Food Security and Biotechnology in Africa

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MODULE 2
BIOTECHNOLOGY: HISTORY, STATE OF THE ART. FUTURE.

LECTURE NOTES: UNIT 3

AGRICULTURAL BIOTECHNOLOGY:
THE STATE-OF-THE-ART

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*This **Unit 3 of Module 2** is an integral part of the **six Master's level course modules** (each of 20 hrs) in the field of agricultural biotechnology as elaborated by the EDULINK-FSBA project (2013-2017) which are:*

- *Module 1: Food security, agricultural systems and biotechnology*
- ***Module 2: Biotechnology: history, state of the art, future***
- *Module 3: Public response to the rise of biotechnology*
- *Module 4: Regulation on and policy approaches to biotechnology*
- *Module 5: Ethics and world views in relation to biotechnology*
- *Module 6: Tailoring biotechnology: towards societal responsibility and country specific approaches*

PRESENTATION OF MODULE 2

INTRODUCTION

Achieving food security in its totality (food availability, economic and physical access to food, food utilization and stability over time) continues to be a challenge not only for the developing nations, but also for the developed world. The difference lies in the magnitude of the problem in terms of its severity and proportion of the population affected. According to FAO statistics, a total of 842 million people in 2011–13, or around one in eight people in the world, were estimated to be suffering from chronic hunger. Despite overall progress, marked differences across regions persist. Africa remains the region with the highest prevalence of undernourishment, with more than one in five people estimated to be undernourished. One of the underlying causes of food insecurity in African countries is the **rapid population growth (**Africa's population is expected to reach 2.4 billion in 2050) **that makes t**he food security outlook worrisome. According to some projections, Africa will produce enough food for only about a quarter of its population by 2025. How will Africa be able to cope with its food security challenge? Is biotechnology is key to food security in Africa?

Biotechnology's ability to eliminate malnutrition and hunger in developing countries through production of crops resistant to pests and diseases, having longer shelf-lives, refined textures and flavors, higher yields per units of land and time, tolerant to adverse weather and soil conditions, etc, has been reviewed by several authors. If biotechnology per se is not a panacea for the world's problems of hunger and poverty, it offers outstanding potentials to increase the efficiency of crop improvement, thus enhance global food production and availability in a sustainable way. A common misconception being the thought that biotechnology is relatively new and includes only DNA and genetic engineering. So, agricultural biotechnology is especially a topic of considerable controversy worldwide and in Africa, and public debate is fraught with polarized views and opinions. Therefore, working at the sustainable introduction of biotechnology for food security in Africa requires a strong conceptual understanding by the learner (stakeholders and future stakeholders) of what is biotechnology.

GENERAL OBJECTIVE OF THE MODULE:

The main objective of this module is to offer a broad view of biotechnology, integrating historical, global current (classical and modern) and future applications in such a way that its applications in Africa and expected developments could be discussed based on sound knowledge of processes and methods used to manipulate living organisms or the substances and products from these organisms for medical, agricultural, and industrial purposes.

SPECIFIC OBJECTIVES:

On successful completion of this module, the 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.
- Select and properly manage information drawn from text books and article to communicate ideas effectively by written, oral and visual means on biotechnology issues.
- Demonstrate an appreciation of biotechnology in Africa especially in achieving food security.

COURSE STRUCTURE

The content of the course is organized in five units as followed:

- 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: Biotechnology in Africa: options and opportunities

UNIT 3:
AGRICULTURAL BIOTECHNOLOGY:
THE STATE-OF-THE-ART
(05 HOURS)

PRESENTATION

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. The anticipated knowledge/skills to be developed are to be familiar with the main applications of biotechnology in: Agriculture, Animal husbandry, Food processing…

Content

The unit is organized in 3 sections as follow:

1. Biotechnology applications in agriculture (*approx. 02 hours*)
2. Biotechnology applications in animal husbandry (*approx. 01 hour*)
3. Other applications of biotechnology (*approx. 02 hours*)

Course Delivery

Lecture Slides

The slides used in lectures are summaries that have as main objective to guide the learner in his personal work (mainly reading the selected literature).

- ***Reading the slides is not an adequate substitute for attending lectures. The slides do not contain anything that the instructor says, writes on the board, or demonstrates during lectures.***

Lecture Notes

The Lecture notes offer an overview of a subject (you will need to fill in the detail) and detailed information on a subject (you will need to fill in the background). It encourages taking an active part in the lecture by doing reference reading. ***Preferably read the technical techniques descriptive documents before the lecture***

To continue

The learner may be interested in:

- Module 1 of FSBA course on "*Food security, agricultural systems and biotechnology*"
- Module 3 of FSBA course on "Public response to the rise of biotechnology"

BIOTECHNOLOGY APPLICATIONS IN AGRICULTURE

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

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 are:

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 (see Fig. 1/3 for tissue culture and Fig. 2/3 for micropropagation illustrations)

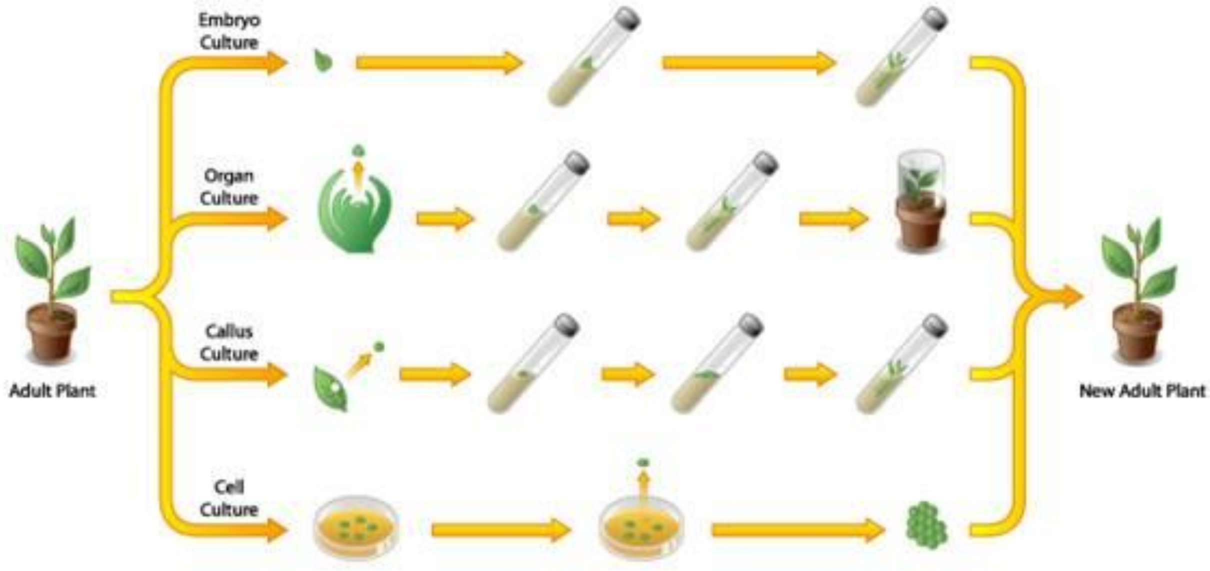


Fig. 1/3: Various Tissue Culture Types

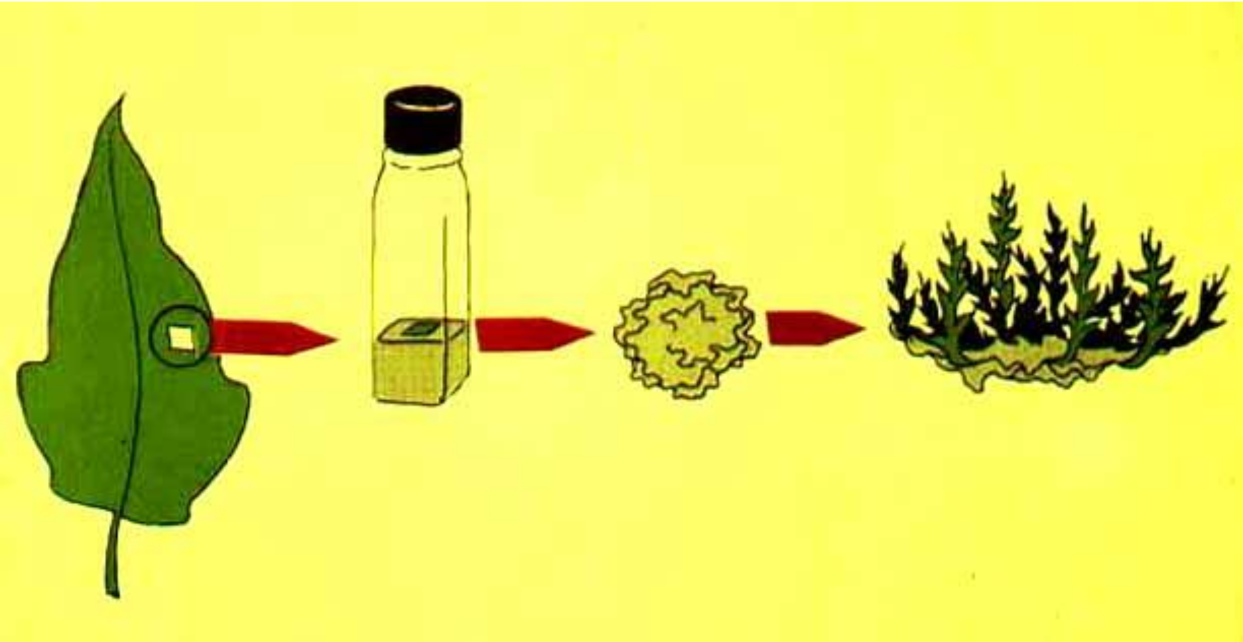


Fig. 2/3: Micropropagation

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.

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.

See more on:
Agrobacterium-mediated Gene Transfer:
http://rubisco.ugr.es/fisiofar/pagwebinmalcb/contenidos/Tema26/agrobacterium.pdf
Particle Bombardment :
http://www.hos.ufl.edu/sites/default/files/faculty/gamoore/ACCELL.pdf
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.

See more on Selection and Plant Regeneration at:
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

See more at:
http://cdn.intechopen.com/pdfs/37968/InTech-Biotechnological_approaches_for_the_control_of_insect_pests_in_crop_plants.pdf

– Protection against Viral Infections

See more at:
http://www.iisc.ernet.in/currsci/feb102003/341.pdf

– Resistance to Fungal Pathogens

See more at:
http://www.isb.vt.edu/news/2011/nov/cropfungalresistance.pdf

– Resistance to Bacterial Pathogens

See more at:
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 cost-effective and sustainable approach, complementing these efforts by reaching rural populations

➲ ***Exemple of HarvestPlus : HarvestPlus is biofortifying seven food crops that can help reduce micronutrient malnutrition (hidden hunger) in Asia and Africa (see Table 1/3).***

Table 1/3: HarvestPlus biofortified food crops in micronutrient 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

See more HarvestPlus biofortified food crops at:

a) http://www.harvestplus.org/what-we-do/crops
b) 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. 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.

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

Feed, Growth and Production

Biotechnology can increase the digestibility of low-quality roughage, and genetically modify plants to improve their feed value, such as the amino acid balance. It can also provide hormones and other substances that enhance animal size, productivity and growth rates. Synthetic hormone bST (bovine somatotropin) was among the first innovations available commercially. It can increase milk yield by as much as 10 to 15 per cent in lactating cows. Current development efforts are looking at a whole spectrum of genes that affect growth and production within the animal. Ways to genetically engineer cattle to increase their own natural hormone production are being considered, thus eliminating the need for synthetic bST. Locally produced recombinant bovine somatotropin (BST) is being used in Korea as a growth stimulant and for increased milk production in cattle. Other important technologies related to feed and digestion include the following: *f*eed additives, Genetic Improvement of Forage Crops, and other.

Feed Additives:

High-protein yeast cell products are being used as a feed additive for cattle, pigs and poultry. Highly palatable and nutritious, these products also help create a healthy balance of bacteria in the digestive tract, and prevent bacterial diarrhea.

A bacterial phytase formula, TRANSPHOS, is being used to replace the costly mineral phosphate used as an additive in the feed of monogastric animals in Korea. In the Philippines, a

bacteriocin is being produced which has antibacterial properties against Listeria monocytogenes, Staphylococcus aureus, and other pathogens found in livestock feed and human food.
L-lysine monohydrochloride, a safe and stable form of lysine, is being produced in Korea by the fermentation of a special strain of bacteria in raw molasses. Lysine is one of the most essential amino acids. Livestock requirements for it are hardly met by the amount present in natural feeds. Lysine supplementation improves the nutrient balance of feed, and feed conversion rates by livestock.

Genetic Improvement of Forage Crops

Tissue culture is being used for the genetic improvement of forage cultivars in Korea, including alfalfa and orchardgrass. A particle bombardment delivery system has been developed in Korea for transferring useful genes with heat tolerance, drought tolerance etc. into forage crops. A DNA product cloned from Brassica campestris confers heat tolerance to forage crops which generally do not perform well in temperatures above 30oC. This will improve the productivity of tropical forage crops, and also help avoid the depression in forage yield seen during the summer in Korea.
Another useful gene being transferred into forage crops gives resistance to paraquat. This is a non-selective herbicide which kills all green plants. If forage crops can be given a resistant gene, paraquat will become a simple and effective way of controlling weeds in grassland.

Other Improvements in Feed

In the improvement of silage, strains of the bacteria Lactobillus planetarium are being selected which increase the lactate content and reduce the pH and ammonia-N content. Copra meal (made from dried coconut after extraction of the oil) is being inoculated with a bacterial soil isolate in the Philippines. The treated meal is a more nutritious and digestible livestock feed, with a lower fiber content, than untreated meal.

Waste Treatment

A bacterium, Rhodopseudomonas capsulata, has the ability to grow rapidly in simple synthetic media. It is being used in advanced swine waste treatment plants in both Japan and Korea. Short chain fatty acids, one of the main sources of the bad odor of swine wastes, decreased dramatically after treatment. The residues after treatment can be used as a safe organic fertilizer.

Animal Reproduction

Biotechnology can greatly accelerate the speed at which desirable characteristics (e.g. better growth rates, or increased milk production) can be introduced into animals. While classical breeding to enhance animal traits works well, it takes decades to produce major changes. Through biotechnology, an organism can be modified directly in a very short time if the appropriate gene has been identified.

A recent breakthrough in animal reproduction is the combined application of the existing in vitro fertilization, and the state-of-the-art ultrasound-guided transvaginal oocyte pick-up (OPU) technique in cattle. When heifers reach puberty at 11-12 months of age, their oocytes may be retrieved weekly or even twice a week for embryo production and embryo transfer. There is even the possibility of applying this technology to juveniles. In this way, high-value female calves can be used for breeding long before they reach their normal breeding age.

Improving the Reproductive Rate

In Korea, Japan and Taiwan, a range of hormone implants and treatments are being used to increase the production of mammalian oocytes and embyros. Various chilling and freezing techniques have been developed for preservation of oocytes and/or embryos, including ultra-rapid freezing by electron microscope grid.

Embryo transfer is being used on valuable animals, so that oocytes and embryos from high-value animals are transferred into the uterus of surrogate mothers. In Korea and Taiwan, a PCR (polymerase chain reaction) test has been developed to establish the sex of cattle embryos. This is very important, particularly when combined with embryo transfer, since it gives control over the sex of the offspring. Similar tests are being developed for other types of livestock. The hypo osmotic swelling test has been developed to evaluate the quality of frozen and thawed bovine sperm.

Improved Transgenic Animals

In Taiwan, transgenic pigs have been bred with a porcine lactoferrin transgene. Lactoferrin is a milk protein which promotes gut growth and prevents diarrhea. Sows with this gene maintain a high lactoferrin level in their milk throughout lactation. Transgenic boars can transmit this gene to their offspring.

Genetic markers for milk production traits have been established for dairy cattle. This would be a great benefit in identifying the best progenitors for a high-yielding dairy herd.

Animal Health

One important benefit from biotechnology is the diagnosis of livestock diseases, and genetically transmitted conditions which damage health and productivity. Biological techniques can also produce cheaper and more efficient drugs. In cases where a natural source material is prohibitively expensive, genetic engineering (in microbial or tissue culture systems) can be used to produce drugs of high value for humans or animals. Examples are insulin, human growth hormone and tissue plasminogen activator (used in treating heart disease).

Vaccines

Vaccines are used to stimulate an animal's immune system to produce the antibodies needed to prevent infection. Recombinant DNA technology has provided the means to produce large quantities of inexpensive vaccines, while a better understanding of the immune system has helped produce vaccines that do a better job of boosting the body's immune system. These engineered products are safer than traditional vaccines. Whereas conventional vaccines sometimes revert to virulent (disease causing) forms, the new vaccines can be engineered to eliminate this threat. Biotechnology is also producing an entirely new use for vaccines. They are being used to modulate hormones to increase growth rates, improve the efficiency of feed conversion, stimulate milk production, contribute to improved carcass quality and leaner meat, and enhance or suppress reproductive functions.

Some recent developments include the following:

– In Taiwan, a DNA vaccine with an encoded target gene is being used to produce new vaccines. Tests have shown that the DNA vaccines consistently induced antibody response, and were resistant to toxin challenge.
– They also have other advantages. They offer protection against diseases for which no vaccine is currently available. Their production does not need dangerous infectious agents. With mass production, they will not cost much to produce. Since they are stable at room temperature, storage costs will also be low.
– Korean scientists have developed a combined vaccine against pleuropneumonia, pneumonic pasteurellosis and enzootic pneumonia in swine. Molecular biology has been used to produce an improved vaccine to protect pigs from swine fever. In the Philippines, it has been used to develop an improved vaccine to protect cattle and water buffalo against hemorrhagic septicemia. This disease is the leading cause of death among these animals. The new vaccine gives improved protection at a very low cost. A field kit has also been developed, to diagnose this disease from nose swabs.

- A number of improved vaccines for poultry have also been developed in the Philippines to protect birds from Newcastle disease, fowl cholera and infectious coryza.

Diagnosis

In Japan and Taiwan, DNA testing is being used to diagnose hereditary weaknesses of livestock. One test identifies the gene which produces Porcine Stress Syndrome in pigs. Pigs with this gene tend to produce pale, poor-quality meat when they undergo the stress of transport or slaughter. Now that pigs with this gene can be identified, they can be excluded from breeding programs, so the gene will become less common.

DNA is also being used in Japan to diagnose a mutation of Holstein cattle that causes leucoyte adhesion deficiency. Cattle with this condition suffer diseases of the gum, tooth loss and stunted growth. They usually die before they are one year old. This test will identify carriers and eliminate them from breeding herds. Bulls used for breeding can be tested to make sure they are not carriers. Another DNA test identifies a hereditary condition that produces anemia and retarded growth in Japanese black cattle.

Animal Products

Biotechnology can lead to new and improved animal products. For example, it can modify the composition of milk, or the fat content of meat. Genetically transformed cows can produce designer milks with superior properties for use in various milk products. Added caseins in milk, for instance, can enhance cheese making. Increasing the phosphate group in casein can enhance the level of calcium. Removal of the source of lactose intolerance in milk can have a significant impact on the market for dairy products, especially among the 90 % of people with an Asian or African background who are lactose-intolerant.

Some new products made possible by biotechnology in the Asian region include:

- microbial rennet which can be used in place of animal rennet to coagulate milk during the making of cheese;
- new lactic acid bacterium produced by cell fusion technique;
- safe anti-microbial agent, made from skim milk and glucose, which prolongs the shelf life of fresh milk;
- Biologically active peptides extracted from animal blood at slaughterhouses. These can be used as an additive in functional foods to improve human health;
- Colorant extracted from animal blood, to partially replace nitrite in meat products.

See more Biotechnology in Animal Husbandry at:

a) https://www.abca.com.au/wp-content/uploads/2012/09/ABCA_InfoPaper_5_v2.pdf
b) 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 friendly Society. The major different types of applications of Environmental Biotechnology are:

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

Biomarkers

Biomarkers are characterized by a unique order in their molecular structures and are the first sentinel's tools for sensitive effect measurements in environmental quality or biotechnological processes assessment. Most of the importance of biomarkers resides in their property to be measurable using different biochemical and molecular approaches. The recent application and or studies of biomarkers and its correlation at the omics era, has revalorized new roles of biomarkers in environmental biotechnology. Some of the common biomarkers actually used, viz, pigments, cytochrome P4501A enzyme induction, acetylcholinesterase inhibition, DNA integrity and metallothiones are analyzed concomitantly to recent applications of Omics technologies to optimize metabolic networks in living biomes. New developments under the umbrella of the culture independent molecular tools applied for the analyses of mixed microbial communities have contributed in understanding catabolism from contaminants in extreme and fragile environments. These approaches open the venue for the new biomarkers for an increased biodiversity expectative of ca. 99% higher than conventional classification. Functional genes by metagenomic arrays, will greatly improve our understanding of microbial interaction and metabolism to facilitate the development of suitable bioremediation strategies for environment clean up. See in Table 2/3 particular molecular biomarkers applications

Table 2/3: Particular molecular biomarkers of biological effects of contaminants on aquatic organisms and respective analytical technique of their measurements

Biomarker	**Detection/Application**	**Analytical Tools**
Pigments	Presence of photosynthesisSpecificantioxidants, Vit A	Fluorescence, HPLC, Mass spectra
Cytochrome P4501A	Presence of organic contaminationcertain PAHs, PCBs, PCDDs, etc.	Enzyme activity (fluorometry andspectroscopy) and amount (Elisa)
DNA—damage	Presence/damage of organicxeno-biotics (PAHs, PCBs and PCDDs)	DNA strand breaks measurement,
AChE inhibition	Indicator of exposure to organo-phosphorous Carbamate, toxins,metals (Cd, Pb, Cu, etc.,).	Enzyme activity (spectrophometer pH)
Metallothioneins	Indicator of exposure to metals(Zn, Cu, Cd and Hg).In: vertebrates (mammals) andAndinvertebrates (molluscs, fish)Algae.	Proteins (pulse polarography, liquidchromatography

Source: Paniagua-Michel J, Olmos-Soto J (2016)

Bioenergy

The replacement of fossil fuels with more carbon-neutral and renewable sources has become a key necessity of the time. The proposition that energy can be obtained from biomass with a decisively positive energy balance and at a scale sufficiently large to have a substantial impact on sustainability and security objectives is both supported by several recent studies. Developing a sustainable economy more extensively based on renewable carbon and eco-efficient bioprocesses is one of the key strategic challenges for the twenty-first century.

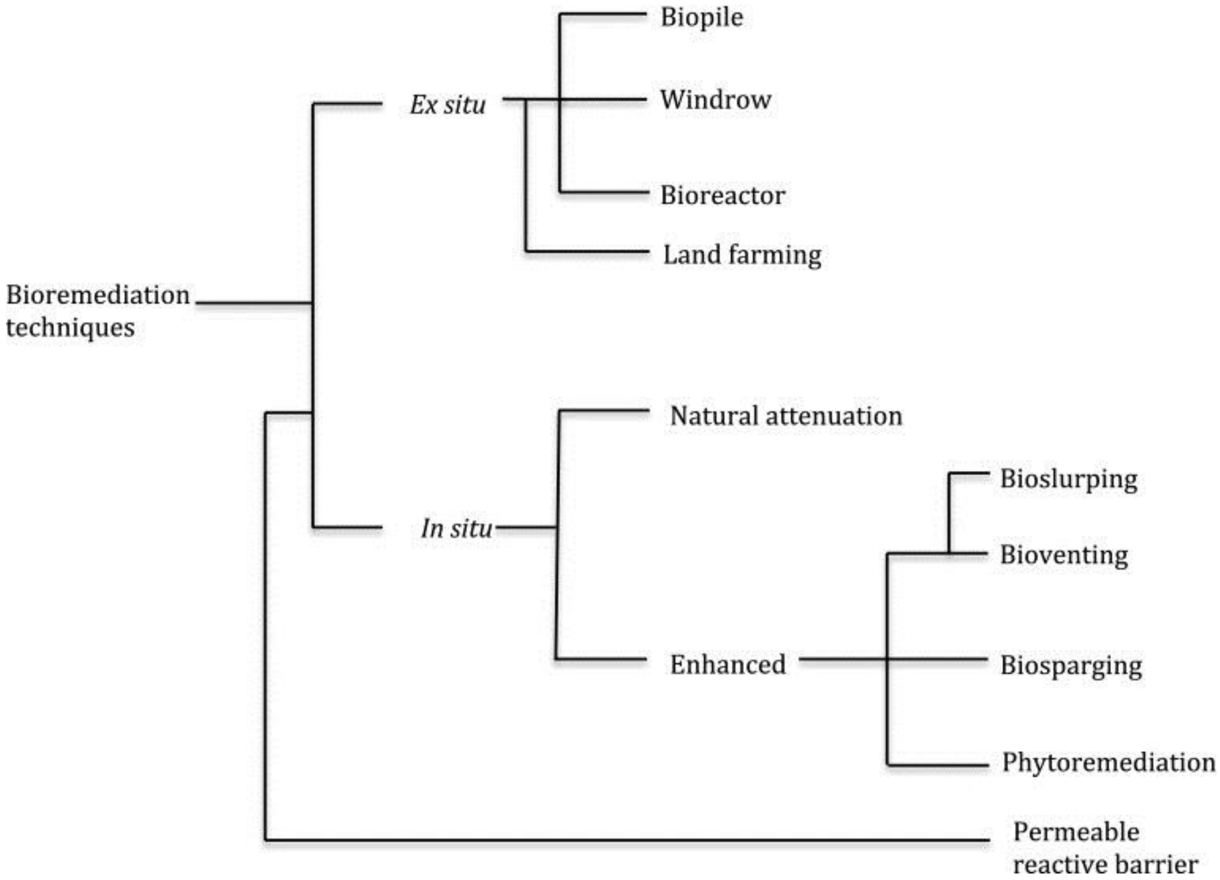
There has been a dramatic growth in the production of biofuels in recent times. Global biofuel production tripled between 2000 and 2007, and biofuels accounted for about 1.6% of global transportation fuel in 2012 (International Energy Agency). In 2015, ethanol production is by far the greatest contribution by biotechnology to energy production, with revenue accounting for $40.9 billion worldwide in 2014 vs. $3.8 billion for biodiesel and $0.019 billion for bio-methane. It is logical to imagine the future contribution of biotechnology to world energy production may increase not only in the area of biofuel production, but also in petroleum production, petroleum upgrading, biogas production, chemical production, crop improvement, bioremediation, microbiologically influenced corrosion, space travel, and other topics.

However, the future contributions of biotechnology to the energy industry are not only influenced by technical advances in biotechnology, but also by the price of fossil fuels, the development of renewable energy generally, politics, global population growth, and other factors. Concerns about the use of crops for food versus fuel production, environmental effects of land use related to biofuel production, decreased oil prices; ever-increasing advances in the generation and use of wind and solar energy, and political will to promote/subsidize the development of alternative energy are also influencing factors.

Bioremediation

The global environment is now facing a highly critical situation due to rapid urbanization and industrialization as well as increasing population in the limited natural resources. The population growth reflects the drastic changes of the life style of the people that created anthropogenic stress on the environment. There is requirement of highly developed environmental management systems and search of biotechnological technology to remove the contaminated materials and reestablish the natural resources Bioremediation is now considered as the most useful alternative method for eradicate the contaminated material from the nature for sustainable waste management. Now with recent advancement of the genetic approach multiplies the bioremediation process for protection of the natural environment by recycling the waste materials.

Bioremediation refers to the productive use of microorganisms to remove or detoxify pollutants, usually as contaminants of soils, water or sediments that otherwise intimidate human health. Bio treatment, bio reclamation and bio restoration are the other terminologies for bioremediation. Bioremediation is not a new practice. Microorganisms have been used for many years to remove organic matter and toxic chemicals from domestic and manufacturing waste discharge. Bioremediation can either be carried out *ex situ* or *in situ*, depending on several factors, which include but not limited to cost, site characteristics, type and concentration of pollutants. (see Fig. 3/3 for bioremediation techniques).



Source: World J Microbiol Biotechnol. 2016; 32(11): 180.

Fig. 3/3: Bioremediation techniques

Biotransformation

Biotransformation of various pollutants is a sustainable way to clean up contaminated environments. These bioremediation and biotransformation methods harness the naturally occurring, microbial catabolic diversity to degrade, transform or accumulate a huge range of compounds including hydrocarbons (e.g. oil), polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), pharmaceutical substances, radionuclides and metals. Major methodological breakthroughs in recent years have enabled detailed genomic, metagenomic, proteomic, bioinformatic and other high-throughput analyses of environmentally relevant microorganisms providing unprecedented insights into biotransformation and biodegradative pathways and the ability of organisms to adapt to changing environmental conditions.

Biological processes play a major role in the removal of contaminants and pollutants from the environment. Some microorganisms possess an astonishing catabolic versatility to degrade or transform such compounds. New methodological breakthroughs in sequencing, genomics, proteomics, bioinformatics and imaging are producing vast amounts of information. In the field of Environmental Microbiology, genome-based global studies open a new era providing unprecedented in silico views of metabolic and regulatory networks, as well as clues to the evolution of biochemical pathways relevant to biotransformation and to the molecular adaptation strategies to changing environmental conditions. Functional genomic and metagenomic approaches are increasing our understanding of the relative importance of different pathways and regulatory networks to carbon flux in particular environments and for particular compounds and they are accelerating the development of bioremediation technologies and biotransformation processes. Also there is other approach of biotransformation called enzymatic biotransformation.

See more Biotechnology in Environment at:

a) https://www.omicsonline.org/open-access/modern-approaches-into-biochemical-and-molecular-biomarkers-keyroles-in-environmental-biotechnology-2155-952X-1000216.php?aid=68300&view=mobile
b) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4741079/
c) https://link.springer.com/chapter/10.1007%2F978-81-322-2065-7_29
d) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5026719/

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). Nowadays medicine is using biotechnology techniques so much in diagnosing and treating different diseases. It also gives opportunities for the people to protect themselves from dangerous diseases. The field of biotechnology, genetic engineering, has introduced techniques like gene therapy, recombinant DNA technology and polymerase chain reaction which use genes and DNA molecules to diagnose diseases and insert new and healthy genes in the body which replace the damaged cells. There are some applications of biotechnology which are playing their part in the field of medicine and giving good results:

Biopharmaceuticals

By using the techniques of biotechnology, the drugs biopharmaceuticals were developed. There are no chemicals involved in the synthesis of these drugs, but microorganisms have made it possible to develop them. Large molecules of proteins are usually the source of biopharmaceuticals. They when targeted in the body attack the hidden mechanisms of the disease and destroy them. Now scientists are trying to develop such biopharmaceutical drugs which can be treated against the diseases like hepatitis, cancer and heart diseases.

These drugs are made by many ways and one method of developing such drugs is bioreactor. Bioreactor is a container which is used to grow microorganisms under the specific temperature and other required conditions. These microorganisms then make biopharmaceuticals. Though genetically modified plants and animals can also be used to make biopharmaceuticals but then there are various ethical and legal issues regarding these animals and plants.

Gene Therapy

Gene therapy is another technique of biotechnology which is used to treat and diagnose diseases like cancer and Parkinson's disease. The mechanism of this technique is that the healthy genes are targeted in the body which either destroy the damaged cells or replace them. In some cases, the healthy genes make corrections in the genetic information and that is how the genes start functioning in the favor of the body.

Pharmacogenomics

Pharmacogenomics is another genetically modified technique which is used to study the genetic information of an individual. It analyzes the body's response to certain drugs. It is the combination of pharmaceuticals and genomics. The aim of this field is to develop such drugs which are inserted in the individual according to the genetic information present in the individual.

Genetic Testing

Genetic testing is a technique of genetics which is used to determine the genetic diseases in parents, sex and carrier screening. The method of genetic testing is to use DNA probes which have the sequences similar to the mutated sequences. This technique is also used to identify the criminals and to test the paternity of the child.

- ***Scientists are working in the research area to develop new drugs and vaccines and are also finding cures for the diseases which were difficult to treat in the past decade. Is Biotechnology a field of miracles ?***

See more Biotechnology in Medicine at:

a) http://www.irjabs.com/files_site/paperlist/r_1035_13081
b) https://www.roche.de/en/innovation/grundlagen/biotechnology_new_ways_in_medicine.pdf
c) http://www.biotecharticles.com/Others-Article/Applications-of-Biotechnology-in-Medicine-134.html

CONCLUSION

Some scientists concluded that no field of science can be successful until it uses the techniques of biotechnology. There is no doubt that biotechnology can bring about improvements in agriculture, animal husbandry, health and environment. It can do this while conserving natural resources and the environment. Since biotechnology is so new, these techniques may not yet be of much benefit to smallholders. The contribution to their future could be enormous, but only if scientists and institutions working in this field focus on farmers' needs. They must ensure that the technology is developed and extended in a way which will benefit ordinary farmers. Advances in biotechnology need highly trained personnel and state-of-the-art equipment and facilities. There is a danger that within countries, and between nations, the poor may remain on the periphery while the prosperous take most of the profits.

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