht	One Health track (minor)		X		60 ECTS
	Utrecht University, all faculties	Honors program One Health	X			45 ECTS
Spain	Veterinary School of the Universitat Autònoma de Barcelona (UAB)	Master Zoonoses and One Health			X	60 ECTS
UK	Royal Veterinary College (RVC)/London School of Hygiene & Tropical Medicine (LSHTM), London	Master One Health (Infectious diseases)		X	X	60 ECTS
	Royal (Dick) School of Veterinary Sciences, Edinburgh	Master One Health			X	180 ECTS
	University of Bristol	Honors program Population Medicine and One Health	X			20 ECTS

European Credit Transfer System (ECTS).

makers from all over the world (48). Also, on European, national and regional scale, One Health and zoonotic diseases are an important topic in many conferences.

Discussion

This overview is likely to be incomplete, as we limited our search to the term 'One Health'. This may have led to an underestimation of the number of articles and research and educational initiatives. Many articles in the area of zoonotic diseases or AMR may not have used the term 'One Health' in their abstract or title. This is illustrated by a publication of Jakob Zinsstag et al. that already described the One Health concept in 2005, but did not come up in the search results (6). Others only described their specific research topic without mentioning "One Health". This may have also been the case for the online search for One Health initiatives. Moreover, other terms, such as 'Eco-Health', 'Ecosystem health', and 'One Medicine', are also known to be used for the multidisciplinary initiatives to improve human, animal and ecosystem health, which can also be categorized under One Health. Authors or institutes using these terms were probably not included in this overview. Additionally, there is a lot of discussion about the research themes that fall under the umbrella term 'One Health'. Any research discipline that can contribute to human, animal, or ecosystem health, including anthropology, sociology, pedagogy or comparative medicine, can be 'One Health'. It was therefore difficult to limit the scope of this overview.

This overview shows that there is considerable recognition for One Health in Europe, although most educational initiatives are recent. Governments and universities increasingly adopt the One Health concept. In Europe, the One Health approach is currently mainly advocated in relation to AMR. This has already resulted in increased collaboration between the human health and veterinary health sectors in the areas of surveillance, control and research. AMR is high on the political agenda which has led to increased research funding. Although the One Health approach in relation to zoonotic diseases receives less media attention at the moment, the number of publications and research funding opportunities are increasing.

Funding initiatives in some countries have stimulated cross-discipline research and training, but these initiatives are lacking in most countries. Consequently, collaboration between different sectors in the area of zoonotic diseases is not in place yet in many European countries. Globally, there is also a segregation between publications from different sectors in disease transmission studies. Also, previous studies show limited medical representation in One Health and infectious disease publications (49, 50). One Health mainly discusses collaborations between human and animal health issues at present but other disciplines, such as environmental and social sciences, should also be integrated (7, 51–53). These partnerships

currently only represent a minor share of the One Health research community.

The One Health concept is predominantly advocated by the veterinary sector. Veterinary organizations such as the FVE promote and advocate a One Health approach in the areas of zoonotic diseases and AMR, but the call for a One Health approach is much weaker from the human medical sector (7, 54, 55). One Health training is embedded considerably more in veterinary schools than in medical training, as is shown by the overview of One Health university training initiatives in Western Europe. Thus, despite lots of political attention, One Health education of human doctors appears to be lagging behind. This is illustrated by surveys that showed that many physicians lack knowledge on zoonotic diseases and the One Health concept is not known to most of them (56, 57).

In line with recommendations of the WHO, AMR and infectious disease research should not be separate topics for research and education, rather should be part of one strategy for infectious disease prevention and control (7, 58). Moreover, One Health research and training initiatives should be both multidisciplinary and multinational as zoonotic diseases and AMR do not stop at country borders. Funding instruments can be used to guide such collaborations.

Conclusion

Although One Health has gained recognition in Europe, the application of the One Health approach in research and education should be further encouraged and facilitated. To assist the progress of the multidisciplinary approach that is needed to fight zoonotic diseases and AMR, an inventory of current barriers for collaboration is needed. Targeted funding can be used to address these boundaries and facilitate multidisciplinary research and training to fight both zoonotic diseases and AMR in Europe.

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