Crop Breeding technologies: - An overview

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teagasc
The Science of Farming and Food

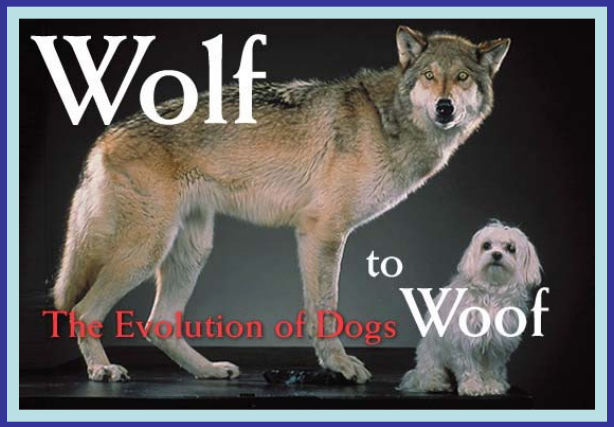
What is Biotechnology?

"The application of living organisms to develop new products"

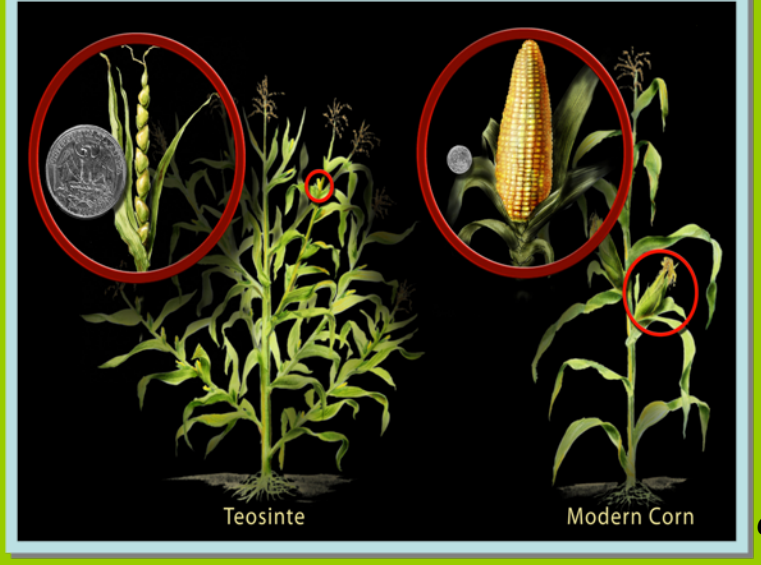
Crop Evolution and Human Civilization

- **Humans have always guided the evolution of crops**

- **A small sample of wild plants were chosen and domesticated**
- **10,000 years of *Selection*.**
- **All crops we grow today were once wild plants. But no crop would survive in the wild any more.**



- **Crops, strains and genes have moved around the globe.**



Courtesy: John Dobley, U Wisc.

Teosinte

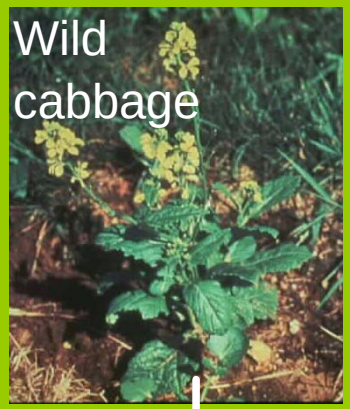
Maize

Slide courtesy *Wayne Parrott*, University of Georgia,

Slide courtesy *Wayne Parrott*, University of Georgia,

Carrot

Slide courtesy *Wayne Parrott*, University of Georgia,



Kohlrabi
Germany, 100 AD

Brussel sprouts
Belgium, 1700's

Many crops never existed in nature

Einkorn x wild wheat

Emmer x goat grass

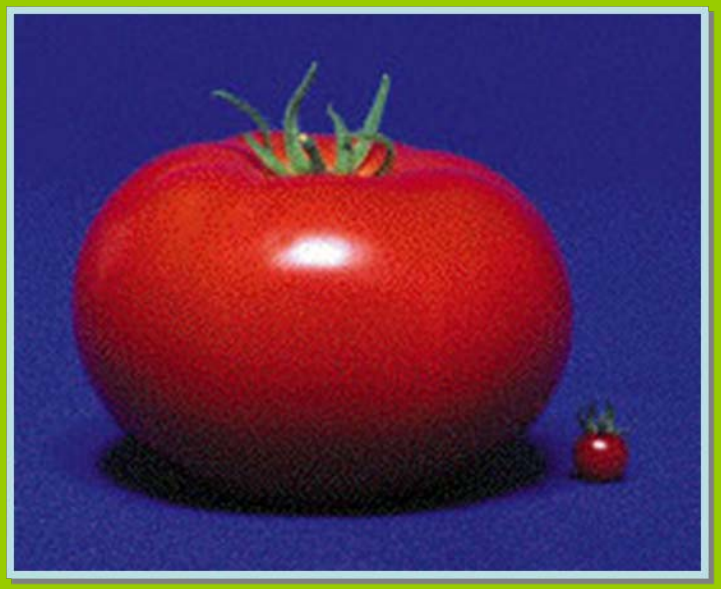
Bread wheat

www.mpiz-koeln.mpg.de/pr/garten/schau/Triticumaestivum/wheat.html

Improving Our Crop Plants

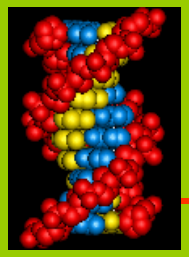
Developing Modern Varieties of Crops

- **Hybridization**
  - **Crosses with Wild Relatives**
  - **Hybrids**
- **Mutation**
  - **Irradiation**
  - **Chemicals**
- **Cell Culture**
  - **Embryo Rescue**
  - **Somaclonal variation**



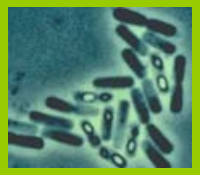
Biotechnology :
An ancient tale with hope for the future . . .

1973: Genetic Modification



1960: Crick & Watson

1865: Gregor Mendel



1861: Louis Pasteur

-4000 BC: Egyptians

2000+ A.D.

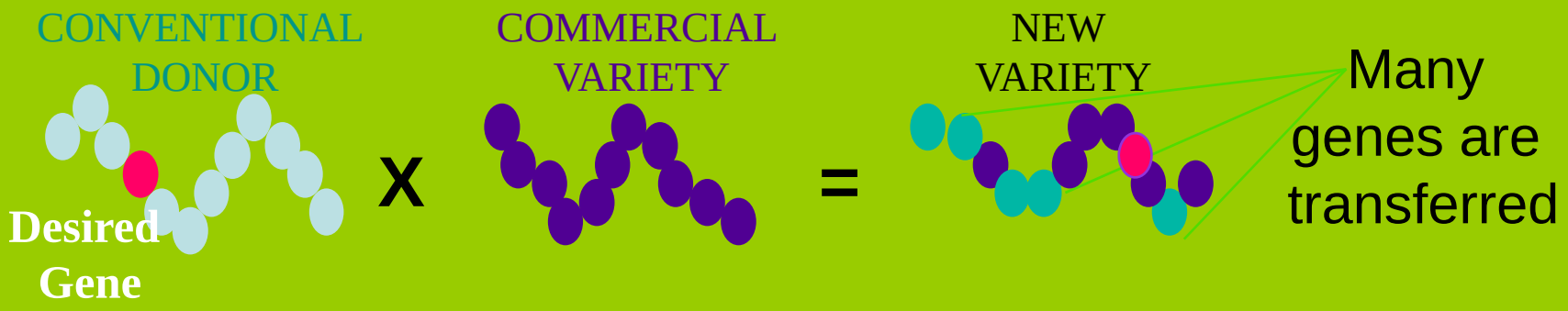
What are Genetically Modified Organisms (GMOs)?

GMOs are bacteria, viruses, fungi, plant & animal cells, plants & animals in which the genetic material has been altered in a way that does not occur naturally by mating or natural recombination

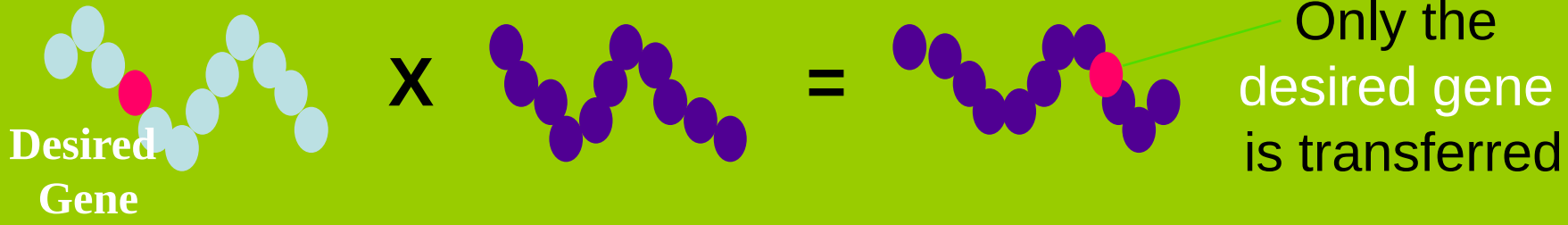
Gene Modification Affects Specific Genes

***Inserting one or few genes to achieve desired traits*.**

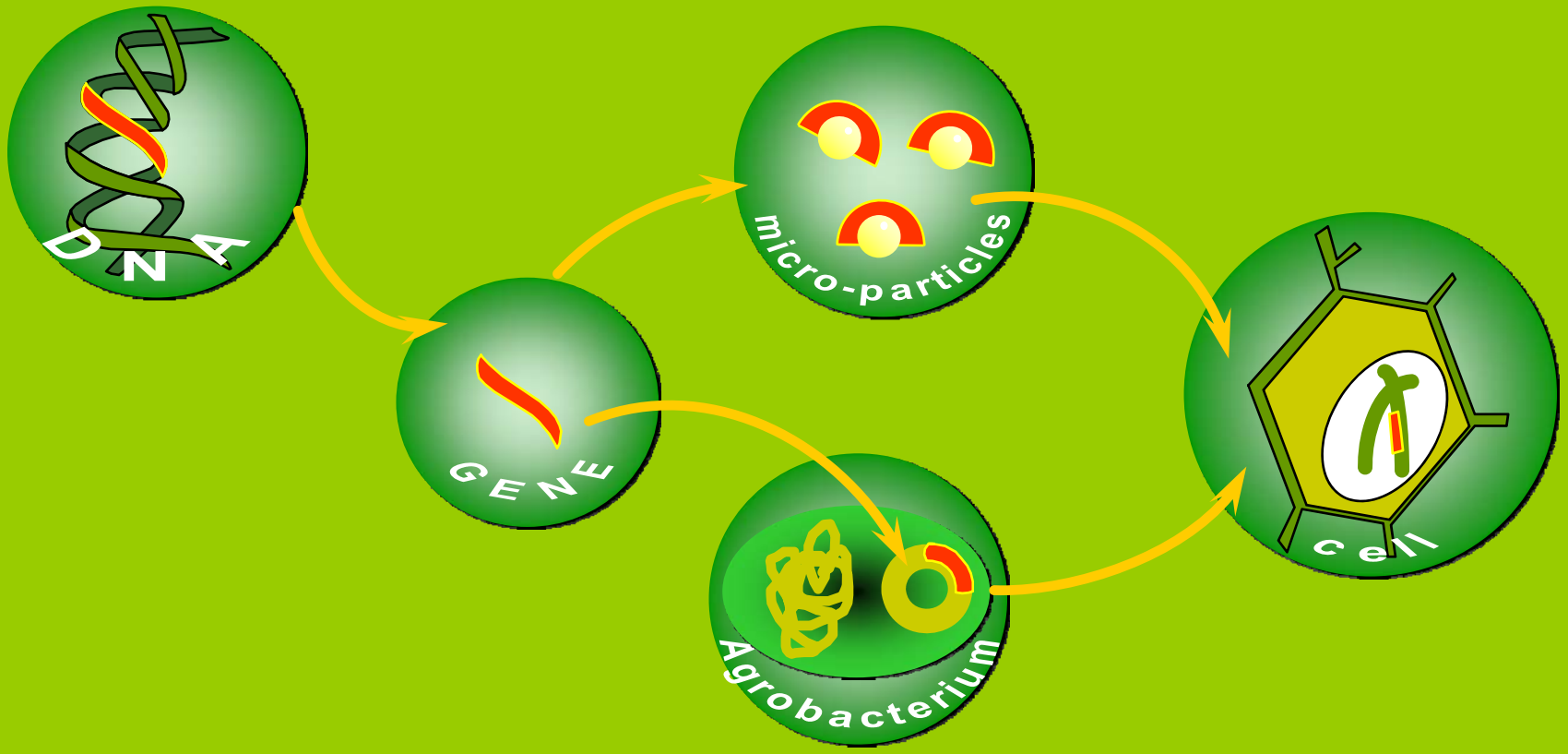
BREEDING



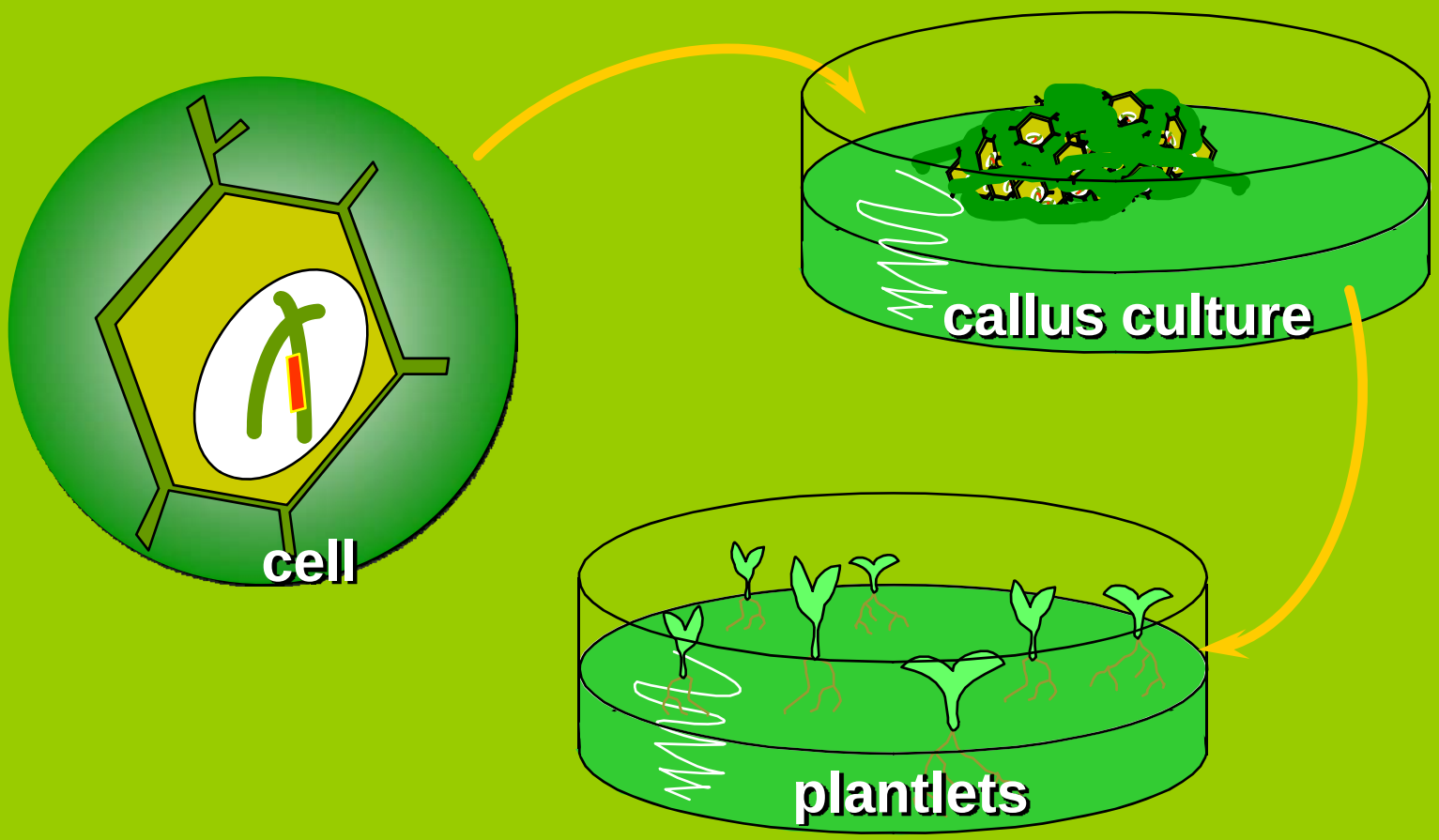
BIOTECHNOLOGY



Gene Transfer Technology



Modified Cell to Living Plant



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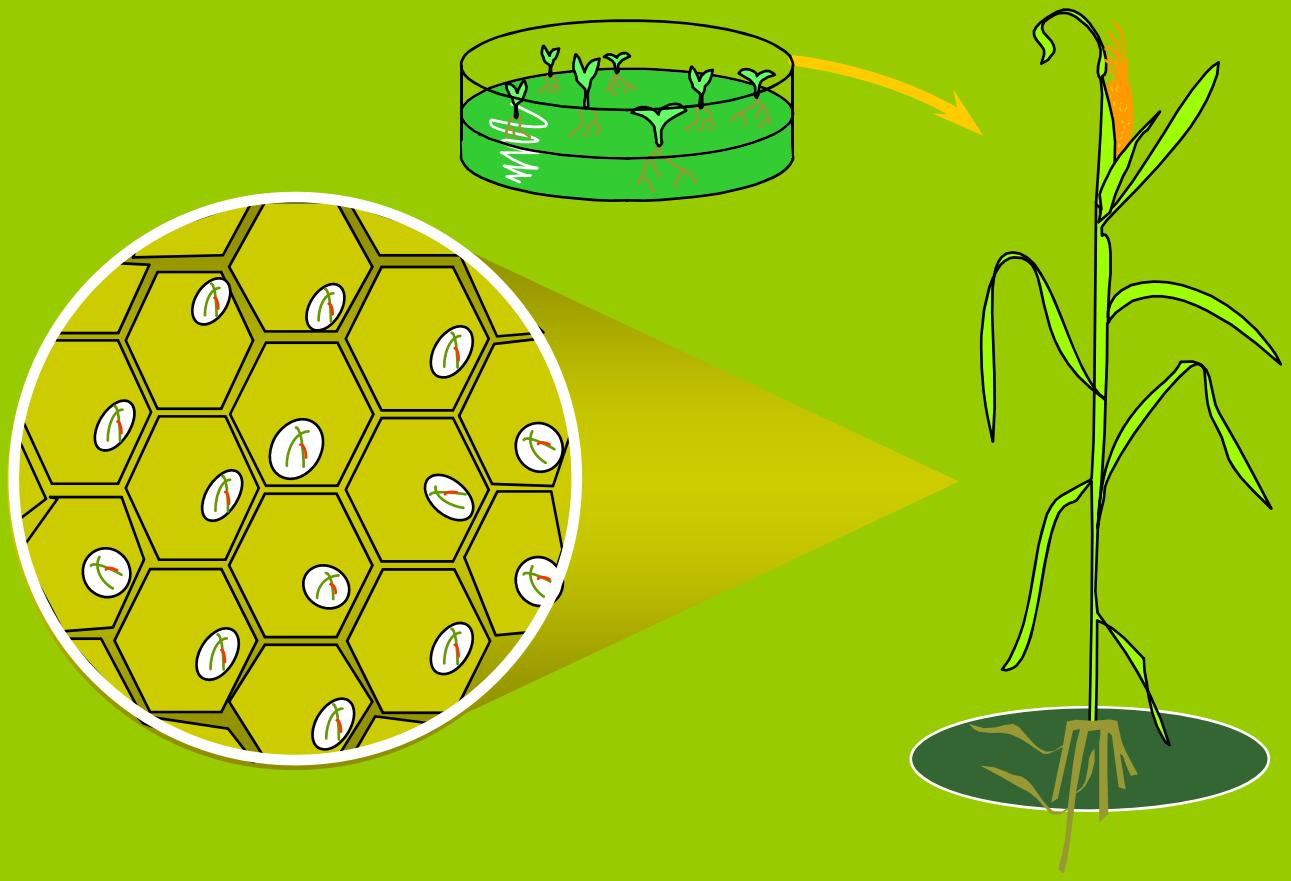


To Develop a New GM Plant ,

Researchers must :

- Identify and isolate a useful gene
- Introduce this gene into the plant
- Stabilise the expression of the gene
- Test the new variety in the field
- Meet government and administrative standards for health and environmental safety

10 years of research and development

Why we need new tools ?

Current technologies approaching limit of yield improvement

Limited natural resource base of land, soil, water, fossil fuels, etc.

Critical need for better ways to maximize production efficiency in more sustainable ways with reduced environmental impact

Exponential population growth over next 50 years will place serious pressure on global food prod.

Four categories of transgenic traits

Pest or herbicide resistance

Altered composition for specific end uses

Greater resource acquisition [e.g. nutrients, water]

Increased tolerance of abiotic stress (heat, drought, nutrients, toxicities, acidity, alkalinity, salinity, etc.)

Pest or herbicide resistance traits

- Requires management strategies that avoid resistance build up - similar to deployment options currently used for Bt and GHT crops, and conventional disease resistance

- At issue is whether existing management options are adequate

  - While Bt resistance seems to be in check, increasing numbers of glyphosate-tolerant weed species suggest improved deployment options are needed for widespread use of GHT crops

Compositional traits

Higher oil, protein, or starch

Requires management practices that optimize expression of desired trait and post-harvest handling for identity preservation

Transgenic high value oils, proteins, starches; secondary metabolic products

Greater resource acquisition traits

- Root-influenced traits
  - Water acquisition from deeper in the subsoil
    - Direct effect of genetic control of rooting depth
    - Indirect effect of soil acidity tolerance in subsoil
  - Uptake traits
    - Nitrogen
    - Phosphorus (proteoid roots, organic acid excretion)
    - Micronutrients
- Light
  - Canopy architecture (erect leaves)
  - Prostrate during early vegetative growth, erect once canopy closes

To move forward – key questions:

- **What we have learned from the past.**
- **What are our challenges and where opportunities lie.**
- **How we will develop a plan—the optimism of plant breeding.**

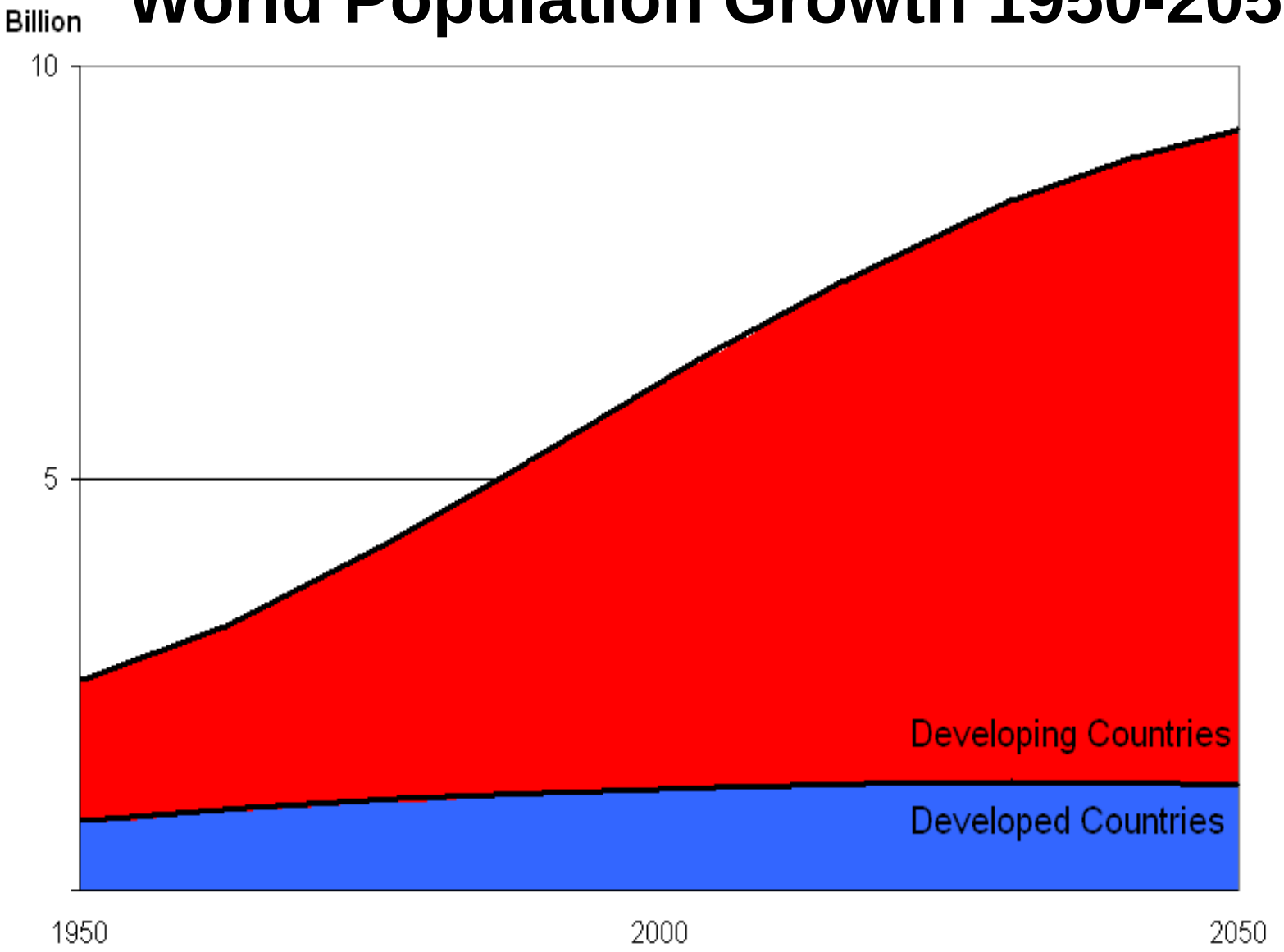
Let us take Wheat as an example.

What Are Our New Challenges?

- Population growth
- Increasing wealth
- Need for improved sustainability (fertilizer, irrigation, pesticides)
- Potentially a poorer growing season (Peng et al. 2004, 2010).

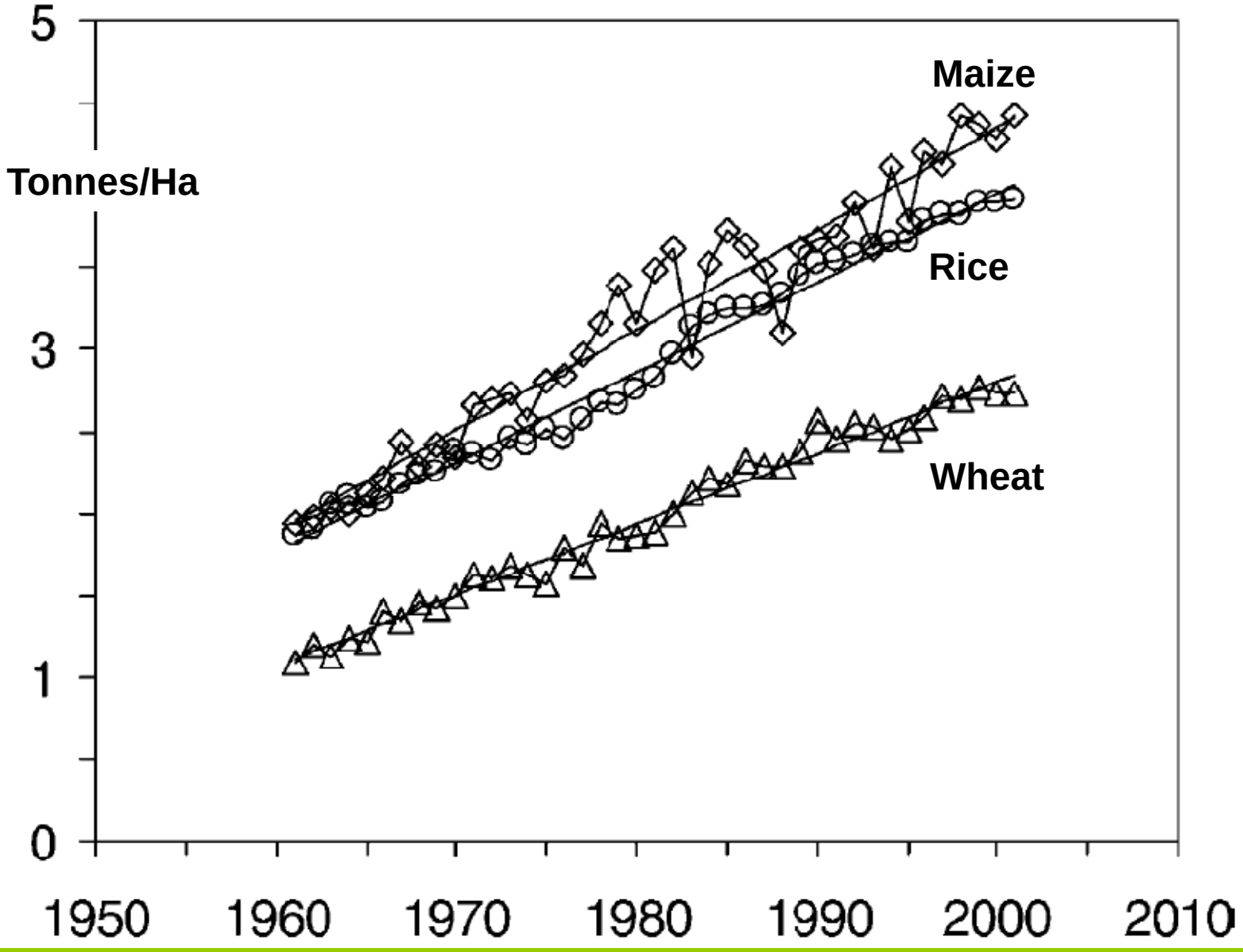
What can genetics and breeding bring to the table?

World Population Growth 1950-2050



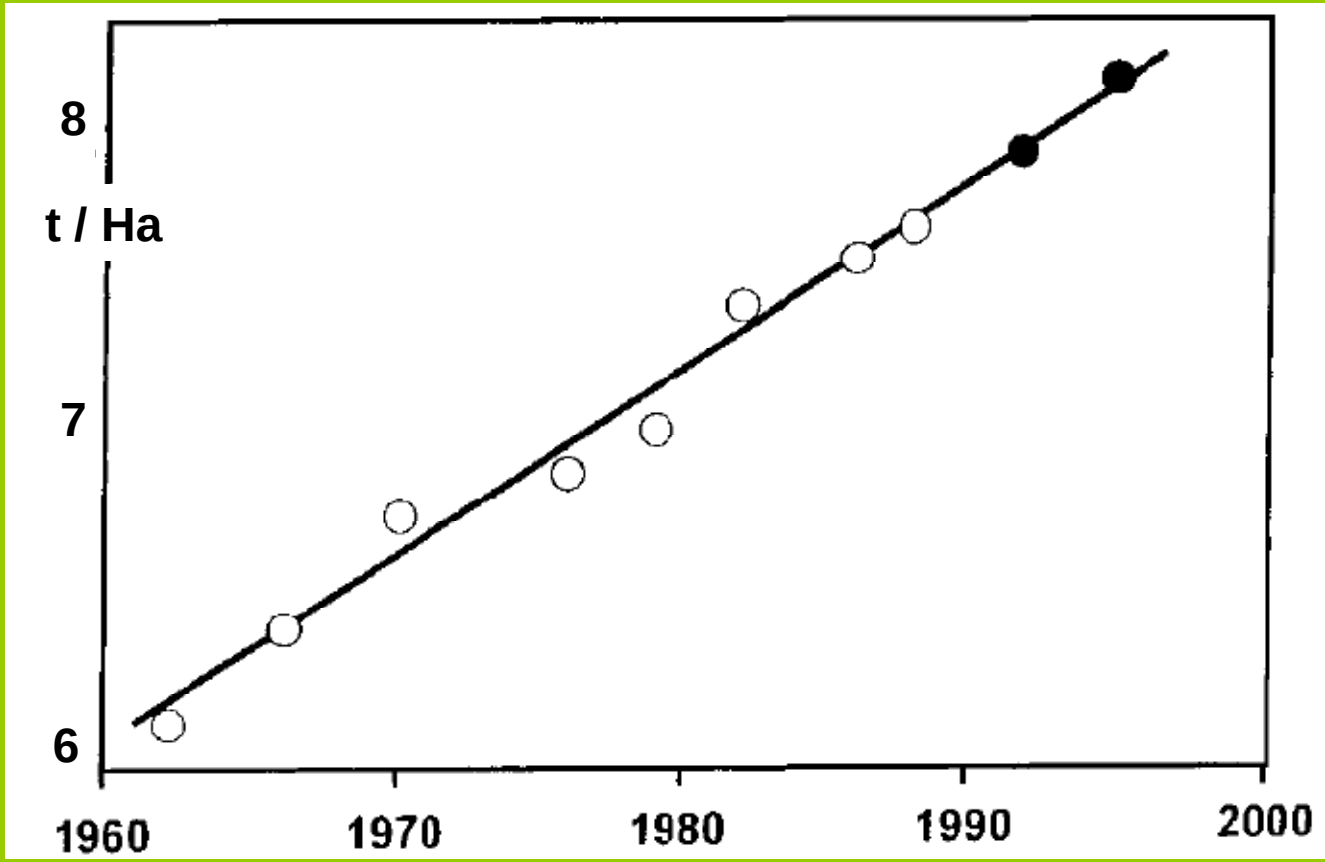
***Source: World Population Prospects, United Nations Secretariat*, 2006**

World Cereal Yields



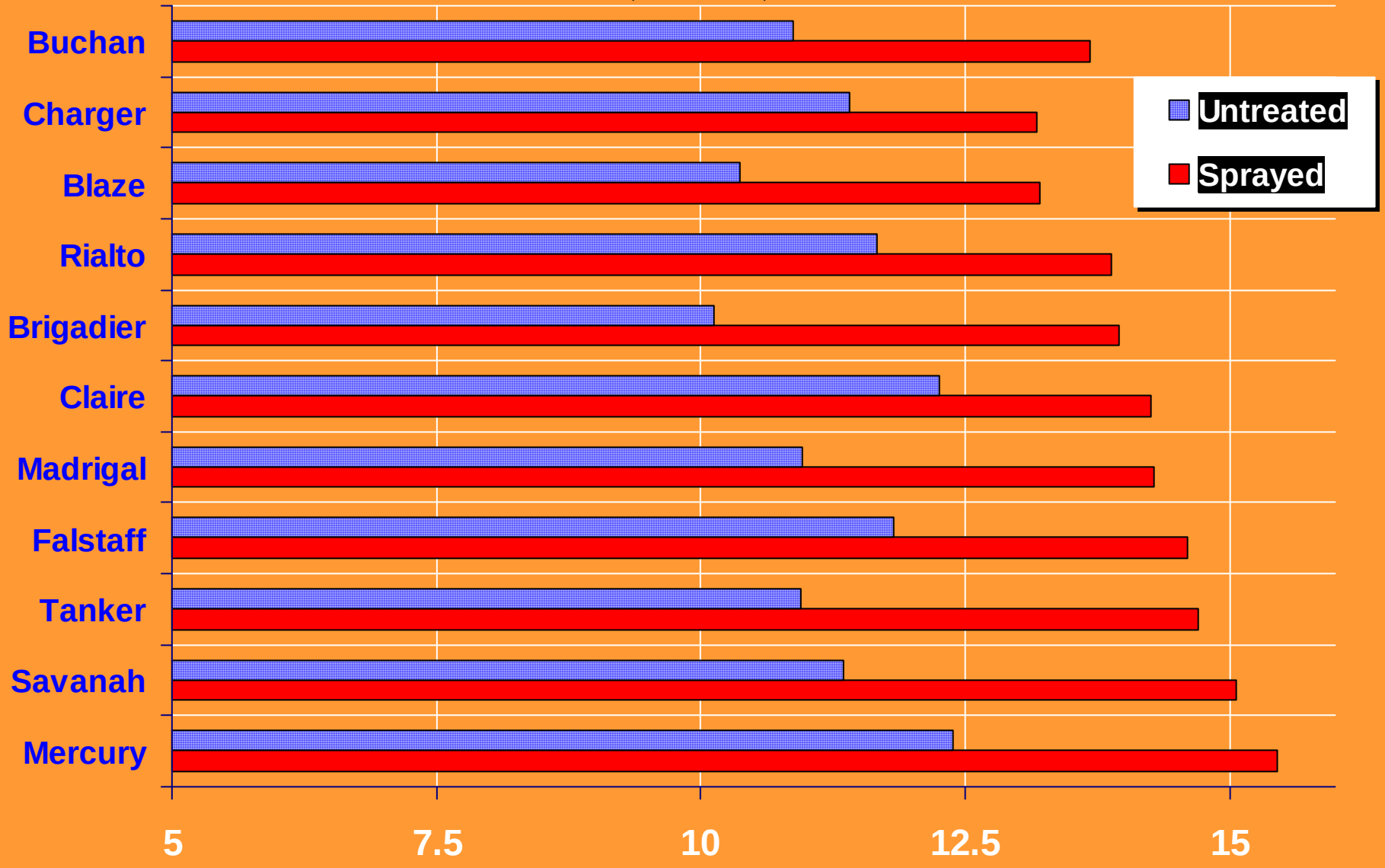
Source: Trends in maize, rice and wheat yields, Hafner, 2003

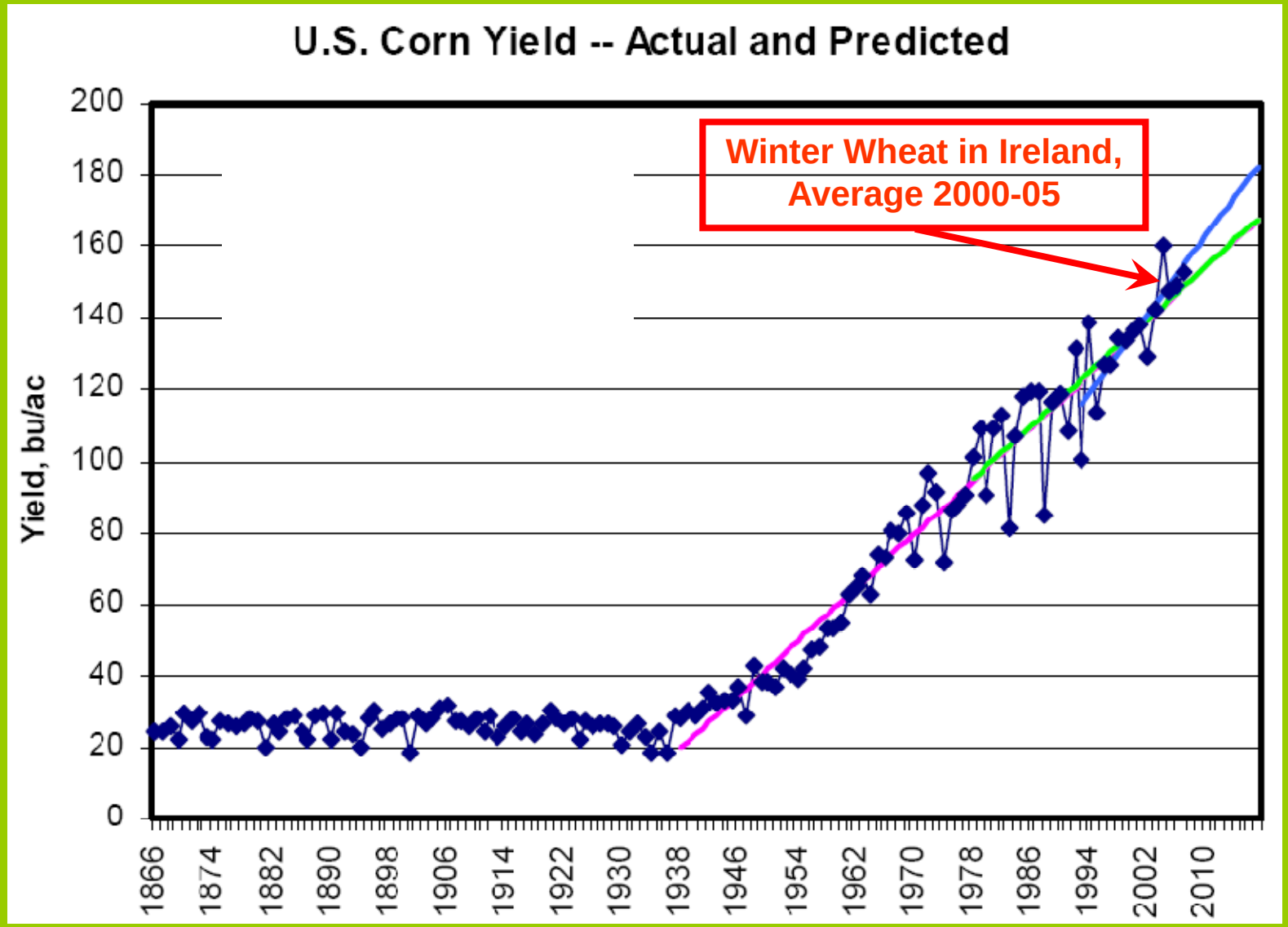
Irrigated Wheat Yield



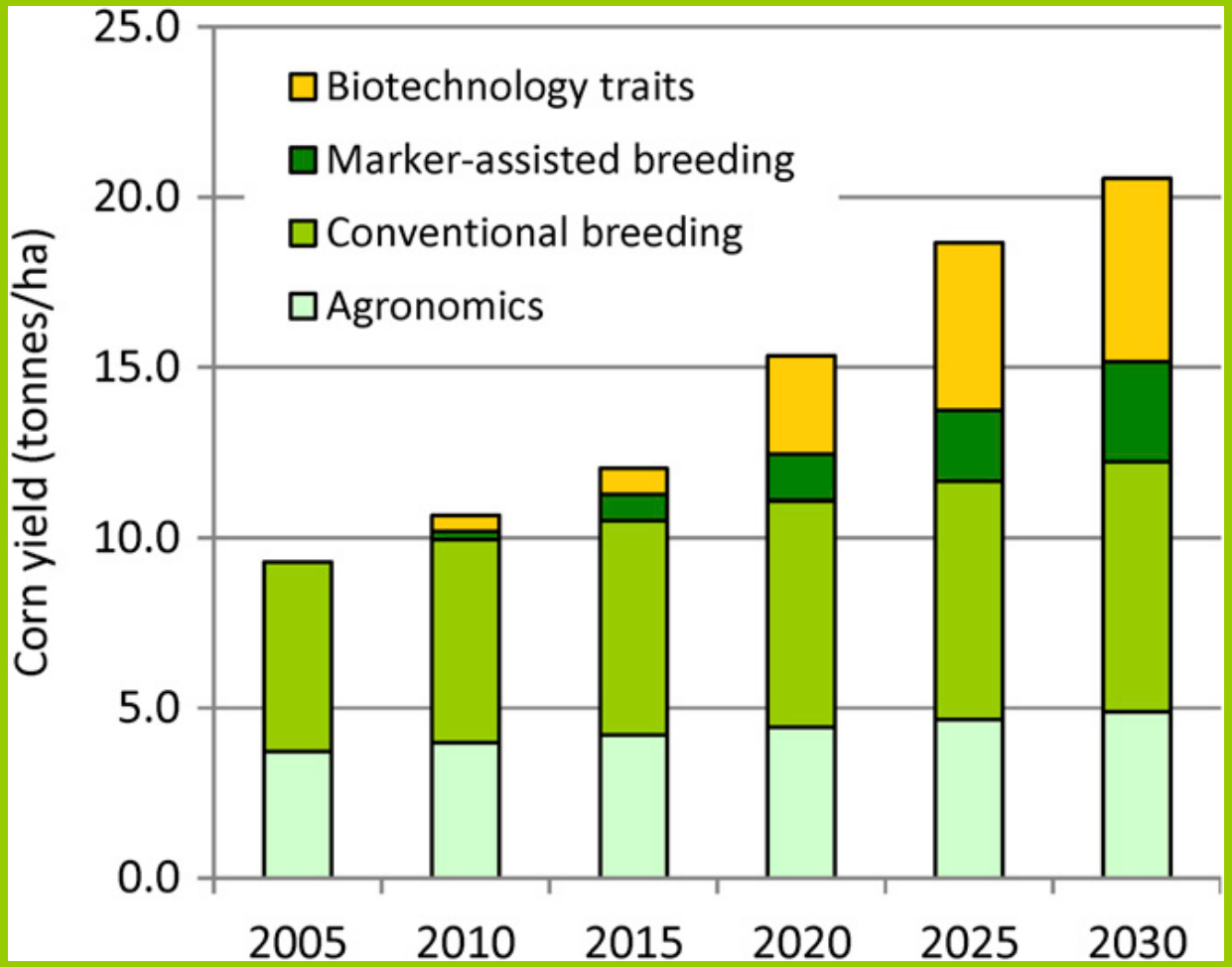
Source: Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT)

Winter Wheat Variety Trials
Mean Yield (T/Ha) Oak Park



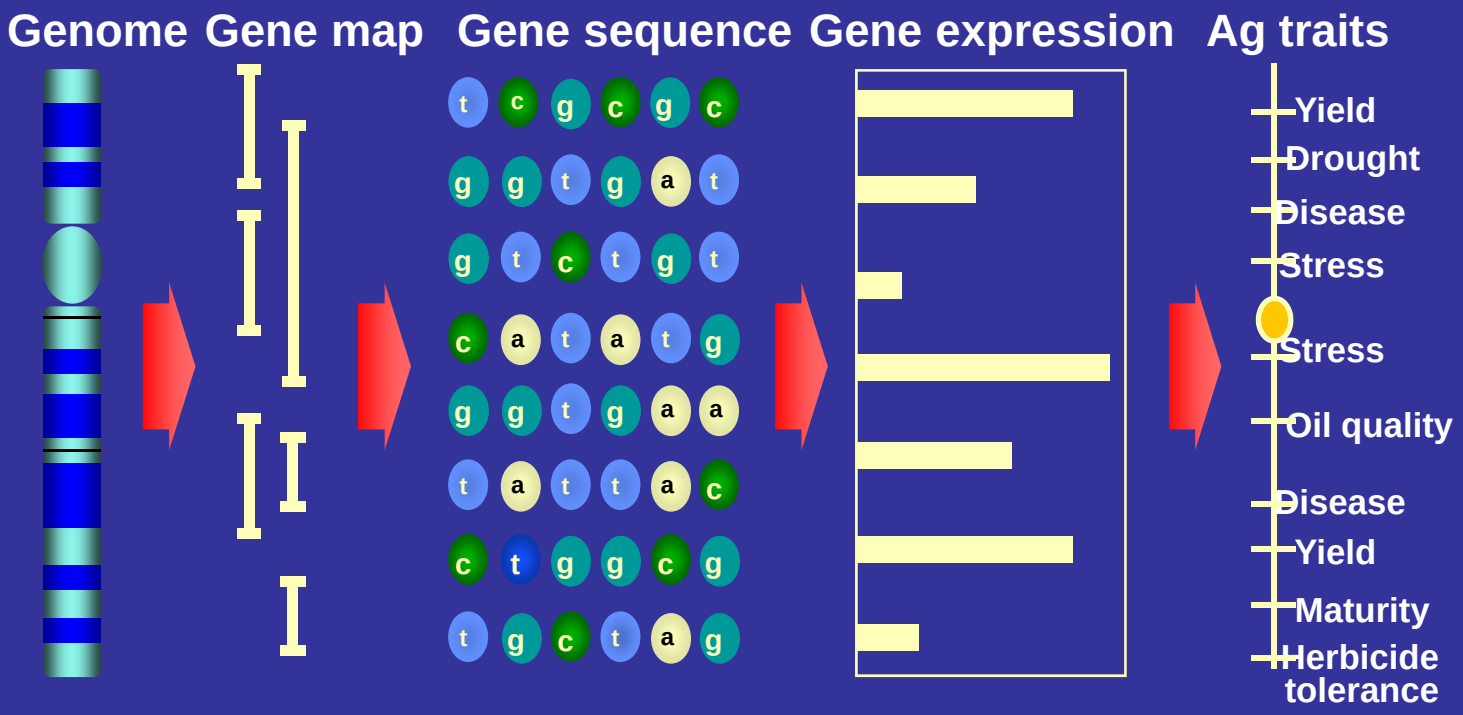

U.S. Corn Yield -- Actual and Predicted
Yield, bu/ac
200
180
160
140
120
100
80
60
40
20
0
1866
1874
1882
1890
1898
1906
1914
1922
1930
1938
1946
1954
1962
1970
1978
1986
1994
2002
2010
Winter Wheat in Ireland,
Average 2000-05

Projected Basis for Corn Yield Predictions?



Source: M.D. Edgerton, 2009, Plant Physiology 149: 7-13.

Advanced Genomics has already & Will continue tp Accelerate Discovery of Next Generation Products



Genetically Modified Crops

Potential Benefits

Economic, Consumer and Environmental

- reduced crop production costs
- reduced crop losses due to diseases, pests and weeds
- improved food and animal feed quality (nutritional and processability)
- novel crop and food products
- renewable raw materials for industry (non food)

Genetically Modified Crops Concerns

1. Food Safety
2. Protection of the Environment
3. Ethical / Moral
4. Restricted / Monopoly Control of Seed by Industry

GM Crops Results To-Date

- No adverse risks to human health or to the environment:
  - Many ‘000’s of scientific field trials
  - In more than 30 different countries,56 different crops
  - Nearly 300 MILLION acres in commercial production

    Soyabean,Maize,Potatoes,Tomatoes,Cotton,OSR

    Asia,Argentina,Australia,Canada,Mexico,USA

Ireland Regulatory Agencies

Environmental Release	EPA	Dept. of the Environment
Food Safety	FSA	Dept. of Health
Variety Registration	Dept of Ag	Dept. of Agriculture
Plant Protection Products	P.C.S.	Dept. of Agriculture

Safety & Biotechnology

* Rigorous research is carried out by Industry

  - effectiveness
  - environmental safety
  - safety to farmers and the end consumer

* Approval given by Government regulatory authorities - however

Safety Contd.,

Rigorous research also needs to be carried out by credible public research institutions particularly on:

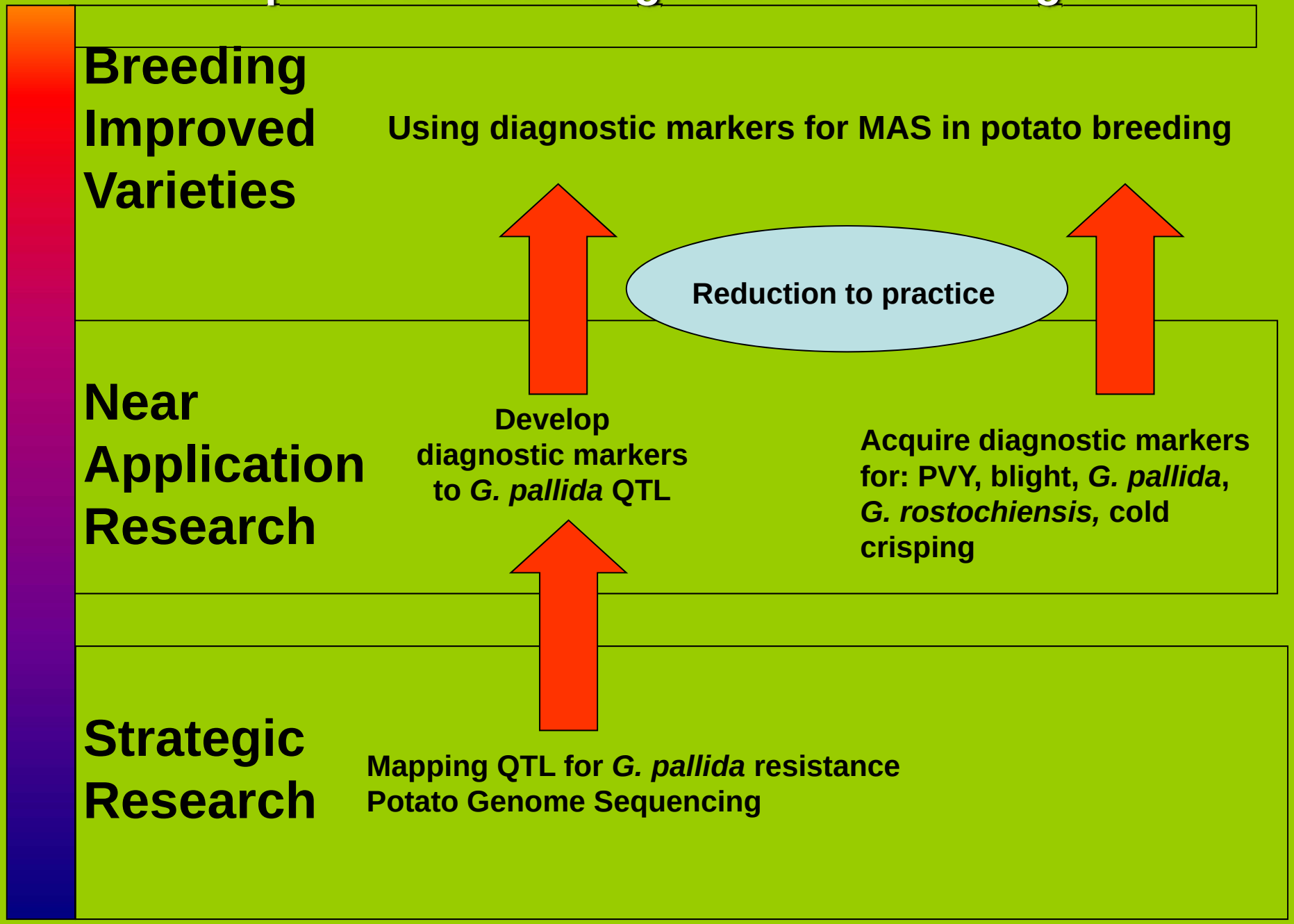
- **environment**

- **Food safety**

GM crops - Patenting Facts

- NO ownership of a gene
  - right to benefit from a specific application of a novel,non-obvious and useful invention,for a specific period of time
- NO automatic right to use the invention
  - May be blocked by health,safety or environmental regulations,international treaties..
- NO secrecy in process
  - Application is disclosed for all world to see,ponder and improve upon.

Example of current Teagasc Research Programme



Teagasc Research Programme
Crop Biotechnology

- Evaluate genetically modified crops developed by industry

- establish the most appropriate cropping practices for GM crops to optimise their positive potential and minimise/avoid possible negative environmental effects

- investigate possible impacts of GM crop on the environment particularly in respect of gene flow and develop coexistence guidelines

‘GENE FLOW VIA POLLEN DRIFT’ ??

All crops have pollen….all crops spread their pollen (wind/insect)

GM pollen travels the same distance/pattern as non-GM pollen

There is no risk in regard to the health and safety of GM pollen

Concern is economic

National Guidelines are currently in place by DAFF to ensure effective coexistence of GM and non-GM crops

WHAT IS COEXISTENCE ?

Co-existence refers to the potential ECONOMIC impact of GM crop cultivation

Co-existence does not address the impact of GM crops on the Environment, animal, human health.

Why??

Each GM crop must pass through EFSA, EPA, FSAI. If GM crop is rejected then it cannot be considered for import as a feed ingredient or for cultivation.

What about a Second Green Revolution ?

- We are going to have to use all of our tools (germplasm, genomics, mutations (TILLING), transgenics, and penotyping /statistics/bioinformatics) on a scale that has not been seen before.
- Reassess the role for hybrids.
- We will have to look at traits/cultivars/hybrids that either are environmentally “flexible” or
- Modify the environment sustainably.
- More emphasis on accurate phenotyping in plant breeding (expanding our tool kit).

The Need for Phenotyping:

- Effective selection.
- Effective use of tying molecular markers (which have become very cost effective) to phenotypes.

Note this also increases the number of lines that require phenotyping and possibly the number of traits that need to be phenotyped to gain the understanding that is needed of the underlying genetics.

- Need automation and interpretation

Plant breeding will evolve to meet the challenge.

We have the correct concepts and many tools (and are creating new tools) that will support this effort.

However, It will not be easy.

The Future - Europe needs to make a choice

- Participate actively in the value creation of Agri-business
- Add new options for sustainable use of farmland

Europe needs 'policy coherence' on plant biotechnology :

- To benefit from research and market potential in Europe
- To build a European basis for innovation led growth in Agriculture