European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

REPORT OF THE CWG AHW STUDY:

EU Animal Health Strategic Research Agenda: 2017 update

European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

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PANGEA

DISCONTOOLS

STAR-IDAZ International Research Consortium on Animal Health

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Executive Summary

The issues

Europe's veterinary public health systems are confronted with growing economic, sociological, environmental changes and challenges. A priority-focused strategy is urgently needed to best utilize the limited resources invested into animal health research for safeguarding and improving animal health for present and future generations.

A foresight study was carried out as part of the ANIHWA project in order to produce an EU Strategic Research Agenda on Animal Health and Welfare (published in 2015) and to identify topics for collaborative activities at European level. This study was executed to assist in updating the strategy and this report details its findings. The study was conducted using expert opinions collected through online surveys; focus groups then discussed the identified priorities.

The results & policy consideration

The results of this study support the set of key priorities identified in the document "An updated SRA covering animal health and welfare" which contains a 15 to 20-year outlook (ANIHWA, 2015) on priority topics in animal health and welfare research. The outcomes of this update are presented in three separate sections of the main body of the text: structural/political, technological, and specific topics' needs. Similar to the needs identified in the 2015 outlook, the research needs and research questions identified in this study are relatively broad, in order to be valid for several EU Animal Health research institutions which often have diverse objectives. More detail on the identified research topics can be found in i) the disease priority box and research questions provided in the appendix, ii) regularly updated databases for specific disease prioritisation, such as DISCOONTOOLS, or iii) in the disease roadmap produced by STAR-IDAZ IRC.

The key actions advised in order to ensure effective prevention, detection and response to animal health diseases, according to previous results, are:

- To favour the delivery of fast and reliable diagnostics, easy to use in the field;
- To optimise vaccinology, addressing studies on DIVA, new adjuvants, host/pathogen interaction, and technological advances with potential to make vaccine development economically viable;
- To empower basic research and increase sharing of information;
- To establish a science-driven response to disease outbreaks (especially vector-borne ones);
- To engage in preparedness by risk-based surveillance;
- To strengthen knowledge/technology transfer;
- To favour networking among countries;
- To establish biosecurity measures and consider animal welfare as tools for healthy production.

Furthermore, the following key actions received major importance in this study than in the previous SRA:

- To encourage public-private partnership, ensuring return of investments to companies developing new drugs;
- To develop standards for data collection/sharing, fundamental for big data integration;
- To ameliorate integrated surveillance systems and encourage their acceptance;
- To facilitate precision livestock farming;
- To strengthen the One Health approach;
- To favour econometric studies to demonstrate positive impacts of investing money in research and thus limit cuts to research budgets.

Acronyms

AI	Avian Influenza
AH	Animal Health
AMR	AntiMicrobial Resistance
ANIHWA	Animal Health and Welfare ERAnet project
ASF	African Swine Fever
ATA	Alternatives To Antibiotics
AW	Animal Welfare
BLAST	Basic Local Alignment Search Tool
BT	Blue Tongue
bTB	Bovine Tuberculosis
CBPP	Contagious Bovine Pleuro-Pneumonia
CASA	Common Agricultural and wider bioeconomy reSearch Agenda
CVO	Chief Veterinary Officer
CWG	Collaborative Working Group
DISCONTOOLS	DISease CONtrol TOOLS
DIVA	Differentiating Infected from Vaccinated Animals
DB	Database
DG-SANTE	Directorate-General for EU policy on food safety and health
EFSA	European Food Safety Authority
EMIDA	Coordination of European Research on Emerging and Major Infectious Diseases of Livestock
ERAnet	European Research Area network
EU	European Union
FMD	Foot and Mouth Disease
FP7	7th Framework Programme
HPAI	Highly Pathogenic Avian Influenza
IT	Information Technology
LPAI	Low Pathogenic Avian Influenza
MERS	Middle East Respiratory Syndrome
MS	Member State
NGS	Next-Generation Sequencing
OIE	World Organisation for Animal Health
PLF	Precision Livestock Farming
PRDC	Porcine Respiratory Disease Complex
PRRS	Porcine Reproductive and Respiratory Syndrome virus
R&D	Research and Development
RQ	Research Question
SARS	Severe Acute Respiratory Syndrome
SCAR	Standing Committee on Agricultural Research
SIV	Simian Immunodeficiency Virus
SRA	Strategic Research Agenda
STAR-IDAZ IRC	Global Strategic Alliances for the Coordination of Research on the Major Infectious Diseases of Animals and Zoonoses International Research Consortium
WG	Working Group

Introduction

The animal health (AH) sector is critical for the health of livestock and for all those activities connected with it, such as protection of public health, food safety and environmental health. Furthermore, the sector contributes substantially to the EU economy in terms of employment and trade of its products. The ever changing environment that surrounds the AH sector, such as the significant and far ranging changes in climate, social needs, technology, economics and politics, increase the need for continuous research and innovation.

Research and development (R&D) have contributed to the growth of the animal health research sector and in making it competitive and efficient. However, continued support of research and innovation in the AH sector is needed to face the new challenges caused by new developments and new consumer trends and demands. Furthermore, it is essential to support the adaptation of such innovations in the farming systems themselves. In order to keep growing, the AH sector requires coordinated and integrated interdisciplinary research, a proactive attitude for identifying future needs, and an effective translation of needs into action and policy making. Strengthening collaborative activities will help avoiding gaps and overlaps, ensuring synergies and facilitating the gathering of a common, efficient strategy for AH.

The Collaborative Working Group (CWG) on Animal Health and Welfare, a forum of research funders and programme owners of the Standing Committee on Agricultural Research (SCAR) with the objective of improved collaboration on research prioritisation and procurement, creates the necessary critical mass and focus needed to deliver the animal health and welfare research needs of our policy makers and the European livestock industry. Furthermore, the CWG currently forms the regional network of STAR-IDAZ IRC, an International Research Consortium (IRC) of research funders and programme owners, aiming to coordinate animal health research globally.

The Collaborative Working Group (CWG) on Animal Health and Welfare started its activities in 2005 and today 28 partners from 20 countries participate in this group. It works on **emerging and major infectious diseases, production diseases and animal welfare of production animals** in the EU, together with capacity and capability (**including infrastructural aspects**). Its scope **includes fish and bees and those conditions which pose a threat to human health**, but excludes food safety issues relating to the handling of livestock products and wildlife diseases, except where they act as reservoirs of infection for humans or production animals.

CASA – a Coordination and Support Action (CSA)-, has an overall objective of **consolidating the common agricultural and wider bioeconomy research agenda** within the European Research Area. CASA will achieve this by elevating the Standing Committee on Agricultural Research (SCAR), which has already contributed significantly to this objective in the past, to the next level of performance as a research policy think tank. CASA will efficiently fortify the strengths and compensate for the insufficiencies of SCAR, thus helping it evolve further into 'SCAR plus'.

The overall objectives of the Animal Health and Welfare ERA-NET (ANIHWA) foresight activities were to take a 20-year outlook on animal health and welfare issues, and develop a long-term Strategic Research Agenda in a European and global context, covering infectious as well as production-related infectious diseases and animal welfare, with particular emphasis placed on identifying future risk and the critical research capacity that needs to be developed or maintained. Specifically, the EMIDA SRA was validated, updated and the scope expanded, including production diseases and welfare, using a range of foresight techniques.

In order to deliver animal health research needs to EU policy makers and the livestock industry, the CWG managed two ERA-NETs over the years: EMIDA and ANIHWA. This study, carried out by the CWG with the support of CASA, provides an updated view of the EU Animal Health Strategic Research Agenda (SRA), specifically on Animal Health, which has also been the part of the ANIHWA Deliverable 5.2 published in 2015. Although the SRA had originally been developed with a 20-year outlook, changing drivers of AH research needs require a constant review of the SRA. STAR-IDAZ recommended conducting a foresight study every five years and formal SRA reviews on a biennial basis. Thus, in 2017, this study was implemented by the CWG with the support of CASA and PANGEA. It focusses on important next steps in AH research, identifying new insights and priority topics for the sector.

This update report has been created to support SCAR and the Member States (MS) in the definition of AH policy. It will help MS research funders to prioritize areas for investments and collaboration, as well as to assist researchers and research managers in focussing their research activities. The SRA creates a shared vision toward the AH future and puts its users in the position to achieve shared objectives and reach common goals and results.

STAR-IDAZ
International Research Consortium on Animal Health

An International Research Consortium (IRC) of research funders and programme owners, aiming to maximise funding for coordinated animal health research, with a higher level of commitment, was built on STAR-IDAZ, an EU-financed Coordination and Support Action (2011-2015) aiming at **coordinating animal health research globally**. STAR-IDAZ IRC was launched at an event hosted by the European Commission in Brussels on 27 January 2016. The overall objective of the STAR-IDAZ IRC is to coordinate research at the international level to contribute to new and improved animal health strategies for at least 30 priority diseases/infections/issues. The deliverables include candidate vaccines, diagnostics, therapeutics and other animal health products, procedures, and/or key scientific information/tools to support risk analysis and disease control. The STAR-IDAZ IRC is governed through an Executive Committee, a Scientific Committee and a variable number of working groups all supported by an EU funded secretariat (SIRCAH).

Starting point: results of the 2015 ANIHWA SRA

In the ANIHWA SRA (2015) the research needs were divided into three groups a) Structural/political, relating to the creation of an enabling environment to support research, b) Technology, where opportunities could be exploited and c) Specific disease/topic challenges and classified as urgent (Priority Box 1), less urgent (Priority Box 2) and important but not urgent (Priority Box 3).

Structural/political

Priority Box 1
Research pipeline – investment in basic research
Sound public polices relating to science and technology - Better impact assessment of new legislation
Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals; capacity in parasitology; neuropathology; Better capacity to address neglected diseases; government/professional bureaucrats
Partnerships/collaborations – global/regional research alliances – sharing information between countries
Knowledge management systems – Big data, GIS; Sharing Data - Integration and better use of existing data
Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry) - Strategy for protecting intellectual property – Public Private Partnerships
Integrated surveillance system/ Centralised diagnostic testing - Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming
Priority Box 2
Improved focus of research activities – gap analysis - Alignment of financial resources and research capacity with needs
Invest in new (more powerful) technologies
One health approach
Social acceptability of new technologies
Biosecurity - Management of waste - Improved inspection at borders
Operating systems in disease prevention and control - Operational research
WTO – lack of ethical issues relating to welfare and environment
Priority Box 3
Better monitoring of medications - Improve the control of drugs

Technology

Priority Box 1
Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR
Vaccine development/New genetically engineered vaccines – Immunology – bioinformatics - Predictive Biology - Reverse genetics – synthetic biology
Alternatives to antimicrobials – antimicrobial peptides – immunomodulators - New antibiotics
Alternative methods to control vectors - Integrated pest management - Biological control - Genetically modified insects
Biosecurity
Systems based approaches/research
Priority Box 2
Surveillance - Syndromic surveillance - Precision livestock farming/Automated disease surveillance; Big data; Risk-based approach to surveillance; More high-throughput technologies (metagenomics, sequencing and bioinformatics); Easy to use field diagnostic technology
Big data – bioinformatics
Nanotechnology – e.g. adjuvants
Animal breeding/genetics - disease resistance – local breeds - Cloned and GM engineered animals
New drug development - New therapeutics for parasitic diseases
Animal identification technologies

Specific topics/disease

Priority Box 1
Improved Understanding of the role of wild life - Epidemiological studies on wildlife - livestock interaction and disease spread
Vector-borne diseases - Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification
Antibiotic effectiveness and availability - Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators
Disease introductions, including trans-boundary animals diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens
Improve food safety – traceability; risk analysis; antimicrobial/Residues
Gut health - Digestive physiology; gut microbiome - pre/probiotics; Improved understanding of the interaction between pathogens and also between the pathogen and the gut
Anthelmintic resistance - Mechanisms of resistance - Markers of resistance
New diseases
Lack of effective indicators of animal welfare
Stress due to intensification
Priority Box 2
Understanding disease ecology - Decrease evolutionary pressure on pathogens
Studies on the impact of diseases on ecology/environment/biodiversity
Socio-economic impact evaluation of main diseases
Sustainability of production systems - New production system; genetics - assure maintenance of biodiversity;
Welfare implications of keeping animals indoors
Controlled environment housing
Trade-off between welfare and cost to society
Public perception of welfare versus health
Priority Box 3
Alternative systems to compensate for downsizing of surveillance/detection systems - Integration and better use of existing data; Syndromic surveillance; Cost effective real-time collection of data; Risk-based approach to surveillance
Neglected diseases

Aim

The aim of this study was to validate and update the scientific and technological needs identified in the SRA delivered in 2015 under the ANIHWA project to prevent, control or mitigate animal health and zoonotic challenges for 2030 and beyond.

Methods

Scope and work plan of the study for updating the EU AH SRA was defined by the Collaborative Working Group for Animal Health and Welfare Research (CWG) and approved by its Strategic Foresight Unit (SFU).

The work was structured in four consecutive phases:

1) a desk study aimed to collect identified animal health research priorities;

2) an online survey, sent to a large panel of selected experts in several disciplines of the AH sector working in EU countries and third countries, to validate and prioritise research topics;

3) a series of e-mails which were circulated among national experts and the SFU of the CWG to develop in-depth research questions on the highly relevant research topics identified in the online survey;

4) a consensus workshop with selected panels of experts, which aimed to discuss the results of the survey and draw conclusions.

A brief summary of the steps followed during the study is summarised in Figure 1.

Figure 1: Steps of the current study updating the EU SRA.

Collection of identified AH research priorities	•Desk study •Consultation with SFU •Generation of a list of identified research priorities
Online prioritisation of recently identified priorities	•Template for online prioritisation •Selection of experts •Run of the online survey to collect expert opinion •Analysis of results
Definition of research questions	•Translation of the highly relevant identified priorities into research questions by selected experts groups
Consensus workshop	•Discussion on the results of the expert opinion •Revise and reword of research questions •Provide further hints

Phase 1: Collection of identified AH research priorities

A list of documents containing AH research needs was identified through a desk study (Figure 2). The compilation of documents was submitted to the SFU to be validated. The research needs taken from this compilation were aggregated with the ones identified in ANIHWA Deliverable 5.2 (2015) “An updated SRA covering animal health and welfare”. A list with a total of 78 AH research needs was generated.

The documents merged with ANIHWA Deliverable 5.2 (2015) “An updated SRA covering animal health and welfare” are the following:

- Aquainnova, Combination of aquainnova outputs. Integration of all thematic working group products (SRA, vision, plan of action), European Aquaculture Technology & Innovation Platform. Deliverable 42 16.
- ATF, A strategic research and innovation agenda for a sustainable livestock sector in Europe. Second White Paper of the Animal Task Force (2016).
- COLOSS, Prevention of Honeybee Colony Losses – monitoring progress report (2012).
- EMIDA ERAnet, Strategic research agenda – 10 to 15 year outlook. 2013 (2011) 32.
- EPIZONE, Final report: EPIZONE, Network of Excellence for Epizootic Disease Diagnosis and Control. Final report (2012) 68.
- EUFETEC, Vision & SRIA document 2030: Feed for Food Producing Animals (2013).
- FABRE TP, Sustainable farm animal breeding & reproduction technology platform Strategic Research Agenda (2008) 32.
- Health for Animals, Innovation in Animal Health: historic success, current challenges & future opportunities (2016) 52.
- S. Messori, R. Zilli, V. Mariano, M. Bagni, Building a strategic research agenda for animal health for the Mediterranean. Results from the second workshop. (2015).
- D. O'Brien, J. Scudamore, J. Charlier, M. Delavergne, DISCONTOOLS: a database to identify research gaps on vaccine, pharmaceuticals and diagnostics for the control of infectious diseases of animals, BMC Veterinary Research. 13 (2017) 1–10.
- STAR-IDAZ, Strategic research agenda: meeting future research needs on infectious diseases of animals and zoonoses. Deliverable 5.2 (2015).

Figure 2: List of sources merged to obtain a list of recently identified animal health research priorities.

Phase 2: Online prioritisation of recently identified research needs

Expert opinions were collected on the 78 recently identified AH research priorities through an online survey sent during summer 2017 to a group of 298 AH experts. The phases of the online survey are summarised in Figure 3.

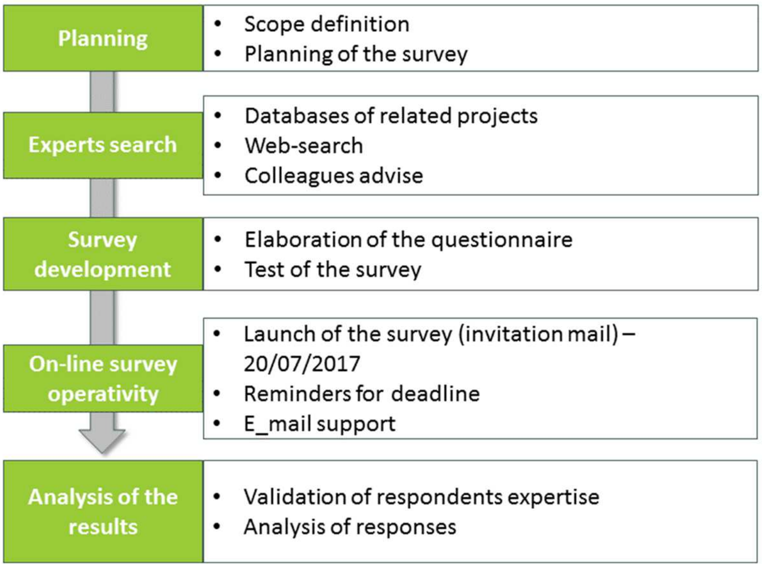


Figure 3: Phases of the online survey sent to AH experts.

The DISCONTOOLS project, originally developed under an EU-funded FP7 project, is nowadays financed by national funders of research from a range of countries with industry providing secretariat support and project management. DISCONTOOLS has the following objectives:

(1) To further develop disease prioritisation methodologies, enabling prioritisation of research in order to stimulate the delivery of new or improved diagnostics, vaccines or pharmaceuticals. This helps to improve our ability to effectively control animal diseases, which is a key input into meeting the challenges of future food supplies.

(2) To further develop the gap analysis for each of the prioritised diseases to identify where research is needed.

The experts approached for their opinions where either national experts identified by CWG partners or experts from DISCONTOOLS disease expert groups. Also OIE national reference laboratories were invited to participate in addressing some gaps in expertise in areas where only a minority of expert participating could be found. This list of experts was further expanded by inquiring the respondents' for other important experts to include. The survey was launched through an invitation email which contained a link to the online survey and some additional reading on the topic of the survey. The email was sent on 20 July 2017 and two reminders were sent before the survey deadline (3 September). During the survey, support to participants was made available by email.

The survey consisted of 15 questions. The main questions were closed-ended questions – either multiple or simple choice questions. The experts were asked to score, on a 1 to 10 scale, the relevance for the sector of each of the research needs and to self-assess their confidence in their answer for each section. The respondents also had the possibility to comment on each question, except for the first questions which were aimed at evaluating the expertise of the respondents. Anonymity of the respondents was guaranteed.

Table 1: List of criteria useful to prioritise animal health research needs

Criteria group	Criteria
Appropriateness: Should we do it?	1. Magnitude and urgency of the problem in relation to current animal health status
Relevance: Why should we do it?	2. Responsiveness to consumer and political demands
	3. Relevance of the research in relation to current research gaps or technical innovation
	4. Cost-benefit of the research
Chance of success: Can we do it?	5. Possibility of conducting the research in relation to financial, technical, infrastructural and human constraints
	6. Capability of the system for research maintenance
Impact of research outcome: What will we get?	7. Impact on public health and food safety
	8. Impact on economy and national/international trade
	9. Impact on animal health welfare and environmental health
	10. Potential for building research capacity

After the first section, which defined expert background (A), the survey consisted of a core section (B) which scored the 78 identified AH research needs; these were presented in four sub-sections:

a) Structural and political,

b) Technological,

c) Specific topics,

d) Specific diseases.

To help the respondents, the identified research needs were prioritised using two criteria only: 1) magnitude and urgency of the problem; 2) impact of research outcomes for animal health, environmental health, veterinary public health (VPH), and food safety. The criteria to be utilised were selected by the SFU through a brief online survey from a list of ten criteria (Table 1).

The results of the survey were analysed using MSOffice Excel®, considering experts' opinions as qualitative data. An average count of the responses was calculated for multiple choice questions. The different opinions of experts were evaluated for usefulness with a weighted average score ($\overline{x}_w$) using the formula in Eq1, which associates the score attributed to the answer (*x*) to the self-attributed confidence score (*w*) from experts to each question.

$$\overline{x}_w = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \quad \text{[Eq 1]}$$

Phase 3: Definition of research questions

Starting from the highly relevant research needs identified by the online survey, additional in-depth research topics were identified and translated into research questions by a group of experts selected from different fields, such as SFU members and experts from National Reference Laboratories. According to a previous foresight project implemented by the UK government on 'Global Food and Farming Futures' (Pretty *et al.* 2011), the research questions had the following characteristics:

1) They had to be answerable and capable of a realistic research design;

2) They had to be capable of a factual answer and not dependent on value judgements;

3) They had to be questions that have not already been answered;

4) Questions on impact and interventions should have a subject, an intervention and a measurable outcome;

5) Questions for which yes or no are likely answers were unsuitable;

6) Questions should be of the scale that, in theory, a team would have the means to attempt answering.

An ideal question suggests the design of research required to answer it or can be envisioned as translating the question into discrete and more directly testable research hypotheses.

The research questions (RQs) were circulated by e-mail for review.

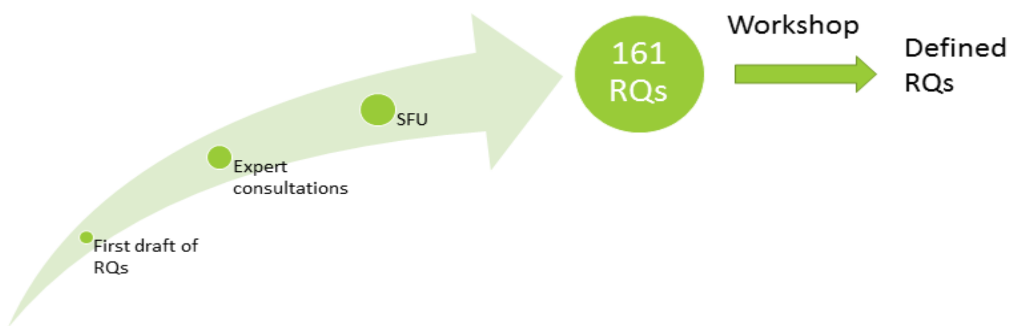


Figure 4: Flow graph for the step definition of RQs.

Phase 4: Consensus workshop

The results of the survey and the RQs produced were discussed in a consensus workshop with a restricted number of participants (n=29). The workshop was held on 28 November in Brussels. Participants were divided into three groups (Annex I) and invited to express their opinion in focus group sessions held in the afternoon (3.5 hrs; Table 2). The panel of participants was selected according to the main outcomes of the survey to ensure that participants would have the relevant expertise and, as much as possible, were selected to represent different European areas.

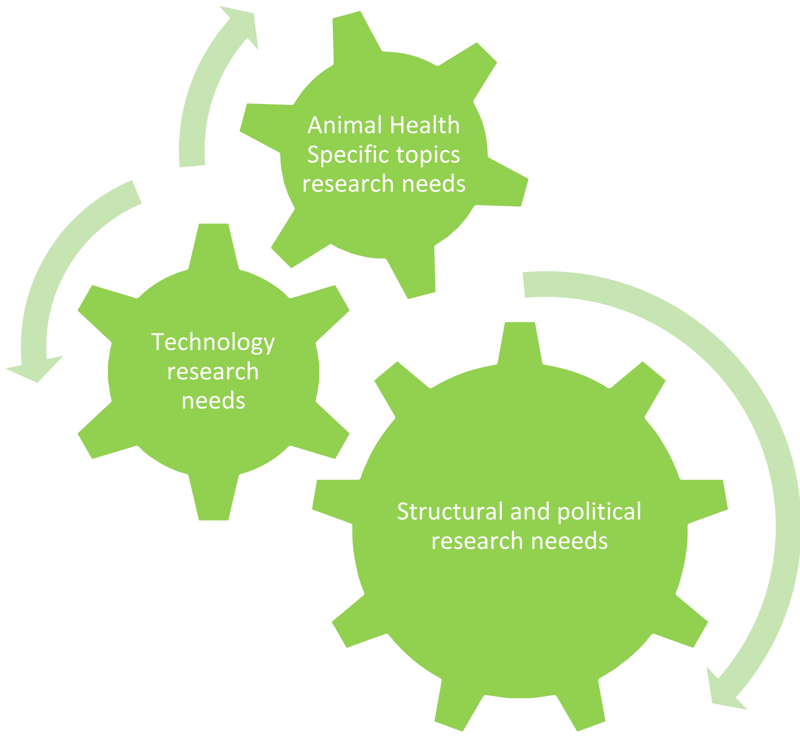
In order to facilitate a more informed and focussed discussion, the participants received the input material in advance by e-mail. Interactive questions were presented by a facilitator to the participants, who then interacted with each other in focussed discussion on: structural/political, technological and AH-specific topics/research needs. During the workshop, further hints on emerging issues/diseases emerged and recommendations for the SRA were provided.

Table 2: Consensus workshop timetable

Time	Activity
11.00–11.15	Welcome – Marina Bagni, Chair of SCAR-CWG on Animal Health & Welfare Research
11.15–12.30	Introduction to the workshop: • CASA and CWGs – Rolf Stratmann • “Updating the EU Animal Health Strategic Research Agenda” – Marina Bagni, Chair of SCAR-CWG on Animal Health & Welfare Research • ANIHWA SRA presentation – Luke Dalton, WP5 of ANIHWA ERA-NET • Expert opinion: main results from the online survey – Valeria Mariano • Workshop workplan – Valeria Mariano
12.30–13.30	Lunch buffet (open format)
13.30–14.00	Exercise 1 : Further hints for research needs/questions
14.00–15.30	Exercise 2: Discussion about current strengths and obstacles of EU animal health research and research needs
15.30	Coffee break
15.30–16.30	Exercise 3: Definition of research questions that, if answered, would have the greatest impact on the animal health research sector
16.30–17.00	Presentation of WGs results (10 min/group)
17.00	Closing remarks – Marina Bagni, Chair of SCAR-CWG on Animal Health &Welfare Research

Results

The results maintain the structure of the ANIHWA EU SRA as produced in 2015, which identified a strong correlation among structural and political research needs, technological research needs and animal health research needs.



Thus, in the following pages, results are presented grouped by section similar to the previous SRA: a) structural/political, addressing the needs for maintenance of capacity and enabling the environment in general; b) technological, recognising that technology is progressing rapidly and the opportunities this provides not just for disease control tools but also the possibility of exploitation for economic growth; and c) specific topics. For each section, the general recommendations provided by the focus groups during the workshop, the priority boxes emerging from the online survey, and the identified research questions produced for the highly relevant research topics, will be reported.

The identified research priorities have a broad range of content in order to be valid and comprehensive for the diversity of EU Animal Health research institutions all with their individual objectives. Any national authority looking for more information on the research topics can consult the specific disease priority boxes and research questions in the Appendix. Otherwise, specific regularly updated disease prioritisation databases, such as DISCOONTOOLS, are available for more detailed, in depth prioritization of research needs.

The different sections may be of interest to different stakeholders. The priorities expressed in each priority box may serve a variety of stakeholders, both at national (e.g., Chief Veterinary Officers (CVOs), Ministries of Agriculture/Health, national research institutions) and international level (e.g., DG SANTE/RTD or AGRI, OIE, SCAR). The RQs provided would mainly be used by research institutions to better focus their research design into an EU framework. Recommendations, on the other hand, have been provided with the main purpose to serve stakeholders at strategic levels such as the EU Commission, OIE, national CVOs, and Ministries of Agriculture/Health.

Participation in the study and background of experts.

A broad range of AH experts participated in the different phases of the study. Specifically, the survey included the participation of 128 experts from 28 countries mainly belonging to public research centres (n=99, 79.20%) (Table 3 & Table 4). The main expertise of respondents was concentrated in the general field of livestock (n=59; 46.83%) and, although all livestock fields were represented, the participation of experts in ruminants (34.92%) and pigs (30.16%) was particularly high (Figure 5). The greatest number of experts with more than 25 years of experience was registered in the fields of animal diseases (n=40; 41.24%), infectious diseases of livestock (n=27; 38%) and veterinary public health (n=16; 26.67%), respectively. The response rate (respondents/invitees) was 42.95%. Further details on the results of the online survey are shown in Annex II. The first draft of RQs involved the participation of 20 AH disease experts, while 29 experts, selected mainly based on their expertise, participated in the workshop. Furthermore, the study endeavoured to maintain a geographically balanced representativeness of north, central and southern Europe as far as possible, and preference was given to experts participating in previous steps of the study and with at least 15 years of work experience.

Table 4: Experts' organisation type.

Type of organisation	Responses	
Private	8.00%	10
Public	79.20%	99
NGO	0.80%	1
National (please specify):	22.40%	28

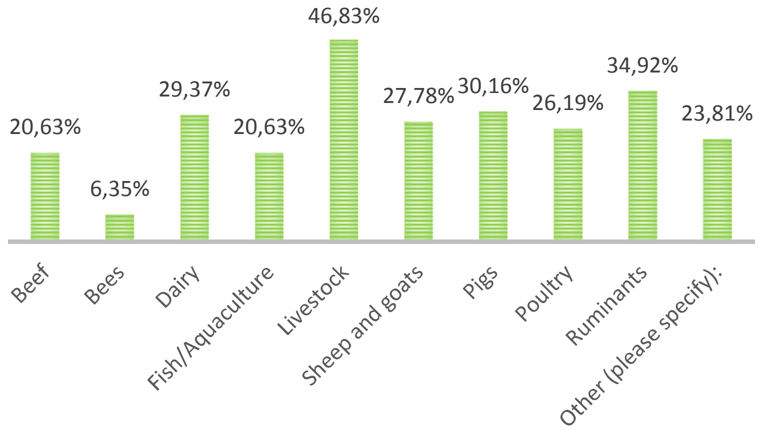


Figure 5: Main sectors participating in survey.

Table 3: List of countries participating in the survey

Countries participating in the survey
Australia
Austria
Belgium
Croatia
Cyprus
Czech Republic
Denmark
Finland
France
Germany
Ghana
Greece
Ireland
Israel
Italy
Lithuania
Netherlands
Norway
Portugal
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom of Great Britain and Northern Ireland

a) Structural and political

General recommendations for the Animal Health R&D sector

Contributors: Participants of the workshop WGa

Structural/political infrastructures are essential for creating an enabling environment for research activities. R&D is fundamental to making the European livestock sector more efficient. The high performance expected by the livestock industry requires coordination of action and continued support from the research sector. In order to ensure synergies and avoid gaps, overlaps and duplication of research, it is essential to enable appropriate alignment and *coordination of research* activities. S*uper partes* leading organisations, such as OIE, might play an instrumental role in *improving international coordination*. Through *implementation of international networks*, additional research and production network services could be enabled, complementing those currently offered or planned by single MS research, avoiding duplication of research or funding. Networking contributes to the exchange and combination of information which is a prerequisite for successful research innovation aiming to provide the necessary flexibility to adapt to the wide spectrum of arising challenges. This enables shared learning and new research opportunities, and generates new research projects, joint applications for funds, and technology transfer. Establishment of international network connections should be independent from the availability of funding and mechanisms should be created to allocate resources to sustain networks and their activities.

To enable networking activities, the development of instruments for parties in search of partners would be greatly appreciated. Different *tools* are needed for the different actors (e.g., funders and researchers); the ones currently in existence unfortunately encounter limits to their functioning, such as *Partner DB of H2020* and *COST*. The limits of *Partner DB of H2020,* a database that finds partners for project ideas among the organisations registered in the portal, should be better investigated in order to be overcome and to make the DB more efficient. A big limitation of *COST*, on the other hand – which is an EU-funded programme that enables researchers to set up their interdisciplinary research networks in Europe and beyond, providing funding for scientific exchange activities – lies in the admittance of only two persons per country, although it is otherwise extraordinarily successful and instrumental in establishing long-term scientific collaborations.

Mapping of current research activities is a basic requirement to successfully incentivise international networking. Comprehensive information on who the actors are, what they do, what their capacities are (e.g., infrastructure, expertise, procedures, DBs, technical capacities), and what their interests are should be collected in a complete form and made freely available. In principle, a*ll kinds of useful data* (e.g., research data, surveillance data) should be made as widely accessible as possible. The use of *Blockchain* to guarantee the source of a specific information should be explored, so as to secure data integrity and fair data use and thus encourage increased use of open data. Information should also be shared with third countries, especially neighbouring ones (e.g., Turkey). It would be important to include *AH and livestock industries in the network*, so as to involve them in development of products to be brought to market and to ensure transfer of results.

Furthermore, in order to have tangible results for improving animal health, it would be important to foster public-private partnerships (PPPs); create a veterinary practitioner network in the field identifying field professionals; and create interactions between the global and local levels, thus facilitating knowledge and technology transfer to end-users.

Research and development are well-known to be important for overcoming the current economic crisis. However, budget restrictions in the research sectors are currently increasing. In order to *limit cuts to research budgets* and thus be able to maintain research capabilities, the AH sector should be able to implement *econometric studies* to assess the consequences of restricting animal health budgets at the field level (e.g., how much would it cost to not invest in surveillance?). It is important also to highlight the *positive impact of investing money in research,* rather than showing only the indirect costs deriving from budget cuts.

It is a matter of fact that managing AH is the fundamental basis/prerequisite of safe food. The AH sector plays a big role in controlling diseases in the human population due to the fact that two out of three animal infectious diseases are inherently zoonotic and hence pose a risk to human health (HH). The *One Health* approach has been appreciated in veterinary health for decades, but its applicability remains difficult. To overcome the weaknesses of collaboration with the human medicine sector, a *bottom-up approach* would be preferable. While some round tables aiming to improve collaboration exist at the global level, such as in the *Tripartite* (i.e., FAO, OIE and WHO), there is a need to have common round tables at local level between veterinary and human practitioners. To allow such a partnership, projects that involve both MDs and VMDs need more encouragement and support at the national level. Infectious diseases are not the everyday priority for human practitioners, who are more frequently confronted with degenerative diseases or cancer; the relevance of combating infectious disease flares once an epidemic has commenced. Usually, in such cases, sensationalist press breaks the news and communication among sectors become rapidly difficult, and with it successful and efficacious management of outbreaks. An improvement of communication in 'peacetime' among the sectors would aid preventing epidemics at early stage and managing outbreaks promptly and efficiently whenever should they occur. In order to enhance such communication, it would be beneficial to include the *dissemination of quality information* to the general public and not only to the scientific community involved in animal health research projects. *Increase exploitation* and *involve the media* encouraging the dissemination of the right information could re-balance the collaboration structure.

Identified structural/political research topics

The research priorities identified by the online survey for the structural/political area are listed in the following table:

Table 5: Structural/political priority box

Priority:	a) Structural political topics	Average
Very high	• Partnerships/collaborations – global/regional research alliances – sharing information between countries	7.71
	• One health approach	7.70
	• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	7.62
	• Knowledge/technology transfer – to end-users (vets, farmers, pharmaceutical industry); Public Private Partnerships	7.36
	• Integrated surveillance system/ centralised diagnostic testing – risk-based approach to surveillance - better surveillance of domestic and wild animals - use of farmers for frontline for disease detection – precision livestock farming	7.34
High	• Knowledge management systems – big data, GIS; sharing data, laboratory network - integration and better use of existing data	7.29
	• Better monitoring of medicines - Improve the control of drugs	6.88
	• Research pipeline – investment in basic research	6.62
	• Biosecurity – waste management - improved border inspection	6.57
	• Improved focus of research activities – gap analysis - alignment of financial resources and research capacity with needs	6.50

Medium high	• Operating systems in disease prevention and control - operational research	6.48
	• Invest in new (more powerful) technologies	6.44
	• Sound public polices relating to science and technology - better impact assessment of new legislations	6.44
	• Implementation of training and education with multidisciplinary approach	6.42
	• Improving infrastructures for research innovation	6.29
Low high	• Explore on farm innovation and develop a framework to analyse their interest and conditions for dissemination	5.63
	• Lack of ethical issues relating to welfare and environment in WTO rules	5.53
	• Social acceptability of new technologies	5.31
	• Improving animal gene bank management	5.18
	• Strategy for protecting intellectual property	4.39

RQs for structural/political research priorities

The list of research questions identified for the highly relevant research topics for structural/political needs is provided in the following table:

Table 6: RQs for structural/political highly relevant research needs.

a) Structural/political research needs	List of research questions developed:
1) Partnerships/collaborations – global/regional research alliances, sharing information between countries	1. How could sharing of information between countries be incentivised? 2. What kind of collaboration would be needed to increase research efficacy? 3. Which objectives could be recognised as strategic in the next future? 4. What strategies should be implemented to increase transparency in country notification of outbreaks (e.g., to the OIE)?
2) One Health approach	5. What combinations of approaches can be developed to secure a One Health approach to improve disease management? 6. How can a collaborative approach among professionals from multiple disciplines for the design of effective health interventions be enhanced? 7. How could communication knowledge and awareness of the One Health vision in the education process be enhanced?
3) Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	8. What political strategy should be developed to secure maintenance and modernisation of capacity? 9. How can we secure continuity in human professional resources?
4) Knowledge/technology transfer – to end-users (vets, farmers, pharmaceutical industry);	10. How can we better promote technology transfer to end-users? 11. How can local and global health systems interact and communicate effectively? 12. How can we develop efficient strategies to inform political leaders and health authorities and identify appropriate stakeholders? 13. How can trust be improved in order to perform effective risk communication?

5) Public-Private Partnerships	14. What kind of political change should we invest in to promote public-private partnership? 15. How can we efficiently merge different stakeholders' priorities, objectives, and expectations to achieve timely effective interventions for disease control? 16. How can the needs of public services and the needs of economic benefit of the private sector be reconciled? 17. How can we improve the social acceptability of PPPs?
6) Integrated surveillance system/ Centralised diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers as frontline for disease detection – precision livestock farming	18. How can we improve integrated surveillance systems in a cost-effective way? 19. How can we promote the acceptability of integrated surveillance systems? 20. How can we incentivise the in-farm utilisation of smart technologies? 21. What kind of benefits can we promote to stimulate farmers/field vets to act as a front line for diseases detection? 22. What benefits would arise from developing integrated surveillance systems that simultaneously investigate the veterinary, medical, ecological, socioeconomic, and policy issues driving the system? 23. How can we make cost-feasible automated disease surveillance by using precision livestock farming? 24. What kind of biosecurity/management protocols should be applied in farm settings and how can we improve their acceptability? 25. How can we secure different scenario modelling based on scientific data to provide advice for decision-makers? 26. How could we highlight the gaps in current European legislation and how could we take proposals from stakeholders? 27. How is it possible to consider the influence of illegal human behaviour in the spread of disease and identify adequate measures to reduce the impacts of these problems?

b) Technology

General recommendations for the Animal Health R&D sector

Contributors: Participants of the workshop WGb

The starting point for efficient and efficacious disease control is the possibility of having a functional *diseases surveillance system*. A crucial goal of infectious disease surveillance is the detection of the onset of animal infectious disease as early as possible. Thus, to promptly detect disease, it would be important to improve technology to deliver easy-to-use and reliable *diagnostic devices*, which are affordable for the farmers. Moreover, the possibility of collecting data directly from mobile health applications or connected devices should be considered. Devices able to collect data, send data to the lab to be analysed, and provide results to users through *smart technology* should be developed. In this way, a *timely collection of true data* could be reached. Furthermore, incentives to produce tech devices such as the above and converting others developed for HH to AH, might reduce the cost of surveillance.

Currently in agriculture, we are witnessing a 'digital revolution', meaning the adoption of many new technologies to collect data: satellites, high-precision positioning systems, smart sensors and a range of Information Technology (IT) applications combined with high-tech engineering. *Precision Livestock Farming (PLF)*/data collecting systems are increasingly developed as integrated systems, where feeding automats/feed/feeding regimes, automated milking systems, motion data, performance recordings, etc. are combined into an all-in-one system from one single vendor who collects, integrates, analyses and feeds back data to the farm via cloud-based services. *Data sharing* is the key ingredient for all of these. Nevertheless, for the time being, most AH information is not included in these systems.

A main problem for the development of *AH-integrated surveillance systems* is the lack of acceptance of data sharing, mainly at farm level due to a certain fear of sharing data. To make early surveillance effective, sharing of relevant data should be accepted by all actors in the system. As a first step, it would be important to *improve trust* among all the actors. *Increasing awareness* of data usage, possibly revising *management of in-farm outbreak restrictions* in different settings, and providing *incentives* for sharing certain information could be possible solutions. Strategies including a simple *return of useful information* to farmers, such as sharing average farms' productivity data with other farmers, would help them realise how they are performing compared with the average; the provision of case studies which demonstrate that data sharing can be valuable would be helpful to increase awareness of data sharing. Moreover, *technologies/algorithms* should be developed to *show returns on investment* in data sharing. Providing feedback from monitoring to the farmers about the infection level (often subclinical)/health status of his flock/herd and enabling them to understand the impact that the increase of infection level has on production/performance, efficiency, and profitability will help with the adoption of appropriate animal health in-farm management and thus achieve more sustainable and profitable livestock production.

Furthermore, at present, AH systems and databases are diverse and fragmented, and most AH IT systems still rely on data warehouse structures. There is a lack of harmonisation of data formats, processing, analysis, and data transfer, which leads to incompatibilities and lost opportunities for AH systems. The *integration of fragmented data* into one system will allow the discovery of relevant associations, early signals, or changes in disease and, therefore, enable better animal health strategies. In order to obtain *centralised and harmonised collection of data* and to create a *network among AH labs*, *standards* for data collection/data sharing should be provided at all levels. Notwithstanding, without new, flexible, and easily expandable *IT infrastructure*, analytic tools, visualisation approaches, work flows, and interfaces, the insights provided by big data are likely to be limited.

In this setting, the need for *regulation* of data management (i.e., data ownership, data utilisation, data protection) also arises. A balance between data restriction and sharing should be found to avoid a monopoly of information and to facilitate data sharing for progress. In addition, a balance between data utilisation and data protection should be found. Protection of personal and animal health data should be assured trough anonymization of data, without losing the possibility of managing diseases for public health security. Data is certainly the new agricultural currency and we need to use it wisely.

Finally, in order to control and fight detected animal health diseases, it is fundamental to *advance therapeutics* and *vaccines*. In the field of vaccinology, in addition to the scarce return of investment, many challenges are presented to vaccine designers, such as persistent or latent infections, highly variable and/or novel pathogens, and complex infections. To address these challenges, researchers are exploring many avenues: new approaches to antigen selection and production, antigen delivery, adjuvants, and vaccine administration. *Enabling vaccine delivery platforms and adjuvants* with promising attributes is nowadays considered to be a priority.

Despite the large amount of studies on the production of new pharmaceuticals, very few new therapeutics and vaccines have been made available on the market. *Public-private partnerships* (PPP), supported by policymakers and funders, would permit a faster development of pharmaceuticals. In fact, private companies with capabilities to patent drugs are not keen to invest in many animal health products because often they cannot ensure a return on investment. On the other hand, public research centres encounter difficulties in patenting vaccines because they usually can't overcome the in vitro study, develop large clinical studies, and do not have the infrastructural capacity for manufacturing. PPPs would overcome this problem. However, defining and protecting the intellectual properties and interests of each party is often difficult. Different levels of PPPs can be observed in different countries. In some countries there is a need to *define conflict of interest* between public and private institutions, while others implement functional strategies which favour PPPs. Based on the experience of some Nordic countries, a *Tech Transfer Office,* which is a structure in the research institution with expertise in market analysis and knowledge of legal frameworks, would be greatly beneficial for building partnerships. In addition, training for researchers on the *know-how to tech-transfer* and a general increase of awareness around 'knowing your market' would be an asset to implementing PPP. *An early engagement by public research with industry* would be important and funding agencies should have *mechanisms to encourage PPPs* and s*tructured procedures* for PPPs to apply for different types of projects.

Identified technology research topics

The research priorities identified by the online survey for the technological area are listed in the following table:

Table 7: Technology priority box

Priority:	**b) Technological**	**Average**
Very high	• Easy to use field diagnostic technology	8.03
	• Vaccine development/new genetically engineered vaccines – immunology - predictive biology- reverse genetics – synthetic biology	7.62
	• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	7.45
	• Big data – bioinformatics	7.16
	• Surveillance - Syndromic surveillance - precision livestock farming (PLF)/automated disease surveillance; risk-based approach to surveillance	7.15

High	• More high-throughput technologies (metagenomics, sequencing and bioinformatics);	7.04
	• New drug development - New therapeutics for parasitic diseases	6.94
	• Alternatives to antimicrobials – antimicrobial peptides – immunomodulators- New antibiotics	6.94
Medium high	• Breeding technologies integration of molecular technologies into breeding programmes, especially for low heritability traits and traits associated with health, animal function and product quality - reproductive technologies, phenomics, genetics and genomics	6.36
	• Animal identification technologies	5.82
	• Nanotechnology – *e.g.* adjuvants	5.80
Low	• Biosecurity	5.62
	• Alternative methods to control vectors - Integrated pest management - biological control - genetically modified insects	5.48
	• Systems based approaches/research	5.00

RQs for technology research priorities

The list of research questions identified for the highly relevant research topics for technology needs is provided in the following table:

Table 8: RQs for technological highly relevant research needs.

b) Technological	
1) Easy-to-use field diagnostic technology	1. What kind of easy-to-use field diagnostic technology can be developed to increase diagnostic efficiency at a reasonable cost? 2. How can we produce a field diagnostic able to make a rapid diagnosis and a rapid report/sharing of information?
2) Vaccine development/new genetically engineered vaccines – immunology, predictive biology, reverse genetics, synthetic biology	3. How could field studies be undertaken in practice in a safe and cost-effective way? 4. What technology do we need to develop and to produce a single-dose, easy-to-apply vaccine? 5. How can we produce DIVA vaccines that induce a clinical broad protection using mass application routes for a combination of diseases? 6. How can we speed up the development of potency tests to demonstrate efficacy and safety of autologous vaccines? 7. How would new delivery systems (e.g., micro/nanoparticles, vector vaccines) to be used as a technology platform be registered? 8. How could the identification of protective antigens and signatures be sped up?
3) Diagnostic tests – express methods, routine deep sequencing methods, real-time PCR	9. How can we produce cheap, stable and sensitive tests that would be cost-feasible for disease detection? 10. What we can do to minimise the price of real-time PCR and sequencing in order to routinely make them?

	11. What technologies should we improve to optimise cost-effective diagnostic-tests? 12. How can we assure an adequate test validation system which is cost-effective?
4) Big data – bioinformatics	13. What are the next steps to collate and manage big data? 14. What kind of informatics technology should we invest in? 15. How can we improve bioinformatics? 16. How can we standardise data collection and integrate all the different datatypes? 17. How can we concentrate data analysis for a faster, time-saving and efficient analysis? 18. What is needed to enhance data sharing in order to accelerate identification of outbreaks, enabling a rapid response and thus reducing the spreading of diseases? 19. How should data ownership, data utilisation, and data protection be handled?
5) Surveillance – syndromic surveillance, precision livestock farming (PLF)/automated disease surveillance, risk-based approach to surveillance	20. What kind of syndrome definitions, protocols for signal detection methodologies, and specific data sources are needed to enhance syndromic surveillance? 21. How can we improve the detection of subclinical syndromes through a cost-effective monitoring of production? 22. What kind of surveillance protocols should be incentivised to promote fast detection of diseases in a cost-effective way? 23. How can a risk-based approach to VPH surveillance be implemented? 24. What technologies should we develop to benefit from precision livestock farming? 25. How can we develop epidemiologically realistic stochastic models for disease transmissions? 26. How would it be possible to improve disease modelling which also incorporates stochastic variables and biological complexity?

c) AH-specific topics

General recommendations for the Animal Health R&D sector

<u>Contributors</u>: *Participants of the workshop WGc*

Diseases have no borders and in a globalised world with free trade they can spread quickly from one country to another. Thus, strategies should be empowered to limit the spread of diseases. *Innovative monitoring systems* for livestock and exotic animals' movements should be promoted and the *role of wildlife* and livestock as a reservoir of pathogens should be better investigated. *Good Farming Practice (GFP)* and *biosecurity* measures adapted to different farm types would be an asset to limit disease spread. *Risk communication* and increased *data availability* from farmers by means of an *integrated sociological approach* should be encouraged. Nevertheless, a multidisciplinary approach should always be taken into consideration and the animal health sector should remain primarily *focussed on research over specific animal health* themes.

The sociological, environmental, and technological drivers of vector-borne disease emergence, such as expanded travel and trade, changing land use, human population growth, urbanisation, and climate change, are well-known and ever-increasing. Thus, it is likely that new vector-borne diseases will continue to emerge and spread in the years to come. *Science-driven preparedness* for the next epidemics is an asset that should be based on the *quick exchange of information* among researchers, disease outbreak managers and policy makers. In order to *achieve preparedness* for the next vector-borne disease epidemic, data integration and sharing should be empowered. *Basic research* on the role of arthropods as actual vectors and the *identification of new vectors* should be carried out. Studies on new methods to assess the impact of climate change on the spread of vector-borne diseases should be implemented, as well as studies to improve *predictive epidemiological surveillance* and define *new parameters to assess risk*.

Field methods and tools which would permit the quick identification of diseases and factors of antimicrobial resistance at farm level should be developed, such as, for example pen-side tools to be used in-farm.

Antimicrobial resistance is becoming an escalating threat. Combating antimicrobial resistance is possible; however, it needs a multi-layered approach that includes *infection prevention*, *appropriate use of antibiotics* and *new drug development*. There is still a critical lack of effective agents and new drug classes, which, if released, will be critically important for human health and thus restricted in use for animals. Consequently, developing new pharmaceuticals such as alternatives to antibiotics and vaccines is considered a priority in AH.

Generally, it is essential to make pharmaceuticals development more financially appealing. In human medicine, developing new antibiotics requires a huge investment in time, money and research. According to a Forbes analysis, a pharmaceutical company will spend $350 million bringing a single agent to the market. The return on investment is quite small by comparison. The potential *return on investment for animal pharmaceutical producers* is even less than those for human pharmaceuticals, with lower sales prices and smaller market sizes, resulting in a much lower investment in R&D of animal pharmaceuticals than in human ones. For example, the market size for the recently launched human vaccine against papillomavirus and cervical cancer is estimated to exceed US $1 billion, while the most successful animal health vaccines (e.g., against foot-and-mouth disease virus in cattle and *Mycoplasma hyopneumoniae* in pigs) enjoy a combined market size of a mere 10% to 20% of this figure. The first step in encouraging pharmaceuticals' development involves an investment in *basic research*.

Empowering basic research and providing the AH industry with a *certified information database* derived from various sectors could be helpful in lowering the cost for companies developing new drugs; examples of data to be shared might be:

- basic mechanisms of conventional vaccines, DIVA vaccines;
- basic mechanisms of host-pathogen interaction;
- basic immunological mechanisms;
- basic mechanisms of action of Alternatives To Antimicrobials (ATA);
- testing the effectiveness of ATA *in vitro* and *in vivo;*
- non-conventional routes of drug administration;
- studies on possible effects of combined use of ATA and conventional antimicrobials;

Identified AH-specific research topics

The research priorities identified by the online survey for the AH-specific topic area are listed in the following table:

Table 9: AH-specific topics priority box

Priority	b) **AH specific topics**	Average
Very high	• Antibiotic effectiveness and availability -better use of antibiotics; alternatives to antibiotics - Host resistance; vaccine development/ vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	8.26
	• Improved understanding of the role of wildlife - epidemiological studies on wildlife - livestock interaction and disease spread	7.01
	• Disease introductions, including trans-boundary animal diseases -generic detection platforms, risk pathway identification, traceability of animals and their products, technology for inactivation of pathogens	7.00
	• Vector-borne diseases - emergency preparedness -alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	6.97
High	• Improve food safety – traceability; risk analysis; antimicrobial/residues	6.77
	• Understanding disease ecology - decrease evolutionary pressure on pathogens	6.60
	• New diseases	6.54
	• Alternative systems to compensate for downsizing of surveillance/detection systems - Integration and better use of existing data; syndromic surveillance; cost effective real-time collection of data; risk-based approach to surveillance	6.53
Medium	• Gut health -digestive physiology; gut microbiome - pre/probiotics; Improved understanding of the interaction between pathogens and also between the pathogen and the gut	6.48
	• Sustainable competitiveness of the sector -social, environment and economic sustainability- New production system; genetics - assure maintenance of biodiversity-improve feed efficiency to reduce green gas emission- profitability of production;	6.30
	• Impact of diseases on ecology/environment/biodiversity	6.17
	• Socio-economic impact evaluation of main diseases	6.13

Low	• Anthelmintic resistance - Mechanisms of resistance - Markers of resistance	6.04
	• Neglected diseases	5.77
	• Investigation on presence of Zoonotic parasites in farmed fish according to EFSA opinion	5.45
	• Understanding of consumer demands- perceptions to assure market success	5.41

RQs for AH-specific research priorities

The list of research questions identified for the highly relevant AH-specific research topics is provided in the following table:

Table 10: RQs for AH-specific highly relevant research needs.

c) AH-specific topics	
1) Antibiotic effectiveness and availability – better use of antibiotics; alternatives to antibiotics, host resistance; vaccine development/vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	1. What are the key factors limiting the fight of antimicrobial resistance and how can we overcome them? 2. How can we develop timely research and prompt clinical assessment for vaccine development? 3. What strategies could be implemented to ensure the return on investment to companies developing new drugs, especially in the veterinary field? 4. What impact can evidence-based decisions have to promote productive strategies and to stop investigations of unproductive approaches to fight antimicrobial resistance? 5. What gaps should we fill to assess the potential of clinical impact, feasibility and safety of different alternatives to antimicrobials? 6. How should we expand the portfolio of research activities to fight antimicrobial resistance to adequately test new clinical approaches in a timely manner? 7. What kinds of studies on alternatives to antimicrobials would ensure a sufficient clinical benefit and a return on research investment? 8. What combinations of alternatives to antimicrobial therapies could be possibly used without antimicrobial support in clinical settings? 9. What alternatives to antimicrobials are most likely to deliver new effective therapies? 10. What immunological mechanisms should be studied to pass multiple protective immunoglobulins to offspring? 11. How might the ability of the immune system to rapidly respond to new antigens be studied to implement vaccine development? 12. What is the impact of co-infections in pathogen-host interactions? 13. What benefit would arise from basic research into maternal immune responses for the development of vaccines able to circumvent the negative effect on vaccination of maternal antibodies? 14. How would different selective pressures affect the evolution of virulence traits?

2) Improved understanding of the role of wildlife – epidemiological studies on wildlife, livestock interaction and disease spread	15. How would it be possible to make available information regarding the consistency and dynamics of the wild population? 16. What ecological interactions should we focus on to understand and control the spread of diseases? 17. What impact might wildlife have on the survival of pathogens? 18. What conditions might regulate disease transmission at the livestock–wildlife interface? 19. How can we control the wildlife reservoir in a cost-effective way? 20. Which wild animals should be used as sentinels of pathogens at the human–animal interface? 21. How can biodiversity affect the epidemiology of pathogen transmission?
3) Disease introductions, including trans-boundary animal diseases – generic detection platforms, risk pathway identification, traceability of animals and their products, technology for inactivation of pathogens	22. How can we fill the gap in knowledge about the dynamics of systems with many host species and multiple pathogen strains? 23. How could the influence of human behaviour in the transmission of diseases be highlighted? 24. What introduction pathways should we consider as risk for disease introductions? 25. How can we limit disease spread in a globalised world with free circulation of people, animals and products? 26. What technologies should we develop to ensure traceability of animals and their products in a cost-effective way? 27. What is the specific importance of each component of the infection pathways that influences host-pathogen interactions?
4) Vector-borne diseases – emergency preparedness, alternative methods to control vectors: a) integrated pest management, b) biological control and c) genetic modification	28. What are the essential biological processes governing the pathways of infection and persistence of vector-borne diseases, and how can we regulate them? 29. How can we improve biological control in order to be effective in reducing vector-borne disease? 30. What kind of host genetic modification should we develop, if any, in order to limit vector-borne disease transmission rates? 31. What benefit can arise from the study of host-pathogen evolution, population genetics and dynamics? 32. How do ecological and evolutionary time-scales interact? 33. How can we prepare for the next vector-borne disease epidemics? 34. What methods of entomological surveillance could increase the preparedness and efficiency of emergency plans? 35. What benefit can arise from the study of the microbiota of vectors and its interaction with pathogens? 36. How can we involve citizens and private companies in the prevention and control of vector-borne diseases? 37. How can we correctly communicate the risk of transmission in peace time and emergency? 38. How can we develop new and cost-effective systems of early warning of pathogen circulation in humans, animals and vectors?

Discussion

This has been the first study to validate, update and expand the ANIHWA SRA produced in EU on issues of AH research, through a series of complete foresight activities such as driver analysis, scenario building and backcasting. This study was conducted two years after the delivery of the ANIHWA SRA (2015), following a recommendation of the STAR-IDAZ global-net, which advised a revision of foresights around at least every two years and to conduct a comprehensive new foresight exercise every five years. The method used to update the SRA was a participatory bottom-up approach, involving the participation of researchers and funding agencies in an online survey, and then in focus groups.

A large number of experts from 28 EU countries participated in this study (128 in the survey, 20 in the drafting of the RQs, and 29 in the workshop). This minimised the effect of biases due to individual preferences in selecting the priorities for the EU SRA. The active participation and commitment of the experts in this study revealed their appreciation of the exercise. The focus groups organised during the consensus workshop turned out to be excellent networking activities for the experts, providing an occasion to exchange opinions on several topics and expand their views through a mutual learning process. In addition, it proved useful to overcome institutional barriers, build a common strategic vision on the EU AH sector and augment the sense of commitment towards a shared EU AH research vision.

An innovative part of the study was the definition of research questions that, if answered, would have a significant impact on the animal health sector. The questions defined together with different European stakeholders, were designed to be answerable and able to address a realistic research design. The list of RQs produced has limitations in that it is incomplete and unable to embrace all the topics; even the single RQs have some limitations. In fact, some of the questions might not express the complexity of the topic addressed, while others which are broad could be broken down into components or tailored for specific settings. An ideal set of such all-encompassing questions has yet to be invented. Nevertheless, the RQs raised in this study can provide a valuable basis for discussion and hopefully they can serve as a principle orientation for both, researchers and policymakers, where to redirect best their research efforts/funding.

Conclusions

This report is the tangible output of a study aimed at updating the EU SRA produced by ANIHWA in 2015. The results kept the structure of the previous report, classifying the AH research priorities into three sections: a) structural/political, b) technological and c) specific topic challenges. Although all of the topics listed are important for the sector, by utilising a quantitative method by scoring priorities online, it was possible to divide them into four priorities of very high, high, medium, and low. The outcomes of this update study are reported in the main body of this report.

Similar to the needs identified in the 2015 report, the research topics and research questions identified in this study are relatively broad in their content in order to be valid for several EU Animal Health research institutions with different objectives. Furthermore, it would be unwise in a SRA with a 20-year outlook to be more specific, because it is impossible to predict what will happen, but it is important to be better prepared for engaging with what may happen. Should a national authority wish to have more detail on research topics, the disease priority box provided in the Appendix or specific disease prioritisation projects such as DISCOONTOOLS, or the disease roadmap produced by STAR-IDAZ IRC, could be used. In addition, for high priority diseases, examples of relevant research questions are published in the Appendix.

In brief, the study confirmed the results of the foresight study presented in ANIHWA deliverable 5.2, whose priorities only slightly changed during those two years (Table 5, Table 7 and Table 9 in the results section). It highlighted a number of key actions such as:

- To favour the delivery of fast and reliable diagnostics, easy to use in the field;
- To optimise vaccinology, addressing studies on DIVA, new adjuvants, host/pathogen interaction, and technological advances with potential to make vaccine development economically viable;
- To empower basic research and increase sharing of information;
- To establish a science-driven response to disease outbreaks (especially vector-borne ones);
- To engage in preparedness by risk-based surveillance;
- To strengthen knowledge/technology transfer;
- To favour networking among countries;
- To establish biosecurity measures and consider animal welfare as tools for healthy production.

Furthermore, the following key actions received major importance in this study than in the previous SRA:

- To encourage public-private partnership, ensuring return of investments to companies developing new drugs;
- To develop standards for data collection/sharing, fundamental for big data integration;
- To ameliorate integrated surveillance systems and encourage their acceptance;
- To facilitate precision livestock farming;
- To strengthen the One Health approach;
- To favour econometric studies to demonstrate positive impacts of investing money in research and thus limit cuts to research budgets.

Apart from the formal results obtained and presented in this report, the study has been useful to instil a future-oriented culture among participants called to provide input to update the EU SRA – both scientists and national research managers – which is essential to create a common sense of belonging to the same EU context. Specifically, this study helped to maintain a network among EU countries and a shared sense of commitment among the participants towards the implementation of the AH strategy.

References

ANIHWA (2015) An updated SRA covering animal health and welfare. Deliverable 5 2 Animal Health and Welfare-ERAnet Deliverable 5.2:58

Aquainnova Combination of aquainnova outputs. Integration of all thematic Working group products (SRA, Vision, Plan of Action). European Aquaculture Technology & Innovation Platform Deliverable 42:16

ATF (2016) A strategic research and innovation agenda for a sustainable livestock sector in Europe Second White Paper of the Animal Task Force

Auffray C, Balling R, Barroso I, Bencze L, Benson M, Bergeron J, Bernal-Delgado E, Blomberg N, Bock C, Conesa A (2016) Making sense of big data in health research: towards an EU action plan. Genome Med 8:71

Badia-Melis R, Mishra P, Ruiz-García L (2015) Food traceability: New trends and recent advances. A review. Food Control 57:393-401

Belay ED, Kile JC, Hall AJ, Barton-Behravesh C, Parsons MB, Salyer S, Walke H (2017) Zoonotic Disease Programs for Enhancing Global Health Security. Emerg Infect Dis 23:10.3201/eid2313.170544

Brugere C, Onuigbo DM, Morgan KL (2017) People matter in animal disease surveillance: challenges and opportunities for the aquaculture sector. Aquaculture 467:158-169

CEMA (2017) Big data on farm. In: http://www.cema-agri.org/page/big-data-farm

COLOSS (2012) Prevention of Honeybee Colony Losses- Monitoring progress report. In: http://144.76.174.138/COLOSS-test/publications/2012-cost-progress-report

Eastwood C, Klerkx L, Nettle R (2017) Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion: Case studies of the implementation and adaptation of precision farming technologies. J Rural Stud 49:1-12

EMIDA ERAnet (2011) Strategic research agenda- 10-15 year outlook. In: http://www.emida-era.net/upload/pdf/EMIDA%20SRA%20final%2020111227.pdf

EPIZONE (2012) Final report: EPIZONE. Network of Excellence for Epizootic Disease Diagnosis and Control Final report:68

EUFETEC (2013) Vision & SRIA document 2030: Feed for food producing animals

FABRE TP (2008) Sustainable farm animal breeding & reproduction technology platform Strategic Research Agenda:32

Ferguson AR, Nielson JL, Cragin MH, Bandrowski AE, Martone ME (2014) Big data from small data: data-sharing in the'long tail'of neuroscience. Nat Neurosci 17:1442

Fournel S, Rousseau AN, Laberge B (2017) Rethinking environment control strategy of confined animal housing systems through precision livestock farming. Biosystems Engineering. doi: https://doi.org/10.1016/j.biosystemseng.2016.12.005

HAELIO (2015) Drug development critical to combating antibiotic resistance. In:. https://www.healio.com/infectious-disease/antimicrobials/news/print/infectious-disease-news/%7Bec88f3ba-ee8d-4303-836b-ad0edf184133%7D/drug-development-critical-to-combating-antibiotic-resistance

Halachmi I, Guarino M (2016) Precision livestock farming: a'per animal'approach using advanced monitoring technologies. Animal: an international journal of animal bioscience 10:1482

Health for Animals (2016) Innovation in Animal Health: historic success, current challenges & future opportunities:52

Hudson PJ, Rizzoli A, Grenfell BT, Heesterbeek J, Dobson AP (2002) Ecology of wildlife diseases

Lalsiamthara J, Lee JH (2017) Development and trial of vaccines against Brucella. J *Vet* Sci 18:281-290

Leroux-Roels G, Bonanni P, Tantawichien T, Zepp F (2011) Vaccine development. Perspectives in Vaccinology. doi: https://doi.org/10.1016/j.pervac.2011.05.005 "

Martellos S, Labra M (2013) DNA barcoding as a new tool for food traceability. Food Res Int 50:55-63

Meeusen ENT, Walker J, Peters A, Pastoret P, Jungersen G (2007) Current Status of Veterinary Vaccines. Clin Microbiol Rev 20:489-510

Messori S, Zilli R, Mariano V, Bagni M (2015) Building a strategic research agenda for animal Health for the Mediterranean. Results from the second workshop.

Murtaugh MP, Steer CJ, Sreevatsan S, Patterson N, Kennedy S, Sriramarao P (2017) The science behind One Health: at the interface of humans, animals, and the environment. Ann N Y Acad Sci 1395:12-32

Neethirajan S (2017) Recent advances in wearable sensors for animal health management. Sensing and Bio-Sensing Research 12:15-29

O'Brien D, Scudamore J, Charlier J, Delavergne M (2017) DISCONTOOLS: a database to identify research gaps on vaccine, pharmaceuticals and diagnostics for the control of infectious diseases of animals. BMC Vet Res 13:1-10

Pretty J, Sutherland WJ, Ashby J, Auburn J, Baulcombe D, Bell M, Bentley J, Bickersteth S, Brown K, Burke J, Campbell H, Chen K, Crowley E, Crute I, Dobbelaere D, Edwards-Jones G, Funes-Monzote F, Godfray HC, Griffon M, Gypmantisiri P, Haddad L, Halavatau S, Herren H, Holderness M, Izac A, Jones M, Koohafkan P, Lal R, Lang T, McNeely J, Mueller A, Nisbett N, Noble A, Pingali P, Pinto Y, Rabbinge R, Ravindranath NH, Rola A, Roling N, Sage C, Settle W, Sha JM, Shiming L, Simons T, Smith P, Strzepeck K, Swaine H, Terry E, Tomich TP, Toulmin C, Trigo E, Twomlow S, Vis JK, Wilson J, Pilgrim S (2011) The top 100 questions of importance to the future of global agriculture. International J Agric Sustain 8:219-236

Puljak L, Vari SG (2014) Significance of research networking for enhancing collaboration and research productivity. Croat Med J 55:181-183

Reidsma P, Janssen S, Jansen J, van Ittersum MK (2018) On the development and use of farm models for policy impact assessment in the European Union–A review. Agricultural Systems 159:111-125

Robinson T, Bu D, Carrique-Mas J, Fèvre E, Gilbert M, Grace D, Hay S, Jiwakanon J, Kakkar M, Kariuki S (2017) Antibiotic resistance: mitigation opportunities in livestock sector development. Animal 11:1-3

Roski J, Bo-Linn GW, Andrews TA (2014) Creating value in health care through big data: opportunities and policy implications. Health Aff 33:1115-1122

Socaciu C (2014) Bioeconomy and green economy: European strategies, action plans and impact on life quality. Bulletin UASVM Food Science and Technology 71:1-10

Stanberry LR, Strugnell R (2011) Vaccines of the future. Perspectives in Vaccinology. 1:151-159 doi: https://doi.org/10.1016/j.pervac.2011.05.006

STAR-IDAZ (2015) Strategic research agenda: meeting future research needs on infectious diseases of animals and zoonoses Deliverable 5.2

Steffens MS, Dunn AG, Leask J (2017) Meeting the challenges of reporting on public health in the new media landscape. Australian Journalism Review 39:119

Tomley FM, Shirley MW (2009) Livestock infectious diseases and zoonoses. Philos Trans R Soc Lond *B* Biol Sci 364:2637-2642

Tompkins DM, Carver S, Jones ME, Krkošek M, Skerratt LF (2015) Emerging infectious diseases of wildlife: a critical perspective. Trends Parasitol 31:149-159

Vet+i (2017) Plataforma Tecnológica Española de Sanidad Animal Agenda Estratégica de Investigación en Sanidad Animal. In: http://www.vetmasi.es/plataforma-tecnologica-espanola-de-sanidad-animal/documentos-y-publicaciones/agenda-estrategica-de-investigacion-en-sanidad-animal_95_11_94_0_2_in.html

Appendix: Specific diseases

Identified diseases

Priority	d) Specific diseases
Very high	• Avian influenza • Bees diseases (Varroa destructor, Aethina tumida, Nosema spp., Tropilaelaps spp…) • African swine fever • Bovine tuberculosis • Bluetongue • Brucellosis • Foot and mouth disease • PRRS*
high	• West Nile fever • Paratuberculosis • Crimean Congo haemorrhagic fever • Lyssavirus • Coronavirus (SARS, MERS…) • Classical swine fever • Peste des petits ruminants • Echinococcosis • Mastitis* • Poxvirus* • PRDC*
Medium high	• Lyme disease • Q-fever • Coccidiosis • African horse sickness • Rift valley fever • Nematodes • Cryptosporidiosis
Low high	• Nipah virus • Liver flukes • Schmallenberg virus • SIV • Histomonas • Non tse-tse transmitted animal trypanosomiasis

*Diseases added in a second step and prioritised trough a second survey

Research Questions for high relevant diseases

1. Avian influenza RQs

a) Structural political	Research questions:
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	• What partnerships can be developed to increase the efficiency in the management of AI? • Which tools/standards can be developed to harmonise epidemiological data collection and to foster data exchange between countries? • What partnerships can be developed and which professional figures and organizations should be involved to increase the efficiency in the AI diagnosis, surveillance, early detection and management?
• One health approach	
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	• What innovative tools coming from research can be more useful to the end-users managing AI in the field?
• Public Private Partnerships	
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming	• What are the impacts of the environment (surface water/sediments) in virus perpetuation? • Which are the environmental drivers of AI? • Which are the factors influencing between-flock and between-farm spread?
b) Technology	
• Easy to use field diagnostic technology	• What cheap and sensitive detection methods could be developed to allow high-throughput generic and subtype-specific testing tools in the field?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology- Reverse genetics – synthetic biology	• What models can be developed to rapidly identify antigenic drifted variants on the base of the genetic sequence data? • How can the authorization process of AI vaccines (i. e., viral vectors) be changed to better address the challenges posed by the control of HPAI/LPAI emergencies?
• Diagnostic tests - Express methods - routine deep	

sequencing methods - Real time PCR	
• Big data – bioinformatics	• What models/methods can be developed to better integrate ultra-deep sequencing data in statistic inferences to reconstruct transmission dynamics?
• Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	• How can computational technologies be used to improve early warning procedures?
c) Specific topics	
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	• What are the most effective methods of application required for a marker recombinant vaccine administered in single doses with other vaccines to control the spreading of HPAI in large flocks?
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• Which tools can be used to spatially direct global wild bird monitoring? • How can surveillance in wild birds and domestic waterfowls be implemented to limit the spread of AI? • Which are the "bridge" species between wild waterfowl and poultry involved in AIV incursions into poultry holdings?
• Disease introductions, including trans-boundary animal diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	• How can a proper vaccination against AI be developed to effectively reduce the risk of transmission of the infection and what is the cost-effectiveness of this approach?
• Vector-borne diseases - Emergency preparedness - Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	

2. Bees RQs

a) Structural political	Research questions:
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	• How sharing of information on bee diseases/pests/losses between countries could be stimulated and improved? • What kind of collaboration/partnership/alliances would be needed to increase research efficacy in the field of bee health?
• One health approach	
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	• How can we maintain over the years a surveillance capacity on bee diseases, pests, killing incidents and exotic invaders?
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	• How can we better promote technology transfer to beekeepers?
• Public Private Partnerships	• How can we efficiently merge different stakeholders (vets, beekeepers, honey industry, regulators) priorities, objectives and expectations to achieve timely effective interventions for disease control? • What policy should we adopt to meet beekeeping industry and competent authorities priorities and expectations?
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers as frontline for disease detection – precision livestock farming	• What type of integrated surveillance system should be designed and implemented for colony losses? • How can be colony losses properly controlled and managed at beekeepers level? • Could citizen science (farmer science) be suitable for colony losses detection?
b) Technology	
• Easy to use field diagnostic technology	• What kind of easy to use field diagnostic technology can be developed for bee diseases and bee mortality/bee killing to increase diagnostic efficiency at a reasonable cost?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology-Reverse genetics – synthetic biology	• What do we know about immunology of bees? • Can we use bacteriophages against bacterial disease?
• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	• What diagnostic technologies can we improve to obtain cost-effective diagnostic tests for bee diseases (virus, bacteria, microsporidia, etc.)? • What strategy can we apply to reduce the costs of real time PCR and sequencing to be routinely applicable for disease detection?

• Big data – bioinformatics	• How can we improve data collection and apply bioinformatics analysis in order to prevent and control honeybee diseases?
• Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	• What are the best methods for an integrated colony health status control? • What improvement in technologies, beekeeping practices, and treatment strategies would result in an overall improvement of the bees colony health status?
c) Specific topics	•
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	• What is the rationale of the use of antibiotics in beekeeping industry? • What benefits can arise from a chemical testing for the control of colony losses related to varroa infestations and what is the cost-effectiveness of these approaches? • What benefit can derive to bee colonies and bee products by an integrated pest management approach? • What knowledge gaps need to be filled, in terms of honeybee physiology, immunity and host-pathogens interaction, to attempt promising development of vaccine for bees' viral control?
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• What gaps of knowledge are still to be filled about the impact of bee diseases on bumblebees and solitary bees (wild pollinators) and the role played by the latter as reservoir of viruses and microsporidia? • Could *Vespa velutina (*Asian hornet), an exotic alien species, spreading be properly understood and prevented? • How could we manage/mitigate the impact of *Vespa velutina* on honey bees?
• Disease introductions, including trans-boundary animal diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	• What pathways shall we consider as risk for bee disease introduction? • What can be done to prevent the introduction of exotic parasites (e.g. *Tropilaelaps* spp.) of bees? • Is there any procedure that could prevent/limit bee diseases/pathogens and pests spreading in a globalized world with free circulation animal and products? • Could we develop feasible and cost-effective technologies for inactivation of bee pathogens/pests at import? • What is the strategy for disease-free queen rearing?
• Vector-borne diseases - Emergency preparedness - Alternative methods to control vectors – a) Integrated pest	• Can a biological control of varroa mites be effective to limit colony losses? • How can we prepare to early detect and properly manage new pathogens and pests of honeybees?

management, b) biological control and c) genetic modification	• What is the role of varroa and nosema mites transmitting viral disease?

3. African Swine fever RQs

a) Structural political	**Research questions:**
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	• What protocols and actions would be necessary to increase timely circulation of information on ASF outbreaks between countries? • How is it possible to make available and usable the epidemiological data regarding the ASF situation in European member states and neighboring countries?
• One health approach	
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	• How can we efficiently improve awareness on ASF in the field staff? • How could the awareness of backyard system be improved (including not only farmers, but even consumers, traders, casual workers, tourists…)? • How could we share experiences in the ASF control adopted in different countries and scenarios?
• Public Private Partnerships	• What strategies could support the involvement of the private sector *(ie.* pharmaceutical companies) in investing in the development of a vaccine for ASF?
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming	• How could the current legislation be integrated with specific measures to control the ASF in endemic situation? • How is it possible to consider the influence of illegal human behaviour in the spread of the disease and individuate adequate measures to reduce the impact of these problems? • What kind of benefits for the control of ASF will be achieved through the implementation of cost-benefit and disease modelling studies?
b) Technology	
• Easy to use field diagnostic technology	• How can we develop non-invasive sampling methods for wild boars?

	• What technology shall we improve to develop field test (*i.e*. pen side test) to speed up diagnosis? • How it possible to perform a field validation for the pen side tests? • How the veterinary public service could maintain an effective control of diagnostic information in case of use of pen side tests? • Is it possible to individuate strategic guidelines to integrate the surveillance based on laboratory and field tests?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology-Reverse genetics – synthetic biology	• What kind of technology development would be needed to produce a vaccine for ASF? • If a vaccine will be available in the future would it be used to prevent the spread of disease or to control it in domestic and wild population? • If a vaccine will be available in the future, who will cover the costs of a vaccination campaign? And moreover, would it be useful to have a strategic stock of this vaccine?
• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	• How to standardize the diagnostic methods applied to Ornithodoros tick? • Woud it be useful to identify cell lines for replacing primary cell cultures
• Big data – bioinformatics	
• Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	• How could we better understand the role of long term carriers especially in wild life and backyards?
c) Specific topics	
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	• What proteins or genes would be useful to target for vaccine development? • How can we fill the gap of knowledge on the immune response to infections especially for the viral interaction with pig macrophages? • What knowledge is still missing to get to the delivery of an ASF vaccine? • What is the role of multigene families in antigenic variability and evasion of immune response? • How can we better identify the genes related to host protection? • Which host factors determine the different clinical forms (susceptibility, tolerance and resistance)?
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• How could be standardized the data collection about the consistency and dynamics of wild boar population in European Union? • How neighborhood transmission occurs in densely populated areas?

	• How could be improved the biosecurity level of pig herds (especially backyard) in relation to risky contacts with wild boar population?
• Disease introductions, including trans-boundary animal diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	• What risk pathways do we need to take into consideration to control the spreading of ASF? • How to improve the quality of information and the surveillance of backyard pig sector regarding the biosecurity level, the (illegal) movements of live pig and pork products and herds management?
• Vector-borne diseases - Emergency preparedness -Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	• What impact ticks biting habits would have in the transmission of diseases? • What new methods can be used to control tick populations? • What new surveillance technology can be used to predict the spread or emergence of infected tick populations?

4. Bovine Tuberculosis RQs

a) Structural political	**Research questions:**
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	
• One health approach	• How could integration of medical and veterinary information be enhanced to improve the surveillance of human bTB caused by zoonotic transmission of mycobacteria of the Tb complex?
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	• Is the existing capacity (national, regional, European) sufficient compared to the knowledge that bTB is one of the earliest zoonoses and still is present in many European countries? What are the gaps? • How would be possible to organize proficiency tests at a European countries level to verify: diagnostic capacity of field tests for living animals and standardization of PPDs used in different countries? • Would be useful to develop an Official Protocol and Defined Interpretative criteria for the Gamma-Interferon test?
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	• What are the effective policies and other interventions to control bTB and how can we make it work in practice? • How could a risk communication campaign be developed to increase social acceptability of bTB control measures?

• Public Private Partnerships	• What are the best partners (e.g. milk industry, vaccine pharma, …) to set up a collaboration? What is their individual role and responsibility?
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming	• Would be cost-beneficial to increase surveillance and control of bTB in wildlife in order to better control bTB? • Would be cost-beneficial an improvement in surveillance and control of bTB in domestic animals other than bovine?
b) Technology	
• Easy to use field diagnostic technology	• What kind of technology should be invested in to produce rapid and specific field tests for living animals? Is gamma-interferon the key to success? • Would be commercially interesting to develop a defined skin test based on specific *M. bovis* antigens to overcome limitations of tuberculin?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology- Reverse genetics – synthetic biology	• What are the technological priorities in the development of DIVA non sensitising vaccine? • What kind of delivery system would be optimal for application of vaccine in wildlife?
• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	• Which diagnostic tests can improve the performance of direct detection of *M. bovis/M. caprae* in tissue samples? • What is the knowledge needed to develop immunological (blood or milk) test?
• Big data – bioinformatics	• How could an international WGS database be created of *M. bovis/M. caprae* to improve molecular epidemiological studies?
• Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	
c) Specific topics	
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management,	• What are the key actions to stop multidrug resistant tuberculosis?

antimicrobial peptides, immunomodulators	
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• Would further study on different wildlife species beneficial to develop efficient vaccination control strategies? • Are super-shedders existing, and what is their role in disease epidemiology? • What is the role of environmental resistance of *M. bovis* in the epidemiology and transmission of TB to cattle?
• Disease introductions, including trans-boundary animal diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	
• Vector-borne diseases - Emergency preparedness - Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	

5. Blue Tongue RQs

a) Structural political	**Research questions:**
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	
• One health approach	
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	
• Public Private Partnerships	• How can we incentivise the production of multivalent vaccine to anticipate and/or timely respond to a crisis?
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance	

of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming	
b) Technology	
• Easy to use field diagnostic technology	• How can we make available pen-side test to be used in field diagnostics?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology- Reverse genetics – synthetic biology	• How shall we produce multivalent, cross-reactive vaccines with longer shelf life and associated DIVA essay?
• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	• What barriers should be overcome to produce and use serological DIVA tests and type specific ELISA? • How can we further develop existing RT-PCR to maintain effectives to detect new BTV isolates/variants? • How can the new deep sequencing methods help to find new targets for molecular diagnosis and test developing?
• Big data – bioinformatics	
• Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	
c) Specific topics	
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• What is the role of wildlife in the transmission and spread of BT?
• Disease introductions, including trans-boundary animal diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	• How can the climate affect the mechanism of virus overwintering throughout Europe?

• Vector-borne diseases - Emergency preparedness - Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	• Can new methods of entomological surveillance increase our preparedness and efficacy in emergency? • What new methods can be used to control midge populations? • What new surveillance technology can be used to predict the emergence and spread of infected midge populations?

6. Brucellosis RQs

a) Structural political	**Research questions:**
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	• What kind of collaborations would be needed to increase research efficacy especially in Balkan and Mediterranean countries? • Which objectives could be recognised as strategic in the next future? • What can be done to improve knowledge sharing to be able to support the countries not free from Brucellosis? • What sort of networking might be created with a view to establishing regional research collaborations as well as OIE regional reference laboratories?
• One health approach	• What combinations of approaches can be developed to secure a One health approach to improve diseases management between EU and third-associated countries? • What is the threat of species adaptation (e.g. that *B*. suis 2 become pathogenic for humans)?
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	• What diagnostic tools can be developed to discriminate vaccine REV1 from field strains? • How can we detect persistent forms of brucellosis? • What are the problems encountered during the surveillance studies and how can they be overcome?
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	• How can local and European health systems interact and communicate effectively? • How can we develop efficient strategies to inform political leaders and health authorities?
• Public Private Partnerships	
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming	• What socio-economics benefit would arise from a better surveillance of domestic and wild animals? • What kind of benefits can we promote to stimulate farmers to act as frontiers for disease detection?

b) Technology	
• Easy to use field diagnostic technology	• How can we develop tools with high specifity and sensitivity to detect brucellosis in the field?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology- Reverse genetics – synthetic biology	• How can a more protective and not abortigenic DIVA vaccine for livestock be developed? • Could an efficient subcellular or DNA based vaccine be produced?
• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	• How can we develop cheaper tests that should be cost-feasible for brucellosis detection? • What is the possible effect of revising the cut-off points of the imported diagnostic kits with regards to the positive sera collected from the field? • What might be done to improve and use DIVA test kits regularly?
• Big data – bioinformatics	
• Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	• What are the benefits of establishing a molecular epidemiology system in the endemic countries? • How many Brucella-endemic countries use bioinformatics system? • What might be the steps to be taken by the countries having the bioinformatics system to improve the system?
c) Specific topics	
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	• What are the stealth mechanism used by *Brucella* spp. and how could these be overcome?
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• How may latent infection in wildlife pose a risk to disease free-status areas? • What kind of control programs can be conducted in endemic countries for livestock and wildlife?
• Disease introductions, including trans-boundary animal diseases -Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	• What studies should be promoted to increase knowledge on disease epidemiology, diagnosis and immune-prophylaxis in less common livestock species (*e.g.* water buffaloes, camelids)?
• Vector-borne diseases - Emergency preparedness -	

Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	

7. Foot and Mouth disease RQs

a) Structural political	**Research questions:**
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	
• One health approach	
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	• How can we improve diagnostic capacity in certain endemic regions? • How can surveillance and control be improved in certain endemic settings?
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	
• Public Private Partnerships	
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming	• How can we improve submission of samples, for agents characterization and vaccine matching studies, from endemic countries to reference laboratories?
b) Technology	
• Easy to use field diagnostic technology	• What is needed to produce field diagnostic tests with multiplex serotyping capability?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology- Reverse genetics – synthetic biology	• How can we develop a longer lasting and more broadly cross-protective vaccine? • How serological tests for the evaluation of vaccine-induced immunity and post-vaccination monitoring could be upgraded? • Can a single serological assay per each serotype be adequate to measure population immunity, irrespective intra-serotype variations?
• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	• Can we improve a rapid and inexpensive diagnostic assay to assist in surveillance? • Are there assumptions for development of serotype-specific RT-PCR capable to overcome and cover intra-serotype variations?

• Big data – bioinformatics	
• Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	
c) Specific topics	
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	• What is the virus transmission and persistence in vaccinated populations? • How can we ensure a high quality and affordable vaccination for FMD?
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• What intervention would be suitable to control FMD taking into account the wildlife situation? • What is the role of buffaloes in the disease epidemiology?
• Disease introductions, including trans-boundary animal diseases -Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	• How can we reduce the risk of spreading of FMD considering the pressure for movement of people, live animals and products?
• Vector-borne diseases - Emergency preparedness - Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	

8. Aquaculture RQs

a) Structural political	**Research questions:**
• Partnerships/collaborations – global/regional research alliances – sharing information between countries	• What networks can be established to increase data sharing for fish disease control? • What kind of collaboration would be needed to increase research efficacy?

• One health approach	
• Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field professionals	• How can we ensure institutional change maintaining research capacity?
• Knowledge/technology transfer – to end-users (vets, farmers, Pharmaceutical industry);	• What are the most effective ways to sharing knowledge that can ensure technical innovation to the widest number of stakeholders?
• Public Private Partnerships	• How can we favour drug marketing authorization in order to increase drugs portfolio availability to fight fish diseases and lower antibiotic resistance due to the high selective pressure for the usage of a too small portfolio of authorized drugs? • How can we help fish farmer associations and Pharmaceutical company to produce and register DNA vaccine to be used in minor species (sturgeon, catfish, grayling, etc)?
• Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to surveillance - Better surveillance of domestic and wild animals - Use of farmers for frontline for disease detection – precision livestock farming	• What protocols should be developed to improve monitoring of zoonotic disease (e.g.: parasites: Anisakis, Diphyllobotrium, Opisthorchis… and virus: Norovirus, HAV, HEV…) in farmed fish and bivalves? • What kind of integrated surveillance system could be applied to monitor fish/mollusc/crustacean diseases?
b) Technology	
• Easy to use field diagnostic technology	• What is needed to produce faster diagnostic tools suitable to be used in fish farming?
• Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology- Reverse genetics – synthetic biology	• What technology shall we improve to produce effective vaccine for farmed fish? • How can we enhance the research about recombinant and DNA vaccine against viral/bacterial diseases of fish?
• Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR	• What improvement in diagnostics tools can be made to ensure a fast and harmonised detection of disease? • How NGS or new biomolecular technics would be useful to better understand the presence of aquatic organisms' pathogens in the water environment? • What diagnostic tests shall we develop to investigate the role of Vibrios as pathogens in molluscs? • What rapid diagnostic methods shall we develop for potentially zoonotic mycobacteria?
• Big data – bioinformatics	• How can we improve the availability of database about specific fish/mollusc/crustacean pathogens (MALDI-TOF, and Basic Local Alignment Search Tool - BLAST)?
• Surveillance - Syndromic surveillance - Precision livestock	• What web based application (smartphone, tablet, etc.) would be useful for a better field surveillance system?

farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance	
c) Specific topics	
• Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management, antimicrobial peptides, immunomodulators	• What guidelines could be suitable for fish farmers, veterinarians and consultants to reduce AMR in farmed fish? • What actions are needed to enhance the setting of MRL in fish? • What are the management actions that would enable aquaculture to improve its productivity in order to meet market and food safety requirements in an environmentally, economically and socially sustainable way? • What kind of sustainable therapies shall we invest on (i.e: phagotherapy, herbal therapy and stimulants for the immunity systems, prebiotics…)?
• Improved understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread	• How wild fish, turtles and bivalve molluscs interact with farmed fish in diseases spread? • Which is the best approach to evaluate cross contamination from wild to farmed fish *et viceversa*?
• Disease introductions, including trans-boundary animal diseases - Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for inactivation of pathogens	• How new technologies could be used to enhance fish and their products traceability? • Are there new low cost technologies (i.e. electro induction heat or photovoltaic equipment) feasible to inactivate aquatic organisms pathogens in the water?
• Vector-borne diseases - Emergency preparedness -Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic modification	• How can we improve the level of biosecurity in aquaculture? • What are the best cost-effective integrated parasites control strategies acceptable for the environment? • Is there any environmental friendly technology to reduce the prevalence of intermediate hosts (snails, tubifex, worms, bryozoa, etc.) essential for fish parasite life cycle?

Annexes:

European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

Annex I: List of workshop WGs participants

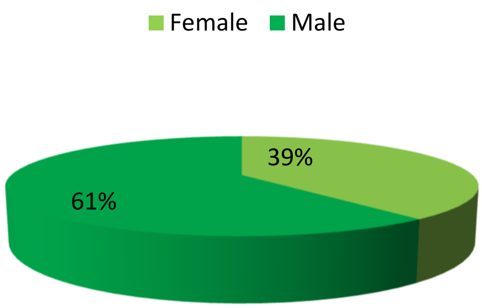
Working Groups	Facilitator	Participants
a) Structural/political	Marina Bagni Stefano Messori	Andrea Porta Antonio Lavazza Francesco Proscia Hein Imberechts Hermann Schobesberger Loukia Ekateriniadou Luke Dalton
B) Technology	Valeria Mariano Carlo Corradini	Giovanni Pezzotti Dominique Vandekerchove Franco Mutinelli Konstantina Bitchava Peter Deplazesp Rolf Stratman Sadharma Sharma Sven Arnout
c) Specific Topics	Romano Zilli Evgenya Titarenko	Amedeo Manfrin Erik Cox Fernando Rodriguez Johannes Charlier Loris Alborali Michel Bellaiche Poul Baekbo Smaro Sotiraki

Annex II: Online survey main results

SECTION A)

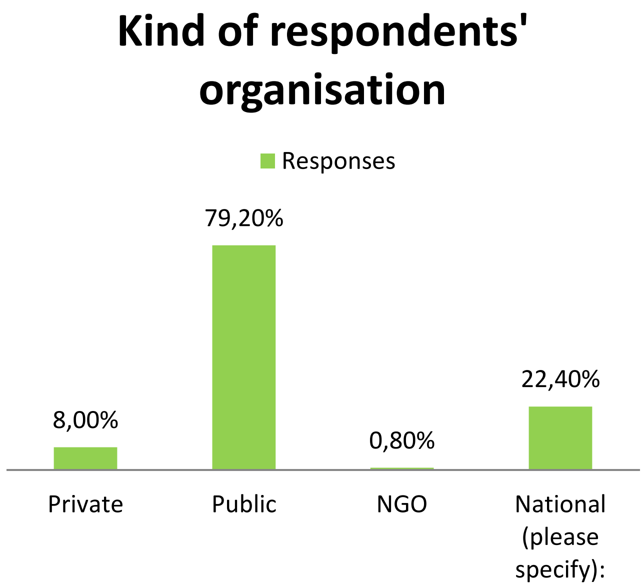
Q1) What is your gender?		
Answer Choices	Responses	
Female	39,02%	48
Male	60,98%	75
	Answered	**123**
	Skipped	**5**

Gender of respondents



Q2) In what country do you work?		
List of respondents country:		
Australia		
Austria		
Belgium		
Croatia		
Cyprus		
Czech Republic		
Denmark		
Finland		
France		
Germany		
Ghana		
Greece		
Ireland		
Israel		
Italy		
Lithuania		
Netherlands		
Norway		
Portugal		
Slovenia		
Spain		
Sweden		
Switzerland		
Turkey		
United Kingdom of Great Britain and Northern Ireland		
	Answered	**125**
	Skipped	**3**

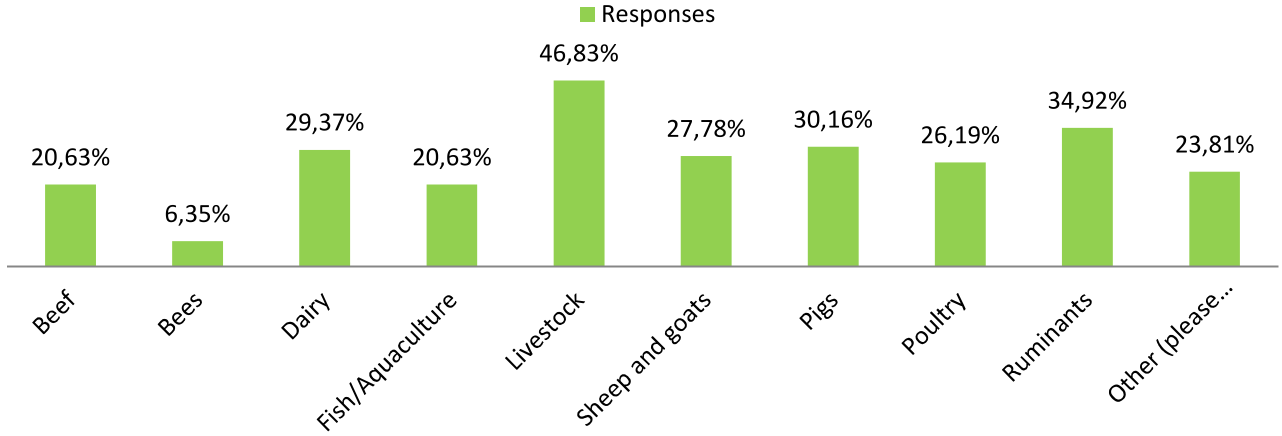
Q3) In what kind of organisation do you work?		
Answer Choices	Responses	
Private	8,00%	10
Public	79,20%	99
NGO	0,80%	1
National (please specify):	22,40%	28
	Answered	125
	Skipped	3



Q4) Please select the main sectors of your work:		
Answer Choices	Responses	
Beef	20,63%	26
Bees	6,35%	8
Dairy	29,37%	37
Fish/Aquaculture	20,63%	26
Livestock	46,83%	59
Sheep and goats	27,78%	35
Pigs	30,16%	38
Poultry	26,19%	33
Ruminants	34,92%	44
Other (please specify):	23,81%	30
	Answered	126
	Skipped	2

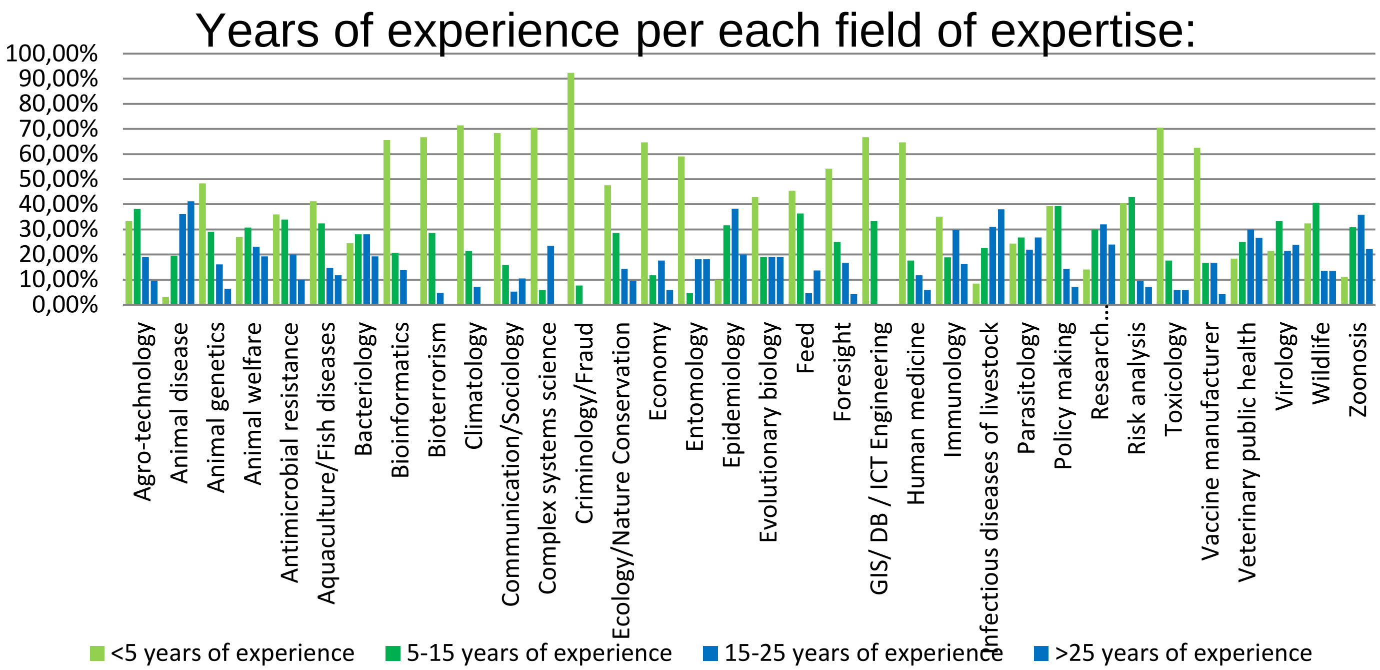
Agricultural economics in animal production, Animal health and welfare - all species above, Antimicrobial resistance, animals and food chain, Biotechnology, Companion animals, Epidemiology, Fish, molluscs, Food safety, Horses, Birds, Rabbits, Humans, Lab biosafety, General research, Microbiology and genetics, VBD, pathology, Veterinary Public Health, wildlife diseases and management

Main sector of respondents



Q5) Please select the years of experience per each of yours fields of expertise:									
	<5 years of experience		5-15 years of experience		15-25 years of experience		>25 years of experience		Tot
Agro-technology	33,33%	7	38,10%	8	19,05%	4	9,52%	2	21
Animal disease	3,09%	3	19,59%	19	36,08%	35	41,24%	40	97
Animal genetics	48,39%	15	29,03%	9	16,13%	5	6,45%	2	31
Animal welfare	26,92%	14	30,77%	16	23,08%	12	19,23%	10	52
Antimicrobial resistance	36,00%	18	34,00%	17	20,00%	10	10,00%	5	50
Aquaculture/Fish diseases	41,18%	14	32,35%	11	14,71%	5	11,76%	4	34
Bacteriology	24,56%	14	28,07%	16	28,07%	16	19,30%	11	57
Bioinformatics	65,52%	19	20,69%	6	13,79%	4	0,00%	0	29
Bioterrorism	66,67%	14	28,57%	6	4,76%	1	0,00%	0	21
Climatology	71,43%	10	21,43%	3	7,14%	1	0,00%	0	14
Communication/Sociology	68,42%	13	15,79%	3	5,26%	1	10,53%	2	19
Complex systems science	70,59%	12	5,88%	1	23,53%	4	0,00%	0	17
Criminology/Fraud	92,31%	12	7,69%	1	0,00%	0	0,00%	0	13
Ecology/Nature Conservation	47,62%	10	28,57%	6	14,29%	3	9,52%	2	21
Economy	64,71%	11	11,76%	2	17,65%	3	5,88%	1	17
Entomology	59,09%	13	4,55%	1	18,18%	4	18,18%	4	22
Epidemiology	10,00%	6	31,67%	19	38,33%	23	20,00%	12	60
Evolutionary biology	42,86%	9	19,05%	4	19,05%	4	19,05%	4	21
Feed	45,45%	10	36,36%	8	4,55%	1	13,64%	3	22
Foresight	54,17%	13	25,00%	6	16,67%	4	4,17%	1	24
GIS/ DB / ICT Engineering	66,67%	12	33,33%	6	0,00%	0	0,00%	0	18
Human medicine	64,71%	11	17,65%	3	11,76%	2	5,88%	1	17
Immunology	35,14%	13	18,92%	7	29,73%	11	16,22%	6	37

Infectious diseases of livestock	8,45%	6	22,54%	16	30,99%	22	38,03%	27	71
Parasitology	24,39%	10	26,83%	11	21,95%	9	26,83%	11	41
Policy making	39,29%	11	39,29%	11	14,29%	4	7,14%	2	28
Research planning/monitoring/management	14,00%	7	30,00%	15	32,00%	16	24,00%	12	50
Risk analysis	40,48%	17	42,86%	18	9,52%	4	7,14%	3	42
Toxicology	70,59%	12	17,65%	3	5,88%	1	5,88%	1	17
Vaccine manufacturer	62,50%	15	16,67%	4	16,67%	4	4,17%	1	24
Veterinary public health	18,33%	11	25,00%	15	30,00%	18	26,67%	16	60
Virology	21,43%	9	33,33%	14	21,43%	9	23,81%	10	42
Wildlife	32,43%	12	40,54%	15	13,51%	5	13,51%	5	37
Zoonosis	11,11%	9	30,86%	25	35,80%	29	22,22%	18	81
Other, please specify (150 characters):									13
						Answered			**126**
						Skipped			**2**



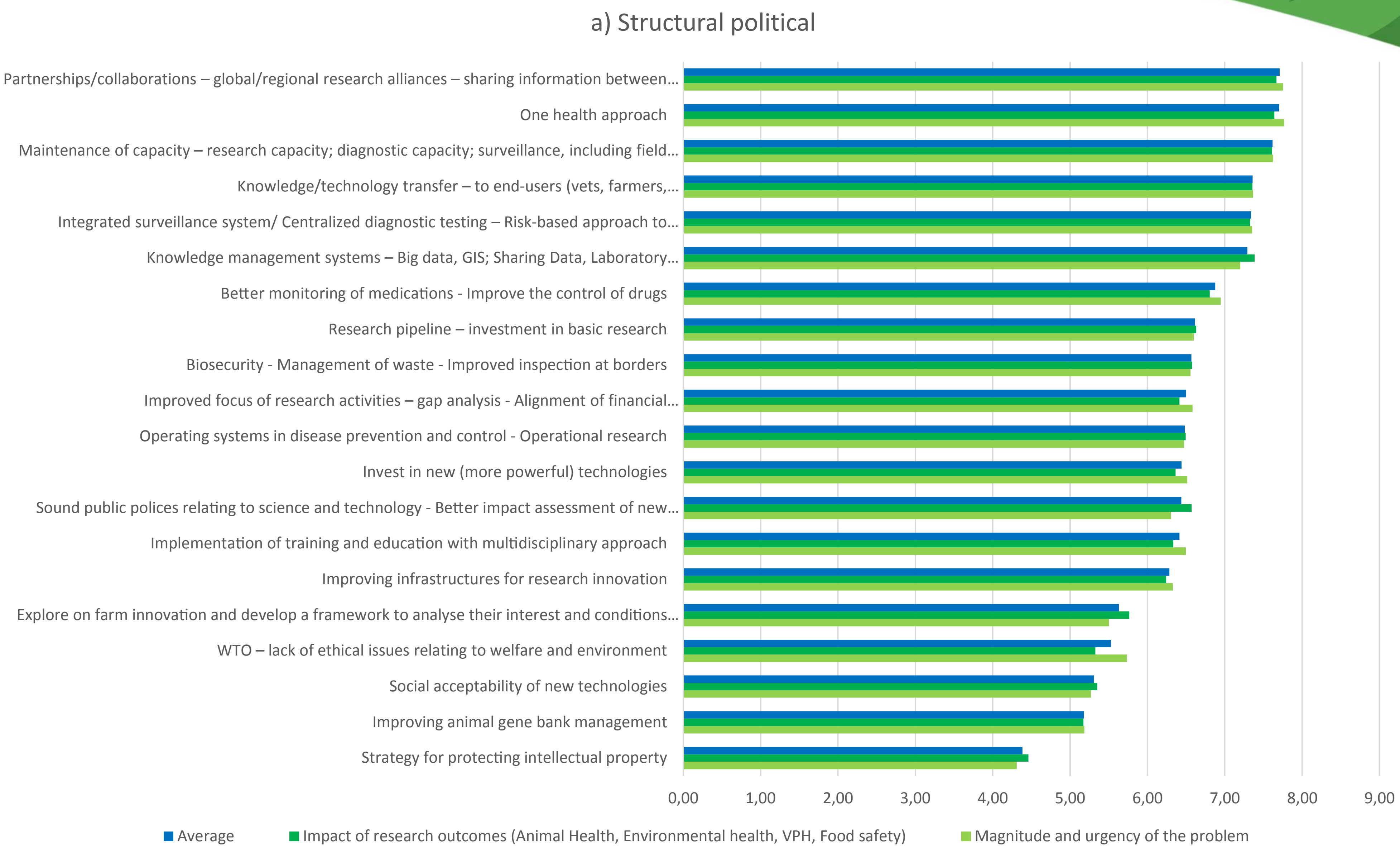
SECTION B)

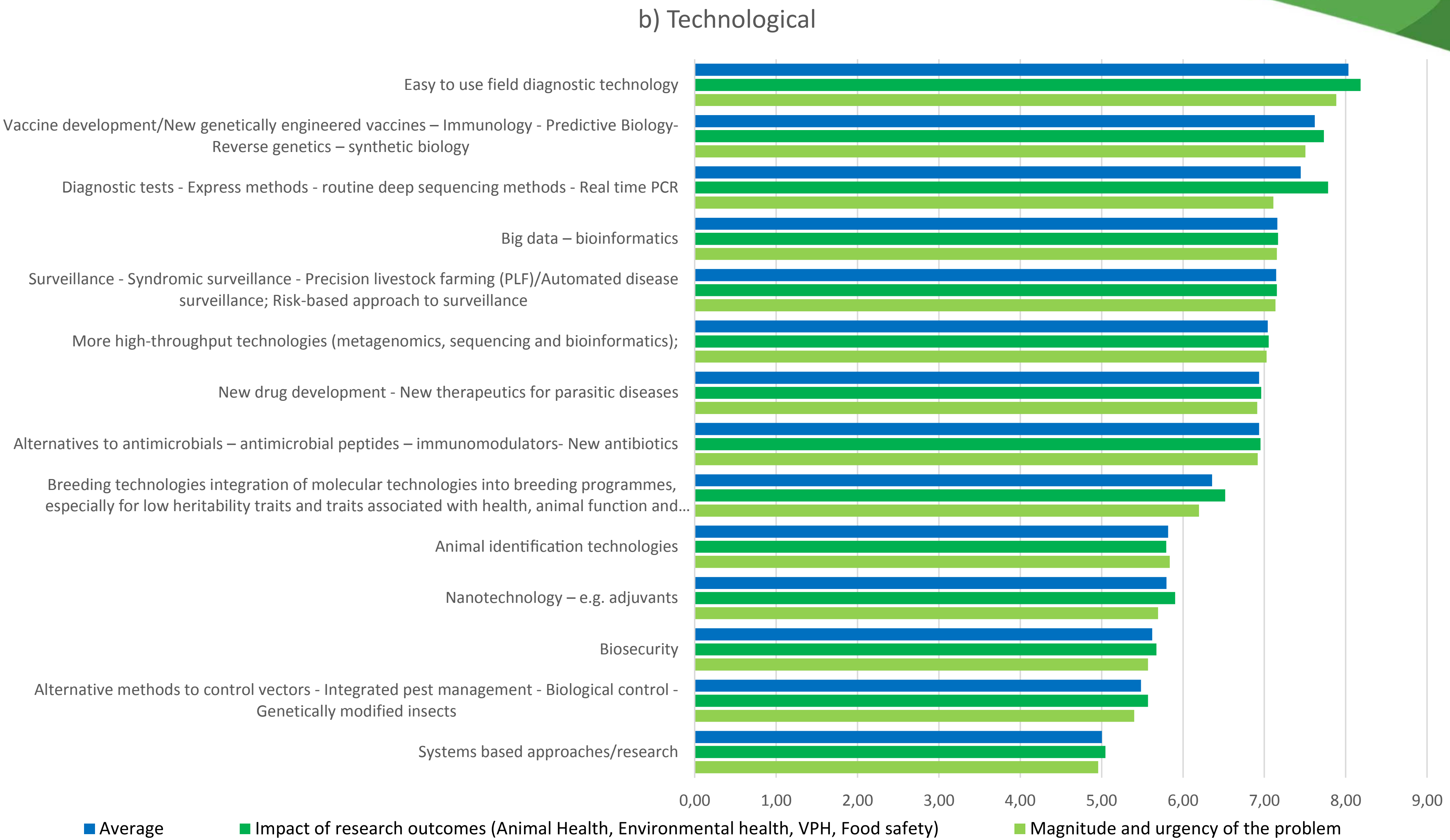
Q 6--8-10)**Please score (1-10) the following research needs accordingly with the provided criteria:**
C1-**Magnitude and urgency of the problem**
C2-**Impact of research outcomes (Animal Health, Environmental health, VPH, Food safety)**
Q 7-9-11)P**lease score your confidence in the answers provided** per each section

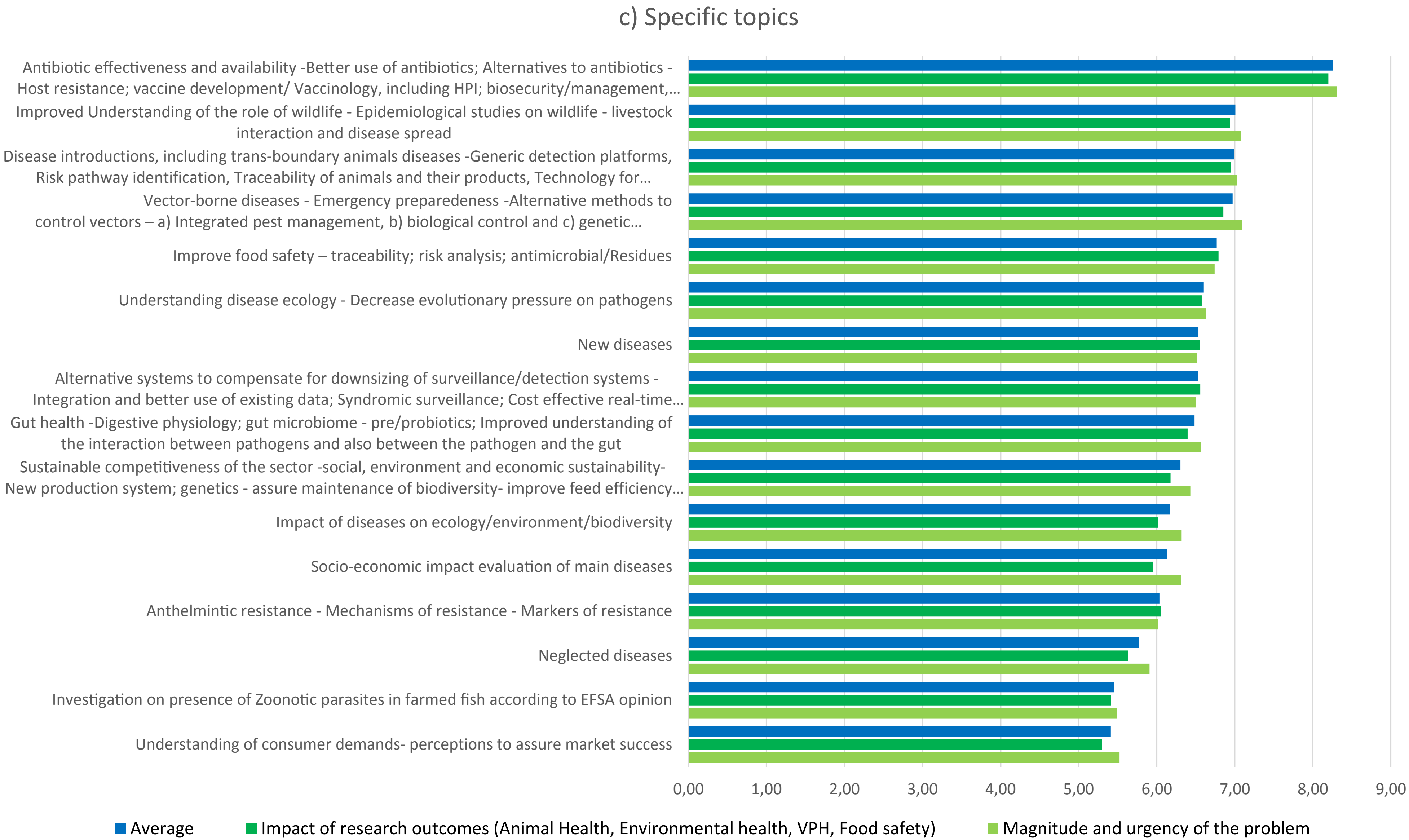
	N° of Respondents	Confidence in responses (Weighted average)
a) Structural political	104	6,73
b) Technology	98	6,85
c) Specific topics	94	6,66
d) Specific diseases	98	6,49

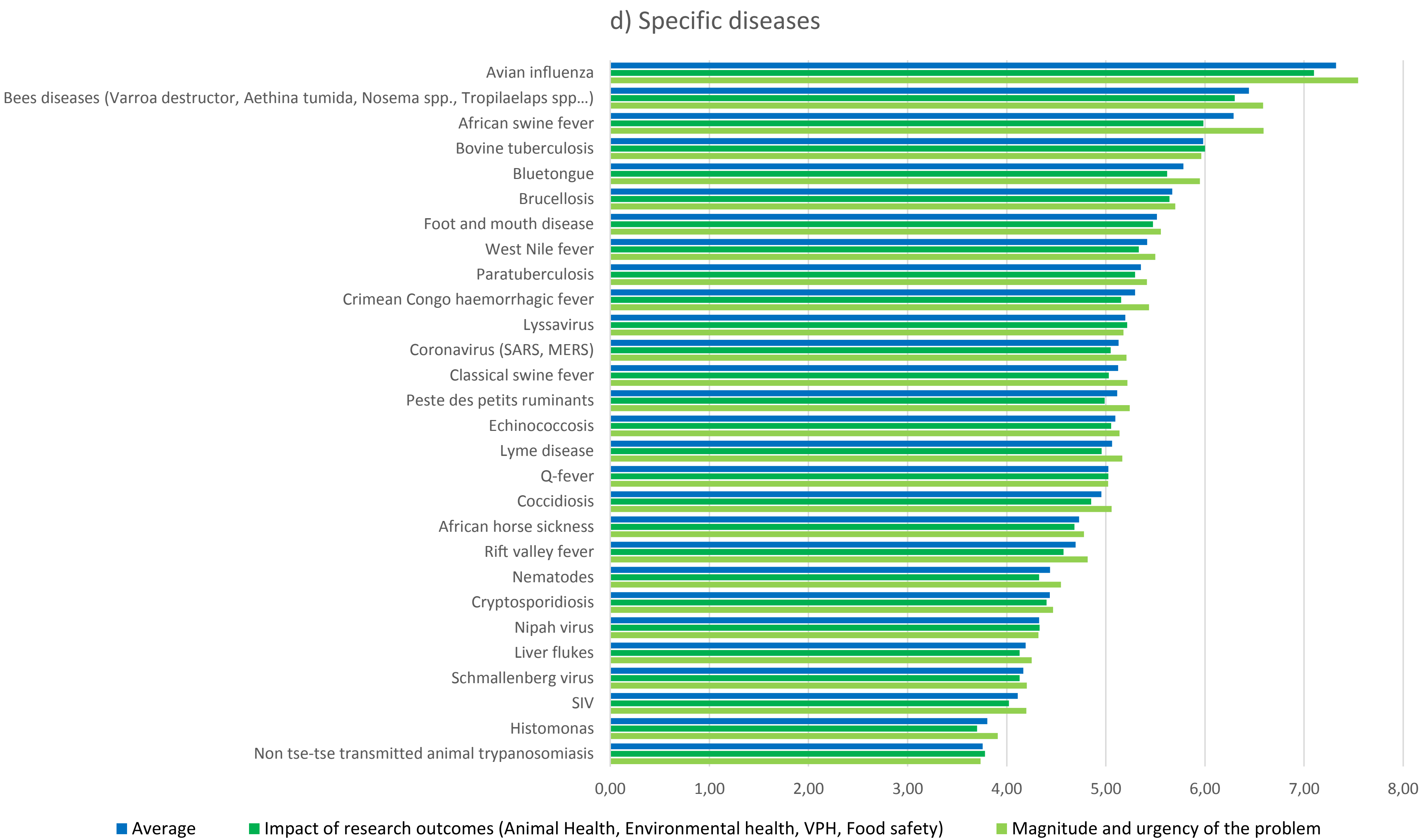
Brief note on the method applied for the results presented for Section B:

- *A weighted average (WA) has been calculated per each research need for both the prioritising criteria utilised.*
- *The average of the two criteria has been considered to prioritise each research need.*
- *The quartile has been used to group the topics into low, medium, high and very high priority research needs.*


a) Structural political
Partnerships/collaborations – global/regional research alliances – sharing information between...
One health approach
Maintenance of capacity – research capacity; diagnostic capacity; surveillance, including field...
Knowledge/technology transfer – to end-users (vets, farmers,...
Integrated surveillance system/ Centralized diagnostic testing – Risk-based approach to...
Knowledge management systems – Big data, GIS; Sharing Data, Laboratory...
Better monitoring of medications - Improve the control of drugs
Research pipeline – investment in basic research
Biosecurity - Management of waste - Improved inspection at borders
Improved focus of research activities – gap analysis - Alignment of financial...
Operating systems in disease prevention and control - Operational research
Invest in new (more powerful) technologies
Sound public polices relating to science and technology - Better impact assessment of new...
Implementation of training and education with multidisciplinary approach
Improving infrastructures for research innovation
Explore on farm innovation and develop a framework to analyse their interest and conditions...
WTO – lack of ethical issues relating to welfare and environment
Social acceptability of new technologies
Improving animal gene bank management
Strategy for protecting intellectual property
0,00
1,00
2,00
3,00
4,00
5,00
6,00
7,00
8,00
9,00
Average
Impact of research outcomes (Animal Health, Environmental health, VPH, Food safety)
Magnitude and urgency of the problem


b) Technological
Easy to use field diagnostic technology
Vaccine development/New genetically engineered vaccines – Immunology - Predictive Biology- Reverse genetics – synthetic biology
Diagnostic tests - Express methods - routine deep sequencing methods - Real time PCR
Big data – bioinformatics
Surveillance - Syndromic surveillance - Precision livestock farming (PLF)/Automated disease surveillance; Risk-based approach to surveillance
More high-throughput technologies (metagenomics, sequencing and bioinformatics);
New drug development - New therapeutics for parasitic diseases
Alternatives to antimicrobials – antimicrobial peptides – immunomodulators- New antibiotics
Breeding technologies integration of molecular technologies into breeding programmes, especially for low heritability traits and traits associated with health, animal function and…
Animal identification technologies
Nanotechnology – e.g. adjuvants
Biosecurity
Alternative methods to control vectors - Integrated pest management - Biological control - Genetically modified insects
Systems based approaches/research
0,00
1,00
2,00
3,00
4,00
5,00
6,00
7,00
8,00
9,00
Average
Impact of research outcomes (Animal Health, Environmental health, VPH, Food safety)
Magnitude and urgency of the problem


c) Specific topics
Antibiotic effectiveness and availability -Better use of antibiotics; Alternatives to antibiotics - Host resistance; vaccine development/ Vaccinology, including HPI; biosecurity/management,...
Improved Understanding of the role of wildlife - Epidemiological studies on wildlife - livestock interaction and disease spread
Disease introductions, including trans-boundary animals diseases -Generic detection platforms, Risk pathway identification, Traceability of animals and their products, Technology for...
Vector-borne diseases - Emergency preparedeness -Alternative methods to control vectors – a) Integrated pest management, b) biological control and c) genetic...
Improve food safety – traceability; risk analysis; antimicrobial/Residues
Understanding disease ecology - Decrease evolutionary pressure on pathogens
New diseases
Alternative systems to compensate for downsizing of surveillance/detection systems - Integration and better use of existing data; Syndromic surveillance; Cost effective real-time...
Gut health -Digestive physiology; gut microbiome - pre/probiotics; Improved understanding of the interaction between pathogens and also between the pathogen and the gut
Sustainable competitiveness of the sector -social, environment and economic sustainability- New production system; genetics - assure maintenance of biodiversity- improve feed efficiency...
Impact of diseases on ecology/environment/biodiversity
Socio-economic impact evaluation of main diseases
Anthelmintic resistance - Mechanisms of resistance - Markers of resistance
Neglected diseases
Investigation on presence of Zoonotic parasites in farmed fish according to EFSA opinion
Understanding of consumer demands- perceptions to assure market success
0,00
1,00
2,00
3,00
4,00
5,00
6,00
7,00
8,00
9,00
Average
Impact of research outcomes (Animal Health, Environmental health, VPH, Food safety)
Magnitude and urgency of the problem


d) Specific diseases
Avian influenza
Bees diseases (Varroa destructor, Aethina tumida, Nosema spp., Tropilaelaps spp…)
African swine fever
Bovine tuberculosis
Bluetongue
Brucellosis
Foot and mouth disease
West Nile fever
Paratuberculosis
Crimean Congo haemorrhagic fever
Lyssavirus
Coronavirus (SARS, MERS)
Classical swine fever
Peste des petits ruminants
Echinococcosis
Lyme disease
Q-fever
Coccidiosis
African horse sickness
Rift valley fever
Nematodes
Cryptosporidiosis
Nipah virus
Liver flukes
Schmallenberg virus
SIV
Histomonas
Non tse-tse transmitted animal trypanosomiasis
0,00
1,00
2,00
3,00
4,00
5,00
6,00
7,00
8,00
Average
Impact of research outcomes (Animal Health, Environmental health, VPH, Food safety)
Magnitude and urgency of the problem