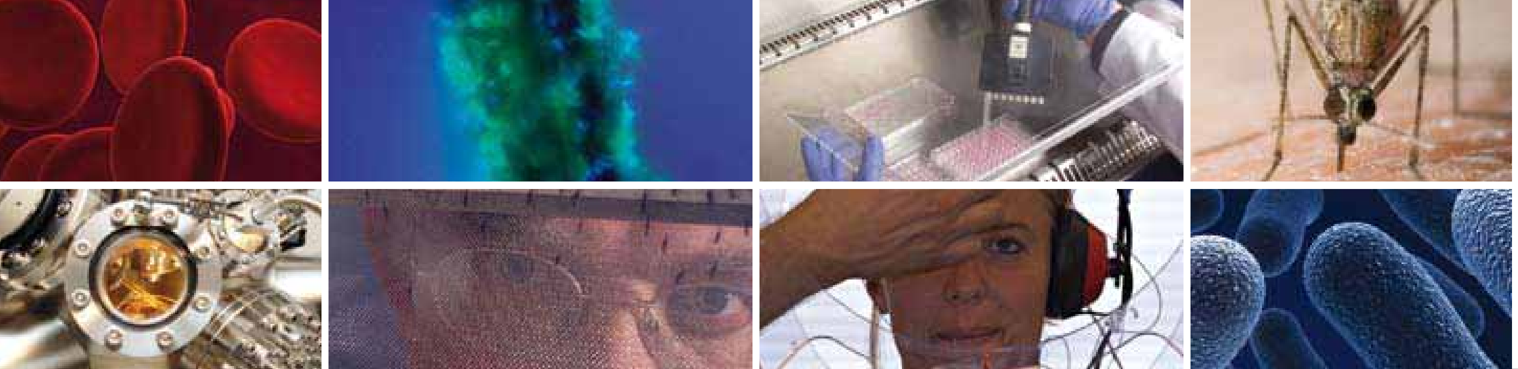

90 years Wageningen University

Science for Impact

ON SCIENCE, SOCIETY AND BUSINESS

WAGENINGEN UR
For quality of life

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Editors

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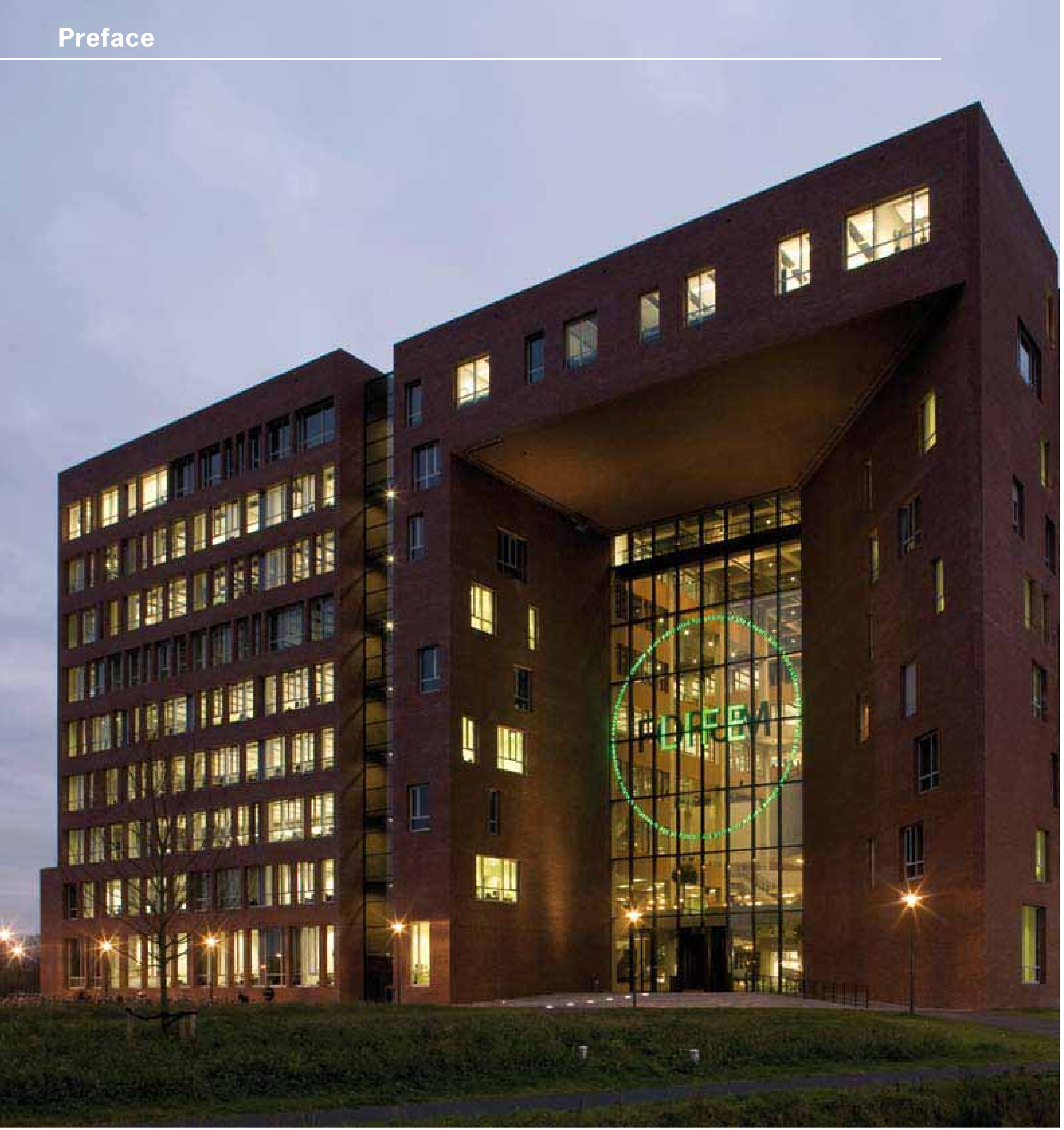


Forum, Wageningen Campus

Gerda Verburg,
Minister of Agriculture, Nature and Food Quality

In the wake of the agricultural crisis of 1886, the Dutch Government decided to invest in training and the development of expertise to withstand the crisis. Now, 122 years further, we are celebrating the 90th anniversary of Wageningen University. As the examples in this volume demonstrate, its respectable age does not deter the University from energetically addressing the issues today.

We see that in Wageningen, both the scientific dynamic and the social dynamic are driving forces behind developments in science and technology. The need to combine education, science, society and practice is a century-old and continuing challenge to the knowledge system.

The University has managed to achieve the right mix: on the one hand research, driven by curiosity, to unravel the secrets of life and nature, and on the other, accessible, applied knowledge to deal with social issues and practical problems.

And all this is done in the typical 'Wageningen' way: not wandering, blinkered, in a single field, but looking beyond the barriers and taking an interdisciplinary approach to research. Perhaps it is this integrated approach which has made Wageningen such a successful player in national and international research consortia.

It is probably also the reason why Wageningen research is so often consulted within the walls of the Ministry of Agriculture, Nature and Food Quality. After all, the University's mission 'To explore the potential of nature to improve the quality of life' comes very close to what my Ministry sees as its motto: living off the land, caring for nature. Our focus is sufficient, healthy food, clean production, innovation, sustainability, animal welfare and a solid economic base for agriculture and horticulture.

Wageningen is extremely active in these fields, as you can see from the examples in this collection. There can be no doubt that University and the Ministry will continue to cross paths frequently over the next 90 years. Personally, I look forward to every meeting.

Gerda Verburg
Minister of Agriculture, Nature and Food Quality

90 YEARS OF SCIENCE FOR IMPACT

ON SCIENCE, SOCIETY AND BUSINESS


Professor Martin J. Kropff, Rector Magnificus

Our world has changed dramatically over the past 90 years as a result of the huge increase in the world population and industrial, green, technological and information revolutions. Nine decades ago, food security was a global issue despite the relatively small world population. This situation gradually changed, and by the late 1990s a food surplus existed in the developed world. Food security was, and still is, an issue for hundreds of millions in the south, however.

At the same time, environmental issues increasingly commanded our attention in the latter decades of the 20th century. Today's major issues include safe and healthy food and food security, pressure on the environment, climate change, energy supply and options for bio-energy, water quality and supply, disease and conflict situations. A number of these issues are addressed in the Millennium Development Goals of the UN.

Most of these topics are central to our domain in Wageningen. Science can help to identify issues, understand the background, design solutions and evaluate the impact of potential solutions on society. The impact of the subjects listed above is such that scientists must take responsibility for how they approach their work and the way they present facts and insights.

Wageningen Campus

Wageningen UR as an institution
The story of Wageningen University and Research Centre (Wageningen UR) began with the founding of the Agricultural College in 1918. In 1986, the college received university status and became Wageningen Agricultural University. Eleven years later, the university merged with the Dutch Agricultural Research Institutes (DLO) to create Wageningen UR.

Wageningen scientists have therefore influenced agricultural research on a national and global level for 90 years. Today, food and health, environmental sciences, human consumption, biotechnology, genomics, geographic information systems, microbiology and nanotechnology are also identified with the Wageningen UR research agenda. Our research and education agenda is defined as an interactive process between science and society.

Wageningen UR now has five Sciences Groups: Social Sciences, Animal Sciences, Environmental Sciences, Agrotechnology & Food Sciences, and Plant Sciences. Each facilitates our fundamental, strategic and applied research and the available education programmes. In 2004, the Van Hall Larenstein University of Professional Education became part of Wageningen UR.

Wageningen UR: mission and domain
Wageningen UR is an internationally leading research and education institute in Life Sciences. Our research focuses on the domain of healthy food and living environment, translated in the Wageningen UR mission statement as: ‘to explore the potential of nature to improve the quality of life’.

The research and education domain of Wageningen UR is illustrated in the figure on page 9. Historically, our emphasis has been on the themes found in the two circles at the base of the figure: food and food production and living environment. While studying a broad variety of issues in these areas, Wageningen scientists gradually incorporated health, lifestyle and livelihood into the scope of their approach and the relation between the two original core areas. This was a logical and essential development considering our responsibilities towards society. The domain of Wageningen UR now consists of three rather than two interconnected core areas:
food and food production, living environment and health, lifestyle and livelihood.

THE DOMAINS OF WAGENINGEN UR

Food and food production
This area includes all aspects of the production and supply side in the food chain. From genes, plants and animals, varieties/breeds, to sustainable agriculture, horticulture, fisheries and aquaculture, international food chains and networks, health aspects of food and nutrition and the use of biomass within the scope of a bio-based economy.

Living environment
Nature, landscape, land usage, water and sea/ocean management, and the various competing claims on space, in terms of global issues such as 'food or fuel' and in local issues such as urban recreational areas. This also includes biodiversity and the sustainability of resource management and production.

Health, lifestyle and livelihood
The influence of people: the behaviour of individuals, communities or societies, and their choices regarding health, food and living environment. The behaviour of consumers, citizens or recreational participants, the attitude towards risk and uncertainty, the perception of quality and safety, and the relationship between food security and safety and poverty, particularly in developing countries.

The orientation towards – and the definition of – a domain as a realm for the activities of Wageningen UR enables us to achieve both the required focus and the necessary critical mass to make a difference as a scientific organisation. This focus makes it clear to stakeholders what they can expect from Wageningen UR research and education. At the same time, staff and faculty are able to identify new stakeholders and explore global trends within our domain. It helps define a challenging and state-of-the-art research agenda and stimulates a top research network with national and international partners that can contribute to it.

The Wageningen Approach: research
At the beginning of the 20th century, science developed quickly and focused on disciplinary developments with a reductionist approach. In this approach systems were unravelled into parts and processes that were studied individually. Insights into systems became more and more detailed at smaller scales of time and space.

This disciplinary focus contributed strongly to scientific progress and numerous (technological) inventions. The second half of the last century saw an exceptional increase in both agricultural productivity and resource use efficiency.

THE WAGENINGEN APPROACH

Scientists unravelled the complete DNA code of organisms such as the Arabidopsis (a model plant for geneticists, see chapter 14), and animal species like the chicken. Knowledge about genes and their function is being used in plant and animal breeding. Various chapters of this book offer examples of this type of research and its applications. We have made a selection from the many fundamental studies of chemical and biological processes, and how scientific insights in these areas are transferred into applications.

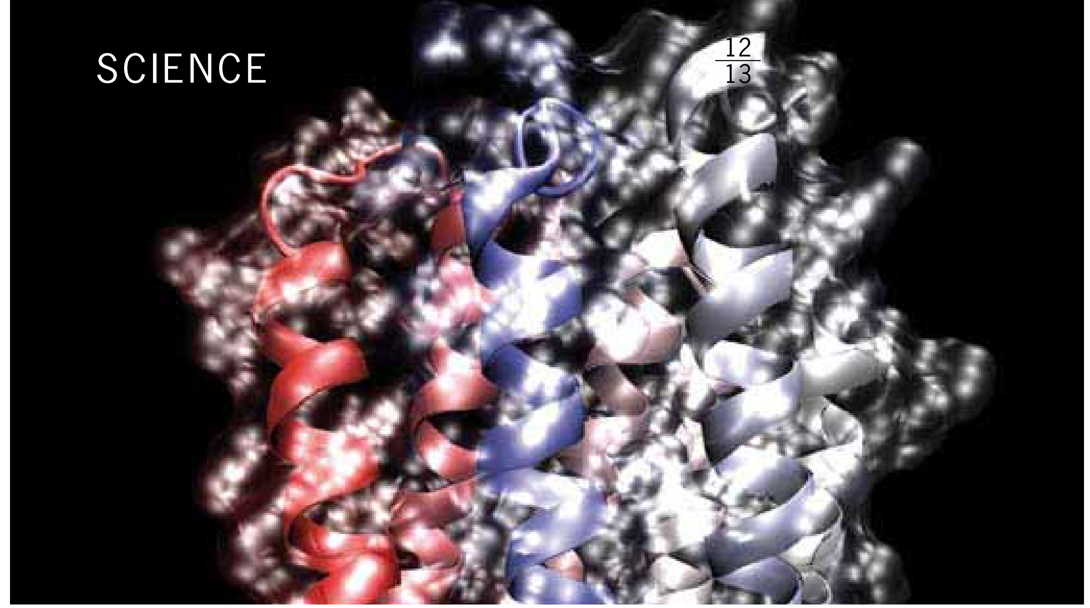
Disciplinary studies continue to provide valuable new scientific insights. The reductionist approach led to enhanced understanding of system behaviour by analysing the relevant processes, such as the different aspects of crop growth in an ecosystem. Reconstructing these processes into a system only became possible with the advent of computers, and simulation models could then be used to process the quantities of available data. In the 1960s, C.T. de Wit (see chapter 12) started an international move towards the use of models that led to the integration of a multitude of scientific disciplines, such as meteorology, plant physiology, soil science and plant protection. In turn, this resulted in models that could integrate biological, chemical and physical knowledge.

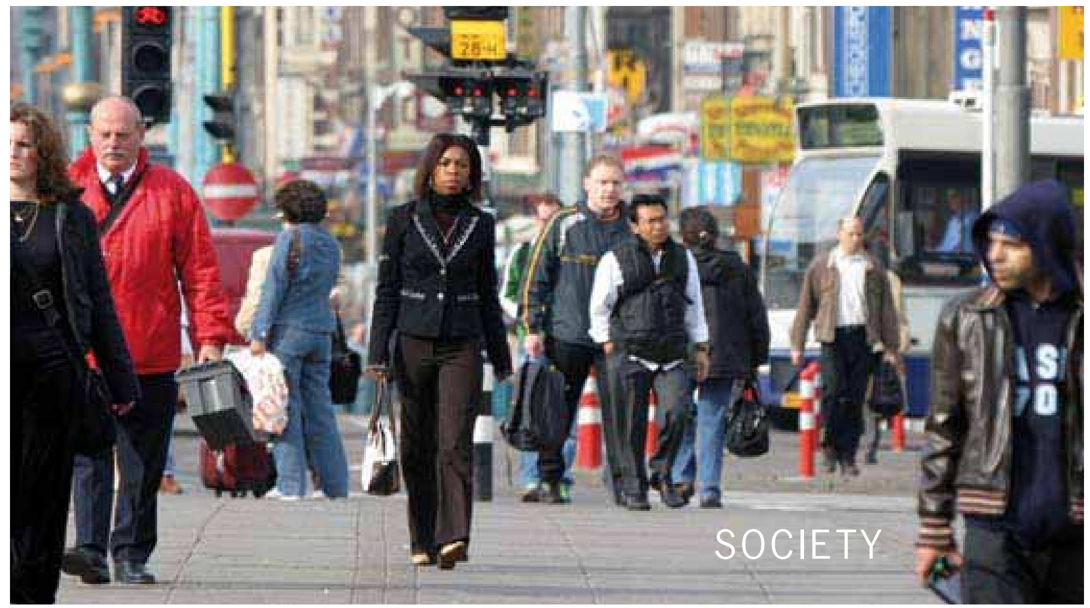
The complexity of societal issues and the fact that social, economic, cultural and technological developments intertwine, demands an even broader perspective (see chapter 16, for example). This implies striving for a closer interaction between natural sciences and social sciences. Such a broad view and interdisciplinary approach towards science is characteristic of the Wageningen UR approach.

The diagram on page 11 illustrates our approach. On the left vertical axis, the different levels of integration in biological systems are illustrated from gene to cell to organism to ecosystem to the planet. On the right, the different levels in the social system are illustrated from individual to household to community to society. Disciplinary science deepens our scientific insight at all these levels.

At Wageningen UR we have expertise groups at all these levels of biological and social systems. What's more, our scientists know how to scale up and down between these levels. This means that they try to understand system behaviour at the ecosystem level, based on knowledge of underlying levels such as individual organisms (e.g. crop models) and so on.

The diagram also shows the relation and interaction between the realms of natural sciences and social sciences. The technologies to produce food and





non-food products from plants and animals link them to consumers. Consumer wishes function as feedback, indicating for instance which specific product qualities are required (e.g. taste or health aspects, see chapter 5). Plant and animal breeders who work on the genomics of organisms use this feedback in their research. The upper horizontal line connects society with the ecosystems, indicating the impact of society and its interacting institutions on our environment. Policies and governance play a major role in those processes.

To play a role in resolving issues such as climate change and its impact, it is obvious that scientific expertise at the different scales in both systems is required. It is equally important that we have the tools for scaling up and down within both systems. A good example is provided in chapter 11, which elaborates on the complex issues related to climate change.

The Wageningen Approach: education

A key responsibility for Wageningen UR is to educate and guide young people in their academic and professional development and to provide lifelong learning opportunities. Our education programmes focus on many of the main issues that are on our society's agenda, such as the Millennium Development Goals or food safety and health. This has attracted generations of national and international students to Wageningen UR. Today, over 30 percent of the students in our Master's programmes are from outside the Netherlands, and more than 50 percent of the 1,100 PhD candidates conducting their research at Wageningen University are not Dutch. With this international orientation, intercultural and international networks are part of the daily life at Wageningen UR.

The Wageningen approach is embedded in our education programmes. This means that our students are trained to be able to place an issue under study within a broader context of science and society. It helps students to evaluate various solution strategies for societal issues in interaction with stakeholders and colleagues from other professional and scientific domains and other cultures. It enables them to combine in-depth professional and scientific training with a broad vision and communication skills. The Wageningen approach will continue to be a challenging and inspiring concept for generations to come.

Today, Wageningen UR's academic (Wageningen University) and professional education programmes (Van Hall Larenstein University of Professional Education) are interlinked. They prepare our students for a future career with different combinations of competencies: knowledge, skills and attitude.

The Wageningen Approach: co-innovation

The Wageningen approach is more than a mere joining of scientific forces from different areas of expertise. Its strength is to combine in-depth scientific expertise and professional skills with a broad understanding of the wider context of any issue under study. In addition to allowing Wageningen scientists to integrate their work with other scientific disciplines, this also places research in a societal context. Technology alone cannot gain societal acceptance for research results or solutions to problems: socio-cultural and socio-economic aspects must be and are taken into consideration. In other words, we look at the big picture and continuously seek out potential contributions from sometimes unexpected scientific domains when starting a search for answers.

We call this concept co-innovation – striving for interaction between science and society. This interaction leads to defining the scope of the issues that need to be resolved. And it is this interaction that formulates research agendas. The co-innovation concept facilitates joint participation in public-private research projects. In other words, innovation processes are a joint activity of all stakeholders.

In business, entrepreneurs take the lead in the process and science contributes to the process by analysing and designing. This can be illustrated with the development of new varieties or new food processing technologies, or new bioprocess technologies to clean wastewater (see chapters 5 and 3 respectively).

The role of science in policy-making processes is even more complex. The different phases in a policy cycle (signalling, design, decision, implementation and evaluation) are long term joint learning processes. This requires an ongoing cooperation and interaction between stakeholders and scientists (see for example chapters 10 and 11).

Many generations of Wageningen researchers, teachers, students and alumni have made and continue to make significant contributions to co-innovative processes, for example in the development of the food business or resolving environmental issues. This impact can be witnessed not only in the Netherlands but all over the world. It has helped to shape the Netherlands into a leading nation with respect to innovation in the food sector (e.g. cattle, seed industry) and environmental protection and nature conservation in a densely-populated, highly-industrialised country. As a result, the Netherlands ranks second worldwide in the export of agricultural products.

The fact that Wageningen UR is internationally renowned for its outstanding and cutting edge research and education means we can justifiably claim the Science for Impact credo. Within this context Wageningen UR collaborates with universities and knowledge institutions in and outside Europe and the doors of our education programmes will always be wide open to students from all nationalities.

OUR DOMAIN: HEALTHY FOOD AND LIVING ENVIRONMENT

The research, education and innovation domain of Wageningen UR consists of three areas:

- Health, Lifestyle and Livelihood
- Food and Food Production
- Living Environment

These core areas are strongly related to each other (see figure below). Our research programmes are relevant for one or more area's in the domain of healthy food and living environment. At the first page of each chapter in this book, the related core area's of the research programs are highlighted in a small version of the figure.

health, lifestyle and livelihood

food and food production

living environment

Flatscreen television

DESIGNING THE MINIATURE

Wageningen scientists were experts at bionanotechnology when it was still called colloid chemistry. Even before that era, however, people were playing with these particles that measure a mere one-millionth of a centimetre. Paint consists of minuscule (yet multimolecular) particles, as does coffee. So humans have actually been nanotechnologists for centuries, and it is only relatively recently that it has been considered as a discipline in its own right.

The Laboratory of Physical Chemistry and Colloid Science at Wageningen University achieved global renown among fellow physicists at the start of the 1980s when two of its scientists formulated the Scheutjens-Fleer theory. 'This theory describes the behaviour of long, wiry molecules that float around in billions of different shapes in solutions,' explains Professor Martien Cohen Stuart. 'It explains in detail how molecules respond once they have attached themselves to a surface.'

The theory turned out to have more applications than was originally anticipated. Manufacturers of television and computer screens use it for example. Lined with fluorescent particles that light up, the quality of these screens depends on how precisely and orderly the makers can arrange the particles on the surface. To ensure that they do not clot, the particles are attracted to the surface of the screen while also repelling each other.

Unsurprisingly perhaps, one of the creators of the Scheutjens-Fleer theory, Professor Gerard Fleer, has since become a scientific consultant to Philips. The department has also been providing consultancy services to the leading photography brand Kodak.

A possible development is creating cell-like structures filled with medicine, which can travel through our body in search of cancer cells

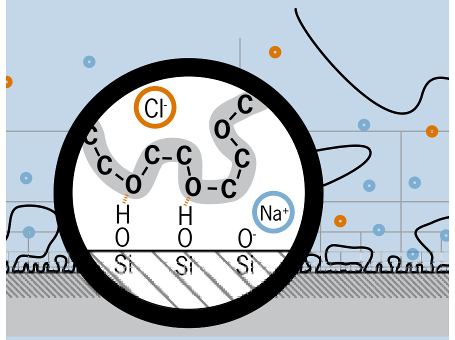
Meanwhile, the laboratory's research has continued to evolve since the 1980s. One spearhead is the behaviour of molecules that form new structures on their own accord, also called self assembly. The group studies, for example, how greasy phospholipids in a liquid form the same membranes that are found in human cells. This research may contribute to the development of cell-like structures filled with medicine, which can then travel through our body in search of cancer cells.

Scientists are also looking into the possibilities of moulding molecules at the nano level elsewhere within Wageningen University. In the laboratory of Professor Remko Boom of the Process Engineering group, for example, vegetable protein particles are being created that can meticulously imitate the structure of meat. 'We don't know what it tastes like yet,' admits Boom. 'But the point is that we can make artificial meat without animals. The food industry has failed to develop a genuine meat replacement that satisfies consumers. The fine fibre structure that gives meat its particular texture and juiciness has yet to be discovered in any product.'

Boom and his team now know how to mould molecules on such a small scale, however. Although the work is still at the laboratory stage, it is a promising start and the research suggests that designing molecules in this way will also impact

The SF-theory

Professor Gerard Fleer explains that the theory of Scheutjens-Fleer was initially the brainchild of his postgraduate student Jan Scheutjens: 'It was the first theory to provide an accurate description of the behaviour of chain molecules on interfaces,' he says. A solid bounded by a fluid is an interface, but so is the boundary between air and water. Scheutjens and Fleer were initially working on creating better purification processes for sewage water. When bacteria carry out this task they are removed from the sewage with a flocculation agent: material consisting of long, wiry molecules to which bacteria attach themselves. Once this occurs, the bacteria cluster, settle and can be removed. 'The first version of the theory described exactly how this occurs,' Fleer recalls. 'In later years our theory was '*expanded*' and applied to more complex systems of chain molecules.'



the food industry in other areas. For instance, scientists from Boom's group have successfully wrapped a variety of compounds in smart molecules, which release their content at a given time.

Nano equals healthy

'We can encapsulate the tiniest drops of artificial odours and tastes so that they are not damaged during the production process,' Boom says. 'In addition, we can make sure that they are released in the mouth at the right moment. We can do the same for healthy nutritional components.'

Boom and his colleagues are considering applications in areas such as probiotics, the healthy bacteria in the intestines which appear to reduce the chance of illness. 'It is not easy to get bacteria to the right part of the body and ensure that, for instance, the organisms survive the gastric juices. This is one of the reasons why the food industry is so interested in the encapsulating technology emanating from Wageningen UR.'

While the nano-encapsulating technology is still under development, other nano-applications have already been used in foodstuffs. Food companies are manipulating molecules on a nano-scale to make sure that chocolate does not melt in the hand, or that bodies absorb the extra calcium in enriched dairy products.

General acceptance

The Market and Consumer Behaviour group investigates how people feel about the use of nanotechnology in the food industry. According to the researchers, studies by independent organisations into the safety of nano-applications will lead to an increase in consumer trust. This will also occur when scientists admit that they do not know everything about the risks of nanotechnology and continue to try and find the answers to any questions that may arise. Only then will consumers know that doubts about nanotechnology are being taken seriously.

'It is equally important that scientists and companies convince consumers of the added value of nano-applications,' says Lynn Frewer of the research group. 'Nanotechnology only has a chance when consumers feel not only that the new technology will benefit them but that it is also safe.'

Frozen plasma


XPS spectrometer

'One possible application of our research involves the regeneration of tissues in or outside the body'

Strangely, however, there has been little toxicological research into nano-applications. Toxicologists are mainly interested in whether bio-active substances can reach certain places in the human body by means of nanotechnology. A European research project into the possible risks of nanotechnological food applications performed by the Toxicology research group of Professor Ivonne Rietjens should provide more clarity on this subject. Trendwatchers believe that this type of research is essential if nanotechnology is to be accepted by consumers.

Blood plasma

Wageningen scientists are also working on medical applications of nanotechnology, for instance in the laboratory of Frits de Wolf at the Agrotechnology and Food Sciences Group. Working on an assignment for the Japanese company Fuji, De Wolf and his team have developed a simple but intelligent protein molecule for synthetic blood plasma.

'This blood plasma can be given to seriously injured people on the battlefield or in a hospital A&E department who have lost a lot of blood,' he says. 'In such situations the first priority is to administer fluids. Unfortunately, saline solutions only have a brief effect as the kidneys quickly discharge the fluid. Add our polymer and the speed at which the fluid leaves the body is reduced as the molecule retains the water.'

An immune response is not initiated as the molecule is recognised as being a part of the body. Enzymes can break down the molecule, which is one of many designer proteins De Wolf has made by adding new genes to the genome of yeast cells. 'What we are really creating are long strings of pieces from natural proteins or chains of proteins that we designed ourselves. We can also determine what shape the proteins will have – threads, spheres, or sheets'.

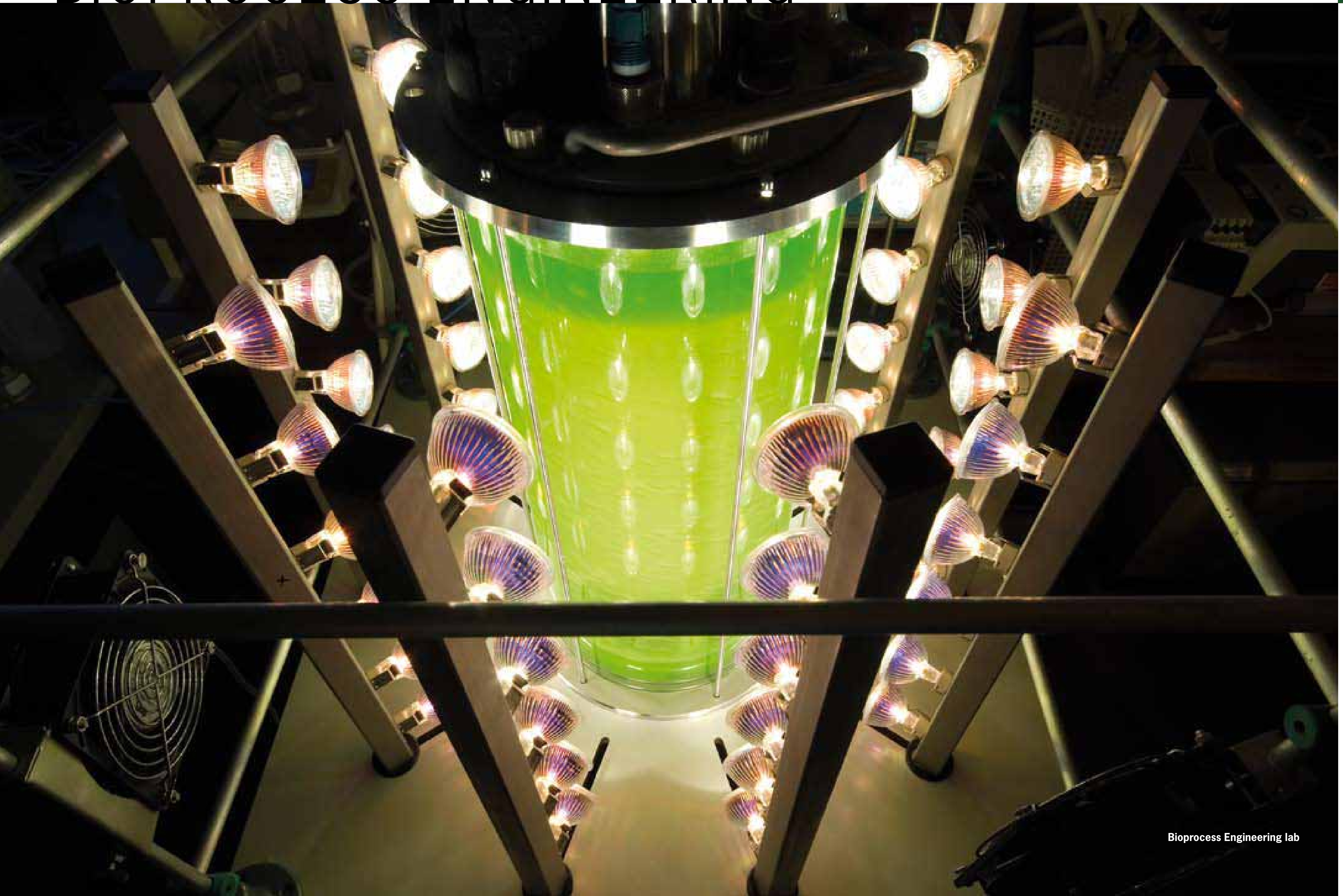
De Wolf's group uses the designer proteins in medical applications. 'One possibility involves the regeneration of tissues in or outside the body,' he continues. 'Perhaps we can make new skin cells grow on these proteins. Inside the body they could be used by doctors to speed up the healing of broken bones or damaged nerve tracks.'

De Wolf is keen to emphasise that there is still a long way to go: 'Although the interest is increasing, this technology is still in its infancy. We have much more work to do.'

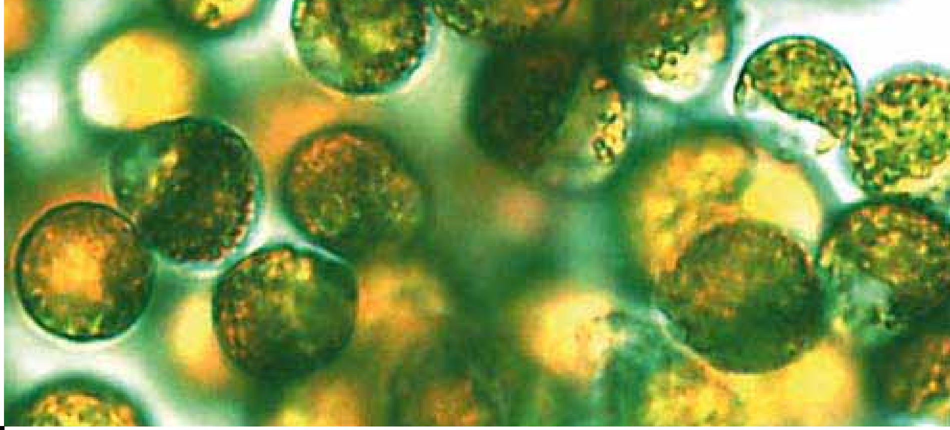
Upper right **Dunaliella algae**

Below right **Test set-up to study efficient conversion of sunlight into alagal biomass**

THE PIONEERS OF BIOPROCESS ENGINEERING



Bioprocess Engineering lab



Algae are interesting as ingredients in cosmetics and as a source of omega-3 fatty acids

The scientists of the Bioprocess Engineering group are growing fungi that can fight malaria mosquitoes, designing bioreactors for the cultivation of algae, and training sponge cells.

Some have hinted that there is a lack of focus in the research of Professor René Wijffels and his predecessor Hans Tramper's group. 'We do take these opinions seriously, but for us it is also a strategy,' Wijffels responds. 'Hans Tramper liked to take a pioneering approach and so do I.'

Tramper was, among other things, a pioneer in the field of animal cell cultivation. While process scientists had built up considerable experience in the cultivation of fungi and bacteria in reactor vessels by the late 1980s, animal cells remained tricky. Slightly over-enthusiastic stirring in a reactor vessel could cause vulnerable cells to die. 'Design guidelines for production processes were developed based on our research into animal cells and these were applied by companies such as the biotechnology firm Cetus,' explains Tramper.

Under Tramper's supervision, bioprocess engineers also developed calculation models for enzymatic reactions during the semi-synthetic production of antibiotics. These models helped predict how the process could achieve a higher output and are now used by DSM.

René Wijffels, the current Professor of Bioprocess Engineering, was one of Tramper's PhD students. As an environmental scientist, he started research into removing nitrogen from wastewater. After obtaining his PhD, Wijffels shifted his attention to unusual creatures (at least for process scientists): sponges and corals. 'At the beginning we thought it would be an easy task but this was definitely not the case in practice.'

Sponges are interesting organisms for the pharmaceutical industry because they make substances that are not present in plants or animals. Pharmacists see the sponges as a potential goldmine for cancer cures and other medications. 'We thought that sponge cells would be easy to cultivate,' Wijffels continues. 'As they grow under very difficult conditions in nature, we expected we could manage in a medium. The results were disappointing.'

About a decade on, Wijffels hopes that he has found the solution. 'It seems that cells in a sponge divide really quickly, as shown by a sponge that we fished out of the ocean near Spain. In our aquarium, the current came from the other side and within a few days the sponge had reconstructed its internal tube system so that the inflow opening was on the right side again. We have also seen evidence of sponges' remarkable healing capabilities in the oceans. Cut a piece off and it will be repaired in no time at all.'

Seeing that the problem was not the speed at which cells divide, Wijffels now thinks that the issue is how fast they die. Sponge cells grow quickly and die just as easily. Although some human cells can last a lifetime, a few weeks is a relatively respectable age for sponge cells. 'We have now decided to work on cell lines in which the gene playing an important part in cell death is deactivated. The research is being carried out in cooperation with the Microbiology group and the Harbor Branch Oceanographic Institution in the USA, and we plan to do more product discovery in cooperation with the Wageningen UR Biochemistry group.'

The Wageningen technologists are not the only ones seeking the chemical treasures of sponges. 'There are other groups outside Wageningen UR trying in different ways,' Wijffels reveals. 'One of them is trying to get the bacteria that grow in sponges to grow individually and hopes to find valuable chemicals in the process. Other scientists believe that these substances could be manufactured via the genetic modification of bacteria. It is important that all these research roads are travelled. The bioactive substances in sponges have such an extremely complex structure that chemical reproduction is impossible.'

Above **Algae are used as a cosmetics ingredient**

Below **Scientists are working on developing bio-diesel made from algae.**

'Our goal is to make the production of biodiesel from micro-algae economically viable'

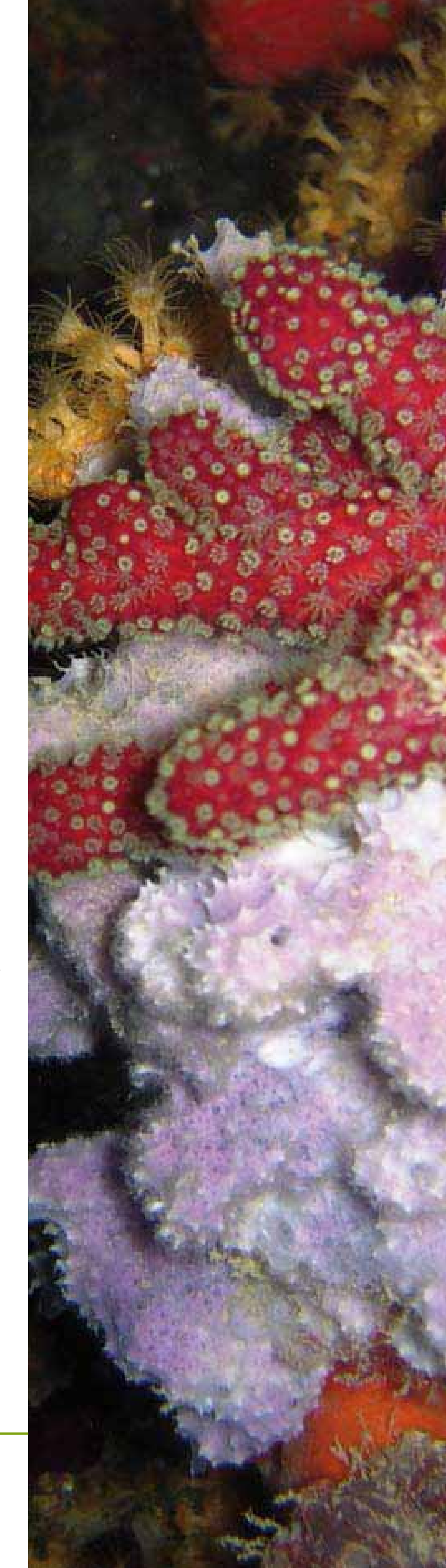
In addition to sponges, another promising subject currently occupying Wijffels is micro-algae. His group has developed special reactors to cultivate these algae and make valuable products. 'For example, we developed a process which we call 'milking the algae'. This involves the production of ß-carotene, an anti-oxidant and pro-vitamin A that is used as an additive in foodstuffs. Some algae produce ß-carotene under stress. In the process that we developed, the substance is harvested with organic solvents without damaging the cells. The cells stay alive after extraction and can produce more carotene. The process is currently being further developed in Germany by Cognis, a major supplier of food additives.'

Algae are interesting as an ingredient in cosmetics, fish feed and as a source of omega-3 fatty acids. The latter can also be found in fish and seems likely to have beneficial effects on the heart and vascular system. Meanwhile, a new application was introduced last year in response to rising energy prices: the algae as oil source. 'Some algae varieties store up to 40 percent of their body weight in oil in their cells,' Wijffels explains. 'These algae could be an excellent source of oil.' The yield of one hectare of algae cultivation could be up to six times higher than a hectare of crops. Moreover, the algae would need hardly any fertiliser as the nutrients from one generation of algae could be reused for the next.

'The fun thing is that new problems arise for us as process scientists,' Wijffels continues. 'We are used to making expensive products without needing to think about issues such as the energy costs of a process. If we want to create energy with algae, every euro will count. We have already been contacted by several companies interested in the possibilities, and plan to develop the technology at the Technological Top Institute Water Technology Wetsus in cooperation with several companies.'

'Our goal is to make the production of biodiesel from micro-algae economically viable. Using the current state of the art, the oil would end up costing four times the price of natural oil. Although this is obviously too expensive, the difference isn't so large that we need to give up. We believe that our research can bridge the financial gap. There are many scientific challenges in this field and Wageningen UR can play a vital part, both by developing technologies as well as improving the algae used, by selecting varieties that will produce a higher yield, or by genetically modifying the algae.'

Dysidea sponges



SEWAGE FOR ENERGY

Wageningen's world-renowned water treatment research can best be described as a search for technology based on natural processes. A remarkable feature of this work is the move towards increasingly compact, decentralised installations. Water treatment now generates power rather than just consuming it.

Purification plant for water

In the Middle Ages, city residents simply threw their faeces out of the window. Later, special sanitary landfills were reserved outside the cities for primitive settling and decomposition of manure in the soil. These sewage fields became separate ditches in which the primary scientific research, including that of the Wageningen Agricultural College, was performed. By the time the modern sewers had been laid in the 1950s and 1960s, the waste flowed out to large basins. In these installations, the urban wastewater is purified by means of bacteria and oxygen. After the removal of organic pollution, the water can be drained off in accordance with current regulations.

There is another side to the story, however. The intensive aeration consumes lots of energy and the method results in truckloads of sludge. Initially, the simple solution was to sell this sludge to farmers as manure. The technology is robust and in the 1970s helped to drastically improve the quality of surface water. Soon each city was constructing sewage treatment plants.

'We carried out a great deal of research into this area,' Professor Wim Rulkens of the Environmental Technology department remembers. 'But the increasingly stringent environmental regulations mean the work continues apace. The removal of phosphate and nitrogen fertilisers is an especially expensive issue. And stricter European regulations mean we will experience problems in Dutch urban areas due to the remains of medications and hormonal residues in wastewater.'

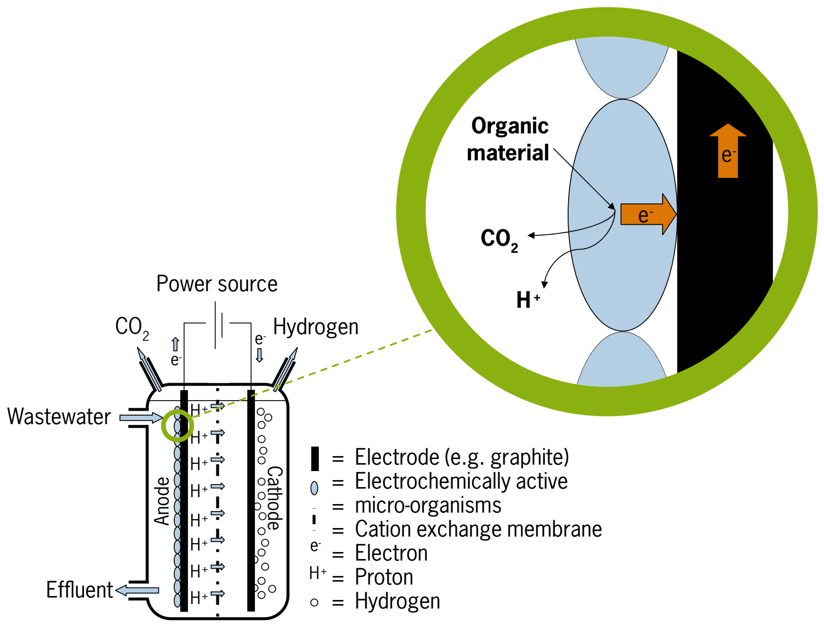
Accordingly, Rulkens thinks that, in the long term, it will become impossible to add purification units to existing large-scale installations. 'The only way forward is to decentralise the treatment of sewage,' Rulkens explains. 'The trick is to treat wastewater as efficiently as possible. Firstly, rainwater must be kept out of the sewers. This so-called uncoupling already occurs in newly-built neighbourhoods. We could also improve our handling of relatively clean shower water: by conducting this past a heat exchanger, the heat can be reclaimed. The cooled water can then be used to flush the toilet, for instance.'

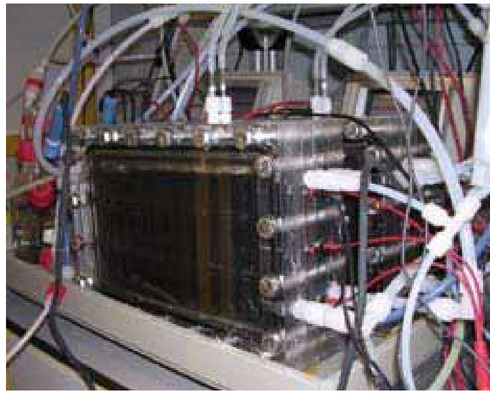
Phosphate and nitrogen can be reclaimed from wastewater to start a new life in the artificial fertilizer industry

The remaining compressed black toilet water (consisting mainly of faeces and urine) can be stored in decentralised units per neighbourhood. Consequently, the phosphate and nitrogen can be reclaimed to start a new life in the artificial fertiliser industry, says Rulkens. A Wageningen experiment being performed in the Dutch city of Sneek should shed more light on this issue.

Reclaiming minerals

This type of decentralised compact purification technology has been widely accepted within the industry for some time. The world can partly thank Wageningen research for the technology, in which bacteria work for free breaking down organic pollution in the water in small-scale reactors. The bacteria operate in oxygen-free (anaerobic) circumstances instead of in large basins. They simultaneously create methane gas power and are neat and tidy. The amount of remaining sludge is well-rotted and small in volume.





Left **Biocatalyzed Electrolysis**

Right **Biocatalyzed Electrolysis cell**

Because this anaerobic technique is compact and supplies net energy, it is extremely suitable for southern countries. The mineral-rich sludge remaining after fermentation can also be used as an effective and cheap fertiliser. The reactor is called a *UASB* (up-flow anaerobic sludge bed) because large amounts of wastewater are introduced beneath a sludge bed of well-settled and highly-active bacteria.

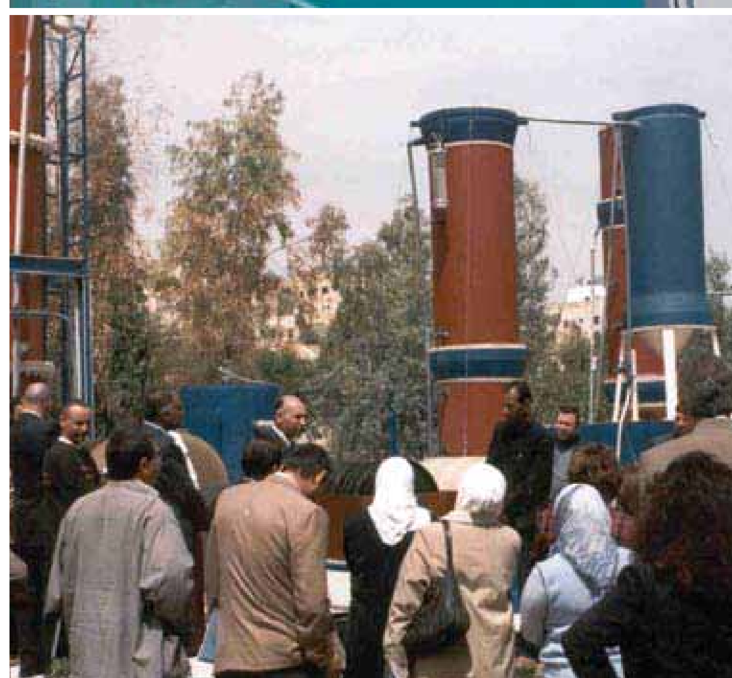
Wageningen Professor Gatze Lettinga was one of the inspired founders of this research in the mid 1970s (see sidebar). His successor, Cees Buisman, Professor of Biological Recovery and ReuseTechnology, envisages plenty of new opportunities for intelligent applications of biological recycling processes available in the environment. During his PhD research under Lettinga, Buisman developed a method for reclaiming sulphur from wastewater.

'We were successfully working on closing the sulphur cycle in the metal industry,' Buisman says. 'By practically intermediating between aerobic and anaerobic bacteria, harmful sulphates and sulphides can be transformed into elementary and reusable sulphur, while allowing metals such as zinc and cadmium to be removed from the wastewater.' The zinc producer Budelco (now called Nyrstar) is benefiting directly from this research.

Certain bacteria might also be useful for removing sulphides from natural gas for the petrochemical industry, including companies such as Shell. This concept is being developed in cooperation with technological company Paques from the Dutch town of Balk. Owner and major shareholder Jos Pâques says the Wageningen anaerobic technique is one of the key elements driving his company. 'We still sell dozens of IC reactors a year, which are the improved version of Lettinga's UASB reactor,' Pâques says.

Another area in which bacteria are useful is in reclaiming the precious metal nickel from wastewater. 'We let bacteria nibble on a nickel-sulphate compound, causing beautiful crystalline nickel sulphide crystals to settle without the iron,' Cees Buisman explains. 'Difficult metals such as arsenic, selenium and molybdenum are next in line to be reclaimed from wastewater, again by utilising bacteria.'

Buisman also points out the possibility of having living plants create bio-energy. 'Not by harvesting them, but by collecting the excess sugars they discharge from their roots and using electrochemical bacteria to transfer this into electricity.' Energy company Nuon is understandably excited by such



Bacteria are used to produce hydrogen

Below Opening USAB-testing station in Amman, Jordan in 2003

'Cars will no longer run on gas, but on fuel cells fed by hydrogen produced from wastewater'

discoveries. 'The technique is constantly improving and we try to help it along by financing PhD students, for instance,' says Maarten van Riet, R&D Manager at Nuon Science. 'Once the principle proven in the laboratory can be used in practice, we are on the brink of a major breakthrough. If a Third World farmer can generate 18 kW of electrical power from one hectare, this can offer an attractive extra source of income.'

Driving on wastewater

In addition to breaking down organic pollution and reclaiming minerals, the latest trend in water technology is the deployment of bacteria to produce hydrogen. 'We have improved the former process of fermenting sugars to release hydrogen power,' scientist René Rozendal explains. 'By conducting wastewater in a special electrolyte cell, we can now utilise the energy content of by-products such as acids that were useless until recently. This increases the energy output from 15 to 90 percent.'

This so-called biocatalysed electrolysis principle has been successful in the laboratory, and Rozendal expects hydrogen production to go commercial within five to ten years. 'At that point, we can really talk of a hydrogen economy. Cars will no longer run on gas but on fuel cells fed by hydrogen produced from toilet water and industrial wastewater.' Rozendal estimates that the total Dutch wastewater can produce sufficient hydrogen to power between 20 to 40 percent of Dutch vehicles.

Gatze Lettinga

'The wonderful thing is that anaerobic water treatment technology also provides a solution for southern countries,' Gatze Lettinga says. 'It purifies wastewater and supplies power and costly fertilisers such as nitrogen and phosphate.' Lettinga, 72 years old, remains an enthusiastic advocate for decentralised water treatment. Over 3,000 reactors worldwide function according to the principle he developed. 'Even though microbiologists increasingly understand the transforming processes, we still don't exactly know how these bacteria work… But they do,' adds Lettinga, who received many awards for his work, including the Shell Award for Sustainable Development and Energy in 2000 and the prestigious Tyler Prize for Environmental Achievement, worth $200,000 in 2007.

There are far more bacteria on earth than expected: according to the latest insights at least 10 to the power of 30. 'An astronomical figure,' emphasises Wageningen microbiologist Professor Willem de Vos. 'And this is only the tip of the iceberg. We only know about one percent of the bacteria that can be cultured in laboratories.'
For a long time, the role of bacteria on earth was underestimated. 'Cyanobacteria provide 40% of the earth's photosynthesis,' De Vos continues. 'These bacteria remove carbon dioxide from the environment, which makes them a key player in the greenhouse gas issue. And those who search for a solution in bio-fuels cannot ignore bacteria.'

THE POWER OF MICROBES

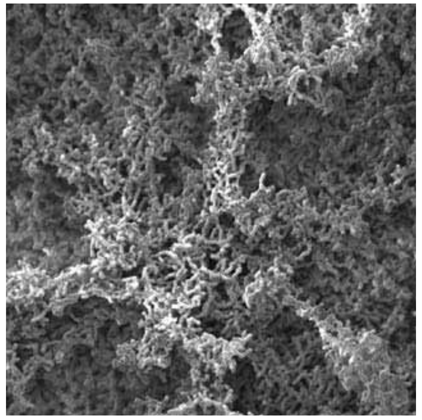
Despite their miniscule size, micro-organisms have always been of great interest to Wageningen scientists. Examples include pathogenic fungi, bacteria and viruses in agriculture and horticulture, and nitrogen-fixing bacteria in the radical tubers of papilionaceous flowers. In dairy production and the food industry, water treatment and soil sanitation, cattle feed and nature development: microbiological knowledge is a cornerstone in many fields.

Talking bacteria

Willem de Vos is fascinated by the 'power of microbes', as he called it in his inaugural lecture. Until 2007, De Vos was programme director of the Top Institute for Food and Nutrition (TIFN), one of four leading Dutch technological institutes established in cooperation with industry. In the 1990s he made the revolutionary discovery that bacteria live in communities and communicate in a chemical language. Bacteria never grow alone. Only if there are sufficient bacterial cells does growth take off, stimulated by communication signals. In multidisciplinary studies performed in collaboration with NIZO food research, De Vos showed that the communication takes place by means of small protein molecules called peptides.
This discovery led to a series of authoritative and often cited publications and numerous patents. De Vos: 'We soon saw many application opportunities. To get the bacteria to communicate, you add communication peptides. Once you speak their language, it becomes easier to raise and train them and make them, for instance, catalyse certain desired conversions. This gave us an important research tool. You can activate or deactivate genes as much as you want, or increase or decrease their activity to specifically study their role in a cell.
It is incredibly important to learn to understand how cells function and cooperate in a network. By using the right molecules, we can activate specific genes and influence gene expression. We can now see what changes in a cell when we activate or deactivate a specific gene, and this allows us to draw up a blueprint of the cell. We are discovering how the switching system works and eventually we want to understand how living organisms function.'
In addition, these innovative induction systems for activating micro-organisms have proven their use in all sorts of industrial processes. By adding communication peptides, the production of a desired protein can be activated. This patented system has been made applicable for many types of bacteria and is used the world over.

Industrial processes

Apparently bacteria feel each other's presence. When they are together in sufficient numbers, they activate certain genes, which help them survive by, for instance, slowing down the growth of other competing bacterial species. Or by absorbing the DNA of other bacteria to create new and better genes. Some pathogenic bacteria kill the host in which they live or competing micro-organisms. A practical application is cheese production, in which pathogenic Listeria bacteria are taboo and gas-forming Clostridium species sometimes cause product putrefaction. Production of anti-bacterial inhibitors reduces decay and improves food quality – a natural way of conserving food.
Bacteria are less complex than plants or animals. 'We can translate their genomes into an computer simulation model, which we can use to make predictions,' says De Vos. 'Then we can use our training tricks to test these predictions and find out how good the model actually is.'



Left **Milk fermentation for cheese production**

Right **Lactic acid bacteria**

De Vos thinks it will be mainly applied in the fermentation industry, for instance the dairy industry, or by companies such as CSM, the largest manufacturer of lactic acid in the world, or DSM, which produces a range of food and pharma ingredients.
De Vos: 'The regulated gene expression allows us to better test our models and this offers greater control over expression systems. Many bacteria have the natural tendency to not produce proteins until the end of their growing phase, when they subsequently stop growing and die. We try to manipulate those production systems in such a way that they start making proteins at an earlier stage. This benefits the production of proteins in the pharmaceutical industry and the production of various enzymes and aromas in the foodstuffs industry. Sometimes the production can be manipulated to prevent bacteria from producing any flavour-spoiling substances and thus create a better tasting product.'

Big business

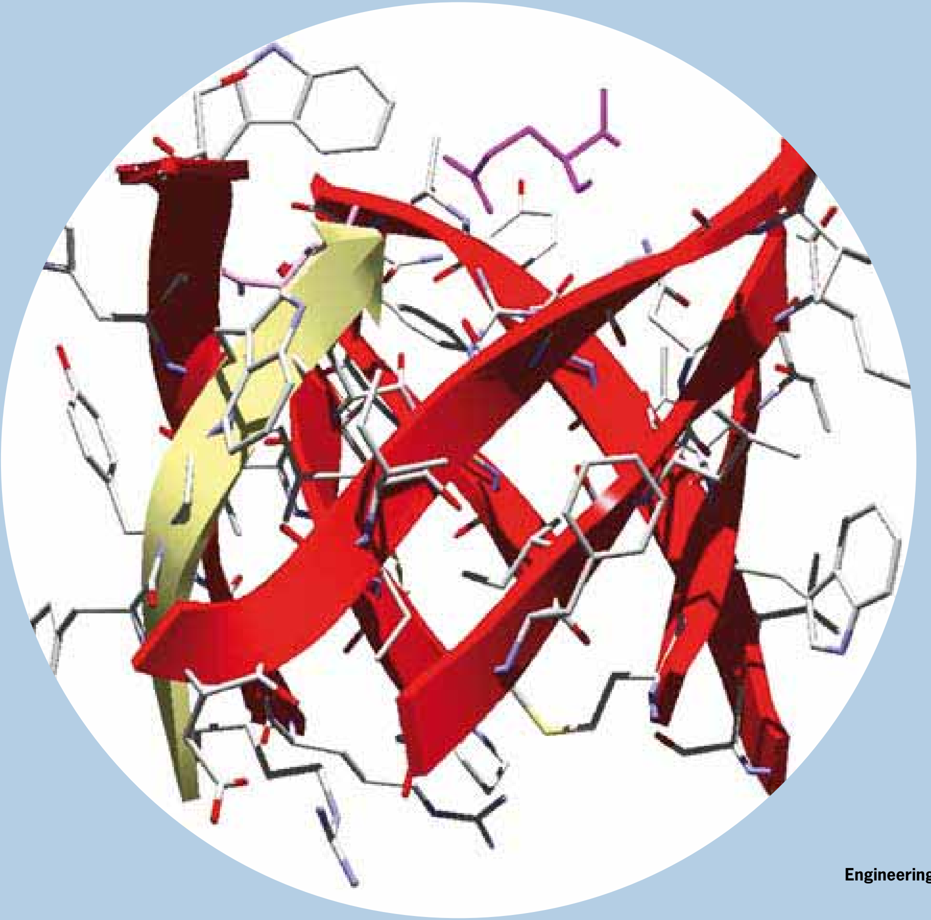
Microbiology is big business. Consider all those healthy yoghurt drinks and other health products with probiotics. Consumers worldwide spend around six billion dollars a year on these products and the market is still growing. The alleged revitalising effect of these probiotic products is based on the presence of *Bacillus bulgaricus*, a bacteria that was isolated from Bulgarian yoghurt in around 1900.
'Microbiologists are currently very interested in these types of benign bacteria,' De Vos tells us. 'A healthy person carries some 1.5 kilos of bacteria around, especially in the large intestine. In the past, the large intestine was considered to be a kind of storage for food which happened to also contain bacteria. Now we know that those colon bacteria are of considerable importance, not least because they make essential vitamins. Bifidobacteria and other bacteria help our body make vitamins B and K and degrade fibres which we would not be able to digest without bacteria. In short, these benign bacteria play an important part in our metabolism.'
De Vos' ultimate goal is to understand the entire cell. 'For the time being we are focusing on single-cell organisms, including bacteria but also more complex organisms such as yeast and fungi. We are also working on the system biology of mixed cultures consisting of multiple types of bacteria. Subsequently we can take the step towards the type of complex bacterial communities found in human intestinal tracts. Another interesting issue is the interaction with human intestinal cells. One thing we want to do is map the fluxes of free fatty acids, which are secreted by colon bacteria. A symbiosis between humans and colon bacteria has evolved over time and we would like to understand this process. The colon bacteria are very much like an organ within an organ.'

Probiotic drink

Bacteria live in communities and communicate in a chemical language

De Vos is developing bacterial biomarkers as criteria for a healthy intestinal tract. It would be useful to gain an understanding of these bacteria and their workings in order to help those suffering from Irritable Bowel Syndrome (IBS), for example, which affects around one to five percent of the global population. The cause of IBS is still not fully understood and various factors are involved. Finnish studies with bacterial mixtures as food supplements have given hopeful results in treating the disorder, and the first products using these results have recently been approved.

Revolution in evolution



Engineering proteins

Evolution in the lab speeds up the improvement of enzymes.
A specialist in this field is John van der Oost, Professor of Microbiology and Biochemistry at Wageningen University. By simulating the natural evolution process of the creation and selection of a large number of protein variables in a laboratory, scientists can more quickly produce a wide range of functional enzymes that, in time, can be used in the pharmaceutical or foodstuffs industries, for instance, or to manufacture biofuels.

According to Van der Oost, natural proteins are often not good enough to be applied in industrial processes. In an industrial reactor, proteins are needed that have a high stability and activity or which react to an anomalous biochemical process. Proteins with these characteristics cannot usually be found in nature. Adjusting their structure to improve the functionality of proteins for such a process demands extreme care.
In the Laboratory for Microbiology of Wageningen University, scientists are using an efficient protein-engineering technique.
They create thousands to millions of varieties of a protein, adding random changes (mutations and recombinations of the corresponding DNA) that can then be tested and selected for efficiency. Within only a few months to a few years, evolutionary processes that would have taken millions of years in nature can be simulated in the laboratory.

John van der Oost's research group combines this activity with complementary computer techniques in close collaboration with American colleagues.
This insilico technique involves computers researching even more (billions) possibilities of small and large mutations of proteins and selects the proteins that it calculates can most efficiently form a compound with or convert substrates. As a result, scientists can design enzymes which are specifically suitable for certain functions and, in the long term, even develop complete micro-organisms that do not occur in nature. Van der Oost hopes to use these enzymes for catalysing specific biochemical processes, for instance as a green alternative to numerous chemical conversions, for the production of medication, or to accelerate processes for the preparation of biofuels from organic material.

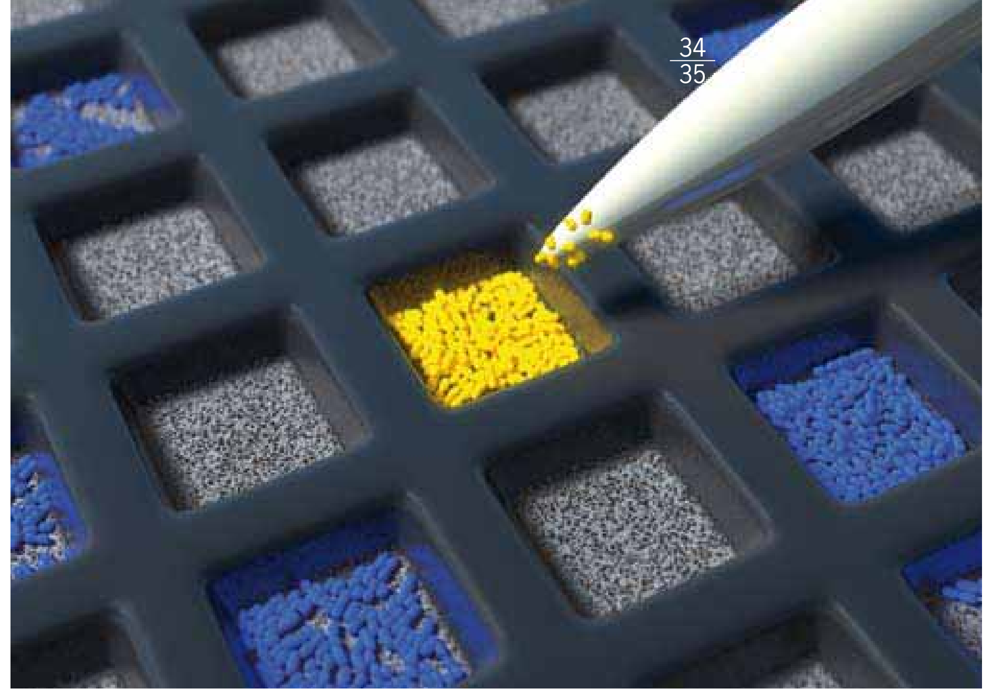
‘A healthy person carries some 1.5 kilos of bacteria around’

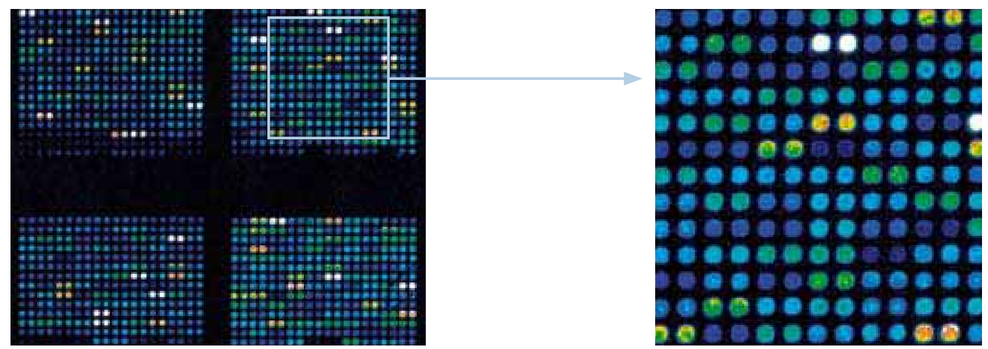
Microchips

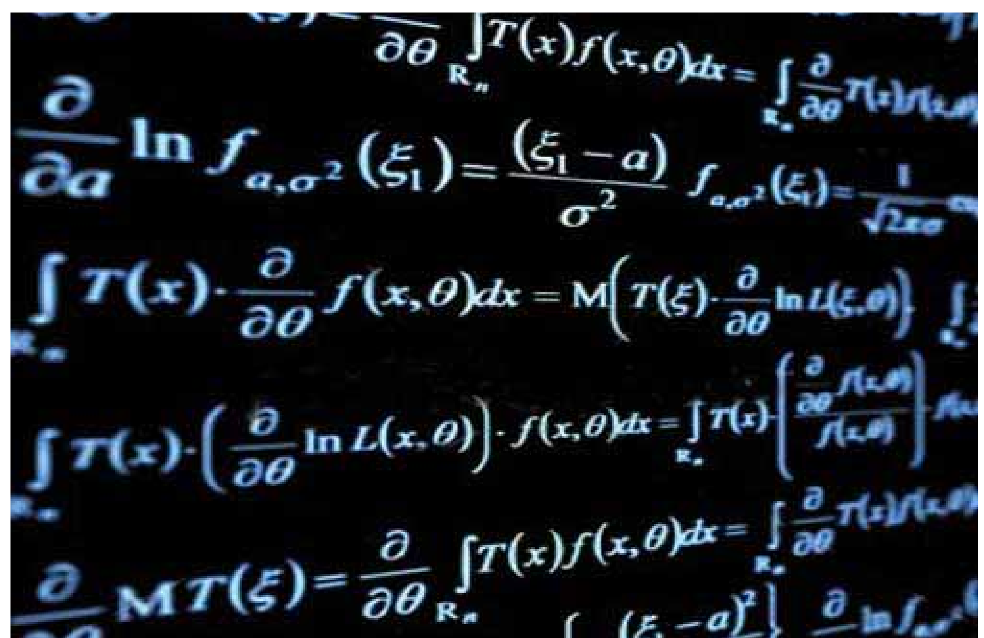
The latest breakthrough is the use of microchips, originating from nanotechnology, to analyse large amounts of micro-organisms at a micro-colony level. These microchips allow scientists to select interesting organisms, such as rare mutants, which will only be found once in a million or billion occasions. De Vos: ‘In high-tech laboratories where these microchips can be employed and a million bacteria can be processed simultaneously, there is a greater chance of finding these mutants without applying genetic modification. Just let nature take its course!’
The microchips provide the opportunity to perform large-scale analyses and to grow organisms. This results in new insights into microbial ecology, physiology and genetics, plus entirely new biotechnological applications. An independent member of the American Academy of Sciences described the work as an ‘incredible development in microbiology, which will result in one of the most powerful techniques in its field.’ The microchips were developed in cooperation with scientists from Wageningen and Twente, and serves as a fine example of how the fields of biotechnology and nanotechnology can be combined.

Systems Biology

Due to the pioneering research into the communication of bacteria and innovative induction systems, the road is now clear for metabolic engineering, manipulating bacteria to make metabolites. The plan is to use metabolic maps as a navigation system for engineering.
Systems Biology is an emerging discipline in which biologists, physicists, mathematicians and computer scientists work together. They are performing groundbreaking research into the way genes, proteins and other substances cooperate within a cell in so-called biomolecular networks. ‘This discipline is very much in the spotlight and developing at high speed,’ says Jaap Molenaar, Professor of Applied Mathematics.‘There is an enormous increase in the amount of conferences, books, magazines… Wageningen is especially well-suited to contribute as we have all the basic disciplines in house: both ambitious biologists as well as mathematically-oriented modellers.’ Molenaar’s group is a part of Biometris, Wageningen UR’s centre of expertise for the application of mathematics and statistics in life sciences.
The current developments surrounding Systems Biology are in tune with the Wageningen tradition. Forty years ago, before the term Systems Biology was invented, Professor C.T. De Wit made a name for himself with eco-physiological models to calculate crop growth in detail (see also chapter 12). Wageningen



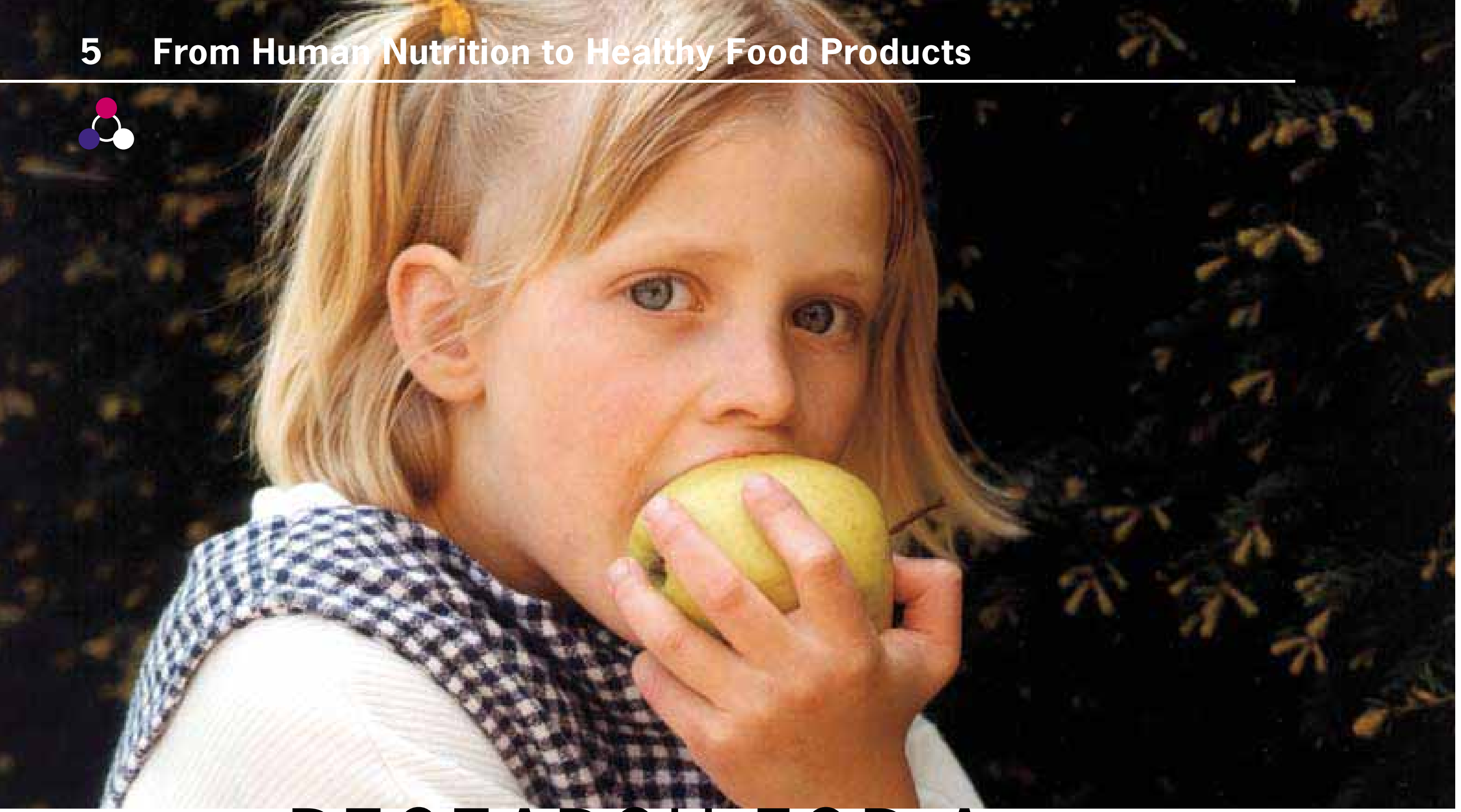




Virtual image of a microbial chip

Centre **Chip visualising thousands of different bacterial species living in our intestine**

epidemiologists led by Professor J.C. Zadoks developed much-used epidemiological models to predict the spread of crop disease.
Molenaar likes to compare Systems Biology to a house: ‘When you are in the cellar of a house – the lowest level where the genes are – and you adjust the switches, you will see the results in the attic. If you change the genes of a tomato plant, eventually you will see the effect in, for example, the colour of its fruit. However, there are many floors between the cellar and the attic and the information has to pass through many different levels.
‘Systems Biology is tasked with making models that link these different levels. Mathematics is the language and computer science the tool. We try to enter all these incredibly complex metabolic pathways into the computer and it is a slow and difficult task. Fortunately much data is currently being generated on all the compounds of a cell. We can detect and keep track of many proteins and enzymes. Then, by means of cluster analyses and regression analyses, we try to understand the network they form.’
Molenaar says that it is amazing how little new knowledge was accumulated when the human genome was unravelled. ‘Those genes are in the cellar.
It is incredibly important to go up one level and to see how these genes work together, what happens during protein synthesis and how the dynamics of these protein networks operate. This is the stage we are in now. We are working towards an ideal: building a computer simulation model of a virtual cell.
It is a tough job – in the simplest cell there are thousands of active proteins.’
With the aid of new disciplines such as genomics, proteomics and metabolomics, Systems Biology maps complex biological processes. Step by step, scientists are unravelling how genes, proteins and metabolites cooperate in time and space within the biomolecular networks that are characteristic for most living things. Applications are being used in public health and the food industry, but also in green alternatives for the chemical industry. One example is rational drug design – the design of medicines which act in specified places and ways within the network. The efficient production of biomaterials and biofuels from green raw materials instead of petroleum is another. ‘Eventually we want to develop an understanding of the relationship between all the processes, from the molecular to the eco-system level,’ Molenaar concludes. ‘The close relation between the development of calculation models and the performing of experiments remains essential. Various Wageningen domains, such as Plant and Animal Sciences, are collaborating. This is how Systems Biology contributes to a better understanding of the building blocks of life.’



RESEARCH FOR A HEALTHY NUTRITION

'The Wageningen research on nutrition and health is unique,' says Professor Frans Kok of the Division of Human Nutrition. 'In our work, we try to approach nutrition issues on three different levels: Cellular, Individual and Population. This multidisciplinary approach is exclusive to Wageningen.'

Cellular – Individual – Population

A fine example of the Wageningen nutrition research on a cellular level are the studies by Professor Michael Müller and his colleagues into PPARs. A PPAR is a molecular sensor which warns cells that fatty acids are nearby. It is sensitive to the poly-unsaturated fatty acids in our food – especially those in fish. This line of research helps us to better understand why a diet with a relatively high level of unsaturated fatty acids is healthy and why food with excessive amounts of saturated fatty acids poses a risk. It seems that the human body stores and burns healthy unsaturated fatty acids more easily than the unhealthy saturated fatty acids.

According to Wageningen University scientists, the elderly benefit mentally from additional B-vitamins

The Wageningen research into fatty acids and health is based on a tradition that can be traced to the 1970s. Back then Wageningen scientists proved that the saturated fatty acids which we mostly ingest from animal products raise the level of the bad LDL-cholesterol. The strongest cholesterol-increasing factor was found in trans fats, which used to be in margarines and can still be found in cookies and pastry.

'In this research we investigated the health effects on an individual level,' Kok tells us. 'And we still do so today. For instance, we are currently investigating how parents can stimulate their children to eat vegetables. It is not easy: the aversion to the bitter taste of many vegetables is probably for a large part based on genetics. Many toxic substances in nature taste bitter and we have many taste buds in our mouth warning us against bitter-tasting substances.'

Another research project at the level of the individual organism concerns the need for elderly people in nursing homes to receive extra vitamins. Shortages of vitamins D and B12 occur in this group on a large scale. Wageningen nutritionists published a study in The Lancet which proved that the elderly benefited mentally from additional B-vitamins.

On a population level, the Division of Human Nutrition conducts large epidemiological studies such as the research into the lifestyle factors that raise blood pressure. These studies confirmed that dietary fibre and potassium in vegetables and fruit lower blood pressure, while sodium in the form of kitchen salt raises it.

It cuts both ways

'The idea that you can impact your health by eating healthily only really started to sink in with the general public over the last decade,' Kok continues. 'This consciousness cuts both ways. On the one hand this means unmistakable support for nutrition research. Companies are more interested in what we do as they wish to create healthier products. On the other hand, we must be careful not to exaggerate the promotion of foods with added ingredients as this could jeopardise the credibility of the nutrition sciences.'

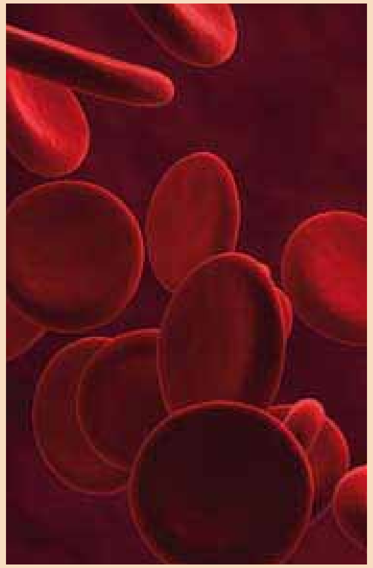
Professor Daan Kromhout, also affiliated with the Human Nutrition division and vice-president of the Health Council of the Netherlands, cites the example of tomato products with added lycopene. 'Lycopene is a compound in the cell wall of tomatoes, and epidemiological studies have indicated that it may offer protection against prostate cancer. Scientists have shown that you absorb

Below **Blood cells flowing through an artery**

Improving products

If a consensus is reached among nutrition scientists that food compounds such as flavonoids, lycopene or glucosinolates indeed protect people's health, Wageningen food scientists have the processes ready for use.

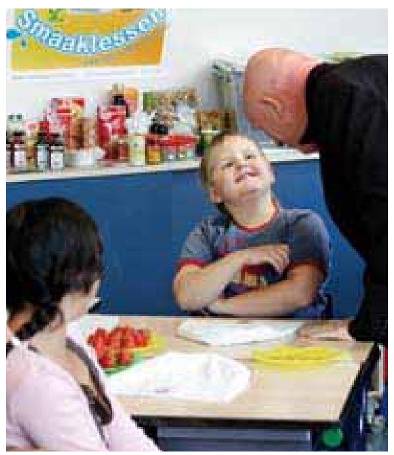
Professor Tiny van Boekel's Product Design and Quality Management group developed a new type of apple juice, for instance, with a much higher flavonoid content than normal. While flavonoids are largely discarded in the production process of normal apple juice, recent studies suggest that they might reduce the risk of cardiovascular diseases. However, as always, the key issue remains that sufficient evidence must be available that a given substance has a significant effect on health.



Upper left **Chef Pierre Wind gives tasting lessons to primary school children**

Below left **Meals in a care facility**

For the prevention of chronic diseases the emphasis should be on the dietary pattern not on individual nutrients or foods



more lycopene if the tomatoes are processed as tomato juice or puree. However, it has not convincingly been shown that you have a low risk of prostate cancer if you consume more of these products. Nonetheless, food companies and technologists who try to make their products healthier emphasise this epidemiological connection. They produce products with more lycopene, while the foundation for the product's effectiveness has yet to be established.'

Kromhout and Kok have warned against these and similar products. Kok urged manufacturers of margarines with fatty acids from fish to be more careful with their advertising campaigns. 'The manufacturers suggest that these margarines are good for the cognitive development of children. If consumers later read in the papers that these *improved* products they spent so much money on are not so favourable after all, the credibility of nutrition science will be damaged.'

Guidelines for a Healthy Diet

Another issue of concern is that products with added nutrients start from a reductionistic perspective: focusing on the effects of a single ingredient on a person's health. This ignores the fact that the total dietary pattern is far more important in terms of overall health, as Kromhout explains. 'Our research showed that the Mediterranean diet, for instance, is healthy and offers a longer life expectancy for the elderly. Scientists from our group published an article on this subject in the Journal of the American Medical Association in 2004.'

What a healthy diet should look like according to current scientific insights is further emphasised by the revised Guidelines for a Healthy Diet published by the Health Council of the Netherlands in 2006. Wageningen scientists played a prominent part in the development of these guidelines.

This does not, however, mean that nutrition science cannot provide the food industry with important insights. 'It is certainly worthwhile to optimise the composition of foods,' Kromhout says. 'But rather than adding ingredients with unproven health effects, we would be better off producing dairy and meat products with less salt and saturated fat; bread, soups and pizzas with less salt; and ready-to-eat meals with less salt and more vegetables. This should be the priority.'

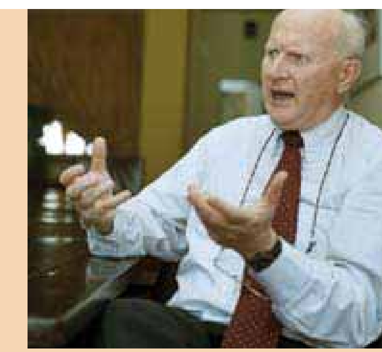
Developing countries

Different nutritional problems prevail in developing countries, as Kok explains: 'Our group has been working in Africa and Asia for decades. In those countries we see a so-called double burden: in large cities there is a growing epidemic of obesity, but in the rural areas we still encounter major deficiencies of key nutrients.'

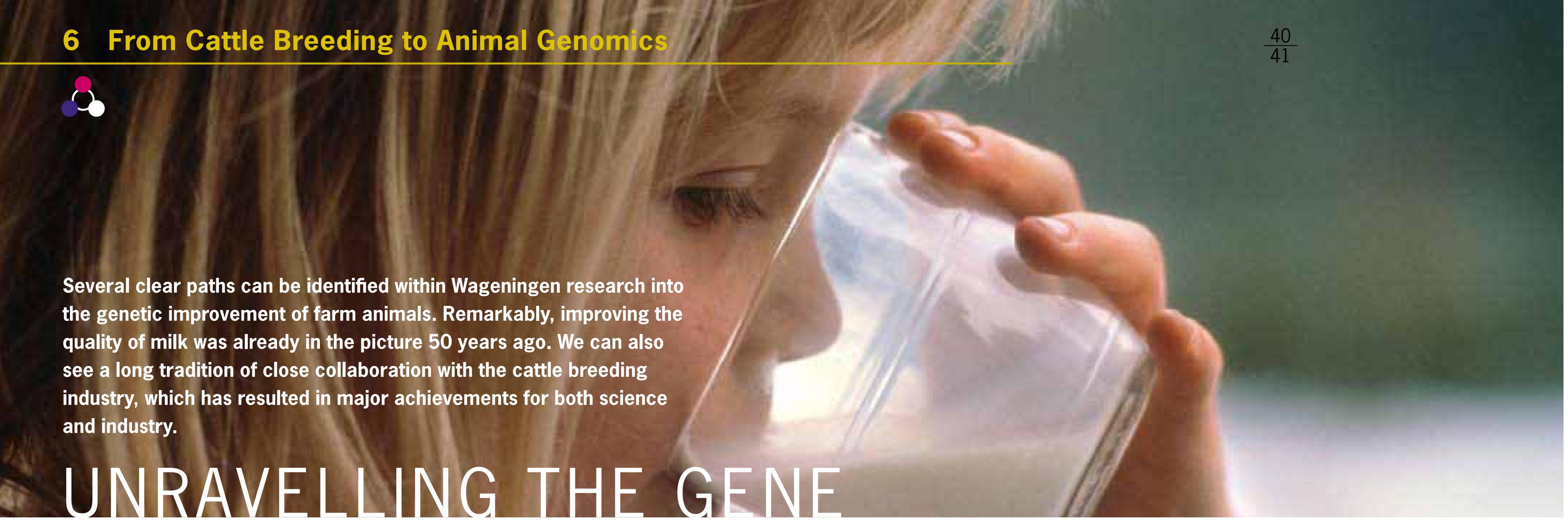
African girl with maize flour at a market stall

Wageningen scientists help the countries concerned with analysing the situation and finding solutions. An example is a recent PhD research project that was performed in Kenya and published in The Lancet in 2007. With financial support from Unilever, a study was carried out among schoolchildren who did not ingest sufficient iron. These children were given iron-EDTA – an iron supplement developed by Akzo-Nobel. This type of iron is better absorbed in the human body. 'The diet of Africans contains relatively high levels of phytates,' Kok says. 'Phytates form a complex with iron, which is poorly absorbed. EDTA, however, forms a compound with iron, which improves the bio-availability.'
Enriched nutrients can have excellent effects in different areas. Kok continues: 'Iron is essential for a wide range of bodily functions. Children need iron for their mental development, among other things. The main reason for failing to introduce such products in poor regions in Africa and Asia is money. It is such a waste that we fight expensive wars while the money could be used in so many better ways.'

More important matters



After Professor Jo Hautvast came to Wageningen from Nijmegen in 1972 to lead the current department of Human Nutrition, he altered the course of Wageningen nutrition research. 'In those days, Wageningen scientists were working on the flavour of the tomato,' Hautvast says. 'That wasn't my cup of tea. I had been the director of a hospital in Tanzania and the nutrition problems I encountered there were much more important than researching the flavour of a tomato.' Hautvast was equally resolute in the early 1990s. When he gave the Foundation Day speech of the University, he foresaw the establishment of a Dutch Food Valley in which scientists and the food industry worked together for better tasting, safer and healthier nutrition. 'We really need this Food Valley,' Hautvast stated. 'Because, let's be realistic, the food industry is what keeps the Dutch economy afloat.' Although not everyone agreed with him at the time, the Food Valley is now a fact.



Several clear paths can be identified within Wageningen research into the genetic improvement of farm animals. Remarkably, improving the quality of milk was already in the picture 50 years ago. We can also see a long tradition of close collaboration with the cattle breeding industry, which has resulted in major achievements for both science and industry.

UNRAVELLING THE GENE

Farm animal breeding programmes are based on two pillars: estimating the genetic potential of the animals, and using those animals with the highest potential. The improvements in both pillars over the past half-century have led to a clear genetic improvement of Dutch stock and an enhancement of Holland's international position as a livestock breeding country.

Even though the fundamentals of quantitative genetics date back to the 1930s, it was only after WW II that they could actually be applied. At that time the genetic potential of animals was estimated based on observing the animal or its relatives. After his appointment as a lecturer at the former Agricultural College in 1960, and then after he became a Professor in 1968, Rommert Politiek was one of the most influential figures in changing this situation.

Breeding programmes in Wageningen have helped to enhance the international position of the Netherlands as a livestock breeding country

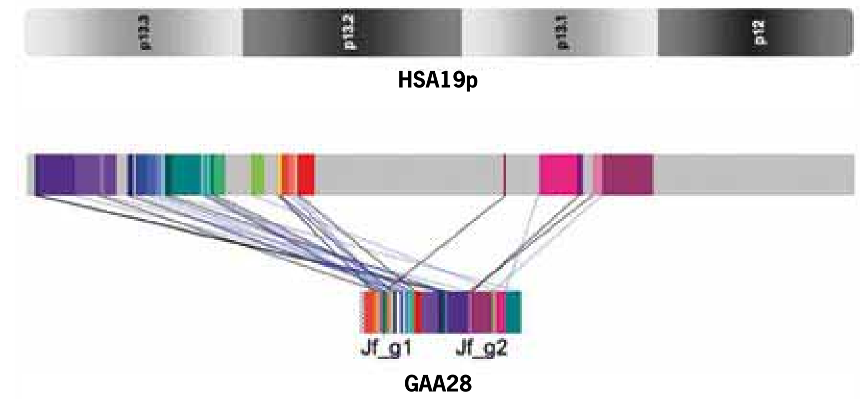
Professor Politiek introduced modern methods of estimating genetic potential of bulls in the Dutch dairy cattle population. He also strengthened the successful alliance between science and herd books, which had started with his predecessor Professor W. de Jong, who was also the director of the Netherlands Cattle Herd Book Society.

Breeding bull

In the 1960s, Politiek discovered that it was possible to improve protein levels in milk through careful selection of bulls and cows. It is illustrative for Politiek's approach that he did not leave the issue there, but got dairy cooperatives to change the payment regulations for milk. The change in farmers' income helped increase interest in protein content in milk. This contributed to the increase in milk protein content from around 3.3% in 1960 to 3.5% in 2006. This increase, which at first sight is not large, was realised despite the major increases in milk production (from 4,353 to 9,109 kilos per cow), which has a negative effect on protein content.

Below **Chicken chromosome 28 and human chromosome 19 have many genes in common**

Source: Genome Research (Cold Spring Harbor Press)



A major milestone in animal genomics: the sequencing of the chicken genome

The large rise in milk production and protein is partly due to the tools that were developed to help cattle breeders focus their breeding programmes on the desired characteristics of offspring. In addition, the increased use of artificial insemination (AI) allowed breeders to select bulls from the international gene pool: due to AI distance is no longer an issue because frozen semen can be transported around the world. Research by Professor Pim Brascamp (firstly under the guidance of Politiek and later as his successor) into predicting genetic response has made a key contribution to the development of current breeding programmes. It laid the foundations for Wageningen's past and current strong position in its field: the ability to swiftly anticipate new developments, including the demand for healthy products from healthy animals.

Despite strong regional sentiments in the breeding industry, Politiek advocated international exchange programmes, especially with North America. He and his successors stimulated cross-border cooperation in the field of education and research. This international orientation has been one of the reasons that the Dutch breeding industry has remained of global importance. For instance, the Dutch herd books for cattle have become the current CRV Holding BV, a multinational which, following the joining forces of Dutch and Flemish cooperatives, has a turnover of € 125 million and subsidiary companies on three continents.

Conveyor belt in modern dairy factory

Researchers use their understanding of the bovine genome to change the composition of milk, which could lead to innovations in the dairy industry

The large research project Milk Genomics, on which Johan van Arendonk, the current Professor of Animal Breeding and Genetics, and his colleagues are working, is more or less a continuation of Politiek's work. Together with CRV and the Dutch Dairy Association (NZO), they aim to use understanding of the bovine genome to eventually change the composition of milk, which could lead to innovations in the dairy industry. Individual milk samples of 2,000 cows from some 400 different dairy cattle farmers have recently been analysed. 'Dairy cattle farmers were already used to including the fat and protein percentage levels of their cows' milk in selecting the next generation of dairy cattle,' Van Arendonk explains. 'Now we take a more detailed look at the composition of milk fat and milk protein, and relate differences between cows to what we know about the bovine genome.'

The research brought to light significant differences in the composition of milk fat and milk protein between animals, and the fact that a substantial part of these differences can be traced back to variations in hereditary factors. Furthermore, two genes were detected which contribute to the genetic variation in fat composition. The knowledge of the bovine genome is currently being used to search for more genes that influence milk composition. Understanding the genetic differences in milk fat composition allows the selection of cattle that produces healthier milk with less saturated and more unsaturated fatty acids. Van Arendonk: 'This knowledge can help the Netherlands take the lead on a global level.'

Rommert Politiek

'Cheese is the most important dairy product in the Netherlands, which is why we should focus on proteins.' This was a key principle for R.D. Politiek, Professor of Animal Breeding in Wageningen from 1968 to 1989. His research into milk protein made a significant contribution to and helped interest people in improving the quality of milk.

Politiek's interest in this subject was pricked when he was still a student and working as an intern at the Friesian Cattle Herd Book. He would later follow up on this research and take his PhD on the same subject.

Politiek was also a founder of the so-called mother-daughter comparisons and breeding value estimation of bulls.

Due to his enormous influence, Politiek is known as the '*Reformer of the Dutch cattle breeding industry*'. With his tall stature and inseparable camera, this Friesian farmer's son made a remarkable impression at the numerous cattle shows and cattle breeding meetings he attended. In the 1970s and 1980s Politiek became the Wageningen figurehead among Dutch dairy cattle breeders. Upon the occasion of his leaving Wageningen, the Friesian Cattle Syndicate organised a tribute to Politiek that would normally be reserved for the winner of the famous Dutch Elfstedentocht ice skating competition: an honorary carriage ride through the Friesland hall in Leeuwarden in front of 6,000 enthusiastic visitors.

Due to fast-moving international developments in the field of molecular genetics and genomics, Wageningen animal scientists focused on one model organism in the early 1990s: the chicken. This choice was partly based on the close cooperation with Euribrid, currently part of Hendrix Genetics, one of the global market leaders in the breeding of pigs, layer and broiler hens. According to Professor Martien Groenen, the chicken was an excellent choice: 'On the molecular level we had to start at zero. There was nothing there and we soon understood that focus was essential to achieve results.' Another consequence was that the chicken is now seen as a model organism for human genetic research.

The hunt for chicken genes led to the publication of the first consensus genetic *map* in 2000, in which Groenen combined the treasure hunts of several scientists. Genetic markers can be found on such maps and used by geneticists to trace which characteristics are situated on what part of the chromosome. These findings help breeders figure out how certain characteristics are inherited from parent to offspring. In late 2004, the three papers on the complete chicken genome were published in the scientific journal Nature.

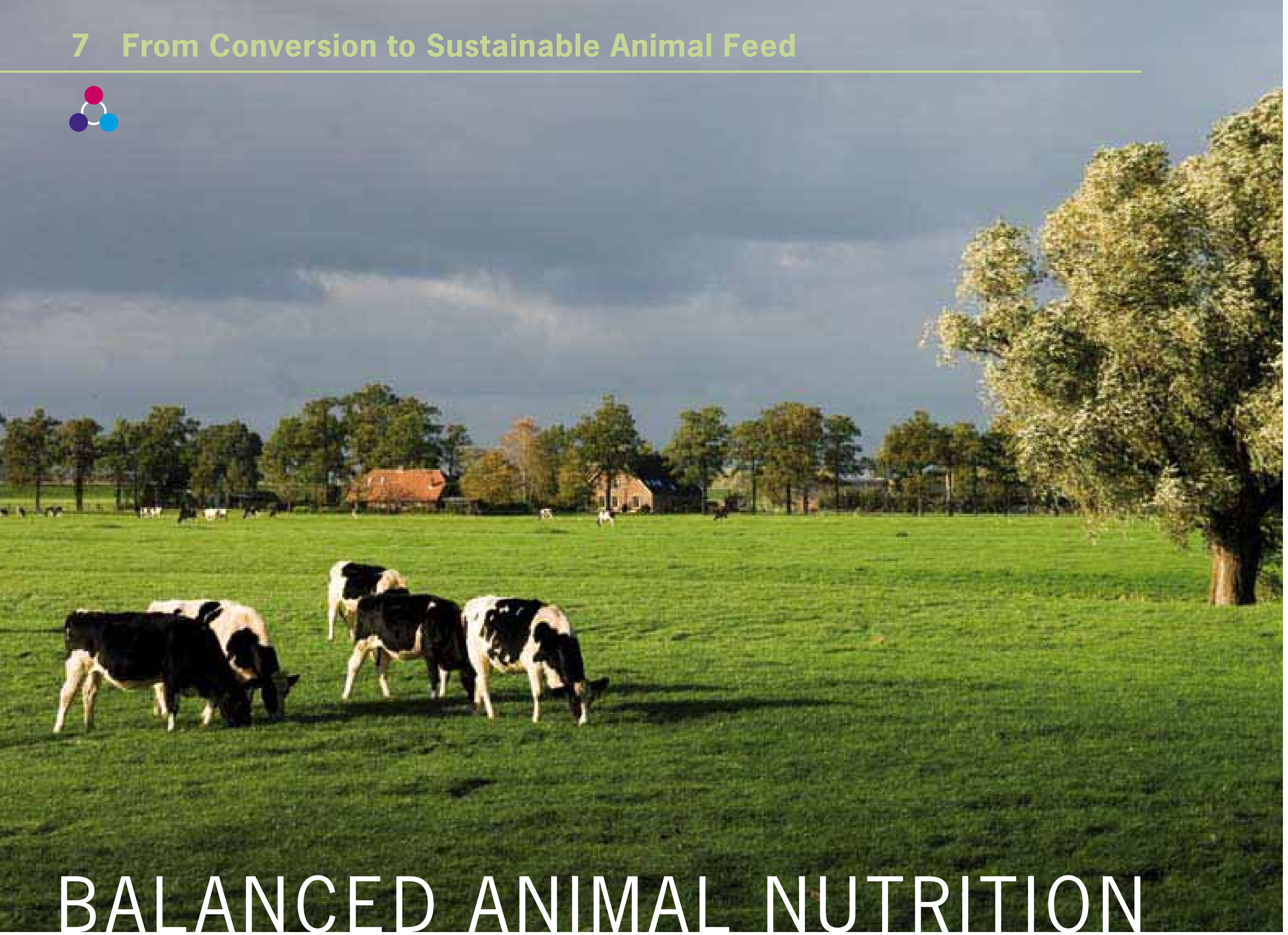
Breeders benefit from this understanding of the chicken genome because, as Groenen says, they can 'pretty much look directly into the genes.' He thinks the knowledge could be applied for troublesome characteristics, such as the predisposition to disease and undesirable behaviour such as feather picking, which are determined by a large number of genes and environmental factors. Groenen: 'We can reach our goals much quicker with this information.'

The genome research has also resulted in a unique situation for Wageningen science. Groenen and his colleagues are (co-)writers of no less than three articles in the aforementioned Nature issue: the dream of many scientists and the equivalent of scoring a hattrick in the World Cup final.

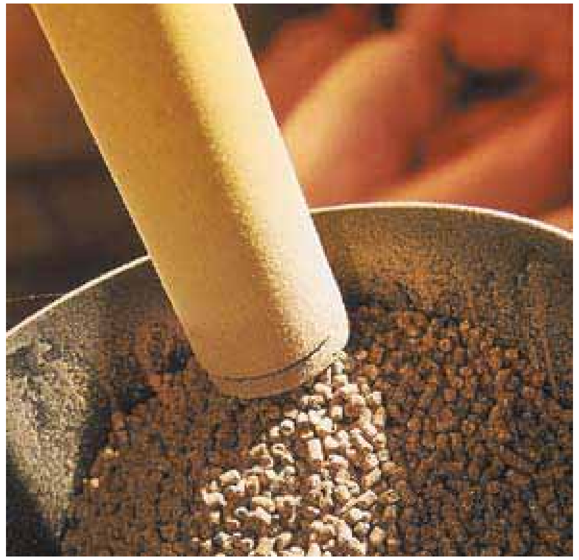
Genomic selection

The Wageningen UR Breeding and Genetics group and its colleagues from the Animal Sciences Group in Lelystad work closely with Hendrix Genetics and Holland Genetics to realise a newly developed and patented application of selection by genetic markers. The accelerated technique, also called genomic selection, uses special software to select animals based on tens of thousands of markers simultaneously. It is also possible to make this selection at a very early age and, in principle, from when the animal is still an embryo.

According to Wiepk Voskamp, manager research & development of dairy cattle breeding organisation Holland Genetics, the introduction of this technique will ensure that the Dutch breeding industry retains its leading position. 'Traditionally, changing the course of a breeding company is like changing the course of an oil tanker: it takes time and forward planning. You can only adjust the direction of breeding companies once you have a good view of the offspring,' says Voskamp. 'By means of a DNA profile, we can do this sooner and with a higher degree of reliability. This in turn speeds up product development.'



BALANCED ANIMAL NUTRITION



Animal nutrition is well managed in the Dutch dairy industry, thanks to two key units for the feeding of cattle (NEL: Net Energy for Lactation and DVE: Intestinal Digestible Protein). This prevents feed being wasted and an excess of minerals from entering the soil. The units are based on Wageningen UR research into digestion processes and energy metabolism for maintenance and production processes. This involved taking measurements of cows and other animals on numerous occasions in unique respiration rooms. These measurements have also led to an improved knowledge of the optimal climatic conditions for pigs. The research has now been extended to other farm animal feed issues, and also dogs and cats.

Left **Dairy cows**

Below **Cattle feed**

Upper right **Respiration tank for fish**

Below right **Respiration cell control room**

NEL (VEM in Dutch) and DVE are terms which have been completely adopted by Dutch dairy farmers and compound feed suppliers. By means of these units, dairy farmers compose a diet of roughage and concentrates that best suits animal needs. The spiritual fathers of these feed units are Wageningen Professors Aren van Es and Seerp Tamminga.

Van Es started his career as assistant to animal physiologist Professor Brouwer. The respiration rooms, enclosed rooms which allow the precise measurements of the respiration and digestion of animals, were Brouwer's 'dowry'. As director of the Institute for Livestock Feeding and Nutrition Research (IVVO) in Hoorn in 1937, Brouwer was only willing to transfer to Wageningen if he was given the facilities to carry out research into the energy metabolism of cattle. Due to the Second World War, it was not until 1956 that the first tests were performed.

The two respiration rooms – a Dutch novelty – gave the researchers the opportunity to perform around 60 tests annually. They were extremely labour-intensive and initially the scientists even slept in the rooms to make sure nothing went wrong. To determine how much energy a dairy cow needs for its maintenance, an exact account was kept of what went in and what came out over 14 days, including the amount of carbon dioxide and methane gas produced and the quantity of oxygen used.

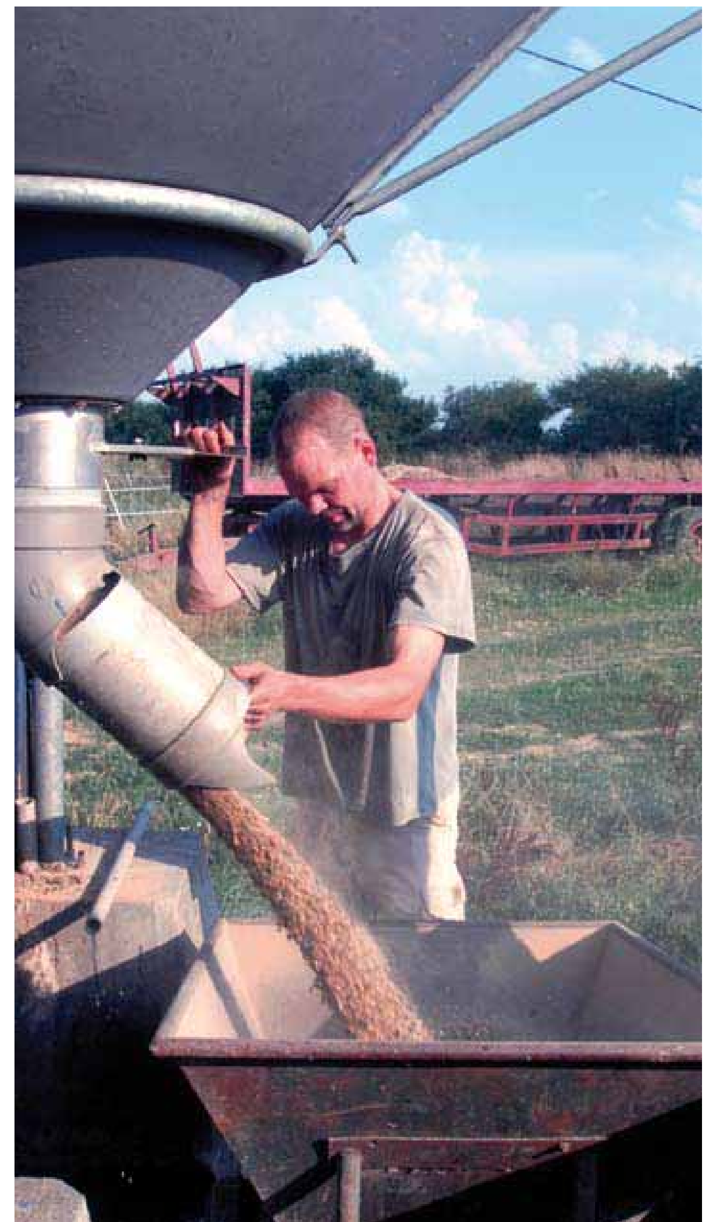
After intensive consultation with extension services and the compound feed industry, the starch equivalent (ZW) for dairy cattle was replaced with the Net Energy for Lactation in 1977. In practice this meant, for instance, that the difference between hay and corn of poor quality for dairy cattle was much smaller than had been indicated by the starch equivalent (ZW). It allowed farmers to organise feeding more accurately and economically. Many elements of the NEL system were also adopted in neighbouring countries.

As long ago as 1970, Tamminga had started research into the utilisation of proteins by ruminants at IVVO. 'The proteins in the feed are by no means all used by the animal. The microbial transformation before the small intestine – mostly in the rumen – determines in what form proteins are actually made available in the gastrointestinal tract,' explains Tamminga, who became a part-time Professor of Animal Nutrition in Wageningen in 1985.

For his research he used cows with artificial fistulas, a kind of hatch in the abdominal wall, which allowed the detailed tracking of the digestion and

Research in respiration rooms allowed farmers to organise feeding more accurately and economically

Respiration cell for pigs



Right page **Distribution of cattle feed at a farm**

‘DVE allowed dairy farmers to work towards reducing their impact on the environment’

degradation of protein. This study led to the term resistant protein, proteins which are not degraded in the rumen, and eventually to the introduction of the DVE (Intestinal Digestible Protein) unit in 1992.

‘DVE allowed dairy farmers to work towards reducing their impact on the environment,’ Tamminga continues. ‘The results became noticeable when the mineral registration scheme was implemented by the Dutch government.’ The introduction of an upgraded feed evaluation has resulted in industry-wide savings which amount to tens of millions of euros annually. Although Tamminga has now officially retired, he is still closely involved with colleagues from Wageningen and Lelystad in the development of a feed evaluation methodology that will replace NEL and DVE by combining them into a single system. ‘We are now trying to remove all the snags in practical tests,’ Tamminga says.

For years, his fellow Professor Martin Verstegen has been involved with research on energy metabolism for monogastric animals in the respiration rooms. New respiration rooms came into use in 1976 and were thoroughly updated around the turn of the century thanks partly to financing from the Netherlands Organisation for Scientific Research (NWO). The size of the eight rooms ranges from 150 litres to 80 cubic metres, making them suitable for both individual animals and for groups. Special aquatic respiration cells were also developed to perform metabolic research into, for instance, cultured fish.

‘We still have one of the most advanced research facilities in the world,’ Verstegen reveals. ‘In the respiration rooms at Zodiac, studies into the energy requirements of all sorts of animals have been carried out: veal calves, pigs, laying hens, chicks, dwarf goats, carrier pigeons, mice, even humans – the list is endless. The added value of this research is that you can actually study the reaction of the animals in terms of energy metabolism and also make the connection between this metabolism and physical activity because of a change in behaviour. In the results you immediately see if certain nutritional, housing and management conditions create more stress for the animals.’

The findings have been crucial in substantiating the housing standards of some species of farm animals. According to Verstegen, a real eye-opener was the discovery that pigs have similar climatic temperature requirements as humans. ‘These studies have led to the adaptation of the climate and housing standards for pigs,’ Verstegen adds. ‘More specifically, you cannot leave a sow with young piglets on a cold concrete floor: she must at least have a warm bed of hay.’ Having supervised over 75 PhD students in his career, Verstegen is among the top of his profession.

When the Wageningen animal scientists move to the new campus, the respiration rooms will naturally come with them. Wouter Hendriks, who became a Professor of Animal Nutrition in 2005, is working on widening the feed research to include animals such as dogs, cats and horses. In his inaugural lecture he announced plans to perform more research into the timing of feeding. ‘It is becoming more and more apparent that the nutrient use of animals fluctuates heavily within 24 hours,’ Hendriks says. ‘Giving nutrients to animals at a time of the day when they are not interested is inefficient.’

At the testing centre of the Animal Sciences Group in Aver Heino, cows are currently receiving concentrates based on dynamic feeding advice. By connecting this to the milk measurements, the system can take into account individual differences between cows’ reactions to concentrated feed. And these differences can be substantial. The system already allows the measurement of concentrate rations per cow per day. Hendriks also sees opportunities for further research by means of genomics into the effects of feed compounds and feeding regimes, and the interaction with genetic backgrounds.

He has also observed that problems such as obesity are threatening to become just as much an epidemic among dogs and cats as for their owners. According to Hendriks, this is one of the reasons to gradually extend the research to include the feeding of dogs and cats. ‘By using the existing facilities and the already planned development of the top quality animal facilities, Wageningen UR is becoming the European centre for independent nutrition research into and education on pet animals.’

Farm infected by avian influenza is prepared for culling

A VERY PUBLIC AFFAIR

Animal health and related issues are no longer of interest to the livestock sector alone. As society has become increasingly involved, an extra dimension has been added to Wageningen UR's research into animal disease and its consequences. In the past, animal disease was primarily considered an economic matter for farmers and a veterinary challenge for veterinarians. Now, almost everything pertaining to animals ends up in the public domain.

'The Achilles heel of animal disease control is tracking and tracing contacts'

Livestock farming has been an element of the University's core business for decades. Since the merger with the DLO institutes for veterinary research at the end of the previous century, research into animal and veterinary science has also become part of Wageningen UR.

The field of research called Animal Health Economics was initiated in the Netherlands in the late 1970s with a study by Professor Jan Renkema and Jentje Stelwagen (both from Wageningen University but then working with the Faculty of Veterinary Medicine at Utrecht University). The study focused on the economic aspects of a longer herd life for dairy cattle. Health problems appeared (and still appear) to be the most important reason for animals being culled prematurely and it was clear that reducing these numbers could result in major economic benefits.

This line of research was continued and elaborated upon by Professor Aalt Dijkhuizen. In the early 1980s he wrote a doctoral thesis into the economic effects of common health problems in dairy farming such as mastitis, fertility problems and lameness. Later he carried out the first study into the economic effects of and control options for infectious animal diseases such as foot and mouth disease and classical swine fever. Pioneering research was subsequently performed into deepening and applying the theory of decision making under risk and uncertainty with respect to control strategies for infectious animal disease, of which the current Dutch Animal Health Fund is a direct result. Working with Professor Ruud Huirne, the Animal Health Economics group has become an international leader in this field and the associated field of risk management since the 1990s.

Wageningen economists Professor Aalt Dijkhuizen, Dr. Paul Berentsen and Professor Arie Oskam had already foreseen in the early 1990s that the opinion of the general public might become an issue in the debate on livestock farming. In 1991 they wrote: 'It is doubtful if the general public will allow the slaughter of animals without clinical signs of the disease.' Looking back, Dijkhuizen says: 'We sensed it. Why? Maybe because of our own close emotional connection with everything to do with animals and farming.'

In the late 1980s the Wageningen economists were invited by the Dutch Ministry of Agriculture, Nature and Food Quality to calculate the potential economic effects of the abolition of the annual vaccination against foot and mouth disease, especially on the export market. This calculation helped the Dutch government take a stand in the European Union's discussion on whether annual vaccinations should take place in all of Europe or not. 'We must remember that this primarily concerned the preventive vaccination of all cattle and pigs, not emergency vaccinations in case of an outbreak,' Dijkhuizen explains.

Their study showed that not giving preventive vaccinations was most profitable for the Netherlands, as was already the protocol. The most important reasons for this were: (1) maintaining the large Dutch dairy and meat export market and expanding export possibilities to markets such as Japan and Korea when gaining and retaining a disease-free status without the vaccinations; (2) annual vaccination campaigns do not make all cattle and pigs immune as animals are born all year round and are then added to the stock; and (3) the fact that, when a few countries in the EU did vaccinate preventively, the most recent outbreaks seemed to be related to the vaccine itself rather than being the result of infection via the field virus.

DIVA marker vaccine

There were many reasons not to vaccinate animals for infectious diseases such as foot and mouth disease, classical swine fever, avian influenza (bird flu) and Aujeszky's disease in the past, as vaccinated animals could not be distinguished serologically from animals infected in the field. The essence of marker vaccines is that the injected animal mainly creates antibodies for the virus components needed to fight the field virus. When contaminated with this virus, the animal also creates antibodies against other components which were not included in the vaccine. This offers a distinction between the animals infected by the field virus and those who are immune due to the vaccine.

The original idea for marker vaccines was developed in 1981 by veterinarian-virologist Professor Jan van Oirschot and further developed by him and many of his colleagues at the former DLO institute ID-Lelystad, the Netherlands. This DLO institute was merged with Wageningen UR in 1997 and is now known as the Central Veterinary Institute (CVI).

Marker vaccines received the international name DIVA (Differentiating of Infected from Vaccinated Animals). The technique was refined further with molecular-biological expertise available in Lelystad. Several DIVA vaccines are currently available in addition to the examples mentioned above. The CVI is currently working on the development of new vaccines against the feared Asian avian influenza (H5N1) which is spreading worldwide and can also lead to health problems in humans.

The DIVA vaccine is accepted globally as the way to control animal disease with vaccinations. The World Organisation for Animal Health (OIE: Office International des Epizooties) has adopted the concept from Lelystad in its disease control strategies.

Dijkhuizen says that these factors are no less relevant in 2008, especially concerning export. 'The Achilles heel of animal disease control is tracking and tracing risky contacts. If we cannot find out quickly and exactly the transport movements made and contacts by the animals and people involved, even emergency vaccinations have little or no result.'

In the Netherlands, the turning point for public opinion on livestock farming was marked by the Dutch outbreak of classical swine fever in 1997. This outbreak showed people how pigs were kept and served as a wake-up call. It was the first time that the management system of animals in the livestock sector was so explicitly discussed in society.

The social disquiet reached its peak when the Dutch government decided on the large-scale destruction of dairy cattle in a large area in the east of The Netherlands in 2001 after an outbreak of foot and mouth disease. The preventive cull of seemingly healthy cattle was highly emotive for both cattle farmers and the general public. There was great consternation about the apparently pointless destruction of healthy cattle, while farmers saw their meticulously built-up breeding lines disappear overnight. The impact of animal disease control on mental health was suddenly a factor of interest.

The outbreaks of infectious animal disease such as classical swine fever (1997), foot and mouth disease (2001), avian influenza (2003) and bluetongue (2006) have kept the Dutch livestock sector in the public eye for the past decade. Social indignation about the mass killing of animals as a response to disease outbreaks has led to the Dutch government lobbying in the international community for the acceptance of so-called marker vaccines. A marker vaccine allows animals contaminated in the field to be distinguished from those that have been made immune by vaccine.

Although calamitous, the disease outbreaks in the Netherlands also resulted in a wealth of information on pathogen characteristics and disease transmission. Based on extensive analyses, models were developed at Wageningen UR which will aid the Dutch government in choosing the right disease control strategies should new outbreaks occur in the future. The Ministry of Agriculture, Nature and Food Quality specifically uses the veterinary expertise at the Central Veterinary Institute in Lelystad (CVI) and Wageningen University's Animal Health Economics group concerning disease control.

More important than the disease control strategies are fast detection methods and early warning systems

Chickens being vaccinated against avian influenza

Below **Virus titration in laminar flow cabinet**

More important than the disease control strategies in case of outbreaks are fast detection methods and early warning systems to quickly detect diseases and nip them in the bud. The CVI is working on the development of such systems. The need to be alert was evident in 2006 when the CVI (then still called the CIDC) became the first institute in northern Europe to detect the bluetongue virus (BTV-8) with a fast test developed in Lelystad.

The outbreak of bluetongue, which was thought to only occur in more southern regions, emphasises the unpredictability of viruses. The Lelystad institute was prepared because emerging diseases have become a real threat due to the expected climate change.

This indicates one of the government's most essential tasks for the CVI. The Ministry of Agriculture, Nature and Food Quality attaches great significance to the scientific knowledge of the research institute. The CVI's expertise also plays an important part in animal disease control and the institute was appointed by the government as the organisation to formally determine infectious animal disease outbreaks.

The approach taken to imminent animal diseases that also pose a risk to humans is an increasingly important theme. As the Dutch government recognises the seriousness of this issue, research is being performed into the spread and behaviour of the avian influenza virus. The Asian bird flu virus (H5N1) has cost the lives of tens of millions of poultry in Asia. Several hundred people also died due to the virus: the threat of possible human transmission is reason enough on its own to control this disease.

Wageningen researchers are trying to develop a basic vaccine with the Faculty of Veterinary Medicine of Utrecht University and the Animal Health Service which can quickly be adapted to the active virus. Although the techniques available in 2008 have already proven to be effective, the vaccine's production time is too long to react adequately to a new virus. And speed is of the essence to both the livestock sector and humans.

This is one example of how the social impact of animal disease has also been important in Wageningen research. 'The public impact now plays a larger role here at Wageningen,' Dijkhuizen tells us. 'We are attempting to make models that include the psychological impact of animal disease, even though it will always be difficult to compare tears with euros.'

Cod fishing, North Sea

Below North Sea herring

The ocean's fish are becoming smaller and start breeding at an increasingly younger age. An article by a group of international fishery biologists in *Science* in 2007 reported that this is a direct consequence of our current fishing methods. 'The fisheries industry is changing the hereditary characteristics of the fish that feed us,' says research leader Adriaan Rijnsdorp of the Wageningen Institute for Marine Resources & Ecosystem Studies (Wageningen IMARES). 'It might take too long to repair these genetic changes.'

THE FUTURE OF SEAFOOD

Fish is a healthy food say nutrition scientists, while fishery biologists emphasise that the seas are at the point of being overfished. This is the complex situation in which scientists from Wageningen IMARES operate. Rijnsdorp started work in 1980 at the former Netherlands Institute for Fisheries (RIVO).

RIVO has been sampling fish caught by Dutch fishermen for decades. 'We noticed that plaice started breeding at an earlier age in the 1980s,' says Rijnsdorp, who wrote his PhD thesis on the phenomenon in 1992. 'It was a remarkable development as there were quite a lot of nutrients entering the North Sea from the rivers at that time. With plenty of food available in the waters, one would have expected first breeding plaice to get bigger. A more important factor, however, was that with the heavy fishing smaller fish had a greater chance of escaping the nets and those smaller fish passed their genetic characteristics onto the next generations.'

Fish is a healthy food, but the seas are at the point of being overfished. This is the complex situation in which we operate

Darwinian debt

As part of a larger international project, Rijnsdorp resumed the project in 2000. Using eco-genetic models, the changes in sole and plaice from the North Sea were studied. 'Our results showed that our current fishing methods are building up a 'Darwinian debt',' Rijnsdorp explains. 'According to our models, this means that fish genes are changing rapidly. The fish will quickly decrease in size and, unfortunately, reducing the pressure of fishing will not necessarily result in the fish reverting back to their old sizes.'

The fisheries sector should work more intelligently as well as less intensively, continues the biologist. 'There are no simple solutions to this problem, but we think that our expertise can help find solutions. In the period that plaice breed, for instance, the fish gather in the southern part of the North Sea, including many more sizeable specimens. Fishermen should leave the fish undisturbed at this time and in that region. If they do fish, they catch a relatively high number of large specimens and prevent these larger fish from spreading their genes. After the breeding season, these specimens can avoid fishermen's nets more easily.'

Right **Beamtrawler**

The ideal situation would be to make farm fish vegetarian

Aquaculture

Intelligent fishing can play a major part in solving the oceans' ecological problems. But a common question is whether we should stop fishing altogether and switch to fish farming. 'This would only be part of the solution,' says Professor Johan Verreth, head of the Aquaculture and Fisheries group.
'The UN Food and Agriculture Organisation predicts that we will be eating more farmed fish than caught fish by 2030. The fisheries industry will never really disappear, however. In fact, intelligent fishing is a good thing because it contributes to a healthy ecological management of the oceans. Nonetheless, aquaculture will become the most important source of the fish we eat.'
The demand for fish is still growing and the gap between supply and demand increasing. At the same time, consumers are demanding sustainable fish and this poses a huge challenge to scientists.

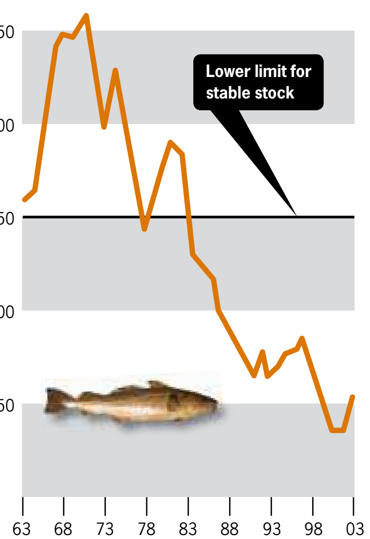
Sustainability is a multifaceted concept and there is no single solution. Consider fish feed, which contains large amounts of fish meal and fish oil produced from caught wild fish. Although the ideal situation would be to make farm fish vegetarian, this would not be a logical development: in evolution fish did not have to adapt to a vegetable diet. Fibres (non starch polysaccharides, NSP) that are abundant in plants are not easily digested and result in the production of slurry that has negative effects on the environment.

Scientists from the Aquaculture and Fisheries group have discovered that grain fibres have very different effects on fish, depending on species and nutrition habits. Grain fibres increase the viscosity of the chyme in the intestines, improving the consistency of the slurry. 'This was an important discovery,' Verreth explains. 'If the slurry does not immediately fall apart in water, it can more easily be filtered and the farm water stays clean.'

Contrary to typical carnivore seafish such as sea bass or salmon, in tilapia NSP was partially fermented and led to a deterioration of the slurry consistency.
In short, the desired replacement of fish meal by vegetable ingredients can sometimes lead to an improvement but equally often to a deterioration of slurry quality. 'The research does show, however, that feed composition influences the physical quality of slurry and does therefore have a role to play in the further development of production systems. Our goal is to produce farm fish with as little residual waste and water use as possible.'

Cod stable stock

North Sea cod x 1000 ton



Source: ANP

Beamtrawl fishing

In 1999, the institute now known as Wageningen IMARES published a report that took the Dutch fisheries industry by storm. Author Han Lindenboom proved that the damage from Dutch fisheries to the Dutch coastal areas was 100,000 times greater than that being caused by the mining of gas and oil. 'And 100,000 was an understatement,' says Lindenboom. 'The current fishing methods have severely damaged the North Sea, where the seabed has been transformed into a ploughed-up plain in all but a few locations. Shellfish such as the ocean quahog are on the brink of extinction.'

According to Lindenboom, the cause is beamtrawl fishing. 'A net is kept open by a beam as it is dragged along the seabed, with chains following behind to unsettle the fish. Add in the fact that the North Sea is being fished intensively and that some areas are trawled by boats more than 50 times and you will understand the pressure the ecosystem is under.'

Lindeboom has for years been promoting the idea of having reserves in the North Sea that remain free from fishing. 'It looks like this might finally be happening,' Lindeboom says. 'At Wageningen IMARES, we are currently working on proposals for the Ministry of Agriculture, Nature and Food Quality. Brussels is also convinced that we will permanently destroy something special if we continue as we are.'

The logical solution to this problem is to start at the source and have fish produce less waste. For example, it is well known that the growth range among individual fish in closed farming systems is very large. Social behaviour (dominant fish eat the most) is usually given as an explanation, but there is no conclusive evidence that this is the case. The group's scientists have shown that the social hierarchy has very little impact and that a form of inherent feeding behaviour prevails. Fast eaters seem to be the most efficient animals: producing more growth with the same amount of feed.

This discovery has also introduced new perspectives for the further development of closed farming systems. Genetic differences can be used in selection: a more homogenous group of fish in a rearing container with a more efficient feed system that results in less production of slurry and therefore reduced waste emissions. These valuable findings will help make aquaculture more sustainable.

Left **Cyanobacteri in the Volkerak lake**

Centre **Nitrogen molecule**

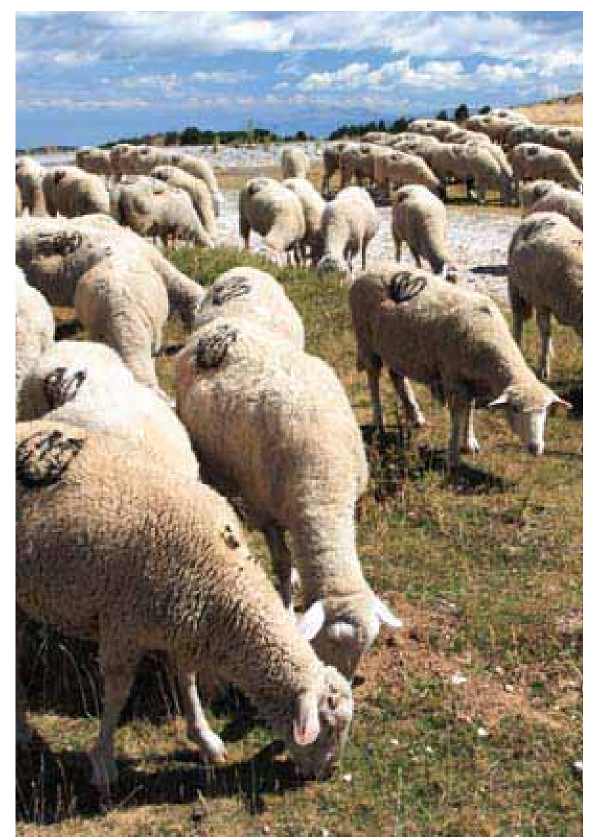
SURPRISING NATURE

Nature management has long been an important theme at Wageningen UR, involving far more than setting some piece of land or water aside as a nature reserve. An essential element is research into how ecosystems work and the ways in which they are affected by human activities. Nature management also demands a willingness to evaluate policy and act accordingly, which is why Wageningen UR prefers to use the term Dynamic Ecosystem Management.

Dutch lakes became turbid because of over-fertilisation

Unpleasant surprises

Why did an area with forests and lakes suddenly turn into the Sahara desert? And what caused coral reefs to suddenly be overgrown with brown seaweed? We are often presented with nature's unexpected and dramatic surprises. Professor Marten Scheffer of the Aquatic Ecology and Water Quality Management group at Wageningen University is studying such phenomena. Nature magazine published his research into 'Catastrophic shifts in Ecosystems' and in 2004 this Wageningen scientist won the Sustainability Science Award of the Ecological Society of America qualifying his research as an exceptional key contribution to this field for 'the greatest contribution to the emerging science of ecosystems and regional sustainability published in the past five years.' Scheffer himself was involved in research into the reasons for many Dutch lakes having shifted to a turbid state from which it appeared very difficult to recover.



He found that too many nutrients were entering the water due to overfertilisation. Although the increase in nutrients was gradual, the lakes turned turbid quite suddenly and a reduction in the nutrient levels did not make the waters clearer. Scheffers' research revealed that lakes have a 'tipping point'. Understanding the process required studying the organisms in the ecosystem, their interactions and reactions. The knowledge gained is now being deployed to manage and restore the Dutch lakes.
The next great challenge is to understand the tipping points in other complex systems, such as coral reefs, human societies and the climate. Scheffer is working on this together with ecologists, social scientists and climatologists: 'These systems are much more difficult to study than lakes and large-scale experiments are needed to gain insights,' he explains. 'However, the fundamental principles of tipping points are always the same and this gives us the chance to detect warning signals, even if we don't exactly understand how a system works.'

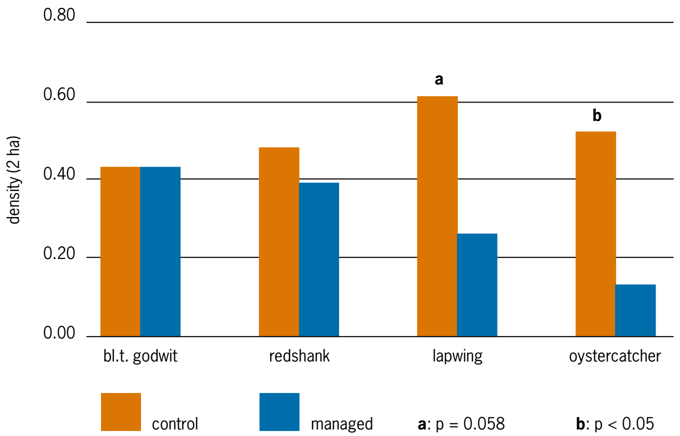
Solid ground

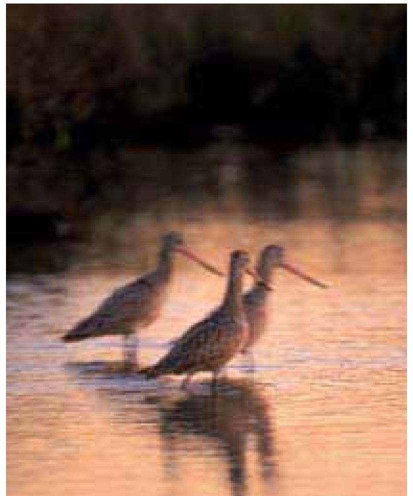
Professor Frank Berendse, who is specialised in the interaction between soil and plants, contributed significantly to the understanding of nature's sudden changes. 'In the 1970s, we noticed that heathland was grassing over at a rapid pace, threatening the existence of typical heath flowers such as the marsh gentian. At this time, the amount of nitrogen falling on heathland in rain was on the increase due to the Netherlands' growing livestock numbers. Grasses were benefiting and pushing out the heath.'
Berendse's research showed that the grasses were putting more nutrients in the soil, which allowed them to spread even faster and caused the entire ecosystem – also after only a small rise in nitrogen supply – to dramatically accelerate. The result was that many Dutch heaths turned into boring grasslands in just a few years. Berendse used this knowledge to create a computer model that calculated how much the nitrogen level in rain would need to be reduced in order to preserve the Dutch heathlands. These critical nitrogen standards remain a key element of Dutch and European environmental policies. The knowledge accumulated on plant-soil interactions was also used to understand the impact of climate change on tundra in the far north. The soils of these ecosystems store large amounts of carbon, which are estimated to

Agricultural nature management proved to be ineffective

comprise over 30% of the amount of gaseous carbon currently present in the atmosphere. The big issue is whether this carbon will be released as greenhouse gas if the temperatures rise and if it will therefore further accelerate global warming. By moving entire peat ecosystems from the north to the south with trucks, Berendse has now proven that climate change can have considerable effects on carbon storage in these environments. This was one of the first clear signs that we will have to take unexpected but fast changes in the north into account when predicting future greenhouse gas emissions and further climate change.
Berendse's name is even more often associated with his research into the effectiveness of management agreements with farmers. This type of agricultural nature management, in which farmers are compensated for changing their mowing methods, was established by the government to protect biodiversity in agricultural areas, especially concerning meadow bird populations. In 2001, the renowned scientific journal *Nature* published

Effects of management agreements on wader birds densities





Berendse's report that the management contracts were ineffective despite the millions of euros they were costing the Dutch government each year. These important findings were bad news for the agricultural sector, which saw part of its income disappear. It was also a setback for organisations campaigning on behalf of meadow birds, who were convinced of the effectiveness of the contracts. Despite the ensuing controversy and objections, the results were eventually accepted and government policy adjusted accordingly, so that now new perspectives arise for the restoration of biodiversity on farmland.

Eye in the sky

While scientists often study the earth close up, it can pay dividends to take a step back. The Laboratory for Geo-Information Science and Remote Sensing is equipped to do just that. Geographers, physicists, geometricians and mathematicians use the laboratory to obtain and apply geographical information.
Professor Arnold Bregt leads the Geo-Information Science research group. One of the remarkable projects in which his group is involved is correlating the information from the various public institutions that manage geographical data, both in a Dutch and a European context. Bregt says that it is unique to see so many institutions cooperate in making geo-information available and standardising it for many different purposes, including the development of climate models.
Geo-Information is often used for ecosystems management. Examples include the monitoring of logging in the Amazon region and the cooperative venture with the Dutch agricultural sector to apply GPS systems so that farmers can use pesticides more accurately.
The Remote Sensing department tries to obtain additional information from available satellites. High-resolution images are obtained by spectrodirectional imaging: analysing the direction and spectrum of the sunlight reflected by the earth and received by the satellite. This allows the height of plants to be

Above **Remote Sensing**

Left page **Black-tailed godwit**

measured and provides an overview of their growth pattern. This was used in Siberia, for instance, where the reduced period of snow is changing growth and where shrubs are growing in addition to grasses. This environmental shift can be observed from a great distance due to these techniques, which were partly developed by Professor Michael Schaepman.

Elephants and corn fields

Geo-Information Science is also used for very different projects. Take the work by tropical ecologists such as Professor Herbert Prins to predict where and when elephants end up in agricultural areas surrounding the Kruger National Park in South Africa. Prins, who is Professor of Resource Ecology, lived and worked in Africa for years and helped to develop a totally new approach to wildlife management: placing an economic value on the animal so that everyone benefits from a healthy population.

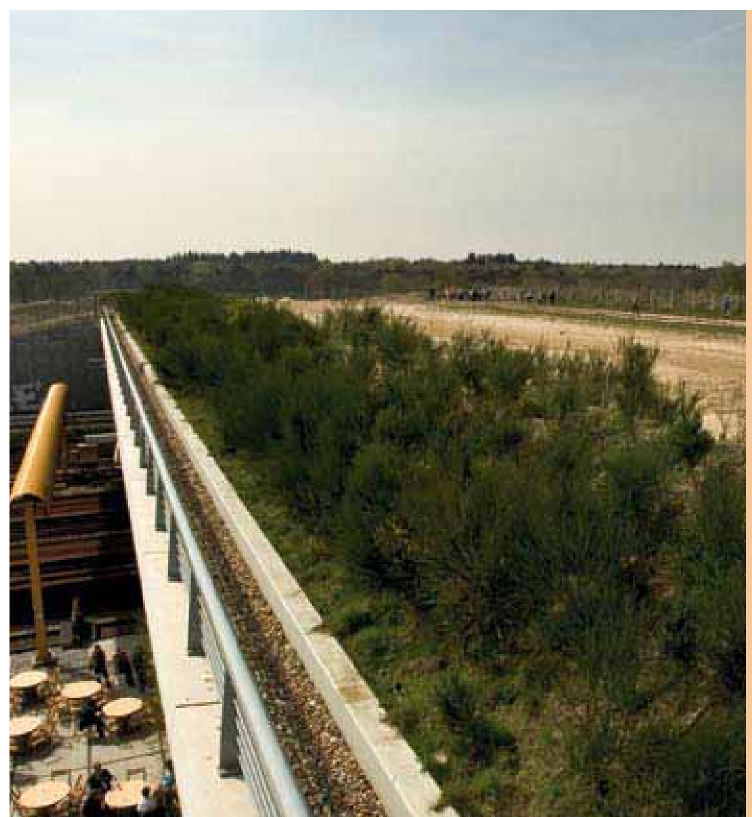
One of the main examples is the elephant. These amazing animals appeal to many people and are a popular subject for nature-lovers. One of the problems of these grey giants is the damage they inflict on the crops of farmers who live near nature reserves. An elephant trampling into a field can destroy an entire year's harvest in a matter of minutes. As it is virtually impossible to fence off a 27,000 square kilometre area, what can we do? 'Don't just think as an ecologist,' Prins says. 'Involve the entire (social) environment in the policymaking process.'

According to Prins, the problem in this case is that the elephant belongs to no one and damages cannot be claimed. As a result the fugitive resource plan was developed: the elephant belongs to the owner of the land it is on – either the nature reserve or the corn farmer. So how does this help the corn farmer? By cooperating with the entire village, the farmer can earn money by having the animal shot by a sports hunter who is willing to pay tens of thousands of dollars. An elephant is no longer a loss-making animal. A sports hunter is willing to pay considerably more than just the value of the ivory, even if the official value is much higher than what the villagers would have received had they let the elephant be poached illegally.

Now, villagers leave the land on the outskirts of the village undeveloped and grow corn close to villages. The result is more space for the animals, a growing elephant population and a local population which also benefits from the situation. In South Africa alone, commercialising nature management has resulted in a much larger privately protected landscape than all the national nature reserves combined. And village communities and white farmers enter into nature protection contracts with national parks, game viewing organisers and hotels. Prins, who has been the recipient of many awards, has made four films about his work with the BBC and National Geographic and is working on a fifth. In addition to his research into large herbivores, he has made a key contribution to the global development of nature management. In 1992, a major UN conference was dedicated to environment and development. The resulting treaty, the Convention on Biological Diversity, pledged to protect global biodiversity and named the ecosystem approach as the primary tool. Prins was asked to further explore this approach and dynamic ecosystem management was given the chance to flourish on a worldwide scale.

Nature can change at an exceptional pace. Policies aimed at the preservation of the world as we like it – clean, green and diverse – must be constantly evaluated and regularly adjusted. Wageningen UR has produced scientists who have proven to be up to the task: evaluating the situation objectively, coming up with creative solutions and fighting for what they believe in.

Elephant crossing the road for a drink



Below **Nature overpass Zanderij Crailoo**

Alterra and the National Ecological Network: resilience in Dutch nature

Alterra, the Wageningen UR research institute for a green living environment, has a significant influence on Dutch nature policies. An example is the cooperation with the Dutch Ministry of Agriculture, Nature and Food Quality to develop the National Ecological Network, one of the spearheads of the national Nature Policy plan since 1990.

The National Ecological Network consists of a series of interlinked nature reserves. Based on research by the former Wageningen Agricultural College, the plan aims to preserve biodiversity in the Netherlands. This includes reserving enough green areas and protecting them from the pressure of encroaching cities, growing traffic networks and the need for business space. Alterra is one of the parties involved in the realisation of the plans. As well as developing guidelines, this includes collaboration with various Ministries, provinces, city councils and coordinating organisations.

According to the Nature Policy plan, the National Ecological Network will be finished in 2018 and result in a cohesive network of nature reserves throughout the Netherlands. According to Professor Paul Opdam from Alterra, this will not be the end of the matter: the network should be seen as a tool to guarantee the existence of nature in the Netherlands. He believes that the protection of biodiversity will have to be redefined due to unavoidable changes in the surroundings: making way for change instead of striving for the preservation of original species in specific locations. Future nature policy should, subsequently, be aimed at resilient ecosystems that can adapt to unstable conditions.

Left **The Botley area of Oxford hit by severe flooding**

Below **Dutch coast after a sea level rise of seven metres**

PREDICTING CLIMATE CHANGE

Climate change has never been such a hot item in both the political and social debate. It is partly due to Wageningen environmental scientists that we know the land and its use plays such an important role in climate change. By emphasising the contribution of vegetation and the dynamics of land use, such as the impact of deforestation on the CO_2 cycle for example, they established an international orientation for the environmental and climate sciences.

Environmental scientists keep finding fresh evidence that the climate is changing and that humans are partly to blame. 'The robustness of climate models has increased,' says Professor Rik Leemans, Professor of Environmental Systems Analysis. 'When the United Nations Intergovernmental Panel on Climate Change (IPCC) first drew attention to climate change in 1990 with its first assessment report, the Netherlands was still attached to the UK in the applied models (using grids of 500 by 500 kilometres). Today we work with grids of 150 by 150 kilometres or less.'

The land has since been added as an influential factor in climate models, which can partly be attributed to the work of Wageningen scientists. 'Until around 1995, the models were mainly made by atmospheric physicists, meteorologists and oceanographers,' Professor of Earth System Science Pavel Kabat recalls. 'Some major developments followed in the five or ten years thereafter, including terrestrial processes and the addition of the interaction between vegetation, land cover and the overlying atmosphere as a complete element in climate models. Wageningen University was partly responsible for this development.'

According to Kabat, the reason that Wageningen played such a key role was its long scientific tradition in the field of hydrology and vegetation. Professors such as hydrologist Reinder Feddes and meteorologist Bert Holtslag, along with their research groups, garnered significant expertise on the way vegetation and land surface influences the turbulent atmosphere. This know-how allowed Wageningen to provide building blocks for the expansion and evaluation of existing climate models.

Vegetation and land surface influence the turbulent atmosphere

Current international climate research is building on this, and Wageningen UR often plays a prominent role. For example, Wageningen scientists have for years been pioneering the meticulous mapping out of land-bound emissions of greenhouse gases as part of a European measurement network. The purchase in January 2007 of a lightweight aircraft allowed Wageningen UR to take measurements on three levels: on the ground at a local level, via anemometer masts for the regional level, and in an aircraft for provincial and national levels. By taking simultaneous measurements at all three levels, scientists can accurately determine how much greenhouse gas is being emitted and use this information to make climate models more robust.
A similar measurement system can also be deployed to monitor emissions at a national level far more accurately than is now the case.

In addition to being a pioneer in the field of measuring greenhouse gas emissions from the surface, Wageningen UR is also a trendsetter in measuring gases absorbed and stored in forests or peat, the so-called sinks. Kabat: 'One of the first anemometer masts in Europe was located in Kootwijk, the Netherlands. Now there are 90 masts located all over Europe and several hundred around the world.' The scientists not only conduct research on the impact of peat in peat moors in the Netherlands, but also take many measurements abroad in large international research programmes. Examples of the latter are the impact of deforestation in Indonesia and the Amazon, and possible emissions should the enormous peat bog covered by permafrost in Siberia begin to defrost.

One of the main characteristics of the way Wageningen environmental scientists work is their strong leaning towards international cooperation. Professor Kabat, Professor Leemans, Professor Pier Vellinga and many other Wageningen scientists are regular contributors to the reports of the IPCC.
In December 2007, the IPCC and Al Gore have been jointly awarded the Nobel Peace Prize. Furthermore, Wageningen scientists often publish articles in renowned scientific journals such as *Nature* and *Science*.

A model provides the first-ever possibility of calculating the vulnerabilities to climate change

The international collaboration is also evident in the PhD programme of Wageningen University, in which many PhD students achieve practical and high-profile results. For example, Professor Holtslag, his colleagues and PhD students developed the Large Aperture Scintillometer, which allows researchers to measure the exchange of water and moisture between land and the atmosphere over distances of ten kilometres. These measurements can then be used by water managers and hydrologists to research the hydrologic balance in basins, by meteorologists to validate their climate models, and by remote sensing specialists to test their satellite data. This equipment has now gone into production.

Led by Leemans, PhD students in the internationally authoritative ATEAM project have developed a model which provides the first-ever possibility to calculate the vulnerability of sectors such as agriculture and tourism to climate change in various European regions. This is also being further elaborated upon in order to serve as a consultation tool for policymakers and politicians. Their publication in *Science* showed that the Dutch agricultural and tourism industries might well benefit from a warmer climate, but Alpine countries and the Mediterranean regions would suffer due to melting ice caps and drought.

Over the past decade, Wageningen environmental scientists in the Netherlands have mainly been applying the expertise they have developed in international collaborations to Dutch dilemmas such as the imminent rise of the sea level and its consequences for agriculture. The relationship between climate and land use also plays an essential role here. For example,the research programme 'Climate changes Spatial Planning' (CcSP), which is financed by natural gas profits and for which Wageningen is the co-ordinator, is specifically focused on ensuring the right knowledge is in place for making decisions on the future climate-resistant and climate-neutral position of the Netherlands. This also involves social and economic issues. In this context, environmental economist Professor Ekko van Ierland calculated that the Netherlands should invest tens of billions of euros in climate-resistant housing estates, adapting nature and creating space for the rivers.

Floating houses in Maasbommel: The houses rise at high tide

Below Time chart predicting first blooms of 2008

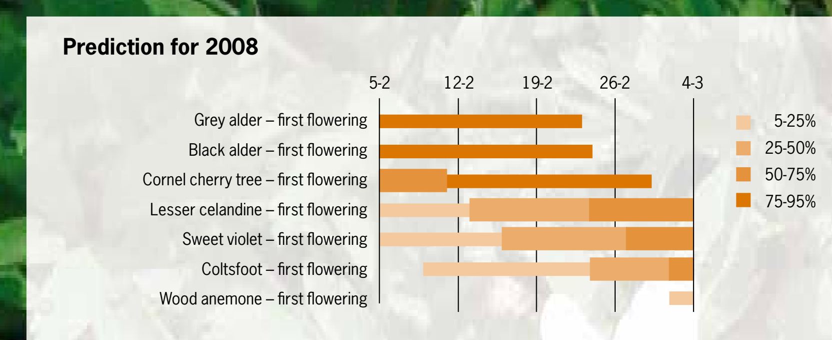
Evidently, meteorological aspects are no longer the only issue when it comes to environmental science, nor are emissions of greenhouse gases. 'It all revolves around an integrated approach,' says Kabat. 'And this fact has become accepted, even by politicians.' In the future, environmental research will also have to address more social-economic dilemmas. According to Kabat, issues that will have to be taken into account include environmental economy, the environment and urban & rural planning, and risk management.

Leemans adds to this list the discussion on bio-fuels and food security. 'In Wageningen it is evident that these things must be linked. Combining such issues is the growth market for the coming five or ten years and will require methods to link not only many different spatial and temporal scales, but simultaneously different levels of governance.' Attaining this interdisciplinary research is a must and all different scales as well as various interest groups should be included in environmental research.

It is also vital to continue to work on making the climate models even more robust, Holtslag believes. 'As the latest IPCC report shows, climate models have improved in many respects. But there are still major differences between observations and model calculations for continental regions above land and ice – especially during nights and winter. So we should keep working on these models. Thanks to a recently received subsidy from CcSP, the Netherlands now has a network of scintillometers available to validate models and satellite information.'

Nature calendar

The 'Nature Calendar' is one of the Wageningen UR projects known best by the general public in the Netherlands. Since project leader Arnold van Vliet sought out a large audience on the popular radio show 'Vroege Vogels' (Early Birds) in early 2001, thousands of people have sent in their observations of the first blooming snowdrop, brimstone butterfly or swallow. The database of observations that results from these contributions is used by scientists to monitor the effects of climate change, and to make predictions about the development of nature, to prevent things such as hay fever, and to sow and treat crops at the right time. This is a perfect example of give and take between science and society. See www.natuurkalender.nl (Dutch only).



MODELLING FOR IMPACT

Crop models, products of the *school of C.T. de Wit*, have made Wageningen famous worldwide. And these models were not just theoretical games – they have provided new insights into how crops perform in various conditions and how we can influence this. They have led to a series of models that are being used to understand system behaviour in research, predict harvests, inspire plant breeders and optimise cropping systems. Furthermore, they are ideal tools for education, land use studies and policy advice.

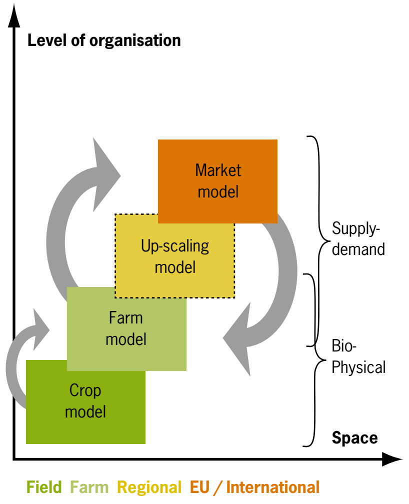
Professor of Theoretical Production Ecology Cees de Wit (1924-1993) became renowned in the 1960s for his plea for more efficient agriculture and the use of crop models to achieve that. University Professor Rudy Rabbinge is proud to be one of *De Wit's boys* (see sidebar on page 69), remembering his mentor as 'a great innovator of agricultural science' and 'the best and most innovative scientist we had in Wageningen.'
De Wit was the first to develop crop models based on physiological, physical, chemical and ecological plant processes with a team of young scientists. Until then, all these processes had been studied separately. The model enabled the integration of the knowledge of different disciplines. They allowed the yield potential of crops to be estimated in many different conditions and at many different levels. 'Based on my theory, it was predicted that wheat could produce 10,000 kilos of dry matter per hectare compared to the 4,000 kilos accepted at the time,' De Wit explained at the end of his career in the late 1980s. 'I was generally laughed at… Yet now the yield has reached 12,000 kilos.'

The first crop growth model, Elcros – Elementary Crop Growth Simulator – was presented in 1968 and was especially intended for research applications. Soon after, a number of models were developed based on Elcros, which also included complex relations concerning the use of light, micrometeorology, soil processes and interactions with diseases, pests and weeds. The models, named with acronyms such as Bacros, Sucros, Lintul, Wofost, Photon, Oryza, Swap and Intercom, were an international success.

'Models are instruments which can create a bridge between different levels of integration such as at the crop level and the underlying process level, such as photosynthesis,' explains Rabbinge, who took over from De Wit in the 1980s. Under his leadership, the crop growth model approach was widened and a number of descriptive, explanatory, summary and exploratory models were introduced. Rabbinge emphasises that every model is unique and can only be used at a limited number of scale levels. Some integrate processes at the level of plant, crop and cropping system, while other models focus on the farming system level or the regional level.

According to Rabbinge, exploratory models have the major benefit of being able to open policymakers' eyes and offer ways to work out scenarios. A good example is the *Ground for choices* report, published under his supervision by the Dutch Scientific Council for Government Policy (WRR) in 1992. This featured four elaborate scenarios for land use in the European Union until 2015.
'The report showed Europe's enormous production potential and that it would not be a problem to convert some of the agricultural acreage into nature without risking food production,' Rabbinge continues. 'Considering the 90 percent pesticide reduction, it would even be better for the environment. The report caused a great deal of controversy and made people realise that forcible land production is expensive and socially undesirable.'

The current Rector Magnificus and crop ecologist, Professor Martin Kropff also one of De Wit's students, says it was a revelation to come to De Wit's research group to study as a biologist from Utrecht in 1983: 'I had almost settled with the thought that everything was too complex and unpredictable in biology and especially ecology. It was a great experience to learn that behaviour of a relatively simple ecosystem as a crop can indeed be understood with models, as long as you make sure that these models are based on accurate descriptions of underlying processes and evaluated with experimental results. Models bridge the gap between experiment and reality.'
He later experienced this in practice when working at the International Rice Research Institute (IRRI) in the Philippines. Operational between 1985 and 1996, the SARP (Systems Analysis and Simulation in Rice Production) programme was a significant example of the value of systems approaches and modelling. According to Kropff, who was one of the programme leaders, SARP had a major impact on fundamental and applied rice research in Asia. Together with Wageningen and IRRI, a network was developed of more than 100 scientists who cooperated in 14 interdisciplinary teams in nine Asian countries,

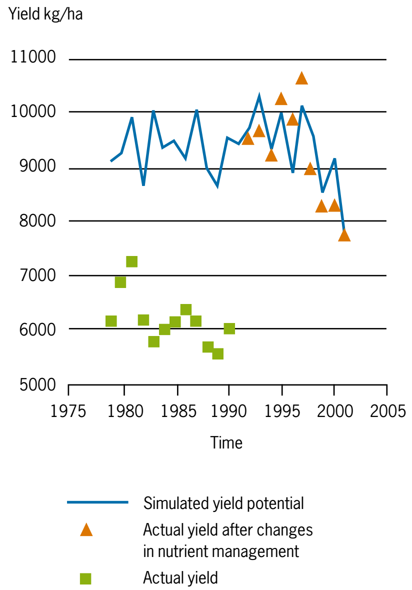


Analyses with SEAMLESS-IF can be done at multiple scales and with varying time horizons

Left page **Rice seedlings**

Above **Wheat**

Rice yields 1979-2001
of the International Rice Research Institute (IRRI) farm



including India, China, the Philippines and Indonesia. The models were developed and used in studies on issues such as improved crop protection and nutrition systems, rice plant breeding by design, cropping systems optimisation and climate change effects on rice in Asia.

The Wageningen-based rice models (the later Oryza series) turned out to be very accurate in predicting rice yield potential. A good example was the study of Kropff and Cassman in the early 1990s, which predicted with models that yield potential was still around 10 tons of rice per hectare. In reality, yields at the IRRI farm had gradually declined from 10 t/ha in 1964 to about 7 t/ha in the 1980s. The modelling studies showed that in continuous rice cropping systems, more nitrogen was needed than had been observed in the 1960s. With better nutrition (more nitrogen), the yield potential was re-established at more than 10 t/ha as illustrated in the figure on the left.
The SARP network was also used to predict the impact of climate change on rice production in various Asian countries. The study resulted in a joint book that was the basis for rice studies in reports of the UN Intergovernmental Panel on Climate Change (IPCC) in the 1990s.
Kropff cites the above as an example of how models can provide an opportunity to explore systems behaviour quickly and cheaply. 'This allows ideas to be generated that might otherwise have been missed. And models can also help in crop control. In Dutch greenhouse agriculture, models developed by Wageningen scientists are used to optimise the greenhouse climate and improve control of the production of horticultural crops such as tomatoes.'

A relatively new feature is the development of virtual plants, in which growth models are given information on the spatial development of crops. For example, the Netherlands Organisation for Scientific Research (NWO) has recently granted a so-called Veni grant to a Wageningen scientist to map the potential of crops to adapt to their surroundings using three-dimensional growth models. According to Kropff, models are of priceless value to education because they provide insights into the functioning of complex biological systems. Crop models are increasingly used in combination with water, soil, weather and climate models, creating an opportunity to further calculate scenarios.
The European research project SEAMLESS – System for Environmental and Agricultural Modelling; Linking European Science and Society – takes this a step further. To develop a set of instruments for fast calculation of the consequences of policy measures on sustainability, crop models are also combined with economic and social models.

Wageningen scientists develop models that are used for land use studies to improve the control of the production of crops

Dr. Martin van Ittersum, who is coordinating this consortium of 30 institutes from 15 countries, compares SEAMLESS to a pyramid. 'Everything comes together at the top and there we see the European and global effects. Its base still consists of crop and other bio-physical models. Sometimes they have different names or shapes, but De Wit's contribution is still often found at the core.'

In SEAMLESS, researchers ensure an accurate combination of data and models to estimate indicators. They also present indicators in a very visual way, such as maps, web charts or histograms. 'Eventually this should lead to a sort of dashboard on which you can see at a glance all the possible consequences of policies at various scales,' Van Ittersum says. Currently a prototype is being used but by 2009 SEAMLESS aims to present a working set of instruments for two policy applications: proposals for liberalising agricultural policies and the effect of the European nitrate guidelines. Van Ittersum also emphasises the merits of models in research and education. 'Everyone speaks of the importance of interdisciplinary collaboration and models are a great instrument to accomplish this. They facilitate genuine integration of scientific disciplines on the work floor.'

C.T. de Wit

As one of the first agricultural scientists, De Wit used computers and dynamic models previously deployed only by economists and physicists. Shortly after achieving his PhD in 1953, De Wit came to work for the predecessor of the Centre for Agro-Biological Research (CABO), an institute of the Dutch Department of Agricultural Research (DLO). In 1968, he also became a Professor of Theoretical Production Ecology at the Agricultural University. His publications on competition between plants and the meaning of photosynthesis for crop growth are considered classics by agricultural scientists. Besides several honorary doctorates, De Wit received the Wolf Prize in Agriculture in 1984, the highest prize awarded in agricultural science.

Agriculture was De Wit's passion, especially when it involved the inadequate food situation in Third World countries. 'I think that the agricultural problems encountered there are more interesting than those in the Netherlands. All we are doing here is solving luxury problems,' De Wit explained in one of his last interviews. 'C.T. de Wit believed strongly that science cannot work in isolation and has major obligations,' adds his successor, Professor Rudy Rabbinge. 'We must pursue science not just out of curiosity but also because of social commitment. Eight hundred million people are starving and yet there is an abundance of food. De Wit wanted to do something about this.'

Thanks to De Wit's models, it was possible to untangle the complex process of crop growth and quantify the processes step by step. This allowed for quantitative statements on the potential production of crops and the limitations resulting from water and nutrient scarcity. His ideas inspired agricultural scientists such as Rudy Rabbinge, Frits Penning de Vries, Jan Goudriaan, Herman van Keulen and Martin Kropff, as well as creating a school: The C.T. de Wit Graduate School for Production Ecology & Resource Conservation, which trains young Wageningen PhD students to become skilled scientists.

ALLIES ON DEMAND

Biological warfare in modern greenhouses: predatory mites on the hunt for the harmful spider mite, parasitic wasps lay their eggs in plant-eating whiteflies… Currently there are over one hundred species of natural enemies being sold for the biological control of many diseases and pests in both greenhouses and fields. Specialised breeding farms supply these *allies* to order and export them the world over.

Thanks to advances in biological pest control, the need for farmers and market gardeners to use chemical pesticides is decreasing. Very few pesticides are now used in Dutch greenhouses, offering a clear and visible example of high-quality scientific research that has direct social consequences. The Laboratory of Entomology has played a pioneering role in this process.

Professor Jan de Wilde (1916-1983) was one of the first to research alternatives to common chemical pesticides. He led a fundamental study into the physiology of insects and insect-plant relationships, giving Wageningen entomologists an excellent reputation worldwide. Professor Joop van Lenteren, head of the Laboratory of Entomology from 1983 to 2003, further explored pesticide alternatives at an ecological level. Van Lenteren received the prestigious Royal Shell prize in 2005 for his ground-breaking research into sustainable crop protection. The jury described his work as a ‘superb knowledge export product’. The Shell prize of 100,000 euros is the largest Dutch scientific award in the field of sustainable development and energy.

Left **Parasitic wasp laying eggs in a caterpillar**

Below **White fly laying its eggs underneath a leaf of a tomato plant**

An entire army of predatory insects and parasitic wasps have been keeping plant eaters in check for millions of years

Sustainable crop protection

The Laboratory of Entomology has been performing fundamental and applied research into sustainable crop protection for more than 30 years. The concept imitates nature: although plant-eating insects can strip crops bare, the world around us remains green. An entire army of predatory insects and parasitic wasps supplemented by pathogens such as fungi, bacteria and viruses have been keeping these plant eaters in check for millions of years.

Practice-based and fundamental research was needed to select, breed, package, transport and deploy these natural enemies optimally for (greenhouse) farming. This has led to many regularly quoted publications in *Science*, *Nature* and other renowned scientific journals. In 2006, Joop van Lenteren, Marcel Dicke and Louise Vet were the first Dutch scientists to receive the prestigious British Rank Prize for Nutrition for their research on multitrophic interactions (90,000 euros).

‘We have accumulated considerable expertise on the organisational patterns of communities,’ Professor Marcel Dicke tells us. ‘Our research revolves around the question of how crops protect themselves from their attackers and how natural enemies then attack the crops’ attackers.’

Dicke is a pioneer in the field of so-called tritrophic interactions. These are interactions between three nutritional levels: plants, herbivores and the herbivores’ enemies. He made his first revolutionary discovery around 1986 when he proved that some crops not only use toxins to prevent being eaten, but that in emergencies they also emit special aromatic substances as pseudo-SOS signals to attract the enemies of their enemies.

‘This all happens on the principle that my enemy’s enemy is my friend,’ Dicke explains. ‘Although crops cannot see or talk, chemicals make communication between crops and insects possible. We want to know which substances are used to communicate. Plant breeders can use this information to their advantage and develop more resistant crops, which could, for example, emit a louder cry for help.’ In his work, Dicke brings together expertise on a molecular and an ecological level. His findings have served as the basis for a new area of ecological research, called molecular ecology.

In 2002, The Dutch Organisation for Scientific Research (NWO) granted Dicke a Vici-subsidy of 1.25 million euros to set up a new research group. Five years later, he was awarded the acclaimed Spinoza prize. 'Ecosystems will change drastically in the coming years. Climate change and the northward movement of climate zones will result in new communities. Some organisms will move North and spread out more quickly than others, and new pathogens and natural enemies will appear. Take a look at the dramatic consequences of the bluetongue virus, for example, which recently moved North from Africa and is being spread among sheep and cows by biting midges.'

Another example is the tomato yellow leaf curl virus, originally from the Mediterranean region, which is transmitted by the tobacco whitefly and has spread worldwide in the past few decades. The tobacco whitefly can be easily controlled with biological measures. 'But when it is carrying that virus, it becomes much more difficult,' Dicke remarks. 'Changing climate leads to important new research issues. We must invest in fundamental knowledge now in order to be prepared for changing circumstances in the future. We are going to extend our area of research to the environmentally-friendly control of animal diseases: finding solutions for chicken mite in the poultry industry, for instance, which has become resistant to all common pesticides and is causing major problems.'

Spinoza award for Marcel Dicke

In 2007, entomologist Professor Marcel Dicke (1957) became the first Wageningen scientist and the first ecologist to receive the prestigious Spinoza award, the highest Dutch science prize. He was awarded the 1.5 million euros prize for his multidisciplinary research into the molecular ecology of plant-insect interactions. Dicke discovered that, as soon as they were under attack from aphids, caterpillars or mites, for example, crops produce special attractive odours that serve as SOS signals to round up a team of 'bodyguards': natural enemies of the attackers. The study can help plant breeders to grow new varieties that can better protect themselves against insect damage and consequently need fewer chemical pesticides. The jury called the research 'outstanding, pioneering and inspiring'. Dicke will use the prize money to research the influence of climate change on the alarm systems of plants, both in the laboratory and in the field.

Enormous learning capacity

In recent years, the connection between above- and below-ground relationships has also received a great deal of attention. 'People used to see these as two separate worlds, but this is not the case at all,' says evolutionary ecologist Professor Louise Vet. 'Volatiles produced by plants above ground can change as a result of insect damage underground.' Vet is Adjunct professor at the Laboratory of Entomology and, since 1999, director of the Netherlands Institute of Ecology (NIOO-KNAW), where she has strongly encouraged research into multitrophic interactions.

Research has shown that despite the small size of their brains, insects have a surprisingly high 'learning' capability. This includes adjusting their behaviour based upon previous life experiences. Vet: 'Parasites are very clever and can constantly adapt, partly due to their comprehensive learning power. Parasitic wasps are quick learners: they recognise the SOS odour emitted by plants and are attracted to it. If this behaviour is successful and their effort is rewarded, they learn to perform the same trick even more quickly and effectively the next time.'

This associative learning capacity enhances their hunting efficiency. This means that they are not only useful in farming; parasitic wasps could in principle be taught to trace all sorts of explosives in the fight against terrorism or find survivors in rubble, for example following an earthquake or an accident at a nuclear power plant. Various institutes around the world are currently working on promising research in this field.

Vet's Entomology group carries out fundamental research into hunting and parasitising behaviour and the life cycle strategies of insects. 'We analyse the selection pressure that has been responsible for the evolution of these organisms' characteristics. One of the things we examine is how natural enemies deal with variation in the spatial distribution of herbivores and their host plants, and how they adjust their foraging decisions and life cycle strategies.'

There are many lines of approach to this study. Some of the variation of these characteristics is determined genetically. 'We study cognition in parasitic wasps from genome to behaviour,' Vet continues. 'How do they learn these plant odours, which parts of the brain and which neurons are involved, and which genes play a part in learning processes? We use the fully mapped genome of the fruit fly and the honeybee to identify the relevant genes, measure their expression and compare this with species that learn well and those that do not.'

'Some organisms will move North and spread out and new pathogens and natural enemies will appear'

Left page **Clutch of cocoons of the parasitoid Cotesia glomerata on cabbage**

Above **Parasitic wasp**

Left **Malaria mosquito on human skin**

Right page **Willem Takken**

A combination of odours will lure malaria mosquitoes away from houses or huts

Resistant malaria mosquitoes
Some insects cause major health problems, such as the malaria mosquito, which is studied extensively at Wageningen University. Worldwide, two people die of malaria every minute. The increasing resistance of mosquitoes to commonly-used malaria medication only serves to underline the urgent need for finding new solutions. The Laboratory of Entomology is following several different avenues to achieve their goals. Professor Willem Takken's group carries out practice-based research with U.S. and African partners, and is supported financially by the Bill and Melinda Gates Foundation. They are searching for a combination of odours that will lure malaria mosquitoes away from houses or huts.

In cooperation with British and Tanzanian colleagues, Wageningen entomologists published two articles in *Science* in 2005. This research unveiled a new method to fight adult malaria mosquitoes biologically, by infecting them with a fungus that is specifically pathogenic for insects. Moreover, this fungus slows down the development of the malaria parasite within the mosquito. Locals can grow these fungi themselves inexpensively, and hang fungus-impregnated cloths indoors. A malaria mosquito that lands on such a cloth will become infected and weakened to such an extent that it barely has the strength to bite people. This is the first time that a pathogenic fungus has been used against adult mosquitoes.

Takken expects that the above methods will be applied together, for example by attracting mosquitoes to a place where they can be infected by fungus spores. Field research into this option is currently underway in Tanzania, Kenya and Ghana.

'Since the publication in *Science*, we have put even more people onto malaria research,' Dicke reveals. 'My colleague Bart Knols is now trying to make these methods more efficient, as well as cooperating closely with the local population in West Africa to implement these measures. After all, smart technological solutions must also be suitable in a societal context. Luring the mosquitoes away is one method, fighting them with fungi is another. Malaria is a many-headed monster and if there is something we have learned in the past decades, it is that there is not one single, perfect weapon to fight it.'

A malaria mosquito that lands on a fungus-impregnated cloth will become infected and weakened

Left page **Seed breeder checks bags of grass seed**

Below **Santana apples suitable for people with light apple allergies**

With a kilo of tomato seeds being worth four times as much as a kilo of gold, the international trade in seeds and other plant production materials is worth a fortune. Thanks to a good marriage between science and industry, the Netherlands has a multi-billion-euro income from seed-potatoes, flower bulbs and vegetable seeds.

HIGHLY VALUED SEEDS

The biggest money-spinner of Wageningen's intellectual property is not a complex technological patent but plant material. For example the Elsanta strawberry and the Elstar apple were major successes for Wageningen after the Second World War. Crop breeding was one of the most important research areas from the outset for the then Agricultural College.

Until WW II, the Institute for Plant Breeding was mainly practically-oriented, and geared towards developing new varieties. This changed after the war as industry took over this role using plant breeders mostly educated at Wageningen. To prevent false competition, Wageningen started focusing on breeding varieties that were not yet explored by businesses, such as the strawberry. Material such as potato was developed and made available to breeding companies for long periods of time at low costs.

As a result, Wageningen was more of an educational resource for plant breeders than anything else. Professor J. Sneep taught many generations of plant breeders and the research facilities of Dutch plant breeding companies are still filled with his graduates. In the 1970s and 1980s, research into new breeding techniques was added to the curriculum. Wageningen breeders developed, among other things, new techniques for complex cross-fertilisation.

In the late 1980s, Evert Jacobsen introduced bio-technology to Wageningen's programme of studies. Today we cannot imagine laboratories of plant breeding companies without genomics and other bio-technological research methods.

For the past few years, the breeders of the DLO institute Plant Research International and the university's laboratory for Plant Breeding have been operating under one roof, led by Professor Richard Visser. This has created a platform for a wide range of research, from fundamental to applied.

Left page **Elstar apples**

Below **Arabidopsis thaliana (thale cress)**

The Dutch combination of science and industry turned out to be very fertile. Where other countries kept the breeding of new plants within the public domain, Dutch breeders built up a strong position on the global market.

The Netherlands is the largest global exporter of seeds and other plant production materials. A quarter of the international seed trade originates from the Netherlands. The export value of these plant production materials adds up to 2.5 billion euros, making the Netherlands a larger exporter than the United States and France, its closest competitors.

Dutch breeding companies spend more money on research and product development in relative terms than the pharmaceutical industry: fourteen cents of every euro earned is re-invested. Part of the investments are made by several companies together: at the Centre of Biosystems Genomics, scientists from the universities of Wageningen, Utrecht and Amsterdam partner with 15 Dutch breeding companies. One of the things the centre is working on is further fundamental genomic research of the potato, tomato and thale cress. This latter crop is the model plant for plant geneticists (see sidebar).

The Netherlands is the largest global exporter of seeds and other plant production materials

The potato has long been an important plant to Dutch breeders and, therefore, Wageningen scientists. Last year, Wageningen UR received ten million euros for researching a potato that is immune to the phytophtora disease. Battling this disease has been a problem for farmers and scientists for more than half a century. The fungus-like organism which causes the disease is extremely flexible genetically and constantly breaches the resistance in potato strains.

With the aid of genetic modification, Wageningen researchers now want to create a new strain that will remain resistant to the disease for years. They will be using genes from plant species with which the potato can cross-fertilise naturally (cisgenesis).

Technological institute Green Genetics, which was granted 20 million euros by the Dutch government, is a step closer to practical breeding. Wageningen UR and Plantum NL (the Dutch association for breeding, tissue culture, production and trade of seeds and young plants) budgeted a similar amount for applied research. Green Genetics strives to develop knowledge that can be immediately used by participating companies. The institute, established in 2007, aims to deliver four patents a year and generate three percent additional turnover for the associated businesses. This fits in completely with Wageningen's entrepreneurial tradition.

Maarten Koornneef, one of the founders of model plant research

It is an unsightly little plant, the Arabidopsis thaliana, also known as thale cress. And yet it has become the model plant for geneticists. Wageningen scientist Maarten Koornneef helped lay the foundation for the weed's unexpected status. When Koornneef started his doctoral research in 1976, the interest in thale cress seemed to be diminishing. After WW II, the plant had attracted the attention of plant scientists: thale cress is relatively easy to grow, provides quick results, and a new generation is produced within six weeks. But the plant's biggest success was still to come. When Koornneef took office at Wageningen, he discovered a solid research foundation and plenty of expertise on the Arabidopsis in the department of Genetics. Koornneef and his students used the available knowledge to create the plant's first genetic map, published in 1983. Koornneef's research subjects include mutants of thale cress, which show deviations in their blooming characteristics or during dormancy, for instance. This provides a wealth of information on how the plant's processes work. Koornneef published many scientific articles on this subject. Most of them are available on www.arabidopsis.org, where information on the model plant is collected.

Koornneef's work is also highly regarded on the international stage. In 1998, he was elected a foreign member of the National Academy of Sciences in the United States, an honour that has been awarded to only a few Dutch scientists. Koornneef is also a member of the Royal Netherlands Academy of Arts and Sciences and a member of the European Academy of Science. In 2004, Koornneef took up the position of research director at the renowned Max Planck Institute for Plant Breeding Research in Cologne. He still works at Wageningen once a week.

Integrated pest management field excursion in the Netherlands

Left page, top **Avian Influenza project in Indonesia, serum research**

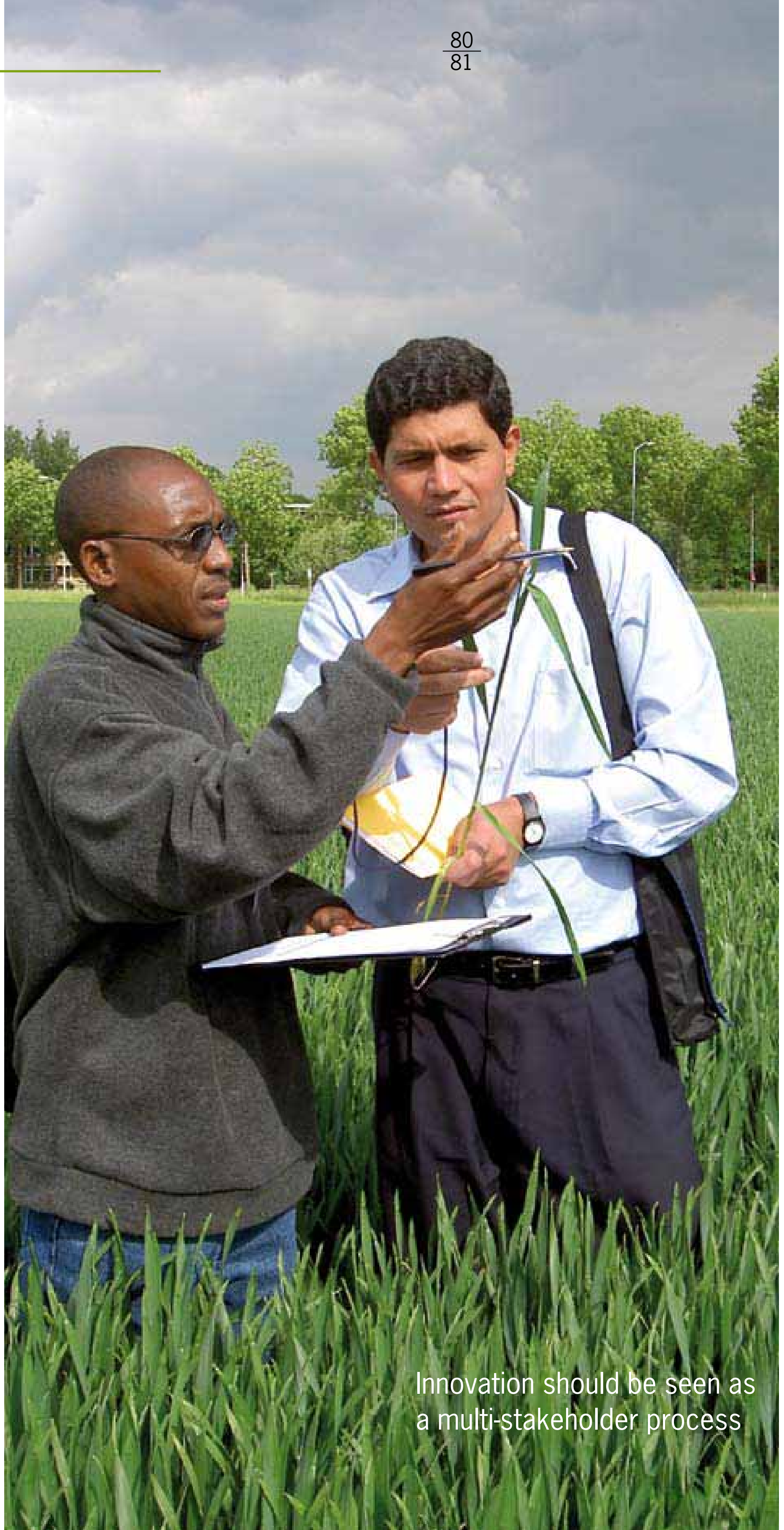
Left page, centre and below **Course 'Contemporary approaches to plant genetic resources, conservation and use'**

THE EMANCIPATION OF A DISCIPLINE

Identify and discuss the problems with those who are affected, then solve them in partnership with the economic and societal parties involved. It may seem obvious but applying these principles in real life can be very challenging. Nonetheless, this co-innovation approach characterises Wageningen UR's approach to communication in change processes.

The interest in co-innovation in networks results from a journey that started when Professor Anne van den Ban established the Extension Education discipline in the 1960s. The post-war optimism was still fresh in that period and people had a rather simplistic approach to stimulating innovation. 'Linear' as current Communication and Innovation Studies Professor Cees Leeuwis calls it.

In the early days, Van den Ban acquainted himself with the theory of American innovation guru Everett Rogers, who saw innovation as a factor brought into society from the outside – in other words from the scientific world – after which successful farmers could contribute to diffusion of the innovation. 'In the early years of Communication Science we had a rather mechanical and isolated image of communication processes,' Leeuwis said in his 2003 oration. 'We thought in terms of individual senders and receivers who exchanged messages (i.e. transferred knowledge) through channels and media.'



Innovation should be seen as a multi-stakeholder process

Doubts began to surface in the emancipatory 1970s. While Van den Ban emphasised the importance of concepts such as empathy (the sender seeks out the frame of reference of the receiver) and feedback (the sender checks whether he is on the right wavelength), communication remained a process in which one of the parties had a solution and tried to communicate this to the other as effectively as possible. What if the receiver misunderstood the message or did not understand it at all? Or what if the message was in no way relevant to the social environment and problems as they were interpreted by the receiver?

In the 1970s there was harsh criticism of development projects that aimed to bring prosperity but which also unsettled entire communities and made them dependent on ineffective trade channels. People started to understand that sending was not the only requirement for bringing about innovation – listening was equally important. A bilateral process was needed, with an equal role for the sender and the receiver.

Van den Ban's successors Niels Röling and Cees van Woerkum further extended the horizon. Röling zoomed in on the interaction between research, extension and users in so-called knowledge and information sys*tems*, while Van Woerkum went on to explore communication within policy networks and between organisations and their environment.

There was much more still to come as new dimensions were added to the equation. 'Innovation should be seen as a multi-stakeholder process,' asserts Dr. Jim Woodhill of Wageningen International, an enthusiastic advocate of what he calls social innovation. 'You enter into a partnership at different levels with a number of parties, including scientists, farmers, agricultural companies, supermarkets, governmental organisations – the entire production chain and the environment.'

Those who heard Van den Ban explain that extension sometimes involves simple, one-dimensional knowledge solutions might wonder whether such a multi-stakeholder process could only make the problem unnecessarily complicated. 'In the 1920s, many farmers in the Dutch province of Drenthe had problems with crop diseases,' remembers the 80-year old Emeritus Professor. 'The farmers were grateful when it was explained that they could solve this problem by using manganese and copper. This made their net economic returns rise.'

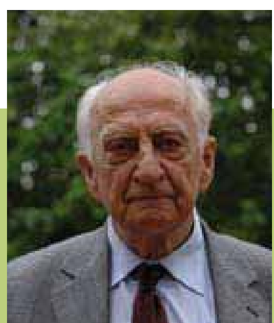
Left page **Co-innovation with Dutch farmers**

Below **Integrated pest management field excursion in the Netherlands**

Woodhill has a clear response. 'Many projects failed because complex problems were oversimplified. In most cases, we are dealing with multiple problems and solutions that might seem simple when regarded individually, but which can only be dealt with in an integrated fashion. Consider the development of organic agriculture in East Africa. This involves small-scale farmers who have to adapt their production methods and work together to produce the volumes needed by the exporters. These exporters in turn have to become interested in the new products and realise their export potential. Infrastructure facilities are required to transport everything and transport companies must pick up the produce. These are all simple problems in their own right but they have to be addressed simultaneously within a network of stakeholders involved. It only needs one piece of the puzzle to be missing for everyone to have a problem.'

We establish partnerships with parties who are looking for change

'Society has become more involved with agriculture,' says current Communication Professor Cees Leeuwis, broadening the discussion. 'There used to be more agreement that expansion and intensification were the way forward. Farmers could simply proceed. This consensus no longer applies and there is much more public debate on issues such as biodiversity, for instance. Today's problems cannot be solved only through technology and science. One has to take into account the wider societal structures of which they are a part.'



Anne van den Ban, pioneer in extension education

Generations of Wageningen students grew up with 'Introduction to Extension Education', Anne van den Ban's standard work of which 70,000 copies were sold in various versions and 13 translations. What began in 1970 as stencilled lecture notes became a published book in 1974. 'When I became a Professor ten years prior to this, the discipline did not exist. I taught classes on all sorts of subjects as I did not have an overview of the entire field.'

This characterises Van den Ban's role as a pioneer of the discipline which is now called Communication and Innovation Studies. Van den Ban, son of an agricultural public relations official, quickly became an authority in the field of agricultural innovation and change. Under his supervision, Van den Ban's department widened the field to include nutrition, health, environment and spatial planning; subjects which attracted more students than agriculture by the time he retired in 1983.
It was an early retirement: at the age of 55, Van den Ban wanted to go into the field – especially in developing countries of which he had then seen little. 'And I had very capable successors ready,' Van den Ban says. He visited 25 countries, gave advice and wrote about it.
In 2006, Van den Ban edited a collection of articles on transformations in agricultural extension in Asia with an Indonesian colleague. And a digital overview (http://library.wur.nl) of more than 300 publications in his name went online in February 2008.

So what is the role science should play, if not to provide solutions? 'In the past, science has often created solutions to non-existent problems,' answers Leeuwis without hesitation. 'Every problem involves an entire network and our job as scientists is to discover the critical questions within this network and subsequently look for answers.' Woodhill adds seamlessly: 'We establish partnerships with parties who are looking for change. Our role is then to play a facilitating role in transition processes.'

Over the past four decades, significant depth and a wealth of new insights have been added to the Wageningen communication sciences for which the foundations were established in the 1960s. This has resulted in better tools and communication strategies for catalysing change. As the founder, Van den Ban sometimes feels that his scientific descendants are at times a little too critical about the past: 'They sometimes forget that farmers also played an important role in innovation processes.' However, Van den Ban remains willing to offer advice. 'This has always been one of his greatest assets,' Leeuwis says. 'Van den Ban is a generous man who creates space for others.'

Competing Claims on Natural Resources programme in Southern Africa: action research between conflicting interests

Along with natural science colleagues and regional universities, Wageningen communication scientists are participating in a major research programme supported by the Wageningen Interdisciplinary Research and Education Fund (INREF). Under the banner of *Peace Parks*, several wild parks are interconnected to provide an enlarged living environment for elephants in Mozambique, Zimbabwe and South Africa. This development has had an impact on a lot of agricultural land and people, who now have to move to make way for migrating elephants. At the same time, the Mozambique government is aiming for a larger production of crops for biofuels, which could create an alternative for the farmers affected.
'There are many networks involved in this struggle for land,' Professor Cees Leeuwis explains. 'These include farmers and their organisations, park managers, tourism and governments at various levels. These parties negotiate with each other in several arenas. Joined by our natural science partners, we conduct research to improve the quality of those negotiations. This is important as a lot of information is lacking. You could call it action research, with a focus on clarifying the questions asked by the various parties. The resulting research will be focused specifically on finding new windows of opportunity, especially for those parties that have fewer opportunities in the process than others. Then we study the communication and dynamics within the network to see if and how the research results are being applied. Eventually this should teach us how science can be made relevant for these types of complex situations.' The research involves 12 PhD students from various universities in Southern Africa and Wageningen University.

WHAT CONSUMERS WANT

'You should listen carefully to customers, but don't believe everything they say.' This is one of the favourite expressions used by Hans van Trijp, Professor of Marketing and Consumer Behaviour. It is illustrative of the focus of his Marketing and Consumer Behaviour Group at Wageningen University.

Marketing strategy with a focus on the final consumer, his or her observable behaviour and new consumer motivations in the areas of health and sustainability. These are some of the key research themes for this group, which changed its name from Marketing and Marketing Research to Marketing and Consumer Behaviour in 2001 when Van Trijp took over from Thieu Meulenberg. 'This change of name simply reflected the direction in which my predecessor had been heading,' Van Trijp says. 'Meulenberg had an unrivalled ability to look 20 years ahead. I recently came across one of his presentations on changes in market and society and it was still fully applicable to today's market situation.'
In fact, as Van Trijp explains, it is precisely these changes that are reflected in the shifted focus of his group. 'After WWII, food was a scarce commodity in the Netherlands. Marketing was relatively simple and the emphasis was mostly on distribution: how do I get the product to where it is needed? This was especially important for perishable agricultural products.' As one of the first two Professors in this popular field of research, Meulenberg had a major influence on the standing of the former Wageningen Agricultural College from the

Left **A wide range of sensors in the lab measure how people evaluate the food they have been served**

Below **Knorr Vie vegetable/fruit drink contains 50% of the recommended daily intake of fruit and vegetables**

moment he started as a lecturer in 1965. As prosperity quickly increased and the Netherlands (prior to its membership of the EU) had a surplus of agricultural products, the college's position was further strengthened. This was also the time when the marketing approach made its breakthrough, with an emphasis on the four Ps: Product, Price, Place and Promotion.
Meulenberg was keen to apply and further develop this new marketing approach to agricultural markets. 'The increasing prosperity provided consumers with choice,' Van Trijp continues. 'This changed the focus of marketing from distribution and price fixing to promotion and product characteristics. And of course the issue of how sales of the abundantly produced products could be increased by means of the four Ps.'
Jos Jongerius of the Livestock, Meat and Egg Product Board remembers that Meulenberg's research group was a trendsetter in the field of market development analysis. 'We worked together often and intensively during this period of growth. The Product Boards had a lot of competitor analyses carried

out during the 1960s, 1970s and 1980s. After that came a time when we could no longer rely on growth and manufacturers increasingly had to concentrate on added value.'

'Western consumers want issues related to small-scale production, animal health and the environment to be taken into account'

This was also the period during which the role of the Product Boards as a collective client became much smaller, according to Jongerius. This was due to the fact that increasingly large agricultural concerns preferred to speak for themselves. Wout Dekker, CEO of animal nutrition company Nutreco, explains the effects of this transition: 'Although Wageningen has always had a major interest in production and production processes, this new area added a whole new dimension. Western consumers want issues related to small-scale production, animal health and the environment to be taken into account. At the same time there are still billions of people who are more concerned about getting some meat on their plates. And there is growing tension around the world between using land for agriculture or energy production. The goal for Wageningen UR is to find a balance between these developments.'

Dekker also puts into perspective the current consumer demands, which are of increasing interest to Wageningen marketing scientists: 'There is a key difference between what people say and what they actually do as consumers. They demand animal-friendly meat, but they still go to supermarkets to do their shopping three times a week.'
'When all products are of a reasonably good quality, people start making distinctions at a higher level in their need hierarchies,' Van Trijp confirms. 'The issues which have become more prominent in recent years are health, environment and sustainability. We call these 'credence qualities' because they often cannot be recognised in a product. These qualities need to be communicated, which brings in issues of trust and credibility.' Credence qualities, such as health, animal welfare, and sustainability are also quite sensitive to social desirability bias leading to a discrepancy between what people say and do.
This is one of the reasons why Van Trijp's group invests quite some effort into 'observational research', for instance in an experimental supermarket setting. 'Scientists always want to know what happens and why,' Van Trijp explains. 'We observe consumer actions and then ask in exit interviews, for example, why they did what they did. It is difficult research to perform as there are many variables involved – the trick is to separate these in your observation and analysis.'
Health claims and nutritional labelling are a prominent topic for this kind of experimental research. A recently published study, carried out with a number of major food companies, showed that consumers fail to distinguish the subtle distinctions that nutritional scientists and legislators make between different types of claims, such as: content claims, structure-function claims, health claims and disease risk reduction claims. Such studies have both marketing and policy implications. Other research focuses on the extent to which consumers are open to recent nutritional developments, such as personalised nutritional advice based on their genetic predisposition.
Food safety is another key focus area for the group, led by Professor Lynn Frewer. For the Dutch Food and Consumer Product Safety Authority (VWA), a consumer-confidence monitor was developed which includes a crisis module. This can monitor the development of consumer trust in the safety of food. In a project for the Dutch Ministry of Food, Nature and Food Quality, research was performed in 80 municipalities to see whether consumers would buy more organic products if they cost the same as conventional products. Prices in supermarkets in these municipalities were adjusted for 13 weeks so as to register the authentic purchasing behaviour of consumers.

'This is a key evolution from the time that Meulenberg was here,' Van Trijp concludes. 'He was more concerned with marketing structures and organisation, while we are now moving more towards consumers and their behaviour.'

Restaurant of the Future: focused on the consumer

A jewel in the crown of Wageningen UR's consumer research is the Restaurant of the Future, which opened its doors in the autumn of 2007. This special area on the new campus features a wealth of facilities designed to measure, observe and analyse the behaviour and experiences of consumers. 'It is unique to have so many research facilities in this area under one roof,' says project leader René Koster, who is currently busy handling the enormous worldwide media attention.

The Restaurant of the Future consists of a university restaurant and laboratories which can run at least five different tests simultaneously. While the restaurant offers a similar variety of meals and drinks as an equivalent eatery, the difference is that, after giving written consent, guests have all their movements and actions registered on camera for later analysis. Sensory research is performed in the laboratories: with the aid of numerous instruments, consumer reactions to product colour, smell and taste are measured. 'We don't measure what people feel or think, but what they actually do,' Koster explains. 'This is the only solid foundation for reliable predictions about their behaviour.'

Although the research being performed here is very complex scientifically, it can give direction to developments in technological and biological research. Examples include the breeding of different species or varieties and the design of processing techniques.

The Restaurant of the Future is a project by Wageningen UR in cooperation with software company Noldus, kitchen supplier Kampri, caterer Sodexho and a growing number of companies and institutions with an interest in these research programmes.

Thieu Meulenberg, one of the first marketing Professors

Wageningen became one of the growth centres of Dutch marketing research thanks in large part to Thieu Meulenberg, who became a lecturer in 1965 and one of the Netherlands' first marketing Professors in 1969. Meulenberg was the pioneer behind the marketing discipline at Wageningen, and from there contributed significantly to the further development of the field in the Netherlands and the rest of the world. In a tribute after his death in 2006, Adformatie magazine described him as an international authority in the field of marketing science. Many of his PhD students went on to become Professors both in the Netherlands and the USA. Among his many affiliations, Meulenberg was a long-time Crown Member of the Dutch Social and Economic Council (SER) and member of the board of leading dairy company Melkunie Holland and the VBA flower auction.

Are we open to developments such as personalised nutritional advice based on our genetic predisposition?

'When we are certifying shrimp farming companies, we focus on mangrove cutting in the coastal areas and the social conditions at the company itself,' reports the website of a large Dutch supermarket chain. Consumers are no longer surprised by terms such as sustainable, ecological or environmentally aware on the packaging of foodstuffs.

IDEALISM PUT TO WORK

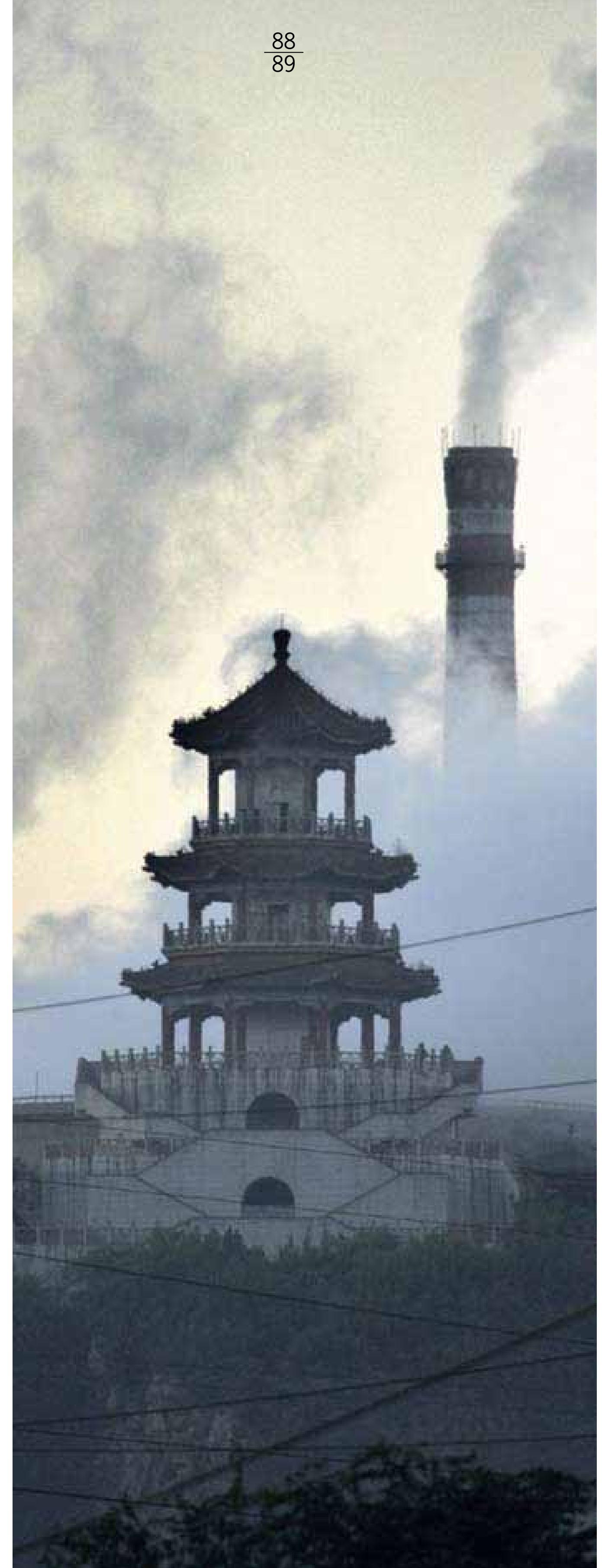
Almost without anyone noticing, environmental policies have made their way into Western kitchens and well-informed people are aware that their dinner choice has an impact on nature and society, both here and on the other side of the globe. Traditionally a governmental concern, environmental policies have spread out to the furthest corners of global markets and societies.

The website sentence is also the result of years of research, contemplation and discussion on how the sustainability principle can be effectively applied. Scientists from the Environmental Policy (ENP) group have made a significant contribution to this long-term process. The Wageningen UR sociologists, political scientists and social geographers have received international recognition for their part in developing the Ecological Modernisation Theory (EMT), which has had a huge influence on environmental policy at a global level. In addition to theory development, the ENP group also played its part in the introduction of the sustainability principle among Dutch and international government authorities, businesses, manufacturers and consumers. And this is why a review panel of independent international experts in the environmental field recently described the ENP as 'excellent and internationally authoritative.'

'Environmental problems demand a wider approach than merely supplying technological solutions'

Going green

The establishment of an academic department focused on environmental policy was the logical result of the activities of environmental authorities and the environmental movement in the 1970s and 1980s according to Professor Arthur Mol, head of the ENP group. 'In the 1970s, the former Wageningen Agricultural University had a major interest in threats to the environment from agriculture, industry and other forms of manufacturing. Traditionally, however, the main emphasis was on technological aspects and measures, such as wastewater treatment, waste disposal and process modifications. So while at a certain point we had the expertise and the technologies to solve problems, these were rarely effective in practice. Both students and Professors understood that environmental problems demanded a wider approach than merely supplying technological solutions.'



A pagoda stands at a power plant in Bejing

The consequence was a demand for social scientists that would primarily focus on the organisation and implementation of environmental policies related to governments, firms and farms, and citizens and consumers. The Environmental Policy Group (ENP) was born.
The development of new markets, products and technologies often places considerable pressure on nature and the environment. In the 1970s, the prevailing belief was that economic growth could not go hand in hand with the environment: nature protection was seen as a limiting factor for economic development. By the 1980s and 1990s, however, the idea had developed that economic and social improvements need not necessarily harm the environment and climate. But production and consumption then have to be fundamentally restructured and changed.
This insight is at the heart of the theory on which the ENP group based its research programme: the Ecological Modernisation Theory of Production and Consumption. In fact it is the scientific equivalent of the so-called Brundtland report (named after the chairwoman of the UN commission concerned), published in 1987 with the title *Our Common Future*. It was the first time that international politics spoke of the combination of economic growth and environmental care in both Western and Third World countries. The world quickly embraced the concept of sustainable development and there was increasing international interest in the scientific translation of this concept into the Theory of Ecological Modernisation, and ENP's role therein.

To the East

'The ENP group has been a leader in extending environmental policy research beyond national states and outside of Europe', according to Mol. 'After all, nature and environmental pollution do not respect territorial borders.' Mol and his colleague Professor Gert Spaargaren decided to dedicate themselves to involving global parties in research and policy-making related to sustainable development. Experience has been gained through major research projects in several Asian countries, including Vietnam, China, Thailand, Malaysia, Nepal and the Philippines. Sustainable fishing (see sidebar on page 91), industrial ecology in fast-growing industrial parks, cleaner agro-industry and environmentally-sound urban infrastructures have been some of the key research topics, always studied in collaboration with Asian partner institutes.

These projects have led to an extensive network of environmental and policy scientists, the Environmental Research Network Asia (ERNAsia), which was initiated and coordinated by ENP. The goals of this active network include building scientific capacity by means of exchanging PhD students and staff, organising conferences in the region, and joint research and education. Only by integrating Asian staff and students in their network, ENP gained the capacity, momentum and localised knowledge to apply its ideas successfully in an Asian context.

The ecological modernisation ideas of these Wageningen sociologists fell on fertile ground. With explosive growth markets, the interest in Asia in sustainable development is growing proportionally to the environmental pollution. The ENP group's concepts are having significant impact in this region, for instance in a recent influential study by the Chinese Academy of Sciences on the ecological modernisation of this (future) superpower. This two-volume report is largely based on the concepts of the Wageningen scientists, without them having been involved.

New challenges

Over the past decade, the ENP group has made a substantial contribution to a better knowledge and understanding of environmental policy around the globe. It functions as both a reflexive and a constructive research group, having a major scientific impact with the theories it developed, as well as with the empirical research and the construction of international, interdisciplinary networks for education and research into sustainable development. But the work is by no means finished. In East Africa, the group is currently working on pro-poor sanitation solutions, in cooperation with Wageningen environmental technologists and development economists. With colleagues from LEI and the Netherlands Environmental Assessment Agency, it is developing a new line of research concerning the greening of everyday consumption including food and food preparation, dwelling, tourism, clothing and mobility.

A new field of interest is biofuels: what happens to the environment and to the more vulnerable groups in society when land is used to grow energy crops for biofuel production? Consider, for instance, the natural habitat of orang-utans in Indonesia, which is rapidly shrinking due to jungle clearing to create agricultural areas for growing energy crops. And are the local Mozambique residents and small farmers benefiting from the large areas which are currently being converted to growing the energy crop Jatropha? Professor Mol : 'The interesting and pressing questions are who is responsible and accountable for these problems, and how can these be governed towards sustainable solutions? Should and can governments take the lead, or business, or NGOs, or a combination of these? Can this be handled in the framework of the WTO? And what does all this mean for consumers?' These kinds of new global challenges also ask for new social theories, currently being developed by ENP. There is enough food for thought and we will undoubtedly continue to hear from the ENP group in the future.

Inhacoongo C3 in Mozambique makes biodiesel from coconuts and nuts of the exotic plant jatropha (Euphorbiaceae family).

We should implement a sustainability label for fisheries

Below **Fish farm in Vietnam**

Gone fishing

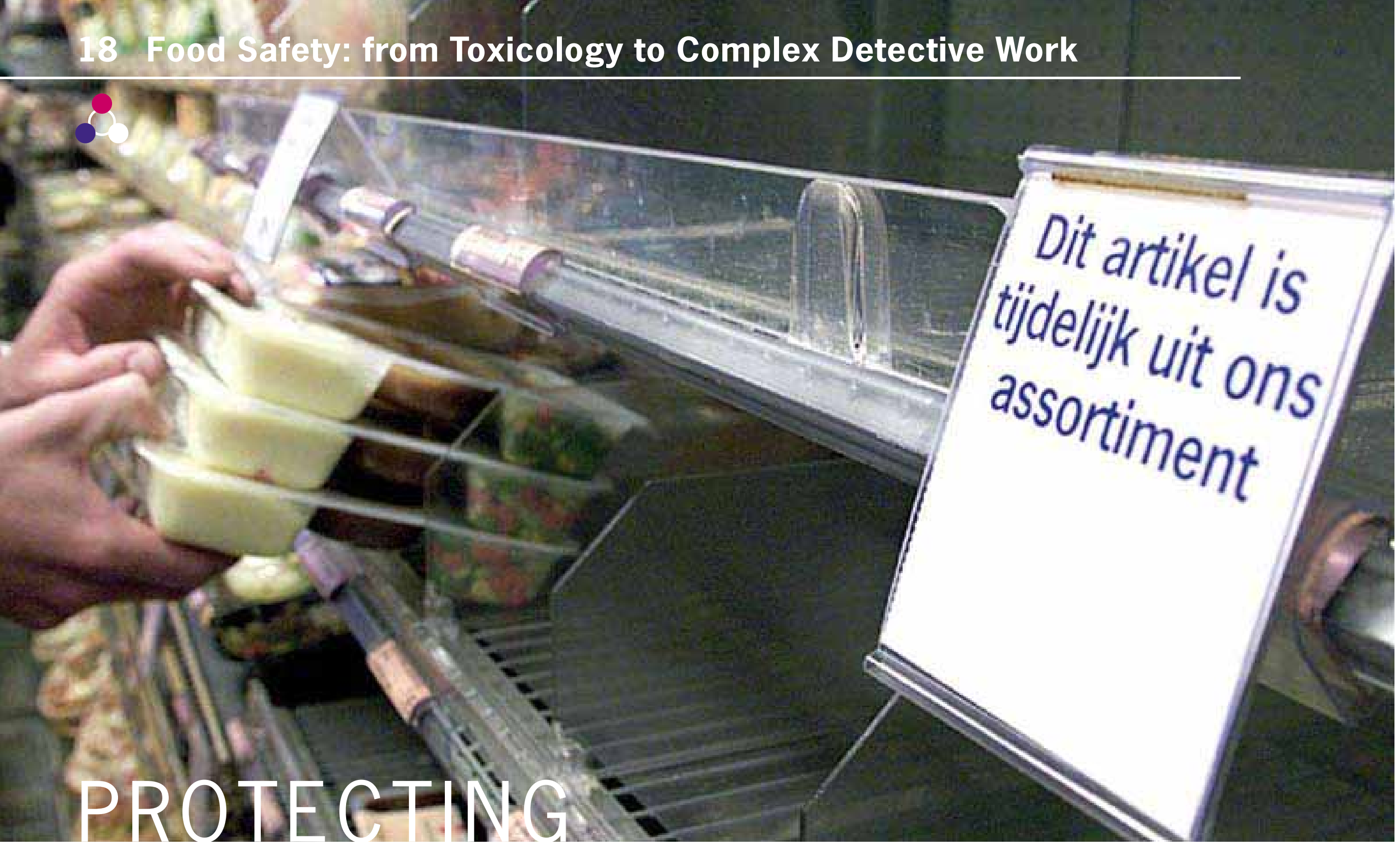
The ENP group is increasingly involved in research on the environmental policy and management of coastal areas and seas, both in Europe and in developing parts of the world. One aspect is research into responsible and sustainable fish farming in Asia. Although intensive industrial breeding seems to be a solution to the problem of overfishing, this new bio-industry comes hand in hand with other problems.

The cultivation of salmon and shrimp, for instance, requires a lot of fish meal, made from white fish. Can fish farming be sustainable if it puts pressure on the stock of wild fish? And what are the consequences of industrial fish ponds for the natural and social surroundings? What is the impact, for example, of shrimp ponds in the Philippine, Vietnamese and Thai mangrove forests? The destruction of the mangrove ecosystem has major effects on the socio-economic conditions of the local population. It is possible to find solutions to these problems, says Peter Oosterveer, an ENP senior scientist who performs research into the sustainability of global food systems.

The ENP group regularly cooperates with other disciplines within Wageningen UR. A good example of this is the collaboration with aquaculture and fishery specialist Professor Johan Verreth on the problems in the Vietnamese Mekong delta. Over the past three years, sea bream production has increased enormously, from 200,000 to 1,000,000 tons a year. In the past this type of fish was only farmed in cages in the Mekong river, but now breeding ponds are also being used. The production is completely chaotic and uncontrolled, and creates problems: high production results in large amounts of organic waste entering the river, which causes eutrophication and rotting. This has a devastating impact on the well-being of the eco-system. Although the Vietnamese government is worried about these developments, it does not possess the skills and capacity to deal with the problems. This is where the Dutch scientists come in. Professor Verreth gives advice on the technical aspects, such as responsible ways to deal with fish feed. But the effect on trade, regulations and decision making – in short the implementation of a new policy – is ENP's specialty.

The group is carrying out research into the value of a labelling system for sea bream, which will eventually lead to sustainability certification. Such a labelling system was already introduced for wild fisheries: the Marine Stewardship Council (MSC), which guarantees that each product with that label has come from sustainable fishing and taken social consequences into account.

A similar label should be implemented for all types of fisheries. Leading players in this field, including the major European supermarket chains and food companies, have been meeting with special interest groups such as the World Wildlife Fund to arrange a certified system for sea bream. ENP scientists are included in this process and partner with their fish breeding colleagues from Wageningen University to justify the claims and investigate how such a system can work in a global market.



PROTECTING THE SAFETY OF FOOD

Banned veterinary drugs in fish, illegal pesticides on fruit, synthetic growth hormones in veal and contaminated animal feed giving rise to dioxins in milk. Substances added to our food on purpose or accidentally. Is our food still safe? How healthy is Dutch food safety?

'The Dutch have a lot of confidence in the safety of their food,' says Andre Bianchi, director of RIKILT, Wageningen UR's Institute of Food Safety. 'Of course it only takes one incident to dent this confidence, which is what happened when a clinical study into probiotics gone awry caused unrest in the food sector in January 2008. Still, our food has never been so safe.'

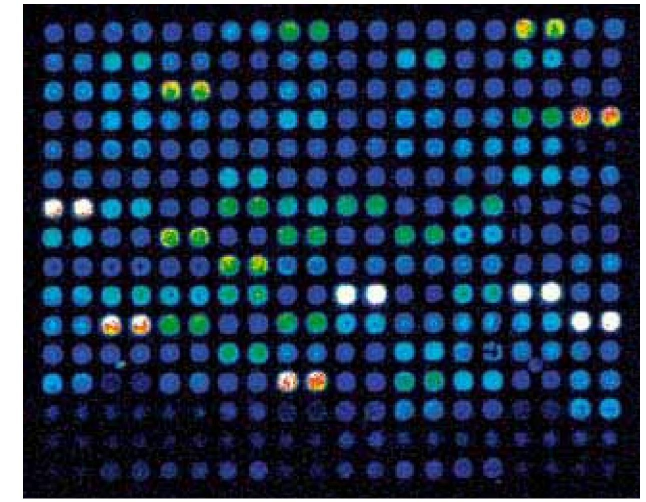
This has not always been the case. Food safety first made the headlines in the 1970s when various food scandals occurred in Europe. Large-scale malversation practices were discovered, such as the cooking oil scandal in Spain in 1981, when adulterated cooking oils were sold on the market with fatal consequences. Another example was the toxic ethylene glycol (antifreeze) which was added to wine in Austria in 1985 to attain a higher classification. The Austrian population was outraged and the local politicians were in uproar. Governments felt obliged to increase food control.

Left page **Over 500 products had to be removed from Dutch supermarkets due to the Belgian dioxin scandal**

Below **Microarray technology enables scientists to measure gene expression of thousands of genes simultaneously**

Dioxin surfaces after checks stopped

Dioxin detection methods need to improve



The Dutch government secured control and monitoring of food products by transferring statutory tasks related to food safety to the research institute RIKILT in 1996. This institute had to carry out its tasks independently, as objectively as possible and in accordance with scientific standards.

'The independent position of the institute was a requirement made by the Dutch Lower House and resulted in intense debate,' Jos Cornelese, research co-ordinator of the Dutch Food and Consumer Product Safety Authority (VWA) remembers. 'The issue was whether the independence of RIKILT could be assured if it also performed research for industry.' The government's requirements were met and now the VWA uses RIKILT's data and advice to come to a risk assessment that is as scientifically pure as possible. It is the Minister's responsability to decide on possible consequences.

'It only takes one incident to dent consumer confidence in food safety'

The institute's tasks have now been confirmed in a so-called Statutory Research Tasks (WOT) agreement, which states that RIKILT provides objective advice on the safety of food products, including animal feed, by means of high-quality, independent research. This 'fire brigade' function is extremely important as the illegal or wrongful use of substances or accidents still result in social unrest and tension. An example is the recent call by the Dutch branch of Friends of the Earth (Milieudefensie) for measures to reduce the chemical pesticides on fruit after analyses had shown that it often contained illegal and excessive amounts of pesticides.

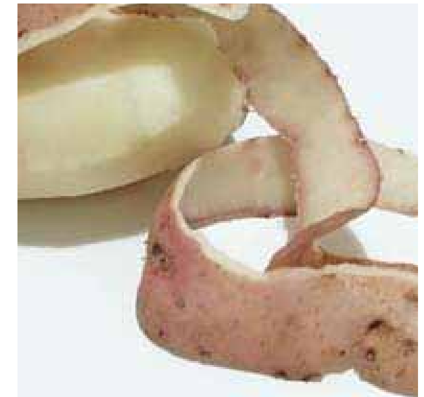
Below **Potato field being sprayed with pesticide**

We have to compete against well-equipped chemists who synthesise growth hormones in illegal laboratories

RIKILT readily takes on the challenge to tackle anonymous fraudsters. Before food safety became an issue, the task was to unmask those who adulterated milk powder with cheaper powdered whey. The current opponents are just as likely to be well-equipped chemists who synthesise complex and sometimes entirely new growth hormones in illegal laboratories and then distribute them to cattle farmers by means of a mafia-like infrastructure.

Caught in the act

Forensic research that can shed light on these activities demands significant and ongoing investments in speed, security and sensitivity. The equipment used is said to increase in accuracy by a factor of ten every four years. Nonetheless, traditional analyses performed with advanced equipment used to be adequate. The gas chromatography combined with high-resolution mass spectrometry deployed in the 1980s may not have been easy to use or maintain and the



equipment costs a fortune. However, the limited amount of samples the equipment could process was sufficient to deal with the 30 to 40 samples a week. The old techniques were aimed at detecting a limited number of specific, pre-selected substances called contaminants. ‘Now we measure much more using bioassays and multi-detection methods,’ explains Bianchi (see sidebar on page 96). ‘This allows us to screen for 300 pesticides in one go, for instance, and is a great leap forward.’

Let us illustrate this development. In the past, an apple pulp sample was specifically and separately screened for ten contaminants. None were detected using this method. Now analysts screen the same sample with a multi-component scan and compare the results with a database containing the characteristics of hundreds of pesticides. If a match is found, it means that a substance is present. The multi-scan showed that the same apple pulp sample nevertheless contained 11 pesticides.

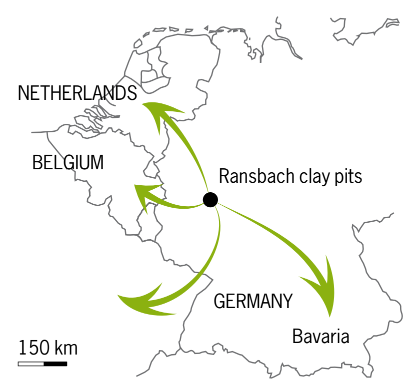
Due to the research results, more batches of vegetables or fruits can be stopped at European borders. Furthermore, the increased chance of being caught discourages farmers from using prohibited or illegally imported pesticides. The Wageningen institute’s expertise led the World Anti-Doping Agency to ask RIKILT to perfect its detection methods for unknown products in sports; this project will end in 2008.

There are major social and economic consequences for those who get caught for food safety violations. Companies are shut down, ships are not allowed to leave harbour, and there is a threat of legal procedures and an image problem. ‘When you find high doses of a dangerous substance you have to be extremely sure of the facts,’ Bianchi says. ‘The first thing the government asks is if you are absolutely sure. Before they have posed that question we will already have analysed a second sample. We cannot afford to make mistakes.’

Cost-benefit

The quicker and more sensitive the instrument, the greater the chance that an unwanted exotic substance is found in an increasing number of samples. The latest methods are sensitive to parts of picograms, one millionth of a millionth gramm, or 10^{-12} gramm. But are such miniscule concentrations a health hazard? While there is often no toxicological risk, the perception of the general public adds another dimension.

Dioxin in food chains



German clay (*mergelklei*) containing dioxins is supplied to various potato and carrot sorting factories.

- This type of clay is used for the sorting of vegetables.
- Dioxin was found in one of the by-products, potato peelings. These are used for animal feed.
- The carcinogenic substance is spread to humans via milk.

Source: ANP

Sample Clean-up for screening on Dioxins and PCB's

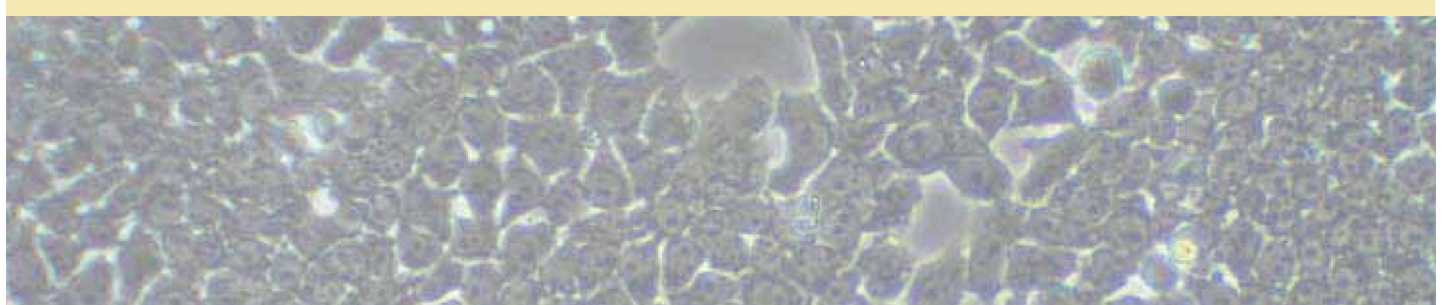
Below **CALUX bioassay: a screenings test with modified cells producing light after exposure to Dioxins and PCB's**

Bioassay method

Bioassays are considered one of the most advanced technologies. Contrary to more common analysis methods, which show the presence of a certain component, bioassays measure the effects of substances, even when a compound is completely unknown. Foremost, they make a distinction between 'suspicious' and 'innocent' samples.

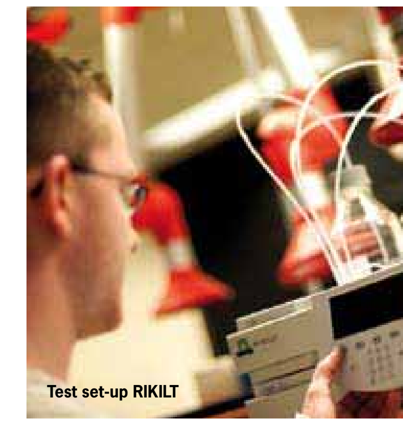
A special type of bioassay is the CALUX-bioassay. Around 1992, toxicologists Professor Jan Koeman and his colleague Bram Brouwer of Wageningen UR, working together with scientists from the University of Michigan, used modified liver cells of rats and mice to analyse polluting substances – usually consisting of a mixture of dioxins and PCBs– much more quickly and less expensively than traditional methods. RIKILT scientists adopted this special bioassay and within two years, in partnership with the Toxicology group, had succeeded in validating the method for the routine screening of milk samples for dioxins. This was seen as a way to tackle the prevailing dioxin problems.

Then came the ultimate test... Dioxin was found in Brazilian citrus peels that had been imported to Europe as animal feed. The scientists received hundreds of samples for screening in a short time span. The CALUX method worked extremely well and was validated for use on all common animal feeds. The method was used again during the Belgian chicken and egg dioxin crisis in 1999, when 75 samples were tested daily. Samples that showed an effect of the bioassay were marked 'suspicious', which did not necessarily mean that the sample contained dioxins. This required another specific technique, GCMS. The hundreds of samples that did not give a light signal were definitely dioxin-free. These negative results – no effect in the bioassay – had positive consequences: companies and factories could be released immediately and without risk, limiting the economic damage.



There is a perception that the risk of unsafe food is high and comparable to dangers such as terrorism and environmental pollution

Based on both these factors and to prevent false alarms, the government has implemented a maximum value for a number of prohibited compounds. If the value of a sample exceeds the maximum, then measures can be taken. The emphasis is on the word *can*, as it might not be necessary and dealing with risks demands common sense.



Test set-up RIKILT

Although it is not easy, RIKILT advice to the government is gradually shifting from the precautionary principle (minimising risks) to accepting certain risks (appropriate risk). Despite the majority of the Dutch general public (62 percent) assuming without question that food is safe, there is also a perception that the risk of unsafe food is high and comparable to dangers such as terrorism and environmental pollution. This high-risk perception can be attributed to the fact that consumers have minimal influence on an individual level.

'It is important to convince consumers that there is no such thing as zero risk,' says Ivonne Rietjens, Professor of Toxicology at Wageningen UR since 2000, when she succeeded Professor Koeman (see sidebar). 'It is time that we find a way to communicate this point more clearly. Consumers and policy-makers must learn to weigh up health risks against health gains, costs against benefits. It is good that people understand that food products are not just healthy or unhealthy. We have already accepted the duality of medications – the side effects being the downside – and we need to extend this concept to food and food components.'

Wageningen UR has many talented scientists. Talent is a main driving force of scientific progress and innovation. Scientists must be able to further explore their ideas and develop their own research lines. Wageningen UR stimulates and facilitates the development of talent in many ways, which has resulted in top science that has an impact on science, society and business.

As the previous chapters of this book make clear, good science often requires a multidisciplinary approach and team effort. Here we have chosen not to present our 'Science for Impact' by elaborating on a scientific theme. Instead, allow us to introduce you to some of our talented researchers: the winners of a prestigious Vidi grant. These scientists have proven themselves as gifted researchers and the Vidi grant* enables them to further develop their innovative ideas.

INNOVATION THROUGH EXCELLENCE

Dr. Bart Knols MBA – Vidi 2003

MalariaSphere: the African environment caged for Malaria research

Entomologist Bart Knols (1965) completed his PhD study in 1996 in Wageningen and Tanzania. In 2006 he received the Ig-Nobel Prize for Biology. A year later he was awarded the Eijkman Medal and the 'International student of the year 2007' award in London.

'Every 30 seconds, a child dies of malaria. Malaria mortality is a good indicator of the economic development of a country. Family planning only becomes sensible when young children in the family have a good chance of survival. With my research, I want to make a significant contribution to solving the problem of this disease. I want to reduce the mortality rate from one child every 30 seconds to one every minute, two minutes or five minutes.

Genetic modification of the malaria mosquito is a hot topic. Many researchers are working on developing a mosquito that is unable to transfer the malaria parasite to humans. Introducing these genetically modified mosquitoes could eliminate the disease over the long term, but only if the mosquitoes stay alive and begin to mate with other members of their species under field conditions. My Vidi research supports this genetic research. We are studying the conditions under which the gene can spread in mosquito populations. How many mosquitoes do you have to grow, and when and where should you release them? Can such a release be effective?

The research began in 2004. In Tanzania, a screened cage was built covering 700 m^2. The mosquitoes are released inside the cage in order to study their mating behaviour and the transmission of the genes within populations.' Knols' behavioural research has already resulted in 19 publications, including an article in the prestigious journal *Science*. After he completes the Vidi project, Knols plans to submit a Vici proposal.

Professor Erwin Bulte – Vidi 2004

The curse of natural resources

Erwin Bulte (1968) is Professor of Development Economics at Wageningen University; he earned his PhD in 1997 in Wageningen. He is also Professor of Economics at Tilburg University and is a Fellow at the University of Cambridge and the University of Oxford.

'Previous research has shown that countries with large stocks of natural resources appear to experience slower economic growth than other countries and are more frequently ravaged by conflict. This is referred to as the '*curse of natural resources*', a paradox that is being studied intensively by researchers, including myself. I initially attempted to explain this curse, but based on new results obtained through my Vidi research, I am now arguing that this so-called curse does not actually exist.'

The previous research, based on a cross-section analysis of multiple countries, brought the researchers to the conclusion that an abundance of natural resources would lead to corruption and greed, and thus to a worsening of the institutions. Bulte: 'In this case, institutions are defined not only by economic rules, such as the security of ownership, but also by political frameworks, such as the democratic content of public administration.'

Empirical research conducted as part of the Vidi project led Bulte to conclude that there is no proof that dependence on natural resources results in slow growth and poor institutions. But there is a correlation between the variables. 'It appears that the causal connection has been reversed: countries which have poor institutions or which are in a state of war become dependent on natural resources because other economic sectors remain undeveloped. Of course, this is hardly a paradox.

Countries are sometimes advised to keep their hands off their own natural resources. This is nonsense. The knowledge that has resulted from this research can help NGO's to improve their policies. In the future, I want to continue investigating the reasons for institutional change and its consequences for economic growth and conflicts such as civil wars, especially in Africa.'

Dr. Monique Nuijten – Vidi 2005

Spatial development in Brazilian slums

Monique Nuijten (1961) earned her PhD cum laude in 1998 in Wageningen. She is Associate Professor at the Rural Development Sociology Group; until now, she has acquired most of her research experience in Spain and Mexico. Her Vidi research in Brazil began in 2006.

Nuijten's research focuses on the use of space in slums in Northeast Brazil and on the processes of spatial redevelopment as conducted by local governments. She studies the extent to which these programmes are actually aimed at improving the living situation of the poorest population groups – as the government claims – or if their real aim is political control. Nuijten: 'The government removes illegal settlements and moves the residents to new housing projects, but does not tackle the basic causes of poverty, such as chronic unemployment and racism.'

In her research, Nuijten uses theories from the social sciences that focus on the dimensions of identity, discipline and power in the use and development of private and public spaces. 'The research shows that housing developments are used by the government as a means to control the drug trade and other illegal activities in the slums. In contrast to the new housing developments, the dense settlements on the river beds are virtually inaccessible for the government and even the police.

We see similar processes with marginalised population groups taking place everywhere in the world, also in the Netherlands. Government programmes that claim to 'help the poor' often neglect the specific backgrounds and lifestyles of these people and do not tackle the actual problems of poverty and exclusion. My Vidi research is very important to acquire more insight into the role that spatial development plays in the lives of people and in political control by governments.' Nuijten is working together with a Brazilian university and plans to continue doing research in Brazil after her Vidi project is completed. She has already begun planning a new research project into the relationship between the city and the rural area in the formation of slums.

Professor Thea Hilhorst – Vidi 2005

Humanitarian aid is under fire

Thea Hilhorst (1961) holds the endowed chair in Humanitarian Aid and Reconstruction at Wageningen University. She earned her PhD cum laude in 2000 in Wageningen and is a member of the Scientific Committee of UNESCO Nederland. She is using the Vidi grant to conduct a five-year research project into the progression and effects of humanitarian aid in Angola.

'Humanitarian aid is under fire: this form of aid often takes place literally under fire (during armed conflicts), and is now under fire in the sense that it is being heavily criticised. Humanitarian aid is intended for emergency situations that occur during natural disasters and armed conflicts. In principle, it is separate from development cooperation, because it serves no political aims and due to the short-term and externally driven character of the aid. However, there is a different story in practice: humanitarian crises are often long term and they take place in contexts of underdevelopment and fragile government structures. As a result, the distinction between emergency aid and development cooperation is being debated, and so is the relationship between humanitarian aid and other actors, including military peacekeeping missions. These issues remain a topic for heated discussion, but have rarely been studied in depth and independently. The aim of my research is to fill this gap.'

By studying the day-to-day practice of humanitarian aid in Angola, Hilhorst wants to acquire a complete picture of how aid works. She wants to know how to improve the linkage with the local institutions and trade customs of the affected people. 'Victims of emergency situations often develop their own survival strategies, and you must link up with these strategies if you want the aid to be effective.'
Another of Hilhorst's aims is for humanitarian aid to become a more prominent research topic. As part of her Vidi research she is organising a world-wide conference on humanitarian aid, which will be held next year in February. 'In addition, I am writing a book about a different theoretical approach to humanitarian aid; besides the political dimension, this approach pays a great deal of attention to social and cultural factors. Of course, I hope that this book can make a real difference in how aid is viewed and studied in the future.'

Dr. René Geurts, Vidi 2006

Evolution of symbiosis

René Geurts (1968) earned his PhD in 1998 in Wageningen, where he is now Assistant Professor of Molecular Biology. One year after receiving his Vidi grant in 2006, he was appointed as a member of the Jonge Akademie (of the Royal Netherlands Academy of Arts and Sciences). His research has received extensive international attention, which is due in part to three articles that were published in the prestigious journal Science.

Geurts' Vidi research focuses on the symbiosis between leguminous plants – such as peas, beans and soy – and nitrogen-binding Rhizobium bacteria. This symbiosis leads to the formation of a new organ on the root of the plant: the root nodule. These nodules contain bacteria, which can then bind nitrogen from the atmosphere. The result is that chemical fertiliser is unnecessary for leguminous plants.
Geurts: 'The aim of my research is to determine what happened during the evolution of leguminous plants. How have leguminous plants changed during evolution so that a symbiosis with Rhizobium became possible? And why is this symbiosis almost exclusively correlated with this family of plants? It is quite an ambitious aim. Therefore I have limited the scope of the research and am focusing on the molecular dialogue between the bacteria and the plant. The bacteria send out a signal to the plant, which then allows the bacteria inside. A number of years ago, we discovered the genes that control this process; there are about nine of them. At that time, we thought that we had reached the goal; we believed that the only task of these genes was symbiosis, but that was naïve. The actual situation is more subtle.
If we can understand exactly what happened during the evolution of leguminous plants, then we can possibly enable other species to engage in this type of symbiosis. For example, if this approach were to be successful with rice, this would have an enormous impact on the use of chemical fertilisers and could possibly help us to increase rice production. My research can contribute to this possibility.'

Dr. Dolf Weijers – Vidi 2006

Baby talk – communication between cells in the plant embryo

Dolf Weijers (1976) completed his PhD research in 2002 in Leiden. Besides a Vidi grant, in 2006 he also received the NVBMB prize as a highly promising young researcher. At the Laboratory of Biochemistry in Wageningen, he leads an international research team that wants to understand how the stem cells of the root are formed in the early plant embryo.

'Many crops have difficulties forming roots in culture. If we were able to change the stem cell populations of plants as desired, this could be very interesting for plant production because these stem cells ultimately generate all roots, leaves and flowers.' Weijers has been doing research for six years into the stem cells of plants, which are located in the growing tips – the meristems . 'Meristems make virtually all organs of the plant. It is now reasonably well understood how meristems do this, but how the meristems themselves are formed is still a big question. I want to understand how this takes place initially in the early plant embryo, in the seed.'
Cells obtain information about who they are and communicate with each other in order to form a meristem. Weijers is mapping out how this process works in great detail. 'The ultimate goal is to be able to modify the stem cell populations as desired so that plants can grow optimally. If we can manipulate the 'main switch' of the root meristem, we can make it easier to propagate crops. We could also adapt plants to environmental conditions, so that edible crops could thrive in dry soil, for example in developing countries.' The research is not only supported by the Vidi grant of the innovation incentive , but also by NWO Earth and Life Sciences and the European Union. After completing this Vidi project, Weijers will continue the research line at the Laboratory of Biochemistry in Wageningen, where he is Assistant Professor.

Dr. Duur Aanen – Vidi 2007

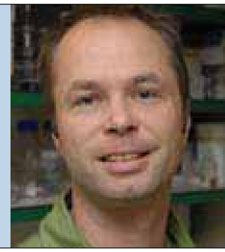
The evolution of stable cooperation

Evolutionary biologist Duur Aanen (1971) earned his PhD in 1999 in Wageningen and then began working as a postdoctoral researcher in Denmark, financed by a European Marie Curie Fellowship. He is currently Assistant Professor at Wageningen University. Since 2000, Aanen has been exploring the evolution of cooperation between species and between individuals of the same species.

'People tend to equate evolution with competition, but evolution can also lead to stable forms of cooperation at various levels. This seems to be a paradox that contradicts the principle of the survival of the fittest, but cooperation is a very important fact in evolution.' Aanen is using the symbiosis between termites and fungi, a million-year-old example of sustainable agriculture as a model system to study the evolution of cooperation between species.
'I am focusing on fundamental research, so I am not thinking directly about applications', explains Aanen. 'Nevertheless, applications are conceivable over the long term. Fungus-growing termites fulfil an essential role not only in the breakdown of organic matter, but also in the redistribution of nutrients in tropical ecosystems. Fundamental insight into this process is essential for the optimal management of agricultural lands.' In addition, the fungus that the termites grow in Africa and Asia is very important as a human food source. Occasionally, the fungus forms mushrooms. 'These are an excellent food for people and are more nutritious than cultivated mushrooms. By optimising the growth of the fungus, you can help people obtain food that is produced in a sustainable fashion.'
After completing his Vidi research, Aanen hopes to continue his research group in genetics. 'I want to take major steps in my research into the evolution of cooperation. I am extremely interested in this research theme. The more I explore this theme, the more questions there are that I want to answer.'

Dr. Martijn Bezemer – Vidi 2007

Biodiversity above and below ground



Ecologist Martijn Bezemer (1971) completed his PhD research in 1999 in London. He currently works in Wageningen at the Laboratory of Nematology and the Netherlands Institute of Ecology. He began his Vidi research in February 2008.

'Traditionally, entomologists look at what is happening above ground with the plant and its pests, while soil scientists look at what is happening in the ground. I am attempting to link these two worlds together.' Ten years ago, Bezemer and his colleagues began doing greenhouse experiments to study the relationship between the above-ground and below-ground worlds. Now Bezemer wants to acquire insight into the relationship between the diversity and function of the above-ground and below-ground communities in the field. To do this, he is using test plots in the Veluwe nature reserve. 'This is an enormous challenge. It is much more complex than conducting research under controlled conditions in the greenhouse. Nevertheless, this research is extremely important. More and more species are becoming extinct, even though we still know very little about the role of the species in ecosystems.'

In his Vidi research, Bezemer is focusing on ragwort (*Senecio jacobaea*), a weed species that causes serious problems world-wide. 'Vast sums of money are spent on controlling ragwort. The plant is poisonous to large grazing animals such as horses. Moreover, it is becoming increasingly dominant in the Netherlands. In their search for control methods, researchers have not yet looked to the soil. I have discovered that the plant disappears in a natural fashion from vegetation when a certain fungus is present in the soil. We can possibly use this fungus for the biological control of the weed.'
'Ragwort is only one example,' says Bezemer. 'The question is larger and more complex than the control of a single weed species. The Vidi grant is a first step towards acquiring better insight into the role that species play in ecosystems and how this role differs above ground and below ground.'

Dr. Jan Willem van Groenigen Vidi 2007

Are greenhouse gases absorbed by or emitted from soil?

Jan Willem van Groenigen (1970) graduated cum laude in soil science at Wageningen, where he also earned his PhD in 1999. He is an expert in the area of greenhouse gas emissions from the soil. His Vidi research project began in January 2008.

'Soil plays an important role in processes of climate change. The soil can be an important source of greenhouse gases such as carbon dioxide, nitrous oxide and methane, but it can also convert these gases into harmless compounds. This all depends on how we deal with the soil. In the future, we will have to feed more and more people. If we do nothing to stop this process, increased agricultural production will be linked with a strong increase in the use of chemical fertilisers. As a result, there will be a rapid increase in greenhouse gas emissions, especially nitrous oxide. The question is, how can we manage the soil in the best way so that food production stays up to par, but the soil emits the smallest possible amount of greenhouse gases, or perhaps even absorbs these gases?'
By fixing carbon dioxide in organic matter, the soil can help to slow the greenhouse effect. An important part of Van Groenigen's Vidi research concerns the role of earthworms in this process. 'On the one hand, worms help to slow the greenhouse effect by fixing carbon dioxide in organic matter. On the other hand, our research shows that they also produce nitrous oxide, which is a much more powerful greenhouse gas. We now want to determine the net effect of earthworms on climate change. Do worms contribute in a positive or negative sense to the greenhouse effect? Of course, worms only produce nitrous oxide because people fertilise agricultural lands heavily. It is up to people to counteract the greenhouse effect, but to do this we have to understand exactly which processes in the soil are responsible for the production of greenhouse gases.'
'I want to help establish good farm management guidelines that farmers can use to keep the emissions of greenhouse gases as low as possible. Should you fertilise and plough or not? If so, how often should you do this and what methods should you use? This fundamental Vidi research could ultimately result in a set of practical measures.'

Dr. Bart Thomma – Vidi 2007

Plant plumbing

Plant pathologist Bart Thomma (1972) earned his PhD in 2000 in Leuven (Belgium). He is currently leading a young, international research team at the Laboratory of Phytopathology in Wageningen. In his Vidi research, he is focusing on the pathogenic fungus Verticillium that infects the water transport system of important crops.

'The Verticillium fungus is very difficult to control and therefore has a major economic impact. The fungus is present world-wide and grows in the xylem tissue of more than 200 crops, where it plugs up the water vessels and can lead to plants wilting or even dying. In the Netherlands, it affects a number of greenhouse crops as well as strawberries, potatoes and ornamental trees. The xylem of plants carries hardly any organic nutrients, since the photosynthetic products are transported in the phloem. In my Vidi Research, I am studying how the fungus is able to thrive in this environment, and why it lives there at all. It may be possible to control the fungus by developing resistant plants.'
Thomma wants to find out how the fungus makes a plant sick and is studying this process at the molecular level. At a higher level, he is studying how micro-organisms cause disease in general. 'Some of the strategies used by fungi and bacteria – whether they are pathogens of plants, people or animals – are comparable. We want to understand how a micro-organism makes its host sick, and what it needs to do this. If we understand which mechanism the fungus requires to parasitise a plant, we can try to deactivate that mechanism in the plant.'
'The best possible result from this research would be if we could prevent Verticillium diseases in plants. Then we could increase production and reduce the use of fungicides as much as possible. This would be good for the environment. Plants are an important source of food for people, as well as feed for animals and biofuel. The world is demanding efficient production of biomass, and we must make every effort to meet this demand. The environment is absolutely one of my strongest sources of motivation!'

* The Vidi grant is part of the Innovational Research Incentives Scheme (Vernieuwingsimpuls in Dutch), a programme of the Netherlands Organisation for Scientific Research (NWO). The aim of this programme is to promote innovation in academic research and three types of grants are awarded:
- Veni grants for researchers who have recently obtained their PhD degree, allowing them to continue to develop their ideas.
- Vidi grants for researchers who want to develop their own innovative line of research and appoint one or more researchers to develop a research group.
- Vici grants for senior researchers to build their own research group.

This chapter focuses on the ongoing Vidi research at Wageningen University. In total, eighteen Veni and twelve Vidi grant winners conduct or have conducted their research at Wageningen University. Four Vici grant winners have been awarded to Wageningen University researchers since the start of the Vernieuwings-impuls programme.

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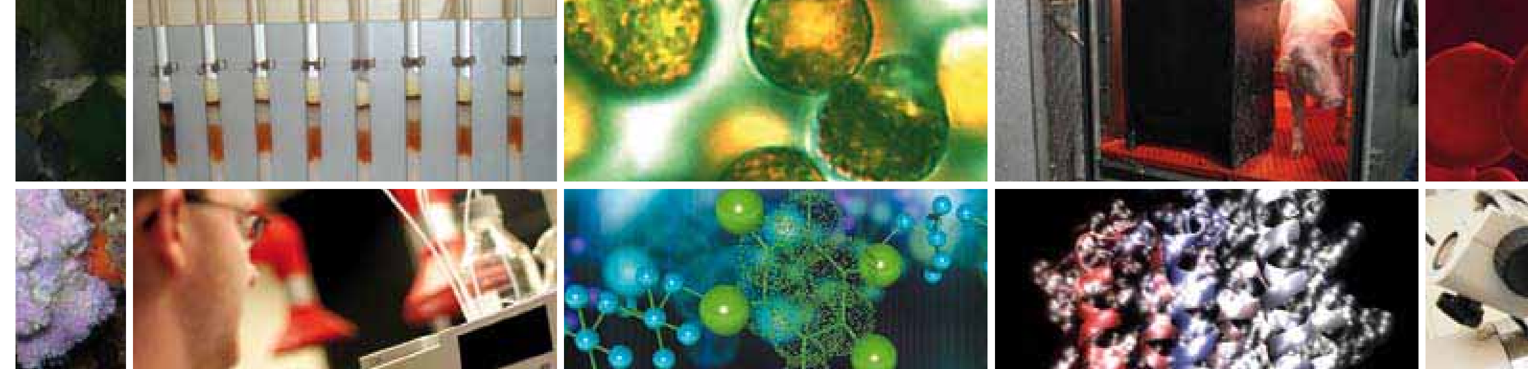

Over the past nine decades what is now known as Wageningen University and Research Centre (Wageningen UR) has had a major influence on scientific, educational and innovative developments within its domain of healthy food and living environment. The national and international impact of its science and education has been profound and this book offers inspiring examples.

Wageningen UR has itself been influenced by developments around us. It has been transformed over the last 90 years into a knowledge organisation that incorporates innovation processes in addition to research and education. Wageningen UR is a leading institute in its domain, with a research, education and innovation agenda that has been developed in partnership with all of its stakeholders. Cultural, social, economic and political changes shape the form and culture of our organisation.

Although individual talent is often seen as the main driving force of scientific progress, our experience shows that teams of talented people are required to make progress in interdisciplinary research. This is why Wageningen UR facilitates this team effort. Interdisciplinary research is needed because our science is inspired by complex issues in the world around us, such as those addressed in the Millennium Development Goals.

This book profiles representative examples of the past, present and future impact of our science. In all cases, teams of scientists have developed new scientific insights that have had or will have an impact on science, society and business.

Editors
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