

Recent Advances in Genetic Engineering-A Review

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Abstract: Humans have been doing genetic engineering, a technology which is transforming our world, for thousands of years on a wide range of plants, animals and micro organism and have applications in the field of medicine, research, industry and agriculture. The rapid developments in the field of genetic engineering have given a new impetus to biotechnology. This introduces the possibility of tailoring organisms in order to optimize the production of established or novel metabolites of commercial importance and of transferring genetic material from one organism to another. In order to achieve potential benefits of genetic engineering the only need is to develop perfect tools and techniques. Once it has been perfected then all of the problems associated with food production can be solved, the world environment can be restored, and human health and lifestyle will improve beyond imagination. No doubt that there are almost no limits to what can be achieved through responsible genetic engineering. Classical field of genetic engineering and some of its advancements are discussed in this review.

Key words: DNA, genetic engineering, gene therapy

INTRODUCTION

Different genes are responsible for the various characteristics and properties of a living organism. To change part of an organism's genome to create some desired or beneficial trait we use genetic engineering. Genetic engineering is a group of techniques used for direct genetic modification of organisms or population of organisms using recombination of DNA. Now it is possible to alter directly a genome and insert or remove a chunk of DNA to create something beneficial.

Common techniques in genetic engineering: According to Zuker *et al.* (1998); various techniques are involved in genetic engineering, some of which are given below:

Recombinant DNA: The oldest of all the genetic engineering techniques uses plasmids or vectors to enter the genetic material into the host cell. Viruses and bacteria are usually used as vectors. Bacteria contain a small size circular plasmid in it. In recombinant DNA technology desired gene of interest forms a ring when inserted into the plasmid. Bacteria start multiplying and make many copies of plasmid along with its own genetic material. It is transferred to the host cell where it locates nucleus and releases gene of interest there. This gene of interest which acts as foreign genetic material combines

with the genetic material of the host cell to show its properties. Synthesis of human insulin took place through this technology.

Microinjection: Is a technique of genetic engineering. In this a glass micropipette is used to inject a substance into the human or animal cells. This is the only technique which does not need plasmid or vectors for undergoing the process. In the process of microinjection genetic material of an organism with a new gene is used to inject into the cells of other organisms. For this purpose a small micropipette is used as cells are quite large whether cells are animal cells or plant cells. Genes of interest find their corresponding genes, when they are inserted into the new cells and combine with them to show certain characteristics or functions.

Bioballistics: Is another genetic engineering technique that uses metal silvers coated with desired gene. These metal silvers which are of very small size usually smaller than a cell along with the desired genetic material are inserted in the shot gun. This shot gun targets the cells of interest and injects the genetic material into it. As the desired genetic material enters the target cell, it finds the nucleus and enters into it and here it combines with the genes of host cell and show desired features.

Electro and chemical poration: Is another genetic engineering technique in which cells are made porous so that the genes can enter into them. Pores are generated into the cells by bathing them into the special chemicals or by bathing the cells with the help of electric current. Through these pores genetic material enters into the cells and reaches to the nucleus. In nucleus the genetic material combines with the genes of the host cell and show desired characteristics.

Advances in genetic engineering: Advancements have been made in the field of genetic engineering, some of which are given below:

To transfer certain advantageous textile properties into micro-organisms, many attempts have been made where they can be more readily reproduced by bulk fermentation processes. According to Ramachandran and Karthik (2004); the spider DNA is transferred into bacteria for manufacturing proteins with the strength and resilience of spider silk for use in bulletproof vests.

According to Montaldo Hugo (2005); cystein seems to be the limiting amino acid for wool synthesis hence the first approach was to increase its production through transfer of cystein biosynthesis from bacterial genes to sheep genome. This was to improve production of sheep wool and to modify the properties of the fiber.

Viruses are now being engineered to infect and modify the DNA of specific cells of human body so that it can produce its own medicine. Due to this human body gets the ability to prevent or cure almost every disease. Haemophilia can be treated through gene therapy which is advancement in genetic engineering. According to Emilien *et al.* (2000); gene therapy for the haemophilias would involve the transfer of genetic information for functional coagulation factor FVIII or FIX into a limited number of somatic cells of a patient with haemophilia in order to stimulate continuous production of functional clotting factor in the patient. The genes for coagulation factors FVIII and FIX have been cloned and to achieve the expression of these factors, a number of different vectors, cells, cell lines, and approaches have been used. The cloning and characterization of the genes which codes for the human coagulation factors FVIII and FIX raises the possibility that gene therapy could be used for the treatment of haemophilia. Gene therapy for haemophilia at present focuses on gene addition technology in which normal functional coagulation factor DNA sequences with appropriate promoter and enhancer elements are added into to cells of a patient with a defective coagulation factor gene FVIII, FIX, FVII so that the modified cells can produce functional protein.

Crops have been genetically engineered for drought-prone environments. According to Ortiz *et al.* (2007); on

the basis of successful genetic engineering of crops like wheat, maize, rice etc., cereal crops can be genetically engineered by using *DREB-like* genes. An important future strategy for facilitating the production of cereals and other crops in drought-prone environments can be genetically engineered cultivars containing various gene constructs to enhance their performance under water stress. They will provide an attractive and complementary option for improving the performance of a plant under stress conditions. Particularly attractive is the single, dominant nature of the transgene that makes the transfer and maintenance of this system in any cultivar much easier than conventional sources based on polygenes.

According to Xiong *et al.* (2005); human Embryonic Stem Cells can be genetically engineered by using Lentiviral Vectors. Human embryonic stem cells *hES* present a valuable source of cells with a vast therapeutic potential. They are an unlimited source of cells for repairing or replacing poorly functioning tissues and organs of the body. They possess the capacity to differentiate *in vitro* to form neural, hematopoietic, endothelial, cardiac, pancreatic cells, and trophoblasts. A major obstacle in their uses for regenerative medicine is their low efficiency of directed differentiation. Differentiation of *hES* may be controlled by the effective and efficient gene transfer into *hES* cells using lentiviral vectors. Genetic engineering of *hES* cells represents an obvious and promising approach for promoting controlled differentiation. Lentiviral vectors *LVs* offer great promise as gene delivery systems for gene and cell-based therapies because these vectors can infect and thereby transduce both dividing and non-dividing cells with very high efficiency. *LVs* are highly efficient in transducing *hES* cells as they stably maintains transgene expression and does not alter the properties of *hES* cells as well. Stable and efficient genetic manipulations of *hES* cells using lentiviral vectors resulted in the establishment of stable gene expression in these cells. Results suggest that lentiviral gene delivery holds great promise for *hES* cell research and application.

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Another recent advancement in genetic engineering is its use for the enhancement of livestock. For example according to Laible (2009); the expression of monoclonal antibodies recognizing specific pathogens can be used to introduce disease resistant properties into livestock. Through this method instant immunity without prior exposure to this particular pathogen is provided. For producing fatal neurodegenerative prion diseases or transmissible spongiform encephalopathies resistant livestock animals, an endogenous gene implicated in the disease pathway has been applied. Thus resistant livestock free of such diseases would eliminate the risk for transmission of the disease to humans and hence provide additional safeguards for biomedical and food applications.

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Mastitis, the bacterial infection of the mammary gland, is one of the most costly diseases in agriculture. They severely affect the health of infected animals thus resulting in death. In dairy cattle it is mostly caused by *Staphylococcus aureus* infection. It is a pathogen and it is particularly difficult to control by using the antibiotic treatment as it has the ability of intracellular survival. A recent study has now demonstrated a successful transgenic strategy for the prevention of mastitis in cattle.

According to Laible (2009); Lysostaphin is an enzyme that naturally occurs in *Staphylococcus simulans*. It is an endopeptidase that cleaves a crucial cell wall component of staphylococci. It has potential as an effective antimicrobial agent and used for the treatment of mastitis. This was first demonstrated in a mouse model. This mammary specific expression of lysostaphin also conferred a protective effect against *S. aureus* infections and recently this concept has been successfully used on cattle. These cattle produced lysostaphin in their milk and showed a high degree of protection against *S. aureus*.

Milk has also been modified to improve its nutritional quality and processing of milk into dairy products. According to Laible (2009); major milk proteins are over expressed and caseins are modified to improve cheese ripening and for increasing calcium content. Recently such a modification of milk composition has been accomplished with the introduction of additional β -casein and k-casein genes in transgenic cattle. Milk derived from these cows showed a minor change for β -casein while a two to three fold increase in k-casein. These changes also affected the physical appearance of the milk from its white color to yellow that clearly indicates its altered composition and unique processing properties. Surface of the casein micelles which are the colloidal protein particles in milk, is coated by k-casein. Increase in k-casein reduces the size of the micelles. Small size of the protein particles affects the light scattering properties and they are considered to be the main cause for color change in the high k-casein milk. Cheese that is manufactured with this milk has greater nutritional value as it has increased levels of essential amino acids.

Trees can be genetically engineered to generate considerable long term environmental and economic benefits. According to Pena and Seguin (2001); viral sequences can be introduced and expressed in plants as they could interfere with the life cycle of the same or a closely related challenging virus. In this way they provide resistance to infection. For example in fruit trees, coat protein gene of plum pox virus *PPV* used in transgenic *Prunus* plants has provided high levels of resistance against the virus. This protection against virus was through the mechanism of posttranscriptional gene silencing. Different strategies have also been proposed to engineer plants for making them resistance against bacterial and fungal diseases. These include production of antibacterial and antifungal proteins through these strategies.

According to Chen *et al.* (2005); defensins being a part of defense mechanisms are a family of antimicrobial peptides which are typically expressed in mammalians, insects and plants. They are an important part of the human immune system as well. Obtaining natural

peptides is of high cost and its availability is also limited. For this human defensins are produced via genetic engineering.

It is a preferred method for producing defensins. Many efforts have also been made to improve the expression efficiency of human defensin.

To modify biomass properties genetic engineering can be used. Approaches of genetic engineering are used to improve bioethanol production from maize. According to Torney *et al.* (2007); two key parts of maize plants can be converted into bioethanol. These two parts are the *kernel*, which is mainly made of starch and the *stover*, which is predominantly made up of lignin and cellulose or cell wall components. For ethanol production they are converted effectively into fermentable sugars. For this purpose a range of approaches have been explored that use genetic engineering. One strategy is to modify the characteristics and properties of starch or lignocellulose. By using this strategy they can be converted more readily to the desired products. The other strategy is introduction of biomass conversion enzymes into plants due to which they can aid the conversion process more effectively.

Abiotic stresses are those caused by high levels of salts in soils, reduced or excess availability of water and sub and supra-optimal temperature regimes. These abiotic stresses adversely affect almost all major field-grown plants which belong to various ecosystems. These stresses cause a great amount of loss. The loss could be in terms of biomass as well as economic returns and the extent of this loss depends on the crop species, its location, growth stage and the intensity of the stress. According to Grover *et al.* (1999); transgenic tobacco plants for enhanced cold and salt stress tolerance and transgenics showing tolerance to salt stress, water stress, oxidative stress, low and high temperature stress have been produced. Genetic engineering is a fruitful approach for obtaining combined tolerance to different abiotic stresses by altering osmolytes as increased levels of osmolytes has enhanced tolerance for water stress, salt stress and cold stress. However, for stress tolerance, genes encoding for antifreeze proteins *AFPs*, unsaturase enzyme and superoxide dismutase *SOD* protein have also proven useful in engineering tolerance to abiotic stresses.

Some natural components in dairy milk also have been modified to improve health attributes. In adult human population lactose, a milk sugar causes intestinal disorders due to the lack of an enzyme activity called *intestinal lactosehydrolyzing* to sufficiently digest lactose after the consumption of milk. According to Laible (2009); to solve this problem two strategies were used, one was knockout and other was knockdown. In knockout strategy expression of α -lactalbumin, an essential component of the lactose synthetase complex is

completely disrupted which results in lactose-free milk. In knockdown strategy α -lactalbumin expression is reduced through RNA interference *RNAi* hence it results in reduction of lactose instead of complete removal. As lactose is the main osmotic regulator of milk secretion hence knockdown strategy is a successful approach for lactose intolerance. It solves the issue of lactose levels and of osmolarity as well.

Adult organs can be genetically engineered without the need of germline modifications such as the brain. It became possible due to the techniques raised from clinical gene therapy. According to Lowenstein and Castro Maria (2001); genetic makeup of individual brain cells is modified through gene transfer techniques. These techniques use viral or non-viral vectors for this purpose, to assess its effects on neuronal physiology and eventually on whole animal behavior without having to engineer the development of the experimental subjects. For gene transfer applications several viruses have been developed for example, *Murine retroviruses* have been mainly used in applications of gene transfer. In this gene is transferred into cells that are then transplanted directly into the brain. For *in vivo* gene transfer into the postmitotic cells constituting the adult brain *Lentiviruse vectors* are derived from human and animals lentiviruses. Murine retroviruses have incapacity to transduce nondividing brain cells while lentiviruse vectors have the capacity to express transgenes in nondividing cells. This is because lentiviruses have the capacity to cross the nuclear membrane and after that they insert their genomes into the DNA of the target cells without nuclear membrane breakdown during mitosis. To achieve targeted delivery of transgenes to particular types of brain cells, *AAV vectors* have been engineered. Moreover vectors allowing the encoding of larger constructs have also been produced and it was recently discovered that different *AAV* serotypes are able to transduce different cell types within the central nervous system of adult animals. High levels of transgene expression are provided by RNA viruses. RNA virus-derived vectors like *Semliki-Forest virus* and *Sindbis virus* have also been exploited for gene transfer into the neurons. Some new generations of lentivirus, retroviruses, *AAV*, *Semliki-Forest virus* and *Sindbis virus* described above are also available. They allow gene transfer to large areas of the brain. Systems have also been developed that can retarget transgene expression through genetic and molecular modification of viral capsids to infect specific cell types. Vectors described here can be used to transfer genes into the brains of adult animals in order to affect behavioral changes. Most recently viral vectors have also been used in the different applications of transient transgenesis of adult animals for example marking experiments, regulated transgene expression, imaging of

transgene expression, growth factor delivery in models of neurodegeneration, physiological modifications of neuronal function etc.

For cut-flower improvement also genetic engineering is used for example new and attractive cut-flower varieties, novel traits such as new colors, altered flower form, flowers with better fragrance etc. According to Zuker *et al.* (1998); foreign genes are introduced into plants that enable the specific alteration of single traits. To genetically modify plant species different strategies have been used. These strategies include the introduction of foreign genes of bacterial, viral and plant origin as well as over-expression or suppression of native genes expression. This aspect of genetic engineering has great importance in cut-flower industry.

Crop plants can be engineered for enhanced resistance by manipulating PR gene expression. According to Campbell *et al.* (2002); PR and PR-like proteins have been identified in crop species like rice, wheat, barley, sorghum and maize and they are plant host proteins that provide pathogen resistance in pathological or related situations. When the expression of individual and multiple PR proteins in various crops has increased, it has demonstrated some success in enhancing disease resistance to particular pathogens hence proved that the extent of the disease reduction correlates with the expression level of the transgene. For example in rice the extent of infection caused by the rice sheath blight pathogen known as *R. solani* reduced due to the over-expression of a rice PR-3 gene. Similarly over-expression of another rice chitinase, Cht-2 reduces the severity of the disease caused by the rice fungal pathogen *M. grisea*. Moreover in wheat also the over-expression of a barley chitinase confers resistance to the powdery mildew pathogen called *E. graminis*. In wheat over-expression of a rice PR-5 gene delays the onset of the symptoms caused by the wheat scab pathogen known as *Fusarium graminearum* in a stable and heritable manner.

Techniques for the transformation of potato plants have been developed. According to Campbell *et al.* (2002); recently vectors such as bacterial artificial chromosome BAC are used which can introduce very large DNA fragments into plants. Through these molecular engineering techniques cultivars that are resistant to insects, viruses and late blight disease *P. infestans* have been developed and are in use. Genetic engineering techniques have been used to introduce genes involved in different abiotic stress responses into a variety of plants including Potato, Arabidopsis, Tobacco and Rice to improve stress tolerance. For example genes have been introduced into potato plants which encode proteins that are related to salt stress such as proline synthase, osmotin-like protein, glyceraldehyde-3-phosphate dehydrogenase,

CBF1, CBF3 and EREBP. Due to the presence of a pathogen or osmotic stress, osmotin-like protein is expressed and it is a pathogenesis-related PR protein. From *Arabidopsis* the gene encoding osmotin-like protein was introduced into potato plants and was over-expressed. The osmotin-like protein provided the salt-tolerance to potato transformants as these plants expressed osmotin-like protein that exhibited elevated proline levels in response to salt stress.

To generate drought-tolerant potato plants genetic engineering is used. According to Byun *et al.* (2007); osmolytes such as proline, glycerol, betaines, mannitol and trehalose accumulates under water stress and high levels of trehalose are present in the plants that grow in arid regions such as deserts. Genes have been introduced into potato plants in order to improve drought tolerance. For this yeast *Saccharomyces cerevisiae* gene encoding the protein trehalose phosphate synthase *tps1* is introduced and over-expressed in potato plants. The resultant plant exhibited increased drought resistance as Trehalose functions as a compatible solute for increasing drought tolerance.

For the transformation of millet crops genetic engineering has been used. According to Ceasar and Ignacimuthu (2009); highest priority among millets in transformation studies has been given to the Pearl millet *Pennisetum glaucm*. Pearl millet was transformed by biolistic method of gene delivery. The first pearl millet transformation was through biolistic method called microprojectile bombardment. In this immature embryos were used as the target explants and Plasmid *pMON 8678* was used for transformation. It contained β -glucuronidase *GUS* or *uidA* gene under the control of *adh1* promoter of maize alcohol dehydrogenase gene. Transformation was confirmed by GUS histochemical assay. Pearl millet was also transformed using plasmids *pBARGUS* and *pAHC25*. It was observed that the expression of the *uidA* gene in plasmid *pAHC25* was superior to *pBARGUS*. Pearl millet transformed by the biolistic method with two plasmids *p35SGUS* contained the GUS gene and *pROB5* contained the hygromycin phosphotransferase gene *hpt* gene conferred resistance to hygromycin. Recently transgenic pearl millet expressing functionally active foreign gene conferring resistance to fungal disease known as *downy mildew* has been produced. For this purpose antifungal protein *afp* gene isolated from the ascomycete, *Aspergillus giganteus* have used. Immature zygotic embryos have been used as targets and the disease resistance was also increased up to 90% when transformed plants were compared to non transformed plants. Another kind of millets called the finger millet resistant to fungal blast disease has also been developed. Finger millet is a primary food source for millions of

people and has nutritional qualities superior to that of rice. *PIN* gene, an antifungal protein gene of prawn was chemically synthesized and cloned in the plasmid *pPin35S* and the *bar* reporter gene was cloned in the plasmid *pBar35S*. This resulted in transgenic finger millet exhibiting high-level of resistance to leaf blast disease.

In flowers, according to Nishihara and Nakatsuka (2010); *Flavonoid* is the component that vary greatly among species and cultivars. Flavonoid is one of the secondary metabolites such as carotenoids and betalains and it is responsible for flower color development. Variation in flower colors is due to the spontaneous changes in accumulated metabolite contents. To control flavonoid biosynthesis in some plant species such as Arabidopsis, Tomato, Petunia and Tobacco, transcription factors *R2R3-MYB* and *bHLH* genes are utilized. Many flavonoids are synthesized in fruits or leaves and few are of importance in flowers for e.g., AtMYB12-expressing transgenic tobacco displayed reduced floral pigmentation. A purple-colored creeping bentgrass was recently produced successfully using the maize transcription factors *Pl* and *Lc genes*. These transcription factor genes are effective to induce abundant accumulation of anthocyanins and conversely suppression of these genes will be useful for reduction of flower color. Transcription factors genes other than R2R3-MYB and bHLH genes can also induce a change in flower color probably due to pleiotropic effects.

According to Gamradt and Lieberman (2004); several gene therapy options have been developed for bone repair. Most preclinical studies have been conducted with DNA that encodes osteoinductive growth factors. These growth factors play key roles in skeletogenesis and bone repair. To insert DNA into target cells both viral and nonviral vectors are used. *In vivo* gene therapy has been successful in inducing bone formation in animal models as it deliver a vector to a site needing augmentation of bone repair. It directly injects a viral vector and can result in good transgene expression at the injection site. By direct injection of BMP producing adenovirus in animal models using *in vivo* gene therapy, several groups have induced bone formation, augmented fracture healing, healed segmental femoral defects or induced spine arthrodesis. Another option is *ex vivo* gene therapy that involves transduction of target cells *in vitro* with a vector encoding the desired protein product. The cells are then delivered to the patient or animal at the desired anatomic site after successful transduction. This *ex vivo* gene therapy has been used successfully in a number of different models of bone repair. Recently adenovirus-BMP-2 has been shown to induce mesenchymal stem cells derived from fat in order to form orthotopic bone in SCID mice. Helper dependent version of this adenovirus-BMP-2 has also

been developed and rat bone marrow cells transduced with this helper dependent virus produce bone *in vivo* in a SCID mouse hindlimb. These helper dependent vectors have been characterized as having efficient, large capacity gene transfer while minimize the toxicity and immune response which is common with adenoviral vectors.

Importance of genetic engineering: Genetic engineering being a field of biotechnology deals with genes. Combination of different technologies come together to make genetic engineering. In this technology genes are taken from one organism and are inserted into other organism to see certain effects. Sometimes new genes are developed and inserted into organism to make various changes. It is a powerful field with aspect that it can be used to develop human organs and inserting them into the body.

Genetic engineering can be used to introduce specific traits into plants. Genetic engineering has the potential to make food producing plants that grow faster, grow in less fertile areas, to produce higher quality harvests, and be more resistant to diseases, and insects. The techniques now being used are not very precise and they require many attempts and efforts before the new plant or animal survives.

It has the potential to slow the aging process and extend the human lifespan well beyond its current limits. It can be used to repair body organs and to develop organs and inserting them into the human body. Among other practical benefits to humanity and the ecosystem, genetic engineering has supplied us with products that alleviate illness, clean up the environment and increase crop yields. Ananda Chakrabarty developed first genetically engineered life form to be granted patent protection. He genetically engineered a common bacterium into *Burkholderia cepacia* which is a variant that digests petroleum products. This bacterium cleans up oil spills and has proven to be both safe and useful. Genetic engineering has also helped create thousands of organisms and processes that are useful in medicine, research and manufacturing. For treating human diabetes genetically engineered bacteria churn out insulin.

Production of insulin would be substantially more expensive without the use of genetic engineering.

According to Koepsell (2007); the first genetically engineered mouse to be patented for use as a model organism for cancer research was *The OncoMouse*. Numerous other knock-out mice have also been used, each missing certain critical genes, or expressing certain genetic diseases. This was useful for the medical researchers as they can test drugs and other treatments for human genetic maladies without risking the lives of human beings and reducing the numbers of experimental

animals. To correct genetic diseases or defects in fully grown humans, gene therapy is used. In this manufactured viruses can deliver repairs to somatic cells with genetic defects.

According to Koepsell (2007); genetically engineered foods reduce the need for pesticides and fertilizers as they produce pest-resistant and drought-resistant crops and increase yields. It also holds the promise of creating new and more productive strains of farm animals for meat and milk production. These new strains may be more resistant to infections hence reducing the need for large and unhealthy doses of antibiotics. They may also be engineered to produce more meat and to produce milk or other products with vital nutrients which otherwise not found in those products hence ensuring a healthier source of such nutrients. Genetic engineering involves integrating or putting the desired *new* gene into a little self replicating virus-like organism called vector which is then allowed to get into the target or the host cell and insert the new gene into the cell along with the already present *old* genes. According to Liao (2004); there are two kinds of genetic engineering known as somatic and germline. Somatic engineering targets the genes in specific organs and tissues of the body of a single existing person and it do not affect the genes in their eggs or sperm. Germline engineering targets the genes in eggs, sperm or very early stage embryos. Given the rapid advances in the human genome project and genetic engineering, it seems that genetic engineering can be used as an alternative method for sex selection. Another ambitious goal of genetic engineering is reducing the susceptibility of livestock to pests and diseases. Bottom line to understand the objectives of the genetic engineering is that it is helpful in duplication of DNA fragments and their manipulation, for agricultural, industrial, medical and research purposes. Ending beneficiary is man kind and the whole life associated with human race.

CONCLUSION AND FUTURE PERSPECTIVE

The use of genetic engineering has both advantages and problems. Although the risk of disaster caused by the misuse of genetic engineering is extremely high, but at the same time the potential benefits of proceeding in this field in a safe and responsible way are astonishing. Usage of cloning must be beware to prevent some ethical and controversial issues.

Researchers have now created a map of the human DNA and are doing the same for other plants and animal species as well. To understand how each section of DNA works is the next step. Once this research has been completed, scientists understand each step in the life cycle of plants and animals and once computers become powerful enough to simulate the consequences of any

changes to DNA, then the humans will be able to safely engineer almost any imaginable and desired type of plant or animal.

In order to achieve potential benefits of genetic engineering the only need is to develop perfect tools and techniques. Once it has been perfected then all of the problems associated with food production can be solved, the world environment can be restored, and human health and lifestyle will improve beyond imagination. No doubt that there are almost no limits to what can be achieved through responsible genetic engineering.

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