Medical & Bio-tech Applications of Genetic Engineering –A review

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Abstract
Genetic engineering is an indispensable and most efficient tool man has used to manipulate the genetic information of living things. It has been restructuring and re-modifying various sectors of human activities (Medical and Agricultural). Its agricultural application involves production of (GM crops) genetically modified crops that maintains stable food production with improved characteristics of being pest resistant, herbicide tolerant, early maturation, long shelf life which is not feasible through cross pollination or breeding. It medical applications are production of gene products using micro organisms (bacteria), offering molecular and diagnostic test of disease causing agents, both in man and animals (plants are not exempted). In spite of all the benefits offered by genetic engineering in our society, there are problems encountered in this field of study. These problems are human health risks (allergenicity), socio-economic problems, and environmental hazard (gene transfer-to non-target organism). Although all these seem quite overwhelming, genetic engineering has promised to improve the health status and ensure food security if properly adopted in our African society. Although Genetic engineering is a very young and is only possible due to developing of biological techniques. Genetic engineering has wide, applications in modem biotechnology. For various industrial processes, this technique may be used in microorganisms as well as with higher organisms. The principle involved is the construction of plasmids of desired biochemical characteristics.
This review is mainly focused on the approaches and applications of genetic engineering, positive and negative impacts of genetic engineering

1.0 INTRODUCTION

In the past, there were many attempts to change natural food stuff into high value products, drugs, food and other biological tools as noted by Cruegar (1999). This has led to advances in biological technology. Some scientists isolated certain DNA from one species and insert it to another species thereby changing some traits of the inoculated organism, which is different from traditional breeds of cross-pollination (Deborah, 2002). These activities were actualized by using the ideas of genetic engineering. Morris *et al.* (1983) defined genetic engineering as a technique used to alter or move genetic materials (genes) of living cells. Anon (2006) noted that genetic engineering is the artificial manipulation, modification and recombination of DNA or other population of an organism. The modified organism possesses some desired traits which were absent before but required to increase the potentials of the organism.

In Africa, Genetic engineering is in its incipient stage, with South Africa as the only country to plant genetically modified and improved crop on a commercial scale. Also several other African states are conducting field trials as reported by (Nsubuga, 2005). In Nigeria, genetic engineering is perceived from the activities of International Institute of Tropical agriculture Ibadan (IITA) in collaboration with the National Biotechnology Development Centre, Abuja (Obel-Lawson, 2005). South Africa serves as the gateway to southern African's agribusiness activities; its strong commercial seed market has made it easier to introduce new seed varieties, good agricultural infrastructure, and privatization of its public research institutions (Nsubuga, 2005). He noted that high vocal and active scientific researches have led to rapid expansion of genetic engineering in the country (South Africa). This has subsequently increased the rate at which multinational corporations move in with genetic engineering technology (Obel-Lawson, 2005).

Furthermore, the economic importance of genetic engineering cannot be over emphasized. It has shown its use in improving crop yield Nsubuga (2005), production of crop with improved nutritional value (Gasengayire, 2002). It aids environmental rehabilitation and maintenance through bioremediation, bioleaching, and waste management by the production of biodegradable product (Obel-Lawson, 2005). It has been applied medically in the treatment of diseases such as sickle cell anemia, cystic fibrosis, e.t.c as reported by Gasengayire (2002), in artificial insemination embryo transfer, in *invitro* fertilization and cloning (Anon 2006).

Ndung's (2004), noted that in Africa precisely south Africa, there are over 600 biotechnology and genetic engineering research projects and 55 companies involved in biotechnology and local production of commercial products mostly in the following sectors: medicals and pharmaceuticals, agricultural/plant, environmentals, food and beverages, chemicals, veterinary and biosafety. It has reported that the rate at which South Africa embarked on genetic engineering is one of the fastest in the world (Lederberg, 2002).

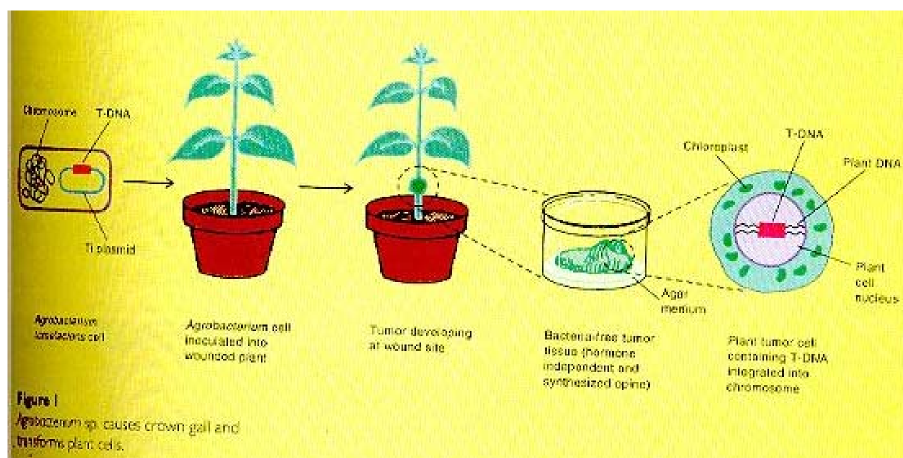
Moreover, this piece of writing gears towards educating and enlightening people concerning the activities of genetic engineering in African societies and to update them with the current issues in this field of study.

2.0 APPROACHES OF GENETIC ENGINEERING

Man has begun to learn how to take evolution into his hand recently, through genetic engineering. This involves altering or manipulation of an organism's genome, to create a new and useful result from novel approaches based on the available techniques and tools. The approaches often used by genetic engineers are many. Eric (2006) illustrated that approaches of genetic engineering generally falls under three categories;

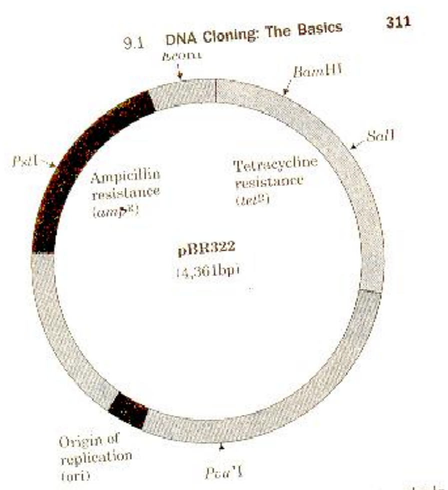
- Plasmid method
- Vector method
- Biolistic method

FIG.1 AGRO BACTERIUM SP. CAUSES CROWN GALL AND TRANSFORMS PLANT CELLS.



Source: Nester, E. W; N. N. Pearsall; D. G, Anderson, and M. T, Nester (1998) *Microbiology*: A human perspective 2nd. Ed. Von Hoffman Press Inc. New York p.185

FIG.2 DIAGRAM OF CONSTRUCTED *E.COLI* PLASMID



Source: Nester, E. W; N. N. Pearsall; D. G, Anderson, and M. T, Nester (1998) *Microbiology*: A human perspective 2nd. Ed. Von Hoffman Press Inc. New York p.183

Levin *et al* (1983) summarized the four general procedures used, during plasmid method approach. They are as follows;

⇒ Place plasmid in a container with special restriction enzyme (Type II restriction endonuclease), that cut the DNA at a certain recognizable sequence and treat the DNA with this enzyme. This procedure creates "Sticky ends" that will fuse together, if given the opportunity.

⇒ Next, introduce the two separate cut-up DNA sequence into a container, allowing them to fuse, forming a ring of DNA with the addition of DNA ligase an enzyme that joins two DNA molecule or fragment.

⇒ There after, add the nearly formed plasmid to a culture of live bacteria with known genome, allow them to take up the free-floating plasmid and express them.

⇒ Finally, allow the successfully altered bacteria to grow, reproduce and also allow to evolve on their own, with a selection pressure.

FIG.2 SCHEMATIC ILLUSTRATION OF DNA CLONING USING PLASMID AS VECTOR IN EUKARYOTIC CELL.

Source: Lehninger Principles of Biochemistry W. H. freeman and company New York pp 312

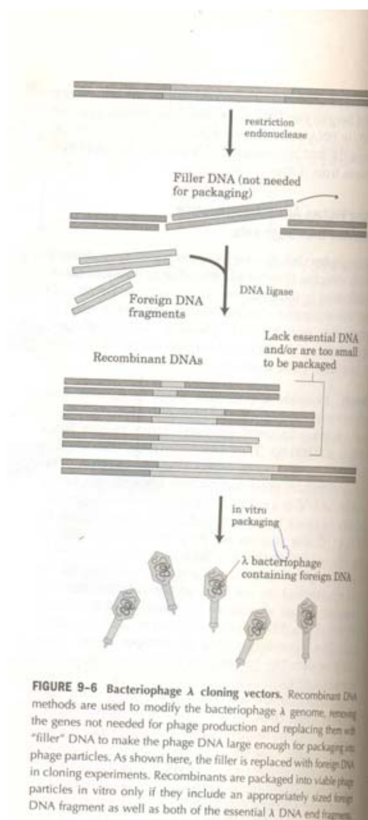


Fig.4 DIAGRAM OF A BACTERIOPHAGE AS A VECTOR

Source: Lehninger Principles of Biochemistry W. H. freeman and company New York pp 312

3.0 TECHNIQUES OF GENETIC ENGINEERING

Genetic engineering is a very young discipline, and is only possible due to developing of biological techniques from the 1960s till date (Anon 2006). Watson and Crick have made these techniques possible from our greater understanding of DNA and how it functions following the discovery of its structure in 1953 (Cohen *et al* 1973). However, the final goal of genetic engineering is usually the expression of a gene; in fact most of the techniques and time in genetic engineering are spent isolating a gene and then cloning it. There are many techniques used by scientist to accomplish a particular task in genetic engineering, based on this, the table below shows various globally adopted technique and their purposes.

TABLE 1. TECHNIQUE IN GENETIC ENGINEERING AND THEIR USES

Technique	Purpose
cDNA	To make a DNA copy of mRNA
Restriction enzyme	To cut DNA at specific points, making small fragments
DNA Ligase	To join DNA fragments together
Vectors	To carry DNA into cells and ensure replication
Plasmids	Common kind of vector
Gene Transfer	To deliver a gene to a living cells
Genetic markers	To identify cells that have been transformed
Replica plating	To make exact copies of bacterial colonies on an agar plate.
PCR	To amplify very small samples of DNA
DNA probes	To identify and label a piece of DNA containing a certain sequence
Shot gun	To find a particular gene
Antisense genes	To stop the expression of a gene in a cell
Gene synthesis	To make a gene from the scratch
Electrophoresis	To separate fragment of DNA

Source: *Genetic engineering in the world.www.med.ca/ecosystem Health educatio/grossry.htm.*

3.1 Complementary DNA

Complementary DNA as explained by Bos (2001), is a DNA used in DNA cloning, usually made by reverse transcriptase and complementary to a given in RNA. The enzyme reverse transcriptase synthesizes this DNA from an RNA template through a process called transcription. Nester *et al* (1998); Nelson and Cox (2005) noted that complementary DNA is produced naturally by a group of viruses called Retroviruses (which include HIV) which helps them to invade cells.
In genetic engineering reverse transcriptase is used to make an artificial gene of cDNA as noted by (Nester *et al.,* 1998). Complementary DNA has helped to solved different problems in genetic engineering. For example the B cells of the pancreas make insulin, cDNA is use to make lots of mRNA molecules coding for insulin. This

RNA can be isolated from these cells and use to make cDNA of the insulin gene reported by (Crueger, 1999).

3.2 Restriction Enzymes

Restriction Enzymes are enzymes used to cut DNA at a specific site (Stahl, 1987). They are properly called restriction endonuclease because they cut the bonds in the middle of the polynucleotide chain (Prescott *et al*, 2002). These types of enzymes (restriction endonucleases) are commonly found in a wide range of bacteria species where they are used to penetrate the host genetic composition. Nester *et al* (1998) reported that in 1968, Werner Arber a Swiss microbiologist discovered restriction enzyme and states that its biological function is to recognize and cleave foreign DNA at a specific point. This discovery later led to the discovery of other restriction enzymes (Type II restriction enzymes) by an American molecular biologist Hamilton. O. Smith (Nester *et al*, 1998). However, these enzymes are enormously useful in genetic engineering for cutting DNA at precise places hence termed "molecular scissors".

There are thousands of different restriction enzymes known Nelson and Cox (2005), with over a hundred different recognition sequences. Restriction enzymes are named after the bacteria species they came from Stahl (1987). For example *ECORI* is from *E.coli* strain R and Hind III is from *Haemophilis influenzae.* The cells receiving the vector are called Host cell (Mose, 1999). Once they have successfully incorporated the vector they are said to be transformed. According to Karcher (1994), there are different ways of incorporating the vector into the host cells depending on the type of host cell, such as: Heat shock, Electroporation and viruses, microinjection, gene gum, plant tumor e.t.c

3.3 DNA Ligase

This is another valuable tool used in genetic engineering. It is an enzyme that repairs broken DNA by joining two nucleotides in a DNA strand (Levin *et al,* 1983). It is commonly used in genetic engineering to do the reverse of a restriction enzyme i.e. to join together complementary restriction fragments. Nester *et al* (1998) noted that during the use of restriction enzyme to treat and cut-up DNA at a specific sequence, "sticky ends" are created. These "sticky ends" allow two complementary restriction fragments to anneal in the presence of DNA ligase only by weak hydrogen bonds.

DNA Ligase and Restriction enzymes can therefore be used together to join lengths of DNA from different sources.

3.4 Vectors

In biology a vector is something that carries things between species (Marvier and Krims, 2000). For example, the mosquito is a disease vector, because it carries the malaria parasite into human body system. In genetic engineering a vector as emphasized by Endress (1999) is a length of DNA that carries the gene we want into a host cell. Levin *et al* (1983) pointed out that vector is needed in genetic engineering because; a length of DNA containing a gene on its own will not actually do anything inside a host cell. Since it is not part of the cell's normal genome it will not be replicated and expressed when the cells divide Endress (1999) and also will probably be broken down quickly. The table below shows various types of vector used in genetic engineering.

Table.2 Types of vectors commonly used in genetic engineering and their sizes

Types of vector	Max length of DNA insert
Plasmid	10k bp
Virus or phage	30k bp
Bacterial Artificial chromosome	500k bp

Source: *Genetic engineering: en.wikipedia Org/wiki/Genetic Engineering*

3.5 Plasmids

According to Endress (1999); (Levin *et at* (1983), Plasmids are by far the most common kind of vector used in genetic engineering. They are short circular bits of DNA found naturally in bacterial cells noted by (Nester *et al* 1998). One common plasmid used is the R-plasmid (or pBR 322). It contains a replication origin, several recognition sequence for different restriction enzyme (Pst1 and ECOR1), and two marker genes, which confer resistance to different antibiotic (ampiciline and tetracycline) (Nelson and Cox, 2005). In plasmid technique or method, the DNA is cut up at a specific sequence with a restriction enzyme, ligated with another enzyme called DNA ligase and the ligated DNA fragment is called Hybrid vector.

3.6 Gene Transfer

Gene transfer is a technique commonly used in genetic engineering and in molecular biology, to move genetic information in a carrier or vector. Marvier (2001), specified that it is the vehicle that will carry the desired gene into a medium where it will be replicated or expressed.

3.7 Genetic Markers

Genetic markers are molecular markers which include protein and nucleic acids that are detestably different "i.e. polymorphic between individuals and can be used to determine familial relationships" (Adekunle, 1992). Genetic markers are needed to identify cells that have successfully taken up a vector and become transformed. In most he technique mentioned above, just less than 1% of the cells actually take up the vector (Adekunle, 1992). A marker is needed to distinguish these cells from all the other cells. As remarked by Bos (2001), Common marker used in the R-plasmid is a gene for resistance to an antibiotic such as tetracycline. Bacterial cells taking up this plasmid can make these gene products and so are resistant to this antibiotic (Bos, 2001). So if the cells are grown on a medium containing tetracycline all the normal untransformed cells together with cells that have taken up DNA that is not a plasmid (99%) will die. Only the 1% transformed cell will survive and these can be grown and cloned on other plate.

3.8 Replica Plating

Replica plating is a simple technique for making an exact copy of an agar plate (Prescott *et al*, 2002). A pud of sterile cloth, the same size as the plate is pressed on the surface of an agar plate with bacteria growing on it as delineated by (Prescott *et al*, 2002). Cells from each colony will be at exact position on the new plate. This technique has a number of uses, but the most common use as explained by Nester *et al*

(1998) in genetic engineering, is to help solve another problem of identifying transformed cells.

3.9 Polymerase Chain Reaction (PCR)

It is a newer technique developed in 1983 by Kary Mullis who won a noble prize in this discovery in 1983 (Nester *et al*, 1998). It is a technique that is used to amplify the number of copies of a specific region of DNA in order to produce adequate amount for usage (Anon, 2006). Moreover, Gene can be cloned by cloning the bacterial cells that contain them. This requires quite a lot of DNA. PCR can clone DNA sample as small as a single molecule by rapid multiplication or replication of that DNA copies (Nelson and Cox, 2005). It involves 3 steps Denaturation, Extension, and Annealing as cited by Nelson and Cox, 2005). They also noted that during these processes enzyme from a thermopile bacterium. *Thermus aquaticus* is used to prevent primers used from denaturing. This method is mostly used for forensic investigation and molecular and diagnostic test of certain biological substance (such as disease causing agent e.t.c) according to (Endress, 1999).

3.10 DNA Probes

A probe is simply a short length of DNA (200-100 nucleotides long) with a label attached to it (Syvan and Kado, 2002). They said that they are used to identify and label DNA fragments that contain a specific sequence. Powell (2002) pointed out two common types of labeled probe commonly used (a) Radio activity labeled probe and (b) Fluorescent labeled probe. DNA probe are used to identify genetic defects, genes from one species that are similar to those of another species, and to identify restriction fragments containing a particular gene out of thousands of restriction fragments formed from a genomic library as reported by (Adekunle, 1992).

3.11 Short Gunning

This is used to find one particular gene in a whole genome. It is called the short gun technique as reported by Anon (2006), because its starts by indiscriminately breaking up of the genome and then sorting through the debris for the particular gene desired. Note also that a gene probe is needed to do this work.

3.12 Antisense Genes

According to Anon (2006) these are used to turn off the expression of a gene in a cell. He explained that the principle is rather simple where a copy of the gene to be switch off is inserted into the host genome the “wrong” way round. This is done so that complementary (or Antisense) strands are transcribed.

3.13 Gene Synthesis

Anon (2006), propounded that it is possible to chemically synthesis a gene in the laboratory. By laboriously joining nucleotides together in the correct order. It is now made easier with automated machines but not up to the limit of 30 bp. Few real gene be made this way. Presently.

3.14 Electrophoresis:

This is a form of chromatography used to separate different pieces of DNA on the basis of their length (Anon, 2006). It might typically be used to separate restriction fragments. The DNA samples are placed into wells at one end of a thin slab of gel made of *agarose or polyacrylamide,* and covered in a buffer solution. An electric current is passed through the gel. Each nucleotide in a molecule of DNA contains a negatively-charged phosphate group, so DNA is attracted to the anode (the positive electrode). The molecules have to diffuse through the gel, and smaller lengths of DNA move faster than larger lengths, which are retarded by the gel. So the smaller the lengths of the DNA molecule, the further down the gel will move in a given time. At the end of the run the current is turned off.

4.0 APPLICATIONS OF GENETIC ENGINEERING IN AFRICA

4.1 Categories of Application

Genetic engineering has changed the entire world drastically, accounting numerous successes and achievements. Some of these successes are seen in the food production drug production, seed marketing, plant and animal gene banking, crop production, animal production, human health and in many other applications that are still at trial levels (Attalkrah, 2004).

All these applications so far as reported by Attalkrah (2004) can be usefully considered into three groups; Gene products, New phenotype, and Gene-Therapy. Based on these categories or grouping he described, "Gene products" as using genetically modified organisms (usually microbes) to produce chemicals, usually for medical or industrial applications, whereas new phenotype" involves using gene technology to alter the characteristic of organisms (usually farm animals and crops), while "Gene - Therapy" involves using gene technology or humans to treat a disease.

4.2 Gene Products

According to Attalkrah (2004), it is the biggest and most successful and of genetic engineering. These products are of medical and agricultural and commercial values (Endress 1999). The table below shows a few of the examples of genetically engineered products that are already available.

Table 3. Genetically engineered products and their uses

Products	Use	Host organism
Insulin	Human hormones used to treat diabetes	Bacteria/yeast
HGH	Human growth hormone, used to treat dwarfism	Bacteria
BST	Bovine growth hormone used to increase milk yield of cow	Bacteria
Factor VIII	Human blood clothing factor used to treat haemophiliac	Bacteria
Anti-thrombin	Anti-blood clothing agent used in surgery	Goats
Penicillin	Antibiotic used to kill bacteria	Fungi/bacteria

Vaccines	Hepatitis B antigen for vaccination	Yeast
AAT	Enzyme used to treat cystic fibrosis and emphysema	Bacteria
Rennin	Enzyme used in manufacture of cheese	Bacteria/yeast
Cellulose	Enzyme used in paper production	Bacteria
PHB	Biodegradable plastic	Plants

*Source:*www.caplmu.de/fgz/portals/biotech/terminology.php

These gene-products are mostly protein (Arpad, 2000), which are produced directly when a gene is expressed, but there can also be non-protein products produced by genetically engineered enzymes. The basic idea is to transfer a gene (often human) to another host organism (usually microbes) so that it will make the gene product quickly, cheaply and ethically noted by (Levin *et.al*, 1983). Moreover, it is also possible to make designer proteins" as emphasized by Powell (2002) by altering the gene sequence. This is a useful research tool, but there are no commercial applications yet.

4.3 New Phenotypes

This means altering the characteristics o organisms by genetic engineering (Arpad, 2000). The organisms that are always altered are generally and commercially important crops or farm animals. The objective is to improve their quality in some way that will beneficial to man consuming and uses. Example of New phenotypic organism produced in this area is the B.t. corn grown in South African in the year 2000.

4.4 Gene Therapy

According to Endress (1999), it is the most significant and conventional kind of genetic engineering. The idea of gene therapy is to genetically alter humans in order to treat a disease. Anon (2006), pointed out that gene therapy could represent the first opportunity to cure incurable diseases. It is also quite different from using genetically modified microbes to produce drugs, vaccine or hormone to treat a disease by conventional means. Gene therapy described by Anon (2006), means altering the genotype of a tissue or even a whole human. Its application is seen in the treatment of cystic fibrosis (CF) caused by a mutation of the gene for protein called cystic fibrosis transmembrane Regulator (CFTR). This gene is located at the chromosome 7. It is cured with production cDNA of (CFTR) by incorporating it into the epithelial cells and also in the gene in the chromosome.

4.5 MEDICAL APPLICATION OF GENETIC ENGINEERING

Medical application of genetic engineering globally are seen in various medical treatment like, tissue transplant, gene transplants, treatment of incurable and genetic diseases. All these and others are well summarized below according to Anon, (2006):

- Treatment of Severe Combined Immunodeficiency Disease (SCID) with genetically engineered enzyme Adenosine deaminase (ADA).
- Treatment of cancer cells by genetically modified white blood cells that produce Tumor Necrosis Factor (TNF) of protein that kills cancer cells.
- Production Monoclonal and polyclonal antibodies for diagnosing and detection of disease causing agents.
- Production of human growth hormone for treatment of growth

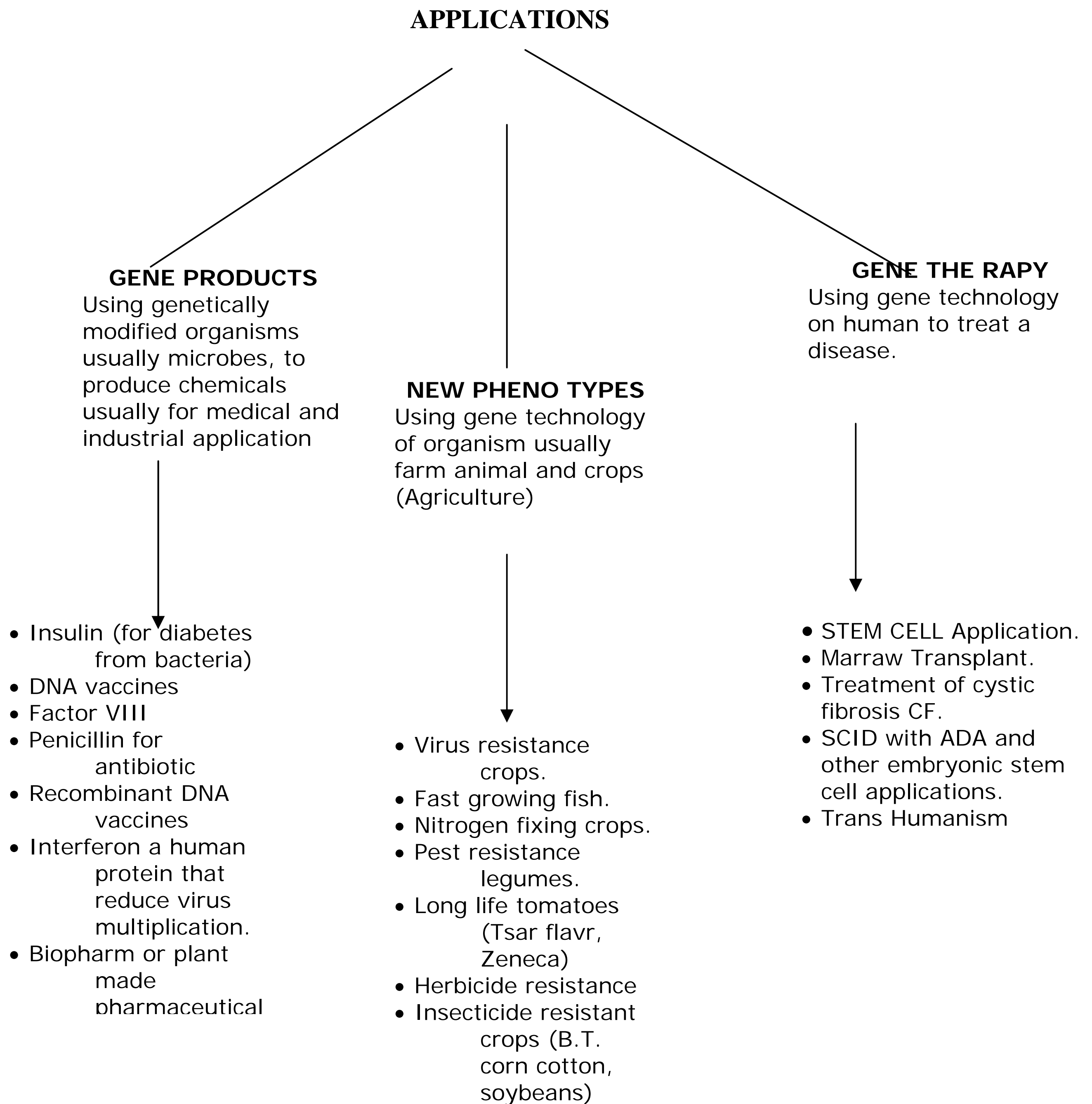
abnormality.

- Production of interferon, a human protein which stops replication/multiplication of viruses in the human body.
- Production of blood clothing factor VIII to treat hemophiliacs.
- Production of insulin for treatment of diabetes.
- Production of Antibiotic using fungi/bacteria.

4.6 AGRICULTURAL APPLICATIONS OF GENETIC ENGINEERING

- Production of pest resistant crop varieties.
- Production of long shelves life and good flavour tomatoes.
- Production of herbicides resistance crops
- Production of bovine growth hormone used to increase milk yield of cow.
- Production of insect resistant crop like Bt. Corn, soybeans cotton and others.
- Production of fast growing fish
- Production of nitrogen fixing crops
- Production of cattle resistant to mastitis disease
- Production of tick resistant farm animals and pets.

FIG 5. SUMMARY OF THE THREE CATEGORIES OF APPLICATION OF GENETIC ENGINEERING GLOBALLY



4.7 GENETICALLY MODIFIED FOOD IN AFRICA

One major application of genetic engineering techniques is in the realm of food production. With the world's population topping to about 6 million, Deborah (2000), and synthetic pesticides decreasing in effectiveness, novel solutions are fast increasing in demand to meet up with the challenges (Obel-Lawson, 2005).

Genetically modified foods could be one such solution that can help to ensure and maintain food security in the world (most especially Africa) as noted by (Deborah, 2000). These plants have been modified in the laboratory to enhance desired traits such as increase resistance to herbicides, diseases, droughts, pesticides and even having long shelf lives as cited by Crueger (1999), Crystal *et al.* (2001), or even to improved nutritional contents. The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and often not accurate (Leplaideur, 2003). Genetic engineering on the other hand, can create plants with extent desired trait very rapidly with great accuracy (Lillehoj and Ford, 1999). For example plants geneticist can isolate a gene responsible for drought tolerance and insert that gene into a different plants. The new genetically modified plant will gain drought tolerance.

Furthermore, not only can genes be transferred from one plant to another plant but genes from non-plant organisms can be used. (Deborah, 2000). The best known example is the use of B.t gene in corn and other crops (Hansen *et al*, 1999). B.t or Bacillus thuriengensis is a naturally occurring bacterium that produces crystal proteins that are lethal to insect larvae. Hence, all these gave rise to the term genetically modified crops/organisms.

The first commercially grown genetically modified food crops as tomatoes plant created by California company calgene called the *flavr Savr* in 1994 (Berg *et al*, 1975). This crop was known for its long – shelf life. The net GM crops created ere insect protected corn and herbicide tolerant soybeans in 1966. (Berg *et al*, 1975).

Table 6.0 **Genetically modified plants and uses**

Plant	Trait	Usefulness
Potato	Increased starch synthesis	Potato chips containing less oil
Rose	Blue flower	Pleasing appearance
Cotton	Resistance to various herbicides	Weeds killed without affecting engineered plant containing genes for herbicide resistance
Corn	*Bacillus thuringiensis* toxin synthesis	Lepidopteran (insect) resistance
Tomato	Synthesis of virus coat protein	Plants resistant to various viruses
Tomato	Antisense mRNA for polygalacturonase	Longer shelf life, spoilage resistance
Rape seed	Enzymes of oil synthesis	Modified oil composition of plant

Source: Nester, E. W; N. N. Pearsall; D. G, Anderson, and M. T, Nester (1998) *Microbiology*: A human perspective 2nd. Ed. Von Hoffman Press Inc. New York p.185

In Africa, at present, South Africa is the only country in Africa to plant GM crops on a commercial scale as noted by Lederberg (2002), although several other Africa States are conducting field trials. South Africa was the eleventh country out of the thirteen countries that grew genetically engineered crops in the year 2000 (Ndung's, 2006). In 1999, over 250,000 lectures of the country were panted with G.E crops (Ndung's,

2006). This figure increased by 100,000 lectures, a 50% increase in the year 2000 (Nsubuga, 2005). He stated also that 28% of cotton and 6% of maize planted in South Africa are genetically modified. Obel – Lawson (2005) reported that at least 175 field trails are underway in South Africa and five commercial releases have been approved. Moreover, permit have also been granted for field trails and experiments with cotton, maize, soybeans, apple, canola, wheat, potatoes, sugarcane, grape eucalyptus trees and a host of microorganisms (Obel-Lawson, 2005). The table below shows countries that grew 99%of the global transgenic crops in the 2003 of which South Africa is among.

Table.4 PERCENTAGE OF GM CROPS GROWN GLOBALLY

Countries	Percentage	Continents
United States	68%	N. America
Argentina	21%	S. America
Canada	6%	N. America
Brazil	4%	S. America
China	4%	Asia
South Africa	1%	Africa

Source: www.caplmu.de/fgz/portals/biotech/terminology.php

As world population tops to 6 billion and is predicted to double in the next 50 years (Deborah, 2000). Ensuring an adequate food supply for this booming population is going to be a major challenge in the years to come. GM foods promise to meet these needs in a number of ways. According to Deborah (2000), production of pest resistance crops e.g. B.t corn, soybeans and cotton, Herbicide tolerance crops e.g. Monsanto created soybeans strain, disease resistance crops; crop with cold tolerance gene (Anti-freezing genes), Drought and salinity tolerance crops, with cold tolerance crops, nutritional quality crops e.g. golden corn, production of pharmaceutical medicines and vaccine e.t.c.

PROBLEMS OF GENETIC ENGINEERING IN AFRICA

There are problems militating against the adoption Genetic Engineering in African society. Firstly; Inability of African farmers to afford the technology fee and chemicals to grow these new genetic engineered seeds. According to Obel-Lawson (2005), he expressed that African countries can not afford to start from scratch if GM turned out to be mistake, unlike rich countries in America and Europe; Moreover, inadequate or lack technology – expertise to meet up with the basic lacks of food and other medical practices; Inadequate public and private research institutes (on genetic engineering) in Africa with the exception of few in South Africa and General poverty in African countries

Genetic engineering in its present form cannot be part of the solution of the food crises in Africa. It is part of the problems. A statement from Bread for the world institute in April 2003 argued that any potential benefits of crop biotechnology must be weighed against potential risks. Ndung's (2004) reported that (in December 2000). Algeria banned the importation, distribution, commercialization, utilization and cultivation of GM foods and raw materials. In January 2000 Egypt banned G.E.

wheat and carried tuna from Thailand (Ndung's, 2004).

According to Nsubuga (2005), many Africa countries are trapped to accept G.E. food aid by pressure and creation of artificial conditions to necessitate their acceptance. For instance Malawi's government was forced by IMF and the world bank to sell of their 2001 food reserves for debt repayment in 2002 so that Malawi world have no choice but to accept G.E. food. About 250,000 metric tons were shipped to Malawi during the drought in 2002 (Nsubuga, 2005). Besides, economic instability and misappropriation of governmental funds; Political problems and instability of the society e.g. civil war, Religious conflicts e.t.c (Ndung's, 2004). Finally, Lack of information; what to produce, how to produce, where to produce, to whom to produce.

SOLUTIONS

⇒ Establishment of public and private research centers.
⇒ Sponsorship and grant offers for scientific researches and educational programmes.
⇒ Creation of doorways for foreign investors and multinational companies/corporations in the area of scientific research.
⇒ Establishment of good government in various African countries to make good governance.
⇒ Dissemination of scientific information and knowledge.
⇒ Training expertise in this area.
⇒ Equitability of world wealth distribution.
⇒ High vocal and active scientific lobby
⇒ Privatization of public research institutes.

5.1 IMPACT OF GENETIC ENGINEERING PRODUCTS (GMOs) IN AFRICA.

⇒ Human Health Risk:- Development of Allergies (Allergenicity). Cancer diseases and death.
⇒ Economic concern:- Bringing a GM food to market is a lengthy and costly process.
⇒ Environmental hazard:- Reduces effectiveness of pesticides Gene transfer to non-targeting species. Creation of super weeds/ mutants.

SOLUTIONS

⇒ Conduction Clinical trials
⇒ Creation of regulatory bodies: FAO, EPA, Monsanto group of companies, WHO, SSDA etc.
⇒ Periodic conduction of risk assessment studies on these GM plants/food and animals.
⇒ Periodic visitation of farms and laboratories to ensure compliance.
⇒ Public out cry on mandatory food labeling of GM food supply.
⇒ Creation of buffer zones around the field of GM crops.
⇒ Creation of GM plants that are male sterile

⇒ Penalty of violation of laws and policies should be steep fines, loss of license and jail sentence.

CONCLUSION

Although all these seem quite overwhelming, genetic engineering has promised to improve the health status and ensure food security if properly adopted.

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