2023

STRATEGIC RESEARCH AND INNOVATION AGENDA

FOR THE EUROPEAN PARTNERSHIP ON ANIMAL HEALTH AND WELFARE (EUP AH&W SRIA)

EUP AH&W LOGO

STRATEGIC RESEARCH AND INNOVATION AGENDA FOR THE EUROPEAN PARTNERSHIP ON ANIMAL HEALTH AND WELFARE (EUP AH&W SRIA)

Contributors

This SRIA has been developed thanks to a collaboration between EUP AH&W, WP6 – ERA-Net co-fund ICRAD, STARIDAZ IRC and SFU - CWG AHW.

Coordination and action plan:

Hein Imberechts (Sciensano, BE), Florence Tardy (ANSES, FR), Hans Spoolder (WUR, NL) and Sven Arnouts (UGent, BE), EUP AH&W
Sadhana Sharma (BBSRC-UKRI, UK) and Scott Sellers (Defra, UK), ICRAD WP6 Leaders
Marina Bagni (MoH, IT), ICRAD WP 6.2 SRIA Task leader
Alex Morrow (IRC STAR-IDAZ, UK)
Hermann Schobesberger (Vet MedUni, AU/ CWG AHW-SFU)

Main contributors to the methodology and contents *(alphabetic order)*:

Giuseppe Arcangeli (IZS VE, IT), Johannes Charlier (DISCONTOOLS, Be), Madeleine Clark (Defra, UK), Carlo Corradini (IZS LT, IT), Thom Errit (Defra, UK), Nikki Mackie (BBSRC-UKRI, UK), Valeria Mariano (SIRCAH/OIE), Danielle Sagar (BBSRC-UKRI, UK), Simon Smith (Defra, UK), Evgenyia Titarenko (IZS LT, IT), Niccolò Vendramin (Aqua DTU, Dk)

Editors:
EUP SRIA: Hein Imberechts (Sciensano, BE), Florence Tardy (ANSES, FR), Hans Spoolder (WUR, NL).
Addendum: Marina Bagni (MOH, IT), Hermann Schobesberger (Vet MedUni, AU/ CWG AHW-SFU), Sadhana Sharma (BBSRC-UKRI, UK), Scott Sellers (Defra, UK)

Graphic editing:
IZS AM , Teramo - WP2 ICRAD

EUP AH&W LOGO

icrad
International coordination of research on infectious animal diseases

European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

STAR-IDAZ
International Research Consortium on Animal Health

Acknowledgments

Many experts provided input to this SRIA:

CWG Animal Health & Welfare

The CWG AHW was closely involved in the preparation of this document, and is composed of Funding Organizations, Research Performing Organizations and experts from the following countries: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Lithuania, Luxembourg, The Netherlands, Norway, Poland, Portugal, Russia, Slovakia, Spain, Sweden, Turkey and the United Kingdom.

Among its observers are: AnimalhealthEurope, COPA-COGECA, COST, EFSA, the European Commission and OIE.

Collaborating entities

In the preparation of the drafting of this document, contact has been taken with the following entities: DISCONTOOLS, EATiP, EPIZONE, FVE, ICRAD, MedVetNet Association, One Health EJP, STAR-IDAZ IRC and VetBioNet.

Working groups

WG Surveillance: Lead Yves van der Stede (EFSA) and Dolores Gavier-Widén (SVA, SE); Kiara Ailello Holden (EFSA), Julio Alvarez Sanchez (Visavet, ES), Silvia Bellini (IZSLER, IT), Clémence Foltz (EFSA), José Gonzales Rojas (WUR, NL), Wim van de Poel (WUR, NL), Arvo Viltrop (EMU, EE)

WG Diagnostics: Lead Pikka Jokelainen (SSI, DK), Bruno Garin-Bastuji (ANSES, FR) and Martin Beer (FLI, DE); and Alain Boissy (ANSES, FR), Isabella Monne (IZS Venezie, IT), Isabelle Behaeghel (Sciensano, BE), Johannes Charlier (DISCONTOOLS), Kris De Clercq (Sciensano, BE), Marc Tabouret ANSES, FR), Miklós Gyuranecz (HIVMR, HU), Stephen Hennart (Diagnostics4Animals), Hans Nauwynck (UGent, BE), Wim van der Poel (WUR, NL), Stéphan Zientara (ANSES, FR).

WG Farming practices: Lead Kristian Møller (SEGES, DK) and Virginie Michel (ANSES, FR); Poul Bækbo (SEGES, DK), Laura Boyle (TEAGASC, IE), Carlo Corradini (IZSILT, IT), Adam Drosio (COGECA), Nadav Galon (II), Vivi Hunnicke Nielsen (AU, DK), Alexandra Jeremiasson (FORMAS, SE), Marianne Berthelot (ANSES, FR), Palić Dušan (VetMed Uni, DE), Marie-Hélène Pinard-van der Laan (INRAE, FR), Hans Spoolder (WUR, NL), Antonio Velarde (IRTA, ES)

WG Treatment & Vaccines: Lead Sven Arnouts (UGent, BE) and Alex Morrow (CABI, UK); Artur Summerfield (Vet Suisse, CH), Edwin Claerebout (UGent, BE), Eric Cox (UGent), Jens Nielsen (DTU, DK), Madsen Lone (DTU, DK), Luca Guardabassi (SUND, DK), Amedeo Manfrin (IZS Venezie, IT), Paul Midtlyng (NMBU, NO), Sabine Riffault (INRAE, FR)

WG Antimicrobial resistance: Lead Annemarie Kaesbohrer (BfR, DE) and Roberto La Ragione (U Surrey, UK); Julio Alvarez Sanchez (Visavet, ES), Rudolphe MADER (FAO), Beatriz Guerra (EFSA), Ernesto Liebana (EFSA), Jeroen Dewulf (UGent, BE), Claire Chauvin (ANSES, FR), Jean-Yves Madec (ANSES, FR)

WG Aquaculture: Lead Marina Bagni (MoH, IT) and Giuseppe Arcangeli (IZS Venezie, IT): Aida Campos (IPMA, PT), Amedeo Manfrin (IZS Venezie, IT), Carlo Corradini (IZSLT, IT) , Kjersti Fjalestad (SWG Fish, NO), Dennis Lisbjerg (EFARO, DK), Aurelio Ortega Garcia (IEO, ES), Ricardo Calado (UA, PT), Edgar Brun (VetInst, NO), Niccolò Vendramin (DTU, DK)

The development of this SRIA would not have been possible without the consultation of more than 300 experts, worldwide, who contributed to the prioritization of research needs. We cannot mention everyone by name, but we would like to thank their valuable contribution to this SRIA.

Table of Contents

Preamble

This Strategic Research and Innovation Agenda for the Partnership Animal Health and Welfare (EUP SRIA) presents long-term strategic vision including broad research themes that will guide the partnership's activities over the coming years. This is a live document and will be kept current based on communities needs and requirements.

Accompanying this high-level strategic document is an addendum that describes methodology and research and innovation needs for short-, medium- and long-term and served as an input into the EUP SRIA. This addendum will be valuable when analysing possible specific domains for the research calls and the 'invitations to collaborate' on integrative activities.

This EUP SRIA and its addendum have been developed through joint working of the EUP AH&W, WP6 – ERA-Net co-fund ICRAD, STAR-IDAZ IRC and SFU - CWG AHW through extensive consultation with broad range of players. Through a desk study, an ICRAD working group identified research and innovation priorities, which were further prioritized with the help of animal health and welfare researchers throughout Europe and beyond in an online survey. In addition, industry associations and stakeholders were consulted, as well as the EUP AH&W experts that contributed to the initial proposal for the Partnership that was sent to and evaluated by the EC in 2022. Finally, an interactive workshop with expected Partnership members and stakeholders was organized, as well as a broad consultation.

List of Abbreviations

3Rs	Replacement, reduction and refinement
ABM	Animal-based measures
AID	Animal Infectious Disease
AH	Animal Health
AH&W	Animal Health & Welfare
AMR	Antimicrobial Resistance
ANSES	Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail
AUTH	Authorities
AW	Animal Welfare
CAP	Common Agricultural Policy
CB	Call Board
CoI	Conflict of Interest
COVID	Coronavirus disease
CT	Coordination Team
DIVA	Differentiating Infected from Vaccinated Animals
DFA	Diagnostics for Animals
DG-AGRI	Directorate-general Agriculture and Rural Development
EAB	Ethics Advisory Board
EB	Executive Board
EC	European Commission
ECDC	European Centre for Disease Prevention and Control
ECI	European Citizen's Initiative (here in relation to 'End the Cage Age')
EDQM	European Directorate for the Quality of Medicines and Healthcare
EEA	European Environment Agency
EFSA	European Food Safety Authority
EFTA	European Free Trade Association
EIC	European Innovation Council
EMA	European Medicines Agency
EUP	European Partnership
EURL	European Reference Laboratory
EB	Executive Board
FAIR	Findability, accessibility, interoperability, and reusability
FAO	Food and Agriculture Organization of the United Nations
FO	Funding Organizations
FVE	Federation of Veterinarians of Europe
GA	Grant Agreement
GenA	General Assembly
GMP	Good manufacturing practice
GO	General Objectives
GovB	Governing Board
HE	Horizon Europe

HERA	European Health Emergency preparedness and Response Authority
ICRAD	International Coordination of Research on infectious Animal Diseases
IP	Intellectual property
KPI	Key performance indicators
MoU	Memorandum of Understanding
mRNA	Messenger RNA
MS	Member States
NGO	Non-governmental organization
NMG	National AH&W Mirror Groups
OIE	World Organisation for Animal Health
OO	Operational Objectives
PMT	Partnership Management Team
R&I	Research & Innovation
RPO	Research Performing Organizations
SAB	Scientific Advisory Board
SCAR	Standing Committee on Agricultural Research
SDG	Sustainable Development Goals
SHC	Stakeholders Committee
SMART	Specific, Measurable, Attainable, Relevant, Time-bound
SO	Specific Objectives
SRIA	Strategic Research and Innovation Agenda
SRL	Societal Readiness Level
TRL	Technology Readiness Level
UNEP	United Nations Environment Programme
VMP	Veterinary Medicine Products
WHO	World Health Organization
WOAH	World Organisation for Animal Health (formerly 'OIE')
WP	Work Package
WPR	Work Programme
WUR	Wageningen University & Research

The European Partnership Animal Health & Welfare (EUP AH&W) will generate key knowledge and develop innovative methodologies, tools and products to promote sustainability in livestock production, both for terrestrial and aquatic animals. It will support the development of an animal friendly livestock sector and reduce the risk of animal infections, both from endemic and emerging origin. The Partnership will also enhance public health and wellbeing by enhancing cross-sector collaboration in a One Health – One Welfare perspective.

EUP AH&W will actively engage with chain actors and stakeholders, and support evidence-based intervention and policy making in the fields of animal health and welfare.

The European Partnership Animal Health & Welfare (EUP AH&W) is a Research and Innovation Partnership set up in the context of Horizon Europe. Its general goals are to progress Europe towards healthy and sustainable livestock production systems (for both terrestrial and aquatic animals), including the reduction of anti-microbial usage, and to greatly improve welfare of farmed animals, in line with the European Green Deal and farm-to-fork strategy. Furthermore, the EUP AH&W will enhance public health and well-being by facilitating cross-sector collaboration in a One Health – One Welfare perspective. To accomplish these goals, the EUP AH&W will generate key knowledge, innovative methodologies, tools, and products by launching internal activities and calls for research and innovation proposals. Next to external calls supported by funding organizations, the EUP AH&W will organize a set of internal activities, which aim to strengthen the international collaboration between its partners, leading to increased awareness and preparedness. Furthermore, the EUP AH&W will set up a portfolio of additional activities, such as education and training activities, knowledge hubs with farmers, vets and citizens, etc. to further strengthen international cooperation, networking, and dissemination and exploitation of results.

The activities of the EUP AH&W will be structured around four priority areas:

I. Surveillance / monitoring systems and risk assessment of animal health and welfare.
II. Procedures, methodologies and tools to assess animal health and welfare.
III. Management and husbandry guidelines on farm and including aquaculture, during transport and at slaughter.
IV. Vaccines and treatments.

In addition, a fifth transversal priority area of socio-economic aspects will be studied along the four previous ones. As such, the outcomes of the Partnership will lead to strengthening

sustainable livestock production and aquaculture and animal welfare, as well as supporting human health and well-being.

The EUP AH&W will consist of partners belonging to research funding organizations (FO), research-performing organizations (RPO), and national authorities. Industry and non-partner RPOs will be allowed to join through external research calls developed for high TRL projects or projects needing specific expertise that is not available within the Partnership. SRL level will also be taken into consideration.

This strategic research and innovation agenda (SRIA) presents the long-term vision of the EUP AH&W and addresses the strategic objectives that will guide the activities of the partnership. Based on a broad input from experts of existing AH&W networks, the SRIA will showcase the vision and ambition of the partnership and its general and specific objectives. It will also elaborate on the organization and governance of the partnership, as well as its intended monitoring framework. The purpose of this framework is to ensure adherence to the partnership's vision and long-term objectives and to provide a comprehensive way to document the progress and impact of the partnership.

Lastly, the EUP AH&W is not intended to be a stand-alone initiative. Through collaboration and exchange with other European initiatives, the EUP AH&W aims to maximize EU added value, societal and economic impact. Complementary European partnerships include the planned partnerships on 'Accelerating farming systems transition: agroecology living labs and research infrastructures'[1], 'Sustainable food systems'[2], 'Rescuing biodiversity to safeguard life on Earth'[3], 'a climate neutral, sustainable and productive Blue Economy'[4], and One Health-AMR[5], to name the most relevant ones. The envisioned collaboration and knowledge exchange with these initiatives is elaborated further in this SRIA.

[1] https://research-and-innovation.ec.europa.eu/system/files/202204/european_partnership_for_accelerating_farming_systems_transition_march_2022.pdf
[2] https://research-and-innovation.ec.europa.eu/system/files/2022-04/ec_rtd_he-partnership-sustainable-food-systems-april_2022.pdf
[3] https://research-and-innovation.ec.europa.eu/system/files/202005/european_partnership_for_rescuing_biodiversity_to_safeguard_life_on_earth.pdf
[4] https://research-and-innovation.ec.europa.eu/system/files/2020-08/ec_rtd_he-partnership-climate-neutral-sustainable-productive-blue-economy.pdf
[5] https://research-and-innovation.ec.europa.eu/system/files/2022-02/ec_rtd_he-partnerships-onehealth-amr.pdf

Context and Problem Description

Animal health and animal welfare constitute a Global Public Good; its preservation and continuous improvement is the mission of the proposed EUP AH&W. The creation of the partnership is timely, as never before has the need for such an initiative been so pressing: climate change, the COVID-19 crisis and increased consumer concern about how animals are kept and how products are made demand a changed approach. The opportunity of achieving significant and sustainable progress on animal health and welfare is promoted and supported through the EU Commission's Farm to Fork strategy. But the challenges at hand and the mobilisation of resources to achieve them require a systemic, cross-cutting, interdisciplinary and coordinated approach at the transnational level.

The **livestock sector plays a major economic role** in agriculture, accounting for €168 billion annually, 45% of total EU agricultural activities, creating 4 million jobs, many of them in rural areas, while linked sectors (dairy products, eggs and meat processing, feed for livestock) have an annual turnover of approximately €400 billion. The value of EU aquaculture production reached €5.6 billion in 2017.

Livestock provides proteins of high nutritional values including meat, fish, crustacean and mollusc, milk and eggs, contributing to food security (see the United Nations Sustainable Development Goals[6], SDG2) and nutrition (SDG3). Furthermore, animal production enhances economic growth (food and non-food products) (SDG8), rural development and vitality of many EU marginal territories (SDG9, SDG15) and certain production systems preserve biodiversity on earth (SDG2, SDG15). A healthy and sustainable livestock and aquaculture sector is a prerequisite for providing sufficient and healthy food to citizens and for establishing well-functioning circular sustainable agri/food systems, in the most efficient possible way. The likely increase in animal production, however, will create new challenges, especially with regard to consumer demands regarding climate challenges, environmental concerns, animal welfare and the need for disease prevention and control.

The One Health principle recognises that human, animal including fish, plant and environmental health are closely linked[7]. If one group is affected, this influences the health of the others. In a One Health perspective, certain animal **infectious** diseases (AID) have an impact, directly or indirectly, on public health. Indeed, the majority of emerging AID are

[6] https://sdgs.un.org/goals

[7] https://www.onehealthcommission.org/en/why_one_health/what_is_one_health/

zoonotic[8], i.e. transmissible between animals and humans, directly or indirectly (e.g. food-borne and vector-borne zoonoses). In a global study[9] 56 zoonoses were assessed, which were together responsible for an estimated 2.5 billion cases of human illness and 2.7 million human deaths per year. EFSA has estimated that the overall economic burden of human salmonellosis could be as high as €3 billion a year. The COVID-19 pandemic has underlined the importance of a robust and resilient food system that functions in all circumstances and is capable of ensuring access to a sufficient supply of affordable food for all citizens[10]. It has also made us acutely aware of the interrelations between our health, ecosystems, animal reservoirs, supply chains, consumption patterns and planetary boundaries. Spread and emergence of resistant bacteria also arise in the environment, due to pharmaceutical leaks, pollution, organic fertilizers, etc. and are passed onto livestock[11]. It is clear that we need to do much more to maintain animal, human and our planetary health. The increasing recurrence of droughts, floods, forest fires and new pests are a constant reminder that **our food system is under pressure** and must evolve towards more sustainability and resilience.

One Welfare emphasises the link between animal welfare, human wellbeing and ecosystem health. Pinillos et al. (2016)[12] introduce the One Welfare concept and emphasise the strong link between animal welfare and human wellbeing. They quote Bayvel and Cross (2010)[13] who state that initiatives to improve animal welfare are "multifaceted, international and domestic, public-policy issues that must take account of not only scientific, ethical and economic issues but also religious, cultural, and international trade policy considerations". Separating human, social and animal welfare is an artificial compartmentalisation[14], as these scientific areas rely on similar measures and are interdependent from an ecological point of view. Pinillos et al. (2016) describe several areas of interaction. They include evidence indicating that poor states of human welfare commonly co-exist with poor states of animal welfare, e.g. in emerging economies[15]. At farm level, the well-being of the animals and their owners is directly correlated:

[8] http://www.oie.int/fileadmin/Home/eng/Media_Center/docs/pdf/Key_Documents/ANIMAL-HEALTH-EN-FINAL.pdf Jones et al, Nature Vol 451|21 February 2008 ; doi:10.1038/nature06536

[9] https://assets.publishing.service.gov.uk/media/57a08a63ed915d622c0006fd/ZooMapDFIDreport18June2012FINALsm.pdf

[10] OECD Policy Responses to Coronavirus – Food Supply Chains and COVID-19: Impacts and Policy Lessons (2020) https://www.oecd.org/coronavirus/policy-responses/food-supply-chains-and-covid-19-impacts-and-policy-lessons-71b57aea/; Niles, M.T., Bertmann, F., Belarmino, E. H., Wentworth, T., Biehl, E. and Neff, R. The Early Food Insecurity Impacts of COVID-19. Nutrients, 12(7), 2096 (2020). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7400862/

[11] https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2021.6651

[12] Pinillos RG, Appleby MC, Manteca X, Scott-Park F, Smith C, Velarde A. One Welfare - a platform for improving human and animal welfare. Vet Rec. 2016 Oct 22;179(16):412-413. doi: 10.1136/vr.i5470. PMID: 27770094

[13] BAYVEL, A. C. D & CROSS, N. (2010) Animal welfare: a complex domestic and international public-policy issue—who are the key players? Journal of Veterinary Medical Education 37, 3-12

[14] Colonius, T. J. & Earley, R. W. (2013) One welfare: a call to develop a broader framework of thought and action. Journal of the American Veterinary Medical Association 242, 309-310

[15] JORDAN, T. & LEM, M. (2014) One Health, One Welfare: Education in practice Veterinary students' experiences with Community Veterinary Outreach Canadian Veterinary Journal 55, 1203–1206

well-kept animals on productive farms are generally associated with positive farmer wellbeing. Efforts to develop communities where animals are looked after well, promote long term viability of livestock production and the availability of animal-derived products. Nevertheless, given current areas of societal concern, O'Riordan (2004)[16] suggests that an "inclusive approach should be taken to protect the soil, safeguarding water, widening biodiversity, introducing local food sourcing, establishing local carbon-neutral energy schemes and housing, and creating community initiatives around sustainability partnerships." As such, One Welfare aims to contribute to sustainable animal production in a very broad sense.

As animal welfare is linked to animal health, the One Welfare concept overlaps and complements the One Health concept. Integrating this concept in future projects will foster interdisciplinary collaboration to improve human and animal welfare and help improve global standards of both human wellbeing and animal welfare.

In recent years, new opportunities become available in the form of new scientific disciplines and advanced technologies such as data science and bioinformatics, OMICS technologies, precision farming technologies and advanced in-line sensory systems at abattoirs and during transport. These ill not only detect any new and emerging diseases and welfare hazards, they can also be applied to monitor entrenched diseases or endemic welfare issues. All the above would help transition from a curative approach to the application of more preventive measures with new and improved diagnostics and assessment schemes.

Global change has accelerated in recent decades leading to far-reaching climatic, economic, sociological and environmental consequences. Animal populations, whether domestic or wild, terrestrial or aquatic, lie at the heart of ecosystems, along with plants, air, water and soil. The populations are confronted with new and more complex challenges in relation to climate change, ecological transformation and habitat loss. Furthermore, demands for increasing efficiency of animal farming and husbandry practices and increased trade to meet the growing demands of developing societies pose additional challenges. Rising temperatures affect the physiology of both animals and pathogens, in both aquatic and terrestrial production, and have the potential to lead to significant increases in disease outbreaks, welfare breaches, and antimicrobial resistance[17] [18] within livestock and aquaculture systems, resulting in severe financial impacts[19]. Similarly, deforestation transforms the interactions between pathogens, arthropod vectors and hosts in multiple and complex ways leading to spread and emergence of infectious diseases.

[16] O'RIORDAN, T. (2004) Environmental science, sustainability, and politics. Transactions of the Institute of British Geographers 29, 234–247

[17] https://www.sciencedirect.com/science/article/pii/S258900422030208X

[18] https://www.nature.com/articles/s41558-018-0161-6

[19] Mediterranean Aquaculture in a Changing Climate: Temperature Effects on Pathogens and Diseases of Three Farmed Fish Species. https://doi.org/10.3390/pathogens10091205

Boundaries

For the purpose of this partnership, **animals** mean living farmed or managed animals, whether **terrestrial or aquatic**[20], including minor species such as bees, as well as companion animals and wildlife when there is a potential threat to animal health, public health or the welfare of production animals. Causative agents responsible for animal infectious diseases include bacteria, viruses, parasites, fungi and prions. Non-infectious animal diseases are included as far as they impact the welfare of animals.

Activities related to sustainable farming, breeding and feeding are within the scope of EU Partnership on Animal Health and Welfare as long as they can be directly linked to animal health or animal welfare. All production systems are considered, including for instance organic farming as well as all phases of production: on farm, during transport and in the abattoir and after fishing.

In close cooperation with the consortium that prepares the future EUP One Health AMR, the EUP AH&W will focus on the antimicrobial resistance (AMR) in pathogens for livestock, as well as on the spread of resistance to livestock and the assessment of alternatives for use the of antibiotics.

The Partnership Approach to address the Challenges

The objectives of EUP AH&W are presented below. When drafting them, the Partnership took care to align these aims with the provisions of Horizon Europe, Cluster 6, Intervention Area 3 (i.e. Agriculture, Forestry and Rural Areas), which broad advice is to address the following:

- Control of contagious and zoonotic animal diseases and assess and improvement of animal welfare.
- Prevention strategies, control measures, diagnostic and alternatives to the use of antibiotics and other substances/techniques to tackle AMR and threats from biological hazards.
- Tackling the links between plant, animal, ecosystems and public health from One Health-One Welfare and Sustainable Development Goals/Global-Health perspectives.

[20] Aquatic animals include marine and freshwater fish.

- Fostering international partnerships for sustainable agriculture for food and nutrition security.

The Partnership's objectives fit well with important initiatives and policies of the European Commission/Union:

- The Green Deal of the European Commission, notably the Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system, was adopted in 2020[21]. As part of it, the Commission planned to take action to reduce overall EU sales of antimicrobials for farmed animals and in aquaculture by 50% by 2030. The Commission also committed to revise the animal welfare legislation, including on animal transport and the slaughter of animals, to align it with the latest scientific evidence, broaden its scope, make it easier to enforce and ultimately ensure a higher level of animal welfare.
- As part of the Farm to Fork strategy, an Action Plan on the development of organic production was published early in 2021[22]. It will help to reach the objective of at least 25% of the EU's agricultural land under organic farming by 2030. Animal welfare will also play an important role in livestock and fish organic production.
- The Communication on the Future of Food and Farming[23] referred to "responding to societal expectations regarding food, in particular concerning food safety" … "The Common Agricultural Policy (CAP) should become more apt at addressing critical health issues such as those related to AMR … in line with an ambitious and encompassing approach with regard to human and animal health - as embodied by the One Health concept". "Identically the CAP can help farmers to improve the application of EU rules on animal welfare and to further increase standards through voluntary initiatives aimed at promoting the market value of animal welfare both within and outside the EU." The Farm to Fork Strategy recognises the role of the CAP in supporting the transition to sustainable food systems. In the context of and subject to the ongoing legislative procedure regarding the CAP, a new system is envisaged from 2023 whereby Member States will be able to use 'eco-schemes' to support a transition to better animal welfare[24].
- In its communication on the European Citizens' Initiative (ECI) 'End the Cage Age[25]', the Commission set out plans for a legislative proposal to prohibit cages/crates/stalls/individual pens for a number of farm animals (laying hens, rabbits, pullets, broiler breeders, laying breeders, quail, ducks, geese, sows, calves). The proposal will come as part of the ongoing revision of the animal welfare legislation. The Communication stated that Horizon Europe would help provide decision-makers and actors with additional scientific evidence, not least with the creation of a European Partnership on Animal Health and Welfare to be proposed for the 2023-2024 work programme.

[21] COM(2020) 381 final
[22] COM(2021) 141 final
[23] COM(2017) 713 final
[24] The list of potential agricultural practices that eco-schemes could support is available at https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/factsheet-agripractices-under-ecoscheme_en.pdf
[25] https://europa.eu/citizens-initiative/initiatives/details/2018/000004_en

- Replacement, reduction and refinement (3Rs) of animal testing is a long-standing objective of the European Directorate for the Quality of Medicines and Healthcare (EDQM)[26]. Needs for transition to reduced animal use in medicine development are increasing. On 16 September 2021, the European Parliament has adopted a resolution on plans and actions to accelerate the transition to innovation without the use of animals in research, regulatory testing and education[27]. In addition, there is the ongoing European Citizens Initiative on a Europe without animal testing, which will likely require new initiatives in this field[28].
- AMR is subject to an EU AMR action plan[29], with one pillar on research highlighting needs, notably in the animal production sector. A number of the EUP AH&W operational objectives are addressing these needs.
- Regarding the contribution of animal health to the preparedness of countries against cross-border and cross-sector infectious threats to humans, EUP AH&W will seek to cooperate as appropriate with relevant initiatives, in particular in the EU4Health programme, the future 'pandemic preparedness' and the 'One Health AMR' partnerships and the European Health Emergency preparedness and Response Authority (HERA)[30].

Animal infectious diseases do not respect frontiers and threaten the lives of animals, compromising their welfare, engender significant production loss, threaten the integrity and diversity of ecosystems, jeopardise the livelihood of farmers and the socio-economy of regions and nations, costing billions of Euros for control and mitigation and place human lives at risk. Therefore, improving animal health and welfare as planned by EUP AH&W will have both direct and indirect impacts on the main cornerstones of Sustainable Development, as well as on most, if not all, of its 17 SGDs but notably on the following ones:

Since the challenges described above are not restricted to the European continent, networking with international projects and initiatives will be sought and international cooperation developed as much as possible. Interaction with international stakeholders such as WOAH, FAO, WHO and UNEP, as well as international research alliances such as STAR-IDAZ International Research Consortium will enable such cooperation.

[26] https://www.edqm.eu/en/alternatives-animal-testing
[27] https://www.europarl.europa.eu/news/en/press-room/20210910IPR11926/meps-demand-eu-action-plan-to-end-the-use-of-animals-in-research-and-testing
[28] https://eci.ec.europa.eu/019/public/#/screen/home
[29] https://ec.europa.eu/health/sites/health/files/antimicrobial_resistance/docs/amr_2017_action-plan.pdf
[30] COM (2021) 576 Final

Vision and Ambition of the Partnership

The Vision

The vision of the EU Partnership on Animal Health and Welfare is to provide society with a sustainable livestock production sector. Infectious animal diseases are controlled with appropriate means, antimicrobials are used prudently, and animal welfare is respected in every phase of the production process, until death. This will be achieved through strengthened cooperation between public research and innovation entities, and collaboration with relevant partners, including relevant authorities, the animal health industry and other stakeholders such as NGOs.

The Ambition

The ambition of EUP AH&W is to build a strong research and innovation framework strengthening Europe's capacity to act on a preventive approach and raise healthy animals in sustainable systems that support a high level of animal welfare. It will bring together authorities responsible for and scientists active in the sectors of animal health, animal welfare, public health, food safety, economic sustainability and the environment. It will cover a large area of activities, such as farm management; animal based (welfare) measures; livestock resilience; zoonoses; vector-borne, food-borne pathogens and emerging diseases at primary

production; and other issues such as antimicrobial resistance. The mobilisation of resources from both RPOs and FOs together with EC co-funding will allow to achieve ambitious, cross-cutting, interdisciplinary and coordinated objectives at the transnational level.

The Intervention Logic of the Partnership

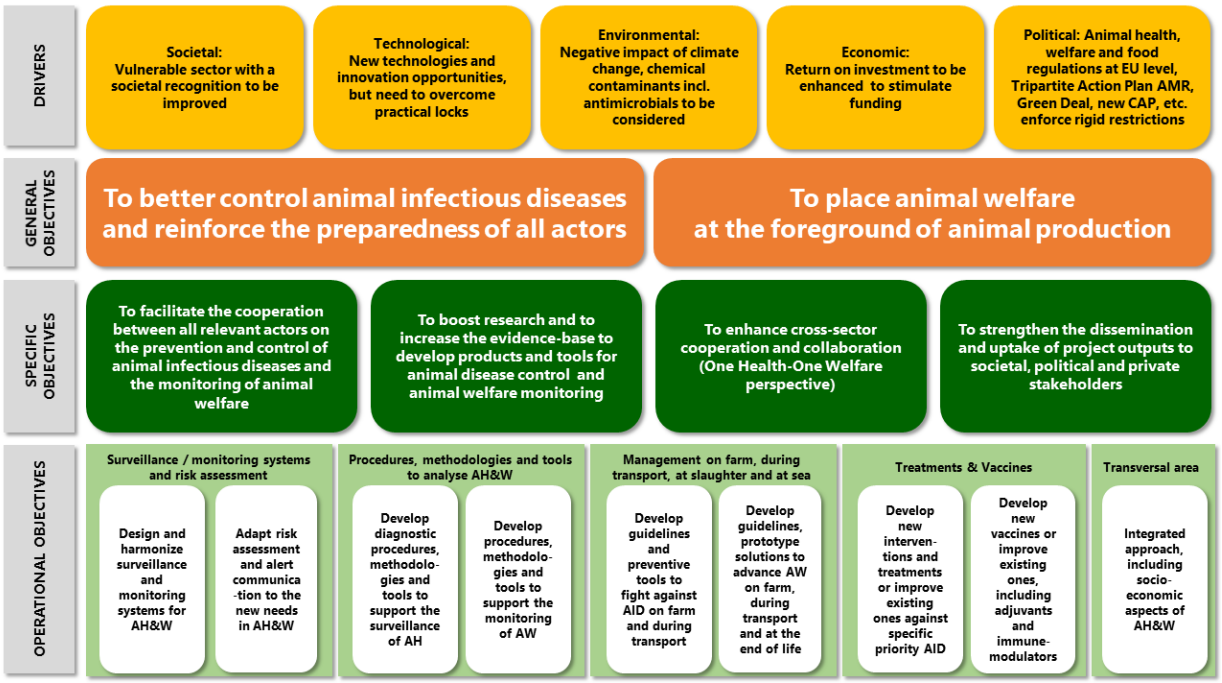
The EU Partnership on Animal Health and Welfare focuses on the following areas:

1. Regulated and emerging diseases for which prevention, monitoring and control have an important policy dimension because of their impact on animal health, food production/safety, regional or global trade and public health.
2. Priority endemic and production diseases, that cause detrimental economic losses to farmers and the animal production sector, may lead to reduced animal welfare, antimicrobial use and, consequently, risk to public health and health of ecosystems. Some of those diseases are often complex to control and some infectious diseases may be notifiable in a number of countries.
3. Animal welfare issues, such as those related to the European citizens' initiative 'End the cage age', in combination with the proposed revision of the European Union legislation on farm animal welfare (due Q4 2023). The aim will be to strengthen the well-being of animals and accommodate animals' needs, as well as meeting societal and political demands for better animal welfare, recognising that animals are sentient beings.

There is a growing interest from the market in animal welfare, including labelling and traceability of products as prioritised in the Farm to Fork strategy of the European Commission. Welfare monitoring and assessment, trade-offs between welfare, farm economy and environmental issues are included in the Partnership's efforts to make livestock production more sustainable, with higher standards of animal welfare. Main strengths of the Partnership Animal Health & Welfare are:

- Bring the main European actors together in a unique AH&W consortium that will support the European livestock sectors.
- Advance AH&W knowledge and perform a responsive, policy driven research.
- Contribute to implement the One Health and One Welfare concept.
- Reinforce the communication, dissemination and exploitation on AH&W to promote the uptake of expected outcomes and thus gain impact.
- Build on and collaborate with existing scientific and professional networks and stakeholders, including other relevant Horizon Europe Partnerships (through links with EU policies and other initiatives) and reach out to private partners.
- Perform both research (internal and external) as well as integrative activities to strengthen the collaboration among the European AH&W actors, to reinforce their preparedness, and to install aligned welfare initiatives.

The diagram below summarises the problems and drivers, as well as the general, specific and operational objectives of EUP AH&W.



The Intervention Logic. Please not that both General Objectives (GO) are related to all the drivers illustrated on top of the figure. Similarly, all Specific Objectives (SO) relate to both GO, and most of the Operational Objectives can be linked to all four SO. As for the expected impact, see paragraph 'The monitoring framework for assessing progress towards the objectives'

The general objectives of the Partnership

GO1. To contribute to better control animal infectious diseases and to reinforce the preparedness of all actors

Improved animal health surveillance, more accurate diagnostics, risk assessment tools adapted to new types of data, modern farming practices including efficient biosecurity management, and new or better vaccines/treatments, will lead to less production loss, decreased use of antimicrobials and reduced AIDs with possibly less spill-over of zoonotic infections and resistant germs to humans.

Suggested indicators:

- Reduced occurrence of some selected AID.
- Reduced use (sales as an estimate) of antimicrobials (especially critically important ones) in livestock/poultry production and aquaculture.
- Reduced burden (e.g. economic, societal) of some selected AID.
- An increase in available integrated data (epidemiological, clinical and genomic) on AID, both endemic and emerging and new ones.

GO2. To place animal welfare at the foreground of animal production

Mitigating or preventing risks to animal welfare addresses societal and political concerns, increases animal resilience to production stressors (including mild pathogenic challenges), and deepens the understanding of the links between animal health and welfare. Research on animal welfare will accompany the implementation and further development of the new European animal welfare legislation. It will also respond to the increased interest of food chain actors and consumers regarding market opportunities for improved animal welfare. Finally, a One Welfare approach will strengthen both human wellbeing and animal welfare and facilitate sustainable livestock production and aquaculture in general. In line with consumer and citizen expectations, measures to support positive welfare will be considered.

Suggested indicators:

- An increase in percentage of available data on trends of animal welfare at farm, transport, at slaughter in the EU for policy, commercial and scientific purposes (EFSA, WOAH, EU Reference Centres for Animal Welfare).
- Progress in the development of the revision of the animal welfare legislation, and subsequent implementation as measured through a reduction of inadequate husbandry systems and management practices.
- An increase in the number and size of animal welfare labelling systems in Europe, with emphasis on the voluntary industry lead initiatives.

The specific objectives of the Partnership

Based on the general objectives outlined above, the following four specific objectives are proposed.

SO1. To facilitate the cooperation between all relevant actors on the prevention and control of animal infectious diseases and the monitoring of animal welfare

Offering public and private players in the field of animal health and welfare the possibility to set up research and other kinds of integrative activities, training, capacity building and education actions, and to share experience, will lead to a reinforced cooperation that will support the realisation of the general objectives of EUP AH&W.

Potential indicators:

- Evolution of the number of stakeholders that are engaged in the EUP AH&W call organisation and experimental designs (e.g. industry, regulation).
- Evolution of the number of partners and/or countries that express interest in joining the Partnership.
- Expansion of the professional AH&W networks that will be created.

- Number of organizations taking part in joint integrative activities (as confirmed through e.g. MoU's and shared resources/infrastructures/tools such as biobanks), including those involved in e.g. risk assessment, agricultural economy, social sciences, ethology and veterinary issues.
- Number and value of joint integrative activities, other activities, i.e. harmonization of methodologies, ring trials, simulation exercises, labelling systems, short term missions, etc. between organizations and stakeholders, common webinar or meetings to exchange information and results.

SO2. To boost research and to increase the evidence-base to develop products and tools for animal disease control and animal welfare monitoring

Joint transnational research and other research and innovation activities will create new knowledge, methodologies, techniques, procedures, data and databases, models, system designs, insights, networks and products, etc. that will be available for further uptake.

Suggested indicators:

- Number and value of joint transnational calls organised, and number of projects selected for funding on this specific objective.
- Number of scientific papers/communications produced by EUP AH&W.
- Number of novel deliverables (i.e. methodologies, techniques, procedures, data, databases and data share, models, preventive/curative/diagnostic tools, etc.) produced.

SO3. To enhance cross-sector cooperation and collaboration (One Health-One Welfare perspective)

The contribution of EUP AH&W to a multidisciplinary approach across sectors will enable targeted actions contributing to sustain the health and welfare of animals, people and ecosystems. Approaches include e.g. the design and implementation of surveillance and monitoring systems, the harmonization of tools and procedures, the design of husbandry systems and management practices, the alignment of the risk assessment, etc. They will target sectors dealing with animal health and welfare, public health, food safety, farm economics and the environment regarding zoonoses, antimicrobial use and animal welfare.

Suggested indicators:

- Number of initiatives that are set up across sectors, i.e. regarding design and implementation of welfare monitoring and disease surveillance systems, laboratory methods, risk assessment, with EUP AH&W involvement and that support public health.
- Number of cross-sector EUP AH&W outputs, e.g. common publications, workshops, capacity building, etc.
- Number of contributions (e.g. reviews, studies, trials, etc.) from EUP AH&W to wider One Health-One Welfare initiatives like Tripartite + or other.

- Number of common actions with other relevant Partnerships and networks.

SO4. To strengthen the dissemination and uptake of project outputs to societal, political and private stakeholders

Upstream and continuous interaction with stakeholders to identify their needs and demands, general and targeted communication on the outputs of EUP AH&W, both dealing with animal health and animal welfare, dissemination of its deliverables to partners, national and international stakeholders, and to all other possible users, will stimulate their uptake and implementation all over Europe.

Suggested indicators:

- Number of EU reference laboratories for animal health and EU reference centres for animal welfare that implement and use outputs developed by EUP AH&W.
- Use of EUP AH&W outputs in reports/opinions of EFSA, ECDC and EEA, in global reference bodies (e.g. WOAH, FAO, WHO), in EU regulatory initiatives, EU and MS welfare labelling schemes, regarding treatments/vaccines by the European Medicines Agency (EMA).
- Number of EUP AH&W outputs taken up by livestock industry and other end users: Intellectual Property Rights/ patents/ marketing authorisations secured, filed or granted or in progress.
- Number of guidelines or methodologies taken up by farmer associations or sectors, etc.
- Increase in the number or proportion of research projects from open calls in which an industrial partner is involved, compared to ERA-NETs (target 30%).
- Number of innovations that have been brought to a high(er) TRL (Technology Readiness Level).
- Number of leaflets, newsletters, website visits, meetings and webinars with the contribution or participation of external participants.

The Partnership's Priority Areas

The above mentioned general and specific objectives have been transposed in nine Operational Objectives (see diagram above). In this section, these Operational objectives are grouped in the four high-level Priority Areas defined in the introduction section, i.e. surveillance / monitoring systems and risk assessment; procedures, methodologies and tools to assess AH&W; management on farm, during transport, at slaughter and after fishing; and finally, treatment and vaccines. The priority areas can be seen as successive, multi-disciplinary steps from detection and characterization of health and welfare issues to actions in the field for prevention and recovery.

Please note. *For each of the actions a recommendation regarding the corresponding activity is proposed, 1) to indicate if the activity should be of research or integrative nature, and 2) to indicate whether it is a priority, meaning that the activity should be initiated in the first two years of the partnership. The EUP AH&W will consult with the Authorities, Funding and Research Performing organizations (i.e. its Governing Board) to define the specific domains on which the research and integrative work will be based.*

Priority Area: Surveillance / monitoring systems and risk assessment for animal health and welfare

For this area there are two Operational Objectives, i.e. dealing with the monitoring and surveillance systems for animal health and welfare, and the methodologies needed for risk assessment, alert systems and communication.

OO1. Contribute to design and harmonize surveillance and monitoring systems for animal health and welfare

Surveillance systems for animal infectious diseases or monitoring systems for animal welfare are the basis of the prevent-detect-respond approach. As defined by the WOAH Terrestrial and Aquatic Animal Health Code, animal health surveillance aims at demonstrating the absence of infection or infestation, determining the presence or distribution of infection or infestation, or detecting as early as possible exotic or emerging diseases. A surveillance system represents a tool to monitor disease trends, to facilitate the control of infection or infestation, to provide data for use in risk analysis, for animal or public health purposes, to substantiate the rationale for sanitary measures and for providing assurances to trading partners. The type of surveillance to be applied depends on the objectives of the surveillance, the available data sources, and the outputs needed to support decision-making.

For animal welfare, as a starting point for a surveillance system, it is highly relevant to collect data on the overall welfare status of livestock and aquatic animals, as is real time information on the occurrence and prevalence of specific welfare issues. Whilst overall strategic decisions can be taken on the general status of welfare in a region or MS, temporary measures (e.g. regarding transport conditions) or risk-based inspections by competent authorities will benefit from reliable real time information on husbandry circumstances and / or associated welfare consequences. However, in particular because most data will ultimately be used for benchmarking purposes, it is important that the collection procedures and the type of indicator are standardised. For animal welfare, data collection in a standardised and harmonised way is a key development to do before monitoring and

surveillance systems can be put in place (see OO4). Still, monitoring and surveillance should be addressed and resolved within the lifetime of the Partnership.

Action 1. Optimize and extend to other countries current surveillance systems for animal health and zoonotic infections ***(Integrative activity, beyond first 2 years)*** and to develop new ones where needed. ***(Research, beyond first 2 years)***

Action 2. Set up a European wildlife network (for both terrestrial and aquatic animals), based on existing wildlife disease surveillance and reporting systems, to coordinate and expand their activities, to analyse wildlife populations in Europe, and to analyse what specific data with reference to potential threat to livestock, aquaculture and humans are needed. ***(Integrative activity, first two years priority)***

Action 3. Create networks that bring together epidemiology, sequencing data including metagenomics and bio-informatics to integrate in a harmonized and aligned way epidemiological, clinical and genomic data, applicable to both livestock/aquaculture and wildlife. ***(Integrative activity, beyond first 2 years)***

Action 4. Surveillance of pathogens of veterinary importance (that are not covered in One Health calls) and their antimicrobial resistance profiles. ***(Integrative activity, first two years priority)***

Action 5. Build networks and develop databases for surveillance of livestock and aquaculture, and implement the FAIR principles for the monitoring of (re)emerging animal health and welfare issues, and to develop a hazard monitoring and early warning service. ***(Integrative activity, beyond first 2 years)***

Action 6. Create a knowledge platform in the EU with the objective to collect, analyse, share and use integrated scientific and technical data on animal welfare, to support all stakeholders. ***(Integrative activity, beyond first 2 years)***

Action 7. Monitor in real time the incidence of specific welfare issues or husbandry conditions that affect animal welfare, to support impact assessment in relation to policy objectives. ***(Integrative activity, beyond first 2 years)***

Suggested indicators:

- Number and extent (and evolution) of networks and reports related to surveillance of health and monitoring of welfare in livestock, aquaculture and wildlife.
- Number of guidelines concerning (that include?) genomic surveillance of AIDs or AMR in animal pathogens.
- Number of pilot studies on novel or improved methods and tools for monitoring and surveillance, and number of participants in those studies.
- Number of new databases on AH or AW established.
- Number of dashboards (inventories) with integrated data and functionalities for real-time management implemented.

OO2. Contribute to adapt risk assessment and alert communication to the new needs in animal health and welfare

In addition to surveillance and monitoring, attention should be given to alert signalling, communication and risk assessment. The extensive movement of both livestock and wild animals, their products, other goods and people around the world facilitates the spread of infectious agents, which underlines the need for efficient exchange of health-related information between relevant stakeholders, from local health units to governments and international agencies. Similarly, the changing political, legislative and economic climate related to husbandry conditions and animal welfare will require a constant monitoring of hazard – consequence relations for risk assessment purposes. To share AH&W data in an efficient and sufficiently transparent way and to set up sensitive alert systems, modern platforms, tools and models are necessary, especially when it comes to the inclusion of new kind of data related to genomics and / or sequencing, climate, movements, post slaughter assessments, etc. Coordinated research and other activities will help aligning of existing methodologies and improving them. It will strengthen the preparedness of the partners to prevent and respond to new and emerging animal infections and changing circumstances for animal husbandry, that will support national and EU policy development on AH&W.

Action 1. Improve rapid risk assessment methodologies regarding the economic, social, environmental and cross sectoral consequences of animal health and welfare issues. ***(Research, first two years priority)***

Action 2. Study and assess epidemiological associations between human interventions such as hunting, trade, transport, rewilding and translocations of wildlife and disease spread, in order to propose harmonized tools to prevent spread of infections and support alert systems. ***(Research, beyond first 2 years)***

Action 3. Adapt existing, or develop new methodologies to integrate genomic surveillance data in risk assessment ***(Research, first two years priority)*** and to draft risk assessment guidelines ***(Integrative activity, beyond first 2 years)*** for the integrated use of epidemiological and genomic data.

Action 4. Assess the risk of spread of AMR in veterinary pathogens and genes encoding resistance. ***(Research, beyond first 2 years)***

Action 5. Build or further map and coordinate emergency networks for scientists and communities, to increase risk knowledge by systematically collecting data and undertaking risk assessments (availability of risk maps and data, knowledge on hazards and vulnerabilities). ***(Integrative activity, beyond first 2 years)***

Action 6. Based on animal welfare surveillance systems (and their evaluation), develop indicators and alarm levels, produce factsheets and any relevant digital infrastructure and methodologies that enable risk assessment of any breach in animal welfare. ***(Integrative activity, beyond first 2 years)***

Suggested indicators:

- Number of existing assessment networks, methods, tools, data and protocols mapped, described and analysed.
- Number of new assessment guidelines and models.
- Number of risk assessment dashboards with integrated data and functionalities for real time management implemented.

Priority Area: Procedures, methodologies and tools to analyse animal health and welfare

Many of the currently used detection, monitoring and characterization methods for several health or welfare issues are not optimal and need improvement, and more accurate diagnostic platforms should be developed. Furthermore, standardisation and harmonisation of diagnostic methodologies, capable of detecting, identifying and characterising pathogens (including emerging ones) with high and proven diagnostic reliability (diagnostic specificity and sensitivity in particular) is very important. Similarly, to obtain real-time, quantitative data that correctly and reliably indicate welfare problems requires appropriate and agreed animal based or management-based measures. In addition, for benchmarking purposes across farms or regions, the methodology of assessment needs to be standardised (e.g. in relation to season, time of day, sample sizes, category of animal).

At the same time, new opportunities become available in the form of emerging scientific disciplines and advanced technologies such as data science and bioinformatics, artificial intelligence, OMICS technologies, precision farming technologies and advanced in-line sensory systems at abattoirs and during transport. Such advanced precision farming technologies cannot only detect any new and emerging diseases and welfare hazards, they can also be applied to monitor entrenched diseases or endemic widespread welfare issues. All the above would help transition from a curative approach to the application of more preventive measures with new and improved diagnostics and assessment schemes.

Two Operational Objectives cover the priority area of procedures, methodologies and tools to support the surveillance and monitoring for both animal health and welfare.

OO3. To develop diagnostic procedures, methodologies and tools to support the surveillance of animal health

Action 1. Gain knowledge on priority pathogens (i.e. bacteria, parasites, viruses, fungi, prions, including resistance patterns) and infectious diseases responsible for important economic losses or high risk of transmission to humans, and their detection methods (including metagenomics approaches, molecular markers of interest, etc.) with the aim to identify possible diagnostic markers. ***(Research, first two years priority)***

Action 2. Development, optimisation and standardisation of reliable, faster, potentially automatable and/or scalable direct (antigen/genome amplification/detection) and indirect

(detection/immune response) assessment tools/technologies; tools for the rapid detection of drug-resistant bacteria, viruses, fungi or parasites; on-farm, pen-site diagnostics for pathogens and antimicrobial resistance; focus on priority pathogens and those that do not have EURL. ***(Research, first two years priority)***

Action 3. Development, optimisation and standardisation of tools to distinguish between (i) infected and vaccinated individuals (DIVA) as well as (ii) presence of unviable or infectious pathogens to study the pathogens' survival in the environment or in effluents and (iii) to study inter- species (including wild animals) circulation of pathogens or resistant variants. ***(Research, first two years priority)***

Action 4. Development of quantitative and multi-target diagnostics to identify infection levels and microorganisms that can interfere with decisions regarding the treatment or prevention of enzootic production diseases in livestock and aquaculture. ***(Research, beyond first 2 years)***

Action 5. Development of non or less invasive and more convenient sample collection methods, including new matrices as well as sample transport and storage, and corresponding diagnostic tools, also suitable for the detection of diseases in free-ranging or wild animals. ***(Research, beyond first 2 years)***

Action 6. Study host-pathogen- environment interactions, i.e. focusing on drivers and markers, on characterisation of microbial ecosystems, on drivers of pathogenicity or resistance. ***(Research, beyond first 2 years)***

Suggested indicators:

- Number of scientific publications (general, across pathogen-types, across animal species, considering AH & AW integration, considering One Health).
- Number of new markers for e.g. host response/vaccine efficacy, drug resistance/efficacy, variants, zoonotic potential, infectivity/virulence, etc.
- Number of new diagnostic procedures validated and/or harmonized.
- Number of new reagents / diagnostic kits developed, optimised, automatized and/or harmonised.
- Number of new biobanks, stocks of reference materials, models etc. to be shared with other partners.

OO4. To develop procedures, methodologies and tools to support the monitoring of animal welfare

Action 1. Further develop the research area of 'positive welfare' (including positive emotions), through the identification and validation of animal-based measures (e.g. behavioural, endocrine and neurological indicators. Research will focus on cognition, preference testing and strength of motivation to obtain rewards. ***(Research, beyond first 2 years)***

Action 2. Development of technologies on the slaughter line to assess animal welfare on farm and/or during transport. Identification of suitable ABM with appropriate level of validity,

sensitivity and specificity; development of in-line sensors, large scale data collection. ***(Research, first two years priority)***

Action 3. Livestock and fish welfare at slaughter and when killing for e.g. disease control and emergency killing; development of technologies, procedures and/or protocols to increase the reliability of methods which assess consciousness and death. ***(Research, first two years priority)***

Action 4. Development of ABM to measure negative animal welfare consequences (e.g. pain, fear or discomfort at individual and group level). These could include behavioural measures, but also measures of physiological stress, impact on immune response and omics (e.g. transcriptomics and metabolomics) ***(Research, beyond first 2 years)***. Standardisation and integration of these indicators should allow inclusion in welfare assessment tools ***(Integrative activity, beyond first 2 years)***, which can be followed up by Activity 7 of OO1 and Activity 6 of OO2.

Action 5. Development of digitally assisted monitoring technologies on farms for increasingly enabling precision management of animal health and welfare. Technology includes visual and auditory surveillance of animal-based measures for welfare, analysing records with deep learning technology, data processing techniques and decision support systems. ***(Research, beyond first 2 years)***

Action 6. Development of technologies to assess animal welfare during transport. Affordable and reliable solutions to prevent serious welfare problems through early detection of signals before and whilst in transit, e.g. lameness, lesions, heat stress, aggression, thirst or hunger, exhaustion, etc. Development of sensor technology, data analysis tools, data collection and integration platforms, decision support for the driver; related staff training. ***(Research, first two years priority)***

Suggested indicators:

- Number of scientific publications on the assessment of welfare on farm, during transport and at slaughter or stunning and killing after fishing.
- Number of new welfare indicators and markers endorsed by the animal welfare community.
- New guidelines and tools, e.g. for welfare diagnosis, for monitoring positive animal emotions, etc.

Priority Area: Management and husbandry guidelines on farm including aquaculture, during transport and at slaughter

Increased productivity, intensification and stocking density, with the aim to satisfy the global protein demand and act on the climate challenges, brings along an augmented risk of production-related disease and welfare problems, frequently multifactorial in nature, and associated with biogenic factors as well as farming methods and management factors.

Mitigating or removing animal welfare challenges on farm, during transport and at the end of life increases resilience to diseases that impair productivity. In addition, it addresses a growing societal concern about the level of welfare in livestock and aquatic production *per se*. The European Citizen's Initiative 'End the Cage Age' and the EC's intention to revise the animal welfare legislation are strong drivers for change regarding livestock husbandry practices and will have to be dealt with by policy makers as well as the industry in the coming decade and beyond. Research and practical results are needed to facilitate the further development and implementation of these developments and will contribute to reinforce the interest of all food chain actors and of the consumers in a sustainable livestock sector. Research should involve all aspects of the animal's life: on farm, during transport and during slaughter, and it should address the trade-offs that exist between animal welfare, environmental impact and the economy of the production chains.

Two Operational Objectives cover this priority area, i.e. OO5 and OO6.

OO5. To develop guidelines and preventive tools to fight against animal infectious diseases on farm and during transport

Action 1. Establish a multidisciplinary network of experts with focus on biosecurity measures to prevent and control AID on farm and during transport. Draft foresight and priority studies on animal health, public health, pandemics and the role of biodiversity, the changing climate, emerging vectors and vector-borne diseases, bird and fish migrations, epidemiology / modelling, bioinformatics, etc. for all animal species, including minority species and aquaculture. ***(Integrative activity, first two years priority)***

Action 2. Reduce the entrance and spread of AID by reinforcing external and internal biosecurity in both terrestrial and aquatic animals, while limiting antimicrobial use, set up innovative systems and models with focus on biosecurity and integrated management. ***(Integrative activity, beyond first 2 years)***

Action 3. Perform research on prudent use of antimicrobials: research on treatment concepts for antimicrobial and antiparasitic usage, on alternatives to antimicrobials including feed additives/nutrition, studying improved vaccination strategies, etc.; development of best practices for administration/application of Veterinary Medicine Products (VMP) in livestock and aquaculture production systems. ***(Research, first two years priority)***

Action 4. Reinforce animal resilience (the natural ability of animals to withstand pathogens), through fundamental and applied research addressing e.g. animal feeding and breeding. ***(Research, first two years priority)***

Action 5. Establish a pan-European network of experts in genetics (breeding), feed additives including pre- and probiotics, applied ethologists, stress physiologists and leading experts in immunology to produce foresight and priority reports on improving animal resilience. ***(Integrative activity, beyond first 2 years)***

Suggested indicators:

- Number and evolution of foresight reports
- Number and evolution of collectively endorsed guidelines on biosecurity measures
- Contribution to AM stewardship initiatives
- Number of research projects on animal resilience launched in EUP AH&W
- Number of new concepts / knowledge produced by EUP AH&W and endorsed by breeding companies.

OO6. To develop guidelines and prototype solutions that advance animal welfare on farm, during transport and at the end of life

Action 1. Establish a multidisciplinary network of experts to draft foresight and priority studies with focus on sustainability aspects related to non-cage systems, indoor and outdoor systems for livestock, animal transportation and slaughter, killing on farm, in slaughterhouses or stunning and killing after fishing, and focussing on ending mutilations, including aquaculture production systems. ***(Integrative activity, first two years priority)***

Action 2. Perform research on how to improve animal welfare while maintaining or increasing farm economic and environmental sustainability. Aims to develop innovative housing systems and addresses the opportunities and consequences of reducing the use of cages in a sustainable way, in terms of economic and environmental impacts. ***(Research, beyond first 2 years)***

Action 3. Perform research on how to improve animal welfare through better understanding of animal cognitive capacities and emotions adapted to each species' needs, opportunities for pain relief, and environmental enrichments technologies. ***(Research, first two years priority)***

Action 4. Develop appropriate livestock and fish stunning and killing techniques to limit pain and reduce stress during slaughter after fishing or in the abattoir, as well as during on farm killing for e.g. disease eradication purposes or euthanasia. ***(Research, first two years priority)***

Action 5. Develop innovative systems for the transport of livestock and fish. ***(Research, beyond first 2 years)***

Action 6. Improve animal welfare through novel husbandry systems including innovative feeding and breeding strategies. Develop nutritional solutions to mitigate prolonged hunger and undesirable behaviours (e.g. broiler breeders, breeding sows) or metabolic and physiological problems (e.g. veal calves, high producing dairy cows). Address the relevance of genetics to reduce wide spread behaviour problems (e.g. tail biting, feather pecking), optimise breeding programmes for welfare (e.g. addressing piglet mortality, leg health issues in broiler). ***(Research, first two years priority)***

Action 7. Set up a pan-European network of experimental farms, which will serve as 'beacons' or demonstration facilities for practical solutions to animal husbandry issues. The network

should cover different species including fish, as well as a range of husbandry conditions present in various regions of Europe. ***(Integrative activity, beyond first 2 years)***

Suggested indicators:

- Foresight reports
- Number of management- and resources-based indicators for animal welfare.
- Number of new welfare technologies on farm, during transport and at slaughter.
- Number of welfare technologies brought to higher TRL levels.
- Number of experimental farms being active part of the network

Priority Area: Treatments & vaccines

Vaccination of animals is often the most cost-efficient measure to prevent and control the spread of AID and can be an important tool to reduce the burden of certain diseases and reduce the use of antimicrobials. With modern technologies and vaccine platforms (e.g., mRNA vaccine technology or multimeric scaffold particles) the efficacy of existing vaccines may be further improved. Production of new vaccines and improvement of existing ones will require significant scientific advances, such as new approaches to antigen selection and production, antigen delivery, improved adjuvants, vaccine administration, and new insights in the immune system function before products can be commercialised.

Research into vaccines and treatments addresses a great number of global challenges. They include e.g. the controlled risk of emerging and enzootic diseases, the limited spreading of resistance against antimicrobials including antiparasitic drugs and the challenge to combine an increasing supply of animal protein with high standards for animal welfare. These broad priorities need to be translated in concrete roadmaps and activities enabling research groups across Europe to turn research results (TRL 2-4) into innovations (TRL 4-7, including proof of concept in target species in controlled challenge and field trials). The innovations should respond to clear market and societal needs and should be the basis for new health applications that reach the market via industrial programs or via the EIC within Horizon Europe.

The following three Operational Objectives (OO7, OO8 and OO9) cover the priority area of interventions, and are described below.

OO7. To develop new interventions and treatments, or improve existing ones, against specific priority animal infectious disease

Action 1. Perform basic research (TRL 1-2) to study interactions between pathogens and host microbiome, focussing on the immune system and trained immunity, and direct or indirect interactions between pathogens (e.g. co-infections), antimicrobial and antiparasitic drugs and

host microbiome, mechanisms of anti-microbial (antibiotic and antiparasitic) resistance, where not covered by EUP AO-AMR ***(Research, first two years priority)***

Action 2. Develop tools such as (i) experimental farm approaches; (ii) in vivo, in vitro and in silico infection models for testing efficacy and safety of new drugs with reduced need for animal testing, new drug-delivery devices, therapeutics including leads for new antimicrobials; and (iii) bioinformatic pipelines for analysis of microbiome and pathogen data; this will be done in collaboration with industry, where appropriate. ***(Research, first two years priority)***

Action 3. Build on the results of Action 1&2 to develop or improve interventions and treatments and deliver first proof of concept, where appropriate, in collaboration with industry: demonstration of immunogenicity and efficacy (minimum immunizing dose) in target species; representative (small scale) animal (challenge) model (TRL 3-4). ***(Research, beyond first 2 years)***

Action 4. In collaboration with industry: bring outputs to higher TRL in early/pre-clinical development (GMP-material; TRL 5-6); (i) for non-food animals: demonstration of efficacy and field safety at large scale in representative animal models or approved alternative methods; (ii) for food animals: lab-scale assessment of animal safety and initiation of environmental safety, user safety, and (if needed) microbiological safety assessments; absence of toxicity/side effects; carcinogenicity studies initiated if needed, and demonstration of efficacy and field safety at large scale in a representative animal model and toxicology studies. Work on TRL 7 to 9 (late/clinical development, marketing authorisation and lifecycle management) will be performed by industry itself. ***(Research, beyond first 2 years)***

Suggested indicators:

- Number of evidence-based treatment schedules.
- Number of publications addressing the physiopathology of co-infections.
- Number of novel drugs, immune-modulators, alternatives to antimicrobials.
- Number of devices for individual and group treatment of animals.
- New tools such as improved (and standardized) assays for assessing efficacy and safety of drugs.

OO8. To develop new vaccines or improve existing vaccines, including adjuvants and immune-modulators

Action 1. Study the role of the immune system of farm animals, including the innate immune capacity of new-born animals and using high-end technologies (e.g. transcriptomics/singel-cell sequencing); the mechanisms that elicit protective immunity at the entry site, factors affecting immune response to vaccines, mode of action of adjuvants (basic research; TRL 1- 2). ***(Research, first two years priority)***

Action 2. Develop tools such as vaccine platforms and expression systems, immunological toolboxes (cell lines, reagents, etc.) and delivery systems, etc.; this will be done in collaboration with industry, where appropriate. ***(Research, first two years priority)***

Action 3. Build on the results of Action 1&2 to develop or improve vaccines and immune-modulators and deliver proof of concept: demonstration of immunogenicity and efficacy (minimum immunizing dose) in target species; representative (small scale) animal (challenge) model (TRL 3-4) or approved alternative methods; this will be done in collaboration with industry, where appropriate. ***(Research, beyond first 2 years)***

Action 4. In collaboration with industry: bring outputs to higher TRL in early/pre-clinical development (GMP-material; TRL 5-6); (i) demonstration of animal safety in target and non-target species; and (ii) demonstration of efficacy in a representative and validated target animal challenge model. Work on TRL 7 to 9 (late/clinical development, marketing authorisation and lifecycle management) will be performed by industry itself. ***(Research, beyond first 2 years)***

Action 5. Develop methods and procedures for comparative evaluation of clinical efficacy of veterinary antimicrobials to feed into antimicrobial guidelines and policies. ***(Integrative activity, first two years Priority)***

Suggested indicators:

- Number of models, immunological and computational tools.
- Number of publications regarding a better understanding of the immune response of targeted animals.
- Number of potency tests to evaluate efficacy of vaccines (3Rs).
- Number of new pilot vaccines and adjuvants developed.
- Number of vaccine platforms, platforms for antigen discovery, production and delivery.
- Number of new or improved delivery systems.
- Number of new immune-modulators developed.
- Number of procedures for comparative evaluation of clinical efficacy of veterinary antimicrobials.

Transversal Priority Area: Integrated approach, including socio-economic aspects of animal health & welfare

This priority area consists of one Operational Objective OO10 on socio-economic aspects, which cannot be seen independently from the other Operational Objectives. The socio-economic research and integrative activities that will be developed will be embedded in the other priority areas. They will cover the surveillance and monitoring systems, the diagnostics for health and assessments for welfare, risk assessment and management, etc. In particular, this transversal priority area will look at any potential trade-offs that may exist between the improvement of animal health and animal welfare through new production methods on one hand, and the environmental and societal impact on the other hand. Therefore, these activities will support AH&W policy making and the sustainability of the European livestock industry.

In some of the Operational Objectives and Actions above reference is made to socio-economic aspects. Here, the emphasis is put on the general dimension and added value of a socio-economic approach in all priority areas of the EUP SRIA.

OO9. To develop an integrated approach on animal health and welfare including socio-economic aspects

Action 1. Assess the economic and societal burden of selected priority diseases (including resistant pathogens), including their control (e.g. cost-benefit of different surveillance components and risk mitigation options). ***(Research, first two years priority)***

Action 2. Assess the socio-economic consequences of the possible changes in livestock and fish farming that may result from e.g. changes in citizen demand regarding animal welfare or that may be an effect of new legislative requirements. ***(Research, first two years priority)***

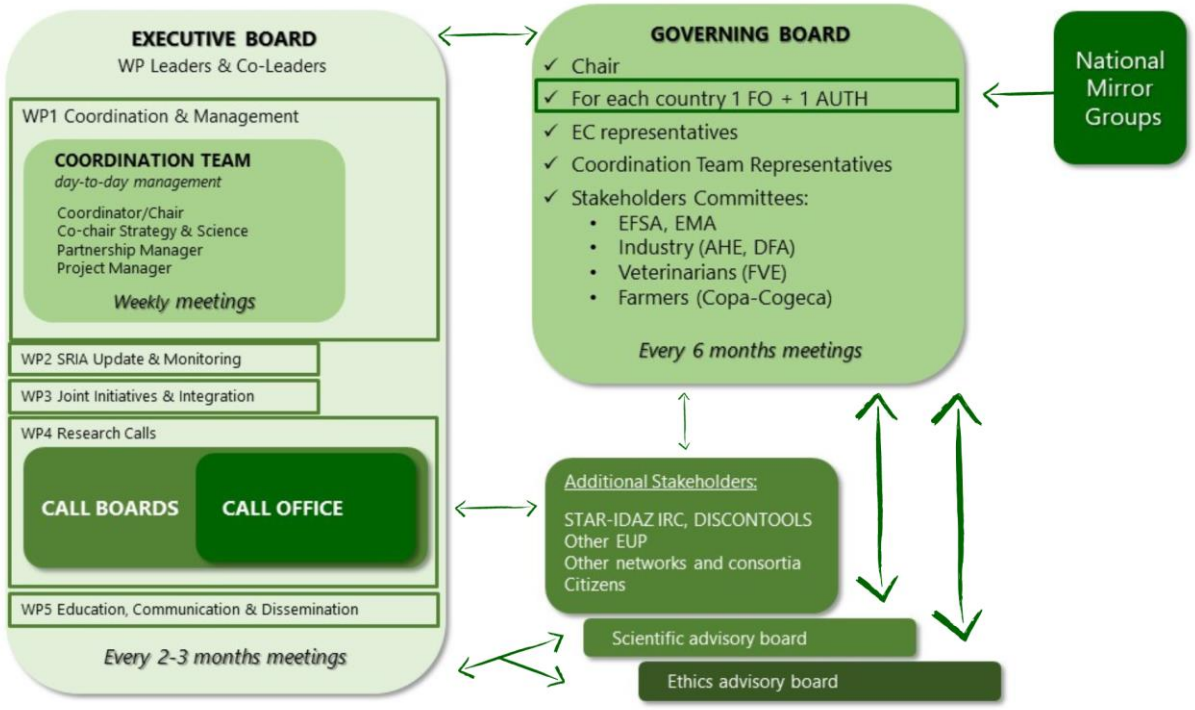
Action 3. Set up social science studies among farmers, consumers and other actors along the production chain on their behaviour (also in relation to AM use) to maintain and improve animal health and welfare, including consumers' willingness to pay for improvements; incentives and barriers to adopt innovations and practices including health- and welfare labelling schemes. ***(Research, first two years priority)***

Action 4. Develop appropriate solutions to facilitate the integration of AID mitigation measures and improved animal welfare and resolve potential trade-offs in the overall context of sustainable livestock production and aquaculture in the EU. ***(Research, beyond first 2 years)***

Action 5. Develop integrated strategies for policy development regarding the control of diseases, including emergency situations regarding animal diseases and zoonoses. This should take into account relevant criteria, such as the epidemiological situation, the cost vs benefits, etc., and will support decision making by national and international risk managers and other relevant stakeholders. ***(Integrative activity, beyond first 2 years)***

Suggested indicators:

- Number of scientific publications on socio-economic studies related to health and welfare.
- Number of data available about the costs of AID to leverage funding.
- Number of new animal welfare labelling schemes initiated by MS and / or industry.
- Number of policy briefs on intervention strategies.



The proposed Organization and Governance of the Partnership

The **Governing Board (GovB)** is the decision-making body of the EUP AH&W that meets every 6 months. It is composed of

- representatives of each beneficiary country who signed the Grant Agreement. For each participating country, two representatives (one FO and one Authority) designated by their national mirror group (if existing).
- representative of the responsible EC-Directorate General.
- European Food Safety Authority (EFSA).
- European Medicines Agency (EMA).
- the industry (Animal Health Europe (AHE) and Diagnostics for Animals (DFA)).
- veterinarians (Federation of Veterinarians of Europe FVE).
- farmers (Copa-Cogeca).
- representatives of the Coordination Team.

The GovB decides on the activities (see below 'strategic document') that should be implemented, the annual Work Programme (WPR, deliverables of the partnership) and the related budget to achieve the partnership's objectives. Other responsibilities of the GovB include partnership membership and a role in arbitrage in case of complaints about the call procedure. The GovB appoints a chair and a vice-chair representing the partnership as necessary.

The **Executive Board (EB**) implements the actions approved by the GovB and will meet every 2-3 months (or when needed). In accordance with the EUP AH&W SRIA and the WP description, it proposes activities bundled into a 'strategic document' to the GovB. This strategic document will include (1) suggested domains of activities (overall scope, not specific topics or activities) and their assignment to the internal programme (integrative or joint activities) or research (internal or external calls), (2) a proposed budget, and (3) a proposed timing of implementation. The EB will execute the decision of the GovB on the proposal of the strategic document, the activities that should be included in the WPR and the related budget. The Executive Board discusses the results/impact of the EUP and prepares a document to present to the GovB. This document contains an overview of the results/outputs and impact and suggests actions to be prepared and executed by the **WP Education, Communication and Dissemination** (both internal to the beneficiaries as external (e.g. to stakeholders and the general public).

Each WP is represented in the EB:

- The **WP Coordination & Management** is responsible for the overall coordination and day-to-day management. It also takes care of legal tasks, like the Consortium Agreement's updates and amendments to the Grant Agreement. It comprises the Coordinator, a co-chair Strategy & Science, a partnership manager and several project

managers in its Coordination Team who meets frequently (weekly). Other members of this WP include financial officers, administrative assistant, UGent EU-Team members, legal and innovation officers. This team has expertise in administrative, legal and financial EU project management.

- The **WP SRIA Update and Monitoring** provides proposal of activities to be scheduled in the WPR based on the SRIA and the WP description of the partnership. When necessary, it proposes updates to the SRIA. It does this based on input received during interactions with the members of the EUP (FO and RPO), the stakeholders and the Scientific Advisory Board. To facilitate these interactions, they are supported by WP Education, Communication and Dissemination. The WP SRIA Update and Monitoring monitors at the level of the whole partnerships which indicators, impacts and results in relation to the objectives of the EUP have been reached and if the SRIA/WPR needs an update and reports to the EB.
- The **WP Joint Initiatives and Integration** is responsible for the activities in the internal program. This WP is responsible for drafting an "invitation to collaborate" to the RPO in the EUP and may seek advice from the stakeholders and Scientific Advisory Board. It consults the RPO of the partnership on their interest to contribute to the proposed activities and on the proposed budget. It provides a proposal of internal RPO who will perform the activities to the Executive Board who will approve or adapt. The final consortium of RPO needs to be approved by the GovB.
- The **WP Research Calls** is responsible for the internal and external research calls. For *internal calls*, the **Call Board** is composed of the WP Research Calls Lead and authorities. It defines specific topics and call text and monitors progress and outputs (milestones and deliverables) of Partnership projects until the final report. For *external calls*, the **Call board** is composed of the WP Research Calls Lead and FO who wish to fund the activities/topics in the call. It defines specific topics and call text and monitors progress and outputs from projects until final report. For both internal and external calls, the **Call Office** organises the calls (announcement, submission, reporting). The WP Research Calls monitors the results of individual projects and provides an overview of the milestones & deliverables and results/outputs generated in individual projects and presents this to the WP SRIA Update and Monitoring and to the EB.
- The **WP Communication, Dissemination, Exploitation and Capacity Building** will contribute to strengthening European collaboration and achieving scientific excellence in the related domains. Developing and applying a dynamic and flexible approach, it will support to maximise the utilisation of the achievements not only by direct potential beneficiaries but also by further stakeholders, policy and decision makers, and other researchers to generate new cycles for innovation. It will raise societal awareness on the impact of the research carried out in the framework of this partnership.

The **Ethics Advisory Board** are independent, external observers consulted for all potential issues of conflict of interest.

The Monitoring Framework for Assessing Progress towards the Objectives

The monitoring of the progress of the activities within the research and non-research projects will be done through the production of reports, databases, procedures, etc., which are deliverables that the corresponding work packages will monitor. Being a strategic document, this EUP SRIA does not contain specific deliverables but describes the planned actions that are linked to the Partnership's operational objectives. The EB will monitor the progress of the research and non-research (i.e. reference, integrative and joint) achievements of the Partnership for each of the priority areas (i.e. surveillance / monitoring and risk assessment of animal health and welfare; procedures, methodologies and tools to analyse AH&W; management and husbandry guidelines on farm, during transport, at slaughter and at sea; and treatments and vaccines), which are linked to the operational objectives. To measure the effect of the actions and activities, their outcomes must be disseminated and exploited first. The possible uptake, diffusion, deployment, and/or use of the project's results by direct target groups will be encouraged, facilitated where possible, and followed up through a convenient monitoring tool in close collaboration with the appropriate work packages.

Under the chapter 'The Intervention Logic of the Partnership' indicators for the general, specific and operational objectives are proposed. The most appropriate and feasible KPI will be selected (amongst suggested indicators for each OO) and new ones may be proposed. The data source will be identified and the KPI will be calculated. In addition, the EC Services made certain general KPI mandatory for all EUP.

The Partnership should make progress everywhere in Europe and in all priority areas. To this end, criteria must be established in addition to the even distribution across the operational lines, for instance the even geographic spread of the activities across Europe, the involvement and engagement of all partners in the activities, the balanced involvement of not only RPO, but also FO and authorities, work on terrestrial animals and aquaculture, incl. minority species, etc.

The procedures that identify all actors and that describe their interaction in order to monitor the progress of the Partnership activities are planned.

Expected outcomes of priority activities (first 2 years of the Partnership)

The main expected outcome of the EUP AH&W is an integrative approach to animal health and animal welfare in Europe, during its lifetime and even beyond. "Integrative" means to bring together actors from different backgrounds (citizens, farmers, scientists, economists, etc…) to share their views, data and developed benefits. For instance, by the end of the Partnership it is expected that within the animal welfare area a common terminology, standardised and agreed indicators are defined for data collection and that methodologies & network are established for further monitoring and surveillance in the EU has learned a lot from the methodologies, networks, etc. of health, and that a common terminology will be used. The construction of this AH&W continuum is a strong expectation from the Partnership. Another likely outcome is the balanced integration of socio-economics aspects in all the priority areas, from surveillance and monitoring, diagnostics and assessment, risk assessment and intervention methodologies. This means that future uptake of the Partnership results will be driven by this reinforced, interdisciplinary culture.

In the table below are listed main expected outputs and outcomes from the activities that have been listed as a priority for the first 2 years.

Surveillance /monitoring and risk assessment

EXPECTED DELIVERABLES	EXPECTED OUTCOMES
Coordinated European network(s) established for mapping selected terrestrial and aquatic wildlife species, including their main infectious diseases and resistance profiles of animal pathogens.	Based on the surveillance of priority wildlife populations, their infectious diseases and resistance profiles of animal pathogens, the risk of infecting production animals can be assessed.
Coordinated European network(s) established in livestock for mapping selected animal pathogens and their resistance profiles.	Based on the surveillance of priority animal pathogens and their resistance profiles, the risk of emergence in production animals and humans can be assessed.
Improved rapid risk assessment methodologies regarding the economic, social, environmental and cross sectoral consequences of animal health and welfare issues.	The improved rapid risk assessment methodologies allow to determine the economic, social, environmental and cross sectoral consequences of animal health and welfare issues.
Adapted and newly developed tools that allow the integration of genomic surveillance data in risk assessment methodologies.	New risk assessment methodologies that integrate genomic surveillance data allow to improve the risk assessment of current surveillance systems.

Procedures, methodologies and tools

EXPECTED DELIVERABLES	EXPECTED OUTCOMES
Scientific peer reviewed publications on priority pathogens responsible for important economic losses or high risk of transmission to humans, and their detection methods.	Based on the better understanding of the pathogenesis of animal pathogens, new diagnostics for their detection and characterization are developed.
New tools are available for the direct and indirect assessment of pathogens, for the rapid detection of drug-resistant bacteria, viruses, fungi or parasites, and for their on-farm detection and characterization.	The newly developed tools and procedures allow the faster and more reliable detection of animal infectious diseases.
New tools are available to distinguish between (i) infected and vaccinated individuals (DIVA) as well as (ii) unviable and infectious pathogens and (iii) to study inter-species circulation of pathogens or resistant variants.	The newly developed tools and procedures allow a better estimation of the risk related to diagnostic results, and therefore the most appropriate action to take.
New technologies on the slaughter line to assess animal welfare on farm and/or during transport, including the identification of suitable animal-based measures and in-line sensors.	The slaughterhouse tools lead to a straightforward methodology that allows the realistic assessment of the welfare of animals on farm and during transport, which makes corrective measures feasible.
New technologies and methodologies for application at slaughter and after fishing to better assess consciousness and death of animals at the end of life.	New tools to optimally assess the consciousness at stunning and killing phase allow to take appropriate measures and protect animal welfare at slaughter and stunning and killing after fishing.
New technologies and tools to assess animal welfare during transport through early detection of signals before and whilst in transit.	New developed tool applied during transport to and transit in the slaughterhouse lead to specific measures that improve the welfare of the animals.

Management and husbandry guidelines on farm, during transport, at slaughter and at sea

EXPECTED DELIVERABLES	EXPECTED OUTCOMES
A multidisciplinary pan-European network of experts with focus on biosecurity measures to prevent and control AID on farm and during transport.	The biosecurity experts collect available functional tools, procedures and methodologies, and perform foresight studies on animal and public health, and taking into account drivers like loss of biodiversity and climate change.
Scientific peer reviewed publications on the prudent use of antimicrobials, on alternatives to antimicrobials and on best practices for administration of Veterinary Medicine	Based on a better knowledge, antimicrobials and other veterinary products are more prudently used, and alternatives for antimicrobials are widely evaluated for use in production animals.

Products (VMP) in livestock and aquaculture production systems.	
Methods to reinforce animal resilience, e.g. through animal feeding and breeding technologies, are developed.	New breeding and feeding techniques are evaluated for use in livestock.
A multidisciplinary network of experts to draft foresight and priority studies with focus on sustainability aspects and focussing on ending mutilations.	Outcomes will benefit the entire livestock sector in general and animal welfare particularly, by strongly reducing mutilation.
Scientific peer reviewed publications on animal cognitive capacities and emotions, opportunities for pain relief, and environmental enrichments technologies.	Improved understanding of positive welfare will lead to more effective measures to improve animal welfare.
Newly developed livestock and fish stunning and killing techniques to limit pain and reduce stress during stunning and killing after fishing or in the abattoir.	Improved methodologies and techniques to end the life of animals not only leads to less suffering, but increases the acceptability of the citizens.
Novel husbandry systems including innovative feeding and breeding strategies.	Advanced husbandry systems that mitigate undesirable behaviours etc. are profitable to the welfare and acceptance by the citizens.

Treatment and vaccines

EXPECTED DELIVERABLES	EXPECTED OUTCOMES
Increased knowledge in host pathogen interactions (e.g. microbiome, immune response and co-infection) and their modulations by antimicrobial and antiparasitic drugs.	Updated training of young scientist.
New tools to mimic infections at the farm, in vivo, in vitro and in silico and to evaluate new drugs efficacy.	Better insight in evaluating new drugs with a reduced use of animal experiments.
Better understanding of protective immunity in order to improve response to vaccines and choice of better adjuvants	Good basis to facilitate uptake by the industry in the course of vaccine development.
In collaboration with industry, developed tools such as vaccine platforms and expression systems, immunological toolboxes (cell lines, reagents, etc.) and delivery systems. Similarly developed methods and procedures for comparative evaluation of clinical efficacy of veterinary antimicrobials to feed into antimicrobial guidelines and policies.	Through private/public collaboration fasten the process of vaccines development or new drug efficacy evaluation.

EXPECTED DELIVERABLES	EXPECTED OUTCOMES
Data about the economic and societal burden of selected priority diseases and their control.	Boost in interdisciplinary publications with data about the economic and societal burden.
Data on the socio-economic consequences of changes in livestock and fish farming practices resulting from citizen demand or new legislative requirements.	Uptake by the authorities of the socio-economic aspects of any changes imposed on farming practices.
Data about consumers' willingness to pay for AW and AH improvements, incentives and barriers to adopting innovations and practices such as welfare labelling schemes.	Integrated view of the social acceptability of any changes in farming practices.

Expected impact

By pursuing the objectives and related activities, the partnership will leverage efforts across countries, sectors and disciplines that will allow achievement of the following key expected impacts.

Scientific impact

- Improved coordination of all actors in animal health and welfare, public health and the environment.
- Increased and aligned investments in research and innovation, infrastructures, education and training, and services in animal health and welfare.
- State-of-the-art science to improve animal health and welfare, and protect public health

Societal impact

- Increased food safety and security, and reinforced capacity of the livestock sector to meet the objectives of related political priorities.
- Improved protection of public health by the improved capacity to reduce zoonoses and reduce inappropriate use of traditional antimicrobials.
- Improved preparedness of all actors and stakeholders and provision of means for farmers and other actors to manage their activities in a way to prevent and control AIDs.
- Improved societal perception of animal production by better addressing animal welfare across the entire chain.

Economical / Technological impact

- Contribute to a more healthy and resilient livestock and aquaculture sectors.
- Create a more dynamic animal health care system/ chain involving a continuum of actors from farmers to veterinarians, scientists, the industry and the consumer.

- Protect economic viability and sustainability of livestock and aquaculture farming systems.
- Uptake by all actors of tools and methods to prevent and control animal infectious diseases and strengthen animal welfare.

Link with other Horizon Europe Partnerships

The Management of EUP AH&W is in contact with the following European Partnerships that are planned under cluster 1 (Health) and cluster 6 (Food, Bioeconomy, Natural Resources, Agriculture and Environment) and that may develop activities related to livestock and aquaculture, animal health and welfare, and the prudent use of antimicrobials. The purpose of such inter-partnership cooperation is, in a common approach, to define the Partnership's boundaries and maximally align their activities, to avoid duplication of work and explore possible synergies.

The following types of collaboration and interactions with these partnerships are considered: a coordinated engagement with the livestock and aquaculture sector and with the general public (citizens science), parallel, aligned and complementary research calls. Mutual participation in stakeholders committees, 'shared' experts in advisory boards, exchange and dissemination of research results, the organization of common events, the organization of common knowledge hubs including various sectors: farmers, vets, feed and other industry, etc. The precise mechanisms of cooperation will be established once the partnerships are operational.

On-going and upcoming partnerships under cluster 6:

- The partnership 'Accelerating farming systems transition: agroecology living labs and research infrastructures' will develop and promote innovative agroecology methods that should lead to a reduced use of antimicrobials, enhanced animal welfare and improved safety of animal effluents used as fertilizers. Because the concept of agroecology is tightly linked to animal health and welfare, synergies between the two EUP will ensure their common success.
- The partnership 'Sustainable food systems', among other areas of work, pays attention to the primary production, both for livestock and aquaculture, as providers of safe food.
- The partnership 'Rescuing biodiversity to safeguard life on Earth' (Biodiversa Plus) is developing activities in the areas of loss of biodiversity, changing wildlife habitats and possible consequence for spread of infectious animal diseases in livestock and the human population.
- To a lesser extent, the partnerships for 'Agriculture of Data', for 'A climate neutral, sustainable and productive Blue Economy', and 'Water security for the planet' (Water4All) plan activities that are potentially related to animal health and welfare.

Upcoming partnerships under cluster 1:

- Discussions to align strategies and activities with the management of the future partnership on One Health-AMR are ongoing. In general, in EUP AH&W antimicrobial resistance in non-zoonotic, veterinary pathogens for livestock will be studied, as well as the spread of resistance to livestock and the assessment of alternatives for the use of antibiotics.
- To a lesser extent, the partnership on Pandemic preparedness and the Innovative Health Initiative Joint Undertaking, a public-private collaboration that enhance the uptake of research outcomes and innovations, are of particular interest to EUP AH&W.

Update of the SRIA

This SRIA will be updated during the lifetime of the Partnership as appropriate, in particular to take into account any new scientific (such a new emerging virus) or regulatory event (such as new constraints on export in relation to some infectious agents) that might impact the priority domains of the EUP AH&W. Depending on the available cash and in-kind budget and the progress the Partnership will make, the actions will be covered by different types of activities and outputs delivered, meaning that the EUP SRIA will need to be revised at the end of the Partnership. The decision to modify the SRIA should be taken by the Governing Board, probably with advice and recommendations of the Stakeholders Committee (SHC) and the experts of the Scientific Advisory Board (SAB). The Work Package 'SRIA Monitoring & Update' will have the lead in this process.

Although the actual EUP SRIA (spring 2023) encompasses all currently identified gaps in the AH&W domains, there will be the need to update the document to e.g. the evolving epidemiological situation, upcoming crisis, changes in political structures and policies, etc. At mid-term and at the end of the Partnership, the Executive Board plan to consult the Governing Board and the Stakeholders Committee during their regular contacts. In addition, as epidemiological, policy or other conditions may change, the above-mentioned boards may suggest the EB to amend the SRIA. Similarly, the scientific community of the EUP AH&W might alert the EB about new pressing needs to be covered to meet the ambition of the EUP AH&W.

For each of the updates, a gap analysis will be set up to compare the planned EUP AH&W objectives and the expected results and outcomes of the on-going and finalized projects. This analysis will identify objectives that have to be included in the subsequent, amended SRIA. In addition, an online survey will be set up among a broad AH&W audience, including regional, national and international contacts (for instance experts that were consulted in a previous SRIA version, the country AH&W mirror groups, etc.) to obtain recommendations for improvement. Based on the outcome of the Governing Board, Stakeholders Committee and Scientific Advisory Committee consultation, the gap analysis and the survey, the EUP

SRIA will be amended. Any updated SRIA will be an EUP deliverable and will feed info future post-EUP AH&W research agenda.

Annex – Initial proposal

The initial proposal for the Partnership (April, 2022)

ADDENDUM

TO THE SRIA FOR THE EUROPEAN PARTNERSHIP ON ANIMAL HEALTH AND WELFARE (EUP AH&W SRIA)

2023

EUP AH&W LOGO

This Addendum to the EUP SRIA has been developed by Work Package 6 (WP6) of the International Coordination of Research on Infectious Animal Diseases (ICRAD ERA-Net, Grant Agreement 862605), in close collaboration with the EU Partnership of Animal Health and Welfare.
It presents the detailed methodology and short-, medium- and long-term research and innovation needs for animal health and welfare .
This detailed analysis of research and innovation needs will be used to further develop the proposal of the Partnership, especially in selecting the more specific domains for the research calls and the 'invitations to collaborate' on integrative activities.

EUP AH&W

icrad
International coordination of research on infectious animal diseases

European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

STAR-IDAZ
International Research Consortium on Animal Health

ADDENDUM

TO THE SRIA FOR THE EUROPEAN PARTNERSHIP ON ANIMAL HEALTH AND WELFARE (EUP AH&W SRIA)

Contributors

This SRIA has been developed thanks to a collaboration between EUP AH&W, WP6 – ERA-Net co-fund ICRAD, STARIDAZ IRC and SFU - CWG AHW.

Coordination and action plan:

Hein Imberechts (Sciensano, BE), Florence Tardy (ANSES, FR), Hans Spoolder (WUR, NL) and Sven Arnouts (UGent, BE), EUP AH&W
Sadhana Sharma (BBSRC-UKRI, UK) and Scott Sellers (Defra, UK), ICRAD WP6 Leaders
Marina Bagni (MoH, IT), ICRAD WP 6.2 SRIA Task leader
Alex Morrow (IRC STAR-IDAZ, UK)
Hermann Schobesberger (Vet MedUni, AU/ CWG AHW-SFU)

Main contributors to the methodology and contents *(alphabetic order)*:

Giuseppe Arcangeli (IZS VE, IT), Johannes Charlier (DISCONTOOLS, Be), Madeleine Clark (Defra, UK), Carlo Corradini (IZS LT, IT), Thom Errit (Defra, UK), Nikki Mackie (BBSRC-UKRI, UK), Valeria Mariano (SIRCAH/OIE), Danielle Sagar (BBSRC-UKRI, UK), Simon Smith (Defra, UK), Evgenyia Titarenko (IZS LT, IT), Niccolò Vendramin (Aqua DTU, Dk)

Editors:
EUP SRIA: Hein Imberechts (Sciensano, BE), Florence Tardy (ANSES, FR), Hans Spoolder (WUR, NL).
Addendum: Marina Bagni (MOH, IT), Hermann Schobesberger (Vet MedUni, AU/ CWG AHW-SFU), Sadhana Sharma (BBSRC-UKRI, UK), Scott Sellers (Defra, UK)

Graphic editing:
IZS AM, Teramo WP2 ICRAD

The development of this SRIA would not have been possible without the consultation of more than 300 experts, worldwide, who contributed to the prioritization of research needs. We cannot mention everyone by name, but we would like to thank their valuable contribution to this SRIA.

EUP AH&W LOGO

icrad
International coordination of research on infectious animal diseases

European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

STAR-IDAZ
International Research Consortium on Animal Health

Addendum Content

Introduction

Safeguarding animal health (AH) and ensuring animal welfare (AW) is central for supporting the health, wellbeing and sustainability of livestock farming and related activities, such as protection of public health, food security and safety, rural economies, and environmental health. Furthermore, the sector contributes substantially to the EU economy through employment and trade of products.

The European Partnership of Animal Health and Welfare (EUP AH&W) is called to answer to the various rising needs of public, husbandry sector, public health authorities in a moment of astonishing global changes. Novel technologies, increased speed of movements (of ideas, people, goods, animals but also of infectious diseases), global heating and the consequences of the extreme growth of animal production seen in the last century have changed the paradigms of environmental stability, treatment efficacy, and ethical acceptance of husbandry techniques; the classic homeostasis model used to describe animal ability to face stressors is replaced by allostasis.

Animal pathogens attract attention in both the livestock and public health sectors for their socio-economics impacts, risk of food safety and security, and human health. These impacts affect at the household, regional, national, and global levels. Disease outbreaks have significant impact on trade, on wild animals and also affecting environment and human wellbeing.

In Europe, there are around 12 million livestock holdings which corresponds to about 77 million cattle, 143 million pigs and 74 million sheep and goat. To keep animals free from diseases and in equilibrium within their environment is a basic principle to protect animal and human health, business and to keep under control costs for farmers and industry, as well as the public sector. Animal health crisis such as Avian Influenza, BSE or ASF self-explain the potential scale of the impacts of animal health disruption. Moreover, it is noted that changes in climate and land use will lead to opportunities for viral sharing among previously geographically isolated species of wildlife, facilitating zoonotic spill-over. The diseases most affected by climate change impact are those connected with the change of the eco-environment of vectors and their adaptation to different geographical areas and those related to the availability and temperature of water for aquatic animals.

In addition, it is important to ensure animal welfare is maintained to high standards as poorly managed animals are more prone to diseases and lesions. Also, societal demand for improved animal welfare has developed at pace as the 'End the Cage Age'. There is growing public concern about rearing of livestock in cages, housing, animal transports and slaughter.

The challenges posed by such issues need the coordinated action of scientific community, regulatory institutions, industry, and associations. In the past, EU has invested heavily in sectors

e.g., food production (both regarding security and safety) and animal health protection under the successive Framework Programmes, allowing the funding of many collaborative projects.

A lot of such projects were focused on strengthening coordination and alignment between research strategies of Member States and associate countries as it was the case with the Collaborating Working Group Animal Health and Welfare (CWG AHW) under the frame of SCAR (Standing Committee on Agriculture Research). The CWG AHW initiated many ERA-NETs and established an international network of research funders on animal health, STAR-IDAZ. It managed to set up a network around 70 countries connecting organisation managing research budgets and programmes. Other noteworthy achievement of CWG AHW was the development of a Strategic Research Agenda (SRA), updated until 2018. The CWG AHW collaborated with the SCAR Strategic Working Group SWG FISH, to develop an SRA on disease prevention in farmed fish and documents evaluating the research needs of freshwater aquaculture and fish welfare. Public-public research partnerships collected successful results in the mobilisation and coordination of over 70 million euros in 5-joint calls funded by MSs through FP7 EMIDA (focused on AID) and ANIWHA (animal health and welfare). ICRAD ERA-NET, another international coordination having a strong EU membership core, mobilised 20 million euros in its first call in 2019, 23.7 million euros in the second call, and it is expected to start the third call in the next year. Other valuable projects linked with the foreseen activities of EUP AH&W are One Health EJP and EPIZONE. The first is a consortium of 44 partners from 22 MS and it is composed from animal health, food safety and public health research organisations. The latter is a network on animal disease diagnosis and control, including disease that may have zoonotic potential. The results and the knowledge acquired by the projects represents the scientific basis for EUP AH&W activities.

While many projects were organised together with the industry, very few of them provided impact on industrial applications. DISCONTOOLS FP7 project is probably one of the best examples for showing the potentiality given by the coordination between European MS and industry, but not many other projects had the same influence on industrial application of animal health research. DISCONTOOLS represents one of the main sources for the elaboration of the SRIA and an inspiration for the creation of valuable links between industry and public institutions.

The aim of the Partnership is to improve the control of AID, and reinforce the preparedness of all actors and to place animal welfare at the foreground of the animal production, according to a specific strategic vision (Box 1); the Partnership identifies four specific objectives:

- To facilitate the cooperation between all relevant actors in AHW big data collection and management, in monitoring, prevention and control of AID and in animal welfare issues
- To boost research and to improve the evidence-base to develop products and tools for animal health and animal welfare monitoring and control
- To enhance cross-sector cooperation and collaboration (One Health- One Welfare perspective)
- To strengthen the dissemination and uptake of project outputs and risk communication to societal, political, and private stakeholders

VISION OF EUP AH&W

To provide society with reassurance on the control of infectious animal diseases with appropriate means, where antimicrobials are prudently used, and on the respect and improvement of the welfare of animals, thus contributing to sustainable animal farming, and the protection of public health and the environment.

Box 1: Vision of the European Partnership AH&W

To reach these objectives, a thematic division was presented as Operational Objectives (OO). The classification in OO was crucial for the selection of the experts consulted for the Survey (see Methodology and SRIA Results Section). The OO were also used for the structure of the Survey itself, allowing both the structuring of an extensive bibliography study of the existing agendas and strategic documents and the organisation of the Survey.

EUP AH&W Strategic Research and Innovation Agenda

The Strategic Research and Innovation Agenda (SRIA) captures the long-term vision of animal health and welfare research and innovation. It aims to create an integrated approach toward AH and AW and put its users in the position to achieve shared objectives and reach common goals and results.

The SRIA will guide European research funders to prioritize areas for investment and collaboration, as well as to assist researchers and research managers to focus their research activities and stakeholders invest their own resources and knowledge.

The SRIA is a joint strategic document for the future co-funded European Partnership on Animal Health and Welfare (EUP AH&W) and for the ERA-NET on International Coordination of Research on Infectious Animal Diseases (ICRAD). It also provides an update of the agendas produced under the SCAR Collaborative Working Group on Animal Health and Welfare (CWG

AHW) in recent years and aims to provide suggested priorities for R&I within Horizon Europe, EUP AH&W and any future transnational call on animal health and welfare.

The SRIA has been developed in collaboration with the ICRAD WP6 team, the core group of EUP AH&W, CWG AHW members and its experts' community. In addition, it involved extensive and broad consultation of experts and academics in scientific areas related to veterinary sciences with a One Health (OH) approach, industry representatives, trade associations and breeders and aligns with the objectives laid down in the Animal Health Law and its principle of "prevent is better than cure"[1] and in the Green Deal, in particular as regards the relationship/connection "from Farm to Fork"[2].

The consultation of the experts was analysed, reviewed, and commented by representatives of the Industry. The results composed a SRIA described from the most general principle to the specific research activities considered crucial and urgent from a complex, inclusive, and independent methodology.

It is important to stress the fact that the present SRIA Addendum results derive from an analysis of existing agendas and strategic documents, from which the research needs were extracted and listed. Experts from all over Europe with different backgrounds and perspectives attributed importance and urgency to every single research need, and at the end, Animal Health and Welfare private stakeholders reviewed the results in dedicated workshops. The process was very receptive of inputs from the participants at any level.

The experts and stakeholders gave an important feedback to the SRIA process. While the single research need was already identified by the bibliographical study activities, the experts gave significant insights and suggestions about the most concrete strategies necessary to reach the set goals.

The process received support in the dossier created to outline the future EUP AH&W and in the scope and calls realised within the ERA-NET ICRAD as part of the additional activities included in its WP6.

[1] Animal Health Law | Food Safety (europa.eu)
[2] Farm to Fork Strategy | Food Safety (europa.eu)

Context

Animal Health and Welfare addressing major global challenges

Contribution to the UN Sustainable Development Goals (SDGs) and Common Agricultural Policy objectives

Animal health and welfare research and innovation (R&I) enhances the contribution of the livestock and aquaculture sectors to the UN 2030 Agenda for Sustainable Development (Figure 1). R&I has a vital role in facilitating the transition of livestock and aquaculture systems to sustainable, healthy, and inclusive food systems that provide safe, nutritious, and affordable food for all. In accordance with the EU farm to fork strategy and the Common Agricultural Policy objectives, which are central to the success of the SDGs, the EUP AH&W is enabling the achievement of the Horizon Europe objectives of fair, healthy, and environmentally friendly food systems, from primary production to consumption.

Figure 1: The SDGs as formulated in 2015 by the United Nations General Assembly (UNGA) as part of the Post-2015 Development Agenda

Healthy animals increase the supply of **safe animal food products** (eggs, milk, meat), rich in proteins and micronutrients, improving global food and nutrition security. This contributes to achieving the SDG 2-zero hunger, SDG3-good health and well-being, SDG12-responsible consumption, and production, & CAP Objective 9 -protect food and health quality (Figure 2).

Further, improved animal health and welfare will reduce production losses due to disease and welfare concerns, ameliorating feed conversion rates and decreasing the greenhouse gas (GHGs) emissions from agricultural systems. This contributes to achieving the SDG13-climate action & CAP Objective 4-climate change action. Environmental care (CAP Objective 5) is also ensured by the positive effect of pastoral livestock systems in maintaining the biodiversity and delivering ecosystem services, such as maintaining the landscape of rural areas and fertilizing the soil with safe livestock-by products.

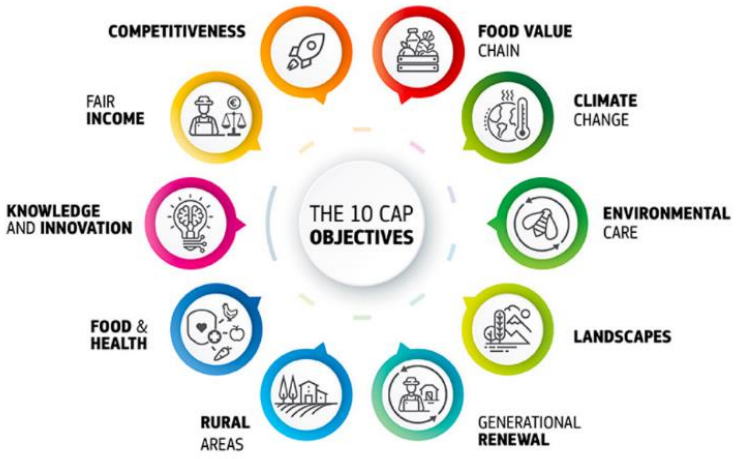


Figure 2: The ten key objectives of the Common Agricultural Agenda

The European livestock sector plays a major economic role in agriculture, accounting for € 168 billion of annual produced value, representing 45% of total EU agricultural activities, while creating employment for around 4 million people in farms and almost 30 million across all the livestock production chains. Consequently, enhancing animal health and welfare, will provide economic benefits all over the food system, particularly in the rural economy, contributing to the achievements of SDG-1 no poverty, SDG 8-decent work and economic growth, SDG9-industry, innovation, and infrastructure; SDG14-life below water, SDG15-life on land & CAP O1-ensure fair income, O2-increase competitiveness, O8-vibrant rural areas.

"Net Zero" Agenda

By ensuring good animal health and welfare we can move towards the Net Zero agenda in agriculture. Infectious diseases are a huge threat to Net Zero agriculture as they contribute to high mortality of farmed animals. Reducing the diseases incidences will reduce impact on climate change by removing unnecessary greenhouse gas emissions associated with animals that die before entering the food chain. Furthermore, disease control reduces emissions by enhancing animal production efficiency but may also directly reduce GHG production through yet unknown mechanisms that include interactions between pathogens and the microbiota. The links between diseases, ruminal and gut microbiota, and the microbiome offer a promising avenue to develop pathogen control strategies and nutritional supplements to reduce GHG emissions from animal production systems while improving animal health and resilience.

Nutrition Security

Nutrition is a critical part of health and development, and better nutrition is related to improved stronger immune systems, safer pregnancy and childbirth, lower risk of non-communicable diseases (such as diabetes and cardiovascular disease), and longer lifespan. Malnutrition, in every form, presents significant threats to human health. Today, the world faces a double burden of malnutrition that includes both undernutrition and obesity, livestock will be key to overcoming this.

Despite the increasing use and development of alternative proteins for food and changing eating habits, livestock and aquaculture remain of great importance for food production as they provide high nutritional value proteins such as meat (including fish, crustacean, and mollusc), milk and eggs, contributing to global food security and nutrition. Further to human health, proper nutrition in livestock promotes good health and welfare, which results in higher productivity. Healthy, happy, and well-fed cattle and poultry will produce more nutritious and higher quantities of milk, meat, and eggs.

Economic Security

Livestock and aquaculture are fundamental when ensuring food security for an ever-growing population. On the other hand, animal infectious diseases (AID) in livestock and aquaculture pose a threat to economic security along the value chains and in the worst case of entire nations. Estimates of global animal production losses due to disease range from 20% up to 50% in developing countries.

Economic AID impact encompasses treatment costs, loss of productive animals, reduced feed conversion, growth and product yield and quality (e.g., meat, milk, egg, etc.). Further economic burden comes from reduced processing suitability, waiting periods and drug residues after treatment as well as elevated control and surveillance measures (e.g., meat inspection, etc.). Disease control measures, restocking costs, reduced consumer trust and thus demand, market constraints and trade restrictions create additional negative economic consequences. Zoonoses add further costs in the form of reduced disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs) and reduce the available labor force. Monetary estimates of such economic impacts can add up to several billions of Euros or Dollars. Even under optimal animal health status, considerable costs occur because of necessary disease surveillance and monitoring, diagnostics, and inspections, to safeguard animal health and welfare and guarantee freedom from disease. Improved cost-effective tools for efficacious disease prevention and control are urgently needed.

New ways of working

Bringing interconnectedness of Animal Health & Welfare

The animal health and welfare are intrinsically linked. While poor animal health is detrimental to animal welfare, animals that are poorly managed are prone to diseases and health conditions. By improving animal welfare and animal health and in unison there will be a reduction in the need for veterinary drugs, a subsequent reduction of antimicrobial-resistance, and improved food safety and quality. Ultimately this will lead to increased health benefits not only for animals, but also for humans and the environment (One Health).

A better understanding of the welfare needs of animals will lead to the adoption of improved housing systems and management practices. It will also allow for more a more targeted response to the needs of the animal and will satisfy both the societal and political demands in relation to animal production. Furthermore, animal well-being plays a role in resilience to disease (both infectious and non-infectious) and improved welfare will lead to a reduction in animal morbidity and mortality.

Understanding impact of climate change on animal health and welfare

Climate change can affect the geographical distribution, abundance, and transmission potential of disease vectors such as ticks, mosquitoes, and flies. It can also directly affect the abundance and survival of pathogens, especially of pathogens with an environmental reservoir like nematodes, disease-carrying rodents, wildlife reservoirs and other intermediate hosts. Up to one third of the 55 infectious diseases in the DISCONTOOLS database are directly affected by climate change, while for another third the effects remain currently unknown.

Beyond these direct effects on disease vectors and pathogens, climate change also affects the animal's access to and quality of nutrition and water, behaviour, and immune response. Heat stress and lower nutritional status reduce the immune response to infectious challenges and vaccination and thus can significantly increase susceptibility to disease.

The importance of risk communication for animal health

One of the most important lessons we have learned because of the main global events that occurred during the 21st century – including the COVID-19 pandemic or the outbreaks of Severe Acute Respiratory Syndrome (SARS), the Middle East Respiratory Syndrome (MERS), influenza A(H1N1), BSE and Ebola disease – is that Risk Communication is an integral factor of success in

responding to health emergencies[3]. Emergencies have always been accompanied by a wave of disinformation that has influenced countries' responses to health emergencies, undermining trust, and compliance, amplifying fears and in the extreme leading to behaviours detrimental for health and economy[4]. In a survey conducted in 10 countries[5] 85% of respondents stated their preference for listening to scientists for information related to diseases) rather than politicians or authorities.

New needs for social science research to improve risk communication for AH and AW

There is an urgent need to increase general societal involvement, acknowledgment, and participation of research top allow for an informed awareness of risks in connection with animal diseases. This will further enable a better educated acceptance of livestock production practices, particularly in relation to animal welfare.

In the immediate future, it is necessary to solicit research aiming to effectively share scientific knowledge on animal health and welfare to make this accessible for consumers and the public and increasing its uptake with appropriate structures as well as human and economic resources, to ensure an effective and coordinated response to future emergencies and rebuild trust when communicating with all stakeholders.

Technological opportunities

New technologies have developed rapidly over recent years, providing new research and innovation opportunities for animal health and welfare. They include omics technologies, monitoring technologies on farm, data science and Artificial Intelligence.

Omics technologies

Omics technologies (genomics, transcriptomics, metabolomics, and proteomics) offers promising tools to improve animal health and welfare to tackle future challenges. Any aspects of animal physiology can be studied with the lens of these techniques, including stress and welfare assessment. They can allow the identification of pathways of adaptation, genetic traits, and specific strains for new breeds more resilient to climate changes, more efficient to convert alternative feedstuffs and more resistant to pathogens. Other innovative applications can serve

[3] "Risk communication and community engagement readiness and response to coronavirus disease (COVID-19)" Interim guidance 19 March 2020, WHO 2020.
[4] Combatting COVID-19 disinformation on online platforms (oecd.org)

[5] Edelman (2020), *Edelman Trust Barometer 2020 - Spring Update: Trust and the Covid-19 Pandemic* https://www.edelman.com/sites/g/files/aatuss191/files/2020-05/2020%20Edelman%20Trust%20Barometer%20Spring%20Update.pdf.
Open URL

the development of new therapeutics and production improvement strategies and point out the direction for future research, increasing the quantity and the quality of data available for multiple purposes

Monitoring technologies

Several monitoring technologies have been designed to improve animal health and welfare management and quality control of animal products (e.g., milk). New technologies and the increased suitability of existing technologies in the field offer support to the decision-making processes. Other tools, such as remote sensors present in the soil, help to evaluate the environmental impact of husbandry practices. Accelerometers, cameras, and infrared thermographers make it possible to assess animal health and welfare more precisely at a group and individual level.

Artificial intelligence

Artificial Intelligence (AI) is a wide term for a large ensemble of informatic tools and theories to solve logical problems, generally using complex algorithms and large datasets. It intersects data science, software engineering, modelling and statistics. Machine learning is an AI method aimed at automatization of model building. Through these methods the software can learn through the evaluation of data, identifying patterns previously unforeseen, and making decisions based on the patterns observed. The large datasets available require and allow the creation of powerful automatically produced models. Predictive epidemiology, precision medicine, diagnostics and host-pathogens interaction are only few of the fields that can benefit from AI technologies.

Data science

Omics and sensor technologies produce large quantities of data. These data need to be standardised to be of use to the animal health and welfare communities. Genes, transcripts, and proteins can then be analysed for known associations with biological pathways and networks, or to confirm hypothetical processes. Our ability to collect and store data has increased exponentially, which has highlighted the need to transform "big data" into "smart data", through the development of pipelines (arrays of software algorithms able to process raw data and generate a list of readable and annotated data or list of variants). Veterinary epidemiologists, and animal health and welfare scientists now need to understand bioinformatics to enable hypothesis-driven research.

Diagnostics

While many control tools already exist, many diseases still lack appropriate means of control. Control tools must firstly depend on the current or projected impact of a disease on society. These impacts can be various and include impacts on food security, animal welfare, pandemic

and zoonotic threats, international trade, and economic impact. The DISCONTOOLS disease prioritisation model allows disease screening against different criteria, which may have relevance depending on the end-user (farmer, consumer, policy maker). On the other hand, development and long-term availability of control tools depends on market demand and a willingness to pay, making market intelligence and involvement of the animal health industry a necessity to develop sustainable products.

There also remains a high need for the development of stable and durable diagnostics that can differentiate infected from vaccinated animals. Moreover, rapid technological advances such as in the field of whole genome sequencing, and miniaturized point-of-care devices, need to be exploited in the animal health domain while ensuring diagnostics remain low-cost and affordable. In terms of veterinary vaccines, fundamental research is needed to improve convenience of use, duration of immunity and establish performant DIVA vaccines, while novel platform technologies are offering new opportunities to fill remaining gaps. Also, research towards therapeutics remains necessary, to develop control strategies for diseases where control tools are currently lacking, to minimize the development of antimicrobial and antiparasitic resistance and effects on the environment.

Global needs and alliances: STAR-IDAZ IRC

Many animal infectious diseases are transboundary, and an increasing number of exotic diseases are expanding their ranges due to international trade, climate change, travel, etc. (e.g., COVID-19). Furthermore, climate change increases the risk of emergence and spread of exotic vector-borne diseases (e.g., Blue Tongue, West Nile Fever, Lumpy Skin Disease, etc.). International coordinated action is therefore important.

STAR-IDAZ is an international network of public research funders aiming to maximise global coordination on animal health research. Throughout its global and regional activities, STAR-IDAZ has established a network of organisations managing research budgets or programmes, which counts around 70 countries among members and associated countries opening new avenues for global cooperation. Existing established European and international networks such as STAR-IDAZ offer unique and timely opportunities to build a partnerships and tackle animal infectious disease as a global level. They provide strong coordination, both on animal health and welfare issues, and help in reducing duplication, promote collaboration where appropriate, and enable synergies[6].

Cross sector cooperation: Public-Private Partnership

The WOAH describes Public-Private Partnership's (PPP's) as "a joint approach in which the public and private sectors agree on responsibilities and share resources and risks to achieve common objectives that deliver benefits in a sustainable manner"[7]. Developing these

[6] www.star-idaz.net

[7] https://www.woah.org/app/uploads/2021/03/ppp-leaflet4p-en-bdpp.pdf

partnerships can lead to stronger economies, greater trust in government and private partners, increased opportunities, and a decrease in risk for the private sector, improved public health and creates solutions to societal issues[5].

It is important to build on public-public and public-private cooperation between stakeholders involved in animal health and welfare. This will allow uptake of priority gaps for applied or basic research to be identified and worked on collaboratively. It is important that research has impact and that efforts are self-sustaining in animal health and welfare research, this would be achieved by successful public-public and public-private cooperation.

An issue which needs a special focus: Aquaculture

Aquaculture is the fastest growing food protein production activity worldwide; it contributes to 52% of human consumption of seafood products[1]. Aquaculture provides a substantial contribution to food security, extremely low contribution to Greenhouse Gas emissions[1] and in general, higher efficiency compared to other animal husbandry in terms of Food conversion ratio, CO_2 footprint as well as use of freshwater.

Aquatic Animal Health (AAH) and Welfare (AAW) are key issues for future sustainability of aquaculture production, especially in the light of implementing new aquaculture technological solutions, with a view to one health approach[1]. A key enabler for reaching the Green Deal objectives is the leverage of the potential of the digital transformation. Aquaculture is an activity where the incorporation of the innovation developed by digital technologies such as artificial intelligence, 5G, cloud and edge computing and the internet of things, can greatly contribute improve the design of processing systems.

In this sense, EU is certainly to be looked upon as well established experimental pilot hub to develop test and implement a set validated and corroborated framework for the surveillance, diagnosis, prevention, and control of diseases in aquaculture, which can be then scaled up and transferred beyond borders.

SCAR-Fish is a strategic group of DG-RTD inside SCAR, with a focus on research and innovation activities in the domain of fisheries and aquaculture. This network will rely on interdisciplinarity to address the sustainability triangle of environmental protection, economic competitiveness, and social acceptability.

Methodology

The summary of methodology used to develop SRIA is below (Figure 3)

Figure 3: The 8-step methodology used for the development of the SRIA

The detailed Methodology is in Annex 1 including research need survey and analysis. Briefly, it included:

Step 1: Establishment of a Working Group in charge of the SRIA process

A Working Group (WG), comprising of representatives from the ICRAD WP6 leaders, SRIA task leader and other main contributors of the task, was established. The WG served, in close consultation with the EUP AH&W core group defined the methodology, delivery plan and timeframe by devising an Action Plan, then proceeded to implement the tasks within the Plan before drafting the SRIA document.

Step 2: Identification of R&I priorities through a desk study

An extensive desk study, performed by the WG, collected, and identified animal health and welfare research and innovation (R&I) needs and priorities from the existing European and global strategic documents. This step was a key component in the analysis of the policy, research, and innovation context for the Partnership. The desk study was carried out in three phases:

- Compilation of existing strategic documents on animal health and welfare
- Literature review and identification of research and innovation needs
- Validation of research and innovation priorities

Step 3: Online prioritization of the identified research and innovation needs

An online survey was generated and consulted with animal health and welfare researchers from European and international scientific centers, higher education institutions, industry/professional associations, research funding organizations, government ministries, community groups / NGOs, private sector companies, veterinary practitioners, and independent public agencies. 126 responses were received from 21 European and non-European countries. Overall, 10 experts from third countries participated in the survey: 2 from Israel, 1 from Mexico and 7 from Turkey. The animal health and welfare research and innovation, which were aligned with the Operational Objectives and Actions as highlighted in the Dossier (Figure 4). The consultees were invited to rank animal health and animal welfare research and innovation, needs based on 'urgency' and 'importance' (**Annex 2**)

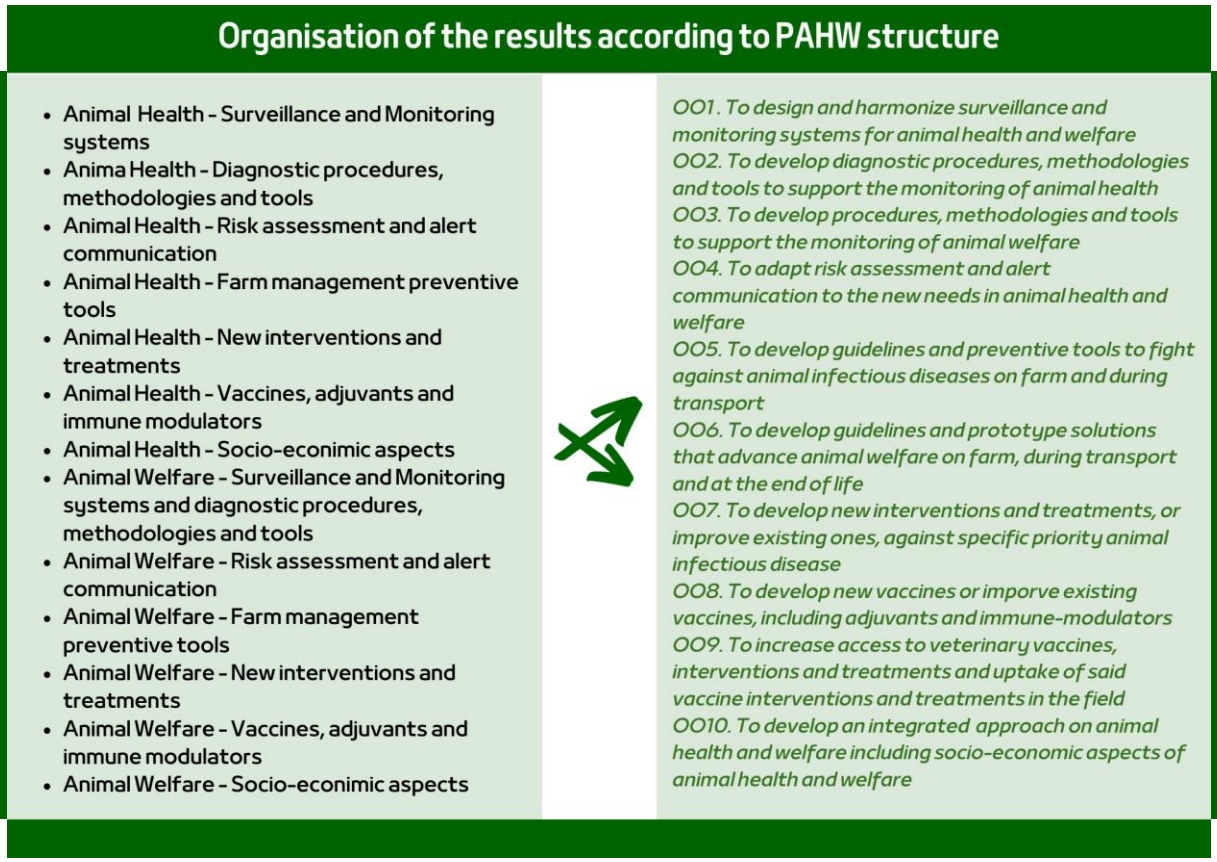


Figure 4: Reorganisation of the results according to EU PAHW structure

Step 4: Consultation 1: Industry and Stakeholders Sectors

To develop the SRIA in an open and participatory manner, the WG consulted with a broad set of stakeholders to make the agenda more responsive to their needs and ensure their interest and commitment. As most respondents to the survey were researchers form academia and research centers, so during the next step it was fundamental to seek input from industries (high tech, diagnostics industry, vet industry, vaccine, and treatment) and EU associations

(farmers associations, livestock associations, animal welfare associations and NGOs). The discussion was focused on:

- Sharing the prioritization of research needs identified by the survey of experts from academia/research institutes
- Considering the perspectives of industry and associations, the prioritization was reviewed regarding importance and urgency and potential uptake within the framework of EUP AH&W
- Investigating/soliciting interest in possible partnership cooperation and joint working in the areas of mutual interest.

Step 5: Drafting of the SRIA

The Working Group produced a draft SRIA based on the survey results considering of requirements of European Commission.

Step 6: Consultation 2: EUP AH&W Experts

Experts that participated in the working groups (i.e., Surveillance, Diagnostics, Farm management, Treatment & Vaccines, Aquaculture, and AMR) that prepared the EUP AH&W Dossier were invited to participate in this exercise. The aim was to update the experts with the research needs that have been selected and with their priorities, to invite them to comment on the choices made, and to indicate if essential information was missing.

The results of this consultation formed the basis of the online SRIA workshop.

Step 7: Consultation 3: Workshop

Prioritisation of Research in Animal Health and Welfare and Innovation

The research and innovation needs identified through desk study and focus group discussions are prioritised into short-, medium- and long-term needs (**Annex 3**). In addition, these research needs are aligned to the operational objectives (OO) and associated actions that were identified in the EUP AH&W dossier submitted to and validated by DG Research and Innovation (https://research-and-innovation.ec.europa.eu/system/files/2022-04/ec_rtd_he-partnership-pahw.pdf).The SRIA proposes specific needs that can be addressed during the first 2 years of the working program.

Animal Health and Welfare R&I priorities are focussed on **6 themes** (

Figure 5) and the section below focuses on the short-term needs under each theme.

Figure 5: the six themes identifying the priorities of the EUP AH&W.

Theme 1: Surveillance and Monitoring Systems

OO1. To design and harmonize surveillance and monitoring systems for animal health and welfare

At a time when the world is facing an unprecedented pandemic, the importance of surveillance for animal diseases is crucial. Surveillance systems and networks designed, and built-in recent years have an essential role in the management of new tools to safeguard the health and welfare of animals, to minimise animal production loss due to disease, to ensure quality assurance for trade in animals and animal products, and to safeguard human health. With increased cross-species transmission and disease impact, there is an urgent need to strengthen preparedness to prevent and respond to animal infectious diseases (AID), AMR and zoonoses through cross-sector research collaboration both in animal health, including wildlife, and animal welfare in a conceptual framework of One Health surveillance system. **A successful multisectoral surveillance system** based on high-quality data will help to support national and EU policy development on animal health and welfare, to foster the standardisation of methods and the harmonisation of their implementation where relevant, to reduce wasteful duplications, to enable synergies and maintenance at the European level.

The near-term research and innovation research needs for both animal health and welfare are

- **Improved preparedness and prediction methods** including understanding of transmission sources of pathogens (including from wildlife) and impact of climate change and ecosystem changes and trade
- **Development of tools and methods** for efficient surveillance systems with harmonized collection and timely data sharing and it's evaluation
- Need for **better use and reuse of data** using bioinformatics and artificial intelligence tools
- Development of **animal welfare surveillance** and its evaluation
- Development of **platforms to support farmers and veterinarians** in collecting and sharing primary data on animal welfare'

With regards to these research needs, focus group participants noted that the potential impacts of these new monitoring technologies on farmers is not captured here and that there will be differences in burden on small farms compared to bigger farms. The social science aspect of acceptance (or not) of these new surveillance systems by farmers is also not captured.

Theme 2:
Diagnostic Procedures, Methodologies and Tools

OO2. To develop diagnostic procedures, methodologies, and tools to support the monitoring of animal health

OO3. To develop procedures, methodologies, and tools to support the monitoring of animal Welfare

Diagnostics are often the first step in any medical process, both regarding individual patients (human and animal) and public health. Any control measure should be tailored to the specific issue and circumstance. Reliable diagnostic tests are crucial that can distinguish between healthy and infected individuals, especially when some individuals can be asymptomatic carriers of the disease. Diagnostic tests should be able to detect new diseases (or new variants) to prevent public health or economic crises.

New methodologies and technologies are made available by the scientific advances, and many tools still need to be developed further to be used for the early detection of AIDs. While the adoption of optimised tools in the surveillance programme belongs to the OO1, many other tools need to be perfected, to increase their sensibility and specificity, their suitability in field conditions and to reduce their invasiveness. Better diagnostics can improve our understanding of disease and allow the improvement of control measures.

Obtaining a full understanding of baseline data and effects of interventions are key factors in the cycle of improvement along with development of procedures, methodologies, and tools for monitoring animal welfare. Enhanced welfare will decrease needs for veterinary drugs and slow down the development of antimicrobial resistance in microorganisms in addition to improving food safety and quality. Over the long term, this form of research has potential to aid the genetic selection of more resilient livestock breeds with superior protective immune and metabolic responses.

In summary in the near-term it is urgent to focus on developing

- deep understanding of **host-pathogen-microbiome interactions** that will enable early detection, mechanisms of spill-over, and are easy to use.
- **novel diagnostics tools** for early detection, wildlife, and AMR
- **high throughput technologies and novel sampling methods** are key consideration for developing novel diagnostics.
- **multi-pathogen diagnostics** to optimize the surveillance systems
- developing **animal welfare surveliiance**
- development of **tools for measuring animal stress** including **identifying factors** contributing to stress e.g., transport
- refinement of **animal-based measures of welfare**

- **work on design of slaughter facilities** to avoid welfare issues like stress, fear, and pain at pre-slaughter phase
- **integration and better use of existing data** and data analysing techniques for animal welfare and **developing platforms** to support farmers and veterinarians in collecting and sharing primary data

In addition, it is important to develop digital toolboxes that centralise all diagnostic data in real time along with sharing data with responsible authorities at a national and international level. To develop a One Health approach, it will be imperative to link to human diagnostic data.

Theme 3: Risk Assessment and Alert Communication

OO4. To adapt risk assessment and alert communication to the new needs in animal health and welfare

Great importance is given to risk assessment and communication in the public discussion regarding animal health and welfare. The movement of animal, goods and people around the world increases the transmission rate of diseases and consequently the need for rapid, accountable communication between health stakeholders, from local health units to governments and international agencies. To deliver data in a sufficiently detailed way, new platforms and tools are necessary. Strong research coordination, both on animal health, including wildlife, on animal welfare and on cross-sector collaborations, will help strengthen preparedness to prevent and respond to AID, support national and EU policy development on animal welfare, standardise methods and harmonise their implementation where relevant, reduce wasteful duplication, ensure joint efforts, enable synergies and maintenance of a knowledge at the European level. To enhance risk assessment:

- **develop integrated risk analysis** based on multiple parameters e.g., farms data, management, animal welfare, antimicrobial resistance, drug consumption, vaccination strategies, biosecurity, and health data.
- **determine and monitor socio-economic and other factors** that increase farm susceptibility to infectious diseases along with **applications of risk criteria** in real life and under different husbandry conditions
- Refinement of **animal-based measures of welfare**
- Develop **animal welfare surveillance** and its evaluation
- Develop thresholds for intervention based on **animal welfare risk assessment data**

One item that was raised by the AW focus group in relevance to these research areas was that there is likely to be significant variation here in terms of species-specific knowledge and that it is important to ensure a distinction between stress and welfare.

Theme 4: Farm Management Preventive Tools

OO5. To develop guidelines and preventive tools to fight against animal infectious diseases on farm and during transport

OO6. To develop guidelines and prototype solutions that advance animal welfare on farm, during transport and at the end of life

Good farm management and comprehensive biosecurity measures will reduce animal disease and minimise the animal distress. Farm management encompasses all practices animals must undergo from birth to slaughter. Various factors must be considered e.g., ethology, production sustainability, biosecurity, nutrition, and many others.

There was less of alignment of research needs prioritizations and urgency ranking between survey and focus group. For example, 'Develop strategies to reduce antimicrobial and anthelminthic use (incl. feed additives/nutrition) and/or to encourage their prudent use' was ranked as the highest priority research need from any thematic area by the survey (6.2 importance score) whilst it was only ranked the third most important research need in the 'Feeding and understanding the microbiome to improve animal welfare' thematic area by the focus group.

The AMR based research needs also gathered some interest from focus group participants. It was noted that this research need in reverse could also be relevant. For example, what impacts improved animal welfare could have on AMR.

Mitigating or removing animal welfare challenges on farm, during transport and at the end of life addresses societal concerns, increases resilience to diseases that impair productivity, and deepens the understanding of the links between animal health and welfare. Research on these aspects of animal welfare will accompany the implementation and further development of the new animal welfare legislation and contribute to increase the interest of food chain actors and consumers in improved animal welfare.

Finally, a One Welfare approach to farming practices, animal transport and end of life will strengthen both human wellbeing and animal welfare and facilitate sustainable livestock production and aquaculture. The following research needs which the survey rated highly on importance and urgency and which the focus group also noted as their greatest priority:

- Deepening the understanding the role of veterinarians in prevention of disease and improving welfare- knowledge and technology transfer to end users/operators
- Develop **strategies to reduce antimicrobial and anthelmintic use** and/or to encourage their prudent use
- Development **of platforms to support farmers and veterinarians in collecting and sharing primary data** on animal welfare
- Improved **understanding of the trade-offs between sustainability and animal welfare**
- Develop and set appropriate **feeding and breeding strategies that consider and improves health and welfare** (not solely focused on production)

- Deepening the understanding of **behaviour towards maintaining and improving animal welfare** plus **understanding factors that compromise welfare** e.g., stocking density, extensive farming, pre-natal stress, epigenetics, and reproduction
- Develop **disease and welfare models** that include climate change, biodiversity, changing vector habitats

The participants of the focus group noted that there are many factors that impact welfare during transport across species and that there is already lots of research in this area. However, there is a lack of more practical, applied research. Secondly, it was noted that what is currently lacking is an ability to assess the transport of animals - what are the correct indicators and measures? Finally, it was noted that there may need to be trade-offs between welfare and sustainability, and these must be considered.

Theme 5: New Interventions and Treatments

OO7. To develop new interventions and treatments, or improve existing ones, against specific priority animal infectious disease

To maintain the health and welfare of animals, control interventions including treatments (e.g., antimicrobials/antibiotics/antiparasitic/antihelminth) are required. Suitable treatments require basic research understanding of host – pathogen interactions to target the infection mechanisms and harness an effective immune response. The emergence of antimicrobial resistance has hampered the effective use of such treatments and it is now paramount that tools are developed to understand the mechanisms of resistance and enhance efficacy and safety testing to improve these treatments. **Working closely with industry** new or improved interventions and treatments can be tested through proof of concept/early/pre-clinical studies.

In the short-term, both basic research and development of tools is urgently needed to:

- Understand **interactions between pathogens, host, and its microbiome**, and to understand the host immunity
- Understand the **molecular and cellular basis of antibiotic and antiparasitic resistance**, reducing antimicrobial resistance and its impact on welfare
- Understanding the **impact of reducing antimicrobials and antibiotic free productions** on animal welfare including evaluating the interaction between feed, the development of immunity and increased resistance of animals to pathogens especially for young animals.
- Develop a **range of novel interventions including antimicrobial molecules, immunomodulators**, novel therapeutics to control parasitic diseases and animal-free models for vaccine development.

Theme 6:
Vaccines, Adjuvants, and Immune Modulators

OO8. To develop new vaccines or improve existing vaccines, including adjuvants and immune modulators

Vaccination of animals is often the most cost-efficient measure to prevent and control the spread of AID and can be an important tool to reduce the burden of diseases and reduce the use of antimicrobials. With modern technologies (e.g., mRNA vaccine technology or multimeric scaffold particles) the efficacy of existing vaccines may be further improved. Production of new vaccines and improvement of existing ones will require significant scientific advances, such as **new approaches to antigen selection and production**, antigen delivery, improved adjuvants, vaccine administration, and **new insights immune system** function before products can be commercialised.

In the AH focus group, most of the stakeholders agreed with the prioritisation resulting from the online survey. Indeed, the results from the survey and the FG were similar. There was only one research need relevant to OO8 which was considered a priority for both the survey and the animal welfare, breeding, feeding, and precision livestock farming focus group. This was to **'develop animal-free models for vaccine development, such as organoids**.

The AH focus group attendees expressed concern regarding the timeline of highly desirable vaccines for a market-ready production. This issue is critical for economically devastating diseases such as weaning diarrhoea in piglets. The animal welfare focus group members did not have any further comments in relation to vaccines.

The stakeholders unanimously asked for **vaccine platforms and a smarter regulatory system**. The platform should foster the development, manufacture, and authorisation of new vaccines. The process is recognised to be already in motion, thanks to the new veterinary regulation and guidance from EMA. A single market for vaccines and other VMPs is considered very important in terms of cooperation. The market should comprehend at least EU/EFTA countries and hopefully North America Countries.

The stakeholders asked for the inclusion of the following topics, which were not initially included in the proposed research topics:

- Environmental risk assessment to vaccine development
- Novel adjuvants
- Mucosal immunity

The need for **improved vaccines particularly for economically devastating diseases** such as weaning diarrhoea in piglets and coccidiosis in broilers and turkeys. The suggestions from both the focus groups align well with the research needs prioritised in the survey. Vaccine development in general was considered an important topic and so each of the actions in the summary table below should be considered a priority.

Theme 7: Socio-Economic Aspects

OO10. To develop an integrated approach on animal health and welfare including socio-economic aspects of animal health and animal welfare

Animal husbandry is a complex human activity, involving not only production factors and direct contact with animals, but a wide range of relationships. Animal health and welfare is a particularly emotive subject for the public, and this can have an impact on consumer choice and demand. Animal diseases (including those with zoonotic potential) have a great impact on consumer behaviour and public health, this is affected by cultural and societal norms. Farmers react to challenges and regulatory requirements depending on the risk communication they are exposed. Incentives (not only economic) are often necessary for the reinforcement of control measures.

This Operational Objective received a spread of high scoring research needs from both the survey and the animal welfare, feeding, breeding and precision livestock farming focus group. The top research needs are listed below:

- Improved **understanding of the trade-offs between sustainability and animal welfare**
- **Establish social science studies along the production chain** to understand incentives and barriers to adopting innovations and practices such as vaccination and welfare labelling schemes
- Study the **integration of animal infectious disease mitigation and improved animal welfare in the overall context of sustainable livestock** production and aquaculture in the EU
- Improved understanding of trade-offs between farming (production and practices) and welfare

Planned Implementation

A broad portfolio of activities (Box 2) will be adopted and implemented that are specific to a particular research and innovation need. These include:

- Investment in multidisciplinary research to enable **data harmonisation** with focus on systematic collection of animal health and welfare data, (re)-use of data, interoperability, adapting existing or develop new methodologies to integrate e.g., genomic surveillance data in risk assessment. Harmonisation of standards Working with researchers, farmers, policy makers and veterinarian **create a data sharing culture** that is trusted by all involved.
- **Building capacity** which includes supporting ***shared infrastructure*** (e.g., animal facilities, laboratories of BSL2 or higher); ***shared repositories*** exchange of reference materials; standardization, etc)
- **Education and training provision** to ensure the breadth of professional, entrepreneurial, and technical skills are available for a wide range of career options, including through collaborative training in partnership with business will be made available. It is envisaged that the Partnership will create a Young EUP AH&W community, 'stable schools' where farmers and veterinarians can exchange needs, challenges and solutions.
- **Multidisciplinary networking** including **a One Health approach** to allow cooperation, collaboration, including networking of EU laboratories, diagnostic facilities, and centres to enable sharing of data, protocols, specimen, technical expertise; build skills and capacities where lacking e.g., bioinformatics, machine learning, artificial intelligence.
- These Networks will bring together ***bioinformatics, epidemiology, machine learning, big data technologies to advance animal health and welfare*** applicable to both livestock/aquacultures.
- Support for transnational research and innovation calls including **joint animal**

PORTFOLIO OF ACTIVITIES

1. Data harmonisation (sharing, (re)-use, integration)
2. Capacity building (including infrastructure; exchange of reference materials; standardization, etc)
3. Education, training, and mobility (exchange of expertise; training courses a different level such as VS, farmers, animal keepers etc.)
4. Capability building (PhD/grant - specific for Academia to generate possibilities but also for RPOs which can offer grant on specific issues)
5. Networking (mapping of existing; new ones; integration with existing)
6. Cross-sectorial initiatives (such as alignment with other EU Partnerships)
7. Joint animal health and welfare initiatives
8. Risk communication
9. Dissemination and communication
10. Exploitation and Uptake (advising authorities this could be useful especially for the regulatory/central authorities' strategies in support to the research)
11. Transnational Research and Innovation Calls (Basic/applied)
12. Foresight studies

Box 2: Porfolio of activities to be adopted and implemented by the Partnership.

health and welfare initiatives and support multidisciplinary research to advance **basic (pre-competitive) and applied (competitive)** knowledge. These calls, either **internal and/or external**, will focus on surveillance of animal health and monitoring of welfare, diagnostics, vaccines, and treatment, supporting fundamental research into understanding host-pathogen interactions, immunology, vectors and vector-borne diseases, microbiome, and AMR. The **internal calls** will be led and delivered by Research Performing Organisations (RPOs) mainly focusing on reinforcing cooperation, reducing duplication, and encouraging alignment to strengthen prevention and control measures. The **external calls** will aim to develop new knowledge, support cutting edge research and innovation for both basic and applied research. Due considerations will be given to developing joint calls with other European Partnerships e.g., measures to fight against AMR with EUP One Health AMR, animal welfare with EUP Agroecology, Pandemic Preparedness.

- In addition, **foresight activities** will be supported to understand future trends, planning and preparedness accompanied with **consultation meetings** with stakeholders and interested parties to identify needs and gaps that will also feed into future planning and updating SRIA.
- To ensure wider benefit are realised, **dissemination and communication** on activities both for scientific community, **policy makers** and public will be a key.

The tables below recommend proposed activities for each research and innovation need.

Table 1: Animal Health and Welfare: Surveillance and Monitoring Systems

OO1: To design and harmonize surveillance and monitoring systems for animal health and welfare

Action	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Optimize and extend to other countries current surveillance systems for animal health, AMR, and zoonotic infections and to develop new ones, where needed	Improvement of preparedness for emerging and exotic diseases through syndromic surveillance	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
	Identify transmission sources and/or sentinels for animal diseases (vectors, arthropods, wildlife, domestic or wild relay hosts, animalcules...) through passive and active surveillance	1, 4, 5, 11
	Better understanding of the effect of extreme weather and ecosystem changes on vector-borne diseases occurrence and transmission	1, 4, 5, 11
	Progress prediction methods to identify new and emerging diseases and when they may become a threat to Europe in relation to international trade, global warming, and climate change (e.g., new diseases, transboundary and vector borne diseases)	1, 2, 3, 5, 6, 8, 10
	Develop methods/tools for the design of efficient surveillance systems for early warning, early detection,	1, 2, 3, 4, 5, 6, 8, 10, 11

Action	Research and Innovation Needs: 1-2 years	Proposed Activities
	monitoring of pathogen diversity, frequency, and animal health implications	
	Develop terrestrial and aquatic wildlife disease surveillance and reporting systems, including methods, systems, and harmonization for assessment of wildlife populations and demography	1, 2, 3, 4, 5, 6, 8, 9, 10
	Progress alternative methods to control vectors: integrated pest management, biological control, genetically modified insects/improving networking with the human and environment sectors	4, 7, 9, 11
	Creation of standardized Next Generation Sequences protocols to run surveillance systems for emerging diseases	1, 4, 9, 11
Action 2. Set up a European wildlife network (both terrestrial and aquatic animals), based on existing wildlife disease surveillance and reporting systems, to coordinate and expand their activities, to analyse wildlife populations in Europe, and to analyse what specific data with reference to potential threat to animals and humans are needed.	Identify transmission sources and/or sentinels for animal diseases (vectors, arthropods, wildlife, domestic or wild relay hosts, animalcules...)	1, 2, 3, 4, 5, 6, 8, 9, 10, 11
	Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	1, 3, 4, 5, 6, 9, 11
Action 3. Create networks that bring together bioinformatics and epidemiology, to harmonise metagenomic data and data collection methods, to integrate genomic, clinical, and epidemiological data, applicable to both	Managing Big data, GIS, NGS; progress bioinformatics, improve sharing data integration and better use of existing data	1, 3, 5, 6
	Integration and better use of existing data and data analysing techniques for animal health and welfare to inform future initiative	1, 3, 5, 6, 7
	Progress artificial intelligence and machine learning techniques that support identification of new pathogens and earlier detection of known pathogens from sequencing and proteomic data	1, 2, 3, 4, 9, 11

Action	Research and Innovation Needs: 1-2 years	Proposed Activities
livestock/aquaculture and wildlife.	Development of platforms to support farmers in collecting and sharing primary data on animal welfare	1, 2, 3, 5, 6, 8, 9, 11
Action 4. Monitor pathogens of veterinary importance (that are not covered in One Health calls) and their antimicrobial resistance profiles.	Develop diagnostic tools enabling the early detection and reliable monitoring of infections, in both vectors and vertebrate hosts	4, 9, 11
	AMR surveillance in connection with measuring animal health and welfare indicators	1, 4, 7, 9, 11
	Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	4, 9, 11
	Development of tools to convert apparent to true prevalences, to enable fit-for-purpose monitoring	4, 9, 11
Action 5. Build networks, develop FAIR data, and implement FAIR principles for the monitoring of (re)emerging animal health and welfare issues, and to develop a hazard monitoring and early warning service.	Progress prediction methods to identify new and emerging diseases and when they may become a threat to Europe in relation to international trade, global warming, and climate change (e.g., new diseases, transboundary and vector borne diseases)	1, 4, 5, 6, 8, 9, 10, 11
	Managing Big data, GIS; progress bioinformatics, improve sharing data integration and better use of existing data	1, 3, 5, 6
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences	3, 4, 5, 6, 7, 9, 11
	Development of quantifiable positive animal welfare indicators	4, 5, 7, 9, 11
	Integration and better use of existing data and data analysing techniques for animal welfare	1, 5, 6, 7, 9, 11
	Design of the data-driven surveillance tools that are useful for the farmer but also provide surveillance information on regional or national level	1, 3, 4, 9, 11
	Validate and use telemetry data (livestock precision farming) in relation to animal's behaviour, fitness and longevity, stress, and physiological parameters	4, 9, 11

Action	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 6. Create a platform on animal welfare in the EU with the objective to provide scientific and technical support to all stakeholders, related to data necessary for the monitoring of animal welfare; develop animal welfare surveillance systems and their evaluation.	Development of platforms (where possible integrated in a meaningful way into existing operational networks) to support farmers and veterinarians in collecting and sharing primary data on animal welfare without making it an administrative burden.	1, 3, 5, 6, 9, 10, 11
	Develop animal welfare surveillance including epidemiology and its evaluation	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
	Need for early warning of Animal Welfare	3, 4, 7, 8
	Validation of those variables that most closely and reliably reflect the animals' affective state and thus their welfare before using these as indicators in automatically collected data	4, 5, 9, 11

Table 2: Animal Health - Diagnostic procedures, methodologies, and tools

OO2. To develop diagnostic procedures, methodologies, and tools to support the monitoring of animal health

Action	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Gain knowledge on priority pathogens (i.e., bacteria, parasites, viruses, fungi, prions including resistance patterns) responsible for important economic losses or high risk of transmission to humans and their detection methods, including metagenomics approaches, molecular markers of interest, etc.	Deepen understanding of host-pathogen-microbiome interactions in animals: mechanisms by which emerging pathogens transgress species barriers	4, 5, 6, 9, 11
	Deepen understanding of the host-pathogen-microbiome interactions that serves the development of diagnostic tools	4, 5, 9, 11
Action 2. Development, optimisation, and standardisation of reliable, faster, potentially automatable and/or scalable direct antigen/genome amplification/detection and indirect detection/immune	Develop new, cheap, accurate, rapid, and easy to use field diagnostic tests and diagnostic techniques, including pen-side diagnostics for the early detection of pathogens	4, 5, 9, 10, 11
	Develop diagnostic tools enabling the early detection and reliable monitoring of infections, in both vectors and vertebrate hosts	4, 5, 9, 10, 11
	Progress rapid, accurate, tests for AMR diagnosis (e.g., LAMP, AST estimation through MALDI-TOF and fluorescence coloration of RNA biomarkers)	4, 5, 6, 9, 10, 11

Action	Research and Innovation Needs: 1-2 years	Proposed Activities
response assessment tools/technologies; tools for the rapid detection of drug-resistant bacteria, viruses, fungi, or parasites; on-farm, pen-site diagnostics for pathogens and antimicrobial resistance; focus on priority pathogens and those that do not have EURL.	Develop routine use of high-throughput technologies (metagenomics, sequencing, machine learning and bioinformatics) for multi-target and quantitative diagnostics	3, 4, 5, 9, 10, 11
	Development of alternative models especially biologically relevant (species-specific) cell culture models that are still lacking for drug screening/testing approaches	2, 3, 4, 5, 6, 9, 10, 11
Action 3. Development, optimisation, and standardisation of tools to distinguish between (i) infected and vaccinated individuals (DIVA) as well as (ii) dead and infectious pathogens for the study of pathogens survival in the environment or in effluents and (iii) to study of inter-species (including wild animals) circulation of pathogens or resistant variants.	Improved competitive vaccines, particularly for economically devastating diseases such as weaning diarrhoea in piglets and coccidiosis in broiler and turkeys	2, 3, 4, 9, 11
	Harmonization of lab tests and result communication	1, 2, 3, 5, 9, 10
Action 4. Development of quantitative and multi-target diagnostics to identify infection levels and silent microorganisms that can interfere with animal production for informed treatment/prevention measures decisions in enzootic production diseases in animals.	Development of multi-pathogen diagnostic tool to optimize the surveillance systems able to identify at once bacteria and viruses	3, 4, 5, 10, 11

Action	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 5. Development of non or less invasive and more convenient sample collection methods, including new matrices as well as transport, storage, treatment strategies and corresponding diagnostic tools, also suitable for the detection of diseases in free-ranging or wild animals.	Develop new sampling methodologies and strategies, incl. widening of the range of biological, also for drug screening/testing approaches samples	1, 2, 3, 4, 5, 9,11
Action 6. Application of new methodologies, i.e., research focusing on application of new detection and characterisation methodologies, on in vitro models; study host-pathogen-environment interactions, i.e., focusing on drivers and markers, on characterisation of microbial ecosystems, on drivers of resistance.	Deepen understanding of the host-pathogen-microbiome interactions that serves the development of diagnostic tools	3, 4, 5, 9, 10, 11
	Development of digital toolboxes that centralize all diagnostic data coming from local laboratories in real time and directly send the information to responsible authorities at a national level and international level and linked to human diagnostic system.	1, 2, 3, 4, 8, 10

Table 3: Animal Welfare - Diagnostic procedures, methodologies, and tools

OO3. To develop procedures, methodologies, and tools to support the monitoring of animal Welfare

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Focus on positive welfare (positive emotions), identification of behavioural, endocrine, and neurological indicators of positive welfare: research focusing on animal cognition, preferences, and motivation to obtain rewards.	Understand stockperson care/management practices and their welfare implications	4, 9, 11

Action 2. Development of technologies on the slaughter line to assess animal welfare (on farm and/or during transport). Identification of suitable animal-based measures (ABM) with appropriate level of validity, sensitivity, and specificity; development of in-line sensors, large scale data collection.	Development of tools for measuring animal stress	4, 7, 9, 11
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences	4, 7, 9, 11
Action 3. Animal welfare at slaughter: i) consciousness and death: development of technologies, procedures and/or protocols to increase the reliability of methods to assess consciousness and death at the slaughter line; ii) improve stunning and killing methods; iii) work on design of slaughter facilities to avoid welfare issues like stress, fear, and pain at pre-slaughter phase; related staff training.	Work on design of slaughter facilities to avoid welfare issues like stress, fear, and pain at pre-slaughter phase	1, 3, 4, 7, 8, 9, 10, 11
	Work on design of pre-slaughter phase including stunning methods	1, 3, 4, 7, 8, 9, 10, 11
	Research on humane methods for on-site killing of large groups of animals i.e., farm de-population in case of disease outbreak	4, 7, 9, 11
Action 4. Development of physiological indicators to measure acute and chronic negative animal welfare consequences on farm. The indicators should identify stress, pain, fear, discomfort, etc. at individual and group levels: measure of physiological stress, impact on immune response and omics (e.g., transcriptomics and metabolomics). Integration of these to metadata welfare tools.	Development of tools for measuring animal stress	1, 4, 9, 11
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences	1, 4, 7, 9, 11

Action 5. Development <u>of digitally assisted monitoring technologies on farms for increasingly enabling precision management of animal (health and) welfare</u>. Technology includes recording visual and auditory signals related to animal-based measures for welfare, analysing records with deep learning technology, data processing techniques and decision support systems.	Integration and better use of existing data and data analysing techniques for animal welfare	1, 3, 4, 5, 9, 11
	Development of platforms to support farmers and veterinarians in collecting and sharing primary data on animal welfare	1, 3, 5, 8, 10
	Develop animal welfare surveillance and its evaluation	1, 2, 3, 4, 5, 6, 7, 9, 10, 11
	Precision Livestock Farming technologies and artificial intelligence for welfare linking to genomic selection data	1, 2, 3, 4, 5, 6, 7, 9, 11
	Data mining of syndromic surveillance/ early warning systems to allow for AW evaluation	1, 4, 9, 11
Action 6. Development of technologies to assess <u>animal welfare during transport</u>. Affordable and reliable solutions to prevent serious welfare problems through early detection of signals before and whilst in transit, e.g., lameness, lesions, heat stress, aggression, thirst or hunger, exhaustion, etc. Development of sensor technology, data analysis tools, data collection and integration platforms, decision support for the driver; related staff training.	Studies on the impact of transport on animal welfare across species including aquatic animal concerns - e.g., oxygenation levels, starving protocols etc	1, 4, 6,77, 9, 11
	Precision Livestock Farming technologies and artificial intelligence for welfare	1, 2, 3, 4, 5, 6, 7, 9, 11

Table 4: Animal Health & Welfare - Risk assessment and alert communication

OO4. To adapt risk assessment and alert communication to the new needs in animal health and welfare

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Enhance rapid risk and consequence assessment methodologies, to assess the economic, social, environmental, and cross sectoral consequences of animal health and welfare issues.	Develop thresholds for interventions based on animal welfare risk assessment data	1, 2, 7, 8, 9, 10, 11
	Investigations into possible application of science-based animal health and welfare risk assessment criteria in real life and under different husbandry conditions including introducing new husbandry systems/technologies	2, 3, 5, 8, 9, 10

	Research on determination and monitoring of socio-economic factors that can increase farm susceptibility to infectious diseases, with the aim to detect less resilient holdings/areas/regions	1, 3, 8, 9, 10, 11, 12
Action 2: Study and assess epidemiological associations between human interventions such as hunting, trade, transport, rewilding and translocations of wildlife and disease spread, to propose harmonised tools to support alert system	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	
Action 3: Adapt existing or develop new methodologies to integrate genomic surveillance data in risk assessment guidelines for the integrated use of epidemiological and genomic data	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	
Action 4: Assess the risk of spread of resistant animal pathogens clones and genes encoding resistance	Integrated risk analysis based on farms data on management, animal welfare, antimicrobial resistance, drug consumption, vaccination strategies, biosecurity, and health data	1, 3, 8, 9, 10, 11
Action 5; Build or further map and coordinate emergency networks for scientists and communities, to increase risk knowledge by systematically collecting data and undertaking risk assessments	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	
Action 6. Develop animal welfare surveillance and its evaluation, develop indicators and alarm levels, produce factsheets and any relevant digital infrastructure that enable risk assessment of any breach in animal welfare.	Develop animal welfare surveillance and its evaluation	1, 2, 7, 9, 10
	Development of welfare surveillance systems	1, 2, 7, 9, 10
	Development of tools for measuring animal stress addressing specifically farrowing crates and piglet castration	1, 2, 7, 9, 10, 11
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences	3, 5, 9, 10, 11

Table 5: Animal Health & Welfare - Farm management preventive tools

OO5. To develop guidelines and preventive tools to fight against animal infectious diseases on farm and during transport

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Establish a multidisciplinary network of experts with focus on biosecurity measures to prevent and control AID on farm and during transport, and draft foresight and priority studies on animal health, public health, pandemics and the role of biodiversity, the changing climate, emerging vectors and vector-borne diseases, bird and fish migrations, epidemiology/ modelling, bioinformatics, etc. for all animal species, including minority species and aquaculture.	Studies on the impact of transport on animal welfare and infectious disease	4, 6, 7, 9, 11
	Improved understanding of climate change and its impact on welfare and on current and new animal diseases as well as the role it may play in an epidemic situation	4, 6, 7, 9, 11
	Develop disease and welfare models that include climate change, biodiversity, changing vector habitats to assess impact including CO2 emissions and socio-economic impacts to develop decision support for improving welfare and animal health	1, 4, 5, 6, 7, 9, 10, 11
Action 2: Reduce the entrance and spread of AID by reinforcing external and internal biosecurity in both terrestrial and aquatic animals, while limiting antimicrobial use, setup innovative systems and models with focus on biosecurity and integrated management	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	
Action 3: Perform research on prudent use of antimicrobials: research on treatment concepts for antimicrobial and antiparasitic usage, on alternative to antimicrobials including feed additives/nutrition, studying improved vaccination strategies etc.; development of best practices for administration/application of	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Veterinary Medicine Products (VMP)		
Action 4. Reinforce animal resilience/resistance (the natural ability of animals to withstand pathogens), through feeding and breeding; establish a pan-European network of experts in genetics (breeding), feed additives including pre-, post-and probiotics and leading experts in immunology to produce foresight and priority reports; both fundamental and applied research supporting animal resilience will be set up.	Deepen understanding of host-pathogen-microbiome interactions	4, 9, 11
	Develop strategies to reduce antimicrobial and anthelmintic use (incl. feed additives/nutrition) and/or to encourage their prudent use	3, 4, 5, 6, 7, 9, 11
	Evaluate the interaction between feed, the development of immunity and increased resistance of animals to pathogens especially for young animals (piglets, chicken)	4, 9, 11
	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	1, 3, 4, 5, 6, 7

Table 6: Animal Welfare - Farm management preventive tools

OO6. To develop guidelines and prototype solutions that advance animal welfare on farm, during transport and at the end of life

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Establish a multidisciplinary network of experts to draft foresight and priority studies with focus on sustainability aspects related to non-cage systems, indoor and outdoor systems for livestock, flow though, pond or RAS for aquaculture animal transportation and slaughter, killing on farm, in slaughterhouses or at sea, and focusing on ending mutilations, including aquaculture production systems.	Development of platforms to support farmers and veterinarians in collecting and sharing primary data on animal welfare.	1, 3, 5, 7
	Investigations into possible application of science-based animal welfare risk assessment criteria in real life and under different husbandry conditions	4, 7, 8, 10
	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	3, 5, 6, 7, 8

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 2. Perform research on how to improve animal welfare while maintaining or increasing farm economic and environmental sustainability. Involves animal cognitive capacities and emotions adapted to each species' needs, opportunities for pain relief, and environmental enrichments technologies. Aims to develop innovative housing systems and addresses the opportunities and consequences of reducing the use of cages in a sustainable way, in terms of economic and environmental impacts.	Establish social science studies along the production chain to monitor behaviour towards maintaining and improving animal welfare, including consumers' willingness to pay for improvements; incentives and barriers to adopting innovations and practices such as welfare labelling schemes	1, 4, 7, 9, 11
	Improved understanding of stocking density and its welfare implications and economic trade-offs	1, 4, 6, 7, 9, 11
	Improved understanding of the trade-offs between sustainability and animal welfare	1, 4, 6, 7, 9, 11
	Improved understanding of impacts of extensive farming on animal welfare and how it effects environmentally positive way	1, 4, 6, 7, 9, 11
Action 3. Perform background science to identify indicators and to develop systems to assess the state of consciousness and death, develop appropriate Precision Livestock/fish Farming and killing technologies to limit pain and reduce stress, alert systems for poor welfare during transport, etc.; develop innovative systems in livestock/fish transport and slaughter.	Development of tools for measuring animal stress	1, 2, 4, 5, 6, 7, 9, 11
	Refinement of Animal-based measures of welfare	4, 9, 11
	Precision Livestock Farming technologies and artificial intelligence for welfare	1, 2, 3, 4, 5, 6, 7, 9, 11
Action 4. Improve animal welfare through feeding and breeding strategies.	Welfare considerations for new methods of rearing	4, 7, 9, 11
	Develop and set appropriate breeding goals that consider welfare implications (not solely focused on production)	5, 6, 7, 9, 10, 11
	Research to improve animal welfare through feeding and breeding strategies	4, 9, 11
	Improve breeding technologies for animal health: e.g., integration of molecular technologies into breeding	1, 2, 4, 9, 11

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
	programs, especially for low heritability traits and traits associated with health and pathogen resistance	
	Increase understanding of how genetic engineering in farm animals affects zoonotic disease resistance	4, 9, 11
	Understanding welfare consideration for breeding of companion animals and welfare risks related to those?	4, 9, 11
Action 5. Evaluate the need and possibility to set up a pan-European network of experimental farms.	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	

Table 7: New interventions and treatments

OO7. To develop new interventions and treatments, or improve existing ones, against specific priority animal infectious disease

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Perform basic research (TRL 1-2) to study interactions between pathogens and host microbiome, focussing on the immune system (e.g., pathobiome), and direct or indirect interactions between pathogens (e.g., co-infections), antimicrobial and antiparasitic drugs and host microbiome, mechanisms of anti-microbial (antibiotic and antiparasitic) resistance; trained immunity.	Improved understanding of direct or indirect interactions between pathogens (e.g., co-infections) and between pathogen and host and its microbiome	4, 6, 9, 11
	Better understanding of host immunity	4, 9, 11
	Better understanding of the molecular and cellular basis of antibiotic resistance	4, 6, 9, 11
	Investigation of the impact of the reduction of antimicrobials and antibiotic free productions on animal welfare	4, 6, 9, 11, 12
	Reducing antimicrobial resistance and its impact on welfare	3, 4, 6, 7, 9, 10, 11, 12
	Evaluate the interaction between feed, the development of immunity and increased resistance of animals to pathogens especially for young animals (piglets, chicken)	4, 5, 6, 9, 11
Action 2. Develop tools such as (i) experimental farm approaches; (ii) in vivo, in vitro and in silico infection models for testing efficacy and safety of new drugs with reduced need	Develop novel antimicrobial molecules e.g., antiseptics, antimicrobial peptides (bacteriophages), immunomodulatory specific agonists or antagonists and bioactive plants or alternative specialty feed ingredients such as plant extracts (essential oils, tannins, etc.)	2, 3, 4, 5, 6, 9, 11
	Develop novel immunomodulators and antivirals	2, 3, 4, 5, 6, 9, 11

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
for animal testing, new drug-delivery devices, therapeutics including leads for new antimicrobials; and (iii) bioinformatic pipelines for analysis of microbiome and pathogen data; this will be done in collaboration with industry, where appropriate.	Develop novel therapeutics/ strategies to control parasitic diseases	2, 3, 4, 5, 6, 9, 11
	Develop animal-free models for vaccine development, such as organoids	2, 3, 4, 5, 6, 9, 11
	Reducing antimicrobial resistance and its impact on welfare	3, 4, 6, 7, 9, 10, 11
	To reduce AMR more research on treatment strategies that reduce both length and dose of the antimicrobial used	3, 8, 10, 11
Action 3. Build on the results of Action 1&2 to develop or improve interventions and treatments and deliver first proof of concept, where appropriate, in collaboration with industry: demonstration of immunogenicity and efficacy in target species; representative (small scale) animal (challenge) model (TRL 3-4)	To foster the research to find new treatments (drugs or protocols) for fish and shellfish which are extremely limited	2, 3, 4, 5, 6, 9, 11
Action 4. In collaboration with industry: bring outputs to higher TRL in early/pre-clinical development (GMP-material; TRL 5-6); (i) for non-food animals: demonstration of efficacy and field safety at large scale in representative animal models or approved alternative methods; (ii) for food animals: lab-scale assessment of animal safety and initiation of environmental safety, user safety, and (if needed) microbiological safety assessments; absence of toxicity/side effects; carcinogenicity studies initiated if needed, and demonstration of efficacy and	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
field safety at large scale in a representative animal model and toxicology studies. Work on TRL 7 to 9 (late/clinical development, marketing authorisation and lifecycle management) will be performed by industry itself.		

Table 8: Vaccines, adjuvants, and immune modulators

OO8. To develop new vaccines or improve existing vaccines, including adjuvants and immune modulators

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1. Study the role of the immune system of farm animals, including the innate immune capacity of new-born animals; the mechanisms that elicit protective immunity at the entry site, factors affecting immune response to vaccines, mode of action of adjuvants (basic research; TRL 1-2).	Better understanding of pathogen biology for better targeting of vaccines and therapeutics, including mucosal immunity	4, 5, 7, 9, 11
Action 2. Develop tools such as vaccine platforms and expression systems, immunological toolboxes (cell lines, reagents, etc.) and delivery systems, etc.; this will be done in collaboration with industry, where appropriate	Develop and improve research and translation of new vaccines (e.g., DIVA, recombinants) including new genetically engineered vaccines	4, 5, 7, 9, 11
	Development of novel adjuvants	2, 3, 4, 5, 6, 9, 11
	Develop animal-free models for vaccine development, such as organoids	5, 6, 8, 9, 10, 11, 12
Action 3. Build on the results of Action 1 & 2 to develop or improve vaccine and immune-modulators and deliver proof of concept: demonstration of immunogenicity and efficacy in target species; representative (small scale) animal (challenge) model (TRL 3-4) or approved alternative methods; this will be done in collaboration with Industry, where appropriate; this will be done in collaboration with industry, where appropriate	**NO SHORT-TERM R&I NEEDS WERE IDENTIFIED**	

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 4. In collaboration with industry: bring outputs to higher TRL in early/pre-clinical development (GMP-material; TRL 5-6). **(i) demonstration of animal safety in target and non-target species; and demonstration of efficacy in a representative and validated target animal challenge model. Work on TRL 7 to 9 (late/clinical development, marketing authorisation and lifecycle management) will be performed by industry itself.**	Environmental risk assessment to vaccine development	5, 6, 8, 9, 10, 11, 12
	Improved competitive vaccines, particularly for economically devastating diseases such as weaning diarrhoea in piglets and coccidiosis in broiler and turkeys	2, 3, 4, 9, 11

Table 9: Animal Health & Welfare - Socio-Economic Aspects

OO10. To develop an integrated approach on animal health and welfare including socio-economic aspects of animal health and animal welfare

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 1: Assess the burden of selected priority diseases (including resistant pathogens, including their control (e.g., cost-benefit of different surveillance components and risk mitigation options)	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	3, 5, 7, 8, 10
Action 2: Set up social science studies among veterinarians, farmers, consumers, and other actors along the production chain on their behaviour (also in relation to AM use) to maintain and <u>improve animal health</u>, including consumers' <u>willingness to pay for improvements; incentives and barriers to adopt innovations and practices</u>	Identify obstacles for acceptance of bio-engineered vaccines	3, 4, 5, 6, 8, 10
	How to enhance UPTAKE of biosecurity and vaccines needs research	3, 5, 6, 7, 8, 10

Actions	Research and Innovation Needs: 1-2 years	Proposed Activities
Action 3. Set up social science studies among veterinarians, farmers, consumers, and other actors along the production chain on their behaviour to maintain and improve animal welfare, including consumers' willingness to pay for improvements; incentives and barriers to adopt innovations and practices, including welfare labelling schemes.	Establish social science studies along the production chain to understand incentives and barriers to adopting innovations and practices such as welfare labelling schemes	1, 3, 4, 5, 6
	Improved understanding of the trade-offs between sustainability and animal welfare	1, 4, 5, 6, 9, 11
Action 4. Study the integration of AID mitigation and improved animal welfare in the overall context of sustainable livestock production and aquaculture in the EU.	Study the integration of animal infectious disease mitigation and improved animal welfare in the overall context of sustainable livestock production and aquaculture in the EU	1, 2, 3, 4, 5, 6, 7, 9, 10, 11
	Improved understanding of the trade-offs between sustainability and animal welfare	1, 4, 5, 6, 9, 11
	Improve epidemiological knowledge to quantify the risks of culling versus vaccination (all epizootic and notifiable diseases)	1, 4, 7, 9, 11
	Improved understanding of trade-offs between farming (production and practices) and welfare	1, 4, 7, 9, 11
Action 5: Develop integrated strategies for the control and prevention of diseases, including emergency situations, considering relevant criteria, e.g., epidemiological situation, cost-benefit etc. to support decision making by national and international risk managers and other relevant stakeholders.	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	3, 5, 7, 8, 10
	Improve epidemiological knowledge to quantify the risks of culling versus vaccination (all epizootic and notifiable diseases)	1, 4, 7, 9, 11
	Develop cost-benefit analyses of active and targeted surveillance in livestock for a selection of high-impact pathogens in the EU	1, 4, 9, 11

Logical Framework

The Logical Framework defines Key Performance Indicators (KPIs) for monitoring progress towards impact and outcomes. The Table 10 below captures deliverables of four key areas, possible outcomes and proposed KPIs.

Table 10: Logical Framework and KPIs

Working areas	Deliverables	Outcomes	Proposed KPIs
Surveillance & Monitoring (OO1 and 4)	Multidisciplinary network(s) (in Europe) with a One Health approach both for animal health and welfare (including wildlife sector)	Coordinated response to AH and AW issues	Scientific production on the related science
		Improved cooperation among vet, farmers, researchers.	No. Multidisciplinary projects funded/started
	Early warning of (re)-emerging diseases system for terrestrial, aquatic and wildlife	Improved science-based understanding of virulence and transmission dynamics of pathogens	**No. of networks and participants (Database of new and/or mapping networks)
	Multi-criteria decision-support for policy, agreed among relevant stakeholders	Evidence based prioritization of targeted control strategies	**DB/Data sharing agreements within the networks
	Input for modelling and prediction	Improved risk assessment and -management or control strategies (and informed decision at Central	No. training on Big Data management/Db software (number of courses/trained stakeholder*)

Working areas	Deliverables	Outcomes	Proposed KPIs
		Authorities level) including emerging and exotic diseases	
	Biosecurity assessment models		No. of multidisciplinary workshops /No. of countries participating
		Improved early detection and improved control of pathogens (including	
	Big data implemented		No. of guidelines /reports produced/contribute to contingency planning
		emerging/re-emerging pathogens)	
			No. of pilot studies on novel or improved methods and tools for surveillance
	Recommendations to CAs for progress in regulatory aspect	Increased understanding of the effects of weather patterns and conditions that lead to increased vector numbers and disease spread.	
			No. Pilot study to assess costs and disadvantages per risk reduction unit of various surveillance and control methodologies
	Effective, evidence-based risk communication	Better prediction strategies and control measures to respond to potential new epidemics/pandemics	
			Number of new assessment guidelines and models
	System for cross-sector cooperation and harmonization of livestock and environment surveillance	Improved outbreak response and management	
			Number of dashboards with integrated data and functionalities for real-time management implemented
		Improved knowledge of different types of production systems and improved biosecurity measures	
	Streamlined process for development of biosecurity plans for farms (livestock and aquaculture, fostering translation of innovations and technological		
		Integration and better use of existing data and data analysing techniques for animal welfare	

Working areas	Deliverables	Outcomes	Proposed KPIs
	advances in farm management procedures) Platforms to support farmers in collecting and sharing primary data on animal welfare Network of farmers to share knowledge of animal welfare surveillance Novel methods and tools for measuring animal stress, early detection, efficient surveillance system	Improved understanding of animal welfare and the artificial intelligence and precision livestock farming techniques used to monitor it	
Diagnostics & welfare assessment tools (OO2 and OO3)	New, cheap, accurate, rapid, and easy to use field diagnostic tests and diagnostic techniques (including screening) High throughput diagnostics utilising 'omics or nano technologies	Early detection (development of new tools) of emerging/re-emerging pathogens) More accurate identification or prediction of hotspots of emergence and disease transmission Increased identification of outbreaks and decreased number of false alerts	Scientific production on the related science. N. of new biomarkers N. Guidelines on new diagnostic procedures, validated and harmonized.

Working areas	Deliverables	Outcomes	Proposed KPIs
	New and improved validated and harmonised diagnostics procedures	Enable sharing of data, protocols, specimen, technical expertise	N. of new reagents developed, optimised, automatized and/or harmonised.
	New tests for detecting helminths	Better intervention against helminths	N. of new biobanks, stocks of reference materials, models etc.
	New DIVA tests	Easier and more effective sample collection	Number of developed alternatives (organoids, *in-vitro* models)
	New non-animal models/assays/procedures for testing efficacy and safety of novel therapeutics	Early detection (development of new tools) of AMR and AHR on farms and within the environment.	No. of mobile applications (different species) with the aim to assess welfare on farm.
	New animal welfare labelling scheme initiated by MS and/or Industry	Reduction in the use of antibiotics, anthelmintics and antivirals.	No. Guidelines to implement good practices for AW
	Novel disease and immunology biomarkers	Increased understanding of parasitic diseases and sustainable methods of reduction and treatment.	
		Science-based understanding of virulence and transmission dynamics (within and between herds) of pathogens.	

Working areas	Deliverables	Outcomes	Proposed KPIs
	Develop thresholds for intervention based on animal welfare risk assessment data	Novel biomarkers (health parameters and ethograms of species-specific behaviour) and welfare assessment tools	
		Better understanding of factors and environments that lead to increased stress responses and negative welfare states	
		Deepen understanding of animal health and behaviour that can link to welfare and stress responses	
		Refinement of animal-based measures of welfare	
Farm management (OO5, OO6, OO10)	Recommendations to CAs for progress in regulatory aspect	Scientific basis for new legislation and regulatory framework	Scientific production on the related science
	New genetic breeds with improved robustness	Improved understanding of underlying mechanisms of resistance to allow more applied research to have specific targets to focus future research efforts.	No. Guidelines on new breeding programme
	Breeding programs adapted to alternative production systems		No. Guidelines on husbandry methods to improve resilience
			No. new breeds (Registry for livestock breeds)

Working areas	Deliverables	Outcomes	Proposed KPIs
	EIP Technical notes on the effects of stress-free livestock production	Deepened understanding of how animal emotional state is affected by the presence/absence of antimicrobials, anthelmintics and antivirals.	No. of guidelines /reports produced
	Guidelines for reporting AMR in pathogens of relevance in veterinary medicine	Improved knowledge on immune memory mechanisms	No. pilot farm with adaptation strategies
	Guidelines on best treatments for pathogens (linked with data on phenotypes)	Deepened understanding of behaviours and physiological parameters that indicate negative/positive welfare states in different farmed animal species.	No of pilot farms with improved management systems and reduced AM/AP usage
	Recommendations for cross-sector cooperation and harmonization of OH strategies (Policy level)	Deepened understanding of heat stress tolerances of different farmed animal species and optimal temperature and climate patterns for those species.	No. of training courses and workshops carried out
	Updated measurements of humane endpoints for livestock species	Greater awareness of the environmental effects of pharmaceuticals on the environment (both within and external to the farming environment)	
	Set-up of European/Global training programmes to educate farmers, transporters and slaughtermen and other relevant personnel on how to carry out	Increased understanding of effects of sustainable livestock production on animal welfare and the balance that needs to be created.	

Working areas	Deliverables	Outcomes	Proposed KPIs
	their duties and care for all livestock species while minimising pain and suffering	Improved knowledge on the ecology and interaction between wildlife/aquatic life and farm animal Improved knowledge on the heredity of resilience traits Deepened knowledge on the impact of transport across different farm animal species Deepen understanding of incentives and barriers to adopting innovations and practices such as welfare labelling schemes Understand the acceptability of new technologies aimed at improving of animal health and welfare Improved slaughter and transport facilities to reduce stress, fear, and pain at the pre-slaughter stage Improve understanding of optimal housing conditions for all livestock species (including fish) to minimise poor welfare conditions and maximise positive welfare experiences	

Working areas	Deliverables	Outcomes	Proposed KPIs
		Increase understanding of the consequences of social interactions/hierarchies and the impact these have on welfare	
Vaccine and Treatments (OO7, OO8, OO9)	**Vaccine** Advices on regulatory aspects for each vaccine Shared platform (scientific and regulatory) based on shared lab network VMP administration protocols **Treatments** VMP administration protocols validated and approved Methods/procedures for comparative evaluation	**Vaccine** Improved knowledge on immune memory mechanisms Improved knowledge on computational systems Scientific basis for new legislation and regulatory framework Reduced impact of diseases **Treatments** Improved sustainability of treatments Deepened understanding of economic and social consequences of novel therapeutic strategies	Scientific production on the related science. VMP protocols finalized for new vaccine/Treatments No. of guidelines /reports produced No. of trained stakeholders or courses No. of pilot farms

Working areas	Deliverables	Outcomes	Proposed KPIs
	of clinical efficacy (of antimicrobials and alternatives)	Effective, evidence-based communication strategies	
	Methods/procedures for registration of alternatives to antibiotics	Scientific basis for new legislation and regulatory framework	
	Timely training activity of stakeholder in new developed therapeutic strategies		
	Advice/recommendations on actions on prudent use of anti-microbials		
	Report on socio-economic impact of changes in practice on use of anti-microbials		

ANNEX 1 - Detailed Methodology

Step 1: Establishment of a Working Group in charge of the SRIA process

A Working Group (WG), comprising of representatives from the ICRAD WP6 leaders and other main contributors of the task was established. The WG served, in close consultation with the EUP AH&W core group defined the methodology, delivery plan and timeframe by devising an Action Plan, then proceeded to implement the tasks within the Plan before drafting the SRIA document.

Step 2: Identification of R&I priorities through a desk study

An extensive desk study, performed by the WG, collected, and identified animal health and welfare research and innovation (R&I) needs and priorities from the existing European and global strategic documents. This step was a key component in the analysis of the policy, research, and innovation context for the Partnership. The desk study was carried out in three phases:

Phase A: Compilation of existing strategic documents on animal health and welfare was done in collaboration with representatives from other European initiatives (e.g., CWG-AHW management board, STAR-IDAZ Executive, EUP AH&W Core group, ICRAD Coordinator, DISCONTOOLS EG leaders, OIE research coordinator, One Health EJP coordinator, Epizone coordinator, Animal Health Europe member)

Phase B: Literature review and identification of research and innovation needs.

The WG reviewed the collected literature, distilling R&I needs and developed an Excel spreadsheet tool to capture the research needs identified, track sources and produce the first quantitative data.

Phase C: Validation of R&I priorities

The final draft of the spreadsheet was sent to the members of the European initiatives, previously involved in Phase 1, to seek additional external feedback. The list of research needs was refined accordingly, and duplications were removed.

Step 3: Online prioritization of the identified research and innovation needs

A survey was used to consult with animal health and welfare experts on the research needs highlighted through the previously explained desk study. The survey process was as follows:

Phase A: Generation of a list of experts covering most disciplines in the fields of animal health and animal welfare, both from European countries and outside of the EU including researchers from scientific centers, higher education institutions, industry/professional associations, research funding organizations, government ministries, community groups / NGOs, private sector companies, veterinary practitioners, and independent public agencies.

Phase B: Online survey development and validation
The research needs identified during the desk study were developed into a survey by the WG. After a series of revisions and validation by the EUP AH&W core group, the survey was converted into an online version using the Surveysparrow® platform.

The survey was split into two components:

- Animal Health (122 questions)
- Animal Welfare (65 questions)

Both components were structured into the following eight sections:

1. General information
2. Surveillance and monitoring systems*
3. Diagnostic procedures, methodologies, and tools*
4. Risk assessment and alert communication
5. Farm management preventive tools
6. New interventions and treatments
7. Vaccines, adjuvants, and immune modulators

8. Socio-economic aspects

* merged in Animal Welfare component.

Phase C: Online survey launch

The survey was launched on 11 February 2022 and closed on 11 March 2022. A total of 460 invitations were sent. Respondent were asked to categories research needs into 'urgent' and 'important'

Phase D: Analysis of online survey results

The results of the survey were analyzed using MSOffice Excel®. "I don't know" responses and skipped questions were ignored during the analysis and are not counted for statistical purposes. Expert comments in open questions were considered as qualitative data. For multiple choice questions a mean was applied as a statistical tool, separately for importance and urgency. Basel correction was applied to estimate sample standard deviation.

Phase E: R&I priorities ranking and alignment with the EUP AH&W Operation Objectives

Within each section of the survey, a list of R&I needs ranked according to importance and urgency (separately) was produced, both for the AH and AW components of the survey. The R&I needs were assigned to the most relevant Action within the 10 Operational Objectives (OO) identified by EUP AH&W and ranked by importance.

Step 4: Early stakeholder consultation

To develop the SRIA in an open and participatory manner, the WG planned to consult a broad set of stakeholders to make the agenda more responsive to their needs and ensure their interest and commitment. Most respondents to the survey were researchers form academia and research centers, so during the next step it was fundamental to seek input from industries (high tech, diagnostics industry, vet industry, vaccine, and treatment) and EU associations (farmers associations, livestock associations, animal welfare associations and NGOs). Consequently, two online focus group meetings

were organized to solicit perspectives of these stakeholders on the most important and urgent animal health and welfare R&I priorities identified by the survey. The WG identified and invited approximately **70** contacts, with **50** participants accepting the invitation.

The first focus group meeting was held online on Monday the 13th June 2022, lasting around 3 hours. The meeting primarily considered research needs relating to vaccines, treatments, diagnostics, biosensors, surveillance, and monitoring systems. The second focus group meeting took place online on Friday the 17th of June 2022, lasting 2,5 hours. This meeting considered research needs relating to animal welfare, feeding, breeding and precision livestock farming.

The main scope of both focus groups was to:

- Share the prioritization of research needs identified by the survey of experts from academia/research institutes
- Consider the perspectives of industry and associations, review the prioritization regarding importance and urgency and potential uptake within the framework of EUP AH&W
- And to investigate/solicit interest in possible partnership cooperation and joint working in the areas of mutual interest

To facilitate a more informed and focused discussion, attendees received the input material in advance by e-mail.

After a series of presentations from EUP AH&W and ICRAD representatives, attendees were involved in a structured discussion guided by a facilitator. A survey in parallel was conducted using a pooling web tool (SLIDO by Webex (AH focus group) and Mentimeter (AW focus group)). For the AH focus group, the participants were provided only high and very high-priority (scored not less than 5.2) R&I needs which fit stakeholder contexts and interest. The participants interacted with each other and the facilitator, reviewed the proposed ranking of R&I needs, discussed mitigation and enabling factors, and gave recommendations. The attendees were also invited to provide further input by e-mail within the following week, if so desired.

The resulting new prioritization and additional inputs were collected, analyzed, and compared to the previous ranking for importance and urgency generated by the survey. Some missing research needs were identified by the focus groups and some strategic rewording of needs was suggested, both of which were incorporated into the final SRIA.

Step 5: Drafting of the SRIA

The WG proceeded to draft the SRIA. During a series of internal and external online meetings, with participation by the EUP AH&W core group, the WG agreed on further development of draft documents and the SRIA structure. As a result, an advanced draft of the SRIA including the survey and FG results was produced by the end of September 2022.

Step: Online consultation of scientific experts (October 2022)

Experts that participated in the working groups (i.e., Surveillance, Diagnostics, Farm management, Treatment & Vaccines, Aquaculture, and AMR) that prepared the EUP AH&W Dossier, plus scientists who collaborated in the online SRIA survey were invited to participate in this exercise. The aim was to update the experts with the research needs that have been selected and with their priorities, to invite them to comment on the choices made, and to indicate if essential information was missing.

The results of this consultation served to amend the SRIA and was presented to the online SRIA workshop.

Step: Online SRIA workshop (10 November 2022)

After an introduction where the draft SRIA were presented, two breakout sessions were held: one with representatives of the EUP AH&W beneficiaries (i.e., FO, RPO and Authorities) and one with stakeholders and policy makers. The objectives were to identify possible missing or inappropriate research needs, to question the beneficiaries on possible areas of research calls, integrative and reference activities, and to invite the stakeholders and policy

makers to check whether the EUP AH&W research and other activities are in line with their strategic and operational objectives. The latter objective is important to assess if the EUP AH&W outcome will be in line and lead to a profitable impact in the areas of animal health and welfare.

Step 6: Late stakeholder consultation

In early 2023, all the stakeholders interested and already involved are invited to comment on the advanced draft of the SRIA. This round of consultation is necessary for the elaboration and refining of the central elements of the SRIA.

Step 7: Broad public consultation

This step involves additional external feedback and consultations for broader validation and finalization. To facilitate the quality and relevance of inputs, the dissemination of the final draft of the SRIA to the public is carried out through targeted invitations by e-mail.

Target groups: Key stakeholder, research community, policymakers, enterprises, industry associations, EU/international NGOs

Step 8: Validation and adoption of the SRIA

The present SRIA is formally approved and adopted by a partnership's management body. It is agreed with the Commission prior to the launch of the EUP AH&W initiative.

Survey Results (step 3)

Participation in the study and background of experts

The survey has gathered 126 responses from a broad range of experts coming from 21 European and non-European countries (Table 11).

Initially the site hosting the survey registered 352 accesses, but only 160 experts started to fill in the questionnaire, 78.75% of which have successfully completed the survey. During the selection of experts, the WG team endeavored to maintain a geographically balanced representativeness of north, central and southern Europe as much as possible. Consequently, a fair geographical distribution of the participants across Europe has been achieved *(Figure 7)*

Furthermore, the Figure 8 illustrates the way different countries were attributed their regional affiliation. Overall, 10 experts from third countries participated in the survey: 2 from Israel, 1 from Mexico and 7 from Turkey. No expert from Eastern Europe participated in the survey.

Albania
Austria
Belgium
Denmark
Estonia
France
Germany
Ireland
Israel
Italy
Malta
Mexico
Netherlands
Rep. of North Macedonia
Norway
Portugal
Spain
Sweden
Switzerland
Turkey
United Kingdom

Table 11: List of countries of origin of experts participated in the survey

Figure 6: Geographical distribution of experts which completed the survey.

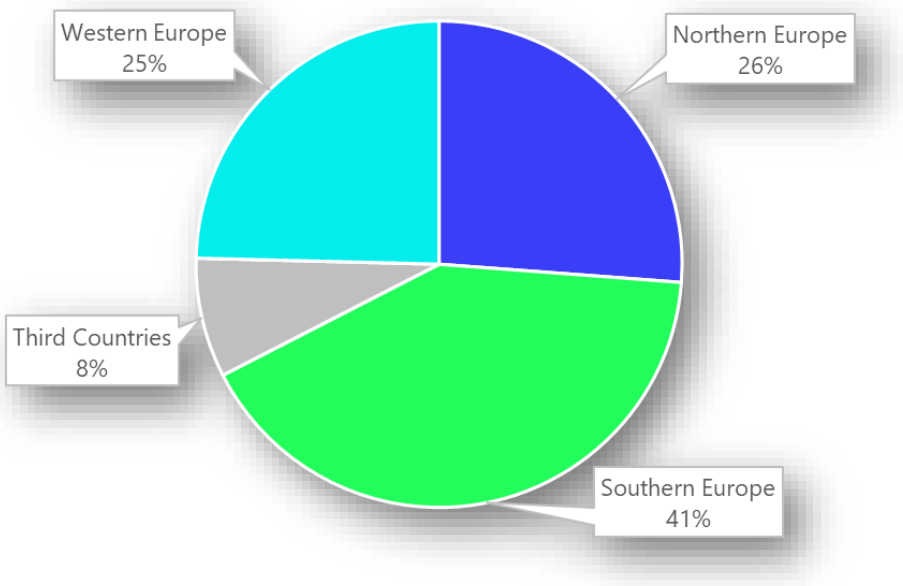
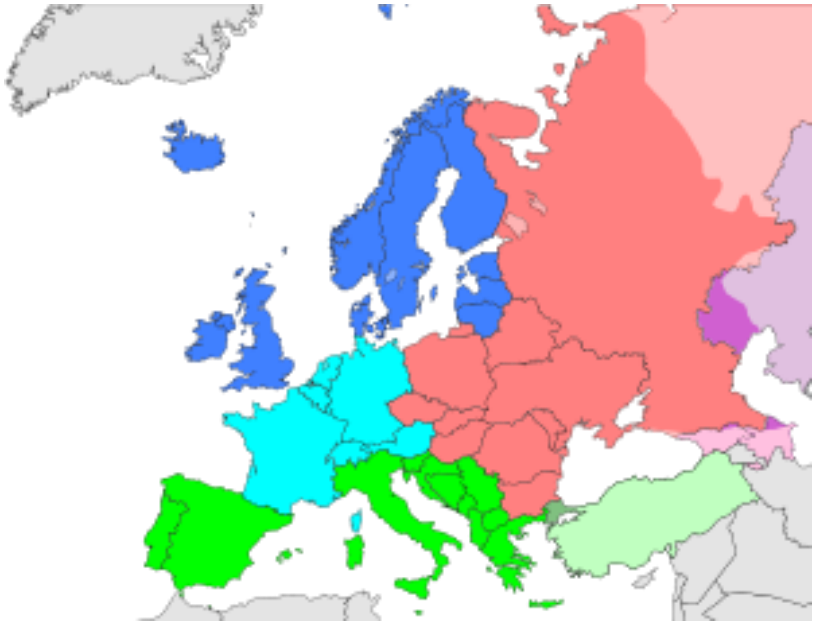


Figure 7: Division of countries in regions.



Most of the experts belonged to academia and research centers and covered a wide variety of scientific fields in animal health and welfare. Specifically, the experts were affiliated mostly to research institutions and universities (32.5% and 27%, respectively). The remaining part of the respondents were related to public and private organizations (Figure 8).

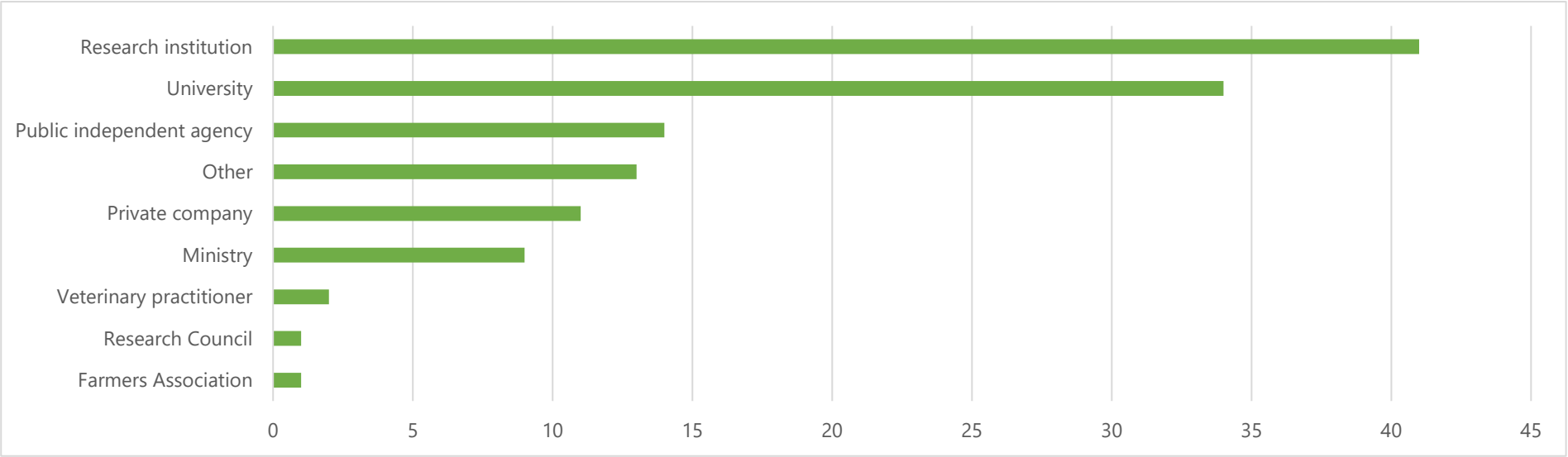


Figure 8: Experts' organisations type

The main expertise of participants was concentrated in the field of diagnostics (49.2%), epidemiology (42.9%) and animal welfare (38.9%). It's worth to note that the experts were given the opportunity to choose as many fields of expertise as they felt necessary. Many experts (30%) chose the option "other", despite the wide range of choice they could select (Figure 9). The field of pathology, biosecurity, risk analysis, vaccinology, animal housing, immunology and therapy were as well highly represented.

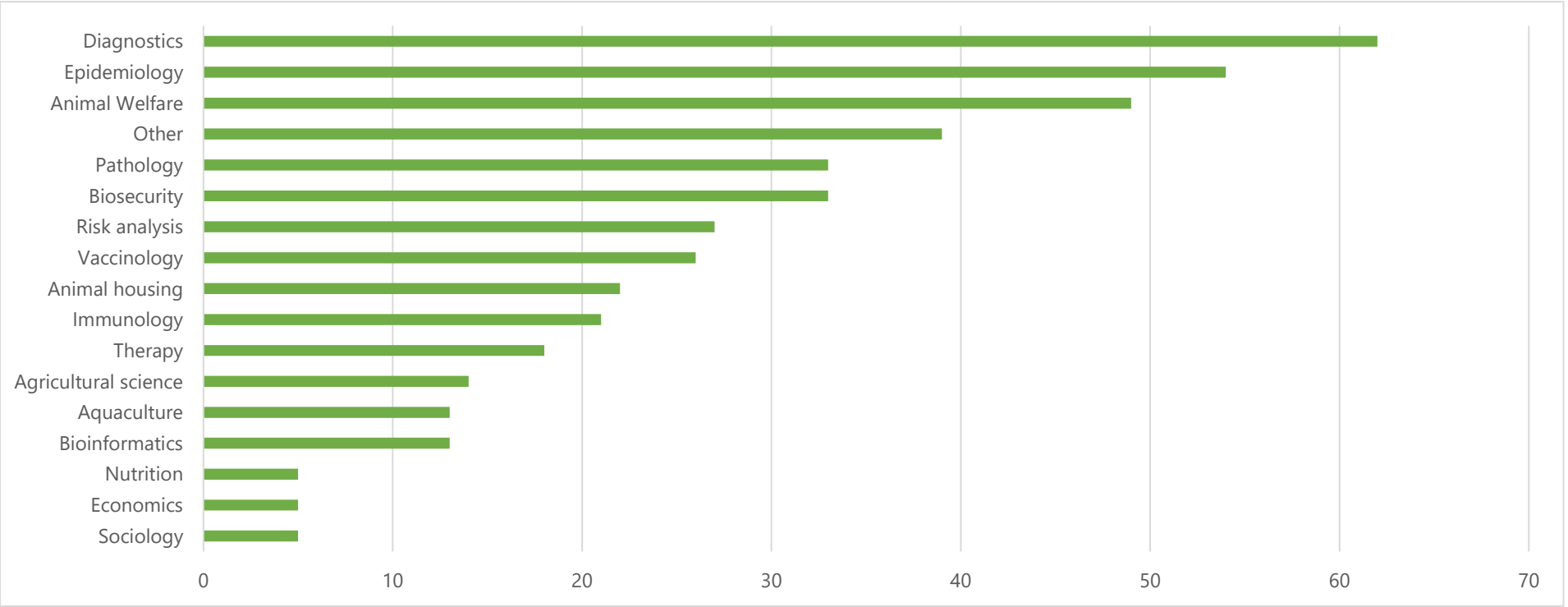


Figure 9: Survey respondents' expertise distribution

At the beginning of the survey the experts could choose to fill in the questionnaire only in Animal Welfare section, only in Animal Health section or in both. One third of the experts filled in both sections, while 54% of them participated only in Animal Health section and 13% only in Animal Welfare section (Figure 10).

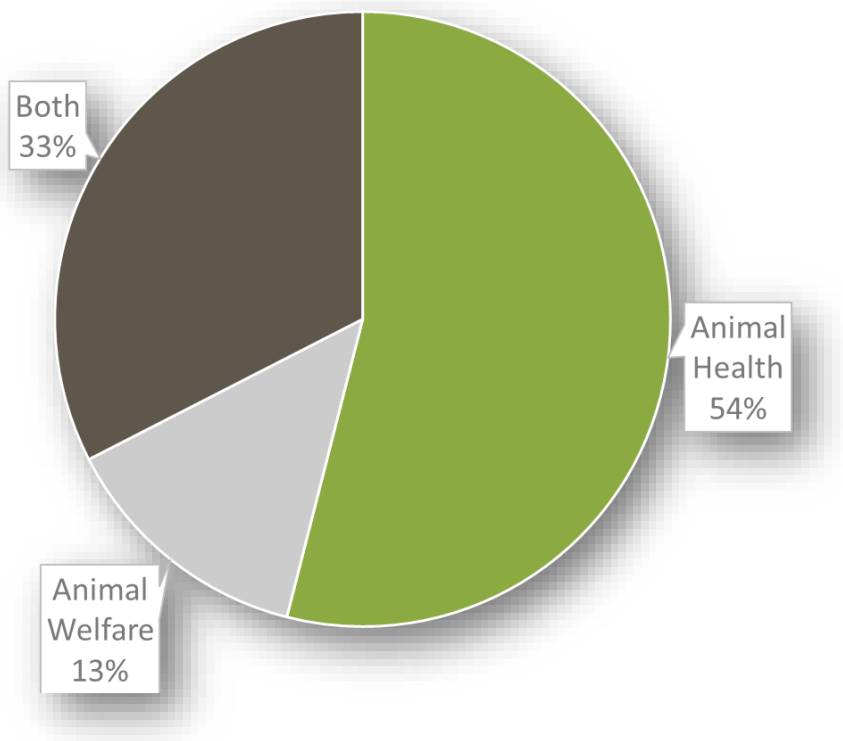


Figure 10: Experts' choice for the participation in two parts of the survey

After the preliminary analysis the research and innovation needs ranked by importance and urgency (scale 1-7 for importance and 1-3 for urgency) were collocated in tables that are aligned with Operational Objectives (OO) and Actions contained in the EUP AH&W dossier (See Figure 6).

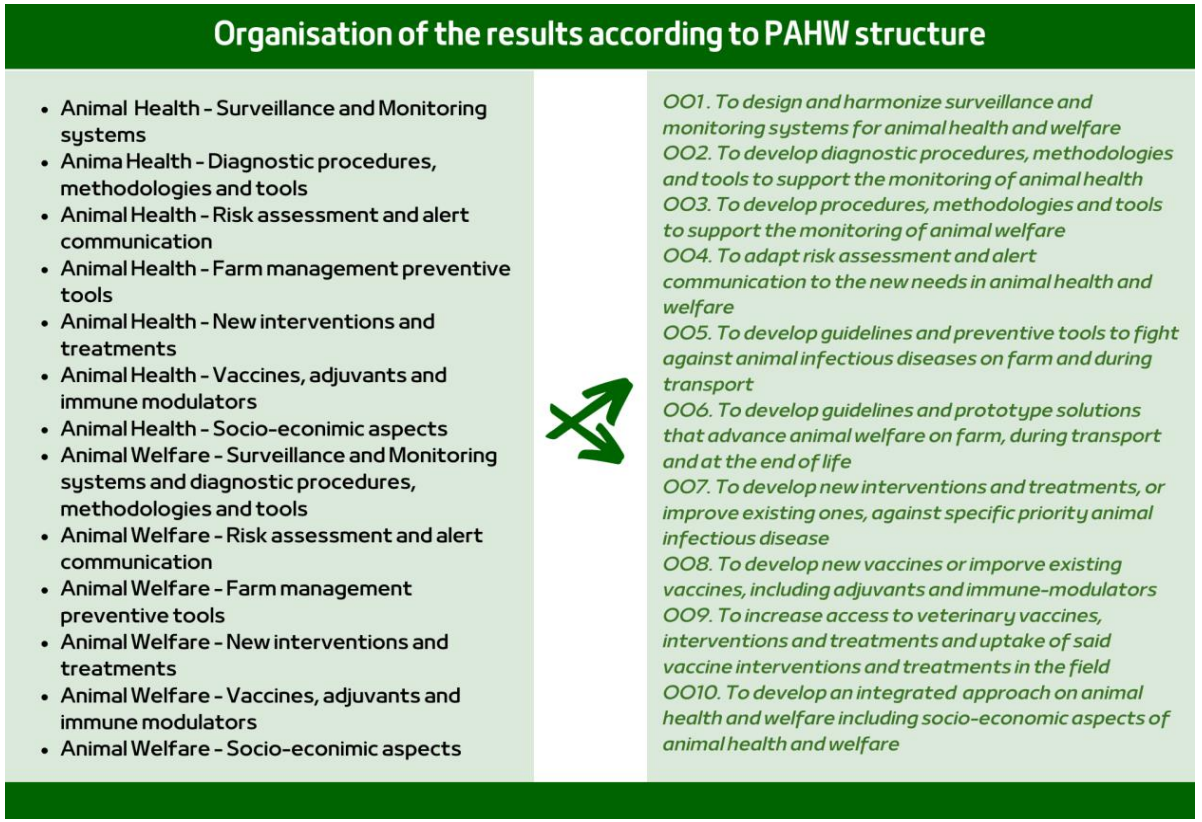


Figure 6: Merging and alignment of survey results with EUP AH&W Operational Objectives

At the end of any OO chapter, a list of experts' suggestions on research needs, strategies and the enabling factors is reported. The overall results were very consistent. The average score for Importance and Urgency were 5.43 and 2.16 for Animal Health and Animal Welfare sections, respectfully. Animal Health shows a standard deviation of 0.41 for Importance and 0.21 for Urgency, while Animal Welfare - 0.39 and 0.20 for Importance and Urgency, respectfully.

In the Annex 2 the results are reported.

Focus Group Results (step 4)

Animal Health

For the AH Focus group most of the participant were experts and consultants for the Animal Health companies dealing with the development of vaccine, diagnostics and treatment involved in Research and Development. Moreover, some representants of experts were chosen from the Core EUP AH&W Working Group (WGs) on Vaccine and Diagnostics which had a role in the Partnership goals definition, who assessed the coherence between the execution of the Focus Groups and the aims of the Partnership according to its dossier.

The most important research needs (as voted by the participants of the survey) were presented to the Focus Group participants. The RNs were categorized into competitive (applied /high TLR) and pre-competitive (fundamental/low TLR) research needs. The stakeholders were asked to express their agreement according to the prioritisation for importance and for urgency resulted from the Experts survey. Especially the indication of urgency was considered crucial to obtain a wider comprehension of industry's needs.

Furthermore, during the FG were presented and ranked strategies, complementary and enabling activities to focalize the support of such factors to the achievement of the research outcomes.

Animal Welfare

Participants in the animal welfare, feeding, breeding and precision livestock farming focus group were a mixture of academics and experts from several European universities and consultants from several companies associated with animal feed, welfare, and breeding.

Participants were presented with a list of thematic areas related to welfare, feeding, breeding and precision livestock farming as determined through a desk study and asked to rank these in terms of importance as well as urgency. The participants were then presented with focused research and innovation gaps (as voted for during the online survey) within each thematic area and were asked to rank them in a similar manner. The participants were also given the opportunity to comment on the research needs and to contribute any extra research needs which they thought were missing.

ANNEX 2 - Survey results: Identified R&I Needs Aligned with EUP AH&W's Operational Objectives

The operational Objects from the EUP AH&W dossier have been mapped to the research needs from the survey and focus groups. Below is an explanation of the OOs.

Animal Health & Welfare - Surveillance and Monitoring systems

OO1. To design and harmonise surveillance and monitoring systems for animal health and welfare

Actions	Research Needs	Importance score	Urgency Score
Action 1. Optimize and extend to other countries current surveillance systems for animal health and zoonotic infections and to develop new ones where needed	**Fundamental Research for Surveillance** - Increase investigations at the human-animal interface of diseases and by increase engagement in networking (One Health approach)	5,97	2,39
	Fundamental Research for Surveillance - Improvement of preparedness for emerging and exotic diseases	5,95	2,54

Actions	Research Needs	Importance score	Urgency Score
	Fundamental Research for Surveillance - Identify transmission sources and/or sentinels for animal diseases (vectors, arthropods, wildlife, domestic or wild relay hosts, animalcules...)	5,89	2,43
	Fundamental Research for Surveillance - Better understanding of the effect of extreme weather and ecosystem changes on vector-borne diseases occurrence and transmission	5,73	2,51
	Development of new tools and technologies - Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	5,98	2,50
	Development of new tools and technologies - Develop optimised terrestrial and aquatic wildlife disease surveillance and reporting systems, including methods, systems, and harmonisation for assessment of wildlife populations and demography	5,36	2,11
	Development of new tools and technologies - Progress alternative methods to control vectors: integrated pest management, biological control, genetically modified insects/improving networking with the human and environment sectors	5,15	2,10
	Development of new tools and technologies - Develop animal identification technologies and systems for traceability of animals and their products for disease prevention, control, and emergency management	4,93	1,99

Actions	Research Needs	Importance score	Urgency Score
	Development of new tools and technologies - Elaborate alternative systems to compensate for downsizing of surveillance/detection systems	4,51	1,73
	Communication - Integrate various surveillance methods and ensure transparency between geographies	5,78	2,33
	Communication- Integrate animal health surveillance systems of different sources	5,78	2,35
Action 2. Set up a European wildlife network (both terrestrial and aquatic animals), based on existing wildlife disease surveillance and reporting systems, to coordinate and expand their activities, to analyse wildlife populations in Europe, and to analyse what specific data with reference to potential threat to animals and humans are needed.	**Fundamental Research for Surveillance** - Increase investigations at the human-animal interface of diseases and by increase engagement in networking (One Health approach)	5,97	2,39
	Fundamental Research for Surveillance - Identify transmission sources and/or sentinels for animal diseases (vectors, arthropods, wildlife, domestic or wild relay hosts, animalcules...)	5,89	2,43
	Fundamental Research for Surveillance - Better understanding of the effect of extreme weather and ecosystem changes on vector-borne diseases occurrence and transmission	5,73	2,51
	Fundamental Research for Surveillance - Study the role of wildlife reservoirs for several diseases which might impact on human and animal health (transmission parameters study, effect of biosecurity measures, wildlife-livestock interactions, physical barriers etc.)	5,48	2,20

ADDENDUM ANNEX 2

Actions	Research Needs	Importance score	Urgency Score
	Development of new tools and technologies - Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	5,98	2,50
	Development of new tools and technologies - Develop optimised terrestrial and aquatic wildlife disease surveillance and reporting systems, including methods, systems, and harmonisation for assessment of wildlife populations and demography	5,36	2,11
	Development of new tools and technologies - Progress alternative methods to control vectors: integrated pest management, biological control, genetically modified insects/improving networking with the human and environment sectors	5,15	2,10
	Communication - Integrate animal health surveillance systems of different sources	5,78	2,35
	Communication - Build a European wildlife network (both terrestrial and aquatic animals) based on existing wildlife disease surveillance and reporting systems	5,57	2,28
	Animal welfare on farm, during transport and at the end of life – Improved understanding of the role of wildlife-livestock interaction	4,90	1,71
	Welfare, sustainable production systems and Biosecurity - Improved understanding of climate change and its impact on welfare	5,35	2,13

Actions	Research Needs	Importance score	Urgency Score
Action 3. Create networks that bring together bioinformatics and epidemiology, to harmonise metagenomic data and data collection methods, to integrate genomic, clinical, and epidemiological data, applicable to both livestock/aquaculture and wildlife.	**Fundamental Research for Surveillance** - Progress prediction methods to identify new and emerging diseases and when they may become a threat to Europe in relation to international trade, global warming, and climate change (e.g., new diseases, transboundary and vector borne diseases)	5,80	2,44
	Development of new tools and technologies - Progress analysis tools that integrate genomic, clinical, and epidemiological data into risk assessment, early detection and disease spread models, including creation of network that bring together bioinformatics and epidemiology applicable to both livestock /aquaculture and wildlife	5,91	2,34
	Development of new tools and technologies - Managing Big data, GIS; progress bioinformatics, improve sharing data integration and better use of existing data	5,89	2,45
	Development of new tools and technologies - Progress artificial intelligence and machine learning techniques that support identification of new pathogens and earlier detection of known pathogens from sequencing and proteomic data	5,37	2,18
	Development of new tools and technologies - Develop tools and systems for syndromic surveillance	4,92	1,91
	Development of new tools and technologies - Research on machine learning based methods for exploring the ontologies of catalogues' values to integrate and network surveillance systems	4,80	1,84

Actions	Research Needs	Importance score	Urgency Score
Action 4. Monitor pathogens of veterinary importance (that are not covered in One Health calls) and their antimicrobial resistance profiles.	**Fundamental Research for Surveillance** - Develop diagnostic tools enabling the early detection and reliable monitoring of infections, in both vectors and vertebrate hosts	6,03	2,55
	Fundamental Research for Surveillance - Better understanding of the effect of extreme weather and ecosystem changes on vector-borne diseases occurrence and transmission	5,73	2,51
	Fundamental Research for Surveillance - Understanding of AMR incidence, prevalence, range across pathogens including study of resistance circulation within and between humans and animals and through food, water, and the environment	5,65	2,33
	Development of new tools and technologies- Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	5,98	2,50
	Development of new tools and technologies - Increase ability to rapidly characterise newly emerged resistance in microorganisms and elucidate the underlying mechanisms	5,53	2,27
Action 5. Build networks, develop FAIR data, and implement FAIR principles for the monitoring of	**Fundamental Research for Surveillance** - Increase investigations at the human-animal interface of diseases and by increase engagement in networking (One Health approach)	5,97	2,39

Actions	Research Needs	Importance score	Urgency Score
(re)emerging animal health and welfare issues, and to develop a hazard monitoring and early warning service.			
	Fundamental Research for Surveillance - Progress prediction methods to identify new and emerging diseases and when they may become a threat to Europe in relation to international trade, global warming, and climate change (e.g., new diseases, transboundary and vector borne diseases)	5,80	2,44
	Development of new tools and technologies - Managing Big data, GIS; progress bioinformatics, improve sharing data integration and better use of existing data	5,89	2,45
	Development of new tools and technologies - Friendly use of platforms supporting farmers and veterinarians in collecting and sharing primary data on animal health. Networks building to develop a hazard monitoring and early warning service	5,56	2,24
	Development of new tools and technologies - Develop FAIR data and implement FAIR principles for the monitoring of (re)emerging animal health issues, and to develop a hazard monitoring and early warning service	5,17	2,08
	Development of new tools and technologies - Develop tools and systems for syndromic surveillance	4,92	1,91
	Development of new tools and technologies - Research on machine learning based methods for exploring the ontologies of catalogues' values to integrate and network surveillance systems	4,80	1,84

ADDENDUM ANNEX 2

Actions	Research Needs	Importance score	Urgency Score
	Fundamental Research for Surveillance - Refinement of Animal-based measures of welfare	5,74	2,43
	Fundamental Research for Surveillance - Development of **indicators and markers for understanding mental experiences of animals**	5,25	2,04
	Fundamental Research for Surveillance - Deepen knowledge between the interaction of animal physical health and animal mental state and emotion	5,20	2,04
	Fundamental Research for Surveillance - Research on animal cognition (e.g., preferences and motivation to obtain rewards)	5,02	1,94
	Development of new tools and technologies - Development of tools for measuring animal stress	5,98	2,41
	Development of new tools and technologies - Integration and better use of existing data and data analysing techniques for animal welfare	5,85	2,43
	Development of new tools and technologies - Validation of diagnostic tests (EEG, artificial intelligence) to assess effective correct stunning at the slaughterhouses	5,50	2,22
	Development of new tools and technologies - Develop FAIR data and implement FAIR principles for the monitoring of (re)emerging animal welfare issues, and to develop a hazard monitoring and early warning service	5,39	2,18

Actions	Research Needs	Importance score	Urgency Score
	Development of new tools and technologies - Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	5,32	2,25
	Development of new tools and technologies - Progress alternatives to animal experiments (e.g., organoid, or in vitro models)	5,27	2,16
	Development of new tools and technologies - Precision Livestock Farming technologies and artificial intelligence for welfare	5,27	2,14
	Development of new tools and technologies - Development of novel big data and bioinformatics techniques for animal welfare	5,04	2,10
Action 6. Create a platform on animal welfare in the EU with the objective to provide scientific and technical support to all stakeholders, related to data necessary for the monitoring of animal welfare; develop animal welfare surveillance systems and their evaluation.	**Development of new tools and technologies -** Development of welfare surveillance systems	5,82	2,52
	Development of new tools and technologies - Development of platforms to support farmers and veterinarians in collecting and sharing primary data on animal welfare	5,62	2,31
	Development of new tools and technologies - Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	5,32	2,25

Animal Health - Diagnostic procedures, methodologies, and tools

OO2. To develop diagnostic procedures, methodologies, and tools to support the monitoring of animal health

To progress toward this operational objective the following Actions are:

Action	Research needs	Importance score	Urgency score
Action 1. Gain knowledge on priority pathogens (i.e., bacteria, parasites, viruses, fungi, prions including resistance patterns) responsible for important economic losses or high risk of transmission to humans and their detection methods, including metagenomics approaches, molecular markers of interest, etc.	**Fundamental research** - Deepen understanding of host-pathogen-microbiome interactions: mechanisms by which emerging pathogens transgress species barriers	5,80	2,27
	Fundamental research - Foster basic research and translational studies to support the development of new diagnostic tools (immunology, microbiology, virology, pathology)	5,63	2,13
	Fundamental research - Develop sensitive biomarkers for early detection of diseases paired with artificial intelligence and remote detection tools	5,40	2,09
	Fundamental research - Deepen understanding of the host-pathogen-microbiome interactions that serves the development of diagnostic tools	5,30	2,11

Action	Research needs	Importance score	Urgency score
	Fundamental research - Expand nanotechnology in animal disease diagnosis	5,19	1,95
	Fundamental research - Identify biomarkers of a healthy (innate) immune system in relation to feed efficiency, disease prophylaxis, pathogenesis, and animal welfare	5,19	1,95
	Fundamental research - Identify stage-specific antigens in helminths that can be used in immune tests	4,30	1,65
	Development of new tools and technologies - Develop new diagnostic tests for helminths detection, including rapid systems for parasitic egg/larvae isolation from faecal and environmental samples, which provide reliable and representative data on e.g., environmental contamination, anthelmintic resistance	4,75	1,84
Action 2. Development, optimisation, and standardisation of reliable, faster, potentially automatable and/or scalable direct antigen/genome amplification/detection and indirect detection/immune response assessment tools/technologies; tools for the rapid	**Development of new tools and technologies** - Develop new, cheap, accurate, rapid, and easy to use field diagnostic tests and diagnostic techniques, including pen-side diagnostics for the early detection of pathogens	5,98	2,44
	Development of new tools and technologies - Develop diagnostic tools enabling the early detection and reliable monitoring of infections, in both vectors and vertebrate hosts	5,86	2,46

Action	Research needs	Importance score	Urgency score
detection of drug-resistant bacteria, viruses, fungi, or parasites; on-farm, pen-site diagnostics for pathogens and antimicrobial resistance; focus on priority pathogens and those that do not have EURL.	**Development of new tools and technologies** - Progress rapid, accurate, pen-side tests for AMR diagnosis	5,69	2,33
	Development of new tools and technologies - Develop routine use of high-throughput technologies (metagenomics, sequencing, and bioinformatics) for multi-target and quantitative diagnostics	5,64	2,22
	Development of new tools and technologies - Tools to study inter-species (including wild animals) circulation of pathogens or resistant variants	5,60	2,22
	Development of new tools and technologies - Develop new screening test for wildlife infectious agents	5,25	2,14
Action 3. Development, optimisation, and standardisation of tools to distinguish between (i) infected and vaccinated individuals (DIVA) as well as (ii) dead and infectious pathogens for the study of pathogens survival in the environment or in effluents and (iii) to study of inter-species (including wild animals) circulation of pathogens or resistant variants.	**Fundamental research** - Develop sensitive biomarkers for early detection of diseases paired with artificial intelligence and remote detection tools	5,40	2,09
	Development of new tools and technologies - Develop DIVA tests	5,67	2,26
	Development of new tools and technologies - Tools that distinguish between dead and infectious pathogens for the study of pathogens survival in the environment or in effluents	5,12	1,99

Action	Research needs	Importance score	Urgency score
Action 4. Development of quantitative and multi-target diagnostics to identify infection levels and silent microorganisms that can interfere with animal production for informed treatment/prevention measures decisions in enzootic production diseases in animals.	**Development of new tools and technologies** - Develop quantitative and multi-target diagnostics to identify infection levels and silent microorganisms for enzootic production diseases in animals	5,61	2,20
Action 5. Development of non or less invasive and more convenient sample collection methods, including new matrices as well as transport, storage, treatment strategies and corresponding diagnostic tools, also suitable for the detection of diseases in free-ranging or wild animals.	**Fundamental research** - Deepen understanding of host-pathogen-microbiome interactions: mechanisms by which emerging pathogens transgress species barriers	5,80	2,27
	Fundamental research - Progress alternatives to animal experiments such as organoid or models in vitro models	5,43	2,21
	New procedures and strategies - Develop non or less invasive and more convenient sample collection methods, including new matrices	5,39	2,10
	New procedures and strategies - Optimise sampling, transport, storage, treatment strategies suitable for the detection of diseases in free-ranging or wild animals	5,16	1,96
	New procedures and strategies - Develop new sampling methodologies and strategies, incl. widening of the range of biological samples	5,08	1,97

ADDENDUM ANNEX 2

Action	Research needs	Importance score	Urgency score
Action 6. Application of new methodologies, i.e., research focusing on application of new detection and characterisation methodologies, on in vitro models; study host-pathogen-environment interactions, i.e., focusing on drivers and markers, on characterisation of microbial ecosystems, on drivers of resistance.	**Fundamental research** - Deepen understanding of the host-pathogen-microbiome interactions that serves the development of diagnostic tools	5,30	2,11
	Development of new tools and technologies - Tools to study inter-species (including wild animals) circulation of pathogens or resistant variants	5,60	2,22

Animal Welfare - Diagnostic procedures, methodologies, and tools

OO3. To develop procedures, methodologies, and tools to support the monitoring of animal welfare

Actions	Research Needs	Importance score	Urgency score
Action 1. Focus on positive welfare (positive emotions), identification of behavioral, endocrine, and neurological indicators of positive welfare: research focusing on animal cognition, preferences, and motivation to obtain rewards.	**Animal welfare on farm, during transport and at the end of life** - Understanding social/group dynamics (for social species)	5,52	2,08
	Animal welfare on farm, during transport and at the end of life - Understanding consequences of social interactions/hierarchies and the impact these have on welfare	5,29	2,12
	Procedures/Methodologies/Tools - Deepen knowledge between the interaction of animal physical health and animal mental state and emotion – Importance	5,20	2,04
	Procedures/Methodologies/Tools - Research on animal cognition (e.g., preferences and motivation to obtain rewards	5,02	1,94
	Fundamental Research: Animal Welfare - Development of indicators and markers for understanding mental experiences of animals	5,25	2,04
	Resilience farming - Understand stockperson care/management practices and their welfare implications	5,80	2,32

Actions	Research Needs	Importance score	Urgency score
Action 2. Development of technologies on the slaughter line to assess animal welfare (on farm and/or during transport). Identification of suitable animal-based measures (ABM) with appropriate level of validity, sensitivity, and specificity; development of in-line sensors, large scale data collection.	**Animal welfare on farm, during transport and at the end of life** - Identify indicators and to develop systems to assess the state of consciousness and death	5,64	2,19
	Development of novel tools and technologies - Development of tools for measuring animal stress	5,98	2,41
	Development of novel tools and technologies- Validation of diagnostic tests (EEG, artificial intelligence) to assess effective correct stunning at the slaughterhouses	5,50	2,22
	Fundamental Research: Animal Welfare - Refinement of Animal-based measures of welfare	5,74	2,43
	Fundamental Research: Animal Welfare - Development of indicators and markers for understanding mental experiences of animals	5,25	2,04
Action 3. Animal welfare at slaughter: i) consciousness and death: development of technologies, procedures and/or protocols to increase the reliability of methods to assess consciousness and death at the slaughter line; ii) improve stunning and killing methods; iii) work on design of slaughter facilities to	**Animal welfare on farm, during transport and at the end of life** - Work on design of slaughter facilities to avoid welfare issues like stress, fear, and pain at pre-slaughter phase	5,94	2,47
	Animal welfare on farm, during transport and at the end of life - Understanding pain recognition and how it varies across species	5,86	2,24
	Animal welfare on farm, during transport and at the end of life - Identify indicators and to develop systems to assess the state of consciousness and death	5,64	2,19

Actions	Research Needs	Importance score	Urgency score
avoid welfare issues like stress, fear, and pain at pre-slaughter phase; related staff training.	**Diagnostics** - Validation of diagnostic tests (EEG, artificial intelligence) to assess effective correct stunning at the slaughterhouses	5,50	2,22
	Development of novel tools and technologies: Animal Welfare - Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	5,32	2,25
Action 4. Development of physiological indicators to measure acute and chronic negative animal welfare consequences on farm. The indicators should identify stress, pain, fear, discomfort, etc. at individual and group levels: measure of physiological stress, impact on immune response and omics (e.g., transcriptomics and metabolomics). Integration of these to metadata welfare tools.	**Animal welfare on farm, during transport and at the end of life** - Understanding pain recognition and how it varies across species	5,86	2,24
	Development of novel tools and technologies: Animal Welfare - Development of tools for measuring animal stress	5,98	2,41
	New interventions and treatments - Studies to further understand infection mechanisms to improve health and welfare	4,87	2,02
	Risk assessment and alert communication - Modelling for the natural behaviour and basic physiological data for different species in different farming systems	5,13	1,89
	Risk assessment and alert communication - Investigations in integration of data originating from transcriptomics, proteomics, and metabolomics methods in animal risk assessment	4,67	1,76
	Fundamental Research: Animal Welfare - Refinement of Animal-based measures of welfare	5,74	2,43

Actions	Research Needs	Importance score	Urgency score
Action 5. Development of digitally assisted monitoring technologies on farms for increasingly enabling precision management of animal (health and) welfare. Technology includes recording visual and auditory signals related to animal-based measures for welfare, analysing records with deep learning technology, data processing techniques and decision support systems.	**Developments of novel tools and technologies: Animal Welfare** - Integration and better use of existing data and data analysing techniques for animal welfare.	5,85	2,40
	Developments of novel tools and technologies: Animal Welfare - Development of platforms to support farmers and veterinarians in collecting and sharing primary data on animal welfare.	5,62	2,31
	Developments of novel tools and technologies: Animal Welfare - Develop FAIR data and implement FAIR principles for the monitoring of (re)emerging animal welfare issues, and to develop a hazard monitoring and early warning service. – Importance	5,39	2,18
	Developments of novel tools and technologies: Animal Welfare - Development of novel big data and bioinformatics techniques for animal welfare – Importance	5,04	2,10
	Developments of novel tools and technologies: Animal Welfare - Develop novel animal identification technologies (e.g., non-invasive biometric identification) for animal welfare monitoring	5,16	2,08
	Risk assessment and alert communication - Develop animal welfare surveillance and its evaluation	6,16	2,49
	Risk assessment and alert communication - Develop thresholds for intervention based on animal welfare risk assessment data	5,58	2,21

Actions	Research Needs	Importance score	Urgency score
	Risk assessment and alert communication - Produce factsheets and any relevant digital infrastructure that enable risk assessment of any breach in animal welfare	5,25	2,04
	Fundamental Research for Surveillance: Animal Welfare - Development of welfare surveillance systems -	5,82	2,52
	Development of Novel Tools and Technologies: Animal Welfare - Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	5,32	2,25
	Development of Novel Tools and Technologies: Animal Welfare - Precision Livestock Farming technologies and artificial intelligence for welfare	5,27	2,14
	Development of Novel Tools and Technologies: Animal Welfare - Precision farming enhanced by developments in (information and communication technology) ICT, GPS-based and sensor technologies for animal welfare	5,54	2,28
Action 6. Development of technologies to assess animal welfare during transport. Affordable and reliable solutions to prevent serious welfare	**Animal welfare on farm, during transport and at the end of** life - Studies on the impact of transport on animal welfare across species	5,92	2,39
	Development of Novel Tools and Technologies: Animal Welfare - Applications of sensors in animal welfare for real-time monitoring.	5,37	2,18

Actions	Research Needs	Importance score	Urgency score
problems through early detection of signals before and whilst in transit, e.g., lameness, lesions, heat stress, aggression, thirst or hunger, exhaustion, etc. Development of sensor technology, data analysis tools, data collection and integration platforms, decision support for the driver; related staff training.	**Development of Novel Tools and Technologies: Animal Welfare** - Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	5,32	2,25
	Development of Novel Tools and Technologies: Animal Welfare - Precision Livestock Farming technologies and artificial intelligence for welfare	5,27	2,14
	Development of Novel Tools and Technologies: Animal Welfare - Precision farming enhanced by developments in (information and communication technology) ICT, GPS-based and sensor technologies for animal welfare	5,54	2,28

Animal Health & Welfare - Risk assessment and alert communication

OO4. To adapt risk assessment and alert communication to the new needs in animal health and welfare

Action	Research needs	Importance score	Urgency score
Action 1. Enhance rapid risk and consequence assessment methodologies, to assess the economic, social, environmental, and cross sectoral consequences of animal health and welfare issues.	**New approaches for risk assessment** - Develop a dynamic risk assessment system and assess methodologies to evaluate the economic, social, environmental, and cross sectoral consequences of animal health issues	5,51	2,18
	New approaches for risk assessment - Improve feedback systems between the actors of the food chain to translate outcomes from risk assessment in policy or control measures	5,23	1,99
	New approaches for risk assessment - Develop real-time traceability in food systems to achieve rapid animal health/public health actions and early warning.	5,72	2,20
	New approaches for risk assessment - Increase risk knowledge by systematically collecting data and undertaking dynamic risk assessments (availability of risk maps and data, knowledge on hazards and vulnerabilities)	5,68	2,32
	New approaches for risk assessment - Develop new or innovative methods/approaches for incorporating machine learning and artificial intelligence in big data-based risk assessment systems.	5,44	2,13

Action	Research needs	Importance score	Urgency score
	New approaches for risk assessment - Improve epidemiological knowledge to quantify the risks of culling versus vaccination (all epizootic and notifiable diseases)	5,23	2,01
	Risk communication - Develop risk perception research to inform policy and improve communication over measures	5,41	2,10
	Risk communication - Investigate and define a method to quantify how the various risk communication strategies are influencing the behaviour of people and, eventually, the occurrence/impact of the diseases	5,37	2,08
	Risk communication - Develop a dynamic risk assessment system and assess methodologies to evaluate the economic, social, environmental, and cross sectoral consequences of animal welfare issues	5,31	2,04
Action 2. Study and assess epidemiological associations between human interventions such as hunting, trade, transport, rewilding and translocations of wildlife and disease spread, to propose harmonized tools to support alert systems.	**New approaches for risk assessment** - Assess epidemiological associations between human interventions such as hunting, trade, transport, rewilding and translocations of wildlife and disease spread, to propose harmonized tools to support alert systems	5,34	2,15
	New approaches for risk assessment - Improve feedback systems between the actors of the food chain to translate outcomes from risk assessment in policy or control measures	5,23	1,99
	Data collection and management - Develop real-time traceability in food systems to achieve rapid animal health/public health actions and early warning.	5,72	2,20

ADDENDUM ANNEX 2

Action	Research needs	Importance score	Urgency score
Action 3. Adapt existing or develop new methodologies to integrate genomic surveillance data in risk assessment and to draft risk assessment guidelines for the integrated use of epidemiological and genomic data.	**New approaches for risk assessment** - Draft risk assessment guidelines for the integrated use of epidemiological and genomic data	5,35	2,10
	New approaches for risk assessment - Develop new methodologies to integrate the data originating from transcriptomics, proteomics, and metabolomics tools in animal health risk assessment	5,02	1,95
	Data collection and management - Develop new or innovative methods/approaches for incorporating machine learning and artificial intelligence in big data-based risk assessment systems.	5,44	2,13
	Data collection and management - Applications of sensors in animal health for real-time monitoring	5,34	1,99
	Risk assessment and alert communication - Investigations in integration of data originating from transcriptomics, proteomics, and metabolomics methods in animal risk assessment	4,67	1,76
Action 4. Assess the risk of spread of resistant animal pathogen clones and genes encoding resistance.	**New approaches for risk assessment** - Asses the risk of spread of multi resistant animal pathogen improving understanding on the patterns of transmission of clones or resistant genes	5,56	2,27

Action	Research needs	Importance score	Urgency score
	New approaches for risk assessment - Molecular profiling of the immune system of the different livestock species and investigations into possibilities of reaching trained immunity over the life cycle of the animals	4,88	1,90
Action 5. Build or further map and coordinate emergency networks for scientists and communities, to increase risk knowledge by systematically collecting data and undertaking risk assessments (availability of risk maps and data, knowledge on hazards and vulnerabilities).	**New approaches for risk assessment** - Animal health risk-assessment-related data sharing and networking among research centres	5,67	2,18
	New approaches for risk assessment - Map existing, standardized EU risk assessment platforms and notification systems and possibilities for their interoperability.	5,38	2,19
	Risk communication - Develop risk perception research to inform policy and improve communication over measures	5,41	2,10
	Risk communication - Boost risk communication and social research to inform and promote disease management and prevention, at all target levels	5,40	2,13
	New approaches for risk assessment - Animal welfare risk-assessment-related data sharing and networking among research centres	5,28	2,04
	New approaches for risk assessment - Produce factsheets and any relevant digital infrastructure that enable risk assessment of any breach in animal welfare	5,25	2,04
Action 6. Develop animal welfare surveillance and its evaluation, develop	**Fundamental Research for Surveillance: Animal Welfare** - Develop animal welfare surveillance and its evaluation	6,16	2,49

Action	Research needs	Importance score	Urgency score
indicators and alarm levels, produce factsheets and any relevant digital infrastructure that enable risk assessment of any breach in animal welfare.	**New Approaches for Risk Assessment** - Investigations into possible application of science-based animal welfare risk assessment criteria in real life and under different husbandry conditions	5,81	2,23
	New Approaches for Risk Assessment - Develop thresholds for intervention based on animal welfare risk assessment data	5,58	2,21
	Development of Novel Tools and Technologies - Applications of sensors in animal welfare for real-time monitoring.	5,37	2,18
	New Approaches for Risk Assessment - Modelling for the natural behaviour and basic physiological data for different species in different farming systems	5,13	1,89

Animal Health - Farm management preventive tools

OO5. To develop guidelines and preventive tools to fight against animal infectious diseases on farm and during transport

Action	Research needs	Importance score	Urgency score
Action 1. Establish a multidisciplinary network of experts with focus on biosecurity measures to prevent and control AID on farm and during transport, and draft foresight and priority studies on animal health, public health, pandemics and the role of biodiversity, the changing climate, emerging vectors and vector-borne diseases, bird and fish migrations, epidemiology/ modelling, bioinformatics, etc. for all animal species, including minority species and aquaculture.	**Development of novel tools and technologies**- Foster sharing of information and uptake of innovation by networking	5,39	2,03
	Biosecurity - Establish a multidisciplinary network of experts with focus on biosecurity measures to prevent and control animal infectious diseases on farm and during transport	5,30	2,17

Action	Research needs	Importance score	Urgency score
Action 2. Reduce the entrance and spread of AID by reinforcing external and internal biosecurity in both terrestrial and aquatic animals, while limiting antimicrobial use, set up innovative systems and models with focus on biosecurity and integrated management.	**Biosecurity** - Improve biosecurity methods to control the spread of diseases and technology for inactivation of pathogens	5,47	2,21
	Biosecurity - Improve biosecurity methods to control the spread of diseases and technology for inactivation of pathogens	6,10	2,41
	Biosecurity - Develop biosecurity strategies on all levels	5,78	2,37
	Biosecurity - Improve efficient and safe management of manure, animal by-products, slurries and water recycle systems	5,72	2,28
	Biosecurity - Identify biosecurity risks associated with organic farming	5,42	2,20
Action 3. Perform research on prudent use of antimicrobials: research on treatment concepts for antimicrobial and antiparasitic usage, on alternatives to antimicrobials including feed additives/nutrition, studying improved vaccination strategies, etc.; development of best practices for administration/application of Veterinary Medicine Products (VMP) in livestock and aquaculture production systems.	**New intervention and treatment** - Develop strategies to reduce antimicrobial and anti-helminthic use (incl. feed additives/nutrition) and/or to encourage their prudent use	6,20	2,64
	New intervention and treatment - Development of best practices for administration/application of veterinary medicine products in livestock and aquaculture production systems	5,67	2,39
	New intervention and treatment - Study on improved vaccination strategies	6,13	2,56
	New intervention and treatment - Study environmental impact of treatments	5,80	2,34

Action	Research needs	Importance score	Urgency score
Action 4. Reinforce animal resilience/resistance (the natural ability of animals to withstand pathogens), through feeding and breeding; establish a pan-European network of experts in genetics (breeding), feed additives including pre- and probiotics and leading experts in immunology to produce foresight and priority reports; both fundamental and applied research supporting animal resilience will be set up.	**Development of novel tools and technologies** - Develop Precision Livestock Farming (PLF) tools and Farm Management Information Systems (FMIS) (data collection, processing and decision making)	5,46	2,19
	Development of novel tools and technologies - Improve breeding technologies: e.g., integration of molecular technologies into breeding programs, especially for low heritability traits and traits associated with health and pathogen resistance	4,86	1,95
	New procedures and strategies - Advance climate change mitigation and adaptation strategies	6,07	2,52
	New procedures and strategies - Develop new production systems and study on their sustainability (both terrestrial and aquatic)	5,74	2,26
	Fundamental Research- Advance genetic selection for animal health resilience, promote the use of local and more resistant breeds, increasing natural disease resistance or tolerance	5,35	2,09
	Fundamental Research - Improve genetic evaluations for animal health	4,98	1,88
	Fundamental Research - Increase knowledge of systems at the level of the transcriptome, proteome and metabolome that contribute to understanding the links between the genome and the traits of interest.	4,85	1,87

Action	Research needs	Importance score	Urgency score
	Fundamental Research - Increase understanding of how genetic engineering in farm animals affects zoonotic disease resistance	4,84	1,85
	Fundamental Research - Advance precision genetic modification using homologous recombination in appropriate stem cells, use of zinc-finger nucleases and RNAi-based gene knockdown.	4,02	1,61
	Health, treatments, vaccines and feeding - Understanding how alternative protein sources (incl. insects) affect animal health (risks/benefits)	5,06	2,04
	Health, treatments, vaccines and feeding - Study on technopathies of terrestrial and aquatic animals	4,73	1,77
	Health, treatments, vaccines and feeding - Advance phenomics – the physical and biochemical traits of organisms	4,58	1,70

Animal Welfare - Farm management preventive tools

OO6. To develop guidelines and prototype solutions that advance animal welfare on farm, during transport and at the end of life

Actions	Research Needs	Importance score	Urgency score
Action 1. Establish a multidisciplinary network of experts to draft foresight and priority studies with focus on sustainability aspects related to non-cage systems, indoor and outdoor systems for livestock, animal transportation and slaughter, killing on farm, in slaughterhouses or at sea, and focusing on ending mutilations, including aquaculture production systems.	**Animal welfare on farm, during transport and at the end of life** - Studies which demonstrate alternative solutions to reduce animal mutilations	6,09	2,52
	Animal welfare on farm, during transport and at the end of life - Develop Pain free and feasible new methods for on-farm	5,60	2,24
	New Procedures and Strategies - Development of platforms to support farmers and veterinarians in collecting and sharing primary data on animal welfare.	5,62	2,31
	Risk assessment and alert communication - Investigations into possible application of science-based animal welfare risk assessment criteria in real life and under different husbandry conditions	5,81	2,23
	Risk assessment and alert communication - Animal welfare risk-assessment-related data sharing and networking among research centres	5,28	2,04

Actions	Research Needs	Importance score	Urgency score
Action 2. Perform research on how to improve animal welfare while maintaining or increasing farm economic and environmental sustainability. Involves animal cognitive capacities and emotions adapted to each species' needs, opportunities for pain relief, and environmental enrichments technologies. Aims to develop innovative housing systems and addresses the opportunities and consequences of reducing the use of cages in a sustainable way, in terms of economic and environmental impacts.	**Animal welfare on farm, during transport and at the end of life** - Understanding the role of environmental enrichment on animal welfare	5,79	2,21
	Animal welfare on farm, during transport and at the end of life - Understanding animal housing - welfare and cost implications	5,73	2,24
	Animal welfare on farm, during transport and at the end of life - Understanding the impact of behavioural restriction/inability to express behaviour on welfare	5,71	2,24
	Risk assessment and alert communication - Develop a dynamic risk assessment system and assess methodologies to evaluate the economic, social, environmental, and cross sectoral consequences of animal welfare issues	5,31	2,04
	Socio-economic - Establish social science studies along the production chain to monitor behaviour towards maintaining and improving animal welfare, including consumers' willingness to pay for improvements; incentives and barriers to adopting innovations and practices such as welfare labelling schemes	6,02	2,46
	Biosecurity - Improved understanding of stocking density and its welfare implications and economic trade-offs	6,00	2,28
	Biosecurity - Improved understanding of the trade-offs between sustainability and animal welfare	5,96	2,38
	Biosecurity - Improved understanding of trade-offs between farming (production and practices) and welfare	5,54	2,31

Actions	Research Needs	Importance score	Urgency score
	Biosecurity - Develop tools/strategies for effective monitoring of air quality to maintain high animal welfare	5,19	2,11
	Biosecurity - Efficient and safe management of manure and animal by-products for improved of animal welfare	4,43	1,64
Action 3. Perform background science to identify indicators and to develop systems to assess the state of consciousness and death, develop appropriate Precision Livestock/fish Farming and killing technologies to limit pain and reduce stress, alert systems for poor welfare during transport, etc.; develop innovative systems in livestock/fish transport and slaughter.	**Animal Welfare Fundamental Research** - Understanding pain recognition and how it varies across species	5,86	2,24
	Development of Novel Tools and Technologies: Animal Welfare - Development of tools for measuring animal stress	5,98	2,41
	Development of Novel Tools and Technologies: Animal Welfare - Progress alternatives to animal experiments (e.g., organoid, or in vitro models) – Importance	5,27	2,16
	Fundamental Research for Animal Welfare Surveillance - Development of welfare surveillance systems	5,82	2,52
	Animal Welfare Fundamental Research - Refinement of Animal-based measures of welfare	5,74	2,43
	Development of Novel Tools and Technologies: Animal Welfare - Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	5,32	2,25

Actions	Research Needs	Importance score	Urgency score
	Development of Novel Tools and Technologies: Animal Welfare- Precision Livestock Farming technologies and artificial intelligence for welfare	5,27	2,14
	Development of Novel Tools and Technologies: Animal Welfare - Precision farming enhanced by developments in (information and communication technology) ICT, GPS-based and sensor technologies for animal welfare	5,54	2,28
	Development of Novel Tools and Technologies: Develop animal-free models for vaccine development, such as organoids	5,51	2,24
Action 4. Improve animal welfare through feeding and breeding strategies.	**Animal welfare on farm, during transport and at the end of life** - Welfare considerations for new methods of rearing	5,69	2,24
	Fundamental Research - Understanding of the Intestinal microbiota and their role in immunity, health, and welfare and across the life course	4,86	1,79
	New Procedures and Strategies - Develop and set appropriate breeding goals that consider welfare implications (not solely focused on production)	5,73	2,24
	New Procedures and Strategies - Research to improve animal welfare through feeding and breeding strategies	5,29	2,14
	New Procedures and Strategies - Develop/Improve reproductive/breeding technologies to select for high welfare traits or improve performance and welfare	5,22	2,22

Actions	Research Needs	Importance score	Urgency score
	Fundamental Research: Animal Welfare - Develop seasonal diets for appropriate nutrition (especially dairy cows and sows) to improve animal welfare	4,79	1,85
Action 5. Evaluate the need and possibility to set up a pan-European network of experimental farms.	**New Procedures and Strategies** - Set up relevant networks	4,91	1,96
	Biosecurity - Deepen knowledge of microbial ecosystems on farms	4,70	1,87

Animal Health & Welfare - New interventions and treatments

OO7. To develop new interventions and treatments, or improve existing ones, against specific priority animal infectious disease

Actions	Research Needs	Importance score	Urgency score
Action 1. Perform basic research (TRL 1-2) to study interactions between pathogens and host microbiome, focussing on the immune system (e.g., pathobiome), and direct or indirect interactions between pathogens (e.g., co-infections), antimicrobial and antiparasitic drugs and host microbiome, mechanisms of anti-microbial (antibiotic and antiparasitic) resistance; trained immunity.	**Understanding of immunology and environment for new interventions and treatments** - Improved understanding of direct or indirect interactions between pathogens (e.g., co-infections) and between pathogen and host and its microbiome	5,87	2,25
	Understanding of immunology and environment for new interventions and treatments - Better understanding of host immunity	5,67	2,20
	Understanding of immunology and environment for new interventions and treatments - Evaluate the interaction between feed, the development of immunity and increased resistance of animals to pathogens especially for young animals (piglets, chicken)	5,64	2,20
	Understanding of immunology and environment for new interventions and treatments - Better underpinning understanding of health ecology and connections between microbial communities, animal health & welfare	5,51	2,21

Actions	Research Needs	Importance score	Urgency score
	Understanding of immunology and environment for new interventions and treatments - Synergy between pharmacological solutions to disease outbreaks and vaccination	5,49	2,11
	Understanding of immunology and environment for new interventions and treatments - Better understanding of direct or indirect interactions between antimicrobial and antiparasitic drugs and host microbiome	5,44	2,04
	Understanding of immunology and environment for new interventions and treatments - Piloting animal ecosystems to reduce pathogen shedding in the environment	5,01	1,89
	Understanding of immunology and environment for new interventions and treatments -Studies to further understand infection mechanisms to improve health and welfare	4,87	
	Antimicrobials and alternatives to antibiotics - Better understanding of the molecular and cellular basis of antibiotic resistance	5,59	2,21
	Antimicrobials and alternatives to antibiotics - Better understanding of anthelmintic resistance (e.g., mechanisms of resistance, genetics, ecology) and markers of resistance	5,25	2,07
	Antimicrobials and alternatives to antibiotics - Investigation of the impact of the reduction of antimicrobials and antibiotic free productions on animal welfare	5,52	2,37

Actions	Research Needs	Importance score	Urgency score
	Antimicrobials and alternatives to antibiotics - Reducing antimicrobial resistance and its impact on welfare	5,42	2,24
Action 2. Develop tools such as **1. experimental farm approaches** **2. in vivo, in vitro and in silico infection models for testing efficacy and safety of new drugs with reduced need for animal testing, new drug-delivery devices, therapeutics including leads for new antimicrobials and** 3. **bioinformatic pipelines for analysis of microbiome and pathogen data; this will be done in collaboration with industry, where appropriate.**	**Antimicrobials and alternatives to antibiotics** - Develop novel antimicrobial molecules e.g., antiseptics, antimicrobial peptides (bacteriophages), immunomodulatory specific agonists or antagonists and bioactive plants or alternative specialty feed ingredients such as plant extracts (essential oils, tannins, etc.)	6,34	2,64
	Antimicrobials and alternatives to antibiotics- Conduct studies on animals to evaluate the effect of pre and probiotics, immuno-stimulants, phages and synthetic microbial communities at different stages of life	5,31	2,16
	Antimicrobials and alternatives to antibiotics - Studies on antibiotic effectiveness and availability	5,27	2,11
	Antimicrobials and alternatives to antibiotics - Conduct in vitro/in silico studies on pre and probiotics, immuno-stimulants, phages and synthetic microbial communities	5,20	2,15
	Tools and Technologies for novel interventions and treatment - Develop novel immunomodulators and antivirals	5,71	2,28
	Tools and Technologies for novel interventions and treatment - Develop bioinformatic pipelines for analysis of microbiome and pathogen data	5,54	2,14

Actions	Research Needs	Importance score	Urgency score
	Tools and Technologies for novel interventions and treatment - Develop novel therapeutics/ strategies to control parasitic diseases	5,49	2,19
	Tools and Technologies for novel interventions and treatment - Utilize Reverse genetics studies for new intervention and treatment research	5,23	2,06
	Tools and Technologies for novel interventions and treatment - Utilise Genomics and Integrated Biology studies for new intervention and treatment research	5,23	2,01
	Tools and Technologies for novel interventions and treatment - Conduct safety and residue studies to expand availability of therapeutics into the minor use/minor species areas	5,19	2,04
	Tools and Technologies for novel interventions and treatment - Utilise synthetic biology studies for new intervention and treatment research	5,14	1,84
	Tools and Technologies for novel interventions and treatment- Develop nanotechnology in animal health for new interventions and treatments	4,80	1,93
	Tools and Technologies for novel interventions and treatment -Develop in vivo, in vitro and in silico infection models for testing efficacy and safety of new drugs with reduced need for animal testing, new drug-delivery devices, therapeutics including leads for new antimicrobials	5,42	2,26
	Tools and Technologies for novel interventions and treatment -Develop pharmacokinetic studies to reduce animal experimentation and provide	5,16	2,14

Actions	Research Needs	Importance score	Urgency score
	effective dosing schedules to reduce incidence of resistance and maximise efficacy		
	Tools and Technologies for novel interventions and treatment - Valid, reliable, and feasible welfare indicators for monitoring drug delivery	4,70	1,83
Action 3. Build on the results of Action 1&2 to develop or improve interventions and treatments and deliver first proof of concept, where appropriate, in collaboration with industry: demonstration of IMMUNOGENICITY and efficacy (MINIMUM IMMUNIZING DOSE) in target species; representative (small scale) animal (challenge) model (TRL 3-4)	**Antimicrobials and alternatives to antibiotics**- Conduct studies on animals to evaluate the effect of pre and probiotics, immuno-stimulants, phages and synthetic microbial communities at different stages of life	5,31	2,16
	Antimicrobials and alternatives to antibiotics - Studies on antibiotic effectiveness and availability	5,27	2,11
	Tools and Technologies for novel interventions and treatment - Develop novel therapeutics/ strategies to control parasitic diseases	5,49	2,19
	Tools and Technologies for novel interventions and treatment - Conduct safety and residue studies to expand availability of therapeutics into the minor use/minor species areas	5,19	2,04
Action 4. In collaboration with industry: bring outputs to higher TRL	**Antimicrobials and alternatives to antibiotics**- Conduct studies on animals to evaluate the effect of pre and probiotics, immuno-stimulants, phages and synthetic microbial communities at different stages of life	5,31	2,16

Actions	Research Needs	Importance score	Urgency score
in early/pre-clinical development (GMP-material; TRL 5-6). **1. for non-food animals: demonstration of efficacy and field safety at large scale in representative animal models or approved alternative methods** **2. for food animals: lab-scale assessment of animal safety and initiation of environmental safety, user safety, and (if needed) microbiological safety assessments; absence of toxicity/side effects carcinogenicity studies initiated if needed, and demonstration of efficacy and field safety at large scale in a representative animal model and toxicology studies** **Work on TRL 7 to 9 (late/clinical development, marketing authorisation and lifecycle management) will be performed by industry itself**.	**Antimicrobials and alternatives to antibiotics** - Studies on antibiotic effectiveness and availability	5,27	2,11
	Tools and Technologies for novel interventions and treatment - Develop novel therapeutics/ strategies to control parasitic diseases	5,49	2,19
	Tools and Technologies for novel interventions and treatment - Conduct safety and residue studies to expand availability of therapeutics into the minor use/minor species areas	5,19	2,04
	Tools and Technologies for novel interventions and treatment - Studies to investigate side effects of treatments and their welfare impacts	5,23	1,98

ADDENDUM ANNEX 2

Actions	Research Needs	Importance score	Urgency score
POSSIBLE NEW ACTION ON RELATION BETWEEN ANIMAL WELFARE AND NEW INTERVENTIONS AND TREATMENTS	**New interventions and treatments** - Investigation of the impact of the reduction of antimicrobials and antibiotic free productions on animal welfare	5,52	2,37
	New interventions and treatments - Develop in vivo, in vitro and in silico infection models for testing efficacy and safety of new drugs with reduced need for animal testing, new drug-delivery devices, therapeutics including leads for new antimicrobials	5,42	2,26
	New interventions and treatments - Reducing antimicrobial resistance and its impact on welfare	5,42	2,24
	New interventions and treatments - Studies to investigate side effects of treatments and their welfare impacts	5,23	1,98
	New interventions and treatments - Develop pharmacokinetic studies to reduce animal experimentation and provide effective dosing schedules to reduce incidence of resistance and maximise efficacy	5,16	2,14
	New interventions and treatments - Valid, reliable, and feasible welfare indicators for monitoring drug delivery	4,70	1,83

Animal Health & Welfare - Vaccines, adjuvants, and immune modulators

OO8. To develop new vaccines or improve existing vaccines, including adjuvants and immune modulators

Actions	Research Needs	Importance score	Urgency score
Action 1. Study the role of the immune system of farm animals, including the innate immune capacity of new-born animals; the mechanisms that elicit protective immunity at the entry site, factors affecting immune response to vaccines, mode of action of adjuvants (basic research; TRL 1-2).	Understanding immunology and pathogen biology for vaccine development- Better understanding of pathogen biology for better targeting of vaccines and therapeutics	5,91	2,36
	Understanding immunology and pathogen biology for vaccine development- Utilise systems vaccinology to identify immune correlates and surrogates of protection including repertoire signatures and response to adjuvants	5,64	2,19
	Understanding immunology and pathogen biology for vaccine development- Study the role of the immune system of farm animals, including the innate immune capacity of new-born animals; the mechanisms that elicit protective immunity at the entry site	5,56	2,22
Action 2. Develop tools such as vaccine platforms and expression systems, immunological toolboxes (cell lines,	**Tools and technologies for vaccine development** - Develop and improve research and translation of new vaccines (e.g., DIVA, recombinants) including new genetically engineered vaccines	6,12	2,54

Actions	Research Needs	Importance score	Urgency score
reagents, etc.) and delivery systems, etc.; this will be done in collaboration with industry, where appropriate	**Tools and technologies for vaccine development** - Establish a pipeline of vaccine platform technologies, expression systems, immunological toolboxes (cell lines, reagents, etc.) and delivery systems, etc.	5,64	2,27
	Tools and technologies for vaccine development - Utilise bioinformatics and mathematical modelling to study efficacy of new treatments and vaccine	5,54	2,20
	Tools and technologies for vaccine development - Develop animal-free models for vaccine development, such as organoids	5,51	2,24

Animal Health & Welfare: Access to interventions

OO9. To increase access to veterinary vaccines, interventions and treatments and uptake of said vaccine interventions and treatments in the field

Animal Health & Welfare - Socio-economic aspects

OO10. To develop and integrated approach on animal health and welfare including socio-economic aspects of animal health and animal welfare

Action	Research needs	Importance score	Urgency score
Action 1. Assess the burden of selected priority diseases (including resistant pathogens), including their control (e.g., cost-benefit of different surveillance components and risk mitigation options).	**Animal health** - Improve the assessment of the burden of selected priority diseases, including their control measures (e.g., cost-benefit of different surveillance components and risk mitigation options)	5,59	2,22
	Animal health - Develop models to assess the cost of antimicrobial resistance and the costs and benefits of intervention plans	5,38	2,08

Action	Research needs	Importance score	Urgency score
Action 2. Set up social science studies among farmers, veterinarians, consumers, and other actors along the production chain on their behaviour (also in relation to AM use) to maintain and improve animal health, including consumers' willingness to pay for improvements; incentives and barriers to adopt innovations and practices.	**Animal health** - Social science studies among stakeholders along the production chain on their behaviour to maintain and improve animal health, including consumers' willingness to pay for improvements; incentives and barriers to adopt innovations and practices	5,63	2,24
	Animal health - Interventions to improve awareness on infectious animal diseases	5,45	2,16
	Animal health - Social science on acceptance of genetic improvement	4,42	1,59
Action 3. Set up social science studies among farmers, veterinarians consumers and other actors along the production chain on their behaviour to maintain and improve animal welfare, including consumers' willingness to pay for improvements; incentives and barriers to adopt innovations and practices, including welfare labelling schemes.	**Animal welfare** - Establish social science studies along the production chain to monitor behaviour towards maintaining and improving animal welfare, including consumers' willingness to pay for improvements; incentives and barriers to adopting innovations and practices such as welfare labelling schemes	6,02	2,46
	Animal welfare - Study the integration of animal infectious disease mitigation and improved animal	5,77	2,25

Action	Research needs	Importance score	Urgency score
	welfare in the overall context of sustainable livestock production and aquaculture in the EU		
	Animal welfare Understanding the role of veterinarians in improving welfare – knowledge and technology transfer to end users	5,64	2,20
	Animal welfare - Social science studies to assess the acceptability of new technologies aimed at improving of animal health and welfare	5,44	2,00
	Animal welfare - Improve cost effectiveness of real-time data collection	5,24	1,92
Action 4. Study the integration of AID mitigation and IMPROVED ANIMAL WELFARE in the overall context of sustainable livestock production and aquaculture in the EU.	**Animal health** - Improve cost effectiveness of data/Realtime collection	5,13	2,07
Action 5. Develop integrated strategies for the control of diseases, including emergency situations, considering relevant criteria, e.g., epidemiological situation, cost-	**Animal health** - Develop integrated strategies for the control of diseases, including emergency situations, considering relevant criteria, e.g., epidemiological situation, cost-benefit, etc. to support decision making	5,84	2,34

Action	Research needs	Importance score	Urgency score
benefit, etc. to support decision making by national and international risk managers and other relevant stakeholders.	by national and international risk managers and other relevant stakeholders		
	Animal health - Interventions to improve awareness on infectious animal diseases	5,45	2,16

ANNEX 3 - Short-, Medium- and Long-term Research and Innovation Needs from Combined Survey and Focus Group Results

Animal Health & Welfare - Surveillance and Monitoring systems

Table 12: Summary table for OO1 activities indicating urgency

Action	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1. Optimize and extend to other countries current surveillance systems for animal health, AMR, and zoonotic infections and to develop new ones, where needed	Improvement of preparedness for emerging and exotic diseases through syndromic surveillance	Increase investigations at the human-animal-environment interface of diseases and by increase engagement in networking (One Health approach)	Develop models and tools to identify the most effective and efficient control methods and control points to protect society from new diseases, also including considerations on socioeconomics, climate effects and biodiversity
	Identify transmission sources and/or sentinels for animal diseases (vectors, arthropods, wildlife, domestic or wild relay hosts, animalcules...) through passive and active surveillance	Integrate various surveillance methods and ensure transparency between geographies	Develop animal identification technologies and systems for traceability of animals and their products for disease prevention, control, and emergency management

	Better understanding of the effect of extreme weather and ecosystem changes on vector-borne diseases occurrence and transmission	Integrate animal health surveillance systems of different sources	Elaborate alternative systems to compensate for downsizing of surveillance/detection systems
	Progress prediction methods to identify new and emerging diseases and when they may become a threat to Europe in relation to international trade, global warming, and climate change (e.g., new diseases, transboundary and vector borne diseases)	Control on introduction of exotic arthropods which are potentially vectors of AID (in point of entry and in the field)	
	Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	Develop ranking, prioritization tools based on risk and impact assessments to support decision makers in control of these new pathogens.	
	Develop terrestrial and aquatic wildlife disease surveillance and reporting systems, including methods, systems, and harmonisation for assessment of wildlife populations and demography		
	Progress alternative methods to control vectors: integrated pest management, biological control, genetically modified insects/improving networking with the human and environment sectors		
	Creation of standardized Next Generation Sequences protocols to run surveillance systems for emerging diseases		

Action 2. Set up a European wildlife network (both terrestrial and aquatic animals), based on existing wildlife disease surveillance and reporting systems, to coordinate and expand their activities, to analyse wildlife populations in Europe, and to analyse what specific data with reference to potential threat to animals and humans are needed.	Identify transmission sources and/or sentinels for animal diseases (vectors, arthropods, wildlife, domestic or wild relay hosts, animalcules...)	Increase investigations at the human-animal-environment interface of diseases and by increase engagement in networking (One Health approach) and identify stakeholders and vulnerable groups	Improved understanding of the role of wildlife-livestock interactions including risk populations. Building partnerships with collaborators to reduce the risks.
	Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	Animal health and welfare risk-assessment related data sharing and networking among research centers	Develop optimised terrestrial and aquatic wildlife disease surveillance and reporting systems, including methods, systems, and harmonisation for assessment of wildlife populations and demography
		Study the role of wildlife host/reservoirs for several diseases which might impact on human and animal health (transmission parameters study, effect of biosecurity measures, wildlife-livestock interactions, physical barriers etc.)	Need for assessment of impact of human interventions on wildlife: hunting, trade, translocation of wildlife
		Build a European wildlife network (both terrestrial and aquatic animals) based on existing network and wildlife disease surveillance and reporting systems	
		Development of tools to assess risk to people and domesticated animals from wildlife considering both health and welfare risks.	
Action 3. Create networks that bring together	Managing Big data, GIS, NGS; progress bioinformatics, improve sharing data integration and better use of existing data	Progress analysis tools that integrate genomic, clinical, and epidemiological data into risk assessment, early detection and disease spread	Develop syndromic surveillance tools and systems to interpret data and

bioinformatics and epidemiology, to harmonise metagenomic data and data collection methods, to integrate genomic, clinical, and epidemiological data, applicable to both livestock/aquaculture and wildlife.		models, including creation of network that bring together bioinformatics and epidemiology applicable to both livestock /aquaculture and wildlife	support decision making by risk managers and society.
	Integration and better use of existing data and data analysing techniques for animal health and welfare to inform future initiative	Development of novel big data, bioinformatics, and Artificial Intelligence tools for animal welfare	Research on machine learning based methods for exploring the ontologies of catalogues' values to integrate and network surveillance systems
	Progress artificial intelligence and machine learning techniques that support identification of new pathogens and earlier detection of known pathogens from sequencing and proteomic data	Improve cost effectiveness of real-time data collection	Broader surveillance informing transmission chain during epidemics or pandemics
	Development of platforms to support farmers in collecting and sharing primary data on animal welfare	Data mining as a potential tool for AW syndromic surveillance/early warning systems	
Action 4. Monitor pathogens of veterinary importance (that are not covered in One Health calls) and	Develop diagnostic tools enabling the early detection and reliable monitoring of infections, in both vectors and vertebrate hosts	Understanding of AMR incidence, prevalence, range across pathogens including study of resistance circulation within	Need for accurate estimates of the impact of AMR on routine treatment success (poultry, swine, cattle, fish) that drive an exceptionally substantial proportion of use of AM

their antimicrobial resistance profiles.	AMR surveillance in connection with measuring animal health and welfare indicators	Increase ability to rapidly characterise newly emerged resistance in microorganisms and elucidate the underlying mechanisms to support selection of correct antimicrobial the first time and avoid repeated treatments	Need for standardized metadata on AMR and AMU
	Develop methods/tools for the design of efficient surveillance systems for early warning, early detection, monitoring of pathogen diversity, frequency, and animal health implications	AMR surveillance in a broader sense, e.g., anthelmintics and fungicides	AMR surveillance in a broader sense, e.g., anthelmintics and fungicides
	Development of tools to convert apparent to true prevalences, to enable fit-for-purpose monitoring	Development of harmonized cut-off point for clinically relevant resistance in animal pathogens	
Action 5. Build networks, develop FAIR data, and implement FAIR principles for the monitoring of (re)emerging animal health and welfare issues, and to develop a hazard monitoring and early warning service.	Progress prediction methods to identify new and emerging diseases and when they may become a threat to Europe in relation to international trade, global warming, and climate change (e.g., new diseases, transboundary and vector borne diseases)	Increase investigations at the human-animal interface of diseases and by increase engagement in networking (One Health approach)	Develop FAIR data and implement FAIR principles for the monitoring of (re)emerging animal health issues, and to develop a hazard monitoring and early warning service
	Managing Big data, GIS; progress bioinformatics, improve sharing data integration and better use of existing data	Friendly use of platforms supporting farmers and veterinarians in collecting and sharing primary data on animal health. Networks building to develop a hazard monitoring and early warning service	Develop tools and systems for syndromic surveillance
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences	Validation of diagnostic tests (EEG, artificial intelligence) to assess effective correct stunning and other welfare indicators (e.g., tail docking pigs, lameness, or cachexia cattle) at the slaughterhouses	Research on machine learning based methods for exploring the ontologies of catalogues' values to integrate and network surveillance systems

	Development of quantifiable positive animal welfare indicators	Develop FAIR data and implement FAIR principles for the monitoring of (re)emerging animal welfare issues, and to develop a hazard monitoring and early warning service	Development of indicators and markers for understanding mental experiences of animals
	Integration and better use of existing data and data analysing techniques for animal welfare	Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	Progress on guidance and application of alternatives to animal experiments (e.g., organoid, or in vitro models)
	Design of the data-driven surveillance tools that are useful for the farmer but also provide surveillance information on regional or national level	Develop FAIR data and implement FAIR principles for the monitoring of (re)emerging animal welfare issues, and to develop a hazard monitoring and early warning service	Development of novel big data and bioinformatics techniques for animal welfare
	validate and use telemetry data (livestock precision farming) in relation to animal's behaviour, fitness and longevity, stress, and physiological parameters		Applications of sensors in animal welfare for real-time monitoring
Action 6. Create a platform on animal welfare in the EU with the objective to provide scientific and technical support to all stakeholders, related to data necessary for the monitoring of animal welfare; develop animal welfare	Development of platforms (where possible integrated in a meaningful way into existing operational networks) to support farmers and veterinarians in collecting and sharing primary data on animal welfare without making it an administrative burden.	Development of artificial intelligence systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	Applications of sensors in animal welfare for real-time monitoring
	Develop animal welfare surveillance including epidemiology and its evaluation	Animal welfare risk-assessment related data sharing and networking among research centres	Research on animal cognition (e.g., preferences and motivation to obtain rewards)
	Need for early warning of Animal Welfare	Development of novel big data and bioinformatics techniques for animal welfare	Precision Livestock Farming technologies and artificial intelligence for welfare

surveillance systems and their evaluation.	Validation of those variables that most closely and reliably reflect the animals' affective state and thus their welfare before using these as indicators in automatically collected data	Go FAIR (**F**indable-**A**ccessible-**I**nteroperable-**R**eusable): long-term stewardship, assess ability, legal interoperability, and timeliness of sharing of data" and "support research communities to adopt and coordinate data standards and mechanisms for FAIR sharing	Develop novel animal identification technologies (e.g., non-invasive biometric identification) for animal welfare monitoring
		The animal welfare surveillance systems should be shifted towards Animal based measures (ABMs) rather than resource-based measures. Need for surveillance/monitoring on AW will support risk assessments on AW	Deepen knowledge between the interaction of animal physical health and animal mental state and emotion

Additional suggestions from the experts

Fundamental research for surveillance	Biome and Pathobiome analyses in different species and their compartments
	Investigation of the role of intraspecific genetic diversity of animals on the likelihood of emergence of AID
	Pathogenesis of emerging and re-emerging AID

	Study of the effects of biodiversity loss on human and animal health
	Studying of drivers and monitoring of trends in wildlife population health applying holistic approach
	Combining slaughterhouse disease reports and welfare biomarkers in large populations (i.e., pig, poultry, aquaculture) to define the correlations between AW issues and disease onset
	Studies on Animal Health - Animal Welfare interaction
	Validation of those variables that most closely and reliably reflect the animals' affective state and thus their welfare before using these as indicators in automatically collected data
Development of new tools and technologies	Development of computerised vision systems at post-mortem to detect findings of relevance for animal health and welfare as well as food safety/quality including digital pathology algorithms for histopathology
	Means of disinfection that are both effective and respectful of ecosystems
	Increase the collection of reliable field data (e.g., distribution of vector species) through the organized sampling at European scale
	Establishing monitoring systems to better understand the mechanisms by which pathogens cross species barriers
	Development of diagnostics and decision support tools, integrated into farm management software, for monitoring of endemic production diseases in livestock
	Development of tools to monitor the progress of on-farm disease control of endemic infectious diseases
	Development of new methods of arthropod vectors containment
	Development of tools to measure and record positive welfare states
	Ensure good coordination between early warning systems across geographical areas and activation of response measures

	Monitoring of wildlife endemic pathogens in livestock - subclinical effects in wildlife systems are widespread, and if present in livestock but undetected may be having impacts on yield and profitability
	Use and standardization of GIS approaches to manage animal disease zones
	Creation of standardized Next Generation Sequences protocols to run surveillance systems for emerging diseases and issues
	Application of surveillance e monitoring system to pet trade
New procedures and strategies	Coordination and interoperability of datasets for efficient and useful animal health information systems 3
	Facilitation of data exchanges between organisations in charge of detection and data collection with research bodies so that they can benefit promptly from field samples.
	Integrating human health surveillance with animal health surveillance (One Heath Surveillance)
	Environmental monitoring within disease surveillance (One Heath Surveillance)
	Risk-based approach to surveillance and monitoring systems
	The increase of European research and infrastructure funding in pathogen biology in the framework of One Health
	Development of innovative methods to promote the effectiveness of operators' training
	Cross-sectorial research collaborations

Animal Health - Diagnostic procedures, methodologies, and tools

OO2. To develop diagnostic procedures, methodologies, and tools to support the monitoring of animal health

Table 13: Summary table for OO2 activities indicating urgency

Action	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1. Gain knowledge on priority pathogens (i.e., bacteria, parasites, viruses, fungi, prions including resistance patterns) responsible for important economic losses or high risk of transmission to humans and their detection methods, including metagenomics approaches, molecular markers of interest, etc.	Deepen understanding of host-pathogen-microbiome interactions in animals: mechanisms by which emerging pathogens transgress species barriers	Foster basic research and translational studies to support the development of new diagnostic tools (immunology, microbiology, virology, pathology)	Develop sensitive biomarkers for early detection of diseases paired with artificial intelligence and remote detection tools
	Deepen understanding of the host-pathogen-microbiome interactions that serves the development of diagnostic tools		Expand nanotechnology in animal disease diagnosis
			Identify bio-, genetic and predictive markers of a healthy (innate) immune system in relation to feed efficiency, disease prophylaxis, pathogenesis, and animal welfare
			Identify stage-specific antigens in helminths that can be used in immune tests
			Develop new diagnostic tests for helminths detection, including rapid systems for parasitic egg/larvae isolation from faecal and environmental samples, which provide reliable and representative data on e.g., environmental contamination, anthelmintic resistance

Action 2. Development, optimisation, and standardisation of reliable, faster, potentially automatable and/or scalable direct antigen/genome amplification/detection and indirect detection/immune response assessment tools/technologies; tools for the rapid detection of drug-resistant bacteria, viruses, fungi, or parasites; on-farm, pen-site diagnostics for pathogens and antimicrobial resistance; focus on priority pathogens and those that do not have EURL.	Develop new, cheap, accurate, rapid, and easy to use field diagnostic tests and diagnostic techniques, including pen-side diagnostics for the early detection of pathogens	Tools to study inter-species (including wild animals) circulation of pathogens or resistant variants	
	Develop diagnostic tools enabling the early detection and reliable monitoring of infections, in both vectors and vertebrate hosts	Develop new screening test for wildlife infectious agents	
	Progress rapid, accurate, tests for AMR diagnosis (e.g., LAMP, AST estimation through MALDI-TOF and fluorescence coloration of RNA biomarkers)	Accredited AST alternatives for fastidious re-emerging bacteria, e.g., Brucella and Coxiella	
	Develop routine use of high-throughput technologies (metagenomics, sequencing, machine learning and bioinformatics) for multi-target and quantitative diagnostics		
	Development of alternative models especially biologically relevant (species-specific) cell culture models that are still lacking for drug screening/testing approaches		
Action 3. Development, optimisation, and standardisation of tools to distinguish	Improved competitive vaccines, particularly for economically devastating diseases such as weaning diarrhoea in	Develop DIVA vaccines and corresponding serological tests for HPAI and ASF	Develop sensitive biomarkers for early detection of diseases paired with artificial intelligence and remote detection tools

between (i) infected and vaccinated individuals (DIVA) as well as (ii) dead and infectious pathogens for the study of pathogens survival in the environment or in effluents and (iii) to study of inter-species (including wild animals) circulation of pathogens or resistant variants.	piglets and coccidiosis in broiler and turkeys		
	Harmonization of lab tests and result communication		Tools that distinguish between dead and infectious pathogens for the study of pathogens survival in the environment or in effluents (e.g., mRNA marker)
Action 4. Development of quantitative and multi-target diagnostics to identify infection levels and silent microorganisms that can interfere with animal production for informed treatment/prevention measures decisions in enzootic production diseases in animals.	Development of multi-pathogen diagnostic tool to optimize the surveillance systems able to identify at once bacteria and viruses	Develop quantitative and multi-target diagnostics to identify infection levels and silent microorganisms for enzootic production diseases in animals	

Action 5. Development of non or less invasive and more convenient sample collection methods, including new matrices as well as transport, storage, treatment strategies and corresponding diagnostic tools, also suitable for the detection of diseases in free-ranging or wild animals.	Develop new sampling methodologies and strategies, incl. widening of the range of biological, also for drug screening/testing approaches samples	Develop non or less invasive and more convenient sample collection methods, including new matrices	Progress alternatives to animal experiments such as organoid or models in vitro models
			Optimise sampling, transport, storage, treatment strategies suitable for the detection of diseases in free-ranging or wild animals
Action 6. Application of new methodologies, i.e., research focusing on application of new detection and characterisation methodologies, on in vitro models; study host-pathogen-environment interactions, i.e., focusing on drivers and markers, on characterisation of microbial ecosystems, on drivers of resistance.	Deepen understanding of the host-pathogen-microbiome interactions that serves the development of diagnostic tools	Tools to study inter-species (including wild animals) circulation of pathogens or resistant variants	
	Development of digital toolboxes that centralize all diagnostic data coming from local laboratories in real time and directly send the information to responsible authorities at a national level and international level and linked to human diagnostic system.		

Additional suggestions from the experts

Fundamental research for diagnostics	*A posteriori* identification of the host species used by vectors
	Study on receptor to develop resistant animal strains
	Veterinary immunology, microbiology, virology
New tools and technologies	Development of diagnostic methods that can be used for samples from both humans and animals
	Development of cheap and accessible diagnostic screening tests for non-infectious diseases (e.g., biotoxins)
	Development of rapid assays to identify mutations of significance in genomes
	Development of quantitative diagnostics and interpretation of results in relation to the usage of antimicrobials
	DNA diagnostic techniques
	Research on high throughput diagnosis methodologies and multiplexing diagnostic tools.
	Development of multi-pathogen diagnostic tool to optimize the surveillance systems able to identify at once bacteria and viruses.
	Development of multi-pathogen diagnostic tool able to identify minor variants of a given pathogen in sample rich in microorganisms.
	Develop accurate point of care (POCT) tests for the main pathologies
	Rapid assays to identify significant mutations in genomes
	Digital PCR for quantification of pathogens and health status e.g., microbiome signatures
	Develop new screening test for wildlife infectious agents and circulation of zoonotic pathogens.
	Test for the biomolecular identification of potential arthropod vectors of diseases

	Development of diagnostics tests using recombinant antigens and monoclonal antibodies
	Development of diagnostics and decision support tools, integrated into farm management software, for monitoring of endemic production diseases in livestock
	Define criteria to strengthen laboratory analysis to distinguish virulent pathogens, from biological bystanders.
	Development of methodology and molecular tools to assess infectivity of pathogens detection in surveillance methods
New procedures and strategies	*In situ* detection of viable versus non-viable pathogens
	Development of new methodology to sample invasive species
	Development of strategies combining cheap point of care tests (POCT) with matrices easy to manipulate (as for example fluids)
	Fostering the collection of quality samples (representativeness of species, geographies, forms of infection) and the sharing of characterized and informed samples
	Improvement the standardization of diagnostic methodologies and techniques
	Develop more reliable in situ techniques for diagnosing infectious diseases and educate more diplomates in diagnostic pathology

Animal Welfare - Diagnostic procedures, methodologies, and tools

OO3. To develop procedures, methodologies, and tools to support the monitoring of animal Welfare

Table 3: OO3 Research needs in relation to Actions and urgency

Actions	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1. Focus on positive welfare (positive emotions), identification of behavioral, endocrine, and neurological indicators of positive welfare: research focusing on animal cognition, preferences, and motivation to obtain rewards.	Understand stockperson care/management practices and their welfare implications	Understanding consequences of social interactions/hierarchies and the impact these have on welfare	Understanding social/group dynamics (for social species)
		Development of positive animal welfare indicators and markers for understanding mental experiences of animals including playing behaviour	Deepen knowledge between the interaction of animal physical health and animal mental state and emotions including understanding individual animal variability
			Research on animal cognition (e.g., preferences and motivation to obtain rewards
Action 2. Development of technologies on the slaughter line to assess animal welfare (on farm and/or during transport). Identification of suitable animal-based measures (ABM) with appropriate level of validity, sensitivity, and specificity; development of in-line sensors, large scale data collection.	Development of tools for measuring animal stress	Identify indicators and to develop systems to assess the state of consciousness and death	Validation of diagnostic tests (EEG, artificial intelligence) to assess effective correct stunning at the slaughterhouses
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences	Development of positive animal welfare indicators and markers for understanding mental experiences of animals	
Action 3. Animal welfare at slaughter: i) consciousness and	Work on design of slaughter facilities to avoid welfare issues like	Understanding pain recognition and how it varies across species and across generation	Validation of diagnostic tests (EEG, artificial intelligence) to

death: development of technologies, procedures and/or protocols to increase the reliability of methods to assess consciousness and death at the slaughter line; ii) improve stunning and killing methods; iii) work on design of slaughter facilities to avoid welfare issues like stress, fear, and pain at pre-slaughter phase; related staff training.	stress, fear, and pain at pre-slaughter phase		assess effective correct stunning at the slaughterhouses
	Work on design of pre-slaughter phase including stunning methods	Identify positive animal welfare indicators and to develop systems to assess the state of consciousness and death	
	Research on humane methods for on-site killing of large groups of animals i.e., farm depopulation in case of disease outbreak	Development of AI systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	
Action 4. Development of <u>physiological indicators to measure acute and chronic negative animal welfare consequences on farm</u>. The indicators should identify stress, pain, fear, discomfort, etc. at individual and group levels: measure of physiological stress, impact on immune response and omics (e.g., transcriptomics and metabolomics). Integration of these to metadata welfare tools.	Development of tools for measuring animal stress	Understanding pain recognition and how it varies across species	Modelling for the natural behaviour and basic physiological data for different species in different farming systems
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences	Studies to further understand infection mechanisms to improve health and welfare	Investigations in integration of data originating from transcriptomics, proteomics, and metabolomics methods in animal risk assessment

Action 5. Development <u>of digitally assisted monitoring technologies on farms for increasingly enabling precision management of animal (health and) welfare</u>. Technology includes recording visual and auditory signals related to animal-based measures for welfare, analysing records with deep learning technology, data processing techniques and decision support systems.	Integration and better use of existing data and data analysing techniques for animal welfare	Develop FAIR data and implement FAIR principles for the monitoring of (re)emerging animal welfare issues, and to develop a hazard monitoring and early warning service	Develop novel animal identification technologies (e.g., non-invasive biometric identification) for animal welfare monitoring
	Development of platforms to support farmers and veterinarians in collecting and sharing primary data on animal welfare	Development of novel big data and bioinformatics techniques for animal welfare	Produce factsheets and any relevant digital infrastructure that enable risk assessment of any breach in animal welfare
	Develop animal welfare surveillance and its evaluation	Development of AI systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	
	Precision Livestock Farming technologies and artificial intelligence for welfare linking to genomic selection data	Precision farming enhanced by developments in information and communication technology (ICT), GPS-based and sensor technologies for animal welfare	
	Data mining of syndromic surveillance/ early warning systems to allow for AW evaluation	Develop Precision Livestock Farming (PLF) tools and Farm Management Information Systems (FMIS) (data collection, processing and decision making)	
Action 6. Development of technologies to assess <u>animal welfare during transport</u>. Affordable and reliable solutions to prevent serious	Studies on the impact of transport on animal welfare across species including aquatic animal concerns - e.g., oxygenation levels, starving protocols etc	Development of AI systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	Applications of sensors in animal welfare for real-time monitoring

welfare problems through early detection of signals before and whilst in transit, e.g., lameness, lesions, heat stress, aggression, thirst or hunger, exhaustion, etc. Development of sensor technology, data analysis tools, data collection and integration platforms, decision support for the driver; related staff training.	Precision Livestock Farming technologies and artificial intelligence for welfare	Precision farming enhanced by developments in information and communication technology (ICT), GPS-based and sensor technologies for animal welfare

Additional suggestions from the experts

Fundamental research for surveillance	Studies on Animal Health - Animal Welfare interaction
Development of new tools and technologies	Validation of those variables that most closely and reliably reflect the animals' affective state and thus their welfare before using these as indicators in automatically collected data
	Application of surveillance e monitoring system to pet trade
	Development of tools to measure and record positive welfare states
New procedures and strategies	Combining slaughterhouse disease reports and welfare biomarkers in large populations (i.e., pig, poultry, aquaculture, pisciculture) to define the correlations between AW issues and disease onset
	Increasing awareness of animal welfare
	One Welfare approach to research
	More funding for Animal Welfare and animal ethology research is required due to scarce scientific knowledge in those areas
	More research in fish welfare is required

Animal Health & Welfare - Risk assessment and alert communication

OO4. To adapt risk assessment and alert communication to the new needs in animal health and welfare

Table 4: OO4 Research needs in relation to Actions and urgency

Actions	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1. Enhance rapid risk and consequence assessment methodologies, to assess the economic, social, environmental, and cross sectoral consequences of animal health and welfare issues.	Develop thresholds for interventions based on animal welfare risk assessment data	Animal health and welfare risk-assessment related data sharing and networking among research centres	Investigations in integration of data originating from transcriptomics, proteomics, and metabolomics methods in animal risk assessment
	Investigations into possible application of science-based animal health and welfare risk assessment criteria in real life and under different husbandry conditions including introducing new husbandry systems/technologies	Develop a dynamic risk assessment system and assess methodologies to evaluate the economic, social, environmental, and cross sectoral consequences of animal health and welfare issues	Produce factsheets and any relevant digital infrastructure that enable risk assessment of any breach in animal health and welfare
	Research on determination and monitoring of socio-economic factors that can increase farm susceptibility to infectious diseases, with the aim to detect less resilient holdings/areas/regions		

Action 2: Study and assess epidemiological associations between human interventions such as hunting, trade, transport, rewilding and translocations of wildlife and disease spread, to propose harmonised tools to support alert system			
Action 3: Adapt existing or develop new methodologies to integrate genomic surveillance data in risk assessment guidelines for the integrated use of epidemiological and genomic data			
Action 4: Assess the risk of spread of resistant animal pathogens clones and genes encoding resistance	Integrated risk analysis based on farms data on management, animal welfare, antimicrobial resistance, drug consumption, vaccination strategies, biosecurity, and health data	Study of impact of antimicrobial use (AMU), and the role of companion animals (CA) in AMR transmission: 1. estimate the AMR burden associated with CA 2. Investigate transmission dynamics between CA and humans, the environment and farm animals 3. evaluate AMU and drivers of prescription in CA 4. identify how to reduce AMU and prudent use in CA	

Action 5; Build or further map and coordinate emergency networks for scientists and communities, to increase risk knowledge by systematically collecting data and undertaking risk assessments			
Action 6. Develop animal welfare surveillance and its evaluation, develop indicators and alarm levels, produce factsheets and any relevant digital infrastructure that enable risk assessment of any breach in animal welfare.	Develop animal welfare surveillance and its evaluation	Development of AI systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	Applications of sensors in animal welfare for real-time monitoring
	Development of welfare surveillance systems	Development of indicators and markers for understanding mental experiences of animals	Develop novel animal identification technologies (e.g., non-invasive biometric identification) for animal welfare monitoring
	Development of tools for measuring animal stress addressing specifically farrowing crates and piglet castration		Develop tools/strategies for effective monitoring of air quality to maintain high animal welfare
	Refinement of animal-based measures for fit-for-purpose assessment of animal welfare consequences		

Additional suggestions from the experts

Fundamental research for risk assessment	*Ex-vivo* and *in vitro* studies for risk assessment of pathogens
	Assess the link between climate change, environmental pollutants, pathogens, AMR

	Standardization of risk assessments
	Multidisciplinary study in ecological vectors diseases
	Relationship between media and experts
	Risk assessment of species jump
	Rresearch on determination and monitoring of socio-economic factors that can increase farm susceptibility to infectious diseases, with the aim to detect less resilient holdings/areas/regions
	Application of slaughterhouse waste as organic fertilizer
	Link between animal health and animal welfare
New tools and technologies	Scientific evaluation of animal-based welfare indicators before wider use
New procedures and strategies	Guidelines for helping health managers to implement preliminary measures against unknown hazards
	Improve communication across sectors
	Develop strategies to improve risk perception
	Training activities to improve awareness on infectious animal diseases
	Sharing information by networking
	Integrated risk analysis based on farms data on management, animal welfare, antimicrobial resistance, drug consumption, vaccination strategies, biosecurity, and health data observed at the slaughterhouse
	Application of effective risk assessment methodologies to pet breeding
	Scientific evaluation of animal-based welfare indicators before wider use

Animal Health & Welfare - Farm management preventive tools

OO5. To develop guidelines and preventive tools to fight against animal infectious diseases on farm and during transport

Table 5: OO5 Research needs in relation to Actions and urgency

Actions	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years+
Action 1. Establish a multidisciplinary network of experts with focus on biosecurity measures to prevent and control AID on farm and during transport, and draft foresight and priority studies on animal health, public health, pandemics and the role of biodiversity, the changing climate, emerging vectors and vector-borne diseases, bird and fish migrations, epidemiology/ modelling, bioinformatics, etc. for all animal species, including minority species and aquaculture.	Studies on the impact of transport on animal welfare and infectious disease	Identify biosecurity risks associated with free-range organic farming	Resilience farming - Set up relevant networks
	Improved understanding of climate change and its impact on welfare and on current and new animal diseases as well as the role it may play in an epidemic situation	Identify economic and realistic interventions that may improve health and welfare adapted to climate change, extreme weather, CO2 emission, biodiversity and new husbandry systems and technologies	Improved understanding of the role of wildlife-livestock interaction
	Develop disease and welfare models that include climate change, biodiversity, changing vector habitats to assess impact including CO2 emissions and socio-economic impacts to develop decision support for improving welfare and animal health		Improved understanding and identification of optimal control points

			Efficient and safe management of manure and animal by-products for improved of animal welfare and reduced risk of disease spread
Action 2: Reduce the entrance and spread of AID by reinforcing external and internal biosecurity in both terrestrial and aquatic animals, while limiting antimicrobial use, setup innovative systems and models with focus on biosecurity and integrated management			
Action 3: Perform research on prudent use of antimicrobials: research on treatment concepts for antimicrobial and antiparasitic usage, on alternative to antimicrobials including feed additives/nutrition, studying improved vaccination strategies etc.; development of best practices for administration/application of Veterinary Medicine Products (VMP)			
Action 4. Reinforce animal resilience/resistance (the natural ability of animals to withstand pathogens), through feeding and breeding; establish a pan-European network of experts in	Deepen understanding of host-pathogen-microbiome interactions	Develop/Improve reproductive/breeding technologies to select for high welfare traits or improve performance and welfare	Understanding of the Intestinal microbiota and their role in immunity, health, and welfare and across the life course

genetics (breeding), feed additives including pre-, post-and probiotics and leading experts in immunology to produce foresight and priority reports; both fundamental and applied research supporting animal resilience will be set up.	Develop strategies to reduce antimicrobial and anthelmintic use (incl. feed additives/nutrition) and/or to encourage their prudent use	Research to improve animal welfare through feeding strategies	Deepen knowledge of microbial ecosystems on farms
	Evaluate the interaction between feed, the development of immunity and increased resistance of animals to pathogens especially for young animals (piglets, chicken)	Advance genetic selection for animal health resilience, promote the use of local and more resistant breeds, increasing natural disease resistance or tolerance	Increase knowledge of systems at the level of the transcriptome, proteome and metabolome that contribute to understanding the links between the genome and the traits of interest
	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	Improve breeding technologies: e.g., integration of molecular technologies into breeding programs, gene editing and genetic engineering especially for low heritability traits and traits associated with health and pathogen resistance	Advance precision genetic modification using homologous recombination in appropriate stem cells, use of zinc-finger nucleases and RNAi-based gene knockdown
		Understanding how alternative protein sources (incl. insects) affect animal health (risks/benefits)	Social science on acceptance of genetic improvement
			Increase understanding of how genetic engineering in farm animals affects disease resistance

		Develop novel antimicrobial molecules e.g., antiseptics, antimicrobial peptides (bacteriophages), immunomodulatory specific agonists or antagonists and bioactive plants or alternative specialty feed ingredients such as plant extracts (essential oils, tannins, etc.)
		Conduct studies in vivo/ in vitro/ in silico to evaluate the effect of pre and probiotics, immuno-stimulants, phages and synthetic microbial communities at different stages of life

Additional suggestions from the experts

Fundamental research for farm management preventive tools	Livestock sustainability and animal health
	Study effect on better feed on gut microbiota to avoid weaning diarrhoea
	Research on how to preserve health rather than treatment
	Alternative proteins such as insect for feed security
	Assess the potential human and animal health risks of circular farming systems and alternative farming systems (e.g., insects)

	Prioritization of emerging pathogens linked with organic farming and new farming practices
	Organic livestock and animal health
New tools and technologies	Safe use of bone meal for food producing animals. Safe use of manure and offal for feed to insects in animal feed production.
	Development of diagnostics and decision support tools, integrated into farm management software, for monitoring of endemic production diseases in livestock
New procedures and strategies	Improve biosecurity and biosafety of all animal keeping, including e.g., petting zoos
	How to enhance UPTAKE of biosecurity and vaccines needs research
	Improve collaboration between veterinary and human science regarding antimicrobial usage
	Focus on the big picture
	Encourage farmers to use antibiotics cautiously
	Advice to farmers with livestock raised outdoors - how to improve biosecurity?

Animal Welfare - Farm management preventive tools

OO6. To develop guidelines and prototype solutions that advance animal welfare on farm, during transport and at the end of life

Table 6: OO6 Research needs in relation to Actions and urgency

Actions	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1. Establish a multidisciplinary network of experts to draft foresight and priority studies with focus on sustainability aspects related to non-cage systems, indoor and outdoor systems for livestock, flow though, pond or RAS for aquaculture animal transportation and slaughter, killing on farm, in slaughterhouses or at sea, and focusing on ending mutilations, including aquaculture production systems.	Development of platforms to support farmers and veterinarians in collecting and sharing primary data on animal welfare.	Studies which demonstrate alternative solutions to reduce animal mutilations	
	Investigations into possible application of science-based animal welfare risk assessment criteria in real life and under different husbandry conditions	Develop pain free and feasible new methods for on-farm	
	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	Animal welfare risk-assessment-related data sharing and networking among research centres	

Action 2. Perform research on how to improve animal welfare while maintaining or increasing farm economic and environmental sustainability. Involves animal cognitive capacities and emotions adapted to each species' needs, opportunities for pain relief, and environmental enrichments technologies. Aims to develop innovative housing systems and addresses the opportunities and consequences of reducing the use of cages in a sustainable way, in terms of economic and environmental impacts.	Establish social science studies along the production chain to monitor behaviour towards maintaining and improving animal welfare, including consumers' willingness to pay for improvements; incentives and barriers to adopting innovations and practices such as welfare labelling schemes	Understanding the role of environmental enrichment on animal welfare	
	Improved understanding of stocking density and its welfare implications and economic trade-offs	Understanding animal housing - welfare and cost implications	
	Improved understanding of the trade-offs between sustainability and animal welfare	Understanding the impact of behavioural restriction/inability to express behaviour on welfare	
	Improved understanding of impacts of extensive farming on animal welfare and how it effects environmentally positive way	Develop a dynamic risk assessment system and assess methodologies to evaluate the economic, social, environmental, and cross sectoral consequences of animal welfare issues	
Action 3. Perform background science to identify indicators and to develop systems to assess the state of consciousness and death, develop appropriate Precision Livestock/fish Farming and killing technologies to limit pain and reduce stress, alert systems for poor welfare during transport, etc.; develop innovative systems in livestock/fish transport and slaughter.	Development of tools for measuring animal stress	Understanding pain recognition and how it varies across species	Progress alternatives to animal experiments (e.g., organoid, or in vitro models)
	Refinement of Animal-based measures of welfare	Development of AI systems for animal welfare for automated scoring welfare issues across farms, transportation, and slaughterhouses	
	Precision Livestock Farming technologies and artificial intelligence for welfare	Precision farming enhanced by developments in information and communication technology (ICT), GPS-based and sensor technologies for animal welfare	

Action 4. Improve animal welfare through feeding and breeding strategies.	Welfare considerations for new methods of rearing	Develop/Improve reproductive/breeding technologies to select for high welfare traits or improve performance and welfare	Understanding of the Intestinal microbiota and their role in immunity, health, and welfare and across the life course
	Develop and set appropriate breeding goals that consider welfare implications (not solely focused on production)	Advance genetic selection for animal health resilience, promote the use of local and more resistant breeds, increasing natural disease resistance or tolerance	Develop seasonal diets for appropriate nutrition (especially dairy cows and sows) to improve animal welfare
	Research to improve animal welfare through feeding and breeding strategies	Understanding how alternative protein sources (incl. insects) affect animal health and welfare (risks/benefits)	
	Improve breeding technologies for animal health: e.g., integration of molecular technologies into breeding programs, especially for low heritability traits and traits associated with health and pathogen resistance		
	Increase understanding of how genetic engineering in farm animals affects zoonotic disease resistance		
	Understanding welfare consideration for breeding of companion animals and welfare risks related to those?		
Action 5. Evaluate the need and possibility to set up a pan-European network of experimental farms.			Resilience farming - Set up relevant networks
			Deepen knowledge of microbial ecosystems on farms

Additional suggestions from the experts

Fundamental research for surveillance	Research in management practices regarding cross-fostering of piglets in highly proliferative sows - impact on health, diseases, immunity, productivity, and welfare during whole growth phase - especially focusing on farms/breeds with low birthweight
	Methods to improve animal welfare and animal health in a sustainable system to influence climate change and risk of zoonoses
	Understanding the social environment for animal welfare in intensive farming
	Research on animal welfare indicator for all common species in the European Union.
Development of new tools and technologies	-
New procedures and strategies	Stunning before slaughter should be obligated and the state should regularly and strictly control whether stunning in slaughterhouses is done within the framework of animal welfare.
	Aquaculture: the air-quality question translates to water-quality here
	One Welfare approach to research
	Improvement of training of the operators
	Improving animal handling practices
	Integrating animal welfare assessment into measurement of environmental, economic, and social/ethical sustainability of farming systems
	Improving breeding strategy in pet animals
	Improving animal welfare, economic sustainability, and environmental sustainability of farming systems
	State-mandated training to train qualified stunners

Animal Health & Welfare - New interventions and treatments

OO7. To develop new interventions and treatments, or improve existing ones, against specific priority animal infectious disease

Table 7: Summary table for OO7 activities indicating urgency

Actions	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1. Perform basic research (TRL 1-2) to study interactions between pathogens and host microbiome, focussing on the immune system (e.g., pathobiome), and direct or indirect interactions between pathogens (e.g., co-infections), antimicrobial and antiparasitic drugs and host microbiome, mechanisms of anti-microbial (antibiotic and antiparasitic) resistance; trained immunity.	Improved understanding of direct or indirect interactions between pathogens (e.g., co-infections) and between pathogen and host and its microbiome	Better underpinning understanding of health ecology and connections between microbial communities, animal health & welfare	Better understanding of direct or indirect interactions between antimicrobial and antiparasitic drugs and host microbiome
	Better understanding of host immunity	Synergy between pharmacological solutions to disease outbreaks and vaccination	Piloting animal ecosystems to reduce pathogen shedding in the environment

	Better understanding of the molecular and cellular basis of antibiotic resistance	Deepen understanding of the host-pathogen-microbiome interactions that serves the development of diagnostic tools	Studies to further understand infection mechanisms to improve health and welfare
	Investigation of the impact of the reduction of antimicrobials and antibiotic free productions on animal welfare	Better understanding of anthelmintic resistance (e.g., mechanisms of resistance, genetics, ecology) and markers of resistance addressing particularly bacterial resistance to anthelmintics	
	Reducing antimicrobial resistance and its impact on welfare		
	Evaluate the interaction between feed, the development of immunity and increased resistance of animals to pathogens especially for young animals (piglets, chicken)		
Action 2. Develop tools such as (i) experimental farm	Develop novel antimicrobial molecules e.g., antiseptics, antimicrobial peptides	Studies on antibiotic effectiveness and availability	Conduct studies on animals to evaluate the effect of pre and

approaches; **(ii) in vivo, in vitro and in silico infection models for testing efficacy and safety of new drugs with reduced need for animal testing, new drug-delivery devices, therapeutics including leads for new antimicrobials; and** **(iii) bioinformatic pipelines for analysis of microbiome and pathogen data; this will be done in collaboration with industry, where appropriate.**	(bacteriophages), immunomodulatory specific agonists or antagonists and bioactive plants or alternative specialty feed ingredients such as plant extracts (essential oils, tannins, etc.)	and development of rapid accredited alternatives to classical antimicrobial susceptibility (AST)	probiotics, immuno-stimulants, phages and synthetic microbial communities at different stages of life
	Develop novel immunomodulators and antivirals	Conduct in vitro/in silico studies on pre and probiotics, immuno-stimulants, phages and synthetic microbial communities	Utilize reverse genetics studies for new intervention and treatment research
	Develop novel therapeutics/ strategies to control parasitic diseases	Develop bioinformatic pipelines for analysis of microbiome and pathogen data	Utilise genomics and Integrated Biology studies for new intervention and treatment research *In vivo* pre-treatments for animals infected with MDR bacteria to re-sensitise them and rendering the bacteria susceptible to Class C and D antibiotics, e.g., plasmid-curing CRISPR-cas9
	Develop animal-free models for vaccine development, such as organoids	Develop in vivo, in vitro and in silico infection models for testing efficacy and safety of new drugs with reduced need for animal testing, new drug-delivery devices, therapeutics including leads for new antimicrobials	Conduct safety and residue studies to expand availability of therapeutics into the minor use/minor species areas

	Reducing antimicrobial resistance and its impact on welfare	Develop pharmacokinetic studies to reduce animal experimentation and provide effective dosing schedules to reduce incidence of resistance and maximise efficacy	Utilise synthetic biology studies for new intervention and treatment research
	To reduce AMR more research on treatment strategies that reduce both length and dose of the antimicrobial used		Develop nanotechnology in animal health for new interventions and treatments
			Valid, reliable, and feasible welfare indicators for monitoring drug delivery
			Progress alternatives to animal experiments (e.g., organoid, or in vitro models)
Action 3. Build on the results of Action 1&2 to develop or improve interventions and treatments and deliver first proof of concept, where appropriate, in collaboration with industry: demonstration of immunogenicity and efficacy in target species; representative	To foster the research to find new treatments (drugs or protocols) for fish and shellfish which are extremely limited	Conduct studies on animals including field trials to evaluate the effect of pre and probiotics, immuno-stimulants, phages and synthetic microbial communities at different stages of life	Conduct safety and residue studies to expand availability of therapeutics into the minor use/minor species areas
		Studies on antibiotic effectiveness and availability	Studies to investigate side effects of treatments and their welfare impacts

(small scale) animal (challenge) model (TRL 3-4)		Develop novel therapeutics/ strategies to control parasitic diseases	
Action 4. In collaboration with industry: bring outputs to higher TRL in early/pre-clinical development (GMP-material; TRL 5-6); **(i) for non-food animals: demonstration of efficacy and field safety at large scale in representative animal models or approved alternative methods;** **(ii)for food animals: lab-scale assessment of animal safety and initiation of environmental safety, user safety, and (if needed) microbiological safety assessments; absence of toxicity/side effects; carcinogenicity studies initiated if needed, and demonstration of efficacy and field safety at large scale in a representative animal model and toxicology studies.** **Work on TRL 7 to 9 (late/clinical development, marketing**		Develop novel therapeutics/ strategies to control parasitic diseases	
		Studies on antibiotic effectiveness and availability	

authorisation and lifecycle management) will be performed by industry itself.	

Additional suggestions from the experts

Fundamental research for new interventions and treatments	Address the impact of new intervention and treatments on pathogens' evolution, virulence, and transmissibility (host-shift)
	Research on Interactions with antimicrobials and environmental pollutants
	Studies to investigate the effect of methane reducing feed additives on dairy cow welfare
Development of new tools and technologies	Studies on the effectiveness and use of bacteriotherapy
	Research on biological control for animal health
	Rediscover ethnoveterinary therapeutic practices to reduce antimicrobial uses
New procedures and strategies	
	To reduce AMR more research on treatment strategies that reduce both length and dose of the antimicrobial used

	To strive to avoid medication (or apply prudent medication) by selection of good genes, offering healthy environment and healthy feed (example: Norwegian land-based animal production)
	Focus on interventions and treatments which are sustainable
	Treatments against poorly controlled diseases should not suffer from the global drive to reduce chemical inputs. It is therefore necessary to continue the research that has proven its effectiveness in the past whenever necessary.
	There is a need in strategic direction for novel interventions and treatment development
	More funding for animal welfare research and ethology
	Apply fish health and welfare consideration also for lab animals used as replacement for mammal studies

Animal Health & Welfare - Vaccines, adjuvants, and immune modulators

OO8. To develop new vaccines or improve existing vaccines, including adjuvants and immune modulators

Table 8: Summary table for OO8 activities indicating urgency

Actions	Research Needs: 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1. Study the role of the immune system of farm animals, including the innate immune capacity of new-born	Better understanding of pathogen biology for better targeting of	Study the role of the immune system of farm animals, including the innate immune	Utilise systems vaccinology to identify immune correlates and surrogates of protection including

animals; the mechanisms that elicit protective immunity at the entry site, factors affecting immune response to vaccines, mode of action of adjuvants (basic research; TRL 1-2).	vaccines and therapeutics, including mucosal immunity	capacity of new-born animals; the mechanisms that elicit protective immunity at the entry site	repertoire signatures and response to adjuvants
Action 2. Develop tools such as vaccine platforms and expression systems, immunological toolboxes (cell lines, reagents, etc.) and delivery systems, etc.; this will be done in collaboration with industry, where appropriate	Develop and improve research and translation of new vaccines (e.g., DIVA, recombinants) including new genetically engineered vaccines	Establish a pipeline of vaccine platform technologies, expression systems, immunological toolboxes (cell lines, reagents, etc.) and delivery systems, etc.	Develop animal-free models for vaccine development, such as organoids
	Development of novel adjuvants	Utilise bioinformatics and mathematical modelling to study efficacy of new treatments and vaccines including the animal individual genetic variability of responses to vaccines	Valid, reliable, and feasible welfare indicators for monitoring drug delivery
	Develop animal-free models for vaccine development, such as organoids	Studies to investigate side effects of treatments and their welfare impacts	
Action 3. Build on the results of Action 1 &2 to develop or improve vaccine and immune-modulators and deliver proof of concept: demonstration of immunogenicity and efficacy in target species; representative (small scale) animal (challenge) model (TRL 3-4) or approved alternative methods; this will be done in collaboration with Industry,			

where appropriate; this will be done in collaboration with industry, where appropriate			
Action 4. In collaboration with industry: bring outputs to higher TRL in early/pre-clinical development (GMP-material; TRL 5-6) **(ii) demonstration of animal safety in target and non-target species; and demonstration of efficacy in a representative and validated target animal challenge model. Work on TRL 7 to 9 (late/clinical development, marketing authorisation and lifecycle management) will be performed by industry itself.**	Environmental risk assessment to vaccine development Improved competitive vaccines, particularly for economically devastating diseases such as weaning diarrhoea in piglets and coccidiosis in broiler and turkeys		

Additional suggestions from the experts

Fundamental research for new interventions and treatments	Address the impact of new intervention and treatments on pathogens' evolution, virulence, and transmissibility (host-shift)
	Research on Interactions with antimicrobials and environmental pollutants
	Studies to investigate the effect of methane reducing feed additives on animal welfare
Development of new tools and technologies	Studies on the effectiveness and use of bacteriotherapy
	Research on biological control for animal health
	Rediscover ethnoveterinary therapeutic practices to reduce antimicrobial uses

New procedures and strategies	To foster the research to find new treatments (drugs or protocols) for fish and shellfish which are extremely limited
	To reduce AMR more research on treatment strategies that reduce both length and dose of the antimicrobial used
	To strive to avoid medication (or apply prudent medication) by selection of good genes, offering healthy environment and healthy feed (example: Norwegian land-based animal production)
	Focus on interventions and treatments which are sustainable
	Treatments against poorly controlled diseases should not suffer from the global drive to reduce chemical inputs. It is therefore necessary to continue the research that has proven its effectiveness in the past whenever necessary.
	There is a need in strategic direction for novel interventions and treatment development
	More funding for animal welfare research and ethology
	Apply fish health and welfare consideration also for lab animals used as replacement for mammal studies

Animal Health & Welfare: Access to interventions

OO9. To increase access to veterinary vaccines, interventions and treatments and uptake of said vaccine interventions and treatments in the field

To progress toward this operational objective the following Actions are:

Action 1. Monitor the results of the EUP AH&W projects and evaluate if they can be the basis of new patent applications.

Action 2. Manage intellectual property (IP) and further development of the deliverables towards European Innovation Council (EIC) or similar programmes and industrial partners.

Action 3. Prepare the regulatory process for novel and innovative vaccines and treatments developed by the EUP AH&W, with implementation of regulatory experts (for each of the projects in the implementation phase), interaction with national regulators and with EMA, considering its recently published paper (Regulatory Science Research Needs78).

Action 4. Develop methods and procedures for comparative evaluation of clinical efficacy of veterinary antimicrobials to feed into antimicrobial guidelines and policies.

This OO focuses on regulation and policy. It was not included in consultation with the research community but would be discussed as a part of the second stakeholder consultation

Animal Health & Welfare - Socio-economic aspects

OO10. To develop an integrated approach on animal health and welfare including socio-economic aspects of animal health and animal welfare

Table 10: OO10 Research needs in relation to Actions and urgency

Actions	Research Needs : 1-2 years	Research Needs: 3-5 years	Research Needs: 5 years +
Action 1: Assess the burden of selected priority diseases (including resistant pathogens, including their control (e.g., cost-benefit of different surveillance components and risk mitigation options)	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	Improve the data collection and data quality in animal health economics	cost-benefit analyses of active and targeted surveillance in livestock for a selection of high-impact pathogens in the EU
		Develop models and collaborations to carry out comparative burden of disease assessment between different diseases	
Action 2: Set up social science studies among veterinarians, farmers, consumers, and other actors along the production chain on their behaviour (also in relation to AM use) to maintain and improve animal health, including consumers' willingness to pay for improvements; incentives and barriers to adopt innovations and practices	Identify obstacles for acceptance of bioengineered vaccines	Study the social strategy to improve acceptance of insect use as a source of protein	Research on determination and monitoring of socio-economic factors that can increase farm susceptibility to infectious diseases, with the aim to detect less resilient holdings/areas/regions and to feed precise risk assessments
	How to enhance UPTAKE of biosecurity and vaccines needs research	Elucidate trade-offs between animal health and animal welfare in new production systems and technologies	
Action 3. Set up social science studies among veterinarians, farmers, consumers, and other actors along the production	Establish social science studies along the production chain to understand incentives and barriers to adopting innovations and practices such as welfare labelling schemes	Social science studies to assess the acceptability of new technologies aimed at improving of animal health and welfare	

chain on their behaviour to maintain and improve <u>animal welfare</u>, including consumers' willingness to pay for improvements; incentives and barriers to adopt innovations and practices, including welfare labelling schemes.	Improved understanding of the trade-offs between sustainability and animal welfare	Investments in philosophical and ethical research on animal welfare issues	
Action 4. Study the integration of AID mitigation and improved animal welfare in the overall context of sustainable livestock production and aquaculture in the EU.	Study the integration of animal infectious disease mitigation and improved animal welfare in the overall context of sustainable livestock production and aquaculture in the EU	Identify biosecurity risks associated with organic farming	
		New economic methods are needed to consider the trade impacts in case of outbreaks, implementation of specific interventions, voluntary measures. The question is how this influence the trading behaviour between countries.	
	Improved understanding of the trade-offs between sustainability and animal welfare		

	Improve epidemiological knowledge to quantify the risks of culling versus vaccination (all epizootic and notifiable diseases)		
	Improved understanding of trade-offs between farming (production and practices) and welfare		
Action 5: Develop integrated strategies for the control and prevention of diseases, including emergency situations, considering relevant criteria, e.g., epidemiological situation, cost-benefit etc. to support decision making by national and international risk managers and other relevant stakeholders.	Deepening the understanding the role of veterinarians in prevention of disease and improving welfare – knowledge and technology transfer to end users/operators	Studies on methods of communication to better inform consumers and citizens about health and welfare issues in a balanced way	
	Improve epidemiological knowledge to quantify the risks of culling versus vaccination (all epizootic and notifiable diseases)	Multidisciplinary projects to develop harmonized methodologies to assess benefits and disadvantages for society of different interventions from multifaceted perspectives such as economy, climate impact, food security and welfare	

	Develop cost-benefit analyses of active and targeted surveillance in livestock for a selection of high-impact pathogens in the EU		

Additional suggestions from the experts

Fundamental research for socio-economic aspects	
	Integration of studies in the human and social sciences (socio-anthropological surveys) to describe the perception of health risks and improve dialogue and collective governance of the management of crisis situations in a process of health democracy
	Research in animal welfare of pets
	Study of impact of antimicrobial use (AMU), and the role of companion animals (CA) in AMR transmission: 1. estimate the AMR burden associated with CA 2. Investigate transmission dynamics between CA and humans, the environment and farm animals 3. evaluate AMU and drivers of prescription in CA 4. identify how to reduce AMU and prudent use in CA

Thematic Area Prioritisation and missing research needs - AW

Although not related to Operational Objectives the focus group participants were asked to rank several thematic areas related to animal welfare, feeding, breeding and precision livestock farming to gather more general results and to help with the structure of the focus group. The highest ranked thematic area in terms of importance to address research an innovation gaps was **'Understanding and measures stress, pain**

and behaviour' with **'Improved and understanding welfare'** ranked second and **'Sustainability/ climate change and animal welfare'** ranked second and third.

The two least important thematic areas according to the focus group participants were **'Feeding and understanding the microbiome'** and **'Alternatives to animal experiments and societal animal welfare issues**.

Participants noted that the thematic areas which were ranked higher tended to be broader, perhaps as they had a wider range of applications and impacts than the more specific areas which were ranked lower.

In the survey and in the focus group, participants were asked whether they felt that there were any research needs missing. Below are common research needs that were missing and should be addressed within the framework of this SRIA:

- Positive welfare
- One welfare
- Links between animal health and welfare
- Fish/aquaculture health and welfare
- Sustainability and farming practices
- Inclusion of more social science – including economics
- Focus on the animal-human interaction e.g., more training
- Companion animal welfare
- Animal welfare indicators

STRATEGIC RESEARCH AND INNOVATION AGENDA
FOR THE EU PARTNERSHIP ON ANIMAL HEALTH AND WELFARE (EUP AH&W SRIA)

© Photos

Page number & ©

COVER	*IZS AM, Teramo and Freepik*
SRIA	
06	*IZS AM, Teramo*
09	*Freepik*
18	*IZS AM, Teramo*
26	*Freepik*
ADDENDUM	
07	*IZS AM, Teramo*
08	*IZS AM, Teramo*

EUP AH&W

icrad
International coordination of research on infectious animal diseases

European Animal Health & Welfare Research
COLLABORATIVE WORKING GROUP

STAR-IDAZ
International Research Consortium on Animal Health

EUP AH&W LOGO