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Research & innovation for a sustainable livestock sector in Europe

Suggested priorities for support under Horizon 2020 to enhance innovation and sustainability in the animal production sector of Europe's food supply chains.

An Animal Task Force white paper

April 2013

Executive summary

The livestock sector contributes substantially to the European economy (€130bn annually), supports food security, the development of rural areas and ecosystem services. The sector encompasses both farmed animals in agricultures (meat, dairy and egg production and also skin, fur and wool) as well as in aquacultures (fish and other seafood). As part of a bio-based economy in Europe, the livestock sector has major opportunities to contribute to a more sustainable, climate smart and more competitive Europe and ensure responsible European animal production in a changing global world. Research and innovation has made Europe's livestock sector as competitive, balanced and efficient as it is today. Continuing support is needed for research and innovation in the livestock sector if the new challenges of ensuring the supply of safe and healthy high quality food, reducing environmental impact, making better use of resources, respecting animal integrity, meeting needs of consumers and contributing to a viable economy in ways that are appreciated by society, are to be met.

This position paper presents the ideas of the **Animal Task Force** (ATF) about priority areas for Horizon 2020 support to the livestock sector. These ideas have not only been developed after consultation between all the ATF members but have also been inspired by the Strategic Research Agendas of several ETPs well as that of the FACCE JPI. It is not a final statement, but rather a spur to develop dialogue with all relevant parties.

The key areas for research and innovation for contributing to a 'Better Society' and 'Competitive Industries' under the Horizon2020 strategy, identified in this position paper are:

- **Resource efficiency** – using limited resources in a sustainable manner by robust and efficient animals; more efficient feed chains that incorporate health and welfare; making better use of livestock by-products and alternative feed resources; and the use of precision livestock farming.
- **Responsible livestock farming systems** – minimise environmental impact of animal production while improving animal health and welfare; increase protein and energy autonomy in Europe; improve productive grassland based livestock production; and create climate smart, robust and resilient animal production systems.
- **Healthy livestock and people** – prevention and control of disease by integrated management of animal health; the microbiome; improve product quality; and increase food and feed safety.
- **Knowledge exchange towards innovation** – cooperation and knowledge exchange with producers towards innovation; implementation of animal welfare management and 'omics' tools.

The paper also identifies major opportunities for fundamental investments in '**Excellent Science**':

- Host-microbiome interactions.
- Long-term effects of environmental effects in early life.
- Predictive understanding of phenotypic expression.
- Immune regulation at mucosae.

To support research and innovation in livestock to contribute to a sustainable, smart and competitive Europe, adequate research infrastructures are essential. Priorities for research infrastructures identified by the ATF are:

- Facilitating pan-European sharing of expensive experimental research facilities.
- Developing high throughput phenotyping infrastructures – physical and virtual.
- Investment in biobanks.

The Animal Task Force

The Animal Task Force promotes a sustainable and competitive livestock sector in Europe. We are a leading body of expertise linking European Technology Platforms and research providers for developing innovation in the livestock sector.

The members of the ATF are research providers from twelve Member States of the EU (Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Poland, Romania, Spain, Sweden, UK) and industry representative bodies that support the interests of Europe's livestock industries (EATIP, ETPGAH, EUFETEC, FABRE-TP). We work together to identify actions that are needed to foster knowledge development and innovation for a sustainable and competitive livestock sector in Europe.

For more information please visit **www.animaltaskforce.eu**.

Prioritisation of research topics

Under the four key areas for research and innovation for contributing to a 'Better Society' and 'Competitive Industries' under the Horizon2020 strategy, this white paper identifies several sub-topics that further specify the four key areas. Although all of these sub-topics are considered important to contribute a sustainable, climate smart and competitive Europe, we would like to give priority to some sub-topics to stress their essential contribution to a 'Better Society' and 'Competitive Industries' under the Horizon2020 strategy.

Prioritisation of the topics is based on a common view of the ATF members, giving equal weight to the input from industry representative bodies (50%) and knowledge institutes (50%).

The sub-topics are ranked with a ★ to highlight their priority, with:

★ indicating an important topic;
★★ indicating a highly important topic; and
★★★ indicating a top-priority.

1. Resource efficiency	
a. Efficient and robust animals	★★★
b. Efficient feed chains	★★★
c. Improving the use of residues in animal production	★
d. Precision livestock farming	★★
2. Responsible livestock farming systems	
a. Assessing EU animal production systems	★
b. Improving protein and energy autonomy of the animal production sector	★★
c. Productive grassland based systems	★
d. Climate smart agriculture	★★★
3. Healthy livestock and people	
a. Prevention, control and eradication	★★
b. The microbiome, animal & human health	★★★
c. Nutritional quality of animal products	★
d. Feed & food safety	★
4. Knowledge exchange towards innovation	
a. Knowledge exchange with farmers and industry towards innovation	★
b. Improving systems for the implementation of 'omics' tools	★★
c. Ensuring animal welfare	★★

PART 1

The importance of research and innovation support
for a sustainable livestock systems for Europe

Introduction: how support to innovation, sustainability and competitiveness in the animal production sector will benefit Europe

Livestock's role in realising a bio-economy for Europe

Through contributing €130bn annually to Europe's economy, being 48% of total agricultural activity and creating employment for almost 30 million people, Europe's animal production sector is a major part of our economy and of European food supply. Animal products make important contributions to a healthy diet and are in increasing demand globally. This creates additional export opportunities for Europe, in terms both of products and of expertise. Europe's livestock sector plays a central role in realising food and nutrition security worldwide.

Food production is a major part of the bio-economic system. In many parts of Europe the animal production industry is inextricably linked with the vitality of rural social economic infrastructures. At the same time the livestock sector can present challenges to the environment and some aspects of human health. While the livestock sector offers multiple opportunities for contributing to a climate smart, sustainable and competitive Europe, it needs imaginative and innovative system approaches and strong, flexible industry-research links to implement the knowledge, technologies and know-how that will equip the sector to meet Europe's challenges for the future.

Some of the challenges to be overcome call for a better understanding of how animal production can contribute more effectively to the bio-economy, deliver ecosystem services and improvements in the food chain. We need to know how we can better select for and manage animals as biological entities ('animals AS systems'); other opportunities call for improvements in the design and management of the production systems and food chains of which animals are just one part ('animals IN systems'). These production systems should fit to the social, economic and technological challenges of today's society. This includes the need for socio-economic elements on chain management, consumer attitudes and governance.

Research and innovation

Research, development and innovation (RD&I) has made Europe's animal production sector as competitive and efficient as it is today. Creating a supportive environment for research and innovation in the livestock sector can lead to ways of production that ensure the supply of safe and healthy food, reduce environmental impact, improve the utilisation of resources, provide ecosystem services, meet the needs of consumers in ways that are appreciated by society, contribute to a viable economy, and are an example to the world. Hence investments in RD&I must continue in the future. Based on this recognition, we strongly recommend a heightened support for the livestock sector in the Horizon 2020 programme, the European Innovation Partnership, and the Common Agricultural Policy.

Agriculture & aquaculture

Livestock includes both animals farmed in agriculture and aquaculture. Aqua-culture has rapidly developed from a pioneer sector cultivating wild fish breeds with general fish feeds into a professional mature stage of fish production based on selective breeding, customised feeding and preventive health control. Many of the topics that we suggest for support apply nowadays equally to 'livestock' in agriculture and in aquaculture.

Integrated approach

This position paper presents important research and innovation opportunities that will make the livestock sector central in contributing to a smart, sustainable and competitive Europe. The topics presented are a shared view of all of the ATF members. It is unique in that way, that it combines the different sectors (feeding, breeding, health) to find integrated approaches to the challenges we are facing. For inspiration, Strategic Research Agendas of several ETPs have been consulted as well those of other organisations.

We first shortly address the priority issues to support a sustainable, smart and competitive Europe, and how these fit within the Horizon 2020 programme and the conditions needed for effective research and innovation. In Part 2, we describe the suggested research and innovation areas for topics within these issues in more detail.

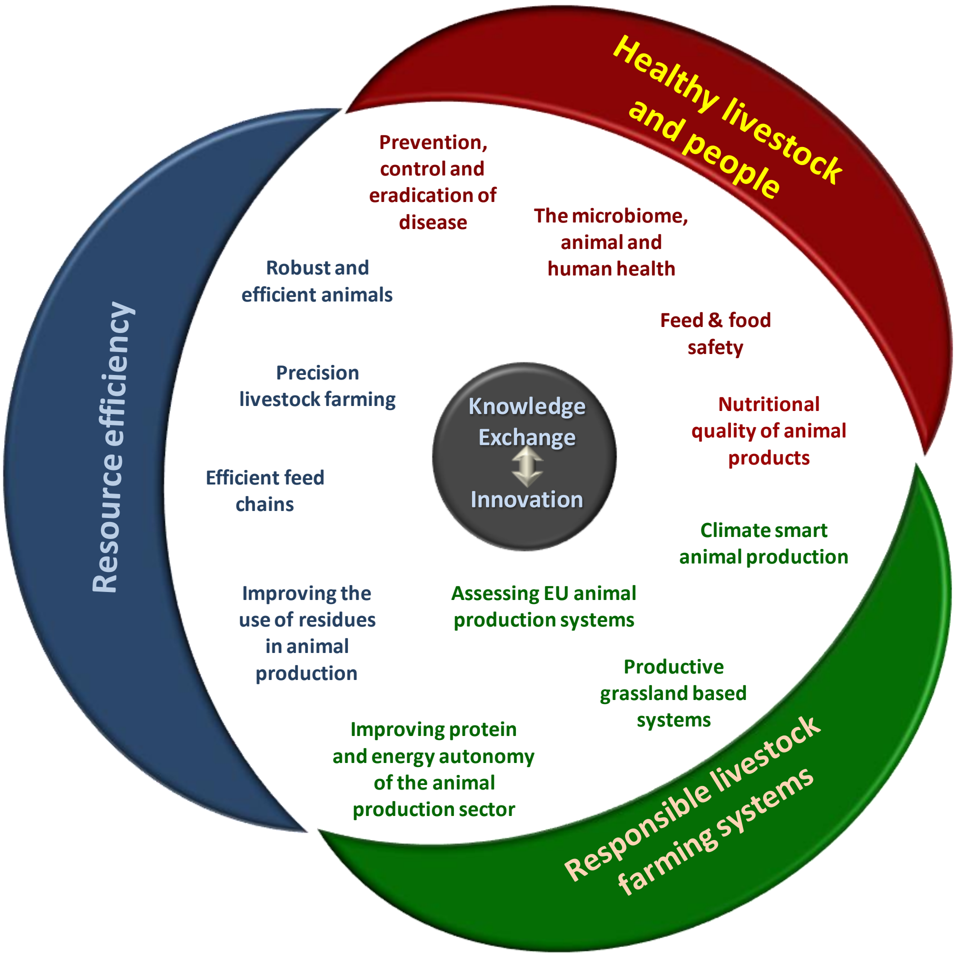
Priority issues to support a sustainable, smart and inclusive livestock economy under Horizon2020

In considering the livestock sector's contribution to a smart, sustainable and competitive Europe, we see the need for supportive action from science to enable:

A number of these issues will depend, for real progress, on developments in more fundamental understanding in a number of areas. Therefore we present a fifth issue:

In the next sections we identify the main topics to address these five issues. For each of these topics we sketch out the background rationale, specific goals, how the goal(s) can be achieved and a comment on the expected impact. These are preliminary drafts but could readily be fleshed out if it is felt to be helpful for the next stages of discussion and development of the Horizon2020 work programme.

The first three main issues (Resource efficiency; Responsible livestock farming; Healthy livestock and people) are quite closely inter-connected. As a result some actions aimed at each one have relevance to the others. You will therefore find a level of repetition in the description of the topics. In order to give a complete overview of each of the topics, we have not eliminated this repetition at this stage.



The figure illustrates the main topics and sub-topics that we suggest as prime areas for further research. Some of the inter-linkages are immediately obvious.
All sub-topics are described in part 2 of this white paper.

Fit with Horizon2020 structure

The Animal Task Force recognises the three different pillars of the Horizon2020 programme. We see the need for investments in research, development & innovation support for the livestock sector in each of the Horizon2020 pillars of 'Better Society', 'Competitive Industries' and 'Excellent Science'.

The majority of the topics suggested in this position paper fall within the '**Better Society**' pillar of the proposed structure for Horizon 2020. While these are predominantly within societal challenge of *'Food security, sustainable agriculture, marine and maritime research, and the bio-economy'*, the main topics we propose also overlap with the societal challenges of '*Climate action, resource efficiency and raw materials*', '*Health, demographic change and wellbeing'*, and '*Inclusive, innovative and secure societies'*.

Many of the suggested topics demand concerted action between industry and research providers to target outcomes for a more competitive industry. The Animal Task Force uses an industry-driven approach by working closely together with relevant livestock industries to have science directed by industry. Some of the topics suggested in this position paper fall within the pillar '**Competitive Industries**' and concern new *Key Enabling Technologies* (KET) and the multi-disciplinary, knowledge and capital intensive approach needed for the development of these new KET. In several cases we would expect an industry lead in the development of RD&I actions.

For success, some specific topics will need underpinning through more fundamental research. These might be considered to fall under the '**Excellent Science**' pillar, regarding *Future and Emerging Technologies* (FET), but we would argue that science done to create a better society should be no less excellent than any other science in its quality and robustness. Nonetheless we identify some key themes that we feel stand out as being essential to fill gaps in scientific understanding to underpin actions to deliver 'Better Society'.
The adequate research infrastructures we consider necessary for research and innovation are addressed in a separate paragraph below.

Fit with other European policy

In addressing Better Society, the Animal Task force also endorses:

- The overall objectives of **CAP reform** to increase the responsible productivity and competitiveness of the agricultural sector through knowledge creation and innovative approaches, and to improve the sector's performance with regard to the environment, mitigation of greenhouse gases and adaptation to climate change.
- The concepts for implementing the **European Innovation Partnership** on Agricultural Productivity and Sustainability whereby multi-actor groups at the local or regional level will link livestock and multifunctional farms with research and extension and other actors, to define problems and promote innovative and sustainable solutions.
- The **Smart Specialisation of regions** under the structural funds which will promote the emergence of a diversity of competitive livestock production systems, and provide economic resilience for Europe for the future, and as well as sustainable technologies and solutions which can be applied elsewhere in the world.
- The completion of the **European Research Area** which will enhance research cooperation in animal sciences and reduce unnecessary fragmentation and overlap, as well as promote researcher mobility and research as a career. In this respect also Animal Task Force values the emphasis given to the Marie Curie mobility support actions in Horizon 2020 and fully supports in particular the concepts of training networks and support for exchanges between research institutes and enterprises.

The proposals presented here fully adhere to:

- The **EU strategy on Innovating for Sustainable Growth**: A Bioeconomy for Europe by supporting the agenda of " creating a more resource efficient society that relies increasingly on renewable biological resources to satisfy consumers' needs, industry demand and tackle climate change".
- The **EU Aquaculture Strategy** to give new impetus to the sustainable development of aquaculture in Europe.

A stratified approach: re-search, research, innovation & validation

There is a danger that, in looking to the future needs for research and knowledge development, we forget the results of research activities that have already been completed, but not adopted, and professional knowledge that can potentially be rolled out in other areas is often overlooked by science because it is not laid down in peer reviewed journal articles. There are also risks that research topics are developed without a thorough assessment of the potential for impact or for potential trade-offs between developments in one area and impacts on others (in the context of integrated systems of production or food chains). We therefore suggest that consideration is given in the development of the Horizon 2020 programme, to a four strata approach that includes actions in:

- *Appraisal (re-search)*: Desk studies to assess current conditions (*do we know the current state of play?*), risks, gaps in knowledge provision and application, and the potential of new developments to make a difference (*what are the limits?*), considering various future scenarios and governance options and the possible trade-offs between social, environmental, economic and health objectives. Such integrated assessments are fairly new and have huge potential.
- *New Research*: Technical studies and biophysical experimentation and demonstration to address specific challenges
- *Innovation & validation:* Designing, testing and demonstration of sustainable solutions, management regimes, and socio-economic models in practice, and in different climatic and demographic circumstances. Such studies will need to integrate different scales in a holistic approach (i.e. farm-level, local and regional food chains, territories in their large diversity, and European and global markets) and societal settings in order to create optimal and sustainable business models. This will need to be collaborative projects (including participatory research) in which industry, farmers, NGOs, researchers, extension services work together. Inclusion of implicit knowledge of professionals is key in bringing innovation to practice. This type of study perfectly fit into strategy of the European Innovation Partnership on Agricultural Productivity and Sustainability.

Research infrastructure needs

We identify needs for improvement in research infrastructures, both material and virtual, for efficiency of delivery and to ensure European resources that are up-to-date and fit for foreseeable purposes. Livestock research facilities (including facilities at farm system level and high containment facilities with BSL 3-4 contingencies) are notoriously expensive to equip and maintain. There is a need to create synergies between different facilities across Europe, and, bearing in mind the range of different production systems and animal breeds, to increase research output of units e.g. by fostering transnational access and shared use. A linked network of demonstration or pilot units supported by modern ICT would greatly speed up the implementation of new technologies and practices, particularly when linked on a regional basis to groups of farmers.

Whilst high throughput phenotyping has been developed for plants and laboratory rodents it is still in its infancy for farm animals whether it be “deep” phenotyping (including ‘omics technologies), i.e. large number of measurements from a small sample of animals or “broad” phenotyping small number of measurements on a large sample of animals. Investment in physical research infrastructure is needed both to link existing facilities and to develop new platforms for deriving relevant phenotypes not only for descriptive phenotyping approaches but with a view to predictive phenotyping of farmed livestock. Investment also needs to be made to develop common data acquisition and storage protocols in order to facilitate sharing between European partners or between projects.

The genetic diversity of European farm animals is a valuable resource that needs to be safeguarded through investment in biobanks of animal tissue. With the application of ‘–omics’ methodologies, such materials also provide new opportunities for understanding mammalian biology, including that of human medical significance.

PART 2

Description of research and innovation topics to support a sustainable, smart and competitive Europe under Horizon 2020

1. Resource efficiency

The main challenge for the world is feeding 9 billion people within the carrying capacity of planet earth. The livestock sector is a valuable component of the bio-economy (in food and non-food functions). In the next decades, on the one hand we expect an increased demand for animal products, because of growth of the global human population, growing incomes and a shift in consumer behaviour worldwide, especially in the upcoming economies. On the other hand we face land scarcity, increasing greenhouse gas (GHG) emissions and limited resources, and it is to be expected that the availability of resources outside Europe for the European market (either as base (feed) or end products) will decrease or come available only at a much higher cost. This is a double challenge: the *efficiency* of the *use* of resources (e.g. energy, N, P, water, manure) must increase whilst at the same time improvements in the *way we produce and use* these resources must be made, so that the environmental footprints are reduced and the requirements for food production (e.g. health, welfare, social acceptance) are fulfilled. The importance of a European animal knowledge sector and ensuring the European animal production capacity can be made available for both the current and the future generation gains recognition.

To find ways to enhance food security in a sustainable way, we will need to pay greater attention to the efficient use of all associated resources. We require to minimise the need for resources, prevent avoidable losses ('wastes') and emissions, re-use unavoidable losses as feed wherever possible, use manure as a valuable residual and search for the optimal systems for the various species, and region-specific circumstances. This requires attention and improvements to the animal *as* a system, the animal *in* a system, and the system itself. Closing the nutrient cycles and re-use of valuable resources are central in this issue.

Animal production chains with increased resource efficiency enable a shift towards more sustainable intensification of food production and competitiveness of EU animal production chains. Socio-economic advantages are food security, sustainability, a reduction of climate change effects and realising a bio-economy. There will be improvements in biological and economic efficiency with reduced waste and emissions. Optimal solutions will recognise potential trade-offs between efficiency gains and health and welfare, or other important disadvantages losses. Identifying 'win-wins', or at least clarifying key trade-offs will enable better decision-making.

We will focus on four main opportunities for improving resource efficiency:

a) Efficient and robust animals.
b) Efficient feed chains.
c) Improving the use of residues in animal production.
d) Precision livestock farming.

1a. Efficient and robust animals ★★★

Background

One aspect of improving resource efficiency in the livestock sector, is to improve the animal *as* system. Improving the efficiency of animals involves reducing its 'feed conversion rate' (FCR: amount of feed needed to produce one unit of animal product) and thereby also contributing to reducing greenhousegas (GHG) emissions involved in livestock production[1]. The FCR has already significantly decreased in the past years by succesfull breeding strategies and more efficient feeding. Further improvements are to be expected by combined breeding and feeding efforts. Health (including fertility issues) and welfare aspects also play an crucial role in resource efficiency. Resource and nutrient efficiency in robust, healthy animals is higher than in animals with health problems. It is estimated by the World Organisation for Animal Health (OIE) that approximately 20% of animal production is lost due to unhealthy animals. Survival of juvenile fish (25-40%) is critical in aquacultures. Resource efficiency is thus also enhanced by reducing direct livestock losses, through, for example, clinical and sub-clinical disease, reproductive and metabolic failures, post-natal losses, 'failure to thrive' and premature culling or exposure to critical transition periods (such as weaning in pigs, onset of lactation in dairy cattle and the early post incubation period in poultry). These losses are not desirable both from an ethical, animal welfare, and a resource-use efficiency point of view.

Goal

Improve resource efficiency of animals by more efficient and robust animals that are more healthy, are more resilient, have an increased well-being, have a lower feed conversion rate.

How to achieve this

Until now, these aspects have been considered separately. To make progress, we propose an integrated approach to create more robust and efficient animals within systems, combining feeding strategies, genomics and health and welfare aspects.

- Appropriate phenotypes and appropriate indicator traits that reflect improved resource-use efficiency need to be identified. Selection using genetic, genomic, metabolomic and phenotypic information will allow gains in efficiency, (GHG) emissions, health and welfare. This includes the identification and implementation of welfare indicators that are animal-centred. The combined use of genetic, genomic, metabolomic and phenotypic information is innovative and provide a profound knowledge and holistic understanding of improving resource efficiency - e.g. feed efficiency - in animal production combined with other gains.
- Improved breeding programmes for robust animals should include systems of feedback of information from the production chain into the breeding programmes through novel means such as automated data collection and genetic linking through genomics tools. Trade-offs between environmental, economic, health and welfare must be made visible
- Identification of new species for European aquaculture based on perspectives for domestication of species with high market potential and high resource efficiency.
- Feeding management and farming systems can substantial contribute to robustness and resilience of animals. E.g. systems that promote early feed intake after incubation of chickens has shown to have long lasting positive effects on health, welfare and performance. A systematic approach to identify key factors that hamper robustness during critical transition periods is needed to find new approaches to cope with these transitions.

Expected impact

More efficient and robust animals contribute to resource efficiency by reducing resource use and resource loss.

[1] Approximately 5% of livestock's contribution to GHG emission originate from feed production.

1b. Efficient feed chains ★★★

Background

Animal feeding plays an important role in livestock production systems. Feeds and feeding are means to influence animal performance, production costs, product quality, environmental impact, animal health and welfare, and food security. Besides selection for improved genotypes that increase efficiency of resource-use within animals (see 1a), more efficient feed chains are needed to ensure future resource efficient livestock agriculture. This requires that a larger fraction of the feeds produced is converted into human edible food and that losses in the feed and livestock industry are minimised. Novel in this topic are the opportunities that precision feeding has to offer for increasing feed efficiency by adapting feed needs to individual animals.

Efficient feed chains also involve alternative feed resources, while not competing with food for humans or having a large impact on land-use change. This covers utilisation of by products of the food industry, finding alternative crops, better use of local resources. This also involves socio-economic aspects as new business models and management systems are needed for specific production systems which allow for the demand for feed of individual genotypes and allow for variations in feed supply. It might be clear that this topic does not stand on its own: robust and efficient animals are required that fit within feed chains to be able to fully benefit from the opportunities for resource efficiency. For Europe the development of alternative protein supply strategies that minimise reliance on imports (i.e. soybean and fishmeal) is also of strategic importance (this is further discussed in section 2c).

Goal

Create new opportunities to improve the efficiency of feed chains by optimising the quantity of feed available for the animal, reducing losses, better use of local resources and creating new feed chains of alternative feed resources and by-products of the food chain, thereby reducing wastes.

How to achieve this

Improving efficiency in feed chains requires an integrated approach that combines nutrition, genetics, supply chain management, geographical knowledge and socio-economic aspects. We propose to focus on:

- Research on the interaction between genetics and nutrition, and exploiting the differences between the individual animals in 'feed efficiency' to match the input to needs as these change with time (and the animal's physiological state), will generate new possibilities for improved feed utilisation. New practical feeding systems should be developed that enable precision management for feed use efficiency (so called 'precision feeding') without unwarranted costs. Development of innovative sensors and intelligent models for monitoring and management of nutrient use (in)efficiencies at animal level (also for animals in groups (herds, sea cages).
- Exploring better use of organic waste streams and unused by-products of food production chains through development of novel and existing technologies. This includes specific processing technologies and technological treatments for meeting the EU feed safety requirements (e.g. for food products no longer destined for food use); to research the response and possible efficiency effects on animal performance to these products (see also 1d).
- The aquaculture development of carnivorous fish species requires increased utilisation of still emerging vegetable feed sources to limit impact of fisheries on wild fish stocks. However, vegetable oils can contain specific toxins and bioactive compounds and vegetable protein can contain specific toxins and anti-nutritional compounds that may affect feed efficiency, processing yields and fish health and welfare during the whole life-cycle, as well as the quality of the product. Research is needed to explore the potential of selective breeding of aquaculture species and genomic information applied to extended phenotypes in various environments and rearing systems to develop breeding programmes that maximise the utilization of vegetable ingredients, while maintaining high levels of product quality and fish health and welfare.

- Current feeding systems are based on the concept of ‘feed values’ and ‘nutritional requirements’ but ignore that the animal responds to the nutrient supply in a dynamic way, and that this response needs to be considered in a multi-facetted manner (e.g., animal performance, emissions, tissue and product composition, health and behaviour). New and innovative models on the nutrition of farm animals, including dynamics and kinetics in digestion and metabolism are expected to significantly contribute to a further reduction of energy and nutrient losses, better quality of animal product and better use of alternative resources. Moreover, there is now a need and willingness to work towards a more harmonised system of animal nutrition in Europe. Although similar concepts have been adopted in many of these systems, terminologies and methods of determination vary greatly from country to country. This makes comparison and cross-use of information very difficult particularly by the feed industry, which is increasingly pan European.
- With ruminants, research should be directed on an integrated approach of identifying the best genetic potential for low energy loss and simultaneously developing diets that lower energy losses as methane. This approach will result in combined management strategies with genetic selection for improving efficiency of nutrient use that will also lower the incidence of metabolic diseases and increase fertility (including reproductive failures, post-natal losses and ‘failure to thrive’).
- A model, based on consequential LCA, needs to be developed to determine the trade-offs in environment-socio-economic impact when decisions are made concerning the use of by-products and alternative resources.

Included in research on new products, technologies and strategies should be the development and testing of business models.

Expected impact

The life cycle impact of dairy, meat, egg and fish production will greatly improve, whilst recognising the animal production potential and management in a holistic way. Increased resource efficiency by improved feeding management systems and optimised feed chains, including the delivery of the best strategies to develop alternative feed resources; reduced protein imports into Europe, and reduced competition between feed and food production. Key enabling technological developments will make Europe frontrunner in re use of by products and protein rich resources for feed.

1c. Improving the use of residues in animal production ★

Background

Manure is often seen as a residual burden rather than a valuable resource. In areas with intensive animal production effective manure management can improve resource efficiency by turning manure into a valuable resource. Especially the re-use of N (replacing artificial fertilisers with their high associated energy costs), and of P (which is a first limiting resource for all plant production and which is in very limited supply globally) offer tremendous opportunities for closing nutrient cycle, increase resource efficiency and restrict pollution and eutrophication of ground waters. Manure (especially solid manure) is a unique source of carbon for soils. In addition, integrated manure management offers new solutions for on farm energy production since the price of fossil fuels is expected to increase.

Goals

More efficient recovery and recycling of food, feed, water and animal waste, including P losses and N emission reduction. Reduced energy costs across animal farming.

How to achieve this

To make progress, there is a necessity for a holistic approach where system analysis is used to assess the total effects of different practices. Besides technological progress, socio-economic studies are needed to create sound business models and organisational models for manure treatment. We propose to focus on:

- Assess the efficiency of different products from manure (from pure minerals to organic matter fractions) for closing the mineral loops. Explore new techniques like refining manure to valorise the individual components of manure and treatments leading to the production of normalised fertilisers that can be exported from high density livestock territories to arable land.
- Assess scale and local systems organisation to improve the efficiency of anaerobic fermentation systems of manure and other food/farm wastes. This includes socio-economic studies and developing business models that can be adapted to regional situations and evaluate the geographic scale that is needed for optimal effects in nutrient dispersion. Ideally this also includes implementation and strategies to upscale successful business models to wider application.
- Assess the efficient recycling of nutrients in manure and the effects of feeding management on manure quality. Innovations have been developed to better handle nitrogen losses, especially NH_3, in buildings, during storage and manuring. It remains necessary to control the entire storage and manuring chain to preserve nitrogen: interactions between different steps in management are thus important and to have a better knowledge of the bioavailability of nitrogen from manure.
- Assess the potential risks for re-circulating infectious agents and evaluate different disinfection and mitigation strategies in order to provide a sustainable use of residual resources.
- Development of energy efficient recirculation systems for aquaculture enabling full control of water and effluent management.
- Development of Integrated Multi-Trophic Aquacultures (IMTA) for combining fish farming with the production of shellfish and seaweed to re-utilise feed residuals.

Expected impact

New unique ways of efficient resource-use at system level that reduce wastes in the feed and food chain; improvements in the re-use of nutrients in manure, and of energy stored in carbon connections, less negative environmental impact. Potential addition of high value added products from manure for other industries.

1d. Precision livestock farming ★★

Background

Sensor-driven livestock technology offers potential solutions. Precision Livestock Farming (PLF) develops management tools aimed at continuous automatic monitoring of animal production, environment, health and welfare in real-time. Sensor technology integrated in monitoring systems will allow farmers to follow the animal's status, to observe their performance or detect diseases at an early stage and to monitor the environment. Today sensors can detect irregularities in such things as physiological measures (e.g. in milk, body temperature), drinking and feeding patterns (to detect disease), social behaviours (to detect oestrus), activity (to detect disturbances in climate control), and locomotion (to detect lameness) are needed to improve the control of unwanted behaviours, and to improve the precision of management for the delivery of quality products, health, welfare and environmental outputs. With the help of this technology, farmers and veterinarians can continuously, and automatically, collect and manage the information needed to manage together the multi-dimensional component of the individual and livestock and assure citizens that livestock production is safe, humane and environmentally sustainable while reducing labour load. ICT technology can help, for example, to measure individual differences for management (e.g. of resource use) or phenotyping in support of new breeding goals.

Goal

To develop and implement future options for innovation in livestock systems that will make Europe's livestock systems more efficient and sustainable. To achieve integration of knowledge between biological, veterinarian, social, economic, engineering and ICT scientists. To combine research and development with product and service development by matching academic and industrial communities.

How to achieve this

- Better support tools that combine information on individual animals with ration formulation and management routines should be developed to achieve optimal productivity and simultaneously avoid wastage. Physiological models must be developed to better interpret and use sensors data. The objective is to convert data from these tools into useful information and decision support systems for farmers and service providers like veterinarians to better manage the individual animals and the herd both on a short term basis (early detection of infections or metabolic disorders, precise feeding considering animal responses, regulation of environmental condition in building) and a medium term (improving the practices from clear historical information). This requires the development of mathematical decision support modelling (e.g. data mining and artificial intelligence), (wireless) sensor technology, ICT-infrastructure (web based, databases), standardisation (e.g. RFID) and user-centric design methods to evaluate the interest of cumulating data from different origins (biological, behavioural) and to improve the quality of the diagnosis and support. Research will focus on biological models and decision support tools and industry (including innovative SME) will consider hardware structure.
- Sensor information will also provide useful information for high speed automated phenotyping technologies which are needed to be further developed and applied to enable real-time management and to provide data for the delivery of new breeding goals.
- The choices for the farmer will touch the socio, economic and technological integration and discussions and should be addressed in the Horizon2020 programme.

Expected impact

New technological developments as described above will make the management of farmers and service providers more efficient, and allow for farming practices that reduce wastes, reduce emissions, give early detection of irregularities and improve welfare and health. However, the biggest social impact is that farmers will be supported in giving care to individual animals that are part of groups, and taking care of the circumstances in which these groups have to function. This will be a system innovation. Further development of precision livestock farming will make Europe's agricultural sector an example for the world.

2. Responsible livestock farming systems

Livestock farming systems generate valuable and desirable products for the human diet including some from resources that cannot otherwise be converted into food (grass-based systems). They also support the development of rural communities (especially in more remote areas), contribute to management of ecosystems and increase biodiversity (especially in uplands) and are in growing demand, globally, to meet changing dietary preferences for ever more affluent communities.

However, the past also showed drawbacks of continuous growth of the livestock sector such as challenges to the environment (through gaseous emissions, pollution and ecosystem damage), human health (through zoonotic diseases) and for the welfare of animals within the systems. This will be part of the continuous discussion between the livestock sector and societal needs. Hence future and present farming systems need to be (re)designed, discussed with society, integrated in a regional and economic context and give social and ethical value to the people working with and in these systems and value to the individual animals living in these systems.

In order to realise such socially and environmentally responsible livestock systems, we suggest focusing on four more integrating and interdisciplinary topics on system level:

a) Assessing EU animal production.
b) Improving protein and energy autonomy of the animal production sector in Europe.
c) Productive grassland based systems.
d) Climate smart animal production.

2a. Assessing EU animal production ★

Background

To identify solutions for a socially, economically and environmentally responsible animal production sector, there is a need to have a sound analysis of the current situation and future options for animal production. Food production is not the only function of the animal sector. Animal systems are an important part of a rural infrastructure, communities, landscape, and recreation. There are many results from past research activities related to animals that have been obtained but not yet adopted or applied in practice. This results in a lack of objective assessment as to the potential for improvements that, realistically can be made, with respect to the diversity of systems needed. To redesign systems an analysis should answers to question such as: What are the specificities of EU systems? What does European and global society expect from livestock in the future? How important are animal production systems to the resilience of community structures in different parts of Europe? What changes in socio-geographic and demographic changes are to be expected, and how will these influence animal production systems and the expectation from society? What are the lock-inns in present production systems? What are the regional differences? Where will animal products feature in future diets? What are the expectations for animal welfare or in terms of identity/traceability, alongside the necessity for efficient and environmentally friendly production systems? How can animal production systems further contribute to the resilience of community structures in different parts of Europe?

Goal

The development of an integrated European approach for the assessment of current systems and their efficiency, that will lay out the future options for improving and redesigning animal production systems that contribute to social, environmental and economic gains. And to understand the contribution of animal production systems to community sustainability, or fragility, in Europe, in terms of other values than food products and to include this in the development and evaluation of production systems, for example the possibility to use livestock farms in 'green care', for recreation, for education, or for the development of rural areas and coastal zones. This requires the development of multi-criteria assessment of livestock systems and food chains.

How to achieve this

Careful analysis of future demands for animal products, and socio-economic appraisal of expectations of the 'means of production' is needed alongside technical exploration of options for production systems. Analysis of the impact of the presence, absence or reduction of livestock agriculture on local/regional rural communities, and on the green infrastructure and biodiversity should be quantified. Traditional livestock breeds could also play a role in multi-purpose production systems; thereby improving the management of domestic animal genetic resources. This includes:

- A yield-gap analysis identifies potential for improvement and gives insight into the difference between the theoretically achievable production in diverse agro-ecological environments and the actual production. This will enable the direction of future target actions towards production systems with the highest potential to improve resource efficiency and to minimise losses, resulting in sustainable intensification.
- Life cycle and system analysis are sound methodologies for a complete chain analysis and focus on a set of environmental impacts. The LCA requires further development and application to support scientifically sound methodological choice enabling a harmonised assessment of improvement options for social acceptability of livestock systems (health, welfare, employment, quality) and environmental performance (emissions to air (ammonia, greenhouse gases), soil (accumulation of phosphorus and heavy metals), water (nitrate and phosphate leaching) and fossil energy use) of the livestock sector. This, and other methods for multi-criteria assessment of livestock systems and food chains, need to be refined and applied, alongside inventory data and other relevant statistics to provide robust analyses of current situations and how they have been changing. This includes novel research on the impact of the

presence, absence or reduction of livestock agriculture on local/regional rural communities and marine areas (environmental pollution, escapes and emerging diseases). The importance of livestock farms for the green infrastructure and biodiversity should be quantified so that effective grazing strategies can be developed.

- Production circumstances and also consumer perceptions differ considerably across European cultures. Achieving a 'livestock farming with care' requires a variety of approaches related to core ethics. Maintaining a 'level playing field' will only be possible if we develop management standards for customised animal care, with no nuisance to the environment and credible for society, and not solely on the *inputs* (or circumstances) we offer our animals or environment (see also 4c 'Ensuring animal welfare').
- The development of an integrated European approach for the assessment of current resources (including food losses), risks and opportunities; Feasibility assessments, trends in regional and global society, trends in technology development and trends in agro&food production systems, assessment of multifunctionality, of social, economic (employment), health and welfare and environmental consequences of innovative production systems; assessment of obstacles and options to enhance adoption, development and evaluation of the potential and drawbacks of technological options to support development of livestock production systems.

Expected Impact

This work will provide, for the first time, an integrated overview of the status quo and the opportunities for redesign of agricultural and livestock systems across Europe.

2b. Improving protein and energy autonomy of the animal production sector in Europe ★★

Background

For Europe the development of alternative protein supply strategies that minimise reliance on imports (i.e. soybean and fishmeal) is of strategic importance. This became clear in the adoption of the European Parliament's own-initiative resolution 'The EU's protein deficit' on 8 March 2011, but also in the recent Communication on the CAP towards 2020, which mentions that the CAP should encourage synergies between crop and livestock farming, e.g. in proteins. There is also a need to find alternative sources of energy at large due to growing competition for energy feedstock, to allow the farming sector to continue fulfilling its primary mission, i.e. production of food and feed. Huge potential lies in the valorisation of organic waste streams, unused residues and existing ingredients in the food production chain through development of novel and existing technologies. These valorised residues can be partly used as animal feed ingredients (in a higher segment), but can also result in valorised products suitable for inclusion in food for human consumption, as well as serving as a substrate for the chemical industry to produce fermentation or biological end-products, such as glucose, sugars, ethanol, methane, lactate, enzymes, etc. The question often is: what geographical scale is needed to improve efficiency and acceptability. New opportunities can be found when livestock and crop production will reconnect, together with biotechnical and social sciences.

Goals

To understand and find opportunities for improving protein and energy autonomy of livestock in Europe by the development of viable systems for optimising the use of current and emerging resources such as co-products from non-food industry (biofuels).

How to achieve this

- Alternative protein sources (e.g. grain and forage legumes, other alternative crops, micro algae, macro algae and biorefinery co-products and former foodstuffs) need to be evaluated in practice as well as new technologies to improve yield for feed production.
- New and better ways are needed to convert by-products from the food industry into valuable feed resources. Certain resources may contain anti-nutrient factors or contaminants at low levels. Detoxification techniques should be developed to allow safe use of these new resources in animal feed, thus reducing the pressure on agricultural resources.
- Close collaboration of animal scientists with plant breeding research and agronomist is necessary to develop new plant production systems and new crops with much higher productivity with lower inputs, lower emissions and high value constituents.
- The genetic background and potential of animal production based on low or at least more variable quality diets needs to be examined in order to be able to breed animals that can produce efficiently under future production circumstances.
- Risk assessments and life cycle assessments (LCA) play a key role in the evaluation of the potential of the new technologies mentioned above. Socio-economic studies are needed to lay out the (economic and geographical) viability and the resilience and robustness of these new systems.

Expected impact

Delivery of the best strategies to develop economically viable and resilient systems with alternative protein resources and reducing protein imports into Europe, and reduced competition between feed and food production.

2c. Productive grassland based systems ★

Background

Grass and forage based systems allow ruminants to produce very high quality proteins for human consumption from resources that are not in direct competition with humans. Such systems, though, have mixed benefits with regards to the delivery of environmental goods. Additionally, grassland-based systems promote a clean, animal welfare-friendly image for ruminant production, and open landscapes with grazing ruminants are highly appreciated by the public. Increased attention should be given to maximising the 'ruminant advantage' by developing grassland-based systems, including improved crop rotational systems, which are productive and more environmentally acceptable and address the trade-offs between competing goals might put this onto our 'novelty' list. Instability of the prices of animal product and the projected price increase of non-renewable energy and mineral fertilizers will reinforce the necessity to develop innovative low inputs systems. Development of grassland and forage based systems for ruminants that are cost effective, environmentally sound and manageable is new and essential in the context of the development of large-scale dairy enterprises with highly productive animals and in the context of remote rural areas that need to be grazed for landscape maintenance for recreation. Nitrogen and phosphorus use efficiency should be increased and water and energy use minimised.

Goal

An integrative approach for grassland management that is cost effective, environmentally sound and manageable, is essential in the context of the development of large scale dairy enterprises with highly productive healthy animals, that benefit from high welfare standards, and in the context of remote rural areas that need to be grazed for landscape maintenance for recreation.

How to achieve this

- Integrated approaches that combine improved management skills, innovative management systems and techniques, feeding and nutrition practices and genetic improvement through selection for robust adapted breeds or genotypes should be evaluated in the context of different systems of production.
- Exploiting the adaptive capacity of herbivores to make better use of marginal land (land on which the only thing that will grow is grass). This would mean a better understanding of adaptive capacity (genetics, early life experience, ability to cope with environmental fluctuations). Also, the need to manage this adaptive capacity, i.e. matching animals to environments, getting the right blend of animals with different capacities in a herd (leads to the notion of the adaptive capacity of a farm), and tailoring management to best exploit adaptive capacity.
- Quantify the importance of grassland and forage based systems for the production of ecosystem services and biodiversity according to their management, and evaluate and develop effective grazing strategies.

Expected impact

A greater proportion of ruminant production will be delivered from grassland and forage based systems with reduced demands on land that can be used for other purposes. The environmental impact of grass and forage based systems will be improved (in relation to climate-changing emissions and biodiversity goals). Competition for land that can be used for purposes other than grass production will be reduced.

2d. Climate smart animal production ★★★

Background

Climate change results in more extreme climatic conditions with longer periods of extreme ambient The animal production sector contributes significantly to the emission of greenhouse gasses (GHG). There is a strong requirement to mitigate these emissions. Mitigation can be linked to the production of feed, enteric methane production, manure production, energy consumption and carbon sequestration in pastures. At the same time, climate change has its effects on animal production systems. The largest risk lies in the increase of extreme weather events, such as prolonged droughts, extreme ambient temperatures or periods with high and intensive precipitation. Although the effects in Europe will be not as strong as in e.g. Africa and Asia, climate change will have an effect on the availability of feed, heat stress and the risk of new diseases. For aquaculture, impact on and effects of climate change are not yet known, but parallels to animal production on land are obvious.

The climate change issue requires an integrated approach, where food security and increased productivity, adaptation to climate change and mitigation of emissions goes hand in hand. This concept is known as climate smart agriculture. Research on integrating adaptation and mitigation in livestock recently started (AnimalChange in FP7), but the concept of climate smart agriculture needs further elaboration in the European context. It is known that improved resource use efficiency reduces emissions of livestock products, but the effects on resilience are not yet known. Moreover, resilience in livestock systems is complex, it requires resilience in plant production, animals and feed production chains. The room for solutions can partly be found in techniques (feeding and breeding) but also in the production chain, at sub- and super national level with intersectoral arrangements. Multidisciplinary research in close cooperation with stakeholders is needed to develop solutions that contribute to maintaining high productive agriculture, with increased resilience and an efficient resource use with low GHG emissions (see also section 1 'Resource efficiency').

Goal

Development of climate smart, low emitting, productive, resilient and robust animal production systems.

How to achieve this

- Integration of current climate variation simulation models and agro-economic models to simulate consequences of climate change and extreme weather events on European livestock sector at regional scale. These models should help the sector to cope with variation of forage and crop production and land use changes (proportion of grassland, annual forages and crops).
- Development of animal production systems and chains that are more robust and resilient to large variations in feed supply from their own land, but also from imported feed and co-products. Apply this solution at different scales (farm, regional, EU). Integrate strategies of adaptation and mitigation by technical adaptation of crop and forage production, herd and manure management.
- Within the system approach, develop technical solutions for high ambient temperatures and emerging diseases. This requires integration with breeding, feeding, farm techniques and veterinary care.
- Development and testing of new plant production systems and new multispecies grassland with a water use efficiency and higher resilience to drought. Some Mediterranean species/cultivar might be considered. Here, close collaboration of animal scientists with plant breeding research and agronomists is necessary.
- Assessment of the risks of climate change for aquaculture in cages, ponds and recirculation systems.
- Increase the knowledge of the environmental impact of in-house and outside animal systems

Expected impact

Adaptation of animal production systems that still ensure a sustainable supply of food to Europe under more extreme variation of climate. Reduced GHG emissions from European animal production due to new smart breeding, feeding and manure management approaches.

3. Healthy livestock and people

Secure animal health is of utmost importance for human health, animal welfare, resource efficiency and for the efficiency of production. We support the '*One Health*' approach to realise a healthy livestock sector and ensuring feed and food safety for people.

The theme covers topics concerning animal health and welfare, public health and the total food chain. Options should be pursued for developing integrated strategies for disease prevention or control and approaches for the evolution of agricultural production systems that are in tune with targets for improved consumer health and protection.
Mutual development of knowledge to improve human and animal health and wellbeing (risk assessments; diagnostics; epidemiological approaches; long-term consequences of dietary and other environmental impacts on health and welfare; zoonoses) is at the core of a 'One Health' approach with challenges at all levels of science, from discovery to implementation. This also includes the necessity to have the right infrastructures for health management, the necessity to survey and anticipate on emerging diseases and to have the right methods and means available for dealing with crisis situations.

The evolution of agricultural systems that promote holistic approaches to human (individual and social), animal and environmental health will demand multi-disciplinary and multi-stakeholder approaches. Improved understanding of ecological and epidemiological drivers of disease emergence, persistence and spread, and applications for improved disease control through integrated strategies requires transnational as well as local actions.

By minimising disease, we also improve resource efficiency so these topics add to this section (above) as well as being important in their own right. Actions under this heading could build on progress made in the DISCONTOOLS project and at the same time adhere to the EU animal health strategy 'Prevention is better than cure'.

Within the One Health theme, we focus on four specific topics:

a) Prevention, control and eradication.
b) The microbiome, animal & human health.
c) Nutritional quality of animal products.
d) Feed & food safety.

3a. Prevention, control and eradication ★★

Background

Secure animal health is of utmost importance for human health, animal welfare and for the efficiency of production (e.g. reduced productivity of 20-40% in pork production leading to reduced growth, increased feed consumption and use of antibiotics). Food safety, zoonotic diseases and the responsible use of pharmaceuticals such as antibiotics all have potential impacts on human health and wellbeing. The control of diseases (also endemic infectious diseases and emerging viruses) is of utmost importance to safeguard the trade in animals and animal products.

Europe has made significant progress to prevent, control and eradicate diseases. However, health issues should be considered at a global dimension and new diseases arise regularly and continue to do so. Continuous risk assessment of new diseases emergence, disease prevention, reducing risks of development of drug resistance, generalised infection control, specific disease control, achievement of a suitable level of preparedness regarding disease outbreaks and coordinated action remain important topics for research and knowledge development. The possibilities to develop holistic systems biology, improve understanding of disease and drug resistance and use genetic/genomic selection for improved disease resistance have been under-researched, partly because of lack of unequivocal phenotypic parameters for health and disease resistance. Also the sources of variation in the incidence of endemic or production diseases, despite apparently similar control regimes, need analysis to improve control systems.

Goal

To develop integrated approaches to disease control and to explore the combined impacts (and trade-offs) of combinations of individual approaches. To develop both the necessary elements of individual control systems (e.g. management procedures / biosecurity; vaccines; disease resistant genotypes; feeding systems, etc.) and the cost-effective approaches required to combine these elements into integrated systems for disease control. To create operating networks and paradigms and to apply them for the appraisal of risks to European livestock (at national, transnational and local levels) and human health of endemic, exotic and emerging diseases.

How to achieve this

Current surveillance networks, data bases and diagnostics need critical appraisal for adequacy in the light of current and foreseeable disease challenges. Strategies and technical approaches to overcome weaknesses/deficiencies should be developed and applied transnationally and linked to local actions. Key risks, once identified should be the target for specific measures to reduce risks, and improve prevention and control. An integrated systems approach is needed for the development of generalised infection control or customised disease control strategies to reduce the incidence and severity of endemic animal diseases taking into account the characteristics of the pathogens, the animals, the farms (open / closed) and their environment (e.g. farm density). We propose to specifically focus on:

- Selection strategies for the delivery of genotypes with enhanced disease-resistance or disease-tolerance (depending on the disease) and feeding systems. Genetic approaches will depend on identifying easy-to-measure phenotypic markers of health that can be assessed in large numbers of animals. It is advantageous if variables are used for both genetical and management purposes.
- Specific actions are needed to control notifiable and zoonotic diseases, aquaculture vaccine development, and the control of the development of resistance to pharmaceuticals such as antibiotics and anthelmintics. This includes research on the mechanisms of development and selection of resistance markers, and their transfer between animals and from animals to humans as well as proper application strategies (including coordination between actors) for use of targeted (instead of broad band) vaccines (so as to minimise the chance that vaccine use in animal production contributes to antibiotic resistance in humans). Significant effort is also needed to explore the combined impacts (and trade-offs) of combinations of these individual approaches. This should be done through simulation and, for promising

strategies, evaluations in practice. Such studies often need experimental infections to be conclusive but are costly and time consuming to perform, however, crucial for the understanding of the pathogenesis of infection diseases and best way of therapy.

- Necessary actions include more rapid and precise diagnostics, vaccine development (especially for diseases that modify immune responses), customised nutrition with additives, integrated management of animal health from world to Europe to country and district level.
- Necessity to better understand and predict the behaviour of stakeholders (breeders, professional breeding organisations or governments) in health management to estimate the effectiveness of intervention measures. The purpose is to assess resource allocations by actors and stakeholders for health management (prevention, monitoring, therapeutic intervention, compensation of losses), as well as the determinants of behavior, including representation of risk. The evaluation of policy instruments or coordination of actors (regulatory, insurance, incentive contracts) must be taken into account especially in the case of strong externalities associated with decisions, inducing a need for integration of health management at a collective level (country or industry).

Expected impact

Improved infection and disease control systems and practical ways to combine actions. Reduction in the growth of antibiotic resistance; animal genotypes and animal systems that are more resilient to disease challenge; reduced risks to human health; reduced losses and improved resource-use. This work facilitates the free trade of animals and their products throughout Europe and strengthens Europe's position to remain self-sufficient where food production for its domestic market is concerned.

3b. The microbiome, animal and human health ★★★

Background

Designing next generation livestock systems asks for robust animals that are less susceptible to disease and require less medicines (antibiotics). Robustness relies on the ability of the immune system to respond to challenging conditions in an appropriate manner: i.e. by displaying the right balance between inflammation and immune tolerance. A major part of the immune system is associated with mucosal surfaces, the gut in mammals and poultry, but also the skin and gills in aqua-cultured animals. Improved understanding of immune competence requires integration of knowledge across various disciplines and levels of biological organisation.

Mucosal health is a multifactorial trait. For example, the epithelial cell layer of the gut is strategically placed between the luminal content and the underlying mucosal immune cells. Microbiota and dietary components signal to the epithelium to maintain and balance an appropriate immune competence. The composition and diversity of microbiota is influenced by host genetics, maternal effects, neonatal conditions, animal nutrition, and environmental conditions. The complex interplay in the gut enforces the development and maintenance of an immune system that has the ability to avoid excessive inflammation and to retain the capacity to defend against challenges. Furthermore, it is known that the pattern of early gut colonization shapes the future immune competence and that variations in host genetics and microbial colonization severely impact immune competence and the degree of disease susceptibility. Specific action in the area of mucosal health is needed to develop approaches for improved immune competence, health and welfare in livestock species but also in man, due to a reduced transmission of pathogens and bacterial antibiotic resistance. We also identify this generic area of science as one that merits significant fundamental effort (see also 5a 'Host - microbiome interactions', proposed under Excellent Science for a more fundamental approach to this topic).

Goal

To enhance understanding of the interactions in the gut between digestion products of animal feeds, residing microbes, and host immune cells (host genetics) with a view to identify routes for the implementation of this knowledge in the management of improved immune competence in livestock species and reduced health risk for humans.

How to achieve this

- Using a multidisciplinary approach to develop and combine knowledge on nutrition science, immunology, genetics, bioinformatics, ecological microbiology, and systems biology with different targeted and "genome-wide" techniques applied at different levels of biological organization.
- Identification of nutritional and microbial factors underlying immune competence at mucosae. Study the interaction between feed stuffs and microbiota in mucosal tissue as the gut and evaluate associations of immune competence and disease susceptibilities. .
- Identification of families or groups of animals which are more robust, i.e. improved immune competence and more resistant or tolerant to environmental challenges and determine genetic factors responsible for this phenotype.
- Development of biomarkers to objectively quantify immune competence to evaluate the impact of external factors, related to gut homeostasis, environment and climate, on immune competence and animal health productivity and welfare.
- Define impact of variation in immune competence of livestock species on the transmission of pathogens and antibiotic resistance genes to human populations.

Expected impact

Better control of feed use and modulation of immune competence in livestock species should lead to the development of more robust livestock animals and improved management systems. Robust animals are less susceptible to diseases and use lesser quantities of medicines (antibiotics) which is beneficial for efficient animal production and animal welfare and limits the transmission of pathogens and antibiotic resistance genes to the human population.

3c. Nutritional quality of animal products ★

Background

Animal products are an important resource of protein, minerals and vitamins in human consumption patterns: they are part of a healthy and balanced diet[2]. Apart from improving the efficiency in producing the products, it is also important to look at improving the products itself. This closely relates to the feed intake of the animal, but also to the genetic background and health status. Nutrigenetics and nutrigenomics combine nutrition and genetics. Animals with different genetic profiles react differently on feed stuff and nutrient intake, have different metabolic efficiency and different nutrient composition in the end product such as egg, meat or milk. Feed stuff, its composition and ratio of nutrients can also alter the expression of certain genes affecting e.g. ratio of long and short chain or saturated/unsaturated fatty acids in the end products. Some properties of animal products, though, are not ideal for a healthy diet. Certain types of meat are often regarded as a high contributor of saturated fatty acids or cholesterol. Improvement of the fatty acid profiles of animal products requires a lower proportion of saturated fatty acids, a lower proportion of n-6 poly unsaturated fatty acids (PUFA) and a lower ratio n-6:n-3 fatty acids. Options to address these issues lie in changing animals (e.g. through breeding) or their management (through feeding) to improve primary products. It has been demonstrated that the fatty acid profile of feed as a direct impact on the fatty acid profile of animal products.

Goal

To improve the nutritional value and health promoting properties of food of animal origin in sustainable production system (e.g. the fatty acid profile of animal products, the amount of essential trace-elements such as iodine or selenium and also critical nutrients such as calcium, zinc, or folate) by understanding the interaction between nutritional composition of feed and genomics. To assess the impact of new feed resources on the nutritional value of animal products.

How to achieve this

Although research on health effects is already being done, attention and integration remains needed to :

- Increase the knowledge of interactions between nutritional composition of feed and genomics to give tools to alter nutritional value of animal products through feed recommendations or through precision feeding (feeding according to genetic profile of the animal/line/breed, see also 1b).
- Assessment of the impact of the nutritional composition of feed, in particular emerging feed materials on the nutritional value of animal products, in particular the proportion of n-3 PUFA, n-6 PUFA and saturated fatty acids, as well as calcium, zinc, vitamins, various bioactive peptides (milks, eggs) and folates.
- Analysis of the food system to support the development and evaluation of measures that will contribute to socially and environmentally responsible livestock production. This includes opportunities to translate consumer demands and information collected along the food chain (in terms of quality of food products (e.g. milk composition or boar taint)) into food system innovations including improved management and breeding practices at farm level (from consumer to farmer). Social and technological consequences of innovations need to be assessed in order to focus on those areas where options and consequences may be most challenging, e.g. upland systems of livestock production.

Impact

Improved nutritional profile of animal products contributing to healthier diets.

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[2] Animal products are an important source of minerals (iron, zinc, magnesium, phosphorus and selenium), contain a range of B-vitamins (B1, B2 B3, B6 and B12), and an important source of fat-soluble vitamins: Vitamin E, Vitamin D and Vitamin A. Some minerals and vitamins (e.g. zinc and vitamin B12) are only present in animal-derived food, and cannot be replaced by plant-based sources.

3d. Feed and food safety ★

Background

Consumers are increasingly aware of the importance of having access to food that is both wholesome and safe to eat. Reputational damage to both the internal (EU) and export markets for food from animals carries heavy threats of economic loss and, in the extreme, to the sustainability of industry sectors. From both a societal and economic view it is essential to improve safety aspects of food provision throughout the food chains that link animals to people. Some of the measures proposed in other sections, e.g. to improve resource efficiency must take into account requirements for food and feed safety. The use of by-products of the food production chain as alternative ingredients for feed (section 1b) requires specific processing technologies and technological treatments that should fulfil requirements for feed safety

Goal

The provision of tools and practical guidelines to ensure supplies of food and feed that are microbiologically and toxicologically safe.

How to achieve this

Efficient control of microbial and chemical hazards to human in the dairy and meat production is the goal of the 'One Health' approach assuring and promoting food security. Studies are needed to improve the efficient control of hazards to human. Tools and methods should be made available that will lead to a further reduction of the risks and dangers of food-borne and antimicrobial resistant pathogens in the food chain. Despite many efforts infections of known and emerging food-borne pathogens from the animal reservoir occur at high frequencies. This leads to a high human burden of disease, social disquiet and great economic damage. Producers and consumers of dairy and meat thus have an interest in detecting, preventing and controlling outbreaks of food-borne pathogens. An array of tools and methods must therefore be developed and optimised to reduce the risks and dangers of pathogens in the food chain. The research in this area must follow a comprehensive approach:

- Inventory: Identification of human exposure and risks of particular pathogens for humans. For example, further research on the effect of low-level contamination, like mycotoxins, should be addressed notably but not exclusively for the organic products.
- Measuring: Surveying the incidence of particular agents and toxins. Improved techniques must be developed for the control of microbiological contamination of feed and food (in particular but not only Salmonella and Clostridia) and incidences of viral pollution on watered shellfish (particularly Vibrio).
- Routing: mapping the transmission routes of pathogens, antibiotic resistance markers and contaminants between animals and farms. For that purpose research in technologies for an optimised measurement and prediction of substance-specific carry-over is crucial to minimise carry-over effects in feed mills.
- Control: implementing methods of control and intervention. Special methods must be developed to reduce the adventitious presence of residues of coccidiostats or medicinal substances in feed for non-target species as a result of carry-over.
- Securing: Identifying monitoring check points.

Expected impact

Improved animal and human health; safer food supply chains.

4. Knowledge exchange towards innovation

Innovation has been at the heart of agricultural developments and the sector's successes in the past. Technical developments in the livestock sector for example, have made it possible for farmers to keep large herds of animals at lower labour costs, reduce wastes and emissions, reduce diseases. New technological developments and innovations will be essential for success in the future: they will ensure the sector becomes more sustainable and remains competitive.
One of the main opportunities for the future are 'tailor-made' solutions. New techniques allow for a highly specialised management systems on the farm, that can make the livestock sector one of the most technological advanced sectors in the world. ICT, precision livestock farming (see 1) and 'omics' are promising new technological developments that should be invested in.

For innovations and technological developments to be successful, it is important that these are developed together with the farmers and industry. Their knowledge greatly contribute to making scientific findings valuable in practice.

Two promising emerging technological developments deserve to be highlighted:

a) Knowledge exchange with farmers and industry towards innovation.
b) Improving systems for the implementation of 'omics' tools.
c) Ensuring animal welfare.

4a. Knowledge exchange with farmers and industry towards innovation ★

Background

It is generally recognised that the barriers to implementing new technologies or new management methods are best overcome by involving the end-user (the farmer in this case) in the research and development activities, and/or in defining the objectives in the first place. Agricultural innovation (i.e. the translation of research results into practical socio-economic benefit, added-value or profit) thereby moves from the traditionally linear innovation model to an interactive and participatory process of knowledge exchange, involving farmers, together with other intermediaries and stakeholders (e.g. farm advisors, NGOs) to create new knowledge and innovation. Approaches that may work in one area (geographical or sectoral) may not work in others. While it cannot be expected that adoption of new or different approaches will ever be uniform across the wide spread of cultural, regional and other backgrounds that are such a rich source of diversity in Europe, there are likely to be significant opportunities for better promotion of 'best practice' or more effective local adoption. The challenge is to identify hurdles to adoption and to explore opportunities to overcome them.

Since new technologies and new types of information also open up new ways of doing things, it is important to evaluate (a) how new developments impact on existing business practices and (b) what new opportunities arise for developing more competitive and sustainable business models, considering the individual farm, the local society and the food chain or sector as a whole.

Goal

To ensure that new technologies are developed in a context which improves the uptake of research results into practice, and allows for (a) a positive impact on farm incomes and (b) the exploration of new business models within systems of production and consumption

How to achieve this

The Animal Task Force endorses the approach of the European Innovation Partnership to support the establishment of multi-actor groups. Such groupings acting in a coordinated manner across Europe provide an excellent opportunity to act as 'test beds' for new technologies, on-farm management methods and new business models, taking account of the full range of livestock production systems (including multifunctional approaches), different geographic settings and bio-diversity. 'Test beds' can be realised for example as 'focus groups', as on-farm participatory research or as experimental or demonstration farms with outreach to farmers. The integration of various data and information streams into practical decision support systems is seen as a key enabler to the uptake of new business models combining social (health and welfare), environmental (emissions, waste, resource efficiency) and economical gains, of new technologies, particularly considering remote sensing, measuring and recording, and making full use of robotics and the future internet. The linkage of facilities which are appropriately equipped to accurately monitoring resource inputs and animal performance will be necessary to carry out measurements on a large number of animals in order to derive relevant phenotypes and to take full advantage from the 'genomic revolution'.

Expected impact

Better cooperation between agricultural research organisations and farmers, improved uptake of new technologies and methodologies, improved farm incomes and more sustainable systems of production and consumption.

4b. Improving systems for the implementation of 'omics' tools ★★

Background

The initial achievements of the ‘genomic revolution’ are currently being implemented. Starting four years ago, breeding companies began to use genomics to select reproducers. Additionally livestock industries (mainly cattle), are close to using ‘-omics’ measures as a herd management tool. The potential utility of such data is clearly huge, albeit difficult to predict. Important challenges exist when attempting to exploit the increasing amount of ‘omics data and utilise it for ‘on farm collected phenotypes’. These include:

i) Utilisation of structural variation (e.g. SNP, CNV) from whole genome sequences to predict the breeding value (expected genetic performance of progeny) of animals across the range of breeding goal traits;

ii) Utilisation of other ‘omics’ measures (e.g. metabolites, protein, RNAseq) as biological markers of phenotypes, possibly collected with the precision farming approach (see above in 4b);

iii) Development of system biology methodologies to link together the information generated in genomics, proteomics and metabolomics.

Nutrigenomics studies the effect of feed on expression of the genes. With a certain feed stuff combination the metabolic pathways and animal’s energy balance can be altered so that at a certain production stage the animal is using the available energy and nutrients in a way that ensures its wellbeing, good health and fertility.

Goal

The ‘omics’- approach has the overall goal to improve knowledge of the genetic, genomic and transcriptomic control of traits in order to assist in breeding decisions and in herd management. The primary goal is to link the changes achieved in breeding with the expression of genes, quantification of proteins and pathways, and the metabolic outcomes of these changes. This will also provide us with tools to better understand and use the potential of ‘omics’ in creating a more sustainable livestock sector. Omics-technologies give also new means to ensure animal wellbeing, health and fertility by understanding the interactions between the nutrient composition of the feed and animal genomics.

How to achieve this

New tools need to be developed to deal with the ‘omic’ data explosion, methods and models need to be developed for use of genomic information in breeding programmes and in on-farm livestock management (e.g. diagnostic tool, management of population in breeding and population genetic variability). These technologies represent a step-change in available tools, hence breeding programmes and advanced farm management systems need to be re-designed to make best use of the new ‘omic’ era. Large experiments are needed where nutrigenomics is used as a tool to improve sustainable animal production.

Expected impact

The availability of tools able to deal with ‘omics’ measures will shift the overall animal sector to a higher technological level, enhancing collaboration of European SME (as currently ongoing) involved in breeding and in advising farmers. This will increase their competitiveness and economic potential. The development of ‘omics’ based tools will strengthen the research-industry interaction and enhance dialogue with other areas of biological science using similar tools.

4c. Ensuring animal welfare ★★

Background

Animal welfare is an increasingly important topic. It centres around the respect for the animal's integrity in a production environment, and includes provisions for good housing and nutrition, a healthy life and conditions appropriate for animals to perform normal behaviour. These elements are key to achieve animal production under responsible welfare conditions. Research into the improvement of animal welfare is interdisciplinary in its nature, as it includes the interaction of expertise areas such as nutrition, ethology, veterinary sciences and animal husbandry. Addressing these aspects collectively is important to realise a socially responsible and sustainable livestock sector.

Ethical, promotional and societal values are factors influencing the welfare perception in the debate on animal welfare. Also, mixing up the concept of ´animal welfare´ with other items of social concern, like sustainability, naturalness, specialty production, specialty systems or farm size has been observed. As few rural people are producing food for many urban people, animal production is more at a distance to citizens. At the same time citizens want to know whether their food is produced responsibly. Ideally, there is a 100% match between the intrinsic welfare of the animal, and the perception of welfare by the farmer, consumer and the citizen.

Production circumstances and also consumer perceptions differ considerably across Europe. Achieving 'good lives' for animals may require a variety of approaches, depending on local circumstances. Conversely, similar inputs or circumstances offered to animals may result in very different effects on the well being of animals. Consider, as an example, the role of straw in hot versus cold climates: straw use in these different regions will have very different effects of the microclimate of the animal. Maintaining a 'level playing field' will only be possible if we develop standards of well-being on the basis of animal-based and real time measured indicators, and not solely on the husbandry inputs we offer our livestock. Despite the growing awareness of animal welfare, and the increased scientific knowledge about animal-based welfare assessment (e.g. Welfare Quality®), it has to be considered that monitoring and practical implementation is proving to be more difficult. There is an urgent need to involve professional knowledge more closely in the development of welfare monitoring tools in the managerial practice of livestock farming. Next to monitoring welfare efforts, there is an increasing interest in agriculture to develop further tools and insights to improve animal welfare in all parts of the animal production chain. The Commission's Strategy on the Protection and Welfare of Animals 2012 -2105 supports this view.

Agriculture has historically been poor at explaining its role in responsible food production and animal care to society. Concepts need to be developed to support the animal sector to improve transparency and communication towards society in a proactive way. Also, studies are required to disentangle the non-welfare concepts (e.g. sustainability, production system or size) from the animal welfare concepts. Strategies are needed to improve involvement of agricultural professionals to achieve sustainable implementation. In addition, new research has an important role to play to provide agriculture and society with scientifically sound and practical welfare monitoring tools, and methods to improve animal welfare in an integrated, holistic way.

Goal

To evolve techniques and new concepts to improve the implementation of animal welfare in farming practices and to provide a level playing field regarding monitoring of animal welfare, in combination with other sustainability aspects (profitability, environmental load, etc.) in a global perspective. To deliver innovation of production systems to ensure intrinsic animal welfare in combination with other sustainability requirements. To enable the achievement of high standards of animal welfare across local production and societal circumstances.

How to achieve this

- Improved husbandry conditions, fostering species specific production circumstances including nutrition, housing, health and animal behaviour requires innovative thinking to include behavioural, physiological and health status considerations. Breeding, climate control, barn design and feed contribute to the improvement of animal welfare. For example, consider the role of diet and development phase of the animal, the role of social behaviour and ethological welfare of animals when able to cope well under group circumstances, the relationship between dry bedding, diet and leg and footpad health of poultry, the relationship between indoor/outdoor systems, disease challenge and mortality, the relationship between treatments and aggression or mortality (e.g., tail biting, cannibalism), and increasing the longevity and lifetime production of dairy cows, sows and laying hens.
- Breeding robust animals is an essential element in improving animal welfare: the development of improved tools to speed up the identification and introduction of important genomic and phenotypic welfare characteristics will be a key factor in improving welfare outcomes simultaneous with other traits important for a sustainable livestock sector.
- Develop standardisation of practical indicators for animal welfare across countries to be able to confirm that corporate and farming efforts are having the desired effects at food chain, farm and animal levels. Research to support endeavours of production chain partners to incorporate welfare quality assurance based on performance parameters; investigation into how to communicate the benefits to consumers and society to achieve the potential added-value for the supply chain. As such, this will also support the EU Welfare Strategy on providing transparent welfare product quality to European consumers.
- Investigation of confounding factors (e.g. sustainability, naturalness, specialty production, specialty systems, or farm size) that must be disentangled from real animal welfare to be able to communicate in a transparent way to society.
- Development of concepts to support the animal sector to show corporate responsibility and improve transparency and communication in society in a proactive way and in a manner that is addressing the perception framework of citizens while staying with the concept of the real welfare of the animal.
- Studies to link responsible management and welfare with sustainability.
- A toolbox of standardised health and welfare outcome indicators to be collected at suitable stages within the production cycle. Promote the establishment of methods for linking new and existing databases for future quantitative benefit assessment of animal welfare. Access to such data will also open possibilities for research determining the strength of the links between specific housing and management inputs (space, use of pasture, feeding systems) and animal-based welfare outcome indicators (of nutritional status, behaviour and lifetime production).
- Development of standardised holistic data gathering mechanisms on health and welfare parameters at the end output level (e.g. slaughterhouses) across European countries, in close cooperation with the industry and farmers´ organisations, with roads for improvement to enhance health, welfare and food safety with built in guarantees to prevent naming and shaming. A European Network of Reference Centres (as piloted by the EUWelnet project) will support this aim.

Expected impact

New methods and tools to ensure animal welfare in management practices in animal production. Better implementation of locally applicable solutions for animal welfare, whilst promoting a level playing field through a common welfare improvement. Support to the livestock industry to open up doors, build corporate responsibility and become transparent in a way society understands. Better implementation of animal welfare monitoring throughout the production chain. Disentangling of the welfare of the animal and possible ´polluting´ non-welfare perception frameworks and integrated product information addressing real (instead of perceived) sustainability aspects. And ultimately, an improved animal welfare in Europe.

5. Opportunities and needs in 'Excellent Science'

A number of issues above will depend, for real progress, on developments in more fundamental understanding in a number of areas. Specific ones that we wish to highlight are:

a) Diet-host-microbiome interactions.
b) Long-term consequences of environmental effects in early life.
c) Enabling the predictive understanding of phenotypic expression.
d) Immune regulation at mucosae.

5a. Diet-host-microbiome interactions

Background

75% of the immune cells in the body are connected to the gastro-intestinal tract. Gastro-intestinal epithelial cells are constantly monitoring the content of the gut and communicate with the underlying immune cells. Intestinal microbes have a strong impact on this crosstalk and are highly influenced by the dietary composition. There is convincing evidence that intestinal microbes influence host immune development, immune responses, and susceptibility to intestinal diseases. Conversely, host and dietary factors affect the composition and metabolic activity of microbes, which in turn modulate disease susceptibility. Thus there is an intimate interaction in the gastro-intestinal tract of animals between host epithelial cells (= host genotype), the residing microbes, and the composition of animal feed.

The intestinal microbiota of mammals is largely symbiotic in nature. In recent years it has become obvious that the intestinal microbiota profoundly influences host biology and imbalances in the microbiota composition have been linked to several intestinal diseases and events in early life may have long-term effects on the host. Functions of the gut microbial community, such as methane production (especially in herbivores) has also been shown to be dependent on the host.
Disentangling the myriad of processes that underlie these events, the factors that influence them (e.g. food or feed consumption by the host; host genotype) and the subsequent synthesis into forms of understanding that will allow this new knowledge to be applied to benefit livestock management, and human health, are at early stages.

Significant support under excellent science is needed for scientific initiatives that will throw more light on this area of fundamental relevance to both livestock science and 'One health' approaches to the management of health and disease, as is described in section 3b (the microbiome, animal and human health).

Goal

To gain an understanding of the symbiotic functions of key members of the microbiota, their metabolism and ecology. Predictive understanding of the factors that affect interactions between the gut microbial community (and lung microbial immunity) and host function, and the means to exploit this understanding for practical benefit.

How to achieve this

Studying the effect of (genetic, environmental, nutritional) factors on immune competence and intestinal health adds a new and important dimension to the current research on the gastro-intestinal tract, which is mainly focused on the effects of feeds, feed ingredients, pro-, and prebiotics on the functionality and immunity of intestinal tissue. With regard to immune competence, research should focus on genetic, environmental and nutritional factors that influence microbiota colonization and immune development. As it is known that there is significant variation in intestinal functionality and health between animals, there is much to gain in this respect. For example, in small scale experiments so-called high and low immunological responders have been identified that differ from each other in their quantitative immunological response against different pathogens and probiotics.

Action to enable prediction of the effects of external (e.g. food and feed characteristics; physical environment) and host (genotype; physiological state) factors on the form and function of the gut microbiota. Exploration of interactions between gut microbiota, cellular function at the gut-lumen interface and subsequent physiological signalling. The creation of European network(s) to enable integration of effort, data management and subsequent synthesis.

To investigate the impact of the microbiome on the host using transcriptomics and metabolomics and the influence of external factors (e.g. food and feed characteristics; physical environment) and host (genotype; physiological state). The effect of key species and their components or metabolites on host signalling and immunity will be investigated using automated high-throughput microscopy and specific cell pathway reporters. This approach will be complemented by the construction of metagenomic libraries and functional screens to identify new bioactive molecules which can health properties and therapeutic applications. The creation of European network(s) to enable integration of effort, data management and subsequent synthesis.

Expected impact

Better management of livestock for environmental, health and production benefits. Better management of human health and disease. The discovery of novel probiotics and microbial products to prevent disease and promote the health of livestock animals.

5b. Long-term consequences of environmental effects in early life

Background

It is increasingly recognised that the pre- and peri-natal environment the animals are exposed to has large effects on performance, health and welfare of animals in later life. E..g. perinatal effects are found of nutritional state of the mother or incubation conditions in broilers effecting development and health. Furthermore thermal programming of chickens during incubation have shown to affect postnatal heat stress tolerance. Postnatal early rearing conditions have been shown to be important in the development of behavioural vices as tail biting and feather pecking. Also early nutrition seems to have long term effects on the development of the immune system. At this moment we are at the start of understanding how large the impact of early life conditions is on long term health, welfare and productivity. Research is partly hampered by the fact that different links in the production chain do not yet realise the impact of their work on the next step in the chain, e.g. impact on resource efficiency by robust and efficient animals (see also 1a).

The microbiota that colonise the gastro-intestinal tract during the neonatal period play a crucial role in shaping the immune system and determining the immune competence of the animal, which in turn, determines immune responses and immune tolerance later in life. The neonatal period is therefore crucial for both local and systemic innate and adaptive immune responses later in life. Colonisation of the gut (and the development of immune competence) is dependent on external factors such as management and feed, but also on the host genotype.

Goals

1. Better understanding of key environmental factors that impact later life.
2. Quantify the relative impact of early life conditions on later health, welfare and performance.
3. Develop a chain approach to integrate this new knowledge in an integrated chain approach.

How to achieve this

Actions to improve understanding of early life impacts particularly on lifetime psychological, behavioural and reproductive outcomes. Action to promote fundamental understanding of the mechanisms governing sex differences in response. Exploration of the ability of postnatal environmental conditions to mitigate the impacts of early life challenge. The development of European-wide network(s) to bring together research in rodent and human models with livestock research to help translate basic understanding from rodent models to livestock species, and to explore the scope and limitations of early life events to alter lifetime development.

Expected impact

Better management of livestock to reduce losses and improve healthy development; better advice for healthier lifetimes in people.

5c. Enabling the predictive understanding of phenotypic expression

Background

A core aim of much of animal science is to understand how animals function so that it may become possible to predict what they will do if treated in certain ways. In other words: we are trying to understand how an animal of a certain genotype will respond when exposed to a particular environment, or a change in its environment. Examples include how an animal 'performs' when it is offered specific feeds, or how an animal responds to exposure to a particular pathogen, or how an animal will change its behaviour in response to some challenge. A core aim of animal (or livestock) science is to enable the prediction of phenotypic expression. This will contribute to e.g. resource efficiency as described in section 1 (robust and efficient animals (1a), efficient feed chains (1b) and the development of precision livestock farming (1d).

The '-omics' revolution has delivered massive capability to describe functional processes in huge detail against a backdrop of well-defined genotypes, and the capability to describe phenotypes at many levels of detail. This presents, at least in theory, the potential to use information from different levels of detail to improve understanding, and subsequently to predict, phenotypic expression. Research into 'Systems Biology' is developing rapidly in the biomedical area, as well as in some model species, but it is hardly developed for livestock species. Europe has the potential to lead in developing and applying Systems Biology tools farm livestock if it can combine resources across its many research providers. No one provider, or even Member State, has the capacity to do all that is needed.

Goal

To create capability across Europe for the development of theory and applications to deliver predictive understanding of phenotypic expression in mammals and birds.

How to achieve this

Create a virtual network of relevant institutions across Europe to agree protocols and operating structures for standardising the collection, collation, sharing and management of relevant data. Develop the necessary data infrastructures. Support a network to develop theory and methods to combine data from different levels of detail to enable interlinkage of 'fine' and 'course' phenotypic descriptions. Identify key areas for focal development of predictive models of phenotypic expression; develop and test such models. Develop a network of physical infrastructures for recording phenotypes of functional relevance.

Expected impact

By creating the capability to combine information from different levels of exploration and using it to develop models of phenotypic expression, Europe will take a world lead in enabling understanding of animal function and the translation of fundamental research into practically meaningful actions.

5d. Immune regulation at mucosae

Background

Development of novel vaccines to prevent infectious diseases among animals and humans is a desirable application of the advances made in biotechnology and immunological understanding. Moreover, many new vaccines are urgently needed. Although the vaccine R&D path is long, the scientific advances in the past decades have made it reasonable to expect that new vaccines can be developed against infections which have not previously been amenable to prevention by vaccination, including endemic diseases that are responsible for large antibiotic use and production losses. It is thus realistic to expect new vaccines that i) induce longer lasting immunity, ii) provide rapid protection, iii) provide sterile immunity, iv) induce immune responses that allow a parallel surveillance of the distribution of the infection by Differentiating Infected from Vaccinated Animals (DIVA), v) can easily be applied by mass application methods, for example by mucosal routes, vi) are safe under all circumstances, and that vii) can be given to maternally immune animals.

Goal

To ensure a preventive animal health care allowing a responsible use of medicines and antibiotics.

How to achieve this

This area requires investments in knowledge development in:

- Immunological Indicators of Protection, in particular protection at mucosal surfaces: It is imperative to identify protective immune mechanisms and to know which immunological or other host-related laboratory read-outs are associated with immunity and which are inevitably linked with clinical end-points.
- Antigen Discovery: The rational use of bioinformatics must lead to selection and synthesis of antigens with optimal possibility to induce protective immunity. This could e.g. employ analysis of microbial genomes with B- and T- cell epitope. Optimized design of antigens would allow protection by eliciting a multi-serotype immunogenicity. In cases where vaccines need an associated DIVA test, DIVA antigen discovery also needs to be factored in. Emphasis should also be given to non-peptide antigens such as lipids or carbohydrate antigen recognized for those diseases, such as tuberculosis, that require cell-mediated immunity.
- System Vaccinology: To accelerate a new generation of vaccines. It is imperative to develop and apply state of the art methods, for example host transcriptome analysis or proteomics in combination with bioinformatical systems of systems biology. All analyses need to be related to clinical endpoints of protection such as absence of pathology, pathogen shedding or absence of clinical signs or survival of challenge.
- Adjuvant Development: The increased knowledge on immune activation and the interplay between innate and adaptive immune responses advertises the possibility to develop adjuvants with tailored induction of preferential immune responses most suited to provide efficient immunity, including specific induction of mucosal immunity with killed vaccines.
- Understanding of Host Immunogenetics: Genetic factors that determine the variable response to vaccination include the highly polymorphic leukocyte antigen system, which is involved in antigen presentation. Other, but less polymorphic pathways involved are the Toll-like receptor pathway, which is involved in antigen recognition and stimulation of the immune system, and the cytokine immunoregulatory network. Knowledge of such factors may direct vaccine development towards vaccines that are effective in genetically diverse populations.

Expected impact

Development of improved and novel vaccines may significantly contribute to secure a healthy and sustainable expansion and improvement of animal production and welfare in Europe. Furthermore, improved and novel vaccines will have the potential to reduce contamination of animal products with zoonotic infectious agents and thus improve food safety. Vaccine R&D holds a strong potential for small or medium sized industries.