Food Security and Biotechnology in Africa

This project is financed by the European Union and implemented by the ACP Secretariat

MODULE 2
BIOTECHNOLOGY:
History, State of the art, Future

Dr Marcel Daba BENGALY

Université Ouaga I Pr Joseph KI ZERBO

Disclaimer

This publication has been produced with the assistance of the European Union. The contents of this publication is the sole responsibility of the University of Ouaga-I JKZ and can in no way be taken to reflect the views of the European Union.

Final Version : February 2017

Module Objective

General objective

The main objective is to offer a broad view of biotechnology, integrating historical, global current and future applications in such a way that its applications in Africa and expected developments could be discussed based on sound knowledge…

Module Objective

Specific objectives

At completion learner should be able to:

- demonstrate knowledge of essential facts of the history of biotechnology and description of key scientific events in the development of biotechnology
- demonstrate knowledge of the definitions and principles of ancient, classical, and modern biotechnologies.
- describe the theory, practice and potential of current and future biotechnology.
- describe and begin to evaluate aspects of current and future research and applications in biotechnology.

Module contents

- Unit 1 Introduction to biotechnology, history and concepts definition
- Unit 2: The Green Revolution: impacts, limits, and the path ahead
- **Unit 3: Agricultural biotechnology: the state-of-the-art**
- Unit 4: Future trends and perspectives of agricultural biotechnology
- Unit 5: Food security and Biotechnology in Africa: options and opportunities

UNIT 3: Agricultural biotechnology: the state-of-the-art (05 Hours)

Dr Marcel Daba BENGALY
Université Ouaga I Pr Joseph KI ZERBO

Unit 3 Objective

The unit objective is to provide in-depth review of the current applications of conventional and modern biotechnology. It emphasizes on the fundamentals and principles of biotechnology techniques applied in key areas of food security such us: biotechnology in agriculture, animal husbandry and food processing.

In the last section of the unit, an overview of other (medical and environmental) applications of biotechnology is given.

Unit 3 Objective

The anticipated knowledge/skills to be developed :

- Be familiar with the main applications of biotechnology in:
  - Agriculture
  - Animal husbandry
  - Food processing

Content

1. **Biotechnology applications in agriculture**
2. **Biotechnology applications in animal husbandry**
3. **Other applications of biotechnology**

This section provides a review of key developments and applications of biotechnology in agricultural.

It focuses on the potential of conventional plant breeding techniques, tissue culture and micropropagation, molecular breeding or marker assisted selection, genetic engineering and GM crops.

Molecular diagnostic tools to improve crop productivity, crop protection and nutritional value are also addressed

Conventional Plant Breeding Methods

Introduction

Since 1900, Mendel's laws of genetics provided the scientific basis for plant breeding. Conventional plant breeding can be considered as the manipulation of the combination of chromosomes.

Main procedures

1. Desired traits can be selected and used for further breeding and cultivation (selection)
2. Desired traits found in different plant lines can be combined together (hybridization).
3. Polyploidy can contribute to crop improvement.
4. New genetic variability can be introduced through spontaneous or artificially induced mutations

Selection

Selection is the most ancient and basic procedure in plant breeding. It generally involves three distinct steps.

First, a large number of selections are made from the genetically variable original population. Second, progeny rows are grown from the individual plant selections for observational purposes.

After obvious elimination, the selections are grown over several years to permit observations of performance under different environmental conditions for making further eliminations. Finally, the selected and inbred lines are compared to existing commercial varieties in their yielding performance and other aspects of agronomic importance

Hybridization

The aim of hybridization is to bring together desired traits found in different plant lines into one plant line via cross- pollination.

The first step is to generate homozygous inbred lines. This is normally done by using self-pollinating plants where pollen from male flowers pollinates female flowers from the same plants.

Once a pure line is generated, it is outcrossed, i. e. combined with another inbred line. Then the resulting progeny is selected for combination of the desired traits.

Polyploidy

Most plants are diploid. Plants with three or more complete sets of chromosomes are common and are referred to as polyploids.

The increase of chromosomes sets per cell can be artificially induced by applying the chemical colchicine, which leads to a doubling of the chromosome number.

Generally, the main effect of polyploidy is increase in size and genetic variability. On the other hand, polyploid plants often have a lower fertility and grow more slowly

Induced mutation

Instead of relying only on the introduction of genetic variability from the wild species gene pool or from other cultivars, an alternative is the introduction of mutations induced by chemicals or radiation.

The mutants obtained are tested and further selected for desired traits. The site of the mutation cannot be controlled when chemicals or radiation are used as agents of mutagenesis.

Because the great majority of mutants carry undesirable traits, this method has not been widely used in breeding programs.

Tissue Culture & Micropropagation

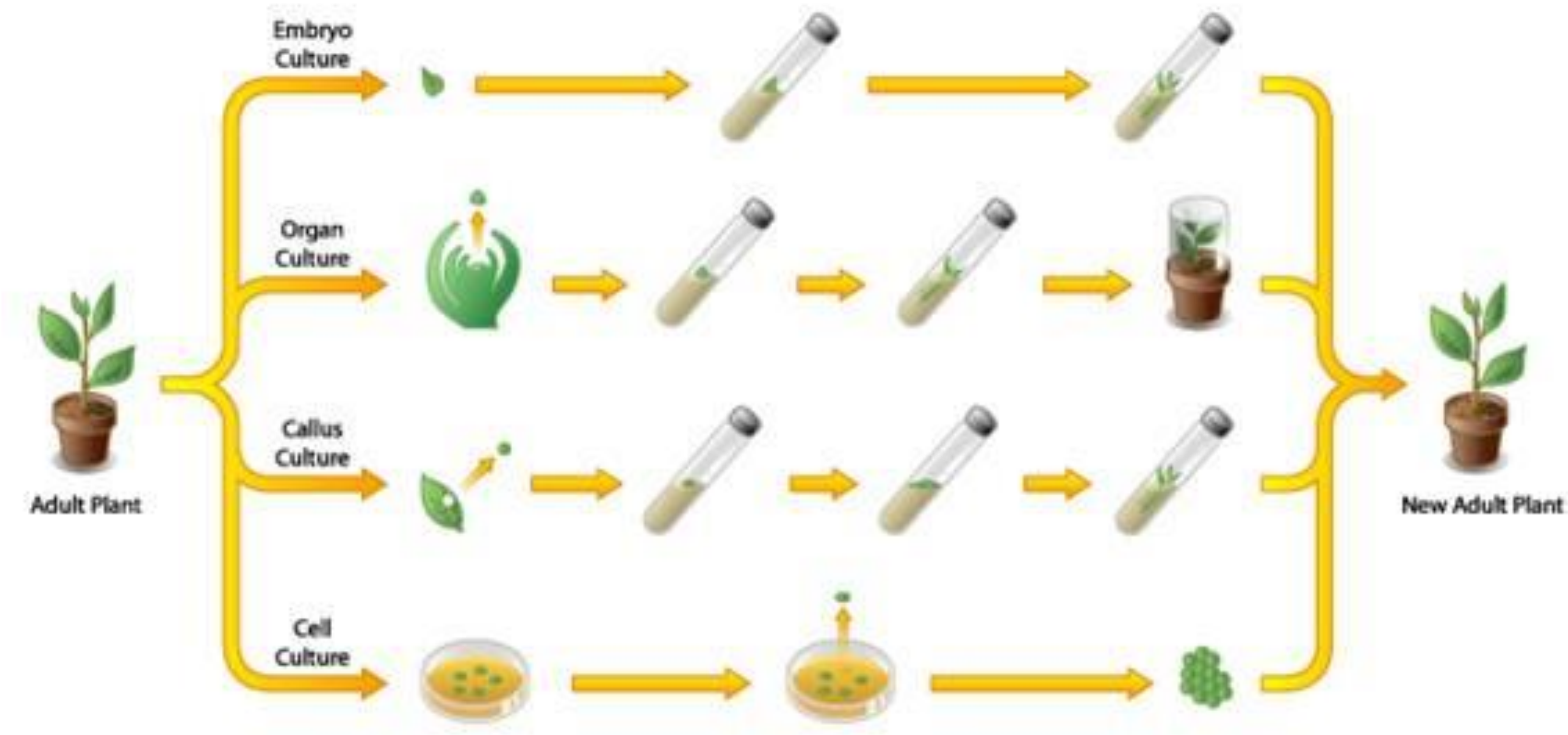
Plant Tissue Culture, more technically known as **micropropagation**, can be broadly defined as a collection of methods used to grow large numbers of plant cells, *in vitro*, in an aseptic and closely controlled environment.

This technique is effective because almost all plant cells are totipotent – each cell possesses the genetic information and cellular machinery necessary to generate an entire organism.

Micropropagation, therefore, can be used to produce a large number of plants that are genetically identical to a parent plant, as well as to one another.

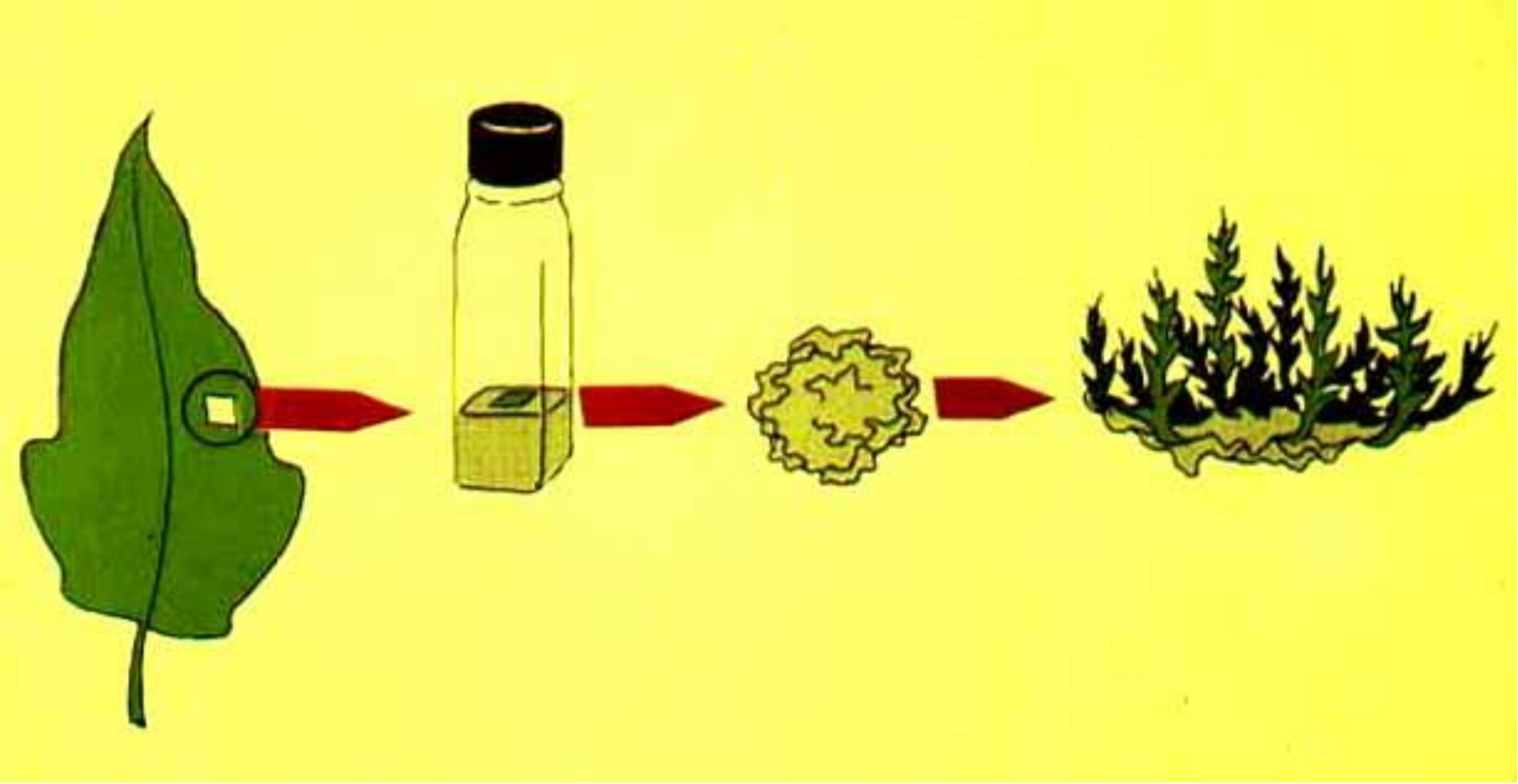
Tissue Culture & Micropropagation

Various Tissue Culture Types



Tissue Culture & Micropropagation

Micropropagation



Genetic Engineering

Genetic engineering is a term used for the directed manipulation of genes (the transfer of genes between organisms or changes in the sequence of a gene).

In plant breeding, the most important and already widely used method of this kind is Restriction Fragment Length Polymorphism (RFLP).

Other methods are : Gene Transfer, Transgene Expression, Selection and Plant Regeneration.

Restriction Fragment Length Polymorphism (RFLP)

RFLP makes use of restriction endonucleases. After treatment of a plant genome which restriction endonucleases, the plant DNA is cut into pieces of different length, depending on the number of recognition sites on the DNA.

These fragments can be separated according to their size by using gel electrophoresis. As two genomes are not identical even within a given species due to mutations, the number of restriction sites and therefore the length and numbers of DNA fragments differ, resulting in a different banding pattern on the electrophoresis gel. This variability has been termed restriction fragment length polymorphism (RFLP).

Gene Transfer

In conventional breeding, the pool of available genes and the traits they code for is limited due to sexual incompatibility to other lines of the crop in question and to their wild relatives.

This restriction can be overcome by using the methods of genetic engineering, which in principle allow introducing valuable traits coded for by specific genes of any organism (other plants, bacteria, fungi, animals, viruses) into the genome of any plant. The first gene transfer experiments with plants took place in the early 1980s. Normally, transgenes are inserted into the nuclear genome of a plant cell.

Gene Transfer

Transgenic plants have been obtained using Agrobacterium-mediated DNA-transfer and direct DNA-transfer, the latter including methods such as particle bombardment, electroporation and polyethylenglycol permeabilisation.

Read More on :

1. **Agrobacterium-mediated Gene Transfer**
   http://rubisco.ugr.es/fisiofar/pagwebinmalcb/contenidos/Tema26/agrobacterium.pdf

2. **Particle Bombardment**
   http://www.hos.ufl.edu/sites/default/files/faculty/gamoore/ACCELL.pdf

3. **Electroporation and Direct DNA Entry into Protoplasts**
   http://www.sonidel.com/NEPA21/Direct_Gene_Transfer_into_Plant_Mature_Seeds_via_Electroporation_After_Vacuum_Treatment.pdf

Selection and Plant Regeneration

In a transformation experiment, the proportion of transformed cells is usually small compared to the number of cells which remain unaltered. In order to select only cells which have actually incorporated the new genes, the genes coding for the desired trait are fused to a gene which allows selection of transformed cells, so-called marker genes. The expression of the marker gene enables the transgenic cells to grow in presence of a selective agent, usually an antibiotic or a herbicide, while cells without the marker gene die. One of the most commonly used marker genes is the bacterial aminoglycoside-3' phosphotransferase gene (APH(3')II), also referred to as neomycin

Read More on : **Selection and Plant Regeneration**

https://ecommons.usask.ca/bitstream/handle/10388/etd-09162010-220916/chammi.pdf?sequence=1

Genetic Engineering for Plant Protection

Strategies using genetic engineering to obtained disease and pest resistant plants achieved different degrees of resistance against insects, viruses, fungi and bacteria with various crop species as:

- Resistance to Plant-Feeding Insects (Read more)
  http://cdn.intechopen.com/pdfs/37968/InTech-Biotechnological_approaches_for_the_control_of_insect_pests_in_crop_plants.pdf
- Protection against Viral Infections (Read more)
  http://www.iisc.ernet.in/currsci/feb102003/341.pdf
- Resistance to Fungal Pathogens (Read more)
  http://www.isb.vt.edu/news/2011/nov/cropfungalresistance.pdf
- Resistance to Bacterial Pathogens (Read more)
  http://arquivo.ufv.br/dbv/pgfvg/bve684/htms/pdfs_revisao/estresse/transgenicapproaches.pdf

Biofortified crop in Micronutrients

Micronutrient malnutrition affects more than half of the world population, particularly in developing countries. Concerted international and national fortification and supplementation efforts to curb the scourge of micronutrient malnutrition are showing a positive impact, alas without reaching the goals set by international organizations.

Biofortification, the delivery of micronutrients via micronutrient-dense crops, offers a costeffective and sustainable approach, complementing these efforts by reaching rural populations

Biofortified crop in Micronutrients

Exemple of HarvestPlus

HarvestPlus is biofortifying seven food crops that can help reduce micronutrient malnutrition (hidden hunger) in Asia and Africa.

Bean	Iron	DR Congo, Rwanda	2012
Cassava	Vitamin A	DR Congo, Nigeria	2011
Maize	Vitamin A	Nigeria, Zambia	2012
Pearl Millet	Iron	India	2012
Rice	Zinc	Bangladesh, India	2013
Sweet Potato	Vitamin A	Mozambique, Uganda	2007
Wheat	Zinc	India, Pakistan	2013

Read More on

HarvestPlus

http://iuss.org/19th%20WCSS/Symposium/pdf/1606.pdf

Biotechnology in Animal Husbandry

Animal biotechnology encompasses a broad range of techniques for the genetic improvement of domesticated animal species, although the term is increasingly associated with the more controversial technologies of cloning and genetic engineering.

Despite the many potential applications of these two biotechnologies, no public or private entity has yet delivered a genetically engineered food-animal product to the global market…,

Biotechnology in Animal Husbandry

The animal biotechnology industry faces a variety of scientific, regulatory, ethical and public acceptance issues.

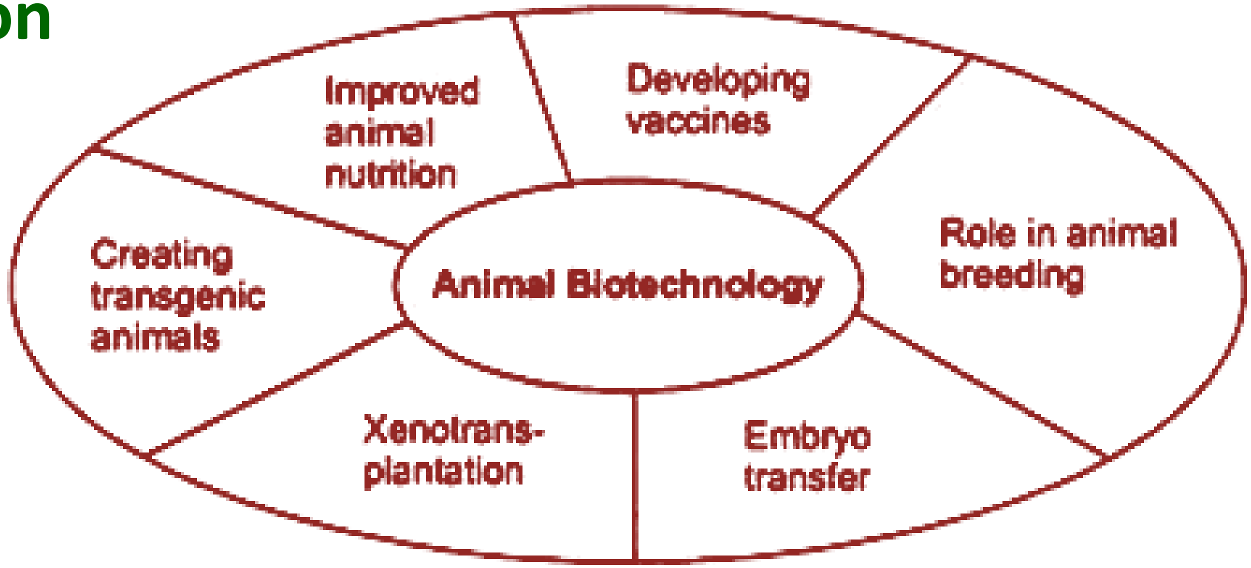
Effective and responsible communication among scientific, community, industry and government stakeholders will be required to reach a societal consensus on the acceptable uses of animal cloning and genetic engineering.

Biotechnology in Animal Husbandry 3/4

In this section, the Biotechnology contribution to animal production by improving the environmental component of the production systems as well as the genetic make-up of livestock is review in this section.

Following this general overview, specific topics as embryo transfer, transgenic, in vitro fertilization, sexing embryos, cloning and gene knockout are reviewed

Read More on



Biotechnology and animal production

https://www.abca.com.au/wp-content/uploads/2012/09/ABCA_InfoPaper_5_v2.pdf

What is the future of animal biotechnology?

http://people.forestry.oregonstate.edu/steve-strauss/sites/people.forestry.oregonstate.edu.steve-strauss/files/VanEenennaam_2006_CalAg_AnBiotech.pdf

Other Applications of Biotechnology

The last section presents non-food applications of biotechnology with specific reference to medicine and environment. An overview of biotechnology advances with new insights into the causes of disease and the opportunities for the development of new therapies, drugs, diagnostic tools and research/clinical instrumentation is given.

The state-of-the-art in environmental biotechnology (bioremediation, biosensor, biofuel, molecular Ecology) is also reviewed. Various relevant topics are chosen to illustrate each of the main areas of environmental biotechnology.

Biotechnology Applications in Environment

The application of Biotechnology to solve the environmental problems in the environment and in the ecosystems is called Environmental Biotechnology. According to the international Society for environmental Biotechnology the environmental Biotechnology is defined as an environment that helps to develop, efficiently use and regulate the biological systems and prevent the environment from pollution or from contamination of land, air and water have work efficiently to sustain an environment riendly Society.

Biotechnology Applications in Environment

There major different types of Applications of Environmental Biotechnology are :

1. **Biomarker (**chemical that helps to measure the level of damage caused or the exposure of the toxic or the pollution effect caused)
2. **Bioenergy (**Biogas, biomass, fuels, and hydrogen)
3. **Bioremediation (**cleaning up the hazardous substances into non-toxic compounds…)
4. **Biotransformation (**changes of the complex/toxic to simple non-toxic compounds)

Biotechnology Applications in Medicine

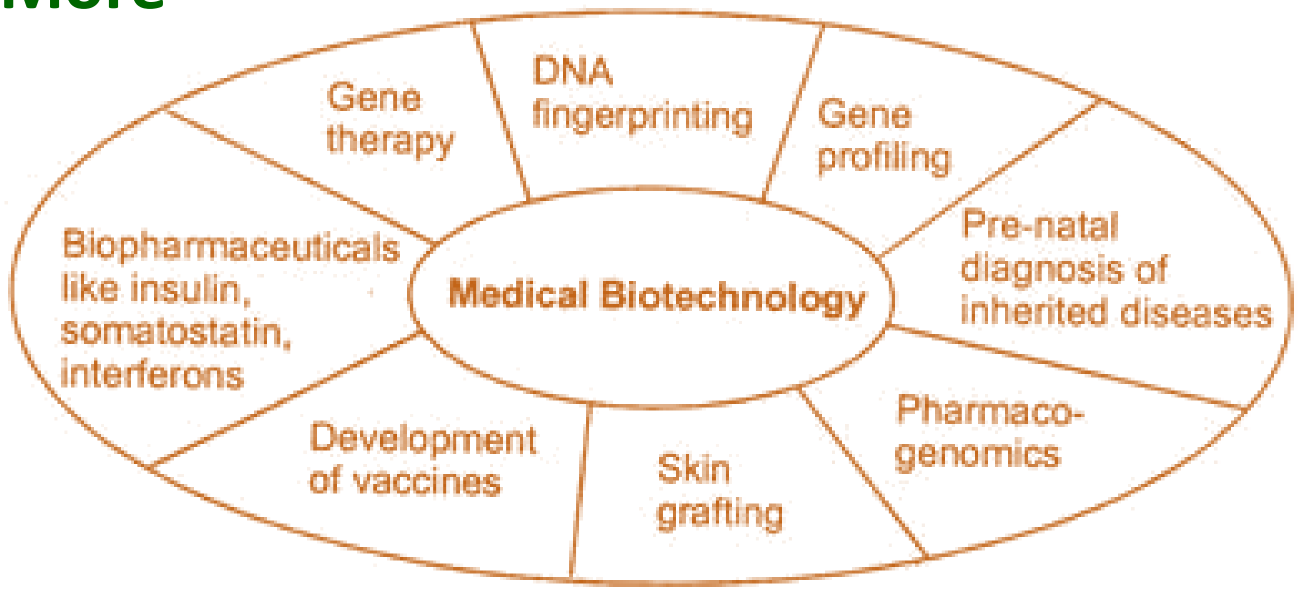
Substantial improvements in human health care and production of useful breeds of plants and animals have already occurred and more will occur in coming year.

Medicine has already gained a lot from new biotechnology.

Human insulin, first product of biotechnology, was released for sale in 1982

Biotechnology Applications in Medicine

Read More



A review article Biotechnology Applications in Medicine

http://www.irjabs.com/files_site/paperlist/r_1035_130815162300.pdf

Biotechnology - new directions in medicine

https://www.roche.de/en/innovation/grundlagen/biotechnology_new_ways_in_medicine.pdf

Applications of Biotechnology