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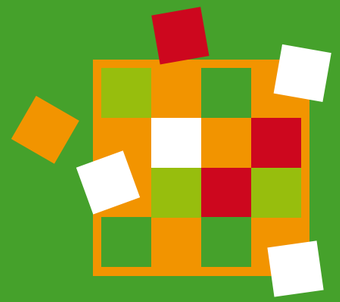


Agriculture

The future of the agricultural life sciences in the Netherlands
A vision for 2020 and beyond

V Agriculture

Executive summary

Covering nature, agriculture and environment, the agricultural life sciences are fundamental to the very existence of the world as we know it today. In 2020, the agricultural life sciences will continue to play a major role in addressing challenges that require innovative technological solutions. Major issues will be feeding a growing global population with healthy food, mitigating climate change and dealing with energy security while avoiding negative impacts on our living environment. Feeding the expected 7.5 billion people requires more efficient production systems, minimizing losses due to pests and (infectious) diseases. Global health is at stake not only as a consequence of malnutrition, but also due to age-related chronic diseases, food-related disorders such as diabetes, obesity and bowel disease and infectious diseases in human and animal. The agricultural life sciences can play a leading role in answering these global problems.

To be effective, the agricultural life sciences need to be rooted in a sound Dutch scientific infrastructure. The current infrastructure, comprising the academic institutes, social organizations and the private industry such as breeding companies, food companies, biotech and the pharma industry, has gained international recognition and is thus fully able to develop the innovative solutions needed and to market the products throughout the world. Public-private partnerships are an effective tool in bringing this innovation process forward.

Only by capitalizing on the full potential of Dutch agricultural life sciences can we develop the products that bring profit to our industry and sustain the wealth and health of our society.

RECOMMENDATION To further strengthen its future position, the agricultural life sciences call for:

1 A stable and strong knowledge base striving for excellence
2 Strong focus and mass on competitive and distinguishing technology in the following fields
- **A secure and sustainable food supply**
- **Animal health**
- **Biorefinery**
- **Systems biology**
- **Micro- and nanotechnology**

3 Continuity of the open innovation systems such as public-private partnerships
4 Technology that is sustainable and acceptable for the society

A. The agricultural life sciences

The agricultural life sciences encompass nature, agriculture and the environment. The agricultural life sciences, therefore, cover organisms such as microbes, plants, animals, human beings and also the many interactions between them. As such, the agricultural life sciences are fundamental to the very existence of the world as we know it. To date, genomics and related technologies have become a formidable driving force within the agricultural life sciences. We now face the challenge of how best to explore the future potential of the agricultural life sciences, in effect, to explore the full potential of nature itself. How will the agricultural life sciences contribute to the quality of life? How can the agricultural life sciences be used to meet major global challenges? What is needed to capitalize on the full potential of the agricultural life sciences? What is the impact that the agricultural life sciences will have on society and how can this become pertinent to decision-making in science, industry and politics?

B. Global challenges

Feeding the world

2020

In 2020, one of the major globally-addressed topics is food security. The global population has reached 7.7 billion and everyone has a right to be fed a balanced diet. A higher agricultural productivity in combination with a better distribution of available food is a major challenge which has to be met. The life sciences meet this challenge with technological innovations. Improved and novel foods, including new protein sources, have been introduced. Insect and aquaculture products like algae are frontrunners of a new and more sustainable food production industry. However, the "classic" animal and plant products are still the major sources of protein. The consumption of animal products in the Western world is decreasing slightly. However, prosperity has grown (e.g. in large parts of Asia). Consequently, the diet of a large part of the Asian population has shifted from a predominantly vegetarian one towards the consumption of more meat and dairy products. This fast-growing demand will put great pressure on the world's resources.

The road to 2020

Feeding more people with an affluent diet calls for considerably higher primary food production. Increasing the agricultural production area is hardly an option in tackling this challenge. The most fertile lands are already under cultivation and exploiting marginal soils demands a considerable input of scarce and valuable resources like energy, water and phosphate. A higher agricultural productivity is therefore the best option to achieve food security. Higher productivity is rooted in three major developments. Firstly, sophisticated plant and animal breeding technologies can increase the potential biomass yield of plants and animals. For example, the efficiency of feed uptake by livestock can be increased by applying the correct combination of animal and feed through the selection for Optimal Feed Conversion Rates (FCR). The potential yield of plants could be increased, say, by improving photosynthetic efficiency. The second intervention is to improve the quality and composition of feed which improves nutrient utilization and total production. The third important action is based on avoiding production losses. Plant diseases, destroying crops both during cultivation and after harvest, can be controlled by advanced agronomic methods. New plant varieties will be developed which are more resistant to pests and diseases. The control of infectious diseases in animals is also of utmost importance in preventing losses in meat and dairy production. Precision agriculture, in combination with well adapted plants and animals, will ensure a high output/input ratio. More predictive approaches (predictive + prognostic tools + early warning methods based on biomarkers) are needed that allow corrective measures to be taken at a very early stage.

The role of the agricultural life sciences

The life sciences are the driver behind all of these developments. A thorough understanding of the functioning of genes and proteins and their interactions with external factors as well as their effects on traits, (micro)organisms,

> "It is a scientific challenge to design four times more ecoefficient agricultural production systems, to ensure that we can feed the world within the carrying capacity of our planet earth."
>
> **Martin Scholten, Director of the Animal Sciences Group of Wageningen University**

environment and agricultural systems are of crucial importance to this sector. The installation of high-throughput facilities to collect relevant data, and especially, the correct bioinformatics to integrate this data (systems biology) necessitate the development of more predictive and preventive approaches in plant and animal sciences. Through higher productivity, enough food can be produced on the existing agricultural area without jeopardizing nature or existing biodiversity. These technological solutions cannot be met through national incentives alone. Global trade in plant and animal products thrives and the EU, including the Netherlands, is a major producer and must therefore collaborate via national initiatives in larger frameworks to develop these technologies.

Climate change

2020

In 2020, temperature rise is no longer an issue for debate. Climate change is considered a fact, and has affected global agriculture. Although a higher temperature, in combination with an increased CO_2 concentration, may even have increased the yield of vegetable production on a global scale, the regional variations are large. Precipitation patterns have shifted and have resulted in desertification of some formerly productive regions, while flooding others. The gradually rising sea level is causing salinization of coastal zones. These shifts especially impact agricultural systems in developing countries, putting food security at risk. Animal diseases (most zoonotic) are rapidly spreading (Bluetongue, Rift Valley Fever, African Horse Sickness, Crimean Congo Fever, Chikungunya fever) and are having significant impact on animal farming and global health. Likewise, plant pests and diseases have spread to new regions, threatening local agriculture.

The road to 2020

Mankind responds to global warming by trying to neutralize the causes (mitigation) and by modifying life to suit the new situation (adaptation). If livestock can consume feed more efficiently, less waste will be released as methane into the atmosphere. The slogan here is "two times more with two times less" referring to the ratio of production to environmental impact. Farm animal breeding and management can contribute to the decrease of environmental output (e.g. by increasing environmental production efficiency and by decreasing output of gas emissions). Precision agriculture and better digestibility will enable a higher output/input ratio, minimizing waste and also the conversion of fertilizer into the major greenhouse gas N2O. Plants act as powerful CO_2 catchments, purifying the atmosphere of CO_2 and converting it into biomass. In addition, new systems and crops/animals will be developed that are (more) adapted to the new climatic conditions. New plant varieties can survive periods of drought or flooding, and resume growth as soon as the extreme situations have passed. To overcome salinization, new cultivation systems and crops adapted to saline conditions will be established for agriculture in brackish regions. Animals will be selected that can thrive on products from salty soil. Prevention of new diseases needs early warning systems and appropriate diagnostic tools.

The role of the agricultural life sciences

The life sciences drive all of these developments. Both mitigation and adaptation necessitate a fundamental understanding of crops and livestock in modern farming systems. Technological advancements make use of natural biodiversity to select the best adapted animals and plants and can even introduce selective traits into the population. Sophisticated breeding technologies will enable the development of robust crops/animals optimally adapted to the changing conditions. The genetic constitution of organisms and populations determines their potential to respond to changing climatological conditions. These responses, in turn, determine the behavior of farming systems and enable the prediction of crop production

systems that are best suited to meet climate change. Both in terms of mitigation and adaptation, the agricultural life sciences are crucial. Correct interventions orchestrated by the agricultural life sciences will help minimize the effects of global warming. The life sciences have the lead in developing new diagnostics and early warning systems on a global scale.

Energy supply and basic resources

2020

In 2020, society can no longer rely fully on fossil resources for energy and industrial raw materials. The bio-based economy has grown to maturity and agriculture has expanded widely beyond its original goal: the production of food. However, this has been shown to create an extra burden on the availability of agricultural resources for the production of food and feed. Energy-neutral (agricultural) production, reuse of waste as fertilizer or as biofuels are, even in 2020, still challenges for the years to come. The focus is on the next generations of biofuels, without jeopardizing food security; biorefinery is in place to maximize the value of biomass. Developing countries, well-suited to the production of biomass, are profiting from renewed interest in biomass.

The road to 2020

The current first and second generations of biofuels competes, with other uses of biomass, for scarce resources like water, land and nutrients. The challenge is therefore to develop new pathways for bio-energy. Exploring the potential of photosynthesis, both for higher biomass production and for the development of BioSolar Cells, is one such new and exciting path and needs to be pursued. Biomass is urgently needed for biomaterials. Where several alternatives to fossil energy are available, the only alternative for fossil-based materials are those originating from biomass. Inevitably, this development will grow in impact over the coming decades, supported by the many new options offered by sophisticated technologies. Biorefinery technologies are needed to maximize the value of biomass. By carefully fractionating biomass into components with different economic values, the overall value of biomass will increase dramatically. Biomass is not used for one or the other application, but for both simultaneously. High-value components may be used for special chemicals; proteins and sugars may be used for food; and the remnants are still a suitable source of energy. This option relies upon advanced technologies and carefully controlled and interdependent processes and production chains.

The role of the agricultural life sciences

New advances in the life sciences open new possibilities for the true development of a bio-based economy. Sufficient production of biomass is a prerequisite for using biomass beyond food purposes. This may be reached either by tailoring crops for growth on what is currently wasteland, or by improving the production capacity of crops in existing systems. Genomics and breeding are key to these developments. The multiuse of biomass calls for new biorefinery concepts and again, for plant varieties that are optimized for broader use. In line with the cradle-to-cradle concept, plants and plant-based systems need to be (re) designed for optimal processing. Animal production systems need to be developed such that waste is no longer considered as waste anymore, but rather as feedstock for further processing. Diminished environmental pollution is an extra pay-off. The life sciences will play a key role in fueling these developments.

Environmental stewardship

2020

In 2020, a sustainable agricultural environment is considered essential for humankind in numerous ways. Animal and plant production is now an integral part of our environment and is functional as a major economic factor in society. Farming comprises both large-scale animal and plant production as well as smallholders with strong emphasis on biological values giving particular attention to the recreational and educational aspects of the profession. With the increased pressure on biotopes through further urbanization, human infrastructure and agricultural land, biodiversity is under great pressure. Environmental stewardship is the prime responsibility of every individual on earth and governments have called for global approaches in order to preserve our environment. Surely the need for space, energy and food are in conflict with environmental needs. Therefore, technological innovations are essential to meeting this challenge for generations to come.

> “We face the challenge to increase our agricultural productivity while decreasing our ecological footprint. The agricultural life sciences are excellently suited to address this challenge and I hope and expect that they will have a growing impact on our agricultural systems to the benefit of mankind.”
>
> **Martin Kropff, Rector Magnificus of Wageningen University**

The road to 2020

Environmental stewardship calls for sustainable production systems without jeopardizing our environment. In ultimo forma, this is conceptualized in the cradle-to-cradle model. In this concept, introduced by William McDonough and Michael Braungart, waste is considered food either for the biosphere or for new production processes. Non-sustainability is not an option, and both ecology and the economy will benefit from this concept if it is consistently implemented. Nature conservation and reclamation need to be pursued to create viable ecosystems where the maintenance of plant and animal biodiversity is optimally guaranteed.

Genetic diversity in plants and animals is recognized as pivotal for many future applications. More and more, plants and lower organisms will be discovered that form the basis for (bio-)pharmaceuticals. Diversity of the intestinal microbiota will be exploited to improve animal health and feed conversion. Diversity will be further exploited in breeding as a source of many important characteristics such as disease resistance and adaptability. Diversity is proving fundamental to resilient ecosystems and adaptive production systems, enabling farmers to respond effectively to a changing environment. Biodiversity is being explored and exploited by local communities to improve their economic situations. Biodiversity is being cherished to save nature as a natural resource of biodiversity. However, the impact of nature reaches far beyond its role as biodiversity source alone. Ecosystems serve as sinks for CO_2, for the production of oxygen, for nutrient cycling and pest regulation, for tourism and well-being, for pollination, for water and climate regulation and so on. The impact of the roles of ecosystems is acknowledged, and consequently environmental stewardship is considered essential for a flourishing future.

The role of the agricultural life sciences

The life sciences play a central role in environmental stewardship. Understanding the complex interactions in ecosystems is essential for maintaining resilient systems. The life sciences will allow us to identify which interventions are possible and needed in order to be able to manage these systems. Modern molecular (-omics) technologies define markers to characterize these ecosystems. The combined genomes of microorganisms present at the interface between animals/plants and their environment form a typical meta-genome reflecting the interaction with

this environment. Combined genomic profiles of individual organisms, often referred to as the barcode of life, shows the detailed composition of the ecocommunity. Together they form the ultimate forensic record of life, activity and functioning of ecosystems. The agricultural life sciences are thus major governors of the genetic diversity which is of fundamental importance for a sustainable future of the sector itself and the environment into which it is integrated.

Global health

2020

In 2020, a long and healthy life is now reality for more and more people due to the rapid developments in (bio-) pharmaceuticals and healthcare. Ever more therapies based on advanced biotechnology are available to cure different diseases in animals and man. However, disease prevention remains a global challenge. The "ladder of health" (Figure 1) depicts the steps that the world has taken from 1900 onwards to improve the basic health of its citizens.

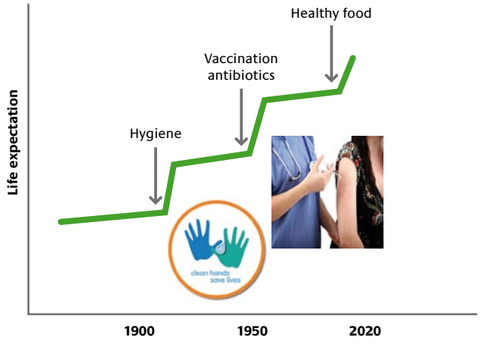


Figure 1: The ladder of health

The impact of hygiene and vaccination/antibiotics has greatly controlled the most common infectious diseases. However, new (mostly animal derived) threats are lurking and still need our attention for the development of new control tools. SARS, Influenza, Tuberculosis, but also Rift Valley Fever, West Nile Virus and others, are not yet under control and need inventive strategies. Food safety is still of utmost importance and will benefit from further innovations in disease monitoring, epidemiology, prevention and treatment. Human and animal risks regarding antibiotic resistance are mitigated by the introduction of alternatives in animal husbandry but are not yet fully under control.

Apart from infections, disorders related to prosperity such as cancer, diabetes, obesity and food allergies have appeared. Although ageing is still a significantly hard to control factor, most of these syndromes are caused by overconsumption of specific compounds like saturated fatty acids or (refined) carbohydrates. This requires novel primary products with less "unhealthy" compounds and more "healthy" nutrients that could even be of beneficial use (healthy food, the next step on the ladder).

The road to 2020

70% of new infections originate from animals and need to be controlled, at the source if possible. Animal health therefore needs to be integrated into human healthcare planning (so-called One Health). Technologies can be developed for exploitation and application throughout the health chain. The animal health industry faces enormous challenges.

Better diagnostics and epidemiological tools are prime for improved control. New strategies need to be developed to mitigate the risks of epidemics and pandemics. Apart from priority listing as is performed by (global) politics, the health sector and industry, new instruments like marker vaccines, anti-virals, immune modulators to broaden efficacy and mass-applicable formulations should be introduced and applied to prevent animals from becoming diseased and spreading the pathogens around the globe. Breeding technologies may enable selection for more resistant animals.

Healthy food can prevent many diseases related to prosperity. Low fat and low sugar foods will help fight obesity and diabetes, and the removal of allergens will avoid allergenic disorders. Foods fortified with "evidence-based" health-promoting components like vitamins, micronutrients and antioxidants will strengthen the constitution of consumers. Breeding and primary production can help the food sector meet these challenges by assuring a healthy supply at the very beginning of the production chain.

The role of the agricultural life sciences

The life sciences are at the basis of the development of global health. The agricultural life sciences are pivotal to human and animal health and the green food sector. The introduction of innovative technologies will result in establishing a sustainable and healthy society. Sophisticated diagnostic and epidemiologic tools will stimulate preventive animal disease management. Systems biology approaches focusing on host-pathogen interactions are key to developing new preventive and therapeutic tools to deal with this challenge. Better understanding of microorganisms is key to developing the appropriate tools. Genomics is at the basis of all of this.

Genomics and breeding technologies can be also be geared towards raising new varieties rich in health-promoting components and free from "unhealthy" compounds. Application of nutrigenomics know-how can develop new animal feeds with a positive impact on animal health, product quality and with a reduced ecological footprint. Not all consumers react to food components in the same way. The diversity of consumers calls for a diversity of food products. Technologically advanced primary production can provide the basic materials needed to establish this variety of next generation healthy foods. As a result, on average, humans will live longer than they did a few decades ago, and in good health.

> "The Ministry of Agriculture, Nature and Food Quality encourages the Dutch agro-food complex to contribute to sustainability of future society. For that purpose we need a strong and internationally competitive agro-food economy with respect for the interests of man, animal and natural environment. It is my believe that strong and proactive public-private partnerships in life sciences can and will contribute to meet these challenges of the future by finding innovative solutions."
>
> **Janneke Hoekstra, Director of the Knowledge and Innovation Department (DKI) of the Dutch Ministry of Agriculture, Nature and Food Quality**

C. State of the art

The Dutch agricultural sector
Since the industrial revolution, the Netherlands has played an important, often leading role in innovative agriculture. As an open economy, the Dutch strategy is based on innovation. This strategy has been very successful. The Netherlands is now among the countries with the highest land productivity, a global leader despite its small size in a number of agriculture sectors, and with a large percentage of its gross domestic product (GDP) based on agricultural export. In 2007, when primary production is concerned, the Dutch agro-complex accounts for 10% of GDP and provides 670,000 jobs, more or less evenly spread over de plant and animal production sectors (dairy and meat). The Dutch agro-complex accounted for 17% of the total Dutch export and contributed EUR 23.6 bn (60%) to the Dutch trade balance in 2008. These statistics underline the economic importance of the agriculture sector and the international success of Dutch entrepreneurs in the sector. The Netherlands plays a leading role in the plant breeding and plant propagation industries. Dutch plant breeding is highly advanced, well organized and is for a global leader in many vegetables, flowers and potatoes. The turnover of the plant breeding and plant propagation industries in the Netherlands exceeded EUR 2.5 bn in 2008. The sector employs over 11,000 people. More than 40% of all plant breeders' right applications (for registering new plant varieties) in the EU come from the Netherlands.

Animal production plays an important role in European society. Optimized animal production systems contribute to a safe, healthy and diverse diet, help maintain sustainable human communities in more marginal regions of Europe and facilitate reductions in our environmental footprint on the planet. A vibrant and effective animal production industry is instrumental in meeting Europe's future challenges in animal agriculture in a rapidly-changing ecological, economic and social environment. Dutch farm industries are global players and supply competitive markets, both European and global. The Netherlands harbors the largest animal meat producer VION, which has a 57% market share in pig production and slaughtering. With sales of nearly EUR 10 bn in 2008 and over 35,000 employees on the payroll, this is an important company for the sector. Plukon Royale is one of the major poultry producers in the EU, with 2008 sales of EUR 600 m. And the Dutch dairy industry is significant, with FrieslandCampina, DSM and Unilever as major players in the entire food sector. Currently, animal breeding companies in the Netherlands play a dominant role in the world. CRV, Topigs and Hendrix Genetics are at the top of this highly developed industry. They therefore have a major influence in determining the genetic make-up of future animals and hence, on the whole of animal production. Fish farming has firmly set foot in the Netherlands, an industry that is growing exponentially and will contribute to future objectives of animal production.

This important industry can only thrive by having high quality support from animal health knowledge institutes and biotech. The Netherlands is still home to the top of animal health pharmacy R&D (Intervet/Schering Plough Animal Health), in association with the privatized Animal Health Service that supports the sector in decision making and healthcare issues.

> "Plant breeding not only remains a driving force in reaching food security in the world, plant breeding will also be key in addressing the global changes as we face them today."
>
> **Hans Dons, Managing Director BioSeeds BV**

> "The global animal breeding industry is consolidating rapidly and technology is a key driver. By acting now, The Netherlands can be a world leader in 2020."
>
> **M. H. M. Hendrix, President Hendrix-Genetics**

Being the best, rather than leaning against protective interventions, forms the basis of the Dutch vision. An example is the Dutch vision of using vaccination strategies against epidemic diseases rather than eradication strategies based on culling. The Netherlands has been advocating these vaccination strategies for years. This perception is embedded in the Dutch agricultural policy and fits the Dutch ambition to develop its economy to be a leader in the global knowledge economy. The Dutch Innovation Platform was established in order to guide and support this ambition, and identified the agricultural sector as one of the most innovative and promising sectors of the Netherlands. Now it is up to the sector to capitalize on this promise.

The Dutch knowledge system
The Netherlands has strong players in agricultural life science research, both academic and industrial. This excellence concerns animal, plant and environmental research. The Faculty of Veterinary Medicine at Utrecht University is ranked among the top five in the world for the quality of its research and the dissemination of results. The Central Veterinary Institute of ASG-WUR is one of the best equipped centers in the EU for high containment research and clinical trials (Prion diseases, HP-Influenza, Q-fever). Research in infectious diseases has received international recognition, and especially the interaction of animal and human infectious diseases is exemplary. Collaboration within Kennisketen Infectieziekten Dier (KID) but also programs on antibiotic resistance and epidemiology of zoonotic infections connect the Dutch human and animal health institutes. The "One Health" concept for humans and animals is becoming more and more anchored in science (see www.immunovalley.nl). Immunology and vaccine technology is an intrinsic competence of many Dutch knowledge centers, with the Netherlands Cancer Institute, Central Veterinary Institute and Netherlands Vaccine Institute as anchors. The Animal Sciences department of WUR is strongly connected to collaborative (EU) research programs often in PPPs together with the Dutch feed and breeding industry.

The Dutch Plant Sciences research system is excellent, exemplified by its rank as third on the global ESI list of high quality scientific publications. This position is reflected in the number of multinational plant breeding companies with a main office established in the Netherlands and the high number of Dutch plant breeders' rights applications. Innovation has been, and still is, the key to the international success of the sector. To this end, research institutes and industry closely collaborate in many national and international research programs and networks. The Netherlands initiated and dominates the ERA-NET Plant Genomics and is leading in research on Solanaceae through, for example, the NGI Centre for BioSystems Genomics. The relevance and economic potential of the sector is acknowledged by

the Dutch Innovation Platform by appointing “Flowers & Food” as one of the *Sleutelgebieden* (key areas) for future innovation.

Fundamental research is essential for innovation and stimulates the development of new technologies and the translation of these technologies into products on the market. Industrial research is essential for the translation of new technologies into products. This can be applied using various strategies, generating business for the industry and income for academic research (IP rights). Quality of research and education go hand in hand. Industrial research thrives in countries with strong research institutes and an excellent education system that provides the next generation of researchers. A key element is the relationship between academic and industrial research, as demonstrated by the financial commitment of both private and public partners in financing public research at the major institutions for animal and plant sciences. Around 50% of the research in these institutions is acquired from competitive programs involving quality-driven investors. This indicates the important role which high quality research plays in the infrastructure of the agricultural food sector. This relationship can be further intensified by synchronizing the research agenda and by stimulating the movement of researchers from academic to industrial research and vice versa. A better aligned research agenda is expected to result in more outsourcing of research activities from industry to academic research. Having access to top scientists, in combination with efficient research cooperation between academic research groups and industry, will stimulate international companies to establish, maintain and/or increase their research presence and capacity in the Netherlands. The role of new initiatives such as Food Valley and Immuno Valley is clearly to address these issues at the interface of politics, science and industry and to promote further knowledge transfer.

The transfer of technology from basic research to product feasibility and from there to development is of central importance. Early involvement of industry is essential to enable effective transfer. Public funding of research has to include this transferability as part of the funded activities. Involvement of industry can only be accomplished effectively if based upon Intellectual Property (knowledge) and adequate regulatory requirements (policy).

The Dutch agricultural sector operates in an entrepreneurial, research-intensive, international, dynamic, innovative and competitive environment. Research institutes, social organizations, industry and the government join forces to stimulate innovations, scientific developments and education. This collaboration reflects a new interaction in the knowledge structure and is often referred to as the public-private partnership (PPP). In this model, market and social partners are leading in defining the objectives of the research agenda. The research organizations contribute by developing innovative solutions for social and economic questions. The government facilitates these innovations and drives the activities within a political, national and international context. The various parties collaborate within networks, combining the expertise needed to address the topics concerned. To date, many successful research activities are based on this new model.

Flourishing public-private partnerships: Milk Genomics Initiative

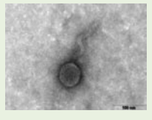
The aim of the Dutch Milk Genomics Initiative is to identify genes that contribute to natural genetic variation in milk-quality traits, in particular milk-fat and milk-protein composition. The program provides tools for improved breeding programs to exploit natural genetic variation in milk-quality traits and contributes to the knowledge base needed for innovative dairy products. The Milk Genomics Initiative combines expertise in the fields of dairy science, quantitative genetics, genomics and bioinformatics.

The industrial partners in the Dutch Milk Genomics Initiative guarantee the utilization of results and ensure a fast diffusion of the relevant knowledge to the practice of dairy cattle improvement and product innovation.

Flourishing public-private partnerships: Immuno Valley ALTANT program

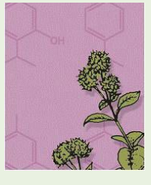
The program was initiated by the Ministry of LNV with seed funding of EUR 3 m, and started on January 1, 2009. The objective is to develop proof of potential for use of alternatives to antibiotics in livestock by December 31, 2010. Immuno Valley has organized this program into four projects:

ASIA: anti-microbial peptides



RESUPLYS: phage/lysin therapy against Streptococcus suis

EVAC: vaccine against Staphylococcus aureus



MODIPHY: phytochemicals with immunostimulating, antimicrobial activity

Both public and private partners are incorporated into (international) consortia. Relevant industry has been invited to monitor the program and to join as soon as is feasible. In 2011, a full PPP will be constructed around the most promising projects, involving up to EUR 18 m. Achievements six months in: 1 new patent application, 1 publication

D. The way ahead

The Netherlands has the ambition to develop further as a knowledge economy. This perfectly fits with the European ambition described in the Lisbon Treaty. The Lisbon Treaty acknowledges that, for future economic development, besides the traditional production factors (nature, labor and capital), knowledge will be essential. The establishment of an Innovation Platform and continued support for innovative public-private partnerships show the way as to how the Dutch government intends to achieve this development. This policy needs to be pursued in the future, but focus is needed to guarantee sufficient critical mass. Open innovation will be key in these developments. Companies will profit from combining external and internal ideas to reach new breakthroughs. Consortia willing to share knowledge, as found in public-private partnerships, are valuable instruments in advancing open innovation. It is the vision of the agricultural life sciences to focus on three socio-economic relevant topics (what), to invest in two platform technologies relevant in these topics (how) and do so with impact on society in conducive networks.

Priority: A secure and sustainable food supply
Food security concerns the entire supply chain (Figure 2). National and EU governments make the rules for food safety and human health, as well as guidelines based on global environmental agreements (climate change, stewardship). Regional governments are mainly involved in landscape and environment and in reducing the ecological footprint of food production. The sector is concerned with productivity (profitability) and industrial competition. These stakeholders are influenced by retailers, consumers and others in society. The driving force will be the higher productivity and profitability of the sector framed by demands of society and policy.

The production chain can be influenced at two major points. Firstly, the source material should be optimized to produce optimal yields given the conditions provided (region, climate, requirements). Sustainability is a precondition of the newly developed breeds and varieties. Feedback will occur from the production process drivers (higher productivity, better efficiency) as well as from the health and welfare controllers (more robust, better pathogen resistance), but certainly also from the marketing and sales system (functional food genes, sustainability criteria, quality labels). Selection or developments of such source material is of utmost importance and will require new knowledge and know-how in the field of genetics and systems biology. Secondly, the production process itself can be positively influenced by developing optimal production systems that minimize waste emissions and reduce production losses due to external sources such as weather, pests and diseases. This can be achieved through innovative solutions developed by specialized knowledge centers in close collaboration with biotech and pharma.

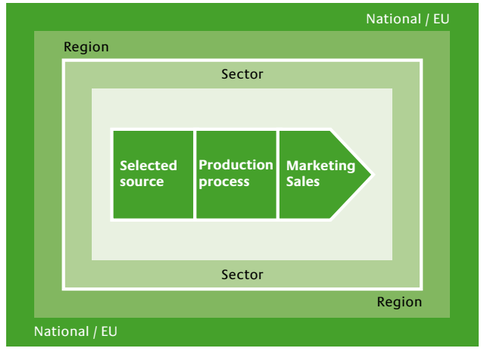


Figure 2: Food production supply chain with its stakeholder environment

> “In 2020 the “One Health” concept, recognizing the (two-way) continuum of communicable diseases between humans and animals, is accepted in its importance and realized in practice.”
>
> **Anton Pijpers, Dean Utrecht University**

Priority: Animal health
Animal health is central to global health and will therefore be a major priority for the agricultural life sciences. The spread of infectious diseases is of global concern and needs to be tackled using a contingency plan that applies modern technology in decision-making and control tools. The integral effects of human activities on the planet are continuously changing ecosystems and disease risk management on a global scale. International technology platforms (ETPGAH and DISCONTOOLS) set the stage for developing the basic tools to improve efficacy of vaccines and the new generations of antimicrobials. Together with the results of improved breeding of robust animals, industry has what it needs to integrate this into the next era of animal (and public) health control. Public-private partnerships are at the foundations of such complex integrations.

Priority: Biorefinery
In the future, agriculture will expand far beyond its current core function: the production of healthy food. Sooner or later, shortages of fossil resources will demand the use of biomass as an alternative source of many compounds now produced via the petrochemical industry. Contrary to this negative driver, however, are the large opportunities which biomass offers. Plants synthesize an enormous diversity of compounds that may be used creatively for a myriad of applications. Plants can be bred to produce specialty compounds or to be more appropriate for particular processing technologies. Using biomass as a resource will open new avenues for the production of all kinds of materials. Advanced biorefinery technologies will allow the separation of valuable compounds and enable the multiple use of biomass. The same batch may be fractionated to obtain specialized compounds for pharmacy, for food or feed (proteins), for clothing (fibers) and more. Optimized source materials and production processes will be essential for effective processing further down the production chain, and through this approach, the agricultural life sciences will merge with the white life sciences to capitalize on the new challenges of the bio-based economy.

Priority: Systems biology and the “$1000 genome”
Putting the life sciences to work calls for a combination of disciplines at various aggregation levels (Figure 3). The developments in genomics and related technologies opens new avenues for data collecting that need to be connected to biological characteristics to reveal their complete meanings. The realization of the $1000 genome will open up new roads for crop and breed improvement and must be fully exploited for maximum impact in areas such as biodiversity screening/monitoring, sequence-based breeding and biomarker generation. Systems biology is a new and rapidly developing scientific area that seeks to do so. Mathematics and statistics, modeling and information technologies are key to this development. Systems biology will help predict and explain the functioning of agricultural systems based on all available information. This will enable agronomists, breeders, molecular biologists, veterinarians and ecologists to predict the behavior of such systems and choose whatever intervention may be deemed necessary.

The agricultural life sciences needs to follow this path to profit fully from the scientific potential and assist the search for solutions to global challenges. This will help the switch from a curative to a more predictive agriculture and animal health strategy. The results of these complex analyses should form the basis for stronger interaction within the natural sciences in order to predict social impact of the underlying technologies.

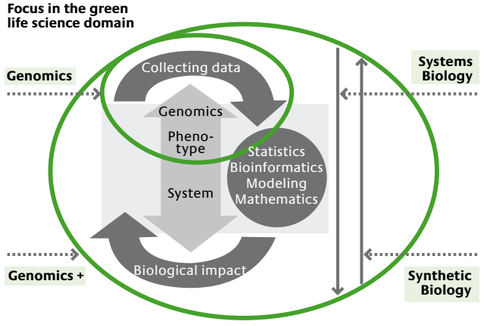


Figure 3: Interacting disciplines and aggregation levels in the agricultural life sciences

Priority: Micro- and nanotechnologies

The application of genomics to investigate important traits in animals and plants will, first and foremost, generate molecular indicators (biomarkers). These indicators can be employed as tools to assist decision-making in the production chain concerning new applications, treatments or destinations (including the destination of biologically active molecules in the body after delivery). As such, these indicators will be essential tools in optimizing quality and sustainability traits. However, this implementation depends on the availability of fast, reliable (and high throughput) detection and monitoring instruments that can be used both in the form of R&D equipment and as detection and monitoring instruments in the production and processing chains. The development of such systems, based on "lab-on-a-chip" technologies, is currently being pursued in the field of micro- and nanotechnology, thanks to the exceptional functional advantages of miniaturization.

Priority: Public-private partnerships

The Dutch agricultural sector is characterized by innovation. Being a forerunner of new developments has been the basis for success and will be the challenge for the future. For both piecemeal and system-based innovations, all relevant stakeholders need to join forces. Science and industry need to collaborate to produce the right answers to the important questions raised, preferably in an open innovation context. The profit-driven industry, however, needs additional incentives to address specific low-profit issues. Politics may help by creating regulatory facilities for emergency problems.

In 2020, public-private partnerships are characterized by open innovation platforms based on actual investment and risk-sharing between large companies, small innovative start-ups and research organizations. Large companies will use the PPPs to explore candidate pipeline products and thus consolidate or improve their economic value. The small companies will benefit by expanding specific technology that will enable them to collaborate or merge with the larger established companies. Involvement of social parties is necessary to guide the innovations. A socially non-acceptable innovation is no innovation at all.

Public-private partnerships must continue to provide the opportunity to bring complementary groups (even from different sectors of science and industry) together to work on key innovative precompetitive topics with two primary goals – feed knowledge into industry, fully (pre-)tailored to current and future needs, and feed manpower into industry, fully trained to meet current and especially future needs. Key to success are excellence, multidisciplinary collaboration and critical mass.

Public-private partnerships may be national, but will increasingly have an international character. The philosophy of open innovation is that all parties profit from access to knowledge from other parties. Consequently, the effect of open innovation will be larger when more parties are involved. In addition, public interests often reach beyond national borders. Global issues like climate change, food security or animal health call for international approaches. In fact, the framework programs of the European Union act as forerunners of international public-private partnerships.

In 2020, the public-private partnerships need to learn from each other to a higher extent than they do today. Interaction at the managerial level must be encouraged and facilitated. Whether this requires a central governing board is open for discussion. The Netherlands Genomics Initiative has shown that the partnerships under it benefit from central governance and have resulted in giving genomics in the Netherlands a visible place on the world stage.

Public-private partnerships are characterized by investments by all partners. Public and private parties alike are required to contribute, in whatever form (knowledge, materials, cash, expertise) to the partnerships. However, this only works if all parties are also rewarded. In this way, the stakes are balanced and the co-innovation is shaped. Success tends to be restricted by the limited resources of the public partners like universities and research institutes. A sound knowledge infrastructure, based on core-financing, is therefore necessary for flourishing public-private partnerships.

A number of successful PPPs have already gained a dominant position in the Dutch agricultural life sciences. Examples of such initiatives are given in boxes throughout this chapter.

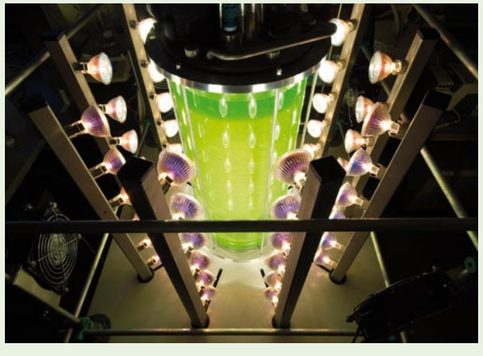
Priority: Impact on society

Consumers must be heard. Society must be involved in shaping social context and in avoiding technical solutions that do not fit social demands. Policy must be involved to frame research within national and international challenges and to monitor and implement relevant scientific breakthroughs wherever applicable. Directed education is needed to raise a new generation of employees experienced in the new innovative technologies.

Animal welfare, animal experimentation, sustainability, genetic modification of living plants and animals and their benefits for society are subjects of public decision making and need to be addressed well in advance. Society cares about animal health, and the culling of animals in cases of disease outbreak is no longer acceptable. Much of this debate can be solved by providing the technological evidence for safety and efficacy, but since risk assessment is often part of the debate, other disciplines such as ethics, anthropologists and sociologists should participate in this discussion. Policy needs to be continually aware of public choice.

> "PPPs perfectly suit the Dutch way of working, they are the ever best investment in our innovation driven economy. Abroad, they envy us..."
>
> **Antoon van den Berg, CEO Hendrix-Genetics**

Flourishing public-private partnerships: Towards BioSolar Cells



A new, EUR 40 m initiative is a PPP especially targeted to exploring and exploiting photosynthesis. Both higher plant production and new sources for sustainable energy have a common denominator: photosynthesis. It is a major limiting factor in plant production, since only 1-2% of the solar energy that reaches a plant leaf is converted into biomass. Improving the energy harvesting efficiency of organisms will have an enormous effect on biomass production, benefitting food, feedstock and energy supply. Even more challenging is designing systems that allow photosynthetic energy-tapping before the energy is converted into biomass. A thorough understanding of photosynthesis, its hierarchical organization and its underlying mechanisms are essential for capitalizing on these approaches.

To accomplish this goal, a consortium of six Dutch universities, 30 partners from industry, social partners and the Netherlands Organization for Scientific Research (NWO) has formed. This consortium is facilitated by the Dutch government, particularly the Ministry of LNV.

Flourishing public-private partnerships: Technological Top Institute Green Genetics.

TTI Green Genetics is a EUR 40 m collaboration between research institutes and industry. The central theme is “Innovative plants for sustainable Flowers & Food”. The research will enable breeders and growers to use the full genetic potential of plants for optimal and sustainable growth under existing and new production systems. Research topics are demand-driven and prioritized by the industrial partners. Research is carried out by selected plant sciences research groups in close collaboration with industrial partners.

Through the implementation of strategic research projects, TTI Green Genetics helps to position the Dutch plant science research infrastructure as one of the top players in the world. Its main focus is to strengthen research, education and capacity building in the plant sciences disciplines physiology, genetics and pathology.

In total, 93 companies and seven knowledge institutes participate. This intensive collaboration between industry and academia has already identified plant traits that are now being commercialized, for instance through Plant Breeding Rights. In the coming years, it is expected that the focus of TTI Green Genetics will shift from exploring plant genetics, to exploiting plant genetics. Therefore the new focus will be on comparative biology, phenotyping and linking genetic and phenotypic data to predict the performance of plants.

Flourishing public-private partnerships: The Centre for BioSystems Genomics

CBSG was initiated in 2003 under the auspices of the Netherlands Genomics Initiative as the Centre of Excellence in plant genomics. The partnership comprises 7 knowledge centres and 15 industrial partners. The applied research programme (ca 100M€ / 10 years) has a strong focus on the two most important Dutch vegetable crops – potato and tomato – for which Dutch industry is also leading the world in terms of market share and crop improvement for both consumer and environmental quality traits. Improving resistance to potato late blight and the taste of fresh tomatoes are two key targets for which great progress has already been made and for which results and new plant materials have already gone out to the industrial partners for implementation in their own improvement programmes.

CBSG is committed to facilitating Dutch industry to move to the next level regarding the exploitation and implementation of state of the art genomics technologies as a means to answer sustainability and social issues on crop production. While forming the focal point, CBSG is also used to act as a major research multiplier through initiating many additional bilateral, multi-lateral and international PP research initiatives to a value exceeding 150M€, thus maintaining Dutch research and industry, centre stage.

E. Recommendations

1. **A strong knowledge infrastructure** must form the basis for prolonged investments by industry and decision-making governmental institutions. Continuity in finance and facilitating the corporate intelligence of the Dutch knowledge system is thus essential in shaping the technological future and the impact of the agricultural life sciences, both to the Dutch economy and society as a whole. The policy should choose for quality of the research by investing in topics (and groups) that achieve global excellence. This will fortify our strengths and attract industry to join.

2. **Focus and mass** are necessary, and therefore choices need to be made for the following priorities:
   - A healthy society based on secure, safe and sustainable water and food supply in association with sufficient strategies for prevention of diseases;
   - Biomass production tailored to a bio-based economy. Focus needs to be on the multiuse of biomass and on high-value applications;
   - A "One Health" approach, central to animal and environmental health, is the basis for human health and well-being and requires investment.

   Two technological approaches are needed to develop the priorities:
   - Systems biology will enable the interpretation and use of the enormous flow of genomic data. New high-throughput technologies will further increase the generation of data in the near future, thus challenging the biological interpretation to keep pace;
   - Micro- and nanotechnologies are needed to develop devices for monitoring production processes, detection and monitoring of pathogens (early warning systems), and for individualized health.

3. **Public-private partnerships** are needed to accomplish all of the above, and should be encouraged. All stakeholders need to benefit from them. Science has to be rewarded for IP generation, and industry will only be driven by profitability. Policy needs to create incentives for industry investment, and society must benefit from these investments.

4. **Acceptance and sustainability** of new technologies are pivotal. Social impact of technological solutions must not be overlooked. Stronger collaboration between natural and social sciences are essential to ensuring the right choices are made for the future. Sustainability is the overarching objective and needs to be accomplished by integrating social demands, technological solutions and opportunities, including economic benefit for all stakeholders.

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Examples of solutions
As examples, the following issues and solutions fit the agricultural life sciences vision and recommendations.

- Varieties and breeds of plants and animals, optimized for maximum performance with a minimal ecological footprint
- Animal health tuned into the prevention of notifiable and human-threatening diseases (e.g. Newcastle Disease, Crimean Congo Fever, Rift Valley Fever, MRSA, Influenza)
- Plant health that reduces the need for pesticides in crop production systems
- Controlling transmission of diseases as the result of complex interactions of individual susceptibility, environmental factors and herd immunity
- Robust diagnostic assays, thus reducing the number of animals to be sampled
- Health and performance checks at the individual and population levels (allowing early warning and control)
- Introduction of functional feed and foods to assist in general health perception of animals and humans
- Identification of the origins of animals and plants or their derived products (quality assurance)
- Resilient agricultural ecosystems, reducing production risks for farmers and enabling adaptation to climate change
- Intestinal health as a result of interaction of the animal with its environment (micro and macro)
- Better prediction of response of a biological system (plant/animal) to changes in environment, treatments, etc.
- Precision farming
- Crops tailored to the biorefinery and bio-based economy
- Possibility for social (gamma) sciences to apply risk assessment in predicting the impact of life sciences induced changes
- Sustainable farming

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