# ANIMAL

# BIOTECHNOLOGY

**Animal biotechnology** is defined as the application of biotechnology to the processing or production of materials by animals (or aquatic species) to provide goods and services. It provides new tools for improving human health and animal health and welfare and increasing livestock productivity. It can enhance the ability to detect, treat and prevent diseases. Moreover, it can improve an animal's impact on the environment.

Scientists are using biotechnology to address some of the major global problems of modern times including the food crisis, health and disease, and conservation, through advances in the following areas:

ANIMAL PRODUCTION
- ✔ Assisted reproductive technologies
- ✔ Animal Breeding
- ✔ Food production
- ✔ Animal health

MEDICINE
- ✔ Transplant organs
- ✔ Pharmaceuticals
- ✔ Research into human disease

INDUSTRIAL APPLICATIONS

CONSERVATION AND ECOLOGY

ANIMAL FORENSICS

ETHICAL ISSUES, SAFETY AND REGULATIONS

Various technologies are employed in each of these areas and recent progress in such technologies has facilitated development in animal biotechnology. These include sequencing and analysis of animal genomes, identification of genes and their variations, an understanding of how these genes are regulated, and advances in molecular markers and diagnostics. Improved and new animal reproductive technologies have also developed the area of animal breeding. Recombinant DNA technology has produced transgenic animals, i.e. animals that contain foreign genes for a specific purpose. The first transgenic animal produced in 1982 was a mouse. Most transgenic animals that have been produced since are mice, used in medical research. As the technology has developed, other transgenic animals have been produced for economic purposes. Cloning technologies have been developed to produce offspring genetically identical to the parent.

## ANIMAL PRODUCTION

### ✔ Assisted Reproductive Technologies

#### ✔ Transgenesis

A transgenic animal is one which has been genetically altered to have specific characteristics it otherwise would not have. In animals, transgenesis either means transferring DNA into the animal or altering DNA already in the animal. There are various techniques that can be used to create transgenic animals.

**✔ Nuclear transfer**

Nuclear transfer involves the transfer of a nucleus into a single egg whose nucleus has been removed. Somatic Cell Nuclear Transfer is a method used to create clones of animals (see fact sheet on stem cells and cloning). Transgenesis differs from cloning in that the nucleus injected into the cell would contain genetically modified DNA. In cloning, the nucleus would be unmodified from the parent animal.

**✔ DNA microinjection**

DNA microinjection of embryos has been the traditional method for generating transgenic livestock. This involves the physical injection of a DNA solution into the pronuclei of a zygote. The DNA in solution then integrates randomly into the cellular DNA, making the process a very inefficient process with a success rate of less than 4%.

**✔ Sperm-mediated gene transfer**

Sperm-mediated gene transfer uses sperm to carry transgenic DNA to fertilise an oocyte. The sperm is pre-incubated with DNA which is randomly picked up by the sperm. This process is also inefficient, however improved uptake of DNA by sperm improve the success rate of creating transgenic animals. Homologous recombination is a method generally used to delete a gene.

**✔ Retrovirus-mediated gene transfer**

Retrovirus-mediated gene transfer uses the natural gene delivery system of the retrovirus to transfer DNA as it infects the host cell, which then becomes integrated in the host cell genome.

**✔ Artificial chromosomes**

Artificial chromosomes are large self-replicating constructs which allow for the transfer of large DNA constructs and ensure better control of transgene expression. The disadvantage is the difficulty in handling such large fragments of DNA.

In addition to the inefficiency in the success of transfer of foreign DNA and creating a transgenic animal, another limitation in the technology is the stability of the expression of the introduced gene. Many of the genes introduced are expressed at low levels or non-specifically. Also, the effects have been reported to decrease over time in the individual or in subsequent generations. Other concerns regarding the technology are the environmental stability/safety. This refers to the potential for the gene to spread to the wild natural populations should a transgenic animal escape or be released, as well as the potential to spread to other animals including humans through consumption of its meat or milk. Another concern is the potential for novel disease being initiated through the process of transgenesis. Also, various ethical concerns have been raised (see paragraph on ethical issues, safety and regulations). All these areas of concern are the target of research into the process of transgenesis.

#### Artificial insemination

**Artificial Insemination (AI)** is defined as collecting sperm from a male and placing it in the uterus of a female. It is one of the oldest animal reproduction technologies. AI is an effective method to prevent the spread of many venereal diseases and diseases of the genital organs that cause infertility. Using semen of superior bulls greatly enhances genetic improvement in a population or herd. Thousands of cows can be inseminated annually with the semen of a superior bull in comparison to thirty to forty cows using conventional mating. AI is the most cost-effective method of breeding, as purchasing the semen of a quality bull is less expensive than purchasing the bull.

#### Oestrus synchronisation

**Oestrus synchronisation** refers to the hormonal treatment of all non-pregnant female animals in a herd to facilitate oestrus in all of the animals at a specific, predetermined time. In other words, oestrus synchronisation brings a large number of cows into heat at the same period. Thousands of cows can be inseminated annually with the semen of a superior bull, greatly enhancing genetic improvement. Both insemination and herd management are simplified by this procedure. Calves are born during the same time period and management practices, such as vaccination, de-horning, de-worming, weaning, etc. can all be performed simultaneously for all the calves. The calves are also more uniform and can be marketed more effectively.

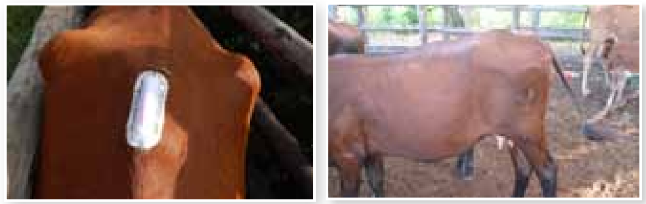


Figure 1 Kamar heat detector placed on the synchronised cows

#### Embryo Transfer

**Embryo Transfer (ET)** technology involves the removal of an embryo from a female of a superior genetic makeup and the placing that embryo into the reproductive tract of a female of average genetic makeup. ET is effective in increasing the prevalence of superior genes in a population and does not increase in the incidence of congenital abnormalities, which has been demonstrated in many studies. Furthermore, this technology allows breeders to exchange their best germplasm locally or internationally without depleting their genetic base. A commercially viable cattle ET industry usually takes time to be accepted by livestock producers due to their reluctance to accept new technology.

Figure 2 Flushing of embryos from the artificial inseminated Nguni heifers

#### In vitro fertilisation

In vitro fertilisation can be a valuable instrument to assist genetic selection strategies and breeding plans for cattle production. It can be utilised to improve pregnancy rates in herds with low fertility or certain reproductive breakdowns, such as ovulation and fertilisation failures or reproductive tract blockage. In vitro fertilisation allows for the more efficient use of semen preserved from deceased genetic lines or highly valuable semen. There is also the potential to amplify the use of small amounts of semen.

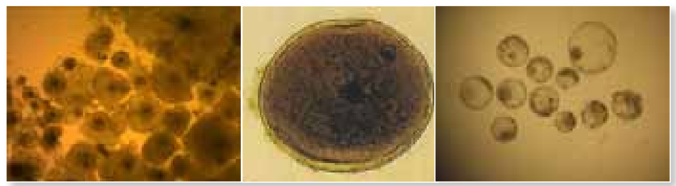


Figure 3 Matured bovine oocytes, zygote & embryo

#### Cryopreservation

**Cryopreservation,** the freezing of live gametes (ova or semen) or tissue at a very low temperature (anything from -80°C to -196°C), is a science that has developed rapidly over the last few decades. It is used to preserve germplasm (embryos, sperm, eggs and somatic cells) of endangered breeds. Techniques have already been developed for the freezing of cattle and chicken semen, and work on sheep, goats and pigs is underway by the Germplasm Conservation & Reproductive Biotechnologies (GRCB) at the Agricultural Research Council. Cattle and sheep embryos have also been frozen successfully. The ultimate aim of these advances is to establish a cryo-bank containing material that can be used to reintroduce livestock breeds that have either disappeared or become endangered as a result of inbreeding and disease.

#### Intracytoplasmic sperm injection

**Intracytoplasmic sperm injection (ICSI)** is a powerful technique in the field of assisted reproduction (ART) and provides opportunities for studying the basic mechanisms of fertilisation and early embryo development. It consists of fertilising an oocyte (egg) by the direct injection of a single spermatozoon (sperm). Its application in agriculture and conservation biology has been greatly hampered by the low success rate reported for this method in respect of economically important species.

#### Embryo Splitting

**Embryo splitting** remains the most effective and rapid method of increasing the number of offspring obtained from an embryo transfer program. Under suitable conditions, embryo splitting can significantly increase the number of live offspring obtained from an embryo transfer programme and maximise the returns from valuable donors.

#### Embryo and sperm sexing

**Embryo sexing** assay enables trained operators to quickly and accurately determine the sex of bovine embryos before they are transferred to recipients. This technology has obvious advantages for livestock producers. Research has shown that when used in conjunction with conventional embryo transfer programs, the use of this technology allows producers to concentrate their genetic improvement on their superior male or female lines. Embryo sexing enables producers to dramatically reduce the overall cost of embryo transfer by eliminating 50% of recipients.

The current development of state-of-the-art reproductive techniques has also made it possible to predetermine the sex (separating of X- from Y chromosomes-carrying sperms), used in AI, IVF and embryo transfer. Sperm sexing enables the producers of livestock to predetermine the sex of offspring prior to conception, thereby maximising productivity, profitability and genetic potential.

#### Multiple Ovulation and Embryo Transfer

Embryo production by Multiple Ovulation and Embryo Transfer (MOET) still accounts for the majority of embryos produced worldwide, but it has high costs and the number of produced embryos is often highly variable and unpredictable. Valuable donors are selected and treated to increase ovulation. Embryos are generally recovered and transferred to synchronised recipients or they are frozen. MOET is of great interest for animal breeding, because of its potential applications in genetic improvement by choosing animals with both high production and environmental adaptability.

Germplasm Conservation & Reproductive Biotechnologies (GRCB) in partnership with Department of Agriculture, Forestry and Fisheries (DAFF) and the Technology Innovation Agency (TIA) is currently conducting research on reproductive physiology and adaptation of assisted reproductive techniques in the livestock industry. Moreover, in collaboration with international institutions as well as national institutions such as the University of Western Cape, University of Free State, University of Limpopo, Tshwane University of Technology, Central University of Technology and University of Zululand, the Agricultural Research Council (ARC), in partnership with TIA and the Gauteng Department of Agriculture and Rural Development, it is currently rolling out a project on introducing and expanding on the dissemination of assisted reproductive technologies. Additionally, training initiatives to educate emerging farmers are being conducted to explain the benefits of ART.

### ✔ Animal breeding

Many animal genomes have now been completely sequenced and a number of gene variants have been described and can be identified. Biotechnology can be used to identify and select animals with multiple desirable characteristics, particularly traits associated with economic importance, and the best combination of gene variants for breeding. The University of Pretoria, Department of Animal and Wildlife Sciences is researching the genetics of Angora goats, particularly to identify a Quantitative Trait Loci (QTL) that is associated with the trait of fine mohair. Being able to identify individuals with a particular makeup with regard to the QTL will improve the efficiency of selection for breeding.

The use of genomic tools (e.g., genome sequences, genetic maps, proteomics, protein structure modeling, bioinformatics software and databases and microarrays) and information they have generated for genetic improvement and the selection of animals have demonstrated the great potential to improve livestock production in agriculture.

Cloning is becoming a viable method of reproducing desired animals of many species. Animals that have been cloned include sheep, pigs, cows, goats, horses, mules, cats, rats and mice. Not only does this have potential significance in maintaining the desired characteristics in livestock for food production (which is debatable of course!), but also has potential significance in conservation of endangered species (see Fact Sheet on Cloning and Stem Cells for more information about the technology).

### ✔ Food production

Population growth and trends in food consumption are expected to result in a net food deficit (i.e. more food being consumed than produced) and widespread loss of food security across the globe within four decades. It is generally accepted that this crisis will have to be met by increased livestock production, using less land, less water and in an environmentally sustainable fashion. The reproductive technologies discussed above contribute to increasing food production. Technologies are being developed to increase food production, to produce more food of higher quality in a shorter period of time. This includes animal biotechnology being applied to livestock to produce animals with a greater size, improved lean muscle mass, increased growth rate, greater milk production, and production of milk with enhanced qualities such as higher protein content or lower fat content. Another example would be chickens with higher quality eggs. Traditional breeding to select and propagate animals with such desired characteristics is a slow and arduous process. Biotechnology has the potential to short-cut traditional/ conventional selection/breeding methods to create animals with the desired traits. An example is seen in transgenic fish created for use in aquaculture fish farming. A growth hormone transgene has been introduced into many species of fish, with many showing increased growth rates.

Coho salmon with a growth hormone transgene showed an increase in growth rate so that fish reached market size in two years in comparison to normal controls which took three years. The fish did not grow beyond the normal adult size finally. A company called Aqua Bounty is engineering salmon, trout and tilapia to grow faster than traditional fish. In the United States, most transgenic animals are regulated by one or more of the Food and Drug Administration (FDA) centres. At this stage no transgenic animals have been approved for use as human food by the FDA.

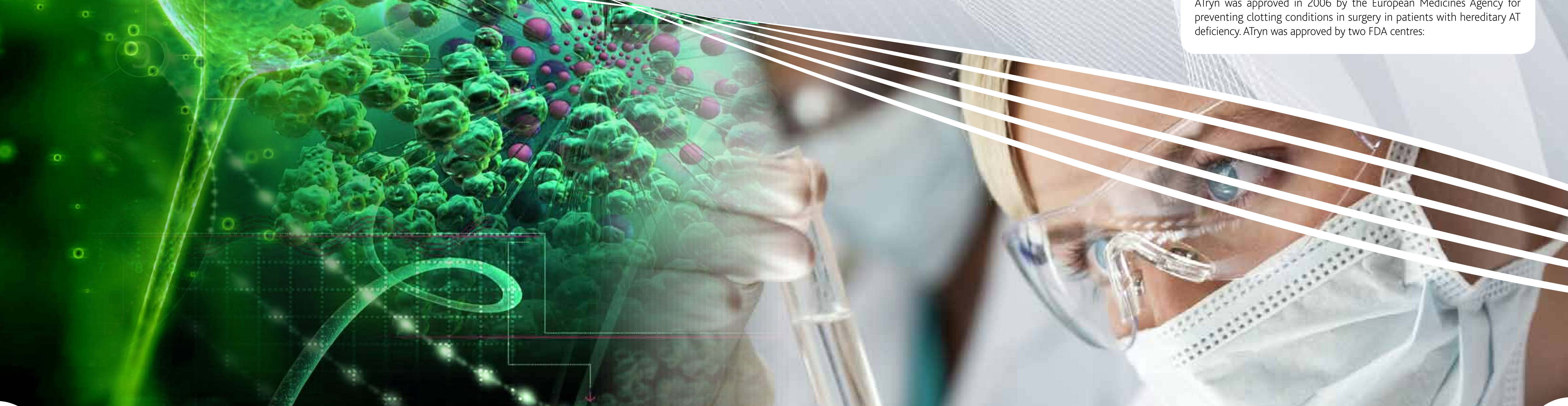
### ✔ Animal health

Although creating disease resistance in animals is not a practical reality as yet, since a limited number of genes are known to be responsible for disease resistance, biotechnology is making advances in preventing diseases such as through the development of vaccines against significant animal diseases. The Onderstepoort Veterinary Institute (OVI) near Pretoria has made significant advances in the development of vaccines against key endemic animal diseases. Research at the OVI has led to the development of unique vaccines against African horsesickness virus in horses, bluetongue virus in sheep, botulism, anthrax, lumpy skin disease and more. At the University of Pretoria, the Department of Genetics has a key research programme into the molecular biology of orbiviruses, largely African horsesickness virus. The aim is to understand important aspects of the virus and its interaction with different cells, its replication process and its virulence, in order to provide insight into the development of new and more successful vaccines.

## MEDICINE

### ✔ Transplant organs

With a shortage of suitable organ donors for failing or diseased organs, science and medicine are looking to other species to make up the shortage. "Xenotransplantation" refers to the process of transplanting organs, tissues or cells between different species. The most promising animal for xenotransplantation to humans is the pig, with organs of similar size to those of humans. However, without genetic manipulation and biotechnology, the pig would not be immunologically incompatible as a donor and organs would be rejected.



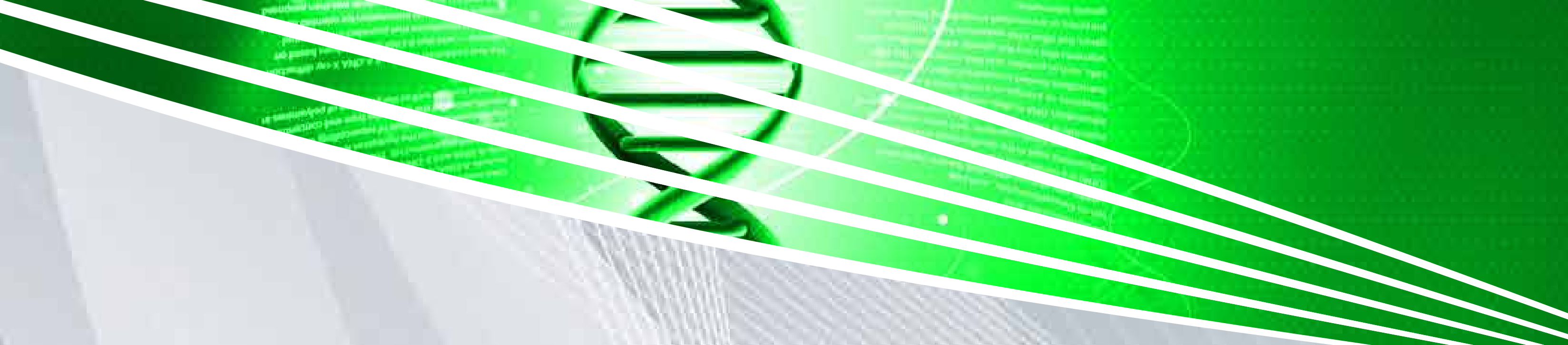
Biotechnology and gene knockout technology (in which a gene is deleted or inactivated) is developing pigs with immunologically compatible organs. One of the major problems in pigs being immunologically incompatible is caused by a type of sugar molecule called Gal-alpha(1,3)- Gal which is attached to protein molecules on the surface of pig cells but not on human cells. In humans it is recognised as foreign, leading to a rapid rejection of the tissue, called hyperacute rejection. In transgenic pigs created for the purpose of organ donation, the gene for the sugar molecule has been "knocked out", so that the sugar molecule is not expressed on the cells of the pig. There are various ethical issues when looking at pigs as a source of donor organs and these issues will need to be addressed as the possibility of using pig organs in humans nears reality. Public education is essential, informed consent and the selection of human donors must be carefully considered, and religious beliefs must not be ignored. Safety is a critical issue. Organs and cells may be rejected, the survival and longevity of xenotransplanted organs are unknown, and additionally, the possibility exists of novel infections being transmitted from the donor animal to the human recipient. There will be many regulatory stages to pass before this technology becomes a real possibility.

### ✔ Pharmaceuticals

Transgenic poultry, pigs, goats and cattle have been developed that produce large quantities of human protein in eggs, milk, blood or urine with the intention to use these products as pharmaceuticals such as enzymes, albumin, clotting factors and antibodies. In a sense, these transgenic animals can be seen as living bioreactors for the production of products of value.

The USA's Food and Drug Administration (FDA) has recently approved the first pharmaceutical produced in genetically engineered animals, called ATryn, manufactured by GTC Biotherapeutics Inc. ATryn is produced in the milk of transgenic goats which have been genetically engineered to contain the gene to produce human antithrombin in its milk. Antithrombin (AT) is a protein that helps to prevent blood clotting in the veins and arteries of healthy individuals. Patients with a rare disease called hereditary AT deficiency lack normal AT. In these patients, ATryn acts as an anticoagulant. Because this disease only occurs in a very small proportion of the population (approximately 1 in 5000 in the USA), the FDA had given ATryn an orphan drug designation, referring to a drug developed specifically to treat a rare medical condition.

ATryn was approved in 2006 by the European Medicines Agency for preventing clotting conditions in surgery in patients with hereditary AT deficiency. ATryn was approved by two FDA centres:



The Centre for Biologics Evaluation and Research (CBER) gave approval based on safety and efficacy, and the Centre for Veterinary Medicine approved the rDNA construct in the goats, stating that seven generations of goats did not suffer adverse effects from the genetic modification. Since the approval of ATryn, new guidelines have been released for the regulation of genetically engineered animals under the new animal drugs provisions of the Federal Food, Drug and Cosmetic Act (FFDCA), entitled "The Regulation of the Genetically Engineered Animals Containing Heritable rDNA Constructs". This provides producers of GE animals recommendations to help them comply with regulations and laws.

Other examples of therapeutic proteins from genetically engineered animals include the production of the protein 1-antitrypsin in sheep's milk. This protein is used to treat hereditary emphysema, cystic fibrosis, and chronic obstructive pulmonary disease which affect over 200 000 people in the US and Europe. This product is in clinical trials in Europe. Another example is human lysozyme produced in the milk of genetically engineered cows. Lysozyme is an antimicrobial protein and so can increase the shelf life of the milk and offer health protection to infants.

✔ Research into human disease

Transgenic animals are useful as disease models. Animals are genetically manipulated using biotechnology to mimic symptoms of disease. In this way they can be used to study therapies and treatments. In particular, developments with transgenesis in mice will contribute to the further reduction in the use of "higher" animals, such as dogs and non-human primates, in biomedical research.

Approximately 80% of mouse genes have a single identifiable orthologue in humans, in other words genes of similar function that originated from a common ancestor. Mice have a short reproduction cycle and their embryos are easily manipulated. This makes them useful to study disease. Over 95% of transgenic animals used in biomedical research are mice. "Knockout" mice can be generated which carry specific mutations in a particular gene of interest. The physical result of that mutation can then be studied. This provides a direct way of studying the function of a gene.

A leading pharmaceutical company, GlaxoSmithKline will be using transgenic mice to carry out some testing of their Oral Polio vaccine. They have also successfully created a transgenic mouse which expresses the CD4 receptor found on the surface of white blood cells, the target of HIV virus. They are able to test drugs which interact with the CD4 receptor in mice instead of higher animals such as the chimpanzee, which possesses a CD4 receptor 98% identical to that of humans.

Porcine (pig) models have also been developed for studying human disease, including the fields of obesity, diabetes, cancer, female reproductive health, cardiovascular disease and infectious diseases. Both natural and induced models have been used. Two examples of natural pig models are (i) a model of Schmid metaphyseal chondrodysplasia (SMCD), a mild skeletal disorder associated with dwarfism, caused by a mutation in the COL10A1 gene and (ii) a model of hypercholesterolemia identified through a mutation in the lipo-protein receptor (LDLR).

## INDUSTRIAL APPLICATIONS

Transgenic animals can not only be created to produce products of pharmaceutical value, but also products of industrial value. An example is "BioSteel", the trademark name for the high strength fibre material made from recombinant spider silk-like protein which is produced in the milk of transgenic goats, made by a company called Nexia Biotechnologies. The protein is harvested from the milk, purified and transformed into microfibers. It is planned to use these fibres for bullet proof vests. In a paper published in Science, they describe the production of a number of different dragline spider silk proteins via cell culture techniques using silk genes derived from two different species of orb-weaving spiders. The silk proteins from one of these species were spun from a solution to produce BioSteel® fibers, which were tested for a number of mechanical properties and compared to natural spider silk. They found they were able to produce fibers with mechanical properties similar to the natural spider silk including toughness, but lower strength. Toughness measures the amount of energy that the fibers can absorb before breaking and spider silks are among the toughest materials in the world.

## CONSERVATION AND ECOLOGY

In addition to the potential benefits of cloning of endangered species, biotechnology also plays a role in discovering, identifying and analysing genetic diversity in endangered species through the techniques of genetic characterisation of individuals in a population. Consequently, this could lead to regulation and conservation of genetic diversity.
The University of Pretoria, Department of Animal and Wildlife Science, is using molecular scatology (study of faeces) as a technique for obtaining information on wild mammal populations. Molecular DNA analysis of faeces gives information as to the genetic structure and demographics of a population. Individual identification can be obtained through "DNA fingerprinting". This is particularly vital in animals that are endangered such as the cheetah, as it improves population management and conservation strategies.

The National Zoological Gardens has a genetic management research group which is focusing on genetic diversity in endangered or threatened species, including the extent and effects of inbreeding, the development of molecular markers for species identification.

The Agricultural Research Council Irene (Animal Genetics Division) has developed a National Genetic Database for game and a Biobank for deposition and storage of biomaterials from a wide range of animal species. This will have various benefits in understanding population structure, the level of gene flow and genetic variation within and among populations and the level of inbreeding which will provide essential information for conservation management programmes. This will include rhino, sable, cheetah, leopard, lion, buffalo, kudu and more. At the Indigenous Genotype Physiology & Biotechnology Development of the Agricultural Research Council (ARC)- Animal Production Institute (API) research is being conducted on conservation of South African indigenous endangered breeds, through cryopreservation of semen, ova, embryo's and somatic cells. Animal biotechnology such as transgenic and nuclear transfer is part of the long term objectives of the group.

Another objective of animal biotechnology is to reduce the environmental impact of livestock farming. Transgenic animals are being created to improve the use of dietary phosphorous to lessen the environmental impact of animal manure. The EnviropigTM is the trademark of a genetically engineered pig developed at the University of Geulph that is capable of digesting plant phosphorous more efficiently than normal unmodified pigs. They produce the enzyme called phytase in their saliva which is active in the acid environment of the stomach and this breaks down the indigestible phytic acid into phosphate which is easily digested by the pig. Grains such as corn, soybean and barley contain 50 to 70% of phosphorous in the form of phytic acid which is indigestible to normal pigs, thus they require phosphate supplements in their diet which increases the phosphorous content of the manure.

In heavy rain the phosphorous in the manure may leach into water in ponds, rivers and streams which facilitates algal growth, resulting in reduced oxygen concentration in the water and a death of fish and other aquatic animals. Enviropigs do not require phosphorous supplementation and excrete less phosphorous, reducing the potential of water pollution.

Another example of the impact of biotechnology on ecology is the production of infertile fish. Some species of fish being farmed are not indigenous to the area and can pose an ecological threat if they were to enter the natural ecosystem. Techniques have been developed to alter the chromosome composition of the fish to make them infertile and thus reduce any risk.

## ANIMAL FORENSICS

Animal forensics is a relatively new and developing field. The Agricultural Research Council's Animal Production Institute, Animal Breeding and Genetics at Irene offers DNA analysis in animal forensic and species identification to reduce the stock theft in South Africa and in SADAC countries. Stock theft is a reality with great economic impact facing farmers. A genetic based positive identification system provides a greater success of prosecution of stock thieves. The ARC maintains a national allele database for domestic animals to ensure animals can be positively identified. A DNA reference catalogue (LIDCAT system) stores samples collected by the owner which can be referenced to a sample collected at a crime scene or in the case of stock theft to make a positive identification. The DNA profiling service covers cattle, horses, goats, sheep, pigs, buffalo, zebra, kudu, blue wildebeest, rhino and ostriches.

Various constraints in the technology which is easily applied to humans have hindered the application in other species. The extraction of DNA from small samples is successful in humans but is not as efficient in all animal species. Also, animals often lack the variability in known genes due to inbreeding and this makes it difficult to distinguish individuals.

## ETHICAL ISSUES, SAFETY AND REGULATIONS

As with any new technology, animal biotechnology faces a variety of uncertainties, safety issues, potential risks and ethical issues. For example, concerns have been raised regarding:

- the use of additional genes in constructs used to generate transgenic animals especially marker genes that are used to test whether the foreign DNA has successfully been transferred,
- the potential effects of genetically modified animals on the environment,
- the possible effect on the direction of evolution through manipulation of the DNA of animals,
- the effects of the biotechnology on the welfare of the animal,
- potential human health and food safety concerns for meat or animal products derived from animal biotechnology,
- Other ethical, moral and socio-economic aspects.

Before animal biotechnology will be used widely by animal agriculture production systems, additional research will be needed to determine if the benefits of animal biotechnology outweigh these potential risks. In January, 2009, the FDA (Food and Drug Administration) issued a final guidance for industry on the regulation of genetically engineered (GE) animals. The guidance explains the process by which FDA regulates GE animals. The United Kingdom has strict regulations regarding transgenic animals covered in the Genetic Modification of Organisms regulations and Environmental Protection Act (1990).

The risk to people working with transgenic animals and the risk or impact on the environment in the event of release of transgenic animals into natural populations are addressed. No transgenic animals are allowed to breed with wild populations to ensure no long-term changes in indigenous populations. In South Africa, genetically modified organisms are regulated by the Genetically Modified Organisms Act, 1997 (Act No. 15 of 1997), which provides "for measures to promote the responsible development, production, use and application of genetically modified organisms". It requires careful evaluation of risks to human health and the environment.

In the field of biomedical research, the animal welfare issues associated with the use of transgenic animals are essentially no different from those associated with other animals. The objective is to minimise pain or distress to individual animals in medical research, not the manner in which the animals are bred. Transgenic animals may suffer more abnormalities than regular research animals, as the introduction of DNA can be complex and the side-effects difficult to predict. Also the processes used to harvest and re-implant embryos may cause harm. Transgenic animals that do not express the foreign DNA are destroyed. All these areas of potential harm are carefully monitored.

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PUBLIC UNDERSTANDING OF BIOTECHNOLOGY