Food Security and Biotechnology in Africa

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

Module 6

TAILORING BIOTECHNOLOGIES: TOWARDS SOCIETAL RESPONSIBILITY AND COUNTRY SPECIFIC APPROACHES

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For detail see word document and supporting PDF materials

Course Structure

1 **Unit 1: Technology and innovation to the rise of biotechnology: 5 hours**

2 **Unit 2: Policy-making and communication: 3 hours**

3 **Unit 3: Value chain, agribusiness, local and global development: 3 hours**

4 **Unit 4: Stakeholder participation: 3 hours**

5 **Unit 5: Case studies of tailor-made biotechnology in specific countries: 6 hours**

The final version of this module is on February 28th, 2017

For detail see word document and supporting PDF materials

General Objective

The objective of this module is to allow students to understand how the innovation and policy making lead to tailor-made of both classic and modern versions of biotechnology to the needs and customs of specific countries. Tailoring biotechnology involves that stakeholders can use the tool within their own context and on their own conditions and have the opportunity to fulfil the required social, financial, ethical and other conditions for the implementation of the new technology.

Specific Objectives

- ❖ Find the multiple currently available technologies and innovation and how they contribute to the rise of biotechnology.
- ❖ Understand the role of poly-making and medias on adopting biotechnology
- ❖ Know how global and local value chain represent for local firms and suppliers in the countries to get access to larger markets and new technologies.
- ❖ The importance and the role of stakeholder perceptions, internalization and appropriation in the process of biotechnology for development.
- ❖ Discover current experience throughout case studies of African countries that apply GMO crops.

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6.1. Unit 1 .

Technology and innovation to the rise of biotechnology

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Objective of unit 1

The objective of this unit is to show how different Biology related technologies, innovation and the capacity to handle the processes have impacted the development of Biotechnology.

Multiple technologies

Process of adaption of new technology and societal issues

Literally Biotechnology is 'the study of tools from living things'.

Biotechnology is a multidisciplinary subject that brings together several aspects of biology, chemistry, biochemistry, physics, microbiology, engineering, computer science, etc.

Process of adoption of new technology and societal issues, ctn..

According to UN-Convention on Biological Diversity (Art. 2)

"Biotechnology is 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".

Modern biotechnology involves direct modification of the DNA (or RNA) molecules, which carry the genetic material of an organism, resulting in a genetically modified organism (GMO). **Except specified elsewhere, Biotechnology in this unit is referred to modern biotechnology.**

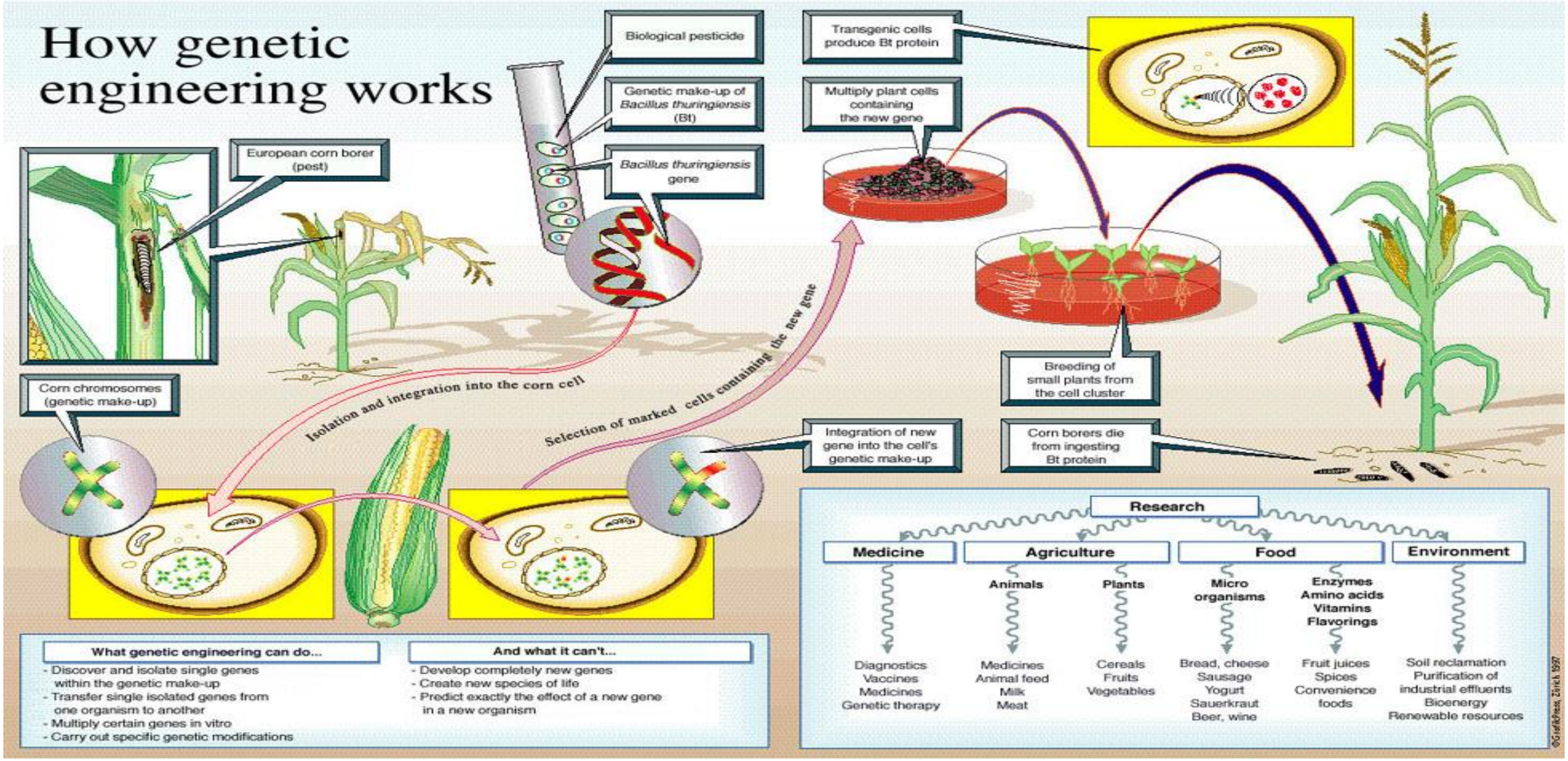
Process of adoption of new technology and societal issues, ctn..

Genetically engineered organisms (**GEO**) or Genetically Modified Organisms (**GMO**) are created by transferring genetic material from one organism to another through a process called genetic engineering (**GE**).

The transferred genes are called *cis* or *trans*-genes.

Biotech plants are known as transgenic plants or genetically modified (**GM**) crops. In some cases such as the *Bt* Cotton, these genes produce proteins that are responsible for the desirable characteristics of the GMO e.g. *Bt* genes produces Cry proteins which confer insect resistance.

Process of adoption of new technology and societal issues, ctn..



The GM crop involves the transfer of a gene from for instance the soil bacteria *Bacillus thurengiensis* into plant seed.

Process of adoption of new technology and societal issues, ctn..

Example of Modern Biotechnology laboratory

Process of adoption of new technology and societal issues, ctn..

Food biotechnology employs modern genetics to enhance beneficial traits of plants, animals and microorganisms for food processing.

The general public has a an interest in how biotechnology can increase **Food Security** while protecting the environment.

Process of adaption of new technology and societal issues, ctn..

Biotechnology may be adopted by human being. However, the adoption of biotechnology because of public concerns and societal issues has focused on both usefulness and ethical implications.

mouse with human ear!!!

is an

Ethical concern

Process of adoption of new technology societal issues, ctn..

In Africa biotechnology is primarily considered and used as an **exogenous instrument for the on-going modernization of agriculture and rural development**.

Farmers do not have a hand in the development of the technology. Nevertheless, biotechnology may have several potentials to raise agricultural systems in order to meet the needs for food for the growing African population.

Process of adoption of new technology and societal issues, ctn..

Biotechnology interest has increased for the following reasons:

- increase in world population and the need to ensure food and nutrition security;

- improvement nutritional quality of foods, especially vitamins (A), essential amino acids (Lysine, tryptophan, etc) and minerals (zinc, selenium, etc,);

- adverse global climatic changes accompanied by detrimental biotic and abiotic stresses to crops and ecosystems;

- human societies searching for novel, non-food plant products such as biomaterials, therapeutics, biofuels, etc.

Process of adaption of new technology and societal issues, ctn..

In Africa as well as other countries the issue of biotechnology is bi-polarized within people:

-**one pole perceives biotechnology as the source of solutions to many of the economic, social and environmental and food security problems that Africa is confronted. Example: Some cotton-breeders witnesses in Burkina Faso and South Africa.**

-**The other considers that the technology will bring more tertiary dependence, profit-driven effort regardless of the risk to human health, social equity or environmental quality. Example: some civil society movement in Burkina Faso and South Africa.**

Process of adoption of new technology and societal issues, ctn..

Controversies surrounding the development of biotechnology in Africa increased focus on industrial crops, perceived dependency syndrome on few multinational seed companies such as Monsanto, Bayer, etc.

However African Agriculture continues to be plagued with poor planting materials, crops with poor yield, nutritionally deficient, long gestation periods, low biotic and abiotic stress resistance, high post-harvest losses, poor distributive channels, etc.

Process of adaption of new technology and societal issues, ctn..

Nevertheless the situation can be improved through a tailored application of science and technology. Tailoring biotechnology implies that it should fit to the viewpoint and needs of stakeholders, e.g. from small farmers to policymakers.

Process of adoption of new technology and societal issues, ctn..

Nevertheless, general public needs to adopt the technology throughout equilibrated communication.

For instance even in USA where GM crops have been introduced since 1990, only 75% of the population is aware on the existence of GMO crops, while only 33% of consumers know that GMO foods are now in supermarkets without any labeling.

Biotechnology may be adopted positively if its impact is seen as that made by green revolution!!!!

What is **Green Revolution?**

Green Revolution: Impacts and limits in Africa

The Green Revolution (GR) to agricultural research and development occurred between the 1940s and 1980s. **It has increased agricultural production worldwide.** India was the first country which has experienced the benefit of GR by increasing its rice production.

This revolution has contributed to **Food Security** by the development of high-yielding varieties of cereal grains, expansion of irrigation infrastructure, modernization of management techniques, dispatching of hybridized seeds, synthetic fertilizers, and pesticides to farmers.

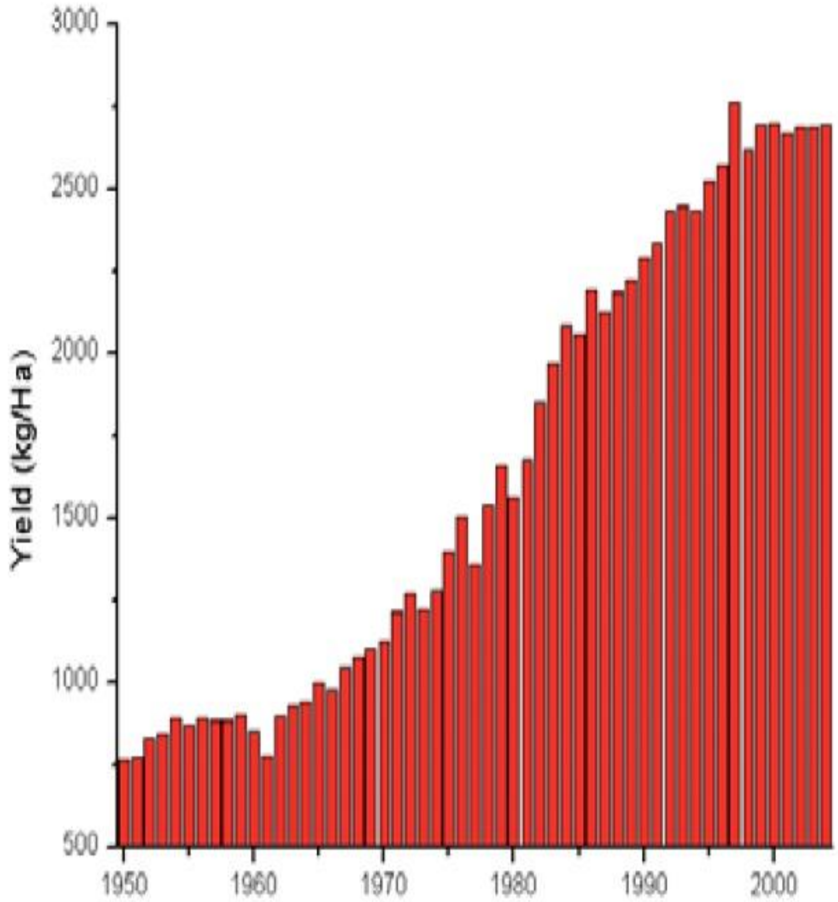
Green Revolution: Impacts and limits in Africa

Example of impact of GR on Agricultural Production

Commodity	Production in 1950 (Million tons)	Production in 2011 (Million tons)
Food grains	50.00	252.0
Vegetables	58.50 (91-92)	125.0
Fruits	28.60 (91-92)	63.6
Milk	17.00	104.8
Eggs	1.80	53.5 billions
Fish	0.75	7.3

4-27 times increase in production of various commodities

Green Revolution: Impacts and limits in Africa



Source: FAO

Wheat yields in developing countries, 1950-2004

Green Revolution: Impacts and limits in Africa

The GR experience in Asia has demonstrated that rapidly increasing agricultural productivity is possible in a relatively short time period. The Asian experience has also shown that such growth has to be supported by a combination of adequate public investments, promoting pro-rural policies and a bundle of measures that enable farmers to access modern inputs, agricultural extension services, financial services, and markets.

Green Revolution: Impacts and limits in Africa

Impact of GR for African Agriculture…

Before GR agricultural growth in Africa was driven by land expansion.

Since further expansion of cultivated agricultural land is reaching its limits the need for a shift towards productivity led agricultural growth becomes urgent in Africa.

That limits have urged governments to shift towards a GR type of productivity-led growth, using Asian, notably the Indian example.

Green Revolution: Impacts and limits in Africa

Impact on Productivity and Food Prices

For low income countries in general, the impact on the poverty headcount has been found to be larger from agricultural growth relative to equivalent growth in the non agriculture sector at a factor of 2.3 times.

For instance in India, it is estimated that a 1% increase in agricultural value added per hectare leads to a 0.4% reduction in poverty in the short run and 1.9% reduction in the long run.

Green Revolution: Impacts and limits in Africa

Impact on Productivity and Food Prices

Although it lagged behind in the GR period, Africa has witnessed positive growth in the post-GR period.

Adoption of improved varieties across sub-Saharan Africa reached 70% for wheat, 45% for maize, 26% for rice, 19% for cassava, and 15% for sorghum by 2005.

Widespread adoption of GR technologies led to a significant shift in the food supply function, contributing to a fall in real food prices. Between 1960 and 1990, food supply in Africa increased 12–13%.

Green Revolution: Impacts and limits in Africa

Impact on Productivity and Food Prices

In sub-Saharan Africa, agriculture's contribution to poverty reduction was estimated to be 4.25 times the contribution of equivalent investment in the service sector.

Because the GR strategy was based on intensification of favorable areas, its contribution to poverty reduction was relatively lower in the marginal production environments.

Green Revolution: Impacts and limits in Africa

Impact on Productivity and Food Prices

One of positive example of GR could be the program in western Africa is introducing a new high-yielding 'family' of rice varieties known as "New Rice for Africa" (**NERICA**).

NERICA varieties yield about 30% more rice under normal conditions, and can double yields with small amounts of fertilizer and very basic irrigation. However, the program met problems for getting easily the rice into the hands of farmers.

. Green Revolution: Impacts and limits in Africa

Limitations of GR

Poverty and Food Insecurity persisted despite the GR success.

In general, the poorest areas that relied on rain-fed agriculture were also the slowest to benefit from the GR, contributing to widening interregional disparities and an incidence of poverty that still remains high.

Green Revolution: Impacts and limits in Africa

Impact on Environment

GR had a controversial environmental impact.

GR driven intensification saved new land from conversion to agriculture, and allowed for the release of marginal lands out of agricultural production into providing alternative ecosystem services, such as the regeneration of forest cover.

However, intensive water use, soil degradation, and agrochemical runoff have had serious environmental impacts beyond the cultivated areas.

Limits of the introduction of hybrid varieties

Based on the early successes of GR for some cereals, the **Consultative Group on International Agricultural Research (CGIAR)** was established specifically to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring sustainable management of natural resources.

After CGIAR-generated knowledge, invention, and products (such as breeding lines) were made publicly available, national public and private sectors responded with investments for technology adaptation, dissemination, and delivery.

. Green Revolution: Impacts and limits in Africa

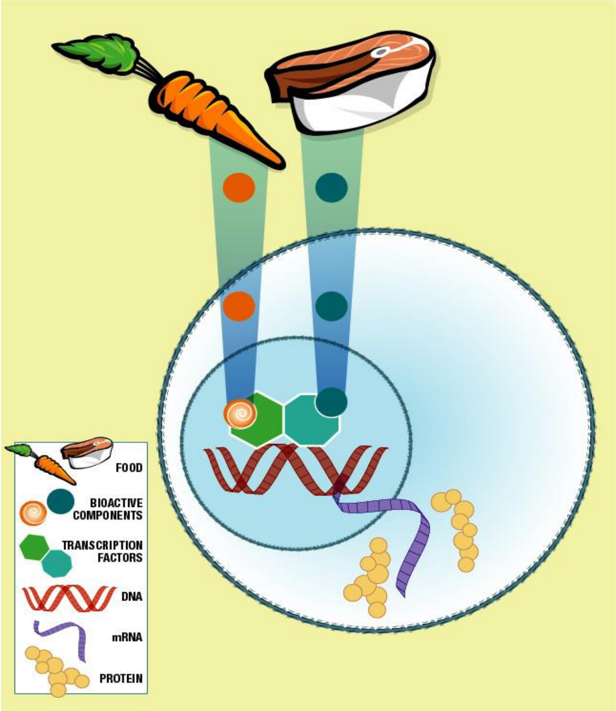
Limits of the introduction of hybrid varieties

Despite that success, in the post-GR period, the need for continued agricultural innovation and productivity growth is still remaining.

Sustaining productivity gains, enhancing smallholder competitiveness, and adapting to climate change are becoming increasingly urgent concerns across all production systems. **That has led to the introduction of new technology such as modern biotechnology with respect to genetically modified crops.**

Current biotechnological processes

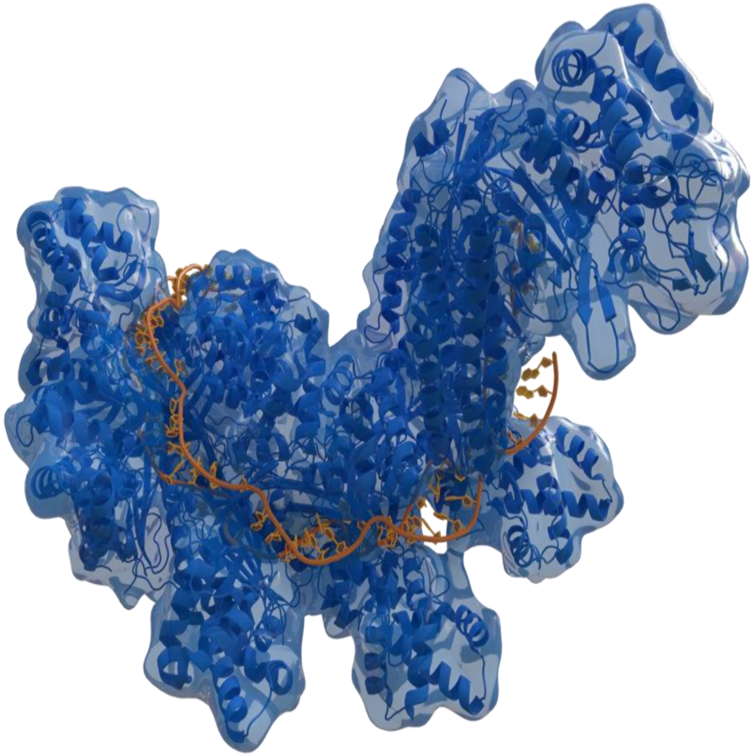
- culture of recombinant microorganisms,
- culture of cells of animals and plants;
- metabolic engineering;
- hybridoma technology;
- genetic engineering;
- transgenic animals and plants;
- tissue and organ engineering;
- protein engineering;
- bioseparations,
- Bbioreactor technologies,
- Omics (geno., transcripto., nutrogeno. etc.)
- CRISPR/cas9 technology,
- synthetic biology or xenobiology
- etc.



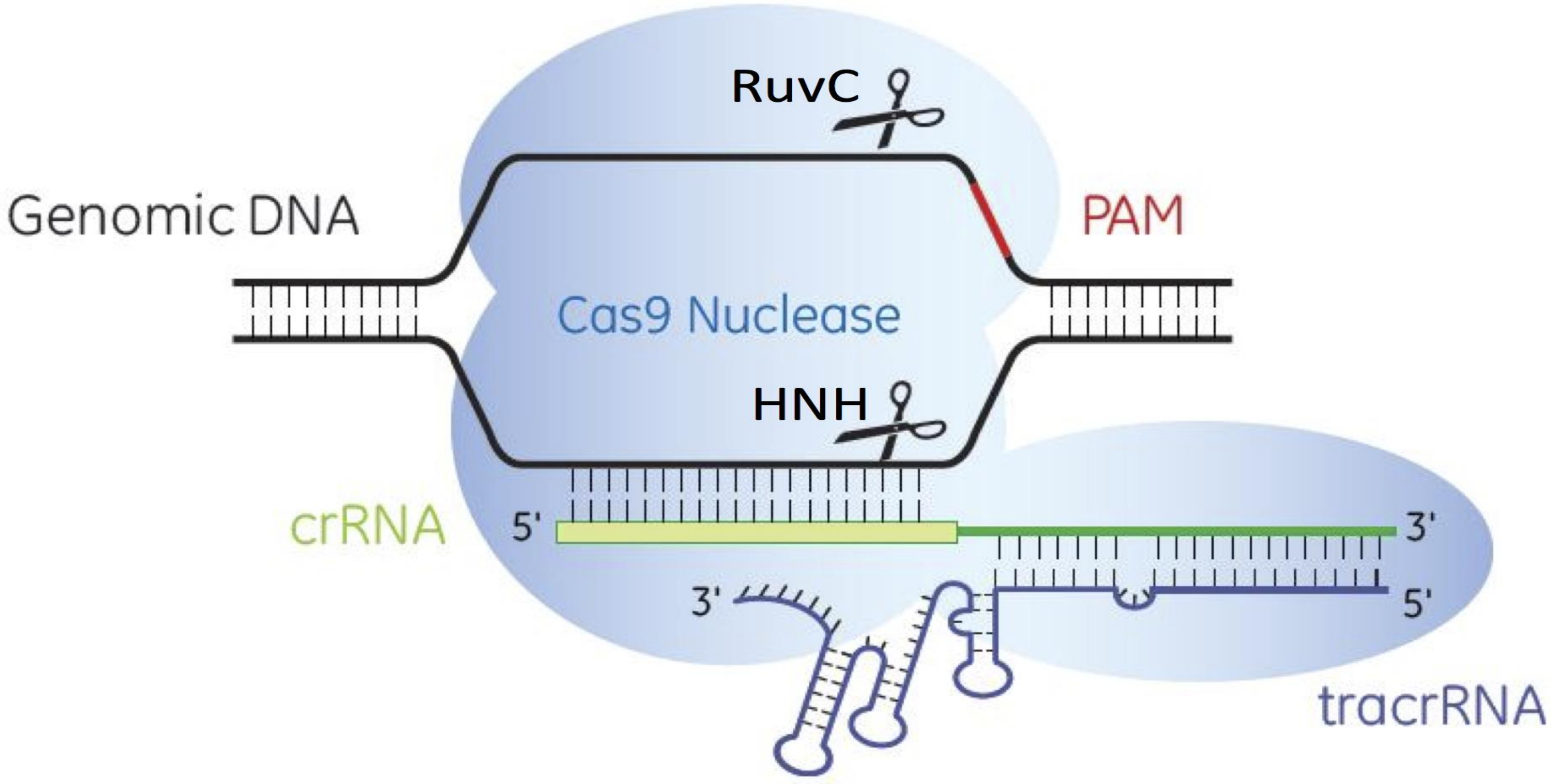
Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR).

CRISPR are segments of prokaryotic DNA containing short, repetitive base sequences. The CRISPR/Cas system is a prokaryotic immune system that confers resistance to foreign genetic elements such as those present within plasmids and phages that provides a form of acquired immunity. RNA harboring the spacer sequence helps Cas proteins recognize and cut exogenous DNA. Other RNA-guided Cas proteins cut foreign RNA. CRISPRs are found in several organisms.

The RNA-guided nuclease CRISPR-Cas9 has been modified to edit genomes. By delivering the **Cas9 nuclease (a restriction enzyme)** complexed with a synthetic guide RNA (gRNA) into a cell, the cell's genome can be cut at a desired location, allowing existing genes to be removed and/or new ones added. The Cas9-gRNA complex corresponds with the CAS III crRNA complex.



Cascade (CRISPR-associated complex for antiviral defense). Structure of crRNA-guided E. coli Cascade complex (Cas, blue) bound to single-stranded DNA (orange).



Mechanism of Cas9 catalysis. Cas9 is recruited to the DNA target site by the duplex tracrRNA:crRNA. The crRNA binds the complementary DNA strand upstream of the PAM sequence. Cas9 HNH and RuvC domains generate a DS break.

The CRISPR/Cas9 gene editing tool appears to work in nearly every organism, from *Caenorhabditis elegans* to monkeys, and in every cell type: kidney, heart, T-cells, etc.

Current biotechnological processes

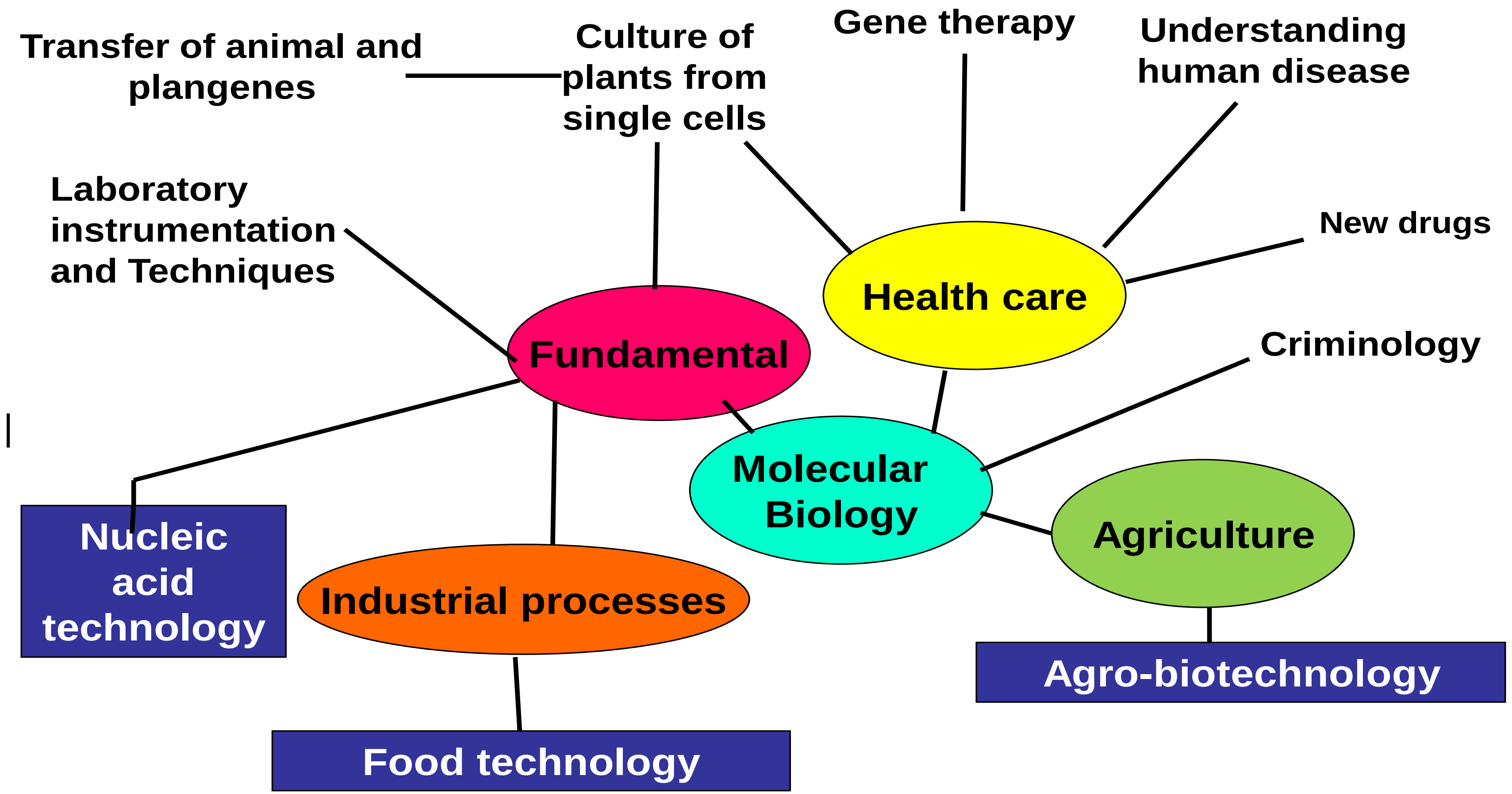
Synthetic biology aims to bring engineering practices common in other engineering disciplines to the field of molecular genetics and thus create a novel nanoscale computational substrate. **Synthetic Genomics** is a scientific field which aims to create unique life form. With broadening knowledges of genetics of bacteria it may be possible to create a unique form of life. It's proved by effort and results of many research laboratories. Their genome will be composed from a series of segments originated from different species or they will be completely new. Their potential is to become a component of future industrial world.

Current biotechnological processes

Expected applications of synthetic biology are:

- Autonomous biochemical sensors
- Biomaterial manufacturing
- Programmed therapeutics
- Smart agriculture
- Engineered experimental systems for biologists
- Diagnostic of disease, etc.
- Creation of new cell or even organism!!!

Overview of biotechnology processes



Current biotechnological processes

All most all biotechnological processes cited above are currently used to increase food and nutrition security.

Innovation techniques are daily invented to face new challenges.

What is Innovation?

Innovation is the mechanism by which individual or organization produce new ideas, products, processes and systems required for adapting to changing markets, technologies and modes of competition.

Innovative biotechnologists will be expected to make major contribution for food and nutrition security, while keeping the environment safe.

Biotechnologists may receive training in techniques that could greatly enhance their creative and innovative potential. Here, it is presented a range of approaches and strategies designed to promote creativity in bioscientists working in academic and industrial environments.

Innovations in Biotechnology
Current techniques

- **Effective brainstorming techniques**.
- **Checklists**
- **Lateral thinking**
- **Mind mapping**
- **Six hats**
- **Morphological analysis**
- **Internal mapping,** use of SWOT,
- **Triple Helix (THRIP),** etc,,

Innovations in Biotechnology
Current techniques

For instance the Triple Helix is one model that is internationally used to stimulate innovation.

The model represents interaction between university, industry and government, working together towards research focused on immediate implementation in industry.

In South Africa Triple Helix is driven under the name **THRIP**: The Technology and Human Resources for Industry Programme (THRIP).

It is an **INCUBATOR** where industry, government and universities are represented.

Integrated local innovations (learning motivation and innovation)

Local innovation and motivation in Biotechnology suppose a strong process of the transformation of agriculture, by appropriation and substitution.

The central question for innovation is whether and how Biotechnology as an exogenous instrument can be re-appropriated by local initiatives and become a catalyst for endogenous developments?

How the partners are aiming to reconnect agriculture to environment as well as to local food consumption by redesigning traditional and modern biotechnologies?

Integrated local innovations (learning motivation and innovation)

For the transformation of biotechnology, as an exogenous instrument into a catalyst for endogenous developments, it is crucial to create a new relationship between agriculture and its environment.

The development of **several purpose crop can** be done by integrating the local need of farmers.

Integrated local innovations (learning motivation and innovation)

For example, in India a dual purpose, early maturity sorghum variety (CSV 15) has been adopted.

The CSV 15 is illustrative of a social/technical ensemble approach, in which the variety itself catalyzes social changes.

It has enabled the farmers to plant chickpea almost one month earlier as a rotation crop, minimizing the incidence of wilt in chickpea and reducing usage of chemicals.

Evaluation of scientific data of GMO risks

The conclusion of the Cartagena Protocol on Biosafety (**CPB**) to the Convention on Biological Diversity (**CBD**) was a major point in the regulation of GM organisms particularly those destined for intentional environmental release.

The CPB has guided the development of biosafety laws, regulations and guidelines in many developing countries that are party to the Protocol. The Protocol is based on the precautionary approach.

However, different countries have interpreted and implemented this approach differently.

Evaluation of scientific data of GMO risks

Some countries such as Burkina Faso have taken precaution to be decision making based on scientific assessment and have consequently put in place regulatory measures based on risk assessment.

The establishment of functional biosafety regulations is moving slowly and arriving at concrete commercialization decisions remains on the whole difficult.

Evaluation of scientific data of GMO risks

As a result of these challenges, the New Partnership for Africa's Development (NEPAD)-African Biosafety Network of Expertise has been assisting African Union member countries to build functional biosafety systems that are flexible and responsive to the needs of African farmers while ensuring safety of this novel technology to the environment and human and animal health.

Discussion of unit 1

- What are new concepts or definition of biotechnology?
- What are the current principles of innovation techniques and which examples in biotechnology can be shown?
- Try to use the current innovation techniques to generate new idea on how biotechnology can improve food security in Africa.
- What is the impact of biotechnolgy in Africa to ensure food security?

Next Unit 2