Dedicated to Professor Ing. Jiří Petr, DrSc., Dr. h.c., to his birthday

THE DEBATE CONCERNING THE EFFECTS OF BIOINFORMATICS ON FOOD PRODUCTION

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The age of communication in which time and space are losing their importance has just begun. And at the same time, bioinformatics is considered to be a new magic word of natural sciences and agronomy.

Bioinformatics wants to explain the function of genes and gene complexes, combining biological and biotechnological data and facts with mathematical algorithms and prediction models in super computers.

Let's have a quick overview on the development in the area of agronomy up to now, and to develop a vision for future.

It is known that until the end of the last century the sum of knowledge doubled every 30 years; hence, a university degree could usually give a whole theoretical background for a whole professional career.

The situation has changed drastically in the last years! At present, the continuous update of academic knowledge and education is needed.

During Professor Petr's activities at the University of Agriculture in Prague-Suchdol as a researcher and rector, the knowledge in agricultural, biological, biotechnological and farming methods doubled several times.

Actually the knowledge in biotechnology doubles every 18 months. This is as dramatic as in the field of informatics. Patents on production methods are often obsolescent at the moment of granting.

The progress in research has more reasons. Among the most important ones is the number of people working in research. Today, more researchers and scientists are involved in this area than during the whole time of the human history until the middle of the last century, i.e. 1950. This is connected with the growth of population on the one hand, but also with the reached level of knowledge on the other hand. Alexander von Humboldt was probably the last researcher, who was aware of all scientific knowledge. Due to libraries and computers the new Babylonian confusion of languages has not spread yet – however, this danger remains. Thanks to the broad education, graduates from agricultural universities are prepared to take part in scientific and management discourses as moderators and mediators between different disciplines.

Not only the biological-agricultural methods and knowledge has been improved, the breakthrough came with the great success in data processing and Internet. During my studies in Hohenheim, we had a large-scale computer with a memory of 65 kB that managed the work of a 8-hour day on a mechanical calculator within 4 seconds. Now, 30 years later the current computer generations with gigabytes don't need more than nanoseconds for the same process. The internet has created a worldwide availability of publications within seconds. Agronomical research is internationalized and globalized and electronic data bases are also helpful in small local and regional projects. Easy access possibilities in data bases and combining of agricultural results have been developed dramatically. Agro informatics is now the new basis of agronomical research worldwide.

In the library of the FAO in Rome, there are 17 km of files with results of agricultural research collected all over the world and the amount of data growth daily. According officials from FAO all these results shall be available for all interested persons on electronic data bases In future. Every day there are thousands of new findings published on international computers. It is overwhelming and inconceivable how much new knowledge will be available every other day. The agricultural informatics has been just enjoying a boom, and the bioinformatics is still in its infancy.

Already more than 2000 data bases are available worldwide for biological data and facts. The price-performance ratio for computers has improved 100 000 times within 20 years; in 1980, a 15 MB hard disc cost DEM 20 000, whereas today a 15 GB hard disc is available for about DEM 200.

Bioinformatics is already a well established branch in the pharmaceutical research. The influence of bioinformatics for food production will be as dramatic as it is in pharmaceutical research today. Nowadays, a lot of bioinformatic – projects are under preparation all over the world, and it is already obvious that we will have a lot of various specializations and segmentations within bioinformatics in future.

Bioinformatics and gene technology – what does this mean today?

The first plant is decoded – the revolution in farming begins; this is what Klaus Ammann, Professor of botany in Bern, wrote in the Frankfurter Allgemeinen Zeitung on December 17, 2000. Some weeks later the same newspaper published: the genome of rice is decoded. The analysis of the rice genome, at cost of US$ 33 million for a Swiss company, means a lot of additional information which is mostly only available against payment.

IBM will participate in the bioinformatics market, the analyst in the market segment of biotechnology, Christian Garbe reported. According IBM estimation the size of the global bioinformatics market in 2003 will be on a level of 9.5 billion dollars. If experts manage to put the necessary supercomputers into operation, what cannot be doubted, bioinformatics, or rather biotechnology and gene technology, and consequently food and medicine research will face a breathtaking future.

The beginning of the human-biotechnological age has also its date: on June 26, 2000, the (almost complete) decoding of the human genetic make-up was published. The American genetic researcher, Craig J. Venter, and the manager of the International Human Genome Project, Francis Collins, announced the success in front of everyone's eyes of the whole world in the White House. The map of human genes with about 32 000 genes and some billions base pairs was published on February 13, 2001.

It was a dramatic finish of the competitive human research race. During the last months, with an enormous technical power and capital from the stock exchange, researcher opened a new great chapter in the book of life:

Now one finding hurries up the next in the genome research. Five years ago, each genetically decoded microbe was celebrated as a great sensation. Last year, decoded bacteria and protozoa started to be counted in a weekly intervals. Now, after decoding 3 billion characters in the human genome text, the higher complex organisms are not more a great task for the modern decoding machines.

Like the green and red biotechnology and gene technology, also the bioinformatics turns to asking questions about crops, animals and humans.

If we here limit ourselves to the green bioinformatics, the following can be stated:

Thale cress is a really modest weed, adaptable and a classical companion of the human culture overall in cracks, walls and rubbish dumps. This delicate plant, whose scientific name is *Arabidopsis thaliana* and which is also called mouse-ear cress, has really gone places: it is represented on all continents and feels so well that it shoots its ripe seeds around to a one-metre wide surrounding, to maintain its reproduction despite of weed control. Nevertheless, this hardly twenty centimetres high meagre plant was amazingly going places also in a different arena: it has advanced to the position of an extra special gene research object, and as it can be easily grown and increases awfully fast it has filled up thick volumes of scientific papers. It delights any researcher, as he can quickly obtain good scientific results during this short life period.

This small plant is so popular that it has the privilege to be now the first higher plant having all its genes charted. Of course, there is another important reason next to its spread; Arabidopsis has only about 8000 genes (less than a half of otherwise usual number), and hence, it can be analysed easier and quicker. The gate into botanists'age of genomes was pushed open on December 16, 2000, when members of the international "Arabidopsis Genome Initiative" introduced the genome map of this plant to the public in Tokyo, Washington, London and Brussels at the same moment. The research in natural sciences and obviously also the bioinformatics, agroinformatics and agronomy will profit tremendously from these discoveries. Somerville was right when he forecasted in his paper published in Science of 16 July 1999 that genome sequence adornment will be completed until the end of the year 2000; we all considered it difficult to believe that time – the project was still in its infancy –; however, it showed once more how huge steps the biotechnological progress has achieved in less and less time.

This breakthrough will change our food production more dramatic than the "Green Revolution" several decades ago. The increase in genetic knowledge will have influencing effects in breeding and will fasten the achieving of goals in breeding of the most widely grown cultivated plants as wheat, corn and rice.

People with agricultural education will easily understand this change and will be able to imagine the amount of data available in future. Up to now, cultivated plants and crop varieties have been described by breeders and variety testing authorities by means of 20–40 phenotypic characters. These description have been supplemented with performance data from different locations to describe agronomical values. The live cycles of crops is described by breeders with up to 100 phases from a seed to the harvest.

Now, new possibilities of description and research of the phenotypic and genotypic type have appeared. The genetic description of rice means 430 million genetic characters. With the help of modern proteomic methods plants can additionally be described from the phenotypic point of view in all 100 phases with up to 20 000 proteins in each stage in future. We will have the chance to identify the different crop varieties and the year of production or year of harvest in the food via proteomics. We will in a position to identify negative and positive influencing factors during the growing of plants. Together with bioinformatic methods the Gene maps for cultivated crop varieties will open the existing "black box of heredity" with which all breeders had to live with up to these days. But the fact of these newly situation is also the possibility to show (from the breeding point of view- intentional or unintentional) a genetic drift of a registered crop variety.

About 30 000 genes controlling germination, growth, disease resistance and generative phases of about 2700 described higher plants are the millionfold detailed knowledge that comes up to us. These are fantastic amounts of

data we shall work or scuffle with in future; however, they offer unexpected possibilities.

From the beginning of gene techniques, when people learnt to transfer individual genes of other organisms into the target crops, they have learnt extremely quick. Some of such transgenetic cultivated crops of the first generation have been introduced in numerous countries with good results for farmers. However, the environmental and economic advantages are still modest and dependent on particular regions. Nevertheless, the farmers who practically grow them are enthusiastic about the advantages.

The big increase in the knowledge of genomes will now help to create resistances against parasitic fungi and pests; today's main risk for large yield and harvest losses. Nonetheless, we should be careful not to simply replace the chemical solution by a genetic one concerning pest control. It would be preferable to engage the elegancy of breeding methods in favour of meaningful goals, Ammann suggests. This means not only agricultural benefits but crops containing substances with an effect on health or with effects against allergies.

At present, a romantic concept of farming can not be reached on gene techniques. The fight in farming – for good crop yields and against pests – will also exist in future. Nevertheless, we should adjust the near-to-consumer and demand research – into the direction of increasing the biodiversity in fields. Our permanent defensive battle against newly upcoming pest attacks in the monotone huge fields forces us to stop and think. If we are willing to improve the food supply and to limit environmental effects we will have to use our creativity to win these battles.

The future researchers and breeders discovering and breeding crop varieties with pharmaceutical content or plant protective agents, spend only 10–20% of their time in labs and fields, while their research colleagues 50 years ago spent 90% of their time there. Now they will spent most of their time in front of computers, searching and combining the results of other scientists with the help of the internet. It is a task for the future to find switches in genes to activate resistance or to produce effective alkaloids. It is well-known that only about 30% of genes are active during crop-growing; as seen in gene transfer experiments there is a natural repairing system which prevents or at least aggravates expressing and activating of transferred genes.

Besides the researcher in biotechnology also the scientist in agronomy will compile data available in agro informatics all over the world before designing a field trial. By doing this he will construct forecast models that will enable him to focus labour-intensive field trials on really new questions or to design field trials even better aimed than up to now.

How has the nature philosophy developed?

The first appeal for farming and research can be found in the Bible. Indeed, Luther's translation of Genesis "Macht Euch die Erde untertan" (Bring earth under your control) is judged as too extreme by many scientists today. Anyhow, this translation determined the goals of research and activities for several centuries. Since the Middle Ages, a so-called physics theology dominated natural sciences; according to it, existence and disappearance of the equilibrium in nature was considered as divinely ordained. The age of rationalism brought another approach of thinking, but it stuck the acceptance of a fully reverse of nature. Despite of a dramatically different view of the world, both before and after the time of rationalism, it was understood by researchers, reversibility of nature was the ethic charter for research projects.

At present, at least our European society understands that not everything that is possible should also be allowed. Otherwise we would establish a permanent change of ethic. On January 22, 2001 the House of Lords in the United Kingdom gave the permission to future cloning of human cells – something that was unusual at that time in the European cultural landscape, or seemed to be unthinkable.

The dream of mankind to be God and the Creator has come a great deal nearer with the new techniques. This February already, a team of doctors introduced a concrete project of cloning a man. The dangers one will meet are diverse; scientists say they can be minimized, but it requires a political will and political actions that go beyond pure economic thinking of many governments in the globalised world.

Every researcher in our culture knows the feeling of doubtfulness and loneliness with his new result and knowledge. At least for a researcher with our European-Christian ethic, which is quite different from Hindus and many natural religions. Every progress towards new findings is comparable for us with a new expulsion from Paradise because of unsureness concerning the truth. But we are forced by nature to search.

Why do I point to it?

The internet has pulled down borders of countries, cultures and time. The dimension of this change are still not realized by many people outside of research. Publications appearing daily all over the world with English summaries, make them understandable for the majority of leading scientists. Every hour searching machines filter information relevant to individual researchers and research institutes. The importance of new information is evaluated by patent offices and research teams every day and checked for the own benefit.

How was it in the good old time?

In 1855, Gregor Mendel reported his revolutionary idea of hereditary principles to the Scientific-Agricultural Club in Brno. The members of the club at this time did not understand his revolutionary findings; his manuscript was forgotten and was getting dusty in the Brno monastery library for 80 years. Hoffmann shows in his book Creativity that, up to now, years or decades passed in cases of a technological progress from the first formulation of ideas to their realization, because researcher's direct neighbourhood did not understand his findings or the publication of the ideas was time consuming and expensive. Thanks to the internet this will change dramatically, as boarders of countries, cultures, languages and time can be overcome with this medium. Interconnection of data bases with intelligent searching programs in a network takes care of the rest.

Today it is general knowledge that this situation has considerable chances, although it contains some danger as well.

What tendencies can be seen in agricultural research?

Scientists in the field of bioinformatics, researchers in agriculture and farmers work in professional surroundings, where the future of the profession is determined above all by
- evolution in perpetuity
- accumulation of knowledge in perpetuity
- natural disasters in perpetuity.

The last 2000 years of the human history were marked by famines, wars, fear of the future, belief in progress and belief in reversibility of the nature.

At present, the balance of the earth has dramatically been changed by the global population explosion.

Today, there are more researchers in the field of natural sciences than in the whole human history until the year 1950 taken together. We can observe dramatic different food markets and food supply in industrial and developing countries. Media reports immediately and all over the world about natural disasters, a surplus of food and famines.

The basic demand of "daily food" requires – when the acreage stays the same – an enormous progress in research and production of food.

The knowledge in biotechnology doubled in less than 2 years.

The findings of Gregor Mendel required nearly 100 years until they were publically known and accepted. Data published today is available to the whole world of science with the only delay of the internet, i.e. several seconds, and that with all consequences of patenting, protection of knowledge and future utilization.

In a few years, very promising genes of cultivated plants will be disclosed. The rice genetic map has already shown a great progress, and large private agro-concerns release results of their research worldwide – some of them free of charge. The new knowledge has enormously increased chances for success in breeding during the last years.

Soon, researchers will not have to wait for accidental results. As cross-breeding will remain the basis of any breeding they will be able to use scientific models to forecast which result a crossbreeding will really give. With the use of marker genes it became also possible to find out what really happened with a new combination of genes in case of a successful crossbred even in the very complex situation of cereals i.e. wheat breeding. Bioinformatics will accelerate breeding of new varieties in an enormous way.

There are more ways of research in future, and all of them should be followed. In the first fascination by new technologies many other strategies of pest control receded into the background. In my opinion too much as modern farming could immensely profit from know-how and experience of bio-farmers who are as important visionaries as genetic researchers.

We should wisely utilize our new knowledge about individual genes for such farming methods which will pay more attention to soil fertility, which will also allow for small weed populations, and which will finally offer accommodation and food to valuable beneficial insects. With new differentiated knowledge about genomes it should be possible to form transgenetic useful plants that will, for example, produce protection agents for themselves against pests – plant-specific pesticides with a time-limited effect that, in the best case, carry out their work just in particular jeopardized organs. Vice versa, the research detects also possibilities to direct genes in such a way that the corresponding active substances are performing only far from the reproduction organs. Thus, the risk of unwanted gene outbreeding can also be elegantly evaded, says Ammann.

That all looks like a pie in the sky. A lot of it will surely be available in only several years, but with the breakthrough that was managed with decoding of genomes, these dreams have a realistic chance.

We can win the future!

The human nature is obviously in such a way organized that learning proceeds by trial and error. Not to make the same mistake for the second time or to avoid new mistakes as far as possible, findings are collected and teached.

Today as well as earlier, policy, science and economy require people who make decisions, people who are aware of the fact that their knowledge is just a part of the whole truth.

To perform in an executive function means today and even more in future "to come closer to the truth in a fair discourse with other scholars." Each decision-maker in the political and scientific life has to learn and then to formulate his own ideas. To fight with powerful argumentation for the own conviction but also accept better argumentation and knowledge of other persons is an old scientific procedure.

Those who learnt logic, emotionality speech and conflict argumentation already as young people in a free-of-fear atmosphere for example at the university, are better prepared for leading positions in the future than others.

Today and tomorrow the research and economical manager as the politician lives not only from his own professional knowledge, but from his ability to communicate, to endure criticism, to solve conflicts and his will to learn in discourses every day.

Having in mind the chances and risks of technological progress in one hand and the own ethic in the other hand we would like to give the following advice to all people involved in food production:

"Examine whether the methods and the results of your work are of **economic and environmental and humanitarian benefit**, and when you are convinced concerning the balance of this benefit-endowment, **then believe in what you do and do what you believe in!"**

The permanent evolution; natural disasters in perpetuity; exploding growth of population with the basic need of food; the "Faustian" search for knowledge; rising competition between researchers of different cultures and overcoming time and space in the Internet – that will change us and our surroundings!

At this place, we have to express thanks to Professor Petr who contributed, as a researcher in the field of agronomy, considerably to the practical understanding of plant cultivation, and who helped, as a rector of the Czech University of Agriculture, to prepare a trustworthy integration of the East and the West.

Thanks to a considerable personal commitment, Professor Petr as a researcher and rector of the University of Agriculture in Prague-Suchdol embraced the windows of change and opened the university gates to globalised science and knowledge during recent decades.

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