The birth of biotechnology and original expectations

The term ‘biotechnology’ was coined in 1919 by Karl Ereky, a Hungarian engineer, who described the term to capture the process by which products could be produced from raw materials with the aid of living organisms. The field has evolved over the decades but really exploded in the latter part of the 20th Century with the advent of the new techniques of genetic engineering. Techniques such as gene splicing and recombinant deoxyribonucleic acid (DNA) technology allowed for the first time the selection of segments of DNA to be taken from one organism and placed into the cells of another organism. The ability to make bacterial or eukaryotic cells produce foreign plant and animal molecules led to a sudden new biological revolution. Foremost, genetic engineering brought biotechnology to the forefront of science and commercial applications soon followed.

Advances and obstacles in the last decade

The first advances came inaudibly with improvements in production methods but the advancements that received the most notoriety came with the production of new medicines and genetically engineered crops. As early as 1978, the synthesis of human insulin had a huge impact on expectations and the biotechnology industry grew rapidly. Successes in plant biotechnology are evident today with an estimated 70% of processed foods in grocery stores containing ingredients derived from biotechnology crops. The first commodity crop, an insect resistant variety of corn, was grown and sold in 1996. The application of biotechnology in animal production on the other hand has had varying successes and limited commercial applications. The initial breakthroughs in animal biotechnology came with making genetically identical copies or clones of animals. The first success made international news in 1997 when a group of Scottish researchers announced the birth of Dolly, which was cloned using a single cell from an adult sheep. Researchers have since cloned other mammals including cows, goats, pigs, and mice. However, the overall low rate of successful cloning and frequent occurrence of developmental abnormalities in cloned animals demonstrate the need for further research before cloning can be practical. It has also been reported that cloned animals may exhibit health problems. There are currently several hundred cloned dairy and beef cattle, though their food products have not been sold to the public.

A notable scientific breakthrough in animal biotechnology came in the form of a research tool whereby a foreign gene could be inserted and expressed in an animal. One of the first commercial applications under consideration was the use of transgenic farm animals as bioreactors for the production of medicines or organs.
donors. Safety concerns over the risk of contamination of the end product with animal pathogens such as bovine spongiform encephalopathy (BSE) have severely limited the application of these technologies. The commercialisation of transgenic farm animals for food has also been elusive with concerns over food safety, animal welfare, and the environment being expressed by regulatory authorities and the public. Not surprisingly, the first transgenic animals to be sold to the public have not been food animals but companion animals. The first transgenic animal to reach the market being the ornamental goldfish, which under black light fluoresce in a brilliant red color due to an inserted gene derived from the sea anemone. The first cloned pet, a cat, was delivered to its owner in December 2004.

Applications in animal health

Some of the most tangible applications of biotechnology have been in animal health. The globalised trade in live animals, animal products, bedding and feeds is leading to a continuously increasing threat of infectious diseases worldwide. The epizootiological situation is further jeopardised by the regular intra- and intercontinental transport of animals for competitions, exhibitions and breeding purposes. The increasingly open borders between many countries, also contribute to a new high risk situation, where infectious agents may easily travel thousands of miles and suddenly appear in areas where they are unexpected and probably unknown. The sudden appearance of an infectious disease in a new region of a country or a continent may lead to delayed or improper diagnosis, resulting in the uncontrolled spread of the agent to susceptible populations of animals in large unrestricted geographic areas. The emergence of vector-born diseases, such as Rift Valley fever, bluetongue and African swine fever, in connection to climatic changes, is also an increasing threat worldwide. To prevent the spread of infectious diseases, the World Organisation for Animal Health (OIE) emphasises the importance of the following basic requirements:

a) the very rapid, accurate, highly specific and sensitive detection and identification of infectious agents; and
b) prompt and effective control of diseases.
The recent achievements of biotechnology are significantly contributing to the development of novel powerful diagnostic assays, such as various real-time polymerase chain reaction (PCR) and isothermal amplification methods, microarrays, protein detection by nucleic acid amplification, recombinant proteins, synthetic proteins, biosensors and many other approaches to detect the pathogens and/or the immune responses after infection. The phylogenetic analysis of the amplified nucleic acid sequences provides novel information on the evolution of pathogens and supports the studies of molecular epidemiology. Evidence for exchange of DNA amongst varying microbial organisms along the evolutionary ladder is redefining our understanding of pathogens and redefining the classification of microorganisms and systematics. Considering that 70%-80% of all new emerging diseases worldwide are zoonotic, biotechnology is also making momentous contributions to preventive medicine by opening new ways to construct genetically modified marker vaccines, DNA vaccines and other tools for improved and safer immunisation against infectious diseases in animals and man. Biotechnology provides the means by which novel and effective tools can be specifically designed for control and eradication. With the investments made in biotechnology research, health authorities worldwide are progressively in a better position to combat infectious diseases, including highly devastating transboundary animal diseases. Considering the emerging biological threats worldwide, biotechnology is providing tools for the detection, prevention and management of natural and bioterrorism induced pandemics. Emerging technology has provided the tools to design much deadlier pathogens in the hands of bioterrorists. However, concomitantly the ability to respond to emerging pandemics to reduce mortality has also improved significantly in the recent years.

According to recent publications there are 105 biotechnology products licensed for animals. Most of these products are biologics, including veterinary vaccines and diagnostic kits. The animal health industry invests more than $400 million a year in research and development. Current sales of biotechnology-based products for use in animal health generate $2.8 billion. Biotechnology has yielded new and improved
medicines for animals that help lower production costs and improve animal welfare by fighting devastating infectious diseases that affect animals worldwide. The advent of biotechnology has provided the means by which animal vaccines can be rationally designed for the specific control and eradication of diseases, including the implementation of DIVA (differentiating infected from vaccinated animals) strategies. Biotechnology has also led to the development of rapid laboratory diagnostic tests to detect disease outbreaks early, a critical element in disease control. Importantly, biotechnology is enabling the development of diagnostic kits that can not only be used in the laboratory but pen-side tests that can be used in the field to make decisions about the exposure of animals during a disease outbreak.

The next frontier, the application of animal genomics in animal health

In the late 20th Century, a new window of opportunity has opened with a new area of research called genomics. The term ‘genomics’ was first coined in 1986 to name a new journal where science generated from efforts to sequence the human genome could be published. Technologies being used at that time included the use of bacterial restriction endonucleases to visualise differences in the sequence of DNA and map chromosomes. This was followed quickly by the development of the polymerase chain reaction (PCR) in 1985, which opened up an entirely new world to detect and to study the differences in the DNA sequences of the various genes of animals. Coupled with genetic markers, PCR became a powerful tool that quickly allowed the development of genetic maps of the livestock genomes in the early 1990s. As the 21st Century began and the human genome moved toward an initial draft sequence, additional technologies became available that allowed researchers to move into large-scale gene expression studies to visualise changes in levels of expression of hundreds of thousands of genes in specific tissues. The agricultural research community was able to capitalise on the infrastructure built by the human genome project by sequencing the chicken genome (Gallus domesticus) and the bovine genome (Bos taurus). The 2006 calendar year marked a major milestone in the history of agricultural animal research with the draft genome sequences completed for chickens and cattle and sequencing initiated for the porcine and equine genomes. The animal health research community now has in place a powerful toolbox for understanding the genetic variation associated with disease susceptibility, host-pathogen interactions, and complex phenotypes such as health traits.

Critical gaps in our understanding of gene structure and function in domestic animals must be filled before animal genomics can be successfully applied to animal health. Domestic animals provide a unique resource to study the primary biological mechanisms underlying gene structure and function, regulation of gene expression, and the genetic contribution to phenotypic variation because, unlike humans, domestic animals have been artificially selected to express or repress specific traits. Significant resources will be needed to support research and
integrate two scientific disciplines that are not traditional partners: quantitative genetics and animal health. In support of that endeavour, the OIE has established an Ad hoc Group on Biotechnology. In this Group experts are working together to assess new technologies and develop scientific guidelines to enable their safe use in animal health research.

Furthermore, OIE sponsored and hosted at its Paris headquarters an International Symposium on Animal Genomics for Animal Health (23-25 October 2007). Advances in animal genomics will require interdisciplinary teams of scientists that address complex issues in animal diseases with state-of-the-art equipment and approaches that include infectious diseases, pathology, physiology, immunology, and comparative microbial genomics.

The following four priorities will be paramount if we are to achieve the full benefits of animal genomics:

1. quantitative population genetics studies to identify markers of health traits;
2. studies in functional genomics to assess host-pathogen interactions;
3. translating genomics information to discover innovative tools to control animal diseases;
4. integrated stakeholder support to advance the application of animal genomics for animal health.

Sandor Belak and Cyril Gay