Food Security and Biotechnology in Africa

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

LECTURE NOTES: UNIT 1

INTRODUCTION TO BIOTECHNOLOGY, HISTORY AND CONCEPTS DEFINITION

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*This **Unit 1 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 1:
INTRODUCTION TO BIOTECHNOLOGY, HISTORY AND CONCEPTS DEFINITION (04 HOURS)

PRESENTATION

Objective

This unit is intended to introduce the concepts and evolution of biotechnology by the development of a well-grounded understanding of biotechnological history and definitions including broad principles, integration of different subject areas, specialized knowledge and the developments in specific subject.

Content

The unit thus includes the followings:

1. Concepts definition (*approx. 01 hour*)
2. History & Evolution of Biotechnology (*approx. 02 hours*)
3. Spectrum of applications of Biotechnology (*approx. 01 hour*)

Course Delivery

<u>*Lecture Slides*</u>

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.***

<u>*Lecture Notes*</u>

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.

To continue

The learner may be interested in:

- Unit 4/Module 2 of FSBA course on "*Agricultural biotechnology: the state-of-the-art*"
- Module 1 of FSBA course on "*Food security, agricultural systems and biotechnology*"

CONCEPTS DEFINITION

What is meant by biotechnology?

The rationale behind this question is that for society to decide how to manage biotechnology, there must be first a common understanding of what it is. This section provides therefore the broadest definitions of biotechnology as "the use of living organisms to meet human needs" in comparison to the narrowest definitions often confined to genetic engineering and recombinant DNA technology according to international and national institutions and organizations. A basic glossary of terms used in biotechnology is provided. At the end, without taking sides, the need to decide what to "choose" biotechnology to mean is discussed as a basic to cope with social (public understanding and acceptance), political and legislative matters.

Origin of the term "Biotechnology"

According to Robert Bud[1], the term *« Biotechnology »* was first used by the Hungarian Károly Ereky during 1919 to describe a technology based on converting raw materials into a more useful product in a book called *"Biotechnology of Meat, Fat and Milk Production in an Agricultural Large-Scale Farm »*. For Ereky, the term "biotechnology" indicated the process by which raw materials could be biologically upgraded into socially useful products. Since its inception, the notion of biotechnology has been variously defined.

Definitions used by governments and organizations

The following is a list of definitions of biotechnology used by the governments and organizations of various countries in assessments of the developing field within their jurisdictions. Most of these definitions encompass both old and new biotechnology.

Canada: Biotechnology is "the application of biological organisms, systems, or processes to manufacturing or service industries". Biotechnology is "the utilization of a biological process, be it via microbial, plant or animal cells, or their constituents, to provide goods and services".

Federal Republic of Germany: "Biotechnology deals with the introduction of biological methods within the framework of technical processes and industrial production. It involves the application of microbiology and biochemistry together with technical chemistry and process engineering"

[1] ROBERT BUD, **History of 'biotechnology'** *Nature* **337**, 10 (05 January 1989)

France: “Biotechnology consists of the industrial exploitation of the potential of micro-organisms, animal and plant cells, and subcellular fractions derived from them”

Japan: Biotechnology is “a technology using biological phenomena for copying and manufacturing various kinds of useful substances”

The Netherlands: Biotechnology is “the science of the production processes based on the action of microorganisms and their active components, and of production processes involving the use of cells and tissues from higher organisms. Medical technology, agriculture, and traditional crop breeding are not generally regarded as biotechnology”

FDA's working definition of biotechnology

FDA's working definition of biotechnology is "*the application of biological systems and organisms to technical and industrial processes*". This definition is necessarily broad. It takes in both the "old" and "new" science: the age-old techniques for making beer or yogurt as well as the most advanced uses of recombinant DNA technology. It takes in many applications, from production of enzymes for laundry detergents, to selective breeding of plants and animals, to genetic engineering of bacteria to clean up oil spills.

OECD definition

In 1982, an expert group proposed a common definition of biotechnology for OECD member countries, in which it was taken as “*the application of scientific and engineering principles to the processing of materials by biological agents to provide good and services*.” This definition is still widely referred to and remains the most informative.

In 2005, members of the OECD’s Ad hoc Biotechnology Statistics Group developed a single, list-based definition of biotechnology. The single definition is: “*the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services*”.

- ➲ *The list-based definition of biotechnology includes the following: DNA/RNA, proteins and other molecules, cell and tissue culture and engineering, process biotechnology techniques, gene and RNA vectors, bioinformatics and nanobiotechnology, etc. The OECD definition of biotechnology is very broad as it covers all modern biotechnology and also many traditional and borderlines activities.*

Example of narrow definitions

Biotechnology at the Hebrew University (1992): “The [direct] manipulation of nature for the benefit of mankind at the subcellular and molecular levels”

U.S. Office of Technology Assessment (1984): "New" biotechnology is the industrial use of recombinant DNA, cell diffusion and novel bioprocessing techniques".

See more on biotechnology definitions at:

a) https://www.princeton.edu/~ota/disk3/1984/8407/840724.PDF
b) http://www.eolss.net/sample-chapters/c14/e1-36-13.pdf
c) http://nvsrochd.gov.in/s_club/biology/ch11_bilas.pdf

Biotechnology a multidisciplinary field

Biotechnology is a clearly multidisciplinary field involving biochemistry, molecular biology, genetics, immunology, microbiology, pharmacology, fermentation, agriculture, to name just a few. Each of the contributing subject areas brings its own special vocabulary and nomenclature standards and considerable difficulties of communication is the result. It is therefore important to become familiar with terminology, for that a glossary of biotechnology and genetic engineering summarizes the status of the terminology in the various disciplines that make up biotechnology is given: http://www.fao.org/3/a-x3910e.pdf.

HISTORY & EVOLUTION OF BIOTECHNOLOGY

This second section further introduces to biotechnology concepts through the presentation of timeline showing the progression from the earliest domestication of crops and animals (before the Common Era) to modern methods of biotechnology in the 21st Century. The classification in ancient biotechnology (1st generation), classical biotechnology (2nd generation) and modern biotechnology (3rd generation) is presented. Dates are benchmarks of scientific, social responses and regulatory breakthroughs, and scientific evidence on the important of the role of biotechnology as tools to improve food production (crops, food, and animal's husbandry) is highlighted.

Biotechnology Timeline

The historical application of Biotechnology throughout is provided below since before the common era; and the evolution in agriculture is summarized in Table 1/1.

Before Common Era

- 7000 BCE – Chinese discover fermentation through beer making.
- 6000 BCE – Yogurt and cheese made with lactic acid-producing bacteria by various people.
- 4000 BCE – Egyptians bake leavened bread using yeast.
- 500 BCE – Moldy soybean curds used as an antibiotic.
- 250 BCE – The Greeks practice crop rotation for maximum soil fertility.

- 100 CE – Chinese use chrysanthemum as a natural insecticide.

Pre-20th Century

- 1663 – First recorded description of dying cells by Robert Hooke.
- 1675 – Antonie van Leeuwenhoek discovers and describes vagina and protozoa.
- 1798 – Edward Jenner uses first viral vaccine to inoculate a child from smallpox.
- 1802 – The first recorded use of the word biology.
- 1824 – Henri Dutrochet discovers that tissues are composed of living cells.
- 1838 – Protein discovered, named and recorded by Gerardus Johannes Mulder and Jöns Jacob Berzelius.
- 1862 – Louis Pasteur discovers the bacterial origin of fermentation.
- 1863 – Gregor Mendel discovers the laws of inheritance.
- 1864 – Antonin Prandtl invents first centrifuge to separate cream from milk.
- 1869 – Friedrich Miescher identifies DNA in the sperm of a trout.
- 1871 – Ernst Hoppe-Seyler discovers invertase, which is still used for making artificial sweeteners.
- 1877 – Robert Koch develops a technique for staining bacteria for identification.
- 1878 – Walther Flemming discovers chromatin leading to the discovery of chromosomes.
- 1881 – Louis Pasteur develops vaccines against bacteria that cause cholera and anthrax in chickens.
- 1885 – Louis Pasteur and Emile Roux develop the first rabies vaccine and use it on Joseph Meister.

20th century

- 1919 – Károly Ereky, a Hungarian agricultural engineer, first uses the word biotechnology
- 1928 – Alexander Fleming notices that a certain mould could stop the duplication of bacteria, leading to the first antibiotic: penicillin.
- 1933 – Hybrid corn is commercialized.
- 1942 – Penicillin is mass-produced in microbes for the first time.
- 1950 – The first synthetic antibiotic is created.
- 1951 – Artificial insemination of livestock is accomplished using frozen semen.
- 1952 – L.V. Radushkevich and V.M. Lukyanovich publish clear images of 50 nanometer diameter tubes made of carbon, in the Soviet Journal of Physical Chemistry.
- 1953 – James D. Watson and Francis Crick describe the structure of DNA.
- 1958 – The term bionics is coined by Jack E. Steele.

- 1964 – The first commercial myoelectric arm is developed by the Central Prosthetic Research Institute of the USSR, and distributed by the Hangar Limb Factory of the UK.
- 1972 – The DNA composition of chimpanzees and gorillas is discovered to be 99% similar to that of humans.
- 1973 – Stanley Norman Cohen and Herbert Boyer perform the first successful recombinant DNA experiment, using bacterial genes.[4]
- 1974 – Scientist invent the first biocement for industrial applications.
- 1975 – Method for producing monoclonal antibodies developed by Köhler and César Milstein.
- 1978 – North Carolina scientists Clyde Hutchison and Marshall Edgell show it is possible to introduce specific mutations at specific sites in a DNA molecule.[5]
- 1980 – The U.S. patent for gene cloning is awarded to Cohen and Boyer.
- 1982 – Humulin, Genentech's human insulin drug produced by genetically engineered bacteria for the treatment of diabetes, is the first biotech drug to be approved by the Food and Drug Administration.
- 1983 – The Polymerase Chain Reaction (PCR) technique is conceived.
- 1990 – First federally approved gene therapy treatment is performed successfully on a young girl who suffered from an immune disorder.
- 1994 – The United States Food and Drug Administration approves the first GM food: the "Flavr Savr" tomato.
- 1997 – British scientists, led by Ian Wilmut from the Roslin Institute, report cloning Dolly the sheep using DNA from two adult sheep cells.
- 1999 – Discovery of the gene responsible for developing cystic fibrosis.
- 2000 – Completion of a "rough draft" of the human genome in the Human Genome Project.

<u>21st Century</u>

- 2001 – Celera Genomics and the Human Genome Project create a draft of the human genome sequence. It is published by Science and Nature Magazine.
- 2002 – Rice becomes the first crop to have its genome decoded.
- 2003 – The Human Genome Project is completed, providing information on the locations and sequence of human genes on all 46 chromosomes.
- 2008 – Japanese astronomers launch the first Medical Experiment Module called "Kibo", to be used on the International Space Station.
- 2009 – Cedars-Sinai Heart Institute uses modified SAN heart genes to create the first viral pacemaker in guinea pigs, now known as iSANs.

– 2012 – Thirty-one-year-old Zac Vawter successfully uses a nervous system-controlled bionic leg to climb the Chicago Willis Tower.

Table 1/1: An agricultural technology timeline

Technology	Era	Genetic interventions
Traditional	About 10 000 years BC	Civilizations harvested from natural biological diversity, domesticated crops and animals, began to select plant materials for propagation and animals for breeding
	About 3 000 years BC	Beer brewing, che0ese making and wine fermentation
Conventional	Late nineteenth century	Identification of principles of inheritance by Gregor Mendel in 1865, laying the foundation for classical breeding methods
	1930s	Development of commercial hybrid crops
	1940s to 1960s	Use of mutagenesis, tissue culture, plant regeneration. Discovery of transformation and transduction. Discovery by Watson and Crick of the structure of DNA in 1953. Identification of genes that detach and move (transposons)
Modern	1970s	Advent of gene transfer through recombinant DNA techniques. Use of embryo rescue and protoplast fusion in plant breeding and artificial insemination in animal reproduction
	1980s	Insulin as first commercial product from gene transfer. Tissue culture for mass propagation in plants and embryo transfer in animal production
	1990	Extensive genetic fingerprinting of a wide range of organisms. First field trials of genetically engineered plant varieties in 1990 followed by the first commercial release in 1992. Genetically engineered vaccines and hormones and cloning of animals
	2000s	Bioinformatics, genomics, proteomics, metabolomics

Source: Adapted from van der Walt (2000) and FAO (2002)

See more on biotechnology timeline at:

a) https://www.currituck.k12.nc.us/cms/lib/NC01001303/Centricity/Domain/761/careersInBiomanufacturing_unit1_biotechTimeline.pdf

b) http://archive.industry.gov.au/Biotechnologyonline.gov.au/foodag/timeline.html

Stages of Biotechnology

Ancient Biotechnology (Pre-1800)

Most of the developments in the ancient period i.e., before the year 1800, can be termed as ‘discoveries’ or ‘developments’. If we study all these developments, we can conclude that all these inventions were based on common observations about nature, which could be put to test for the betterment of human life at that point in time.

Food, clothes, and shelter are the most important basic needs of human beings irrespective of whether they lived in the ancient period or the modern period. The only factor that has changed is their types and origins. Food has been an inevitable need since the existence of man as well as for continuous existence of human beings. Early man used to eat raw meat, whenever they found a dead animal. However, during harsh weather, there was a paucity of food, hence, as per the saying, ‘necessity is the mother of all inventions’, which led to the domestication of food products, which is named as ‘agriculture’. In ancient times, humans explored the possibilities of making food available by growing it near their shelters, so that the basic need for food could be met easily. They brought seeds of plants (mostly grains) and sowed them near to their shelters. They understood the importance of water, light, and other requirements for the optimal growth of food plants. Similar principles and needs also led them to start domestication of different wild animals, which helped them to improve their living conditions and to satisfy their hunger. The need to hunt for animal was done away with it; as now animals were available to them at closer proximity, and also they did not have to deal with the dangerous conditions of hunting. Domestication of wild animals was the beginning of observation, implications, and applications of animal breeding. Certainly, we can say that this was the initial period of evolution of farming, which led to another needs like the development of methods for food preservation and storage. They used cold caves to preserve food for long-term storage. It also made the way for the evolution of pots to store food products, in the form of leather bags, clay jars, etc.

After domestication of food crops and wild animals, man moved on to other new observations like cheese, curd, etc. Certainly, cheese can be considered as one of the first direct products (or by-product) of biotechnology, because it was prepared by adding rennet (an enzyme found in the stomach of calves) to sour milk, which is possible only by exposing milk to microbes (although this understanding was not there, at that time). Yeast is one of the oldest microbes that have been exploited by humans for their benefit. Yeast has been widely used to make bread, vinegar production, and other fermentation products, which include production of alcoholic beverages like whiskey, wine, beer, etc. Vinegar has a significant importance because of its low pH. Vinegar is capable of preventing growth of certain microbes, and therefore, vinegar can be used successfully for food preservation. The discoveries and benefits of these observations led people to work on further improvement of the process. Fermentation was a powerful tool to improve their living conditions, even though they were ignorant about the principle behind it.

One of the oldest examples of crossbreeding for the benefit of humans is mule. Mule is an offspring of a male donkey and a female horse. People started using mules for transportation, carrying loads, and farming, when there were no tractors or trucks. Mule is comparatively easier to obtain than Hinny (offspring of a male horse and a female donkey). Mule and Hinny both have a chromosome number 63, unlike horse (64) and donkey (62).

Classical Biotechnology

The second phase of evolution and development of biotechnology can be called 'Classical Biotechnology'. This phase existed from 1800 to almost the middle of the twentieth century. During this period various observations started pouring in, with scientific evidences. They were all very helpful toward solving the puzzle/s of biotechnology. Each and every contribution from different individuals helped to solve the puzzle and pave the path for new discoveries.

The basics for the transfer of genetic information are the core of biotechnology. This was, for the first time, deciphered in plants, i.e., Pisum sativum, commonly known as Pea plant. These observations were decoded by Gregor John Mendel (1822-1884), an Austrian Augustinian Monk. Mendel at that time presented "Laws of Inheritance" to the Natural Science Society in Brunn, Austria. Mendel proposed that invisible internal units of information account for observable traits, and that these 'factors' -later called as genes, which are passed from one generation to the next. However, the sad part of the story is that Mendel failed to get due recognition for his discovery for almost 34 years after his death, when other scientists like Hugo de Vries, Erich Von Tschermak, and Carl Correns validated Mendel's work in 1900. The reason why Mendel's study remained unnoticed for such a long period of time was because at the same time Charles Darwin's Theory of Evolution was so consuming that it shadowed the significance of work done by Mendel.

Almost at the same time Robert Brown had discovered nucleus in cells, while in 1868, Fredrich Miescher, a Swiss biologist reported nuclein, a compound that consisted of nucleic acid that he extracted from pus cells i.e., white blood cells (WBC). These two discoveries became the basis of modern molecular biology, for the discovery of DNA as a genetic material, and the role of DNA in transfer of genetic information. 1n 1881, Robert Koch, a German physician described the bacterial colonies growing on potato slices (First ever solid medium). Walter Hesse, one of the co-workers in Koch's laboratory, discovered agar when he asked his wife what kept the jelly solid even at high temperature of summer. She told, it is agar agar, since then nutrient agar became the most acceptable and useful medium to obtain pure microbial cultures as well as for their identification. In 1888, Heinrich Wilhelm Gottfried Von Waldeyer-Hartz, a German scientist coined the term 'Chromosome', which is considered as an organized structure of DNA and protein present in cells or a single piece of coiled DNA containing many genes, regulatory elements, and other nucleotide sequences. Other important discoveries during this period were vaccination against small pox and rabies developed by Edward Jenner a British Physician and Louis Pasteur a French Biologist.

By this time the development and growth of biological sciences seemed to be reaching to the exponential phase. The principle of genetics in inheritance was redefined by T H Morgan, who has shown inheritance and the role of chromosomes in inheritance by using fruit flies, i.e., Drosophila melanogaster. This landmark work of T H Morgan was named, 'The theory of the Gene' in 1926. Before the publication of Morgan's work, in 1909, the term 'Gene' had already been coined by Wilhelm Johannsen (1857-1927), who described 'gene' as carrier of heredity. Johannsen coined the terms 'genotype' and 'phenotype'. 'Genotype' was meant to describe the genetic constitution of an organism, while 'Phenotype' was meant to describe actual organism. By this time genetics started gaining its importance, which led to the start of Eugenic Movement in USA, in 1924. As a result of this, in 1924, the US Immigration Act was used to restrict the influx of poorly educated immigrants from Southern and Eastern Europe, on the grounds of their suspected genetic inferiority.

Almost at the same time, in Britain, Alexander Fleming a physician discovered antibiotics, when he observed that one microorganism can be used to kill another microorganism, a true representation of the 'divide and rule' policy of humans. Fleming noted that all bacteria (Staphylococci) died when a mold was growing in a petri-dish. Later he discovered 'penicillin' the antibacterial toxin from the mold Penicillium notatum, which could be used against many infectious diseases. Fleming wrote, "When I woke up just after dawn on September 28, 1928, I certainly didn't plan to revolutionize all medicine by discovering the world's first antibiotic, or bacteria killer". As a matter of fact vaccines and antibiotics turned out to be the best saviors of humanity. Can we attribute these two discoveries for the ever increasing population as well the ever ageing population of the world?

Modern Biotechnology

The Second World War became a major impediment in scientific discoveries. After the end of the second world war some, very crucial discoveries were reported, which paved the path for modern biotechnology and to its current status. In 1953, JD Watson and FHC Crick for the first time cleared the mysteries around the DNA as a genetic material, by giving a structural model of DNA, popularly known as, 'Double Helix Model of DNA'. This model was able to explain various phenomena related to DNA replication, and its role in inheritance. Later, Jacob and Monad had given the concept of Operon in 1961, while Kohler and Milestein in 1975, came up with the concept of cytoplasmic hybridization and produced the first ever monoclonal antibodies, which has revolutionized the diagnostics.

By this time it seemed like the world's scientific community had almost all the basic tools available to them for their applications, along with majority of basic concepts had been elucidated, which has fast forwarded the path for important scientific discoveries. Dr. Hargobind Khorana was able to synthesize the DNA in test tube, while Karl Mullis added value to Khorana's discovery by amplifying DNA in a test tube, thousand times more than the original amount of DNA. Using this technological advancement, other scientists were able to insert a foreign DNA into another host and were even able to monitor the transfer of a foreign DNA into the next generation. The advent of HIV / AIDS as a deadly disease has helped tremendously to improve various tools employed by life-scientist for discoveries and applications in various aspects of day-to-day life. In the mean time Ian Wilmut an Irish scientist was successful to clone an adult animal, using sheep as model, and he named the cloned sheep as 'Dolly'. Craig Venter, in 2000, was able to sequence the human genome; the first publically available genome is from JD Watson and Craig Venter, himself. These discoveries have unlimited implications and applications. In 2010, Craig Venter has been successful in demonstrating that a synthetic genome could replicate autonomously. Should that be considered as a new possibility for creating life in a test tube, which could be planned and designed by human being using a pen, pencil, computer, and bioinformatics as tools? In future, can we produce life as per our imagination and whims?

Biotechnology has brought humanity to this level of comfort; the next question is, where will it take us? Biotechnology has both beneficial and destructive potentials. It is, WE who should decide how to use this technology to help humanity rather than to destroy it.

SPECTRUM OF APPLICATIONS OF BIOTECHNOLOGY

The core concept of this section is that biotechnology is nowadays a very broad based field of scientific research and the term "biotechnology" encompasses many processes and applications. Many of these uses don't immediately spring to mind when the term "biotechnology" is mentioned. This section covers the spectrum of the main applications of biotechnology using the colours code: green biotechnology related to agriculture, red related to medicine, white related to industry, etc (see Fig. 1/1).

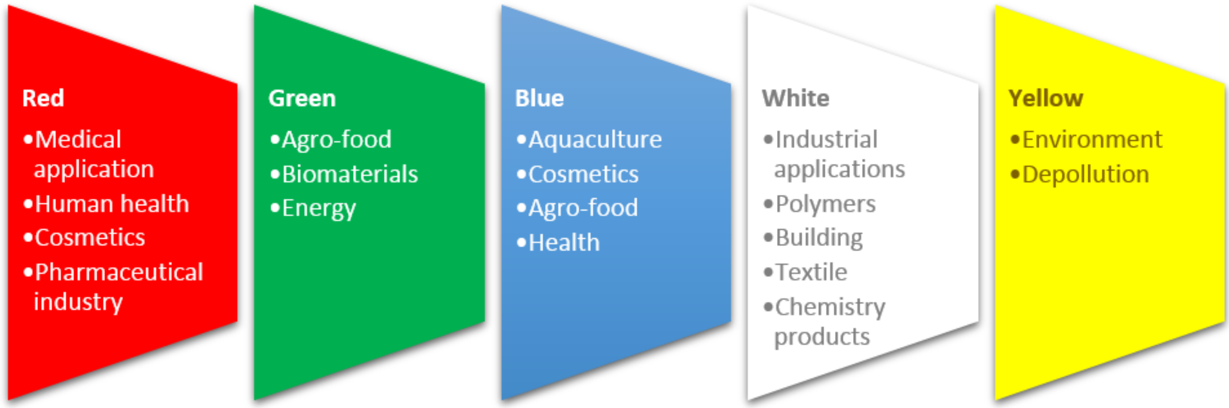

Fig. 1/1: Main applications of biotechnology using the colours code

Red biotechnology/Medicine

Red biotechnology brings together all those biotechnology uses connected to medicine. Red biotechnology includes producing vaccines and antibiotics, developing new drugs, molecular diagnostics techniques, regenerative therapies and the development of genetic engineering to cure diseases through genetic manipulation. Some relevant examples of red biotechnology are cell therapy and regenerative medicine, gene therapy and medicines based on biological molecules such as therapeutic antibodies.

See more on medical biotechnology at:

a) http://archive.unu.edu/unupress/sample-chapters/medicalbiotechnology.pdf
b) http://www.wtec.org/loyola/nano/IWGN.Research.Directions/chapter08.pdf

White biotechnology/Indutry

White biotechnology comprises all the biotechnology uses related to industrial processes - that is why it is also called 'industrial biotechnology'. White biotechnology pays a special attention to design low resource-consuming processes and products, making them more energy efficient and less polluting than traditional ones. There can be found many examples of white biotechnology, such as the use of microorganisms in chemicals production, the design and production of new materials for daily use (plastics, textiles ...) and the development of new sustainable energy sources such as biofuels.

See more on industrial biotechnology at:

a) https://www.eolss.net/sample-chapters/C17/E6-58-05-00.pdf
b) http://scs.illinois.edu/~zhaogrp/publications/HZ82.pdf

Grey biotechnology/ Environment

Grey biotechnology includes all those applications of biotechnology directly related to the environment. These applications can be split up into two main branches: biodiversity maintenance and contaminants removal. Regarding the first, it should be mentioned the application of molecular biology to genetic analysis of populations and species that are part of ecosystems, their comparison and classification and also cloning techniques aimed to preserve species and genome storage technologies. As for pollutants removal or bioremediation, grey biotechnology uses microorganisms and plants to isolate and dispose of different substances such as heavy metals and hydrocarbons, with the added possibility of subsequently making use of these substances or by-products from this activity.

See more on Environmental biotechnology at:

a) http://library.umac.mo/ebooks/b28045907.pdf
b) https://www2.hcmuaf.edu.vn/data/quoctuan/Environmental%20Biotechnology%20-%20Theory%20and%20Application,%20G%20M%20Evans%20&%20J%20C%20Furlong.pdf

Green biotechnology/Agriculture

Green biotechnology is focused on agriculture as working field. Green biotechnological approaches and applications include creating new plant varieties of agricultural interest, producing biofertilizers and biopesticides, using in vitro cultivation and cloning plants. The first approach is the one to undergo further development and attract the most interest and social controversy. Producing modified plant varieties is based almost exclusively on transgenesis, or introducing genes of interest from another variety or organism into the plant. Three main objectives are pursued by using this technology. First, it is expected to get varieties resistant to pests and diseases -for example, currently used and marketed maize varieties resistant to pests such as corn stalk borer. Secondly, use of transgenic plants is aimed at developing varieties with improved nutritional properties (eg, higher content of vitamins). Finally, transgenesis in plants is also studied as a means to develop plant varieties able to act as bio-factories and produce substances of medical, biomedical or industrial interest in quantities easy to be isolated and purified.

See more on Agricutural biotechnology at:

a) http://pdf.usaid.gov/pdf_docs/Pnacn153.pdf
b) https://pdfs.semanticscholar.org/664b/d7ad053069c4e2903a9159f09ffade01f30b.pdf

Blue biotechnology/Sea

Blue biotechnology is based on the exploitation of sea resources to create products and applications of industrial interest. Taking into account that the sea presents the greatest biodiversity, there is potentially a huge range of sectors to benefit from the use of this kind of biotechnology. Many products and applications from blue biotechnology are still object of study and research, although some of them are actually used on a daily basis.

- No doubt using raw materials from the sea represents the most widespread blue biotechnology in many different sectors. These materials, mostly hydrocolloids and gellings are already being widely used in food, health, treatment, etc. Medicine and research are other major beneficiaries of development in blue biotechnology. Some marker molecules from marine organisms are now commonly used in research. Enzymatically active molecules useful in diagnostics and research have also been isolated from marine organisms. Some biomaterials and pharmacological or regeneratively active agents are being produced or investigated for their use in these sectors. Finally, sectors such as agriculture and cosmetics analyze the potential of blue biotechnology for its future development.

See more on Sea biotechnology at:

a) http://nopr.niscair.res.in/bitstream/123456789/7759/1/IJBT%205%283%29%20263-268.pdf
b) https://bionine.files.wordpress.com/2014/08/v-blue-biotechnology.pdf

CONCLUSION

Biotechnology as "the use of living systems and organisms to develop or make products, or any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use" has developed new tools and products by Which are useful in research, agriculture, industry and clinic. However there are four main societal concerns in the biotechnology field:

1. **Harm to the environment** - This concern is perhaps the most widely cited by those opposed to GMOs. It is very difficult to predict what will happen in an ecosystem where a new organism has been introduced, whether genetically modified or not.
2. **Bioterrorism** - Governments are worried that terrorists will use biotechnology to create new Superbugs, infectious viruses, or toxins, for which we have no cures.
3. **Laboratory/production sa**fety - It's hard to protect oneself if you don't know what you're working with. Some new technologies, usually nonbiologicals such as nanoparticles make commercial production lines before they have been sufficiently tested for safety. There is also concern about technician safety in laboratories, even under secured conditions, when working with organisms of unknown virulence.
4. **Ethical issues** - Besides the age-old debate over whether cloning genes is sacrilegious, innumerable ethical questions arise over the appropriateness of licensing genetic inventions and other IP issues. In addition, the construction of genes from scratch (the first artificial gene was actually synthesized in 1970) means we might someday be able to create life from a chemical soup which will most certainly go against the ethical or religious beliefs of a significant number of people.

Today there is a tendency to overestimate the problem of the fear of biotechnology (especially GM) and to ignore the appropriate counterfactual situation. In the area of food security: ***What would have been the magnitude of hunger and poverty without the yield increases of the Green Revolution and with the same population growth?***

All Biotechnologies do not mean GM…

Beyond GMOs, there are emerging new biotechnologies (Cisgenesis & Intragenesis, Synthetic Genomics, Genome editing, etc.)...

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