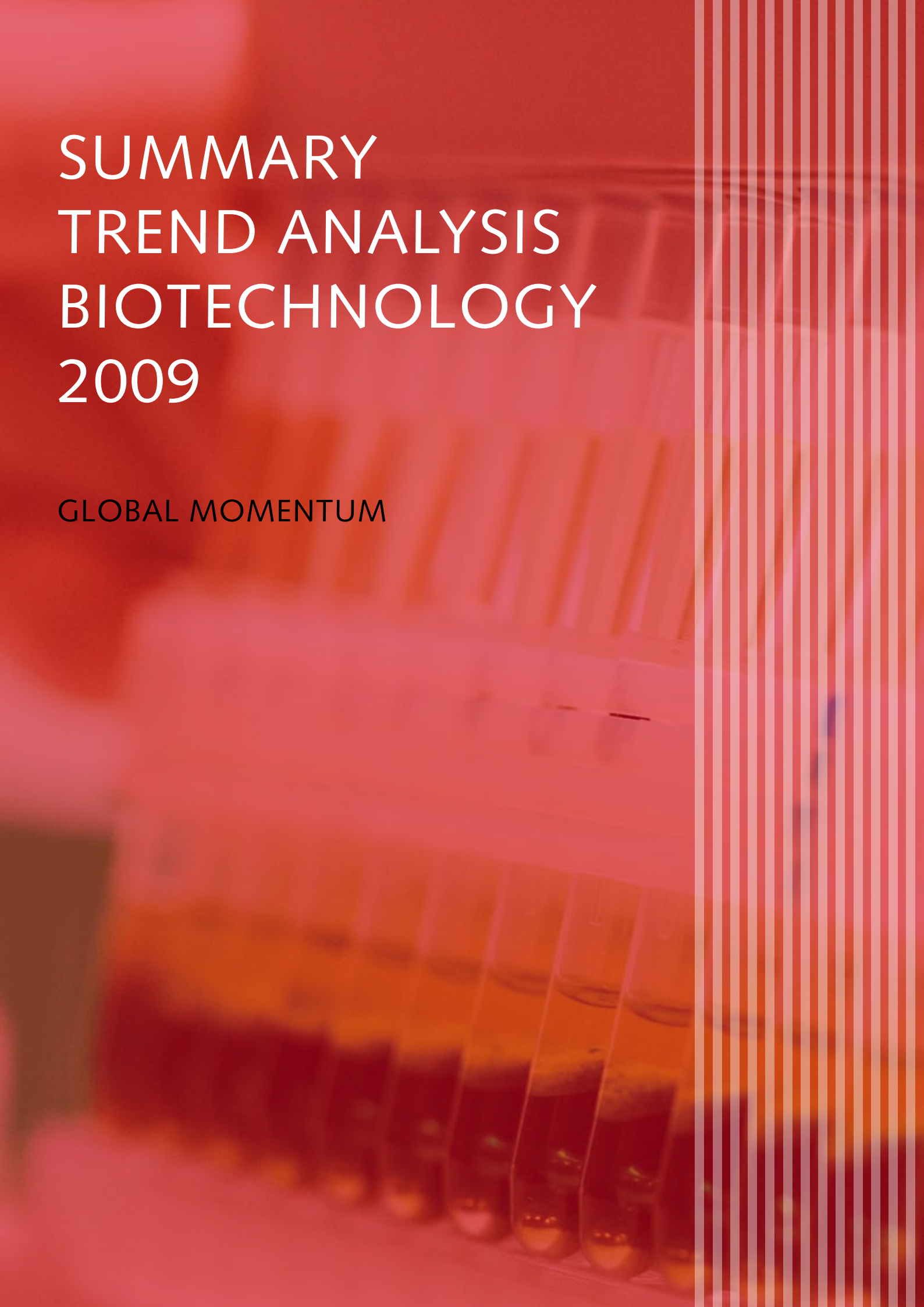
SUMMARY TREND ANALYSIS BIOTECHNOLOGY 2009

GLOBAL MOMENTUM



SUMMARY TREND ANALYSIS BIOTECHNOLOGY 2009

GLOBAL MOMENTUM

Colofon

This is a joint publication of the Netherlands Commission on Genetic Modification (COGEM), the Health Council of the Netherlands and the Commission on Biotechnology in Animals (CBD)

December 2009

Design: Avant la lettre, Utrecht
Photos: Ivar Pel
Infographics: Fallen Serenity Productions
Print: De Resolutie, Utrecht

POLICY SUMMARY

The world stands on the verge of a period of great change involving major challenges such as climate change and the growth of the world population, including the consequences of the ageing population in the Western world. These trends call for political and social changes and technological solutions. Biotechnology is seen as one of the leading edge technologies for surmounting these major challenges. Biotechnology is being used to develop new applications in the fields of healthcare, agriculture, food production and the environment. Besides the opportunities biotechnology offers, the new technological possibilities also pose ethical and social questions, making them a subject of public debate.

Numerous biotechnological developments deserve attention from the political and policy-making community. In this trend analysis we identify five trends that throw up ten political and policy dilemmas. The trends were selected on the basis of the social consequences of the technological developments.

The trends and associated questions and dilemmas presented in this trend analysis are not all new: some aspects have been reported already and some trends have been discussed, at least in part, in the previous trend analysis published in 2007. The reason for examining the trends in this trend analysis is the rate at which technological developments are progressing. Questions and dilemmas which were previously expected to become an issue in many years time have suddenly become more urgent and concrete. In the opinion of the authors of this trend analysis there is an urgent need for political and policy judgements on the issues arising from these trends.

TREND 1
MEDICAL BIOTECHNOLOGY: SEARCHING FOR THE SIGNIFICANCE OF THE HUMAN GENOME

X-omics and the $1000 genome

Over the next ten years research into the molecular properties of cells (X-omics) based on large-scale data collection will deliver a growing body of knowledge about the functioning of cells and organisms. The symbolic goal of this quest is the '$1000 genome': determining the complete genome sequence of an individual for $1000. It is expected that within ten years genome analysis will have become a widespread practice within the healthcare sector, partly because the costs of the complete sequencing of a genome will be lower than other analytical methods. Sequencing of individual genomes could in time replace several current diagnostic and screening methods, such as the heel-prick tests for newborn babies and carrier screening. Some healthy adults will also want to have their genome sequenced (either commercially or not) to find out whether they have any hereditary conditions, risks or predispositions to certain diseases or disorders.

Biobanks

The complete sequencing of individual genomes generates large amounts of data. The first requirement, therefore is to have a safe database, such as an electronic patient record, but to understand the meaning and significance of this enormous volume of data we also need to acquire more knowledge. At the moment we are only certain of the meaning of just a small part of the information contained in a complete genome: what it codes for and the processes in the cell in which it plays a part. To be able to improve and increase links between molecular biological properties, illness, physical characteristics and environmental factors, it is essential that researchers have access to such data through biobanks containing human tissue, genome sequences and related information, not only from patients but also healthy participants.

Opportunities

The advantages of putting the $1000 genome into practice are legion. Genetic screening or diagnostics will eventually become cheaper, and as knowledge of the genome and the relations between genes and the occurrence of disorders grows, facilitated by biobanks, screening by complete genome analysis may well become more useful than the current analysis per gene. The possibilities for prevention and early treatment of illnesses will grow, in turn improving average health levels. It will also be possible to determine the expected response by patients to treatments and their susceptibility to side-effects before a treatment is begun, and to adopt new health-promoting strategies.

In short, the $1000 genome – and X-omics research in general – will make it possible to tailor more individualised prevention and treatment strategies, a field known as 'personalised medicine'. Much of the required knowledge has become available because of the existence of biobanks. Biobanks are not only essential for increasing our knowledge and revealing the significance of the genome; participation in biobanks can also provide patients with valuable health information, in any case at the collective level, and, depending on the future regulations, at the personal level as well.

The collection and storage of human tissue combined with medical and other personal information also offers major advantages. Biobanks make it possible to investigate the genetic basis of some diseases, document the relationships between physical characteristics and health or disease, and develop new forms of treatment.

Issues

The $1000 genome also raises questions. For example, how can privacy be guaranteed? This question is becoming increasingly important, for one reason because of the increasing number of international links between data collections and biobanks. Another question is what the consequences of this technology will be for people's autonomy – their right to know and not know as well as control over their own body material.
Genome research will generate much more data than is possible with current techniques, whereas the significance of a large proportion of this information will only become apparent at a much later date. Moreover, new knowledge about diseases will become available without there being the possibility of prevention or treatment. It is difficult to determine the extent to which people can make well-informed choices to know or not know, and how parents can make such decisions responsibly for their children. In short, there are many questions about how people can adequately deal with the new technological possibilities and impossibilities.

Political and policy dilemmas

The government faces a difficult task in accommodating these new developments and familiarising people with them, while at the same time minimising the risks. This presents politicians and policy makers with two dilemmas. The first reflects the tensions between privacy and public health. The second concerns the discussion about autonomy versus the government's duty to look well after its citizens.

1. On the one hand the new medical technologies offer considerable benefits for public health, but on the other hand the introduction of these technologies may have adverse consequences for the privacy of patients and citizens.

Traceability versus privacy
The power of the new technologies lies in the availability of data on large numbers of people, while retaining the ability to trace the data back to individuals. Analysing large quantities of data on patients and healthy people makes it possible to identify correlations between physical characteristics and health or illness, and thus develop new forms of treatment. Maximising accessibility and traceability therefore facilitates innovation and improvements in healthcare, but the traceability of data compromises the privacy of the individual.
Many people believe it is important to contribute to the expansion of knowledge about health and treatment options. They are also keen for the data to be traceable because this can lead to health benefits for themselves. For these reasons they believe privacy is sometimes less important. At the moment, however, the future consequences of this incomplete protection of privacy remain unclear.
The new techniques are important for improving healthcare services, but the long-term consequences for privacy are still unpredictable. The challenge facing the government is to put developments on the right track with privacy protection as a major point of attention.

Instruments for guaranteeing privacy
The government has several instruments at its disposal for guaranteeing privacy, such as European directives. In addition, the users of databases – researchers and healthcare professionals – are bound by codes of conduct. These should ensure that the sources of data can be traced without infringing individual privacy. But because genetic data are by their very nature tightly bound to personal identity, these instruments may in future provide insufficient guarantees, especially when databases become much larger and increasingly accessible from outside national and European borders.
Possible new instruments could include:
- raising awareness of privacy issues among citizens and researchers, while recognising both the importance of protecting privacy and the social benefits of access to data;
- new international strategies for protecting privacy through legislation, international conventions or codes of conduct.

2. Personal autonomy over health decisions is at odds with the duty of government to protect the health of its citizens, with the duty of healthcare providers and carers to care, and with the social pressures for behavioural change.

Provision of information
An important aspect of this dilemma is the provision of information. Diagnostics and screening often deliver such complex information on disease carriage and risks that citizens, and even professionals, have great difficulty in interpreting it correctly. Large-scale complete genome analyses will exacerbate this problem because many of the data still have too little significance or predictive value. Moreover, informed consent in its original sense is no longer possible because advances in scientific insights will not only give new meaning to old genome analyses, but also give rise to new analyses outside the given informed consent.

Right to not know
The complexity of the potential consequences of information about the genome has made it virtually impossible for parents, guardians and legal representatives of children or adults incapable of giving informed consent to come to a decision on the right to not know. The question is how society should and wants to respond to this dilemma. Is it enough to inform

citizens better so that legal representatives can make well-informed decisions, or should such decisions always be left to professionals in the interests of protecting children and legally incapable adults?

Autonomy under pressure
Mentally competent adults can face difficulties too. If they choose to have their genomes read, they must be able to understand and cope with the resulting information; they must decide what information they want to know and what they are going to do with it. There is a risk that personal autonomy will be compromised, that people will not be able to withstand the social pressure to let the information from the genome analysis dictate their decisions.

Instruments for managing information and personal control
Instruments that the government could use are:
- new forms of informed consent, which appear to be essential in the light of the emerging technological possibilities and could be incorporated into the draft Control of Human Tissue Act;
- better information provision for citizens about the usefulness or otherwise of knowledge of the genome so that citizens and professionals can make sound judgements about the potential applications of biotechnology;
- legislation or codes of conduct on genome analyses for children and legally incapable adults to provide optimal protection for the autonomy of these citizens.

TREND 2
MEDICAL BIOTECHNOLOGY: POSSIBLE APPLICATIONS IN HEALTHCARE

The developments in X-omics will pave the way for applications in the healthcare sector. Regenerative medicine and gene therapy will give a new dimension to personalised medicine.

Personalised medicine
Personalised medicine is the trend in medical practice in which treatments are developed for even smaller groups of patients and individual molecular biological characteristics are sought that can provide indications of the likely success of a treatment. The results of molecular diagnostics can be used to determine appropriate treatments, for example with drugs. Regenerative medicine, particularly stem cell therapy, and gene therapy are relatively new forms of medicine that can also be attributed to the field of personalised medicine.

Stem cells
The development of induced pluripotent stem cells (iPS) is a major breakthrough in stem cell research because it gives rise to fewer ethical objections than the use of embryonic stem cells. Although it will be a long time before iPS cells can be used in clinical applications, the prospects are encouraging. Moreover, iPS cells have important research applications and thus contribute to increased understanding of the origins, course and treatment of diseases. The use of embryonic stem cells in research will gradually be replaced by iPS cells.

Gene therapy
Gene therapy – the treatment of a genetic defect by introducing hereditary material into the cell – has a long and somewhat unfortunate history, but this seems to be changing. Numerous promising applications are under development and phase one clinical trials have been successfully completed. The first gene therapeutics are at the market authorisation stage in the US and Europe, while in China gene therapy has been in use for some time.

Opportunities
Personalised medicine offers opportunities for the healthcare sector: it improves preventive care, medications are only administered to people that will benefit from them, side-effects can be minimised, and if stem cell therapy and gene therapy can live up to their expectations, adequate treatments will become available for some serious illnesses. In short, public health will improve as a result of better preventive care and treatment, possibly even for serious illnesses. Many more people will be able to play a more active role in society, especially people with serious illnesses for which gene therapy or stem cell therapy has made treatment possible. In some cases, personalised medicine may also reduce healthcare costs by improving the effectiveness and efficiency of prevention and therapy.

Issues
Little cohesion between policies
In many cases the use of new technologies will increase healthcare costs. Whether this will also be the case for personalised medicine cannot be predicted with any certainty. Personalised medicine will lead to a reduction in some healthcare costs and to an increase in others, for example more expensive medicines and expensive advanced therapies for ever smaller target groups. What is certain is that under the current system the costs and benefits will not always accrue to the same people and organisations. An example is when the improved public health is gained at higher costs, but also relieves the burdens on informal carers and improves participation in the labour market. The lack of cohesion between the various policy areas may impose a constraint on further developments.

Obstructive legislation
A second constraint is that the current legislation sometimes (intentionally or otherwise) inhibits research and the introduction and use of personalised medicine products. Such barriers may lead to research activities being moved to other countries, which can have adverse consequences for research and industry in the Netherlands and lead to problems when knowledge and products resulting from that 'exiled' research are offered on the Dutch market. Obstacles to the implementation of personalised medicine in the healthcare sector, often a result of unfamiliarity and inexperience with these new products in the current system, will prevent or delay access to these innovations for people in the Netherlands.

Political and policy dilemmas
The more far-reaching applications of personalised medicine present opportunities for the government to make progress towards objectives like better health and a longer life. But there are obstacles to realising these opportunities.

> 3. Specific therapeutic applications may lead to better healthcare. However, the inherently high costs of therapies for increasingly small target groups can prevent their widespread application, requiring political decisions to be made in each case.

Public health and healthcare costs
In the current economic climate the government's task of improving public health while keeping the costs of care under control is becoming increasingly acute. Personalised medicine offers major opportunities for public health, but will sometimes involve higher costs. The costs and benefits often accrue to different government organisations, which may inhibit further developments.

There may come a time when the government has to decide not to pay for expensive treatments because it cannot justify covering these costs from the public purse. Such decisions are painful and can create inequalities between rich and poor, and may even undermine social solidarity.
The challenge for the government is to create more common interests and reduce the obstacles to the introduction of personalised medicine by weighing up the costs and benefits at the macro level. This will involve addressing important underlying normative questions, to which society – government and citizens – will have to find answers.

4. Implementing personalised medicine products efficiently to gain the benefits they deliver is made difficult by ethical considerations and the current legislation. A reappraisal of these ethical and legal frameworks is needed, involving political and administrative choices.

Innovation in healthcare is stimulated by the government as part of its general duty to promote social wellbeing (including longer healthier lives), but also by the drivers of the knowledge economy. But at the same time progress is being slowed down, either consciously or not.

Combination of diagnostics and therapy
At the moment diagnostic and therapeutic products are appraised and reimbursed through separate channels. This situation will no longer be workable when the strength of a product lies in a combination of diagnostics and therapy.
Neither is the research system of holding clinical trials for new medicines or treatments before introducing them into the healthcare system entirely appropriate for the new developments. The rules for clinical trials set by governments do not appear to be suited to the new combination products, which makes modernisation of current international practices desirable.

Instruments for promoting efficiency
The challenge facing the government is to ensure that the system deals efficiently with these combination products so that patients can benefit as soon as possible. The government can decide to:
- modify the appraisal procedures to suit modern medical innovations, such as combinations of diagnostics and therapeutics;
- consult with healthcare practitioners about the criteria that clinical trials for modern medical products should meet in order to provide sufficient information and comply with new and existing appraisal procedures;
- exchange views with healthcare practitioners about efficient implementation of positively appraised innovations so that opportunities do not remain unexploited.

The Dutch Embryo Act does not permit research into the effectiveness and safety of new reproductive techniques in the Netherlands. This stands in contrast to the importance attached in the Netherlands to the treatment of infertility and to healthy reproduction in cases where there is a genetic risk of a serious disorder. Various techniques are offered in such cases, including preimplantation genetic diagnosis. Moreover, dubious situations arise when new reproductive techniques become available in the Netherlands as a result of research with embryos conducted outside the Netherlands. These obstacles are at least partly intentional, because creating embryos solely for research purposes is considered to be socially unacceptable.

The question facing the government is whether:
- the normative principles underlying this decision need to be revised;
- or, if they do not, how the Netherlands should respond to fertility treatments that have been made possible by foreign research using embryos.

TREND 3
INDUSTRIAL BIOTECHNOLOGY: TOWARDS A BIOBASED ECONOMY

Humanity faces the challenge of overcoming the global problems of fossil fuel scarcity and greenhouse gas emissions. The basic condition for meeting this challenge lies in switching to an economy that does not use fossil raw materials but renewable (biological) raw materials. This biobased economy is a society in which companies use green raw materials and biotechnology for non-food applications, such as energy generation and the manufacture of chemicals. At the moment, considerable attention is being given to the production and use of biofuels. In response to the undesirable environmental and price impacts of first generation biofuels, a new generation of sustainably produced biofuels that avoid these impacts will soon be available. Algae are seen as a promising resource for energy generation and for use in other applications in the chemical industry. Industry is looking for ways to optimise production processes and make them more sustainable, which includes finding optimal uses for by-products and residual streams.

Opportunities
Industrial biotechnology is one of the key technologies in the development of a biobased economy. With the introduction of the biobased economy, the Netherlands will become less dependent on fossil fuels and will contribute to ameliorating the effects of climate change. It is expected that in about ten years time industrial biotechnology will have more biotechnological alternatives for existing processes under development and on the market. Currently promising technologies such as bioplastics and second generation fuels will have reached the pilot plant or process plant stage. Industry will make much less use of food crops as raw materials and much greater use of by-products and residual streams, which will therefore be used much more efficiently.
Over the coming decade the extensive facilities and expertise in industrial biotechnology in the Netherlands will allow it to lead by example in furthering research into and implementation of biotechnology in industrial production. The pursuit of greater biological production by Dutch industry will also have a positive effect on the Dutch economy.

Issues
Before the industrial sector can switch completely to biotechnological production it has to overcome several technical and social barriers. First, considerable long-term investments are needed in research and scaling up new technologies. This requires a favourable investment climate, which depends partly on government action and the market potential of biomass as a raw material.
Second, 'new' biological resources are being tapped for exploitation as raw materials in industrial production. The use of these resources, such as maize and oil palms, can have undesirable impacts on the environment and food security. Although these impacts can be averted through the use of more sustainable raw materials, the drawback is that the strict standards applying to sustainable production inhibit attempts by developing countries to exploit biomass resources. This is because they do not have the expertise and financial means to meet these sustainability requirements.

Besides, little is known about the possible disadvantages of switching from petrochemical to biological raw materials. For example, by-products and residual waste streams from agricultural production chains can be a 'new' source of raw materials for industrial production, but many of these products are already used in the production of animal feed and other applications. The new industrial markets for these products will push up the demand for them, which could be accompanied by undesirable effects such as price rises or displacement of existing uses. Doubts have also been expressed about whether in the longer term higher levels of agricultural production of biological raw materials can be maintained, because phosphate deficiency, among others, will become a limiting factor.

Political and policy dilemmas

5. Creating a biobased economy will require major investments in industrial biotechnology. In the face of uncertain market conditions and the possible erosion of public support, the government must decide whether and how it should support the transition to a biobased economy.

The successful implementation of biotechnological production in the industrial sector will require long-term and costly investments by industry in research and pilot plants. A favourable investment climate for industrial biotechnology depends in part on the competitive position of biological raw materials with respect to petroleum. For the time being, market forces will work to the disadvantage of biological raw materials because using petroleum is cheaper. Before industry can make a definite transition, the price of biological raw materials must be consistently lower than that of petroleum over a long period, because otherwise major investments would be too risky. Wide fluctuations in prices, as we have seen in recent years, form an obstacle to investors. To get the biobased economy of the ground, it will probably be necessary for the government to provide long-term subsidies for research programmes, scaling up technologies, and applications.
The government faces the question of whether and how it should stimulate and facilitate the use of industrial biotechnology. Possible options are subsidising research, subsidising production, for example of second generation biofuels, and stimulating the market, for example by lowering the duty on biotechnological products.
Public support for the use of biological raw materials has been eroded by the criticisms levelled at first generation biofuels. Many people are indignant that the use of food crops to produce biofuels is pushing up food prices. There is also resistance from environmental and nature conservation groups, among others, to the clearance of rainforest to cultivate biomass. Justifying stimulating industrial biotechnology in the face of these criticisms presents the government with quite a challenge.
The following considerations need to be taken into account:

- On the one hand, recognising and responding to current public perceptions about biofuels by setting stricter sustainability requirements could slow down the transition to a biobased economy.
- On the other hand, ignoring this public perception could lead to reduced acceptance of biotechnological applications that make a better contribution to sustainable development.

6. Using residual streams and by-products in industrial production presents opportunities, but at the same time it can lead to price rises and displacement of original uses. The government must choose whether or not to develop policies to avert the possible undesirable side-effects.

In response to the negative image of first generation biofuels and the desire for more sustainable production, industry is shifting its focus from food crops to other biomass resources. Attention is now shifting from food crops to by-products of chemical conversions and residual streams from agricultural production chains. However, these by-products and residual products already have an economic function. For example, beet pulp, potato steam peel and straw are used livestock feed. A new market for these products as raw materials for biobased production will increase competition for them and the resulting price rises could be considerable.
The increased market demand for by-products and residual products can lead to fierce competition with other uses and the displacement of other markets. The use of residual streams as animal feed may force the animal feed industry to switch to agricultural products, with the unintended effect of increasing the agricultural area or competition with food production. This may in turn lead, via a different route, to the same undesirable effects as those caused by first generation biofuels, such as forest clearance and rising food prices.

The question now facing the government is whether:

- besides any incentive measures, research should also be done into the impacts on the scarcity of agricultural raw materials of switching from petrochemical-based to biobased processes, and the effects on nutrient cycles, such as phosphate;
- measures should be taken to manage any competition for by-products and residual products.

TREND 4
PLANT BIOTECHNOLOGY: THE DIVIDE BETWEEN THE EU AND THE REST OF THE WORLD

The volume of genetically modified (GM) crops or agricultural products on the world market will rise sharply in the coming years. Not only will the area of land under GM crops grow, but other GM crops will also be grown commercially. Furthermore, a wider range of traits will be introduced into GM crops. In the years to come GM crops with new disease resistances, drought and salt tolerances, higher concentrations of 'health-promoting' substances and other alterations to compounds or processes of the plant itself will be introduced onto the market. GM plants will contain larger numbers of inserted genes through the stacking of genes via genetic modification or crossing of GM plants.
Crops with new traits will be developed more quickly through the use of plant biotechnological techniques in breeding programmes. Techniques such as marker assisted breeding have now become an integral part of plant breeding. In future, biotechnological techniques will be used more widely in plant breeding, further blurring the boundaries between genetic modification and other biotechnological techniques. Techniques from genetic modification will be used as tools in the breeding process without this resulting in a transgene or 'unnatural' modification in the genome of the final breeding product, the plant. Genetic modification techniques will also become more refined: within the next ten years it will probably be possible to induce targeted changes to specific genes in the plant genome and to insert new genes at specific sites in the genome.

Opportunities

Agriculture stands at the threshold of several major challenges. In 2050 there will be about nine billion mouths to feed, which will require a 70% increase in agricultural production. However, the ability to raise the levels of agricultural production is hampered by a lack of suitable new agricultural land and water. Future climate changes, which are expected to make some agricultural areas too dry for cultivation, will make this problem even more

acute. Increasing production must be made possible by introducing improved varieties with disease resistance and drought and/or salt tolerance, and preferably with a higher nutritional value. Plant biotechnology is one of the key technologies available for meeting these challenges. These technologies, such as marker-assisted breeding, can considerably speed up the breeding process. Genetic modification is also seen as an important tool for faster breeding. However, the use of these technologies is controversial, particularly in Europe.

Issues

Rising prices

The technical and commercial development of GM crops is taking place largely outside the EU. The EU is influential as a market for food products.

In the coming years the prices of agricultural products on the world markets will rise as demand increases, especially from Asian countries. This increased demand for agricultural products will reduce the influence of the EU market. Because GM crops often have certain advantages over conventional crops and will give growers secure markets for their products, the cultivation area of non-GM varieties outside the EU will decline.

Inadequate legislation

The development of biotechnological techniques will blur the scientific and legal boundaries between genetic modification and conventional plant breeding methods. Sometimes use is made of genetic modification techniques or genetically modified intermediate products, without the final breeding product, the crop, containing a genetic modification. European legislation does not address such situations.

Monopolisation

For a long time now the scale of plant breeding operations has been increasing. Plant breeding companies have merged or been taken over to create large multinational corporations. This applies particularly to agricultural crops, but the vegetable seed sector has also undergone a period of strong consolidation. Most of the large Dutch plant breeding companies are already divisions of a multinational. Biotechnological research is capital intensive and therefore an important driver of this process, which carries the risk of monopolies being created, a reduction in the diversity of companies and weakened competition.

Patent law

Since the introduction of biotechnology into plant breeding, patent law has taken hold in the sector and plant traits and varieties are now frequently patented. This conflicts with the conventional model for protecting intellectual property in this sector, plant breeders' rights and the important breeders' exemption, which gives breeders the right to use varieties as parent material.

Political and policy dilemmas

7. As the area of GM crops elsewhere in the world increases, mixing of GM and non-GM crops in imports to the EU is also increasing, while effective control of non-authorised GMOs is impossible. The government must choose whether to accept this or revise the legislation.

As GMOs become more common throughout the whole production chain, the mixing of GM and non-GM crops in imports to the EU and the Netherlands will rapidly increase. Effective control by government seems virtually impossible because of the high costs, the lack of detection methods for unknown GMOs and the size and diversity of imports. The Netherlands is particularly affected by this problem because Rotterdam is the biggest transit port in Europe.

Most people will associate mixing with GMOs with safety risks. However, the vast majority of cases will involve unintentional mixing with products that have been assessed and authorised elsewhere. These cases of mixing are therefore more an infringement of consumer choice than a safety risk.

At the same time, the increasing area of GM crops will in future drive up the costs of some conventional agricultural products, such as maize and soy, relative to the cost of the GM product.

The government has the following options:

1. **Accept**: The EU authorities can decide to maintain current policy and accept that total control is not possible and mixing will occur. The question is whether the public and consumers can be convinced that unintended mixing does not as a matter of course involve safety risks, but rather implies a restriction on consumer choice.
2. **Accelerate:** In addition, the government can decide to speed up the EU procedures for authorising GM crops to reduce the problems of mixing with GM products not (yet) available within the EU. It should be noted that this will only solve the problem of GM crops for which EU authorisation is applied for.
3. **Tolerate:** Following the example of Switzerland, the EU can also decide to accept a low percentage of mixing with non-authorised GMOs as long as the GM products have been assessed for safety in other countries. The question here is whether, and when, a safety assessment can be considered equivalent to the European assessment procedure. In other words, which countries' assessment procedures will be accepted and which will not, and on what grounds?

8. The developments in plant biotechnology have outdated the current EU GMO regulations, putting freedom of choice and innovation at risk. The dilemma facing the government is that solutions based on current legislation will lead to further inconsistencies, whereas amending the legislation will be seen by some of the population as an unwarranted exemption from the GMO regulations.

It is not clear when products of molecular breeding techniques do or do not fall under the EU GMO regulations. This may lead to trade conflicts. Countries such as the US and Canada have a different type of legislation. In these countries crops that are engineered using genetic modification techniques, but do not contain any genetic modification, are not classified or registered as GMOs. Because these crops and their products are classified and treated as conventional products in Canada and the US, when imported into the EU they are not labelled as GMOs. It will be impossible to control these products because it is very difficult or impossible to distinguish them from conventional plant breeding products. Should the products of such techniques be classified as GMOs within the EU, this would create an uneven playing field for companies operating within or outside the EU. Within the EU they would have to comply with the GMO regulations, with all the strict and expensive assessment and authorisation procedures this involves, while outside the EU there would be no regulatory costs. This could prompt companies to relocate their research activities to countries where they believe they would be subject to less restrictive regulations. Large multinational companies in particular are better placed to do this, whereas smaller companies have fewer opportunities to relocate. Smaller companies are therefore most affected by differences in the innovation environment within countries.

The Dutch and European authorities face the dilemma of either taking a decision for each new molecular breeding method whether its products should fall under the EU

GMO regulations, or revising the scope of the legislation. Both approaches have their disadvantages:

- The assessment of each new technique will give rise to inconsistencies and uncertainties for companies, citizens and consumers, because appraisals are based on the scientific insights and political circumstances at the time they are made. As these circumstances change, decisions made at another time could well be different.
- Revising the legislation could lead to some products no longer being classified as GMOs in future. This could meet resistance from certain consumer groups and citizens.

9. Given the developments in the protection of intellectual property and concentration in the international plant breeding industry, the government faces the choice of whether, and in what way, it can help to prevent the possible undesirable effects of monopoly forming in food supply.

The trend towards larger-scale operations in the plant breeding sector, driven in part by the introduction of technological and capital intensive methods, can have adverse effects such as monopolisation and reduced competition. Monopolisation could lead to a reduced supply of crop varieties and even to 'genetic erosion' of agricultural varieties, and in the longer term could present a threat to global food security. More widespread use of patent law in the plant breeding sector to protect the intellectual property rights on traits and plant varieties may further strengthen these adverse effects. Because patent law, in contrast to breeders' rights, does not recognise breeders' exemption, it prevents plant breeders from using varieties developed by others that have the characters they seek to develop better varieties themselves.

Possible options for the government are:

- taking measures to improve the position of small and medium-sized plant breeding enterprises with respect to multinationals with the purpose of resisting further monopolisation in a market that is essential for future global food supply;
- taking measures to prevent undesirable effects of patent law and breeders' rights issues in the plant breeding sector.

TREND 5
BIOTECHNOLOGY IN ANIMALS: THE ADVANCE OF CLONING

In the Netherlands, and to a lesser extent in Europe, there are ethical and social objections to the application of biotechnology in animals. In the Netherlands the application of biotechnology in animals is restricted to biomedical research for human health purposes. In other parts of the world the application of biotechnology in animals is viewed differently. In countries in Asia and the Americas and in Australia, research is conducted on animals in other fields of biotechnology as well, including research into the production of medicines in animals, cloning animals or genetic modification of farm animals and fish for food production, or combinations of genetic modification and cloning. In anticipation of market introduction, the US FDA has stated that meat from cloned animals is safe for human consumption.

Opportunities

Biotechnological techniques are increasingly used in animals around the world. In the Netherlands, biotechnology in animals is used primarily in biomedical research. This research is of great scientific, biomedical and medical importance. Research in the fields of cancer, ageing diseases, metabolic diseases, congenital abnormalities, etc. is unthinkable without using GM animals. Besides biomedical research, research is also being conducted outside the Netherlands into the genetic modification of animals for the purposes of animal health or environmental impact assessment, to produce valuable biological compounds, such as medicines, or for other purposes. Besides genetic modification, cloning animals is also seen as an important technological development. Cloning of animals can be used for the rapid introduction of traits into the population, the conservation of original breeds of domesticated animals or extinct breeds, cloning highly valuable breeding animals such as top sport horses, and for more exact biomedical research. For these purposes it is not the intention, neither is it economically feasible, to clone animals on a large scale. Worldwide there are at the moment a few thousand animals that have been cloned for these purposes.

Issues

At the moment, cloning animals is forbidden in the Netherlands, unless the minister grants an exemption on the basis of a major overriding public interest. Animal cloning is permitted in other countries for various purposes, including food production, medicine production or sports purposes. Cloned animals are genetically identical to the donor and to each other, and their progeny cannot be distinguished from animals bred in the normal way. Neither can products from cloned animals or their progeny, such as milk and meat, be conclusively identified as such.

Although there is no scientific reason to think that meat from cloned animals could be unsafe, this development raises new policy issues and political questions for the Netherlands because meat and other products from cloned animals could enter the Dutch market. The production of medicines using cloned animals or the use of cloned animals in for example horse sports, are also realistic developments that could strain current policies.

Political and policy dilemmas

10. Cloning animals is forbidden in the Netherlands, but an import ban on cloned animals and their progeny or on products from cloned animals is not enforceable. The government must choose whether to accept imports or to revise the legislation.

Because cloned animals, their products or their progeny cannot be conclusively identified as such, an import ban cannot be enforced. This is made even more difficult because these animals are probably not registered as being cloned in the countries where they were developed. An import ban could also lead to trade disputes arising from WTO agreements. The import of cloned animals and products will also undermine the current, socially accepted 'no, unless' policy, because citizens and consumers will have to be informed that no guarantees can be given on the traceability of animals and products. At the same time, prohibiting producers and researchers from doing the same as their foreign colleagues will have to be justified. A change in policy regarding the cloning of animals for food production and other purposes to bring Dutch legislation more in line with other EU countries will provoke opposition from certain groups or civil society organisations.
The government can deal with this situation in three ways:

1. **Absolute prohibition**: Develop a policy to prevent such products entering the Dutch market.
2. **Qualified prohibition**: Accept these animals and products in the Netherlands, while maintaining the current 'no, unless' policy for cloning research.

3. **Qualified permission:** Accept these animals and products in the Netherlands and permit and tolerate the cloning of animals in the Netherlands: a 'yes, proved that' policy.

INTERACTION BETWEEN TECHNOLOGY AND SOCIETY

This policy summary contains a synopsis of the key opportunities, problems and dilemmas arising from the prioritised trends. These are not the only questions thrown up by the trends. A more comprehensive overview of the relevant developments and associated issues is given in the main body of the report.

In the first chapter of the trend analysis the trends are set within a broader context by identifying and discussing several more general social questions recurring in the various trends. In the final chapter the evolution of the trends over time is outlined by examining the similarities and differences between the three past biotechnology trend analyses.

New connections and globalisation

The development of biotechnology and its applications cannot be divorced from more general developments such as globalisation and the gradual merging of scientific disciplines. The boundaries between biotechnology, ICT and physics are blurring and the increasing linkages between them are giving rise to new fields of science, such as synthetic biology and nanobiotechnology.

Globalisation is highlighting global challenges like climate change and sustainable development. These challenges are also driving developments in biotechnology, because these developments are expected to deliver solutions.

Globalisation is also driving the formation of large international networks for scientific research and technology development. These restrict the room for manoeuvre available to national governments for making policy to steer technological developments.

Democracy, policy and politics

Several recurring topics in the various biotechnological trends relate to the social embedding of biotechnology and the implications for democratic control. Examples are the sometimes tense relationships between government and citizens, the emphasis on people's autonomy and the pressures on them to make certain choices, the possible erosion of solidarity between citizens as a result of technological developments, the discussion about ownership and property rights on knowledge and knowledge products, inadequate or outdated legislation, and finally the need for new steering concepts that reflect the global context of developments.

Identifying biotechnological trends therefore implies also devoting attention to the social context and the relation between that context and biotechnology. The questions this raises include: how can public confidence be won; how can international solidarity with the poorest people in the world be maintained; how should ownership and intellectual property rights be regulated; what sort of legislation is effective and socially acceptable; how can citizens play a part in this; and, not least, what role and responsibilities do scientists and technologists have in answering these questions?

In the search for answers and solutions to these questions, civil society, citizens, consumers and the corporate sector have an important part to play and a responsibility to work with governments, in international dialogue, to steer technological developments in a desirable direction.