Human health via plant health and quality

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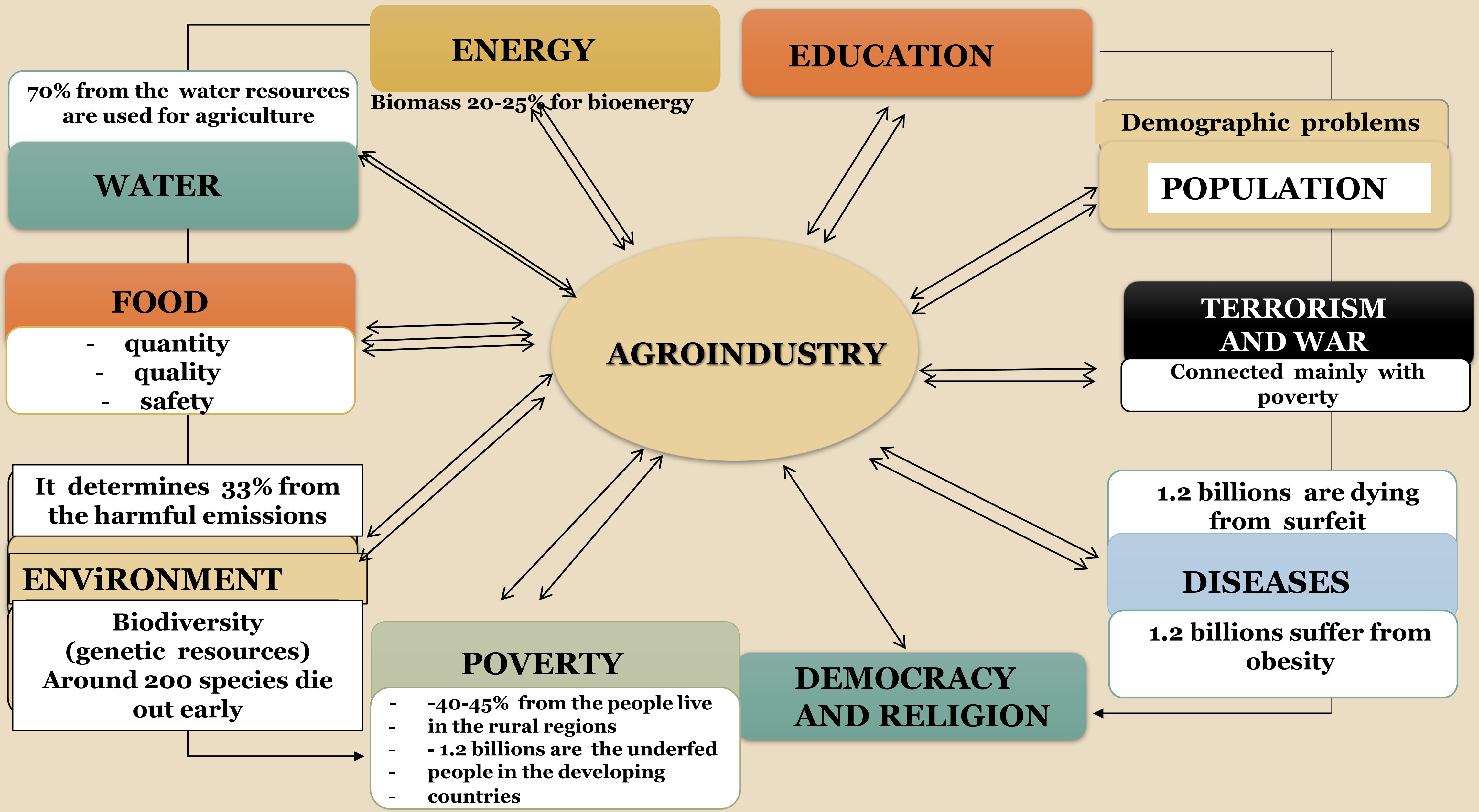
27th October 2021

Virtual event

THE TEN BIGGEST PROBLEMS FOR THE HUMANITY IN THE NEXT 50 YEARS



In 2050 we face

Modern agriculture

Twice less
- Arable land
- Labour (farmers)
- Water (70% for agriculture)

We need twice
- Grain
- Meat, milk, eggs, etc.
- Vegetables, fruits, etc.

New technologies

New management

Water availability

Climatic changes
(gas emissions,
contaminations, wastes)

Biodiversity
16 mln species exists
1 mln species are under extinction
Gene banks contain only 1% of them

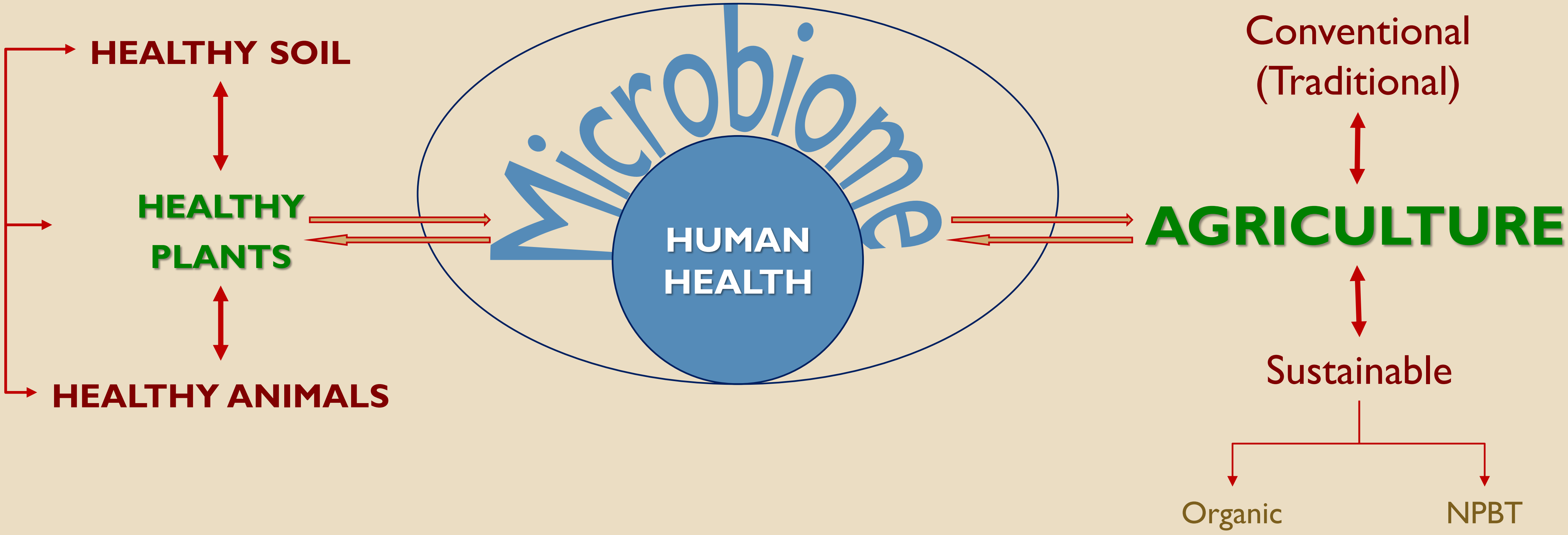
The origins of human nutrition

Plant sources	60 – 70 %
Animal sources	10 – 20 %
Aquacultures	5 – 8 %
Other (algae, insects, etc.)	1 – 2 %

The origins of animal nutrition

Plants are the primary source of nutrition for livestock

Basic factors determining human health

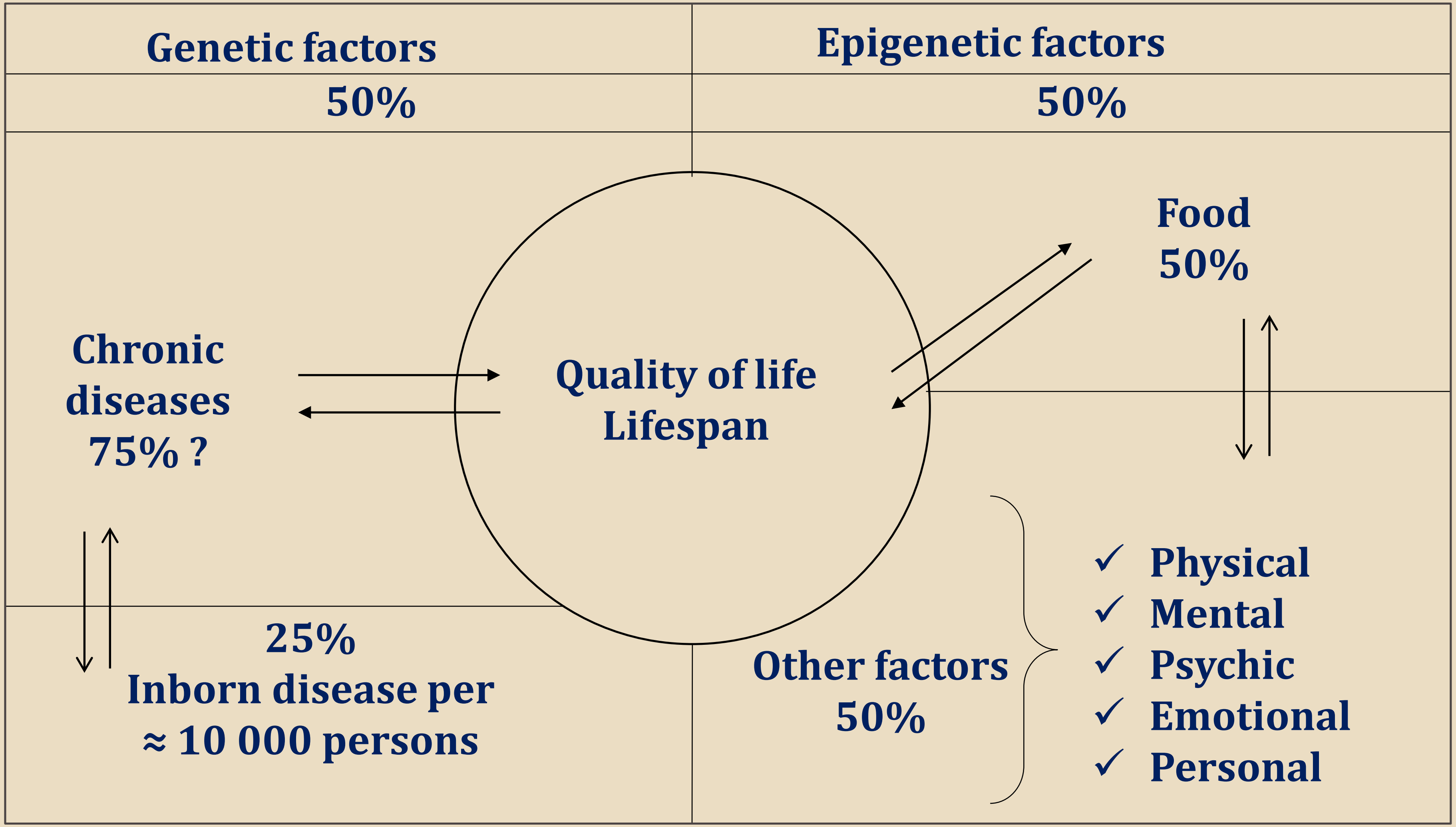


Some facts - future expectations …

- By **2050** the number of people over the **age 80** will **triple** globally.
- These **demographics** would come of great costs to individuals and economics if the number of not healthy people is bigger.

Biological agriculture - food and human health issues

GENETICS VS EPIGENETICS



Some facts - Food chain and human health (evolutionary relationships)

Micro-algaes (blue-green, etc.) absorb the broadest spectrum of solar energy and the photosynthesis and are the basis of the food chain (~ 80% of the biomass on Earth), produce the bulk of O_2 and thus provide development conditions for all others living organisms. They are completely autotrophic and do not need fertilizers, pesticides, etc.

↓

The impact of soil composition and soil fertility increases

The entire entropy is increased and energy is reduced. The harmful ingredients (pesticides, insecticides, herbicides, zoocides - more than 5000 types) pass along the chain and gradually accumulate in the next ones.

↓

Finally all this leads to an increase in diseases in animal species and humans.

Sustainable farming – there are no one solutions…

Plant health as a part of one's health

United Nations declared the year 2020 to be the international year of plant health (IYPH)

Plant health is vital to sustain human and animal health and is a **critical component** of the complex interactions among the environment, humans and animals

Case study theme	Plant health insult	Plant health impact	Public health impact
Food security Plant pathogens	Invasive bacteria; Xanthomonas caused wilting, fruit rotting and plant death in banana in East and Central Africa	Loss of staple crop Higher crop prices	Altered household eating practices, including decreased intake of staple crop, disproportionately affecting low-income communities
Food safety Mycotoxins	Mycotoxin produced by Aspergillus contaminated maize a mayor staple crop in Kenya	Ingestation of aflatoxin via homegrown maize and stored wet grains	Outbreak of acute liver disease, resulting in 317 cases incl. 125 deaths. Chronic exposure may lead to liver cancer and immune suppression.
Food safety Human pathogens	Romaine lettuce contaminated by E.coli during production in a single farm in USA	Ingestation of E.coli contaminated foods	Outbreak of E.coli O157:H7 resulting in 91 clinical illnesses and 35 hospitalizations in USA and Canada
Food security/safety Pesticide use	High levels of pesticide use in plant-based agriculture in Suriname	Dietary exposure to residual pesticides via produce	Chronic exposure may lead to depression and neuro-degenerative disease in adults, and neuro-developmental toxicity in children, disproportionately affecting non-urban less-educated communities

Plant Health – Problems & Solutions

- Traditional
- Organic
- GMO

AGRICULTURE

FORESTRY
FISHERIES
INSECTS

PROBLEMS:

- Water use
- Soil production?
- New varieties and breeds
- Microbiome
- Pollination efficiency
- Rotation efficiency
- Postharvest losses

SOLUTIONS:

- New agricultural products
- Irrigation efficiency
- Plant protection
- Fertilization efficiency
- Digitalization
- Robotization
- New plant breeding techniques;
- CRISPR/CAS9
- Underutilized crops
- Epigenetics
- Synthetic DNA

Less water, gas, emissions (CO_2, CH_4), energy, wastes

New agricultural practices – some examples

- Non-tillage
- Less ploughing
- Crop remnants
- Green fertilizers

Microbiome degradation of organic residue

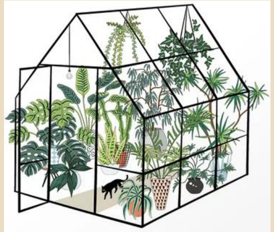
Targets for reduction of greenhouse gas emissions by 2050

2019

25 years < | >10 years

Land use
Peaty soils;
Farmland, forest
and nature

Livestock
Reduction
in methane
emissions



Greenhouse horticulture
energy saving

~5 Mt

~3.5 Mt

~1.5 Mt

~1 Mt

~1 Mt

New agricultural practices

Breathing out methane

Methane is very potent greenhouse gas – 25 times more than CO_2;

Cows are responsible for 65% of livestock farming gases;

Low-methane-cow design by:

- selecting microbiome producing least methane;
- introduction of microorganisms, that break down methane;

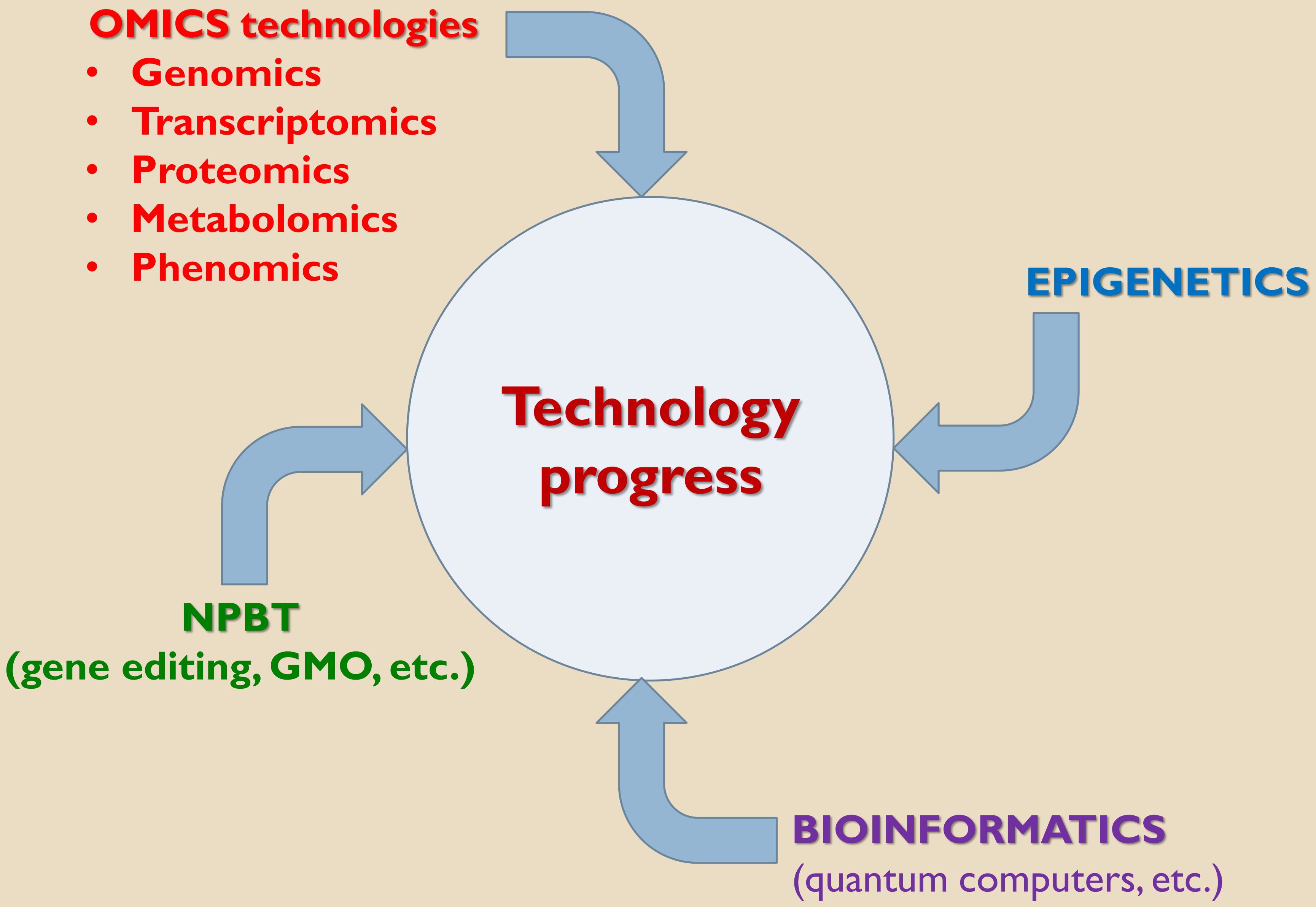
Can underutilized crops save the world

More than 6000 plan species can be consumed as a food source.

They have many characteristics that make them desirable for breeding

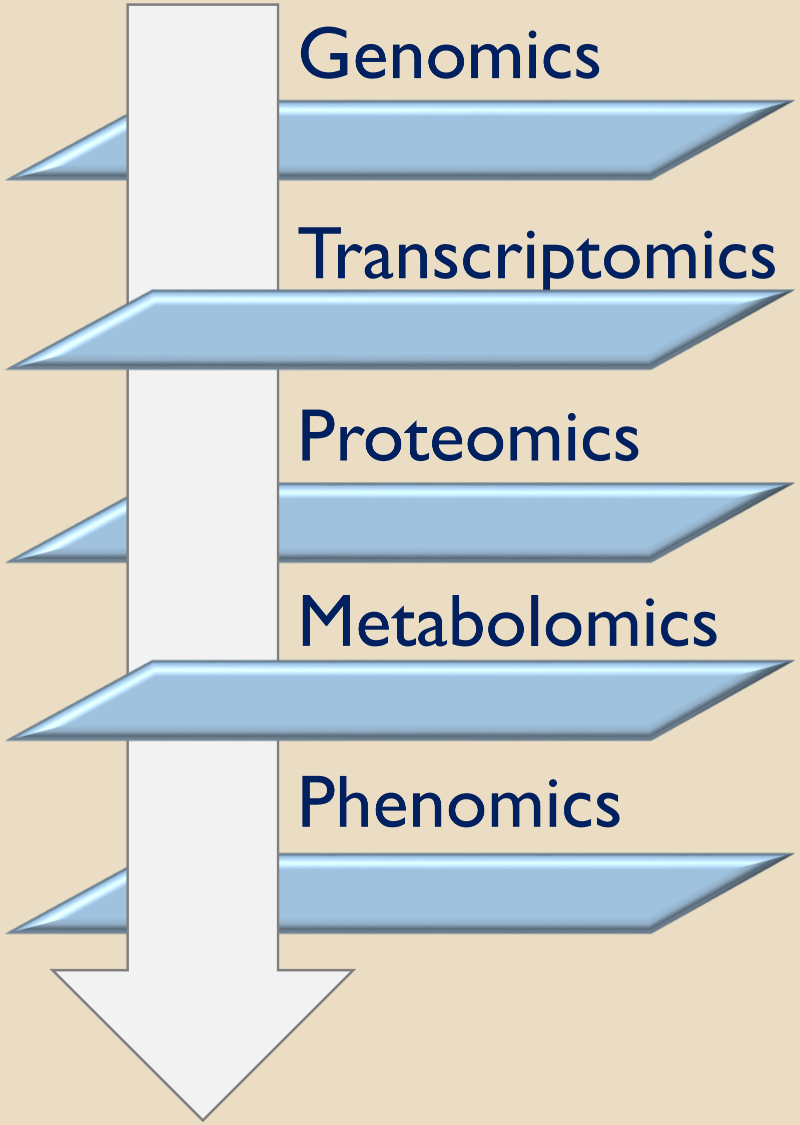
- Readily adapted to changing climate;
- Diverse nutritional composition;
- Improve soil fertility;
- Control diseases through crop rotation;
- Improve food sustainability;

Extremely important for small farmers – sorgo, topinambur, chia, tef etc.

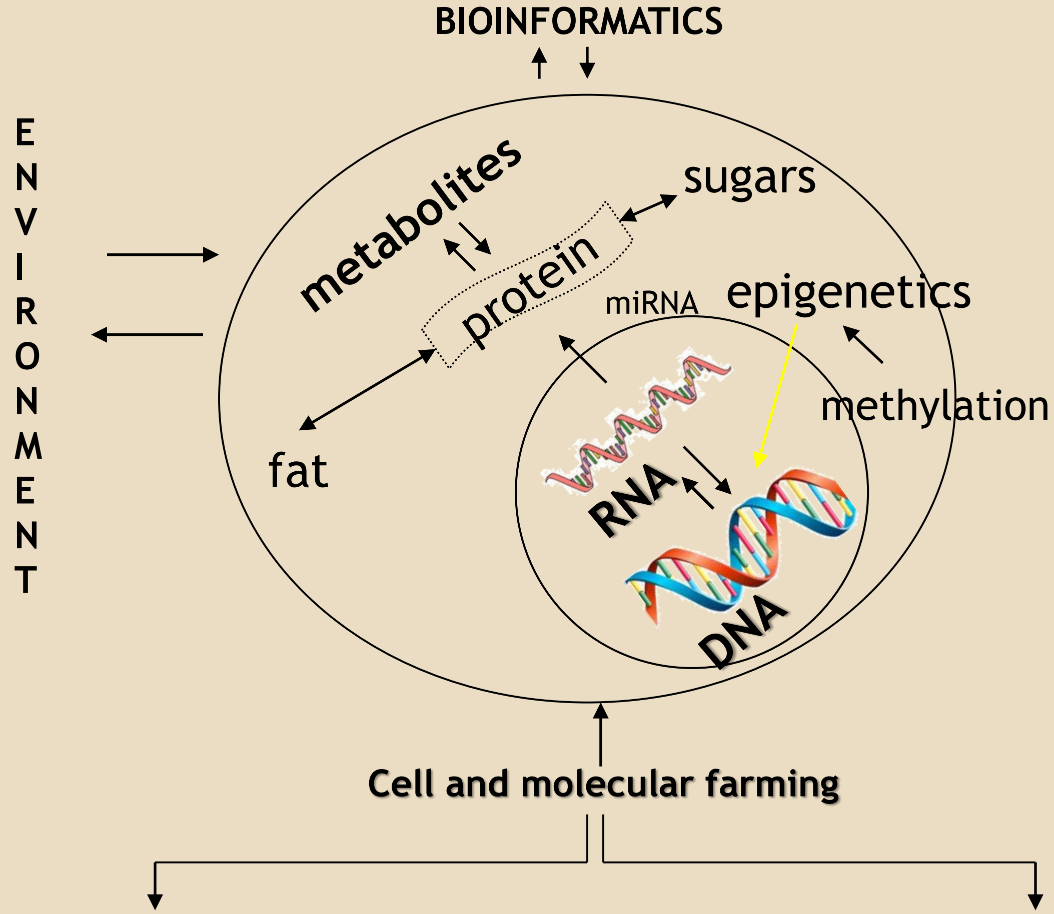

OMICS technologies
• Genomics
• Transcriptomics
• Proteomics
• Metabolomics
• Phenomics
EPIGENETICS
Technology progress
NPBT
(gene editing, GMO, etc.)
BIOINFORMATICS
(quantum computers, etc.)

The omics revolution

- Big data
- Digitizing agriculture
- Exploiting natural resources
- Counteracting climate change



What is GENOMICS (the common name of system biology approach)



DNA (Deoxyribonucleic acid)
The genes are in it - about 2-3% = 25-50 thousand
(<u>GENOMICS</u>)

↓↑

Protein
(<u>PROTEOMICS</u>)

↓↑

METABOLITES
(Secondary active compounds
~300 thousands)
- **phenols**
- **vitamins**
- **Alcaloids**
- **Otganic acids, etc.**

- Food and feed
- Medicines
- Textile and Garment
- Chemistry
    - Bio-energy
    - Bio-plastics
    - Bio-colouring agents, etc.

- How do genes, proteins, metabolites work
- Is there a difference between them in various organisms, what is their composition and structure
- How they interact
- What and how regulates them
- Why proteins and secondary metabolites are food and medicines, while DNA is not

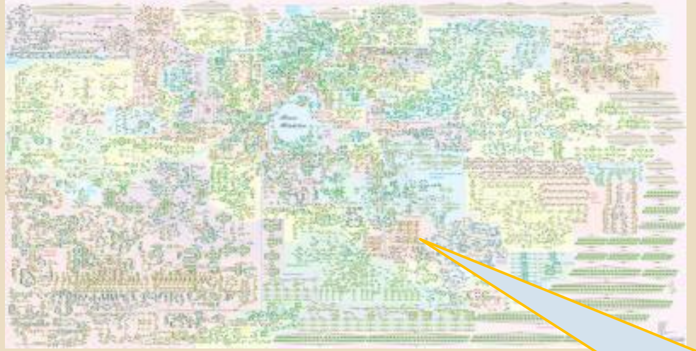
Metabolic profiling - a new and powerful tool in plant breeding

The amount and type of nutritional metabolites are strongly affected by genetic and environmental factors, which are major contributors to nutrient diversity.

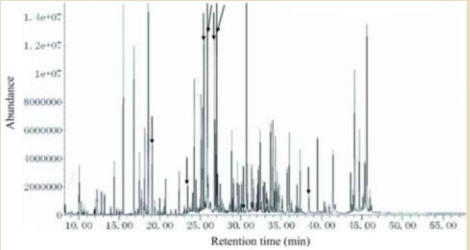
Both biotic and abiotic stresses induce the diversity of metabolites and also affect the nutritional quality of crops. Most metabolites such as sugars, organic acids, amino acids, vitamins, hormones, flavonoids, phenolics, and glucosinolates are essential for plant growth, development, stress adaptation, and defense, and the diversity of these metabolites also determines the nutritional quality, color, taste, and smell as well as antioxidative, anticarcinogenic, anti-inflammatory, antimicrobial, and cholesterol-lowering properties of food.

Taking advantage of high-throughput metabolic profiling and genome sequencing, a series of advances have been made in the structural identification, biochemical characterization, genetic basis of synthesis, localization, and health benefits of crop nutrient metabolites.

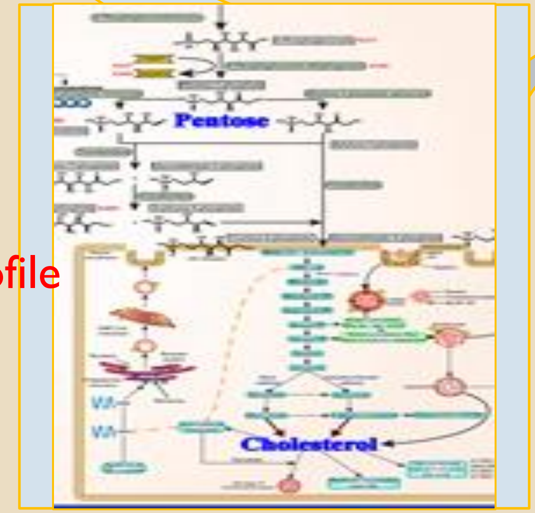
Metabolic profiling - a new and powerful tool in plant breeding



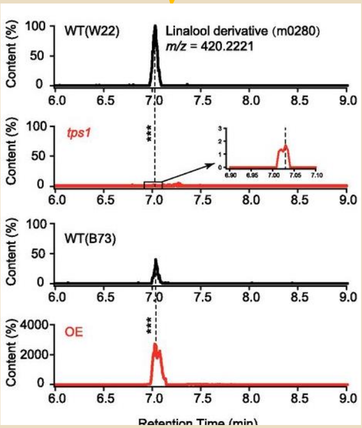
untargeted metabolic profile



targeted metabolic profile



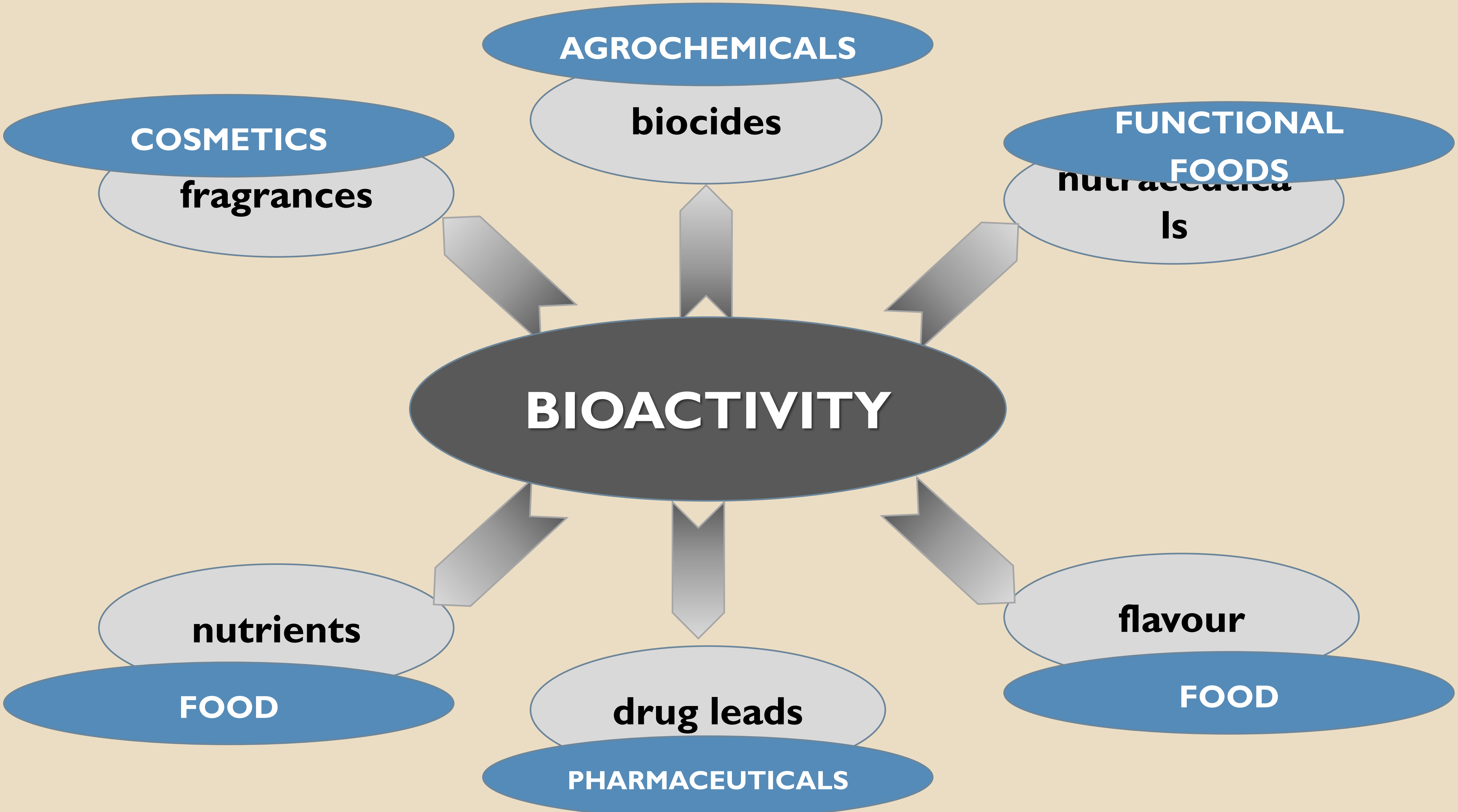
specific methods



- **Building a database:**
BASF has modified a model plant by knocking out each of the more than 30 000 genes and build a database with all resulting metabolic profiles;

- **Setting the benchmark:**
The platform is unparalleled in industry;

- **Measuring changes:**
Metabolic profiling is an analytical process that measures changes of 1000 important metabolites quickly and precisely;


AGROCHEMICALS
biocides
COSMETICS
fragrances
FUNCTIONAL FOODS
nutraceutica
ls
BIOACTIVITY
nutrients
FOOD
drug leads
PHARMACEUTICALS
flavour
FOOD

Water solutions for agriculture?

Strategic options

- Crops suitable to water availability (e. g. in areas with limited water supply replacement of rice with wheat, sorghum or maize with sorghum), adoption of cvs. more efficient in water use.

Agronomic options

- Effective weed control.
- Seeding and harvesting in optimal timing.
- Frequent irrigations in different growing phases, instead of few with high water volumes.
- Irrigations in the less hot hours of he day or at the base of the plants.
- Application of irrigation models.

Structural and technological options

- Establisment and recovery of natural and artificial reservoir.
- Recovery and reclamation of wastewater.
- Reductions of leaks in supply structures (e.g. ditches).
- Desalination.
- Installation of sensors.
- Construction of pumping systems.
- Sprinkling and drip irrigation instead of flood system irrigation

Crop pollination by insects

FAO had showed that global area of cultivated crops that requires pollination by bees or other insects, has been expanded by 137% while crop diversity had increased by just 20%.

This imbalance does not provide efficient nutrition for pollinators.

This work should sound as an alarm to policymakers.

Important solutions

Future (2018 – onwards):

- ✓ UHT sequencing & Big data & Virtual reality breeding toward simultaneous improvement of 100’s of genes;
- ✓ UHT mutagenesis (e.g. via gene editing) + Synthetic biology;
- ✓ All crops (field crops, vegetables, ornamentals, orphan crops, vegetatively propagated crops, new crops);

Next-generation sequencing

plant

U-HMV DNA isolation

sequencing

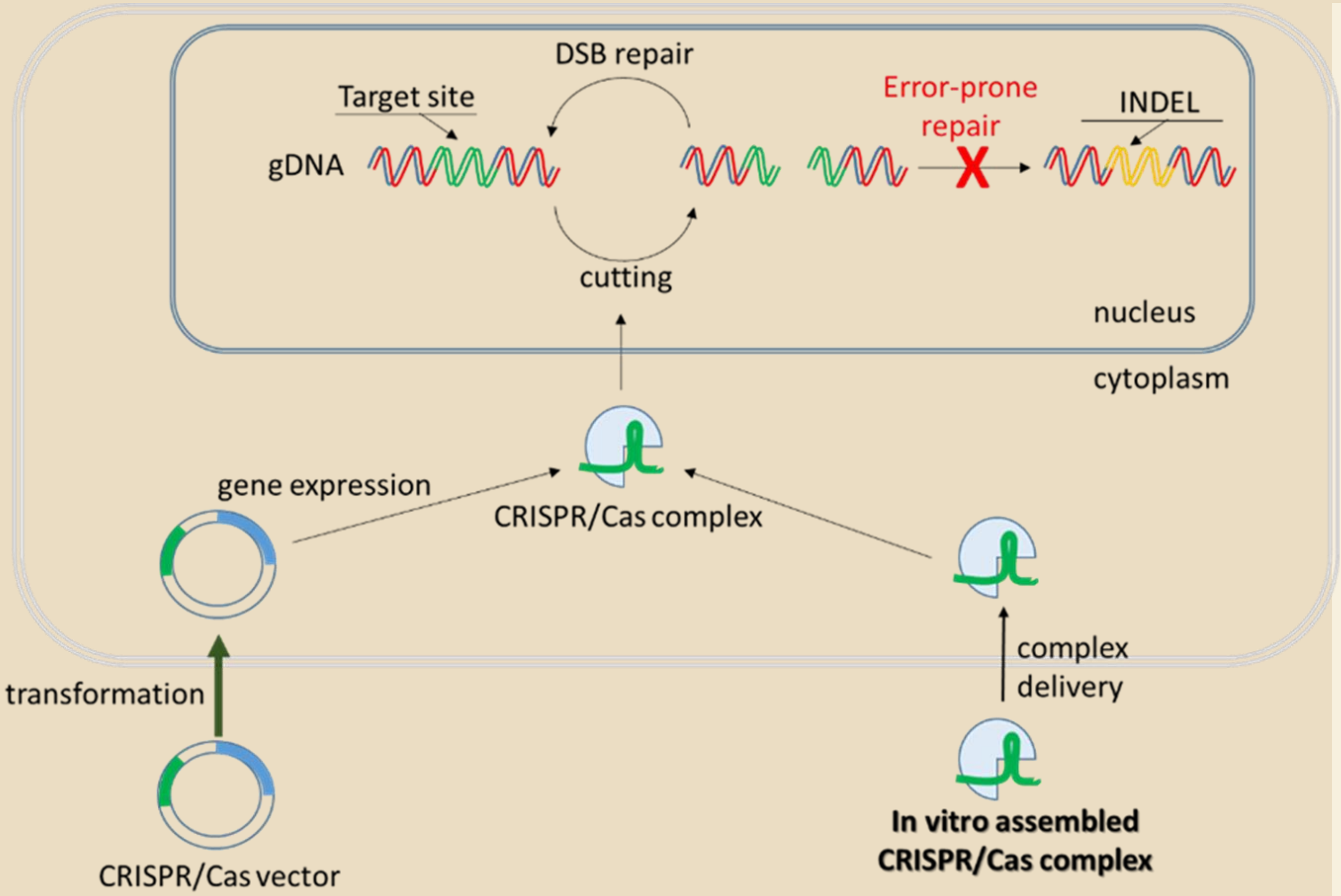
assembly

A perfect ref genome sequence

1000' genomes sequencing

Info in proprietary, interactive databases: CropPedia

Gene editing - CRISPR/Cas



CRISPR-Cas technology is based on elements of bacterial immune system that recognizes viruses attacking the bacterium and renders them harmless by cutting the virus DNA.

Scientists in labs have managed to reengineer CRISPR-Cas such that it can also make cuts in the genetic material of plants, for instance.

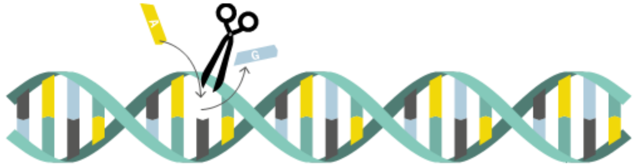
A CRISPR-Cas cut results in changes in genetic information.

Gene editing – CRISPR/Cas

GMO REGULATION

European legislation does not see conventionally mutated crops as an environmental risk. Because the technique has been in use since 1930, there is a lot of knowledge about its safety. Techniques such as CRISPR-Cas do not have that kind of track record yet, and therefore come under the strict GMO regulation.

The DNA of a tomato has one billion DNA letters. If you compare a modern tomato with a wild ancestor, 20 million DNA letters differ. Those differences came about through breeding and using radiation or chemical treatments: **mutagenesis** techniques.



CRISPR-Cas is a new technology for creating genetic variety. This precise gene-editing technology is used to cut through a DNA letter at a particular location. The technology is developing very fast. There are now variants that not only cut through the DNA, but also change DNA letters, from a C to a T, for example. This makes the outcome more predictable.

Cost of the modern varieties

Classic and GMO technologies:
The development of a variety, resistant to biotic or abiotic stress tok 13 years and cost ca. 130 million USD.
This financial burden could be carried by giants like Monsanto, Syngenta, DuPont…

New technologies i.e. CRISPR-Cas:
Genome editing and AI application makes the breeding affordable for small companies, institutes and universities. New technologies alse ease to some extent the market access.

The goal is to spent 5 USD and to see 15 USD in return…

Epigenetics

Profound understanding of the relationships between crop genotype and environment.

To evaluate the mechanisms that plants have developed to fight sudden changes in environment by epigenetic variations which:

- Modify plant gene regulation without changing DNA sequence, but in inheritable way;
- To expand epigenetic regulation such of DNA methylation , histone modification to the smallest player with big role – regulatory RNAs.

Microbiome, food and human health

plants & microbiome

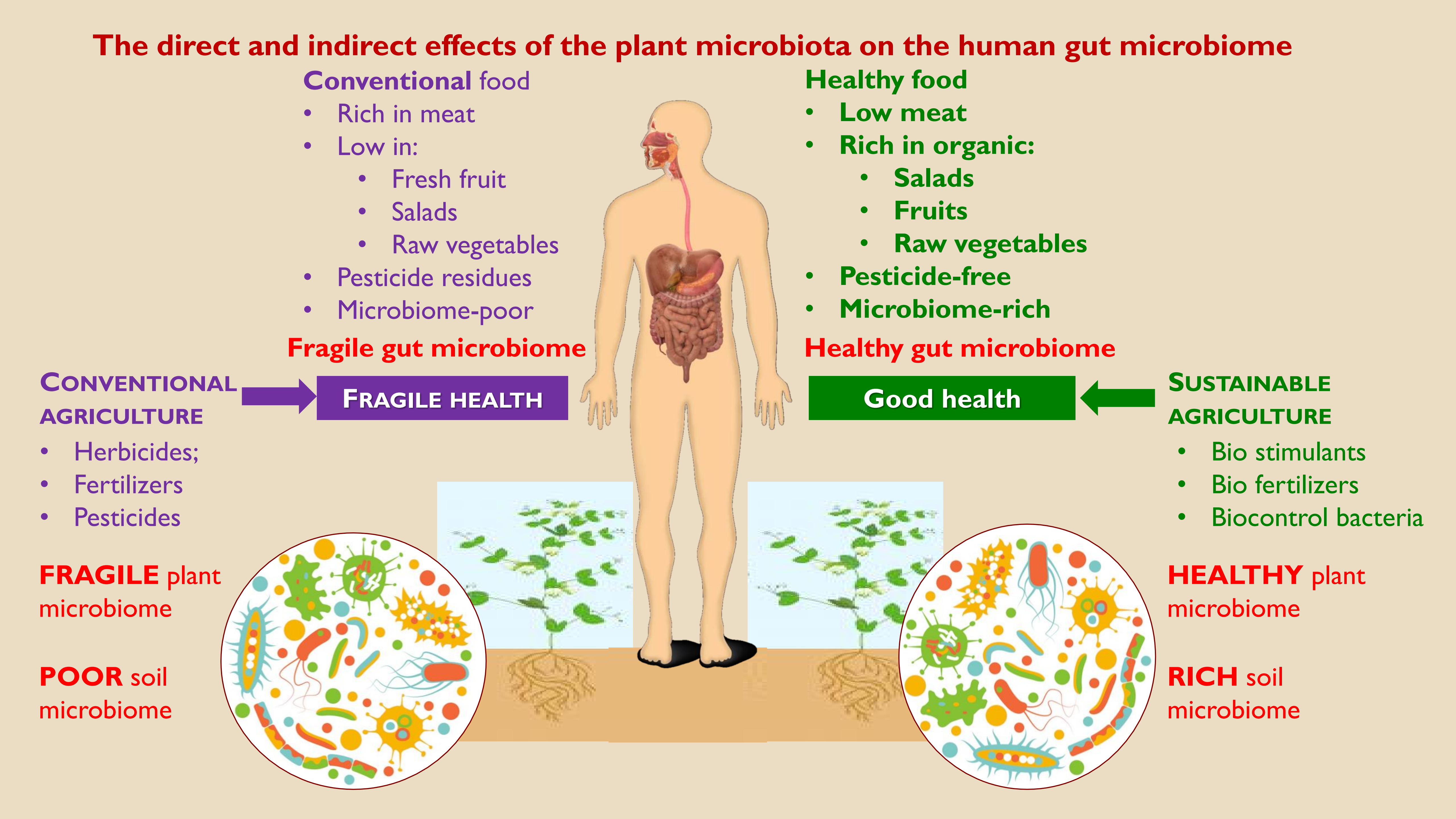
animals & microbiome

man & microbiome

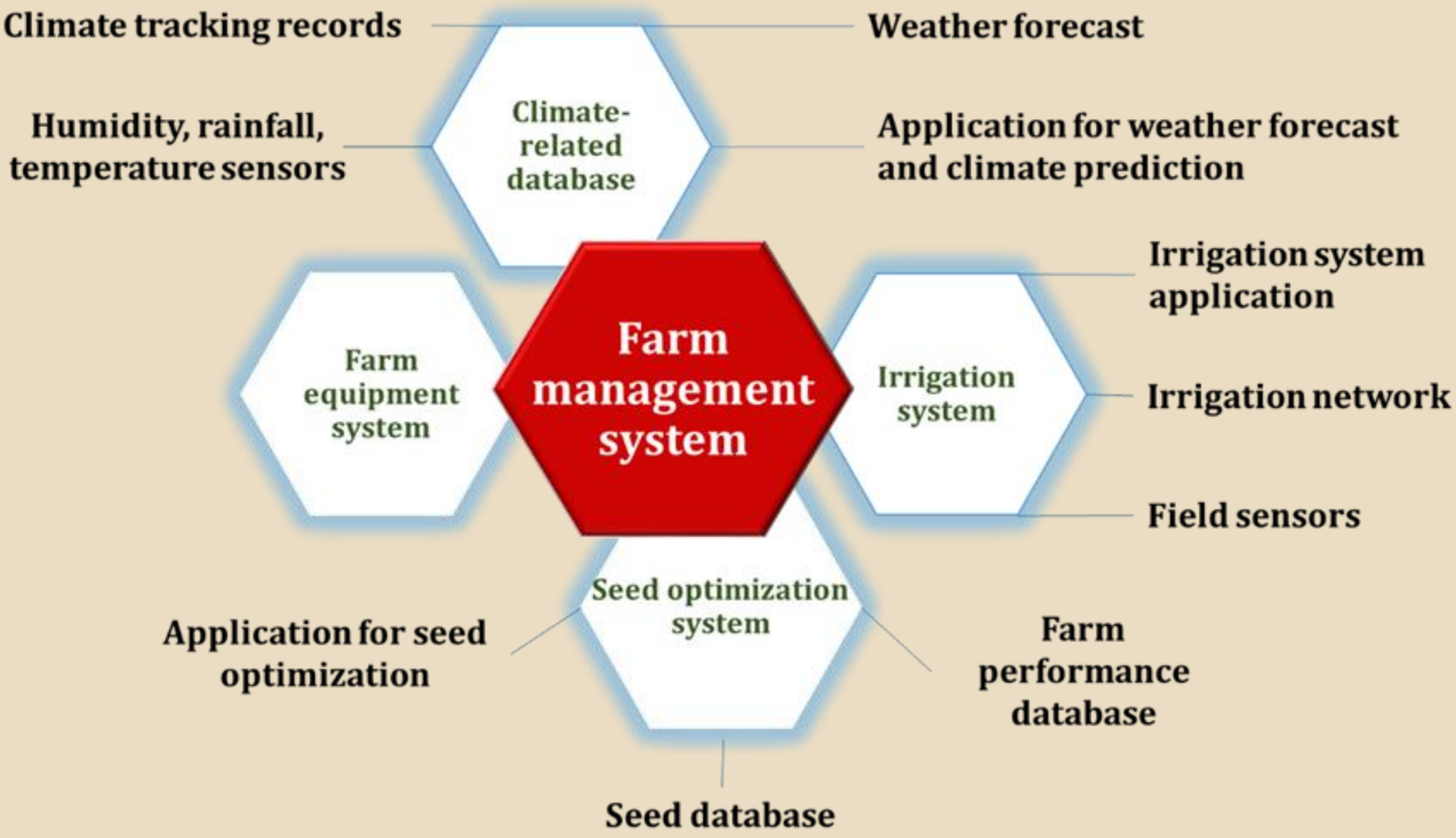
FOODS → **HEALTH**

Research on symbiosis mechanisms and synergistic effects

(fundamental to biological farming)


The direct and indirect effects of the plant microbiota on the human gut microbiome
Conventional food
• Rich in meat
• Low in:
• Fresh fruit
• Salads
• Raw vegetables
• Pesticide residues
• Microbiome-poor
Fragile gut microbiome
Healthy food
• Low meat
• Rich in organic:
• Salads
• Fruits
• Raw vegetables
• Pesticide-free
• Microbiome-rich
Healthy gut microbiome
CONVENTIONAL AGRICULTURE
• Herbicides;
• Fertilizers
• Pesticides
FRAGILE HEALTH
Good health
SUSTAINABLE AGRICULTURE
• Bio stimulants
• Bio fertilizers
• Biocontrol bacteria
FRAGILE plant microbiome
POOR soil microbiome
HEALTHY plant microbiome
RICH soil microbiome

Problem solution – precision farming



Harnessing the power of machine learning for breeding programs (computomics)

- Robotic agricultural systems are efficient and more sustainable
- Sensors for proper ripening status - Ripe for picking (harvesting) – work for pepper, tomato, etc.
- Eliminate enemies – multispectral sensors
- Silicon soil saviors – soil quality
- Animal trackers – health and welfare

Food additives
Pharmaceuticals & cosmetics
Composts, etc.

Essential oil plants (i.e. rose, lavender)

Output of biomass conversion

Vegetables & fruits (i.e. tomato, pepper, grape's skin and seeds)

Animals (i.e. sheep's wool)

Transforming to meatless future
(slowing global warming)

Why – the livestock (animal husbandry) is the most powerful source of methane – a gas with 80 times more powerful greenhouse effect that CO_2 (Nature 2021 506:461)

- Synthetic meat
- Plant-based meat
- Other meat sources (algae, insects, etc.)

An extraordinary revolution

Pharmaceutical companies today are spending decades and billions of dollars to discover molecules that affect us. But soon, quantum computers will allow us to model molecular interactions at a level like never before.

Google recently announced Bristlecome – the new quantum computer with 72 qbits. When upgraded to 300 qbuts, it will perform more calculations than there are atoms in the known universe.

Imagine an individual working on a quantum computer on the cloud who is able to look at the interaction of a particular molecule with all 20000 proteins, encoded in human genome. Drug discovery will go off the charts. This isn't happening 30 years from now, but in the next decade.

Thank you for attention