# FOOD, FAMINE and the FUTURE of FARMING

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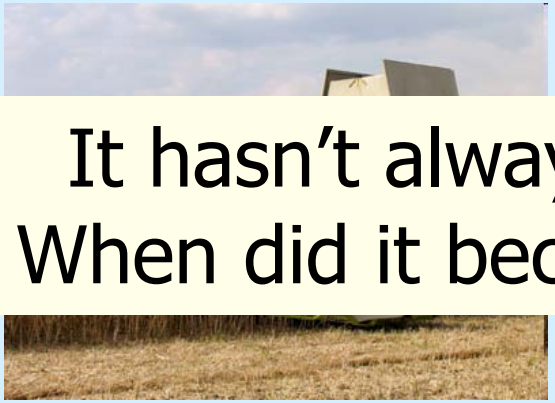
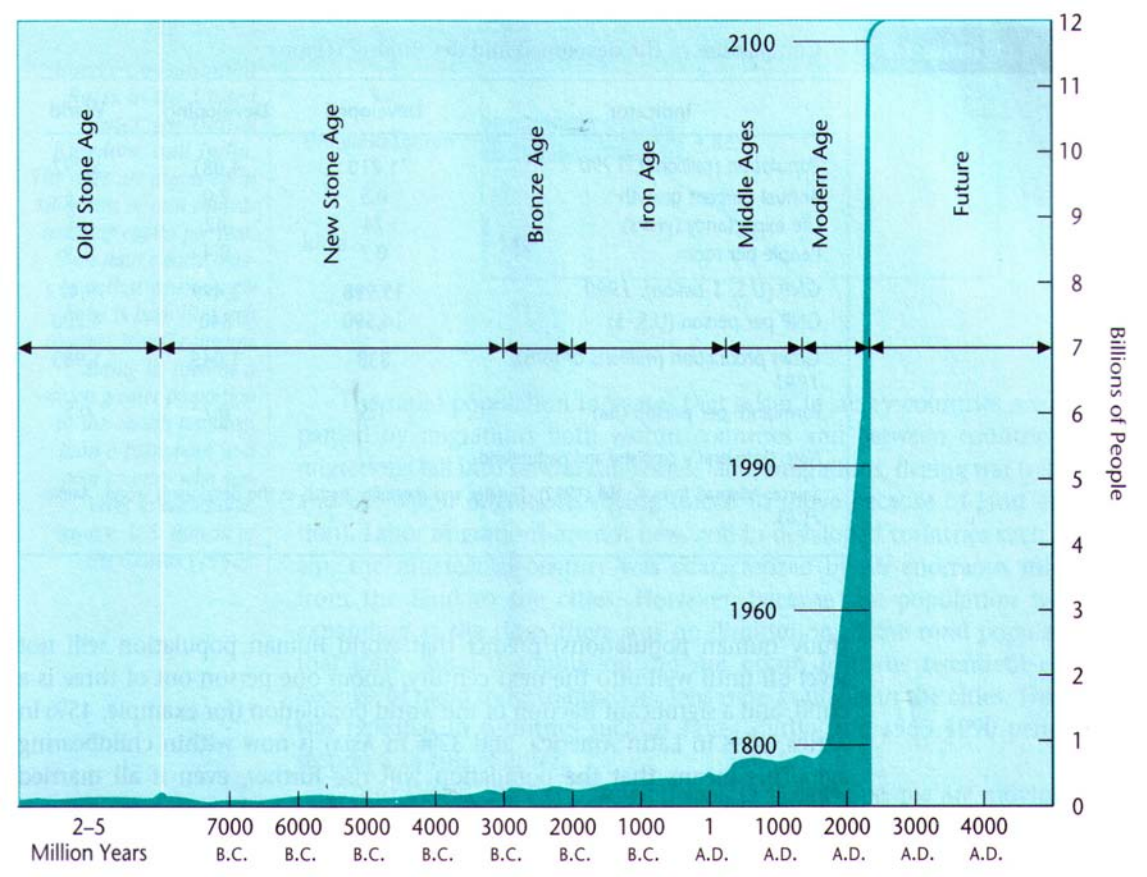
Images of our world today bring up issues of population explosion and food production required.



It hasn't always been like this. When did it become so crowded?

# History of Population Growth

2,000 years ago – there were 300 million people worldwide – approximately same as in the U.S. today!




2000 years ago:
500 people were added to world each day.
Today: 200,000!

*SOURCE: "Plants, Genes, and Agriculture", Chrispeels, M.J. and Sadava, D.E. (editors) 1994.*

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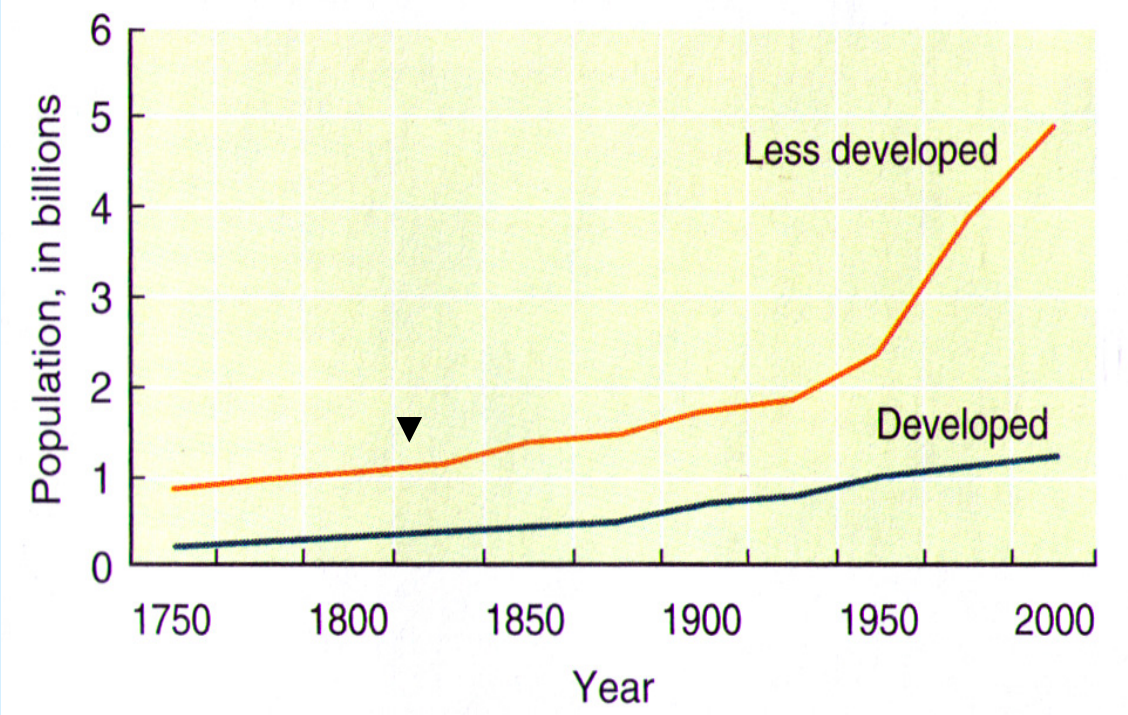
In early times, hunting/gathering lifestyles resulted in moderately high birth and death rates.

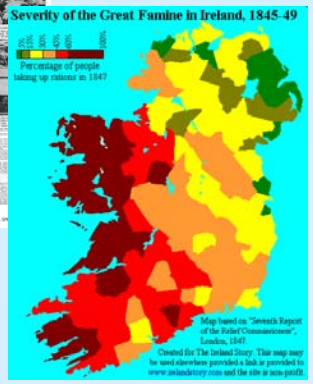
~10,000 years ago, agriculture began replacing hunting/ gathering.




Reliable food supplies and a settled existence led to dramatic birth rate increases up to 1800 – but…

*SOURCE: "Plants, Genes, and Crop Biotechnology", Chrispeels, M.J. and Sadava, D.E. (editors), 2003*

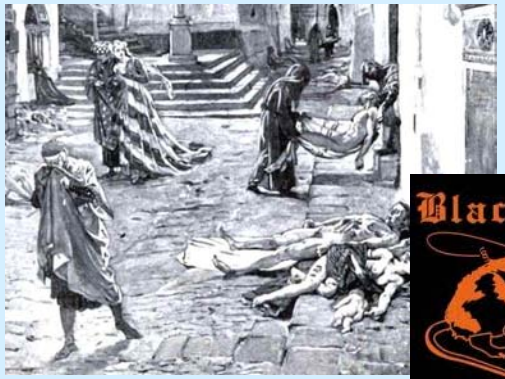
FAMINE,


WAR,

and

DISEASE



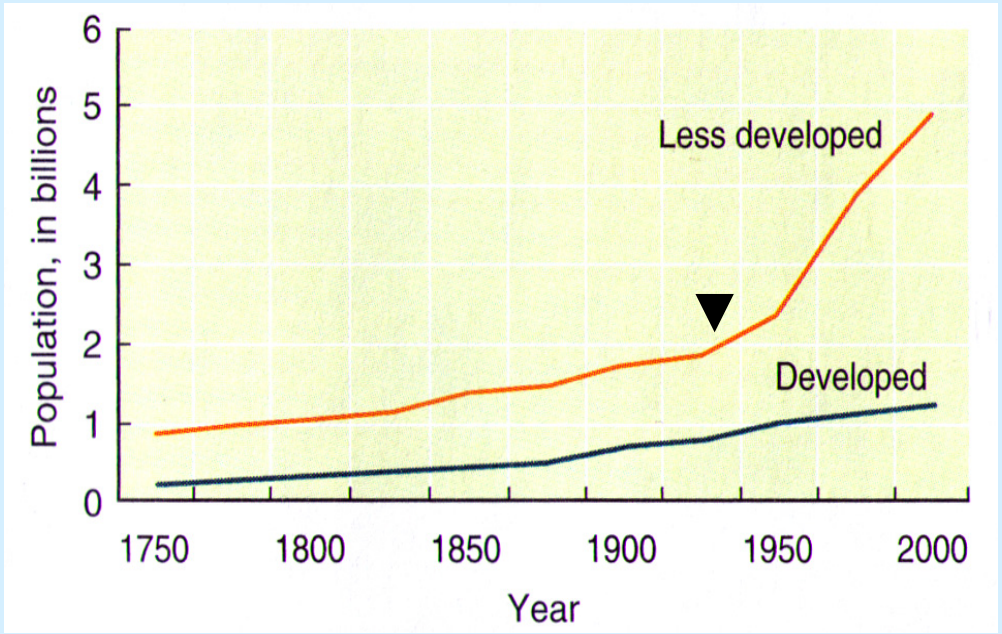

kept population down

A dramatic population explosion occurred in last 80 years.

Because?

Rising income = more people could buy food

Improved housing/ public hygiene, decrease in infectious disease




Food production more dependable; improved transportation

Medical advances: disease agent identification / treatments to control diseases

*SOURCE: "Plants, Genes, and Crop Biotechnology", Chrispeels, M.J. and Sadava, D.E. (editors), 2003*

In Europe and North America, industrialization occurred over several hundred years

But, in Asia, Africa, Latin America, improvements occurred "overnight" (last 50 years) causing populations to grow extremely rapidly

## Comparison of developed and less developed regions

| Indicator | Developed | Less Developed | World |
|---|---|---|---|
| Population (millions), 2002 | 1,193 | 4,944 | 6,137 |
| Annual percent growth | 0.1 | 1.6 | 1.3 |
| Life expectancy, years | 75 | 64 | 67 |
| People per room | 0.7 | 2.4 | 1.9 |
| Mortality under 5, per 100 births | 0.8 | 6.1 | 5.6 |
| GNP per person, US$ | 20,520 | 3,300 | 6,650 |
| Grain production, millions of tons | 810 | 1,259 | 2,069 |
| Farmland/person, hectares | 1.5 | 0.6 | 0.7 |

Despite the 16-fold greater rate of increase in population in less developed countries, grain production only increased 1.5-fold! Why?

*SOURCE: "Plants, Genes, and Crop Biotechnology", Chrispeels, M.J. and Sadava, D.E. (editors), 2003*

Lack of increases in grain production was due in part to the mass exodus from rural areas (and farming)…

to urban areas, as a result of industrialization, which put increased pressure on agricultural systems

# Also types of foods people eat affects agricultural production

**Comparison of the diets in India and United States**

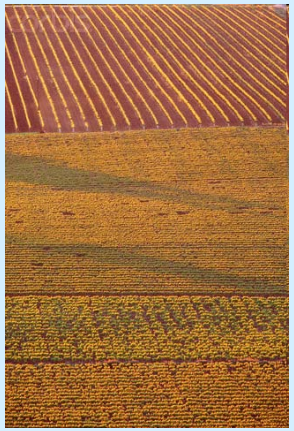
| Food | Source of calories | | Source of protein | |
|---|---|---|---|---|
| | India | United States | India | United States |
| Cereals, starchy foods | 65% | 25% | 64% | 21% |
| Sugars | 6 | 12 | — | — |
| Beans, lentils | 10 | 4 | 18 | 3 |
| Fruits, vegetables | 2 | 6 | 1 | 4 |
| Fats, oils | 4 | 19 | — | — |
| Milk, milk products | 7 | 14 | 11 | 26 |
| Meat, poultry, eggs, fish | 6 | 20 | 6 | 46 |

*Sources:* Data from Food and Agriculture Organization and U.S. Department of Agriculture.

In less developed countries, protein needs were satisfied with cereals and beans – now preferences are shifting to milk and meat – which affects agricultural production because….

**Efficiency of energy transfer from plants to humans through eating beef is ~1%**

# How were increases in the food supply able to keep up with increases in population?



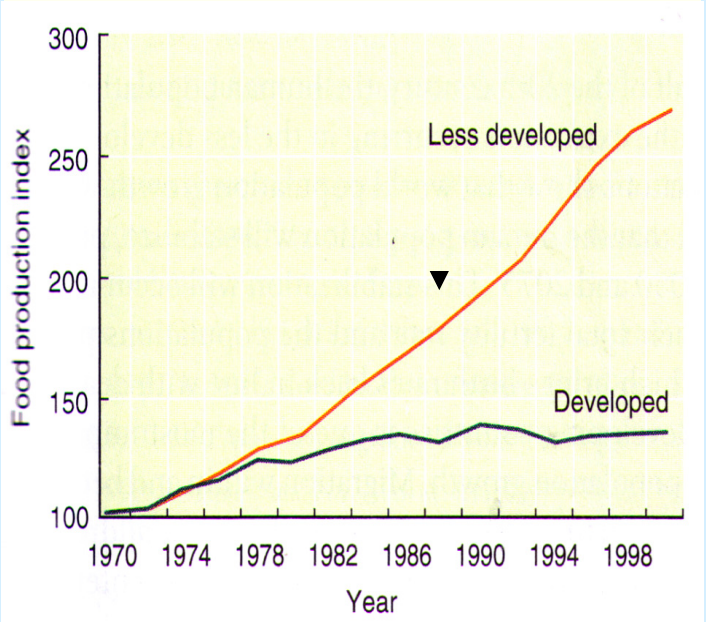
From 1860 to 1978 land used for food production increased.

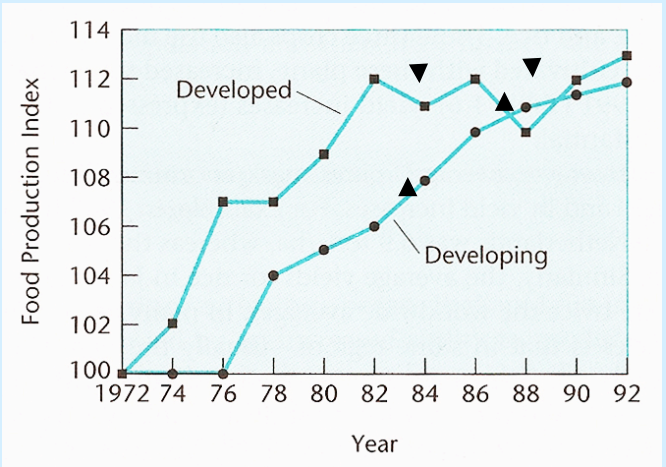
But since 1978 amount has remained steady, causing amount of cultivated land per person to drop by 25%.

*SOURCE: "Plants, Genes, and Crop Biotechnology", Chrispeels, M.J. and Sadava, D.E. (editors), 2003*

# This meant less land per person and more people to feed!

Overall food production in developing and developed countries




But, total food productivity rose dramatically in less developed countries. Good, right?

But, due to increasing populations, per capita food production was static.

But in developed countries per capita food production continued to rise. Why?

*SOURCE: "Plants, Genes, and Crop Biotechnology", Chrispeels, M.J. and Sadava, D.E. (editors), 2003*

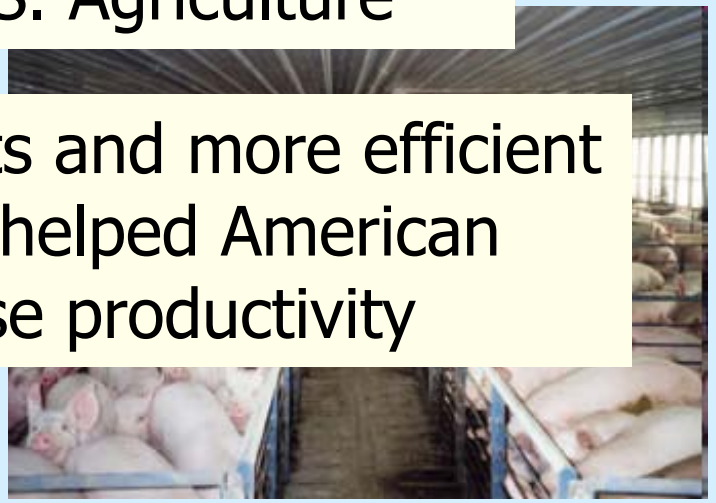
| | 1930 | 2009 |
|---|---|---|
| % of people involved in farming: | 21% | ~0.7% |
| Number of farms: | 6,295,000 | 2,200,000 |

BOTH DECREASED

But productivity of average US farmer INCREASED…

In 1930 fed 10
In 1960, 24
In 1990, 100
In 2009, 155

Let's look at productivity in U.S. Agriculture



Genetic improvements and more efficient farming practices helped American farmers increase productivity

http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/st99_1_063_063.pdf

http://prb.org/Datafinder/Geography/Data.aspx?category=6&region=72&region_type=3

Some 300 different crops provide food worldwide…but 24 supply the bulk of our food and feed.

Eight crops supply 85%. **Three account for over half of our food - directly or indirectly.**

Corn

Wheat

Rice

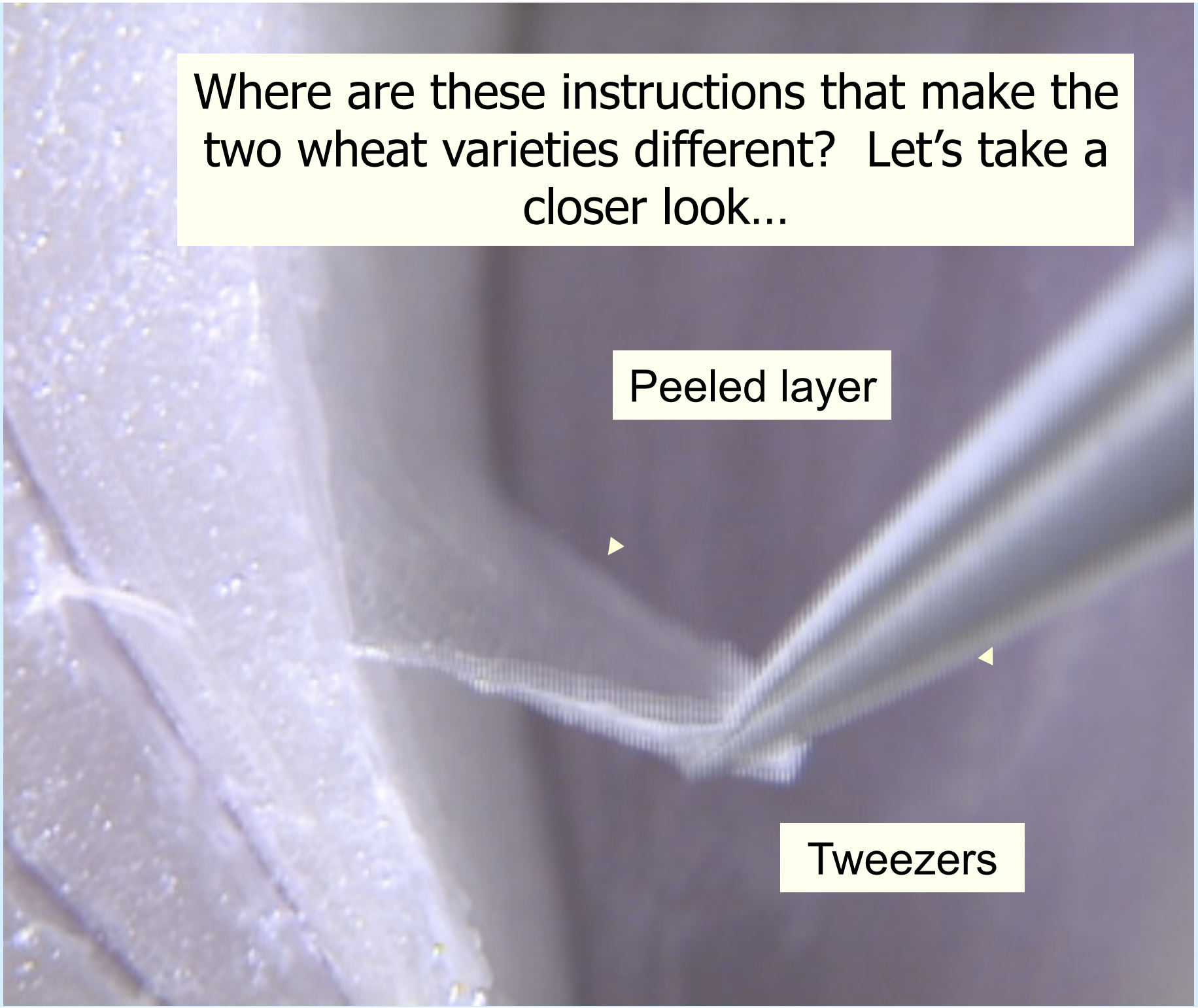
How has crop productivity increased?

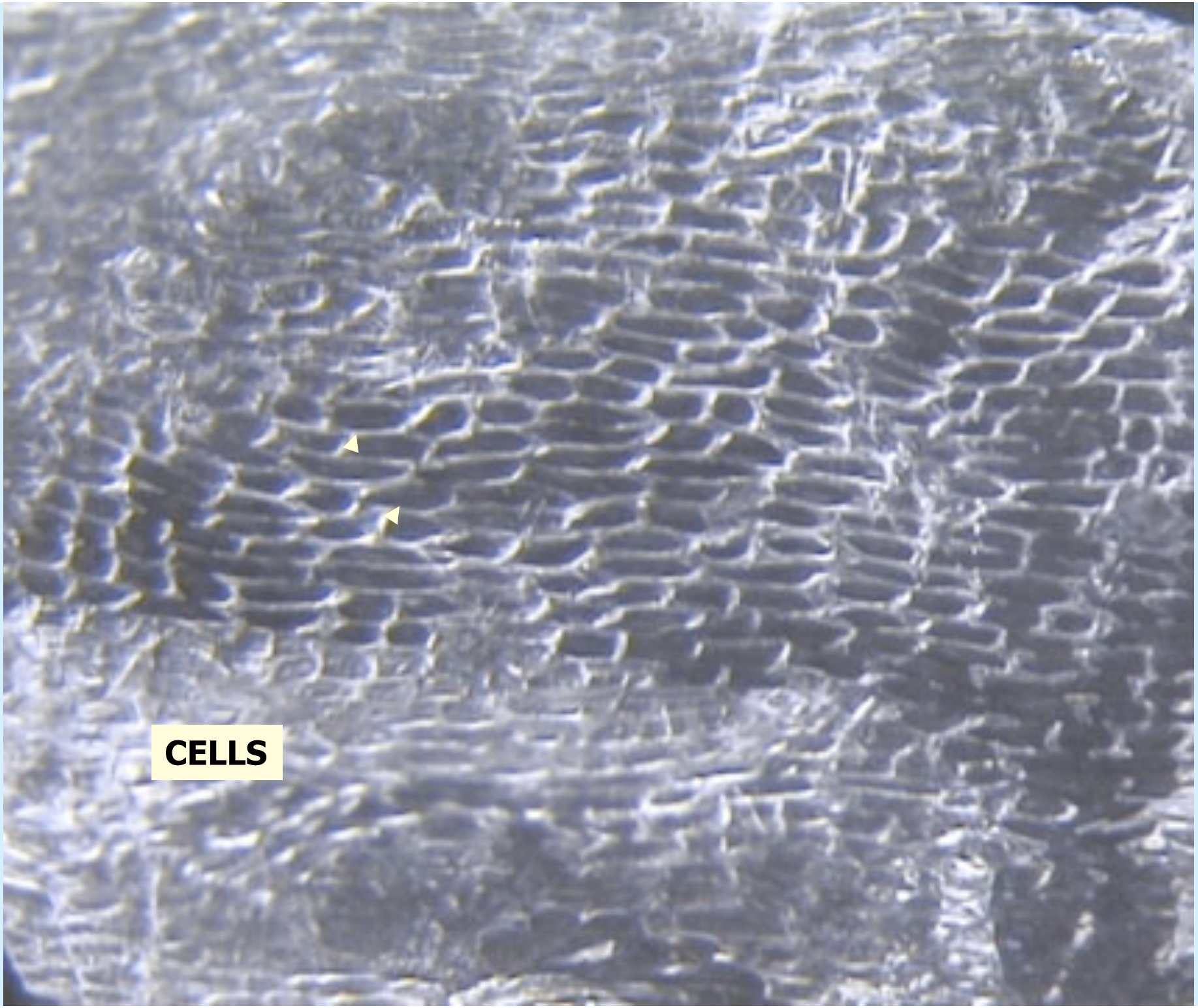
One way of making productivity improvements in crops takes advantage of genetic differences among varieties?

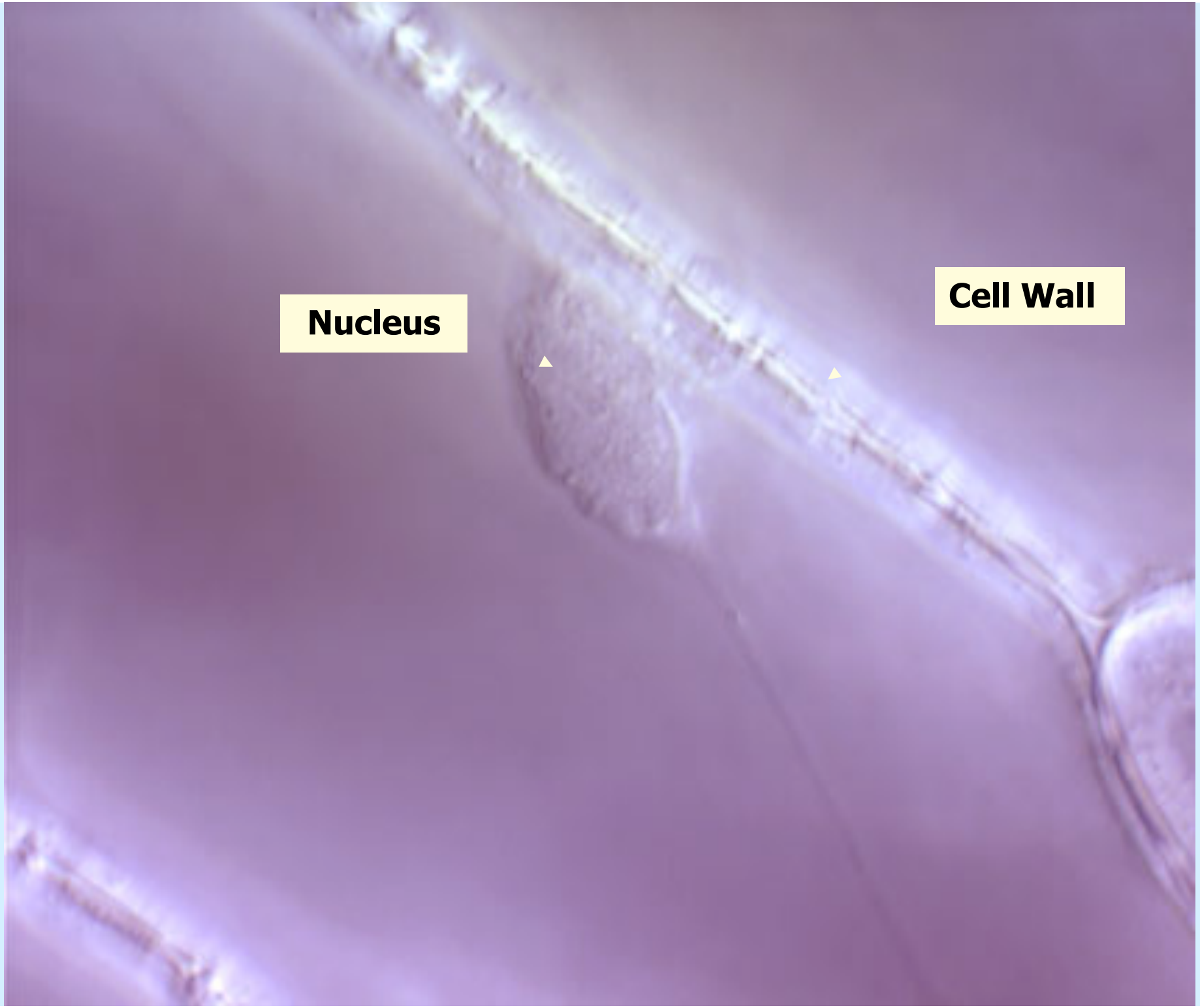
The approach involves manipulating the instructions, or genes, responsible for different traits

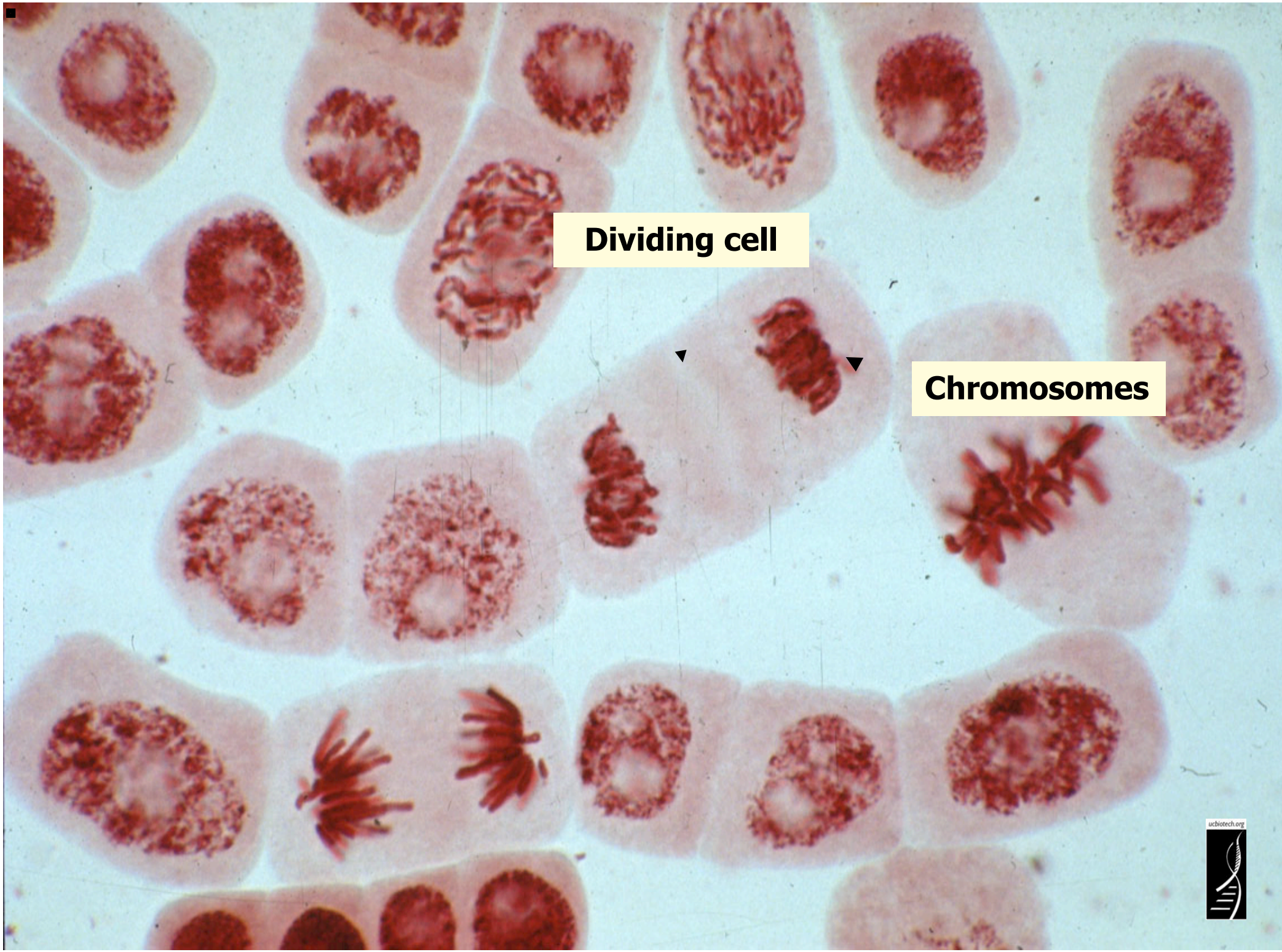
*Triticum aestivum*
**Modern bread variety**

*Triticum monococcum*
**Ancient variety**


Where are these instructions that make the two wheat varieties different? Let's take a closer look…
Peeled layer
Tweezers


CELLS


Nucleus
Cell Wall


Dividing cell
Chromosomes
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# How is the genetic information manipulated to create crops with increased productivity?

*Triticum aestivum*

**Modern bread variety**

*Triticum monococcum*

**Ancient variety**

# Information in the wheat genome

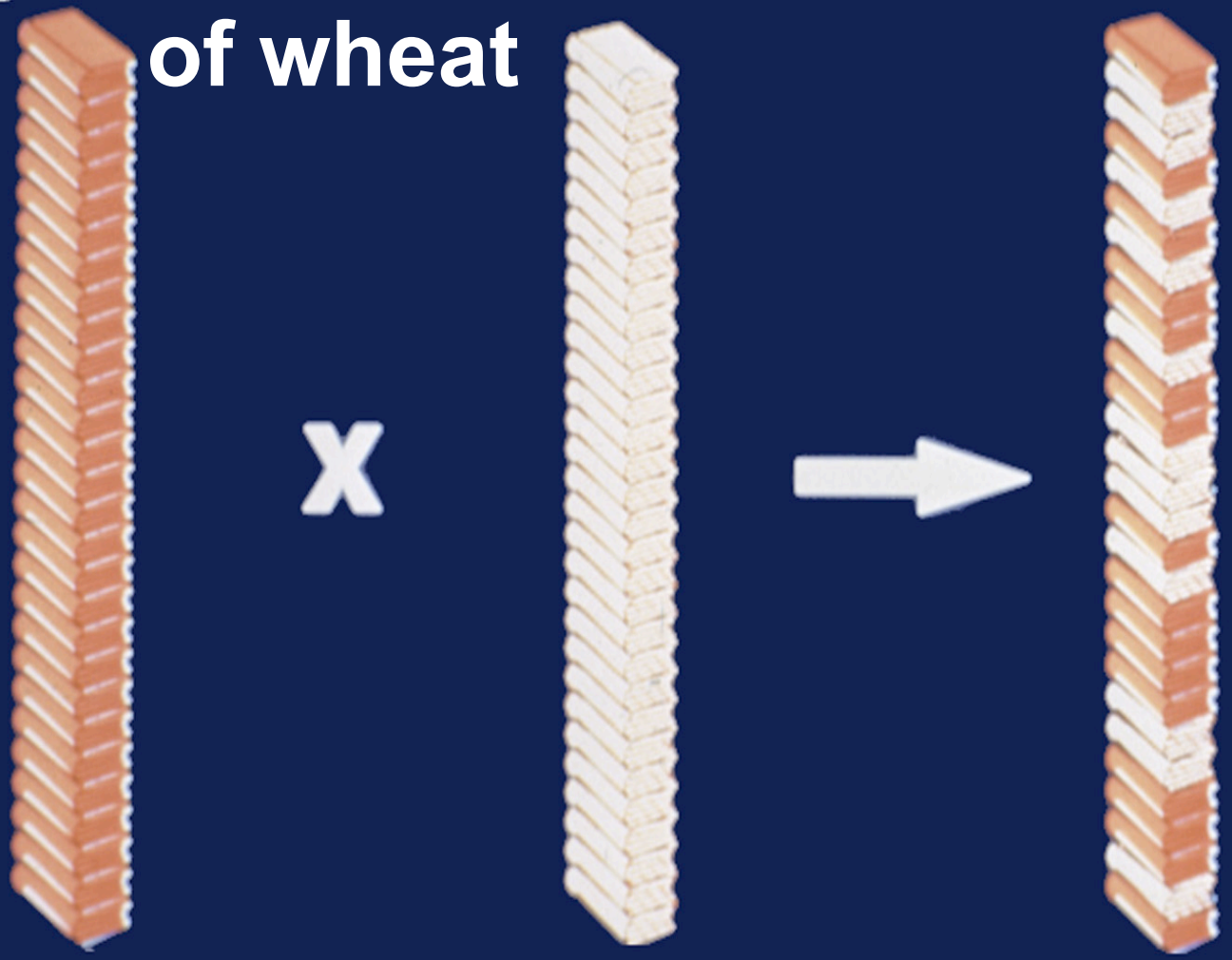
Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...

1700 books
1000 pages each

1700 books
(or 1.7 milion pages)

# Hybridization or cross breeding of wheat



Random retention of information from each parent

1700 books (or 1.7 million pages)

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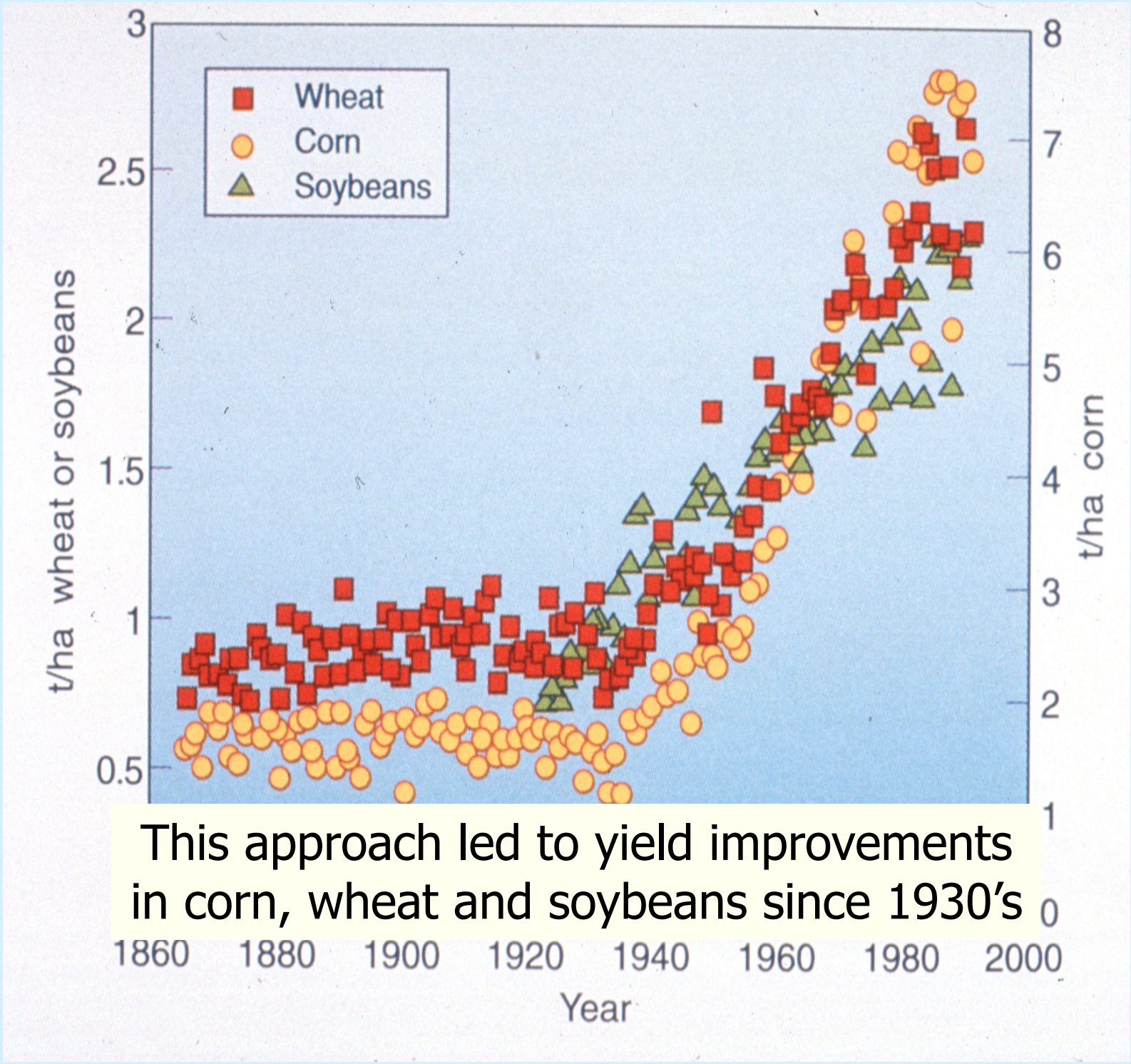


This approach led to yield improvements in corn, wheat and soybeans since 1930's


But there are other ways to create new varieties using modern genetic tools
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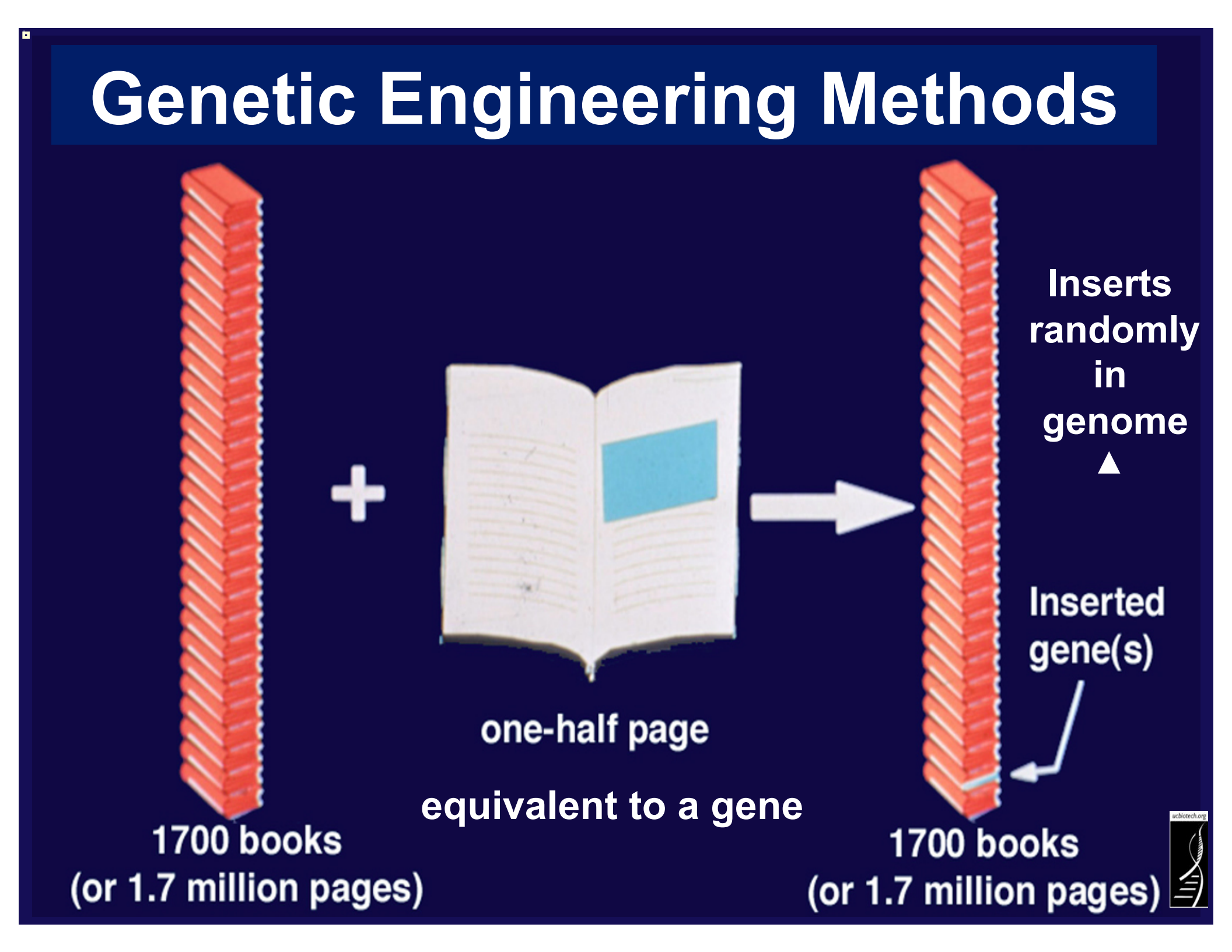
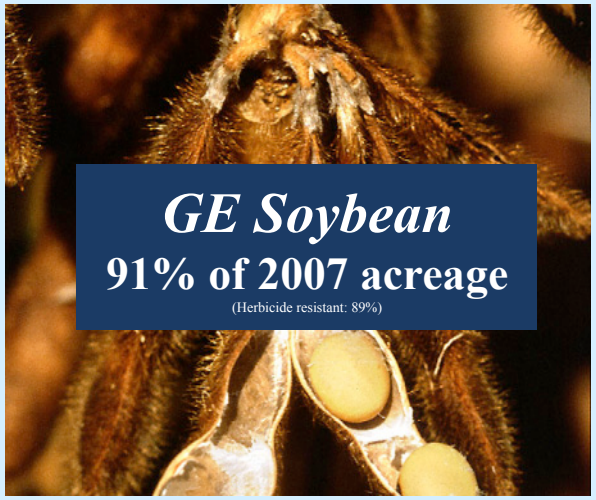
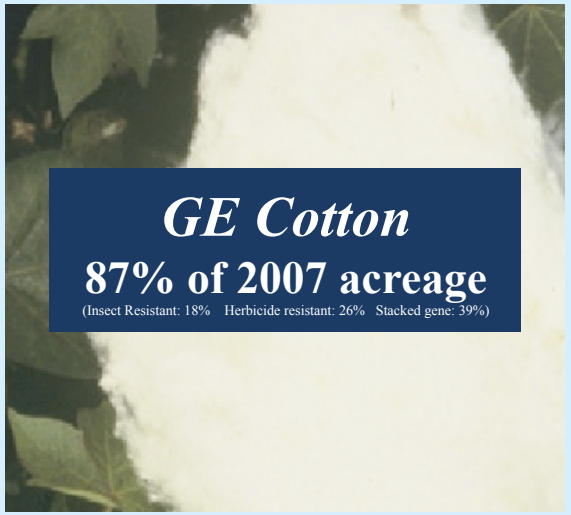
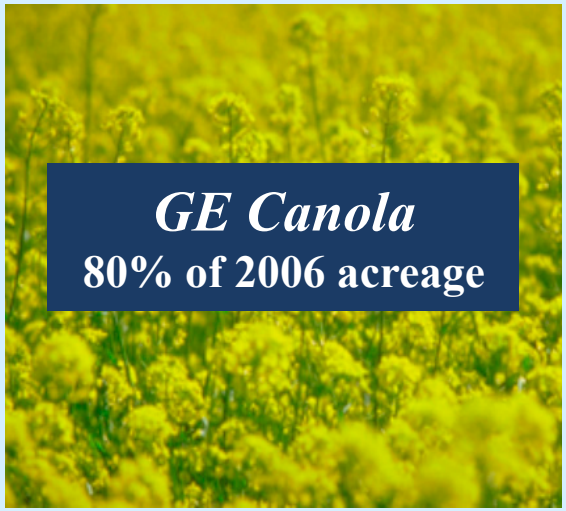
# Genetic Engineering Methods

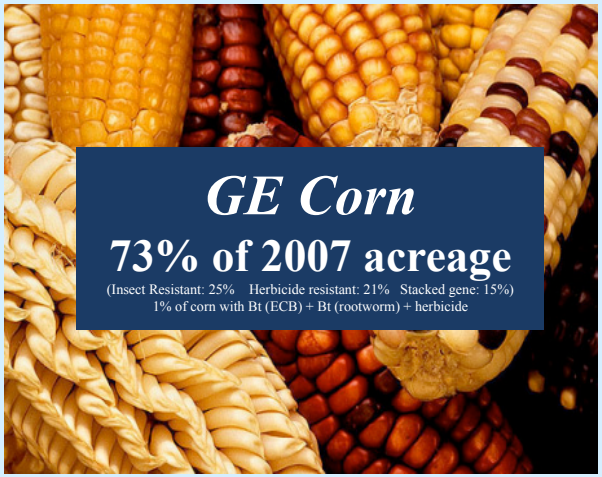


# What's in the commercial field in the U.S.?

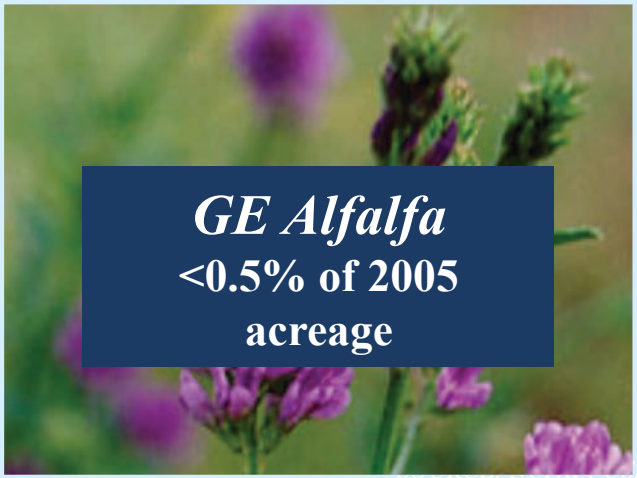




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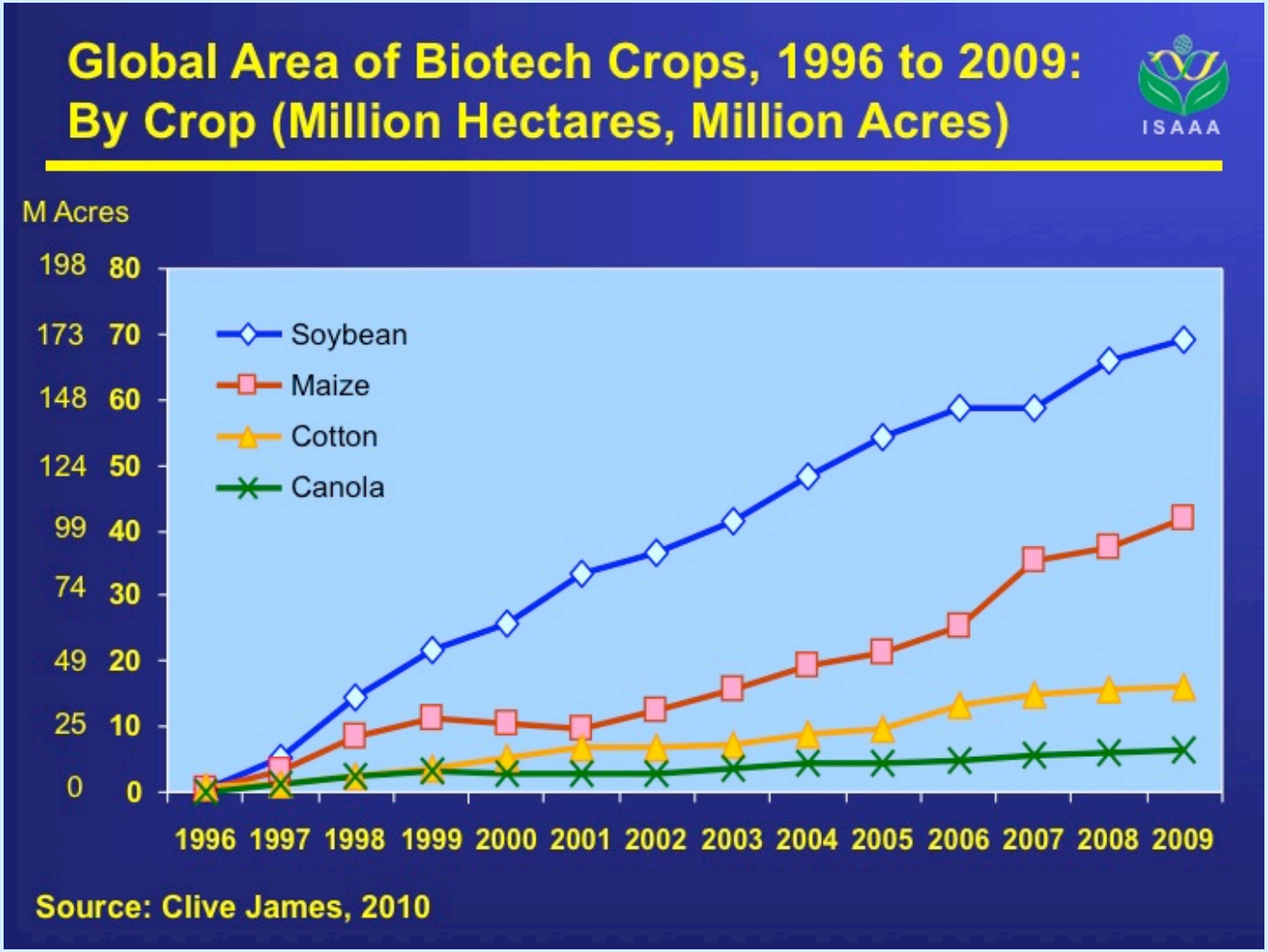
SOURCE: USDA ERS

Only a few whole foods on the market are genetically engineered

What is the situation with GE crops worldwide?






Worldwide 515,625 square miles were grown in 2009 (equal to combined areas of CA, TX and ID) in 25 countries,

...rapidly adopted but only a few traits – insect and herbicide tolerance

25 industrial and developing countries in order of acreage:

United States, Brazil, Argentina, India, Canada, China, Paraguay, South Africa, Uruguay, Bolivia, Philippines, Australia, Burkina Faso, Spain, Mexico, Chile, Colombia, Honduras, Czech Republic, Portugal, Romania, Poland, Costa Rica, Egypt, Slovakia.

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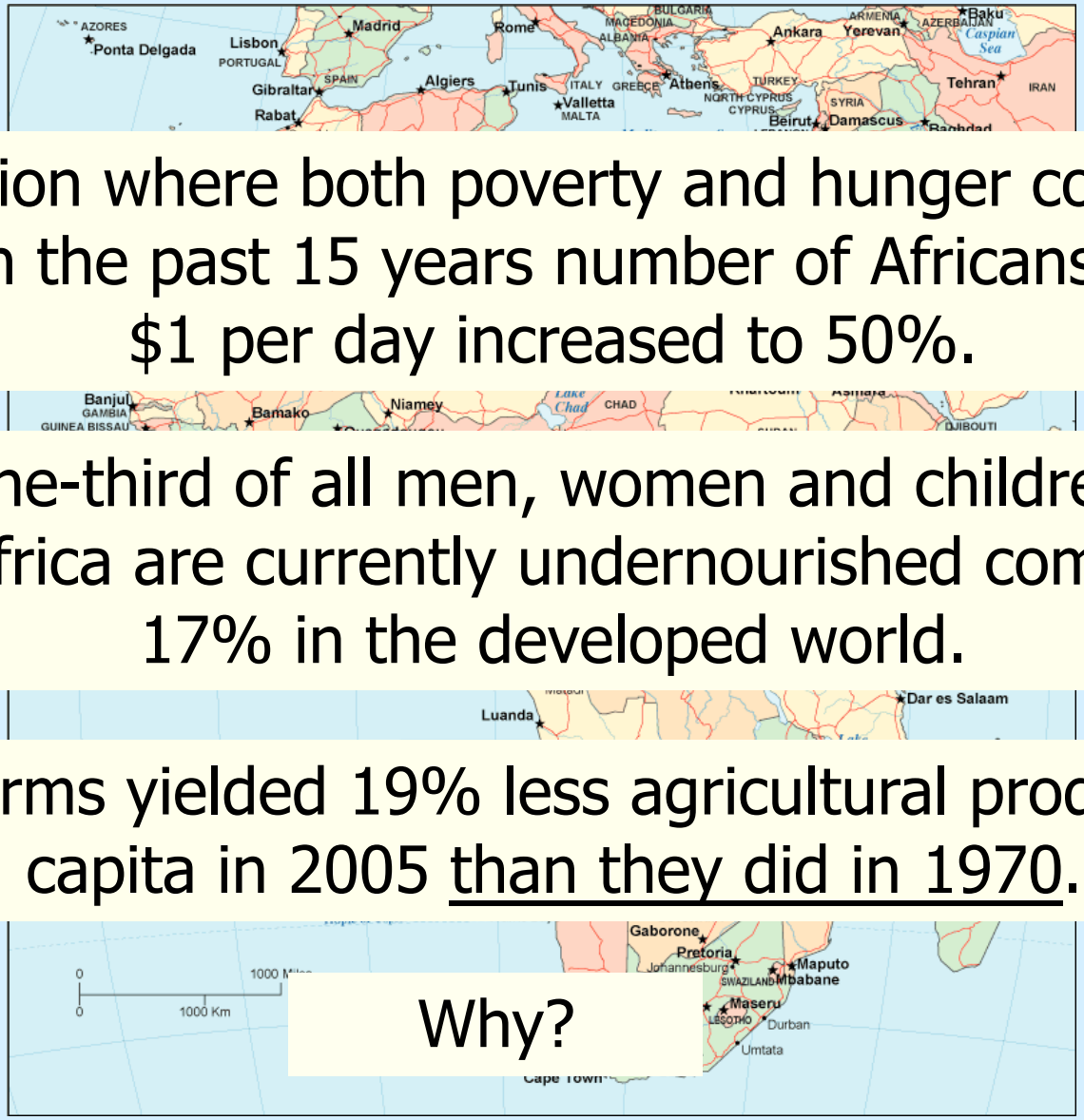
The situation with agricultural production in less developed countries perhaps requires some different solutions.

Why? Let's look at the situation in Africa.




Only region where both poverty and hunger continue to increase. In the past 15 years number of Africans living on < $1 per day increased to 50%.

Nearly one-third of all men, women and children in sub-Saharan Africa are currently undernourished compared with 17% in the developed world.

Africa's farms yielded 19% less agricultural production per capita in 2005 than they did in 1970.

Why?

**From "Starved for Science: How Biotechnology Is Being Kept out of Africa" by R. Parlberg 2008**

**Senegal**

**United States**

Technologies used for agriculture in Africa and other developing countries are different from those in the developed world…

Also crop productivity is lower in Africa and India vs. developed countries because yields are lower.

| CROP | YIELD (kilograms per hectare) | | | | |
|---|---|---|---|---|---|
| | Kenya | Ethiopia | India | Developed World | |
| Maize | 1,640 | 2,006 | 1,907 | 8,340 | 5X |
| Sorghum | 1,230 | 1,455 | 797 | 3,910 | 5X |
| Rice | 3,930 | 1,872 | 3,284 | 6,810 | ~3X |
| Wheat | 2,310 | 1,469 | 2,601 | 3.110 | 2X |
| Chickpea | 314 | 1,026 | 814 | 7,980 | 25X |

WHY?

For many reasons…among them varieties are not optimized for higher yields in these environments.

# This leads to a difficult situation in Africa today?

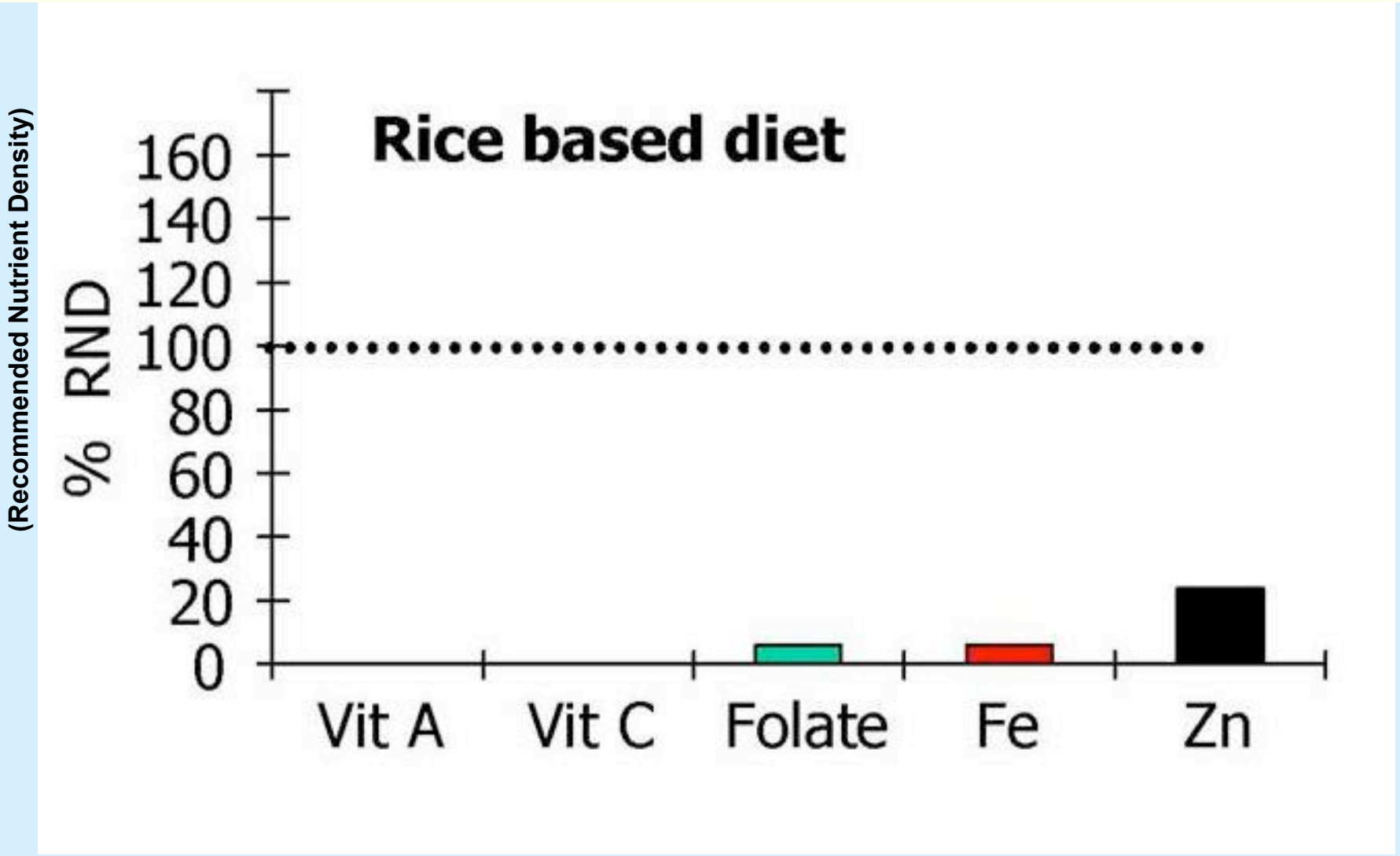
- One billion of the world's poorest people depend on their own agriculture for food
- 820 million people go to bed hungry each day
- Malnutrition leads to stunted physical and mental development, increased disease susceptibility

Can biological improvements in crops help?

Global Development Program, Gates Foundation: http://www.gatesfoundation.org;

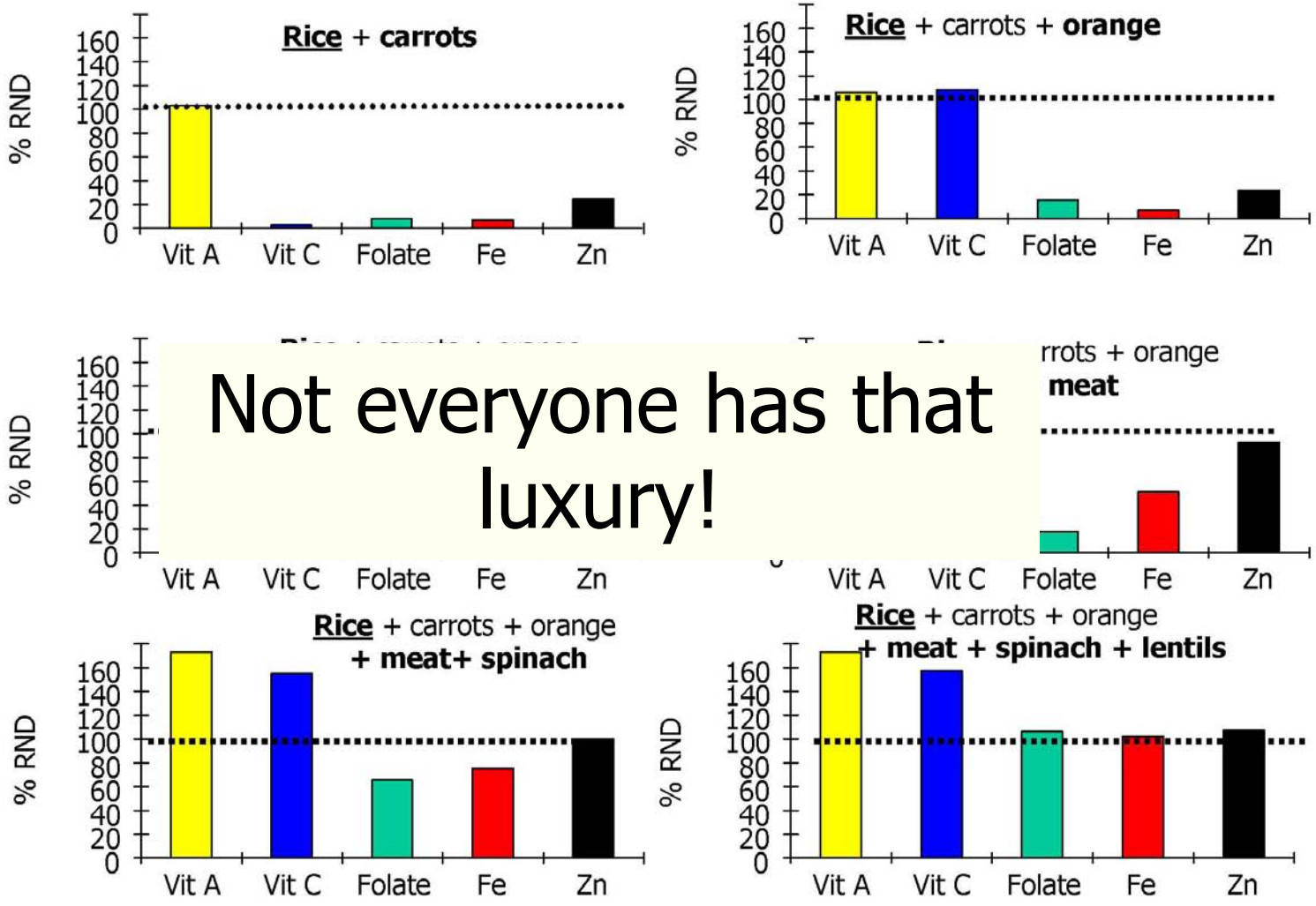
Starved for Science. 2008. Robert Parlberg, Harvard University Press.

In many less developed countries rice often serves as the main, or only, source of calories. Rice, like other cereal crops, is a poor source of vitamins and minerals




From: "Nutrition: A Cornerstone for Human Health and Productivity", Richard J. Deckelbaum. Seminar, Earth Institute of Columbia University, April 14, 2005

**Modified from G. Barry, IRRI**



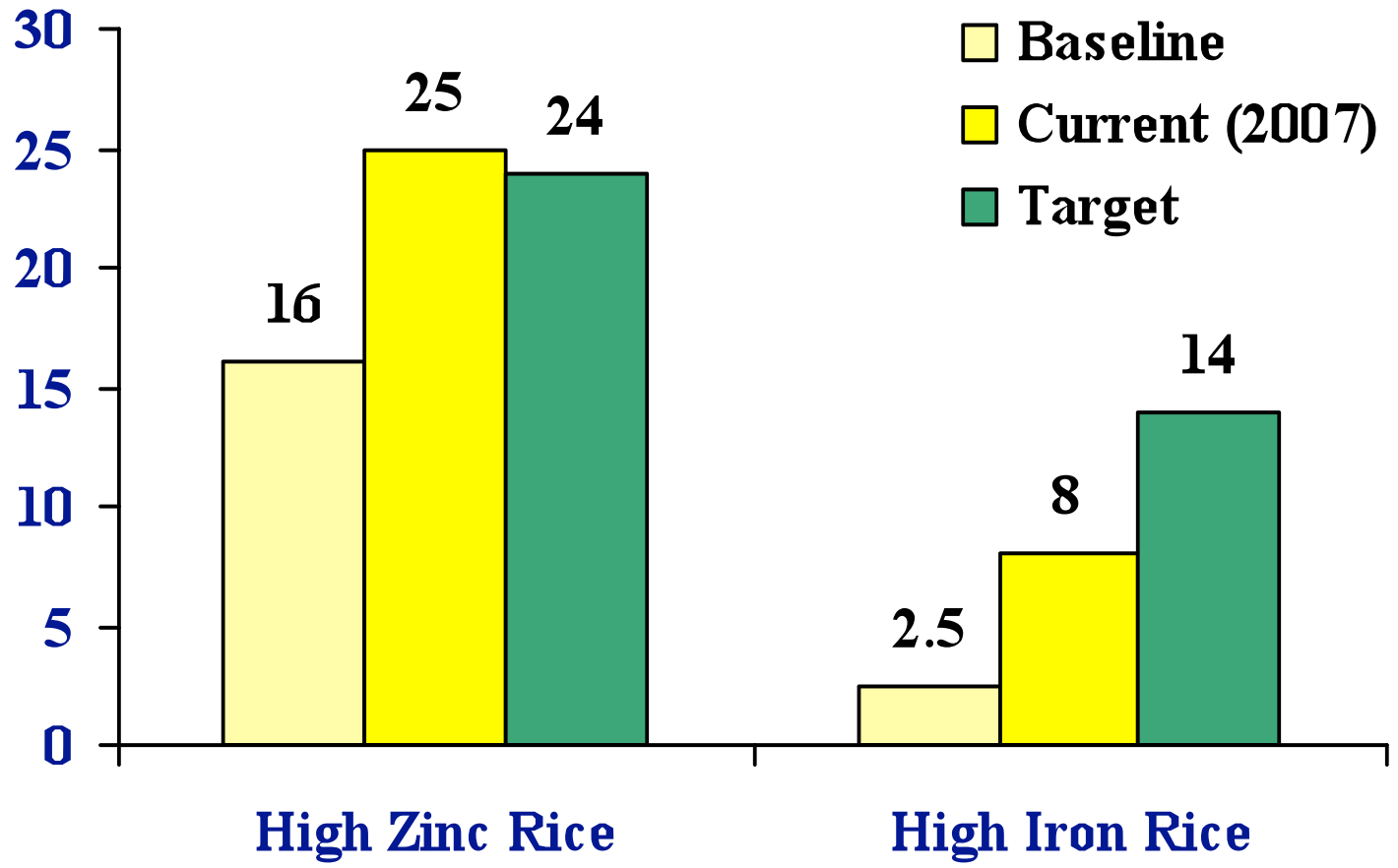

Can't rice diets just be supplemented with other fruits, vegetables and meat to add these nutrients?

**Modified from G. Barry, IRRI**

: "Nutrition: A Cornerstone for Human Health and Productivity", Richard J. Deckelbaum. Seminar at The Earth Institute of Columbia University, April 14, 2005

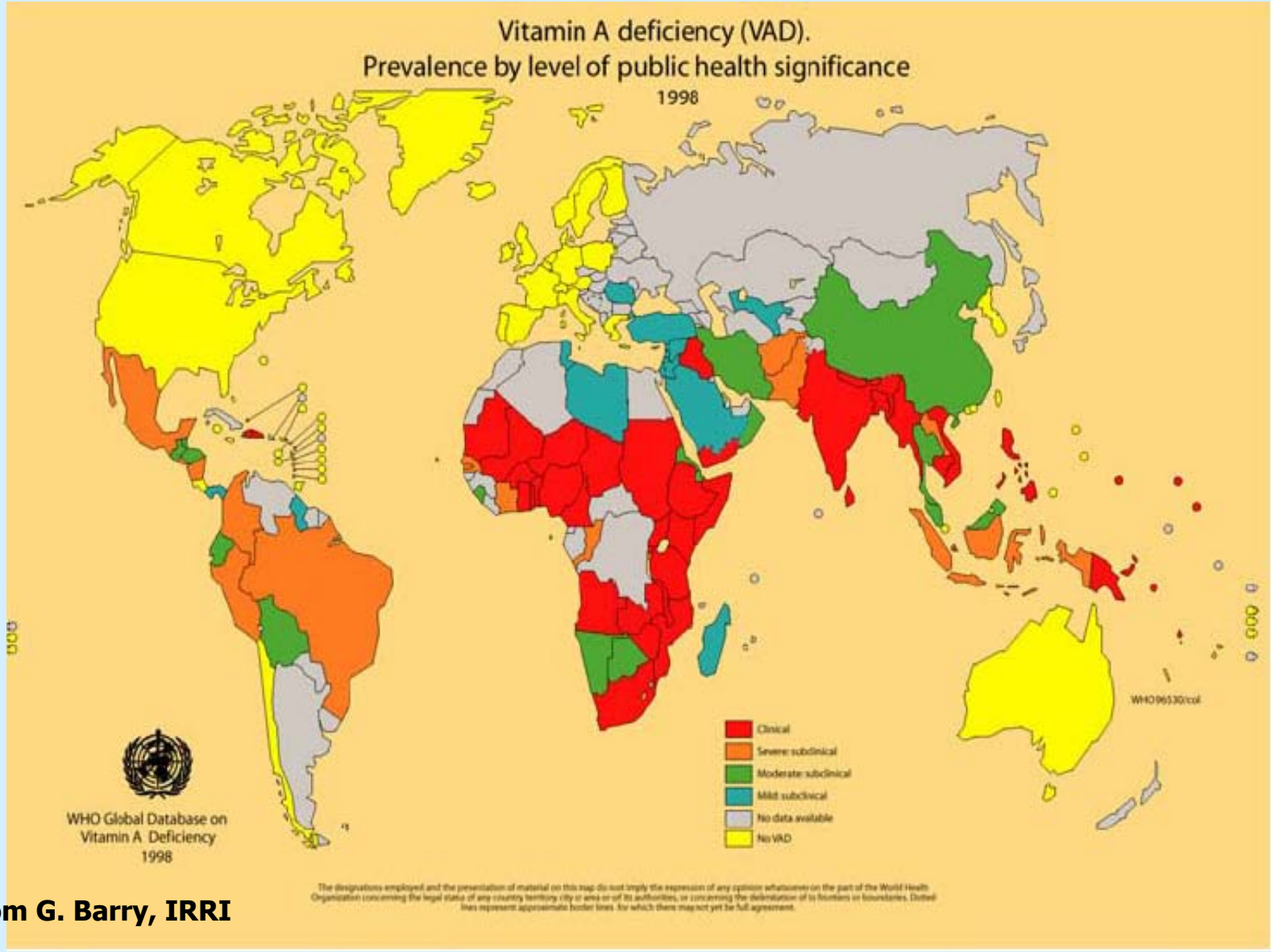
Progress has been made fortifying rice with iron and zinc using cross-breeding with other varieties…

But this approach is not feasible for Vitamin A since there are no compatible varieties with high levels of this vitamin.




E. Boncodin, Fedl Budget Secy Manila Philippines

# Vitamin A deficiency causes severe health problems, vision loss, poor brain development, immune system failure




**Modified from G. Barry, IRRI**

# Golden Rice was engineered to have pro-Vitamin A


Normal portion of Golden Rice 2 provides half of a child's Vitamin A needs

# NO MAGIC BULLET

A second cereal crop is also nutritionally deficient in:

Vitamins
Minerals
Amino acids
(like most cereals)

But, uniquely, it is also

Poorly Digested

What is this crop?

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University of California, Berkeley joins Africa Biofortified Sorghum (ABS) project

## University of California, Berkeley Scientists join Africa Biofortified Sorghum Project

The Africa Biofortified Sorghum (ABS) project is funded by a $17.6 million grant from the Grand Challenges in Global Health initiative to Africa Harvest Biotechnology Foundation International, a non-profit organization dedicated to fighting hunger and poverty in Africa.

"Our goal is to develop sorghum that will provide increased calories and needed protein in the diet of African consumers," said Bob B. Buchanan, UC Berkeley professor of plant and microbial biology and one of the lead scientists on the project. "We are extremely happy to offer our expertise and materials for this important project for the public good."

The announcement of UC Berkeley's participation was made from Nairobi, Kenya, today (Monday, April 10) by project leader Florence Wambugu. "All the project consortium members are delighted that researchers from UC Berkeley will be joining the team," said Wambugu, who is a plant pathologist and CEO of Africa Harvest. "Their contribution will provide a second avenue to ensure success in achieving the important goal of increasing digestibility of sorghum."

Peggy G. Lemaux, UC Berkeley Cooperative Extension specialist in plant and microbial biology, and Bob Buchanan, professor of plant and microbial biology, inspect sorghum plants in a controlled temperature growth room. (Rosemary Alonso photo)

The Grand Challenges in Global Health initiative is supporting nutritional improvement of four staple crops - sorghum, cassava, bananas and rice - as one of its 14 "grand challenges" projects that focus on using science and technology to dramatically improve health in the world's poorest countries. The initiative is funded by the Bill & Melinda Gates Foundation, the Wellcome Trust, and the Canadian Institutes of Health Research.

In June 2005, the initiative awarded $16.94 million to Africa Harvest to head a consortium of public and private research institutes for the ABS project. The Gates Foundation has just supplemented this amount with $627,932

Sorghum was chosen as one target for nutritional improvement by the Bill and Melinda Gates Foundation Grand Challenges for Global Health – a project in which my lab and Bob Buchanan's participated.

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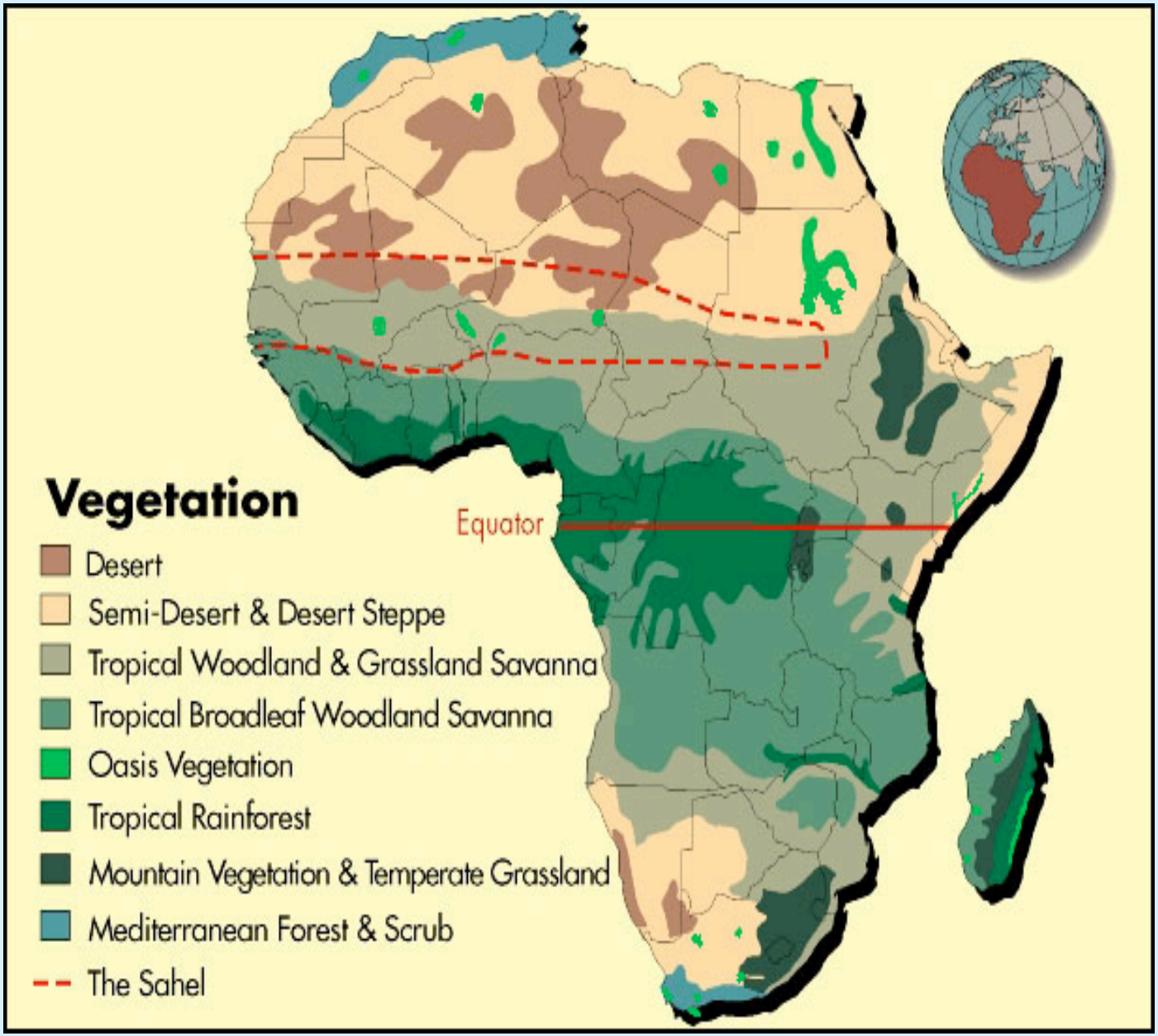
# Why Pick Sorghum as a Target?

- Fifth most important food grain worldwide
- 90% grown in Africa and Asia in arid and semi-arid regions
- Staple food for 300 million in Africa and, like rice, is nutritionally deficient

Cultivated sorghum

Wild outcrossing species

# Sorghum is uniquely adapted to Africa's climate – withstanding both drought and water logging



Recently success of the first nutritional improvement was announced. Sorghum was engineered to make provitamin A, a compound that is converted to vitamin A in the body.

The ABS Project has produced the world's first golden sorghum enabling pro-vitamin A to be used as the visible marker for final ABS product

## ABS Project Produces
# World's First Golden Sorghum

Africa Harvest CEO and Coordinator of the Africa Biofortified Sorghum (ABS) Project, Dr. Florence Wambugu, told a recent Bio2Biz SA Forum in South African that the Project had produced the world's first golden sorghum "enabling pro-vitamin A to be used as the visible marker for final ABS product".

Making her presentation "ABS Project: Networking African & International Biotech Capacities to Deliver a Nutrient Rich Product to the Needy", Dr. Wambugu said the new development was made by Pioneer scientists. She said the project has been able to significantly increase transformation efficiency, paving the way for it to transit into the Product Development & Deployment phase.

Dr. Wambugu told scientists drawn from South African research institutions and the private sector that the ABS Project had trained 11 African scientists and breeders in a short period of less than five years. She said the project had conducted six field trials in four years and contained greenhouse work was continuing in Kenya and South Africa.

Bio2Biz SA is hosted by South Africa's Biotechnology Innovation Centres (BICs) comprising of BioPAD, Cape Biotech, LIFElab and PlantBio, together with the Innovation Fund and eGoli Bio. It brings together biotechnology researchers and industry to create mutually beneficial relationships. This year, the meeting was held at the Durban International Conference Centre (ICC) from September 20th to 23rd.

But digestibility remains a problem because…

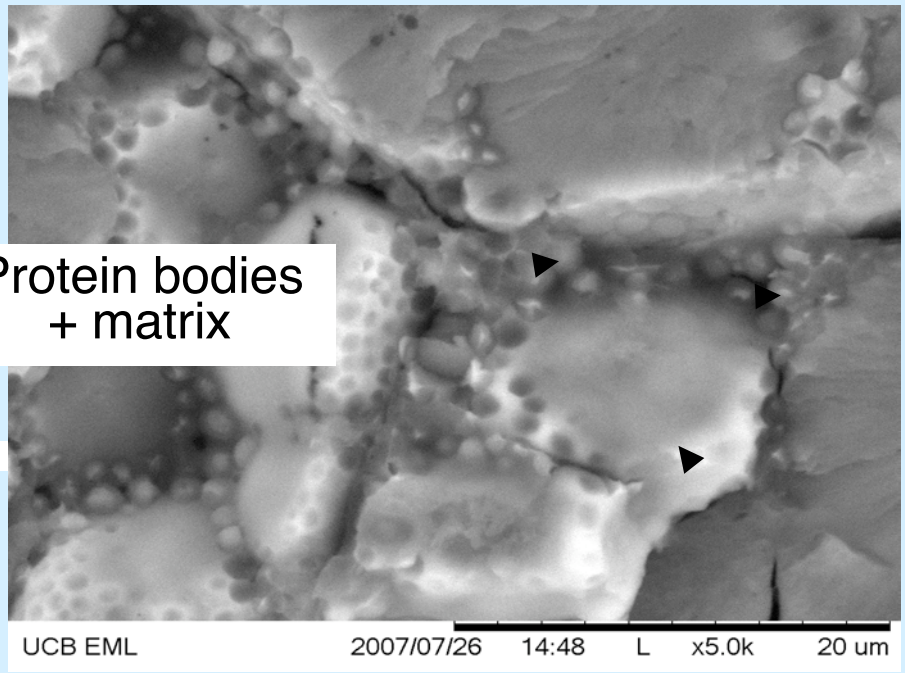
In Africa, 74% of sorghum is consumed at home as cooked porridge

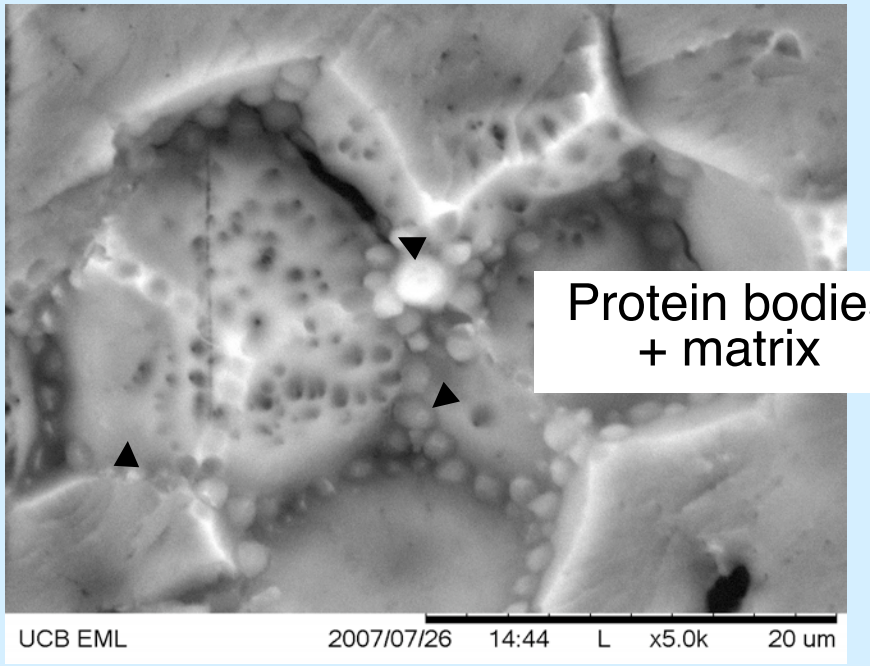
Elderly woman making cooked sorghum porridge

But, of major cereals, sorghum is the least digestible following cooking

| | % Digestibility | | |
|---|---|---|---|
| **Cereal** | **Uncooked** | **Cooked** | **Decrease** |
| **Sorghum** | **80.8** | **56.3** | **24.5** ◄ |
| **Maize** | **83.4** | **79.3** | **4.1** ◄ |
| **Barley** | **93.2** | **80.2** | **13.0** |
| **Rice** | **91.1** | **82.1** | **9.1** |
| **Wheat** | **91.3** | **85.9** | **5.4** |

Our efforts continue on improving digestibility by interfering with the chemical connections between proteins that interfere with starch and protein digestibility upon cooking.




Starch granules

# Some Concluding Thoughts


Are Genetically Engineered Crops a Magic Bullet?

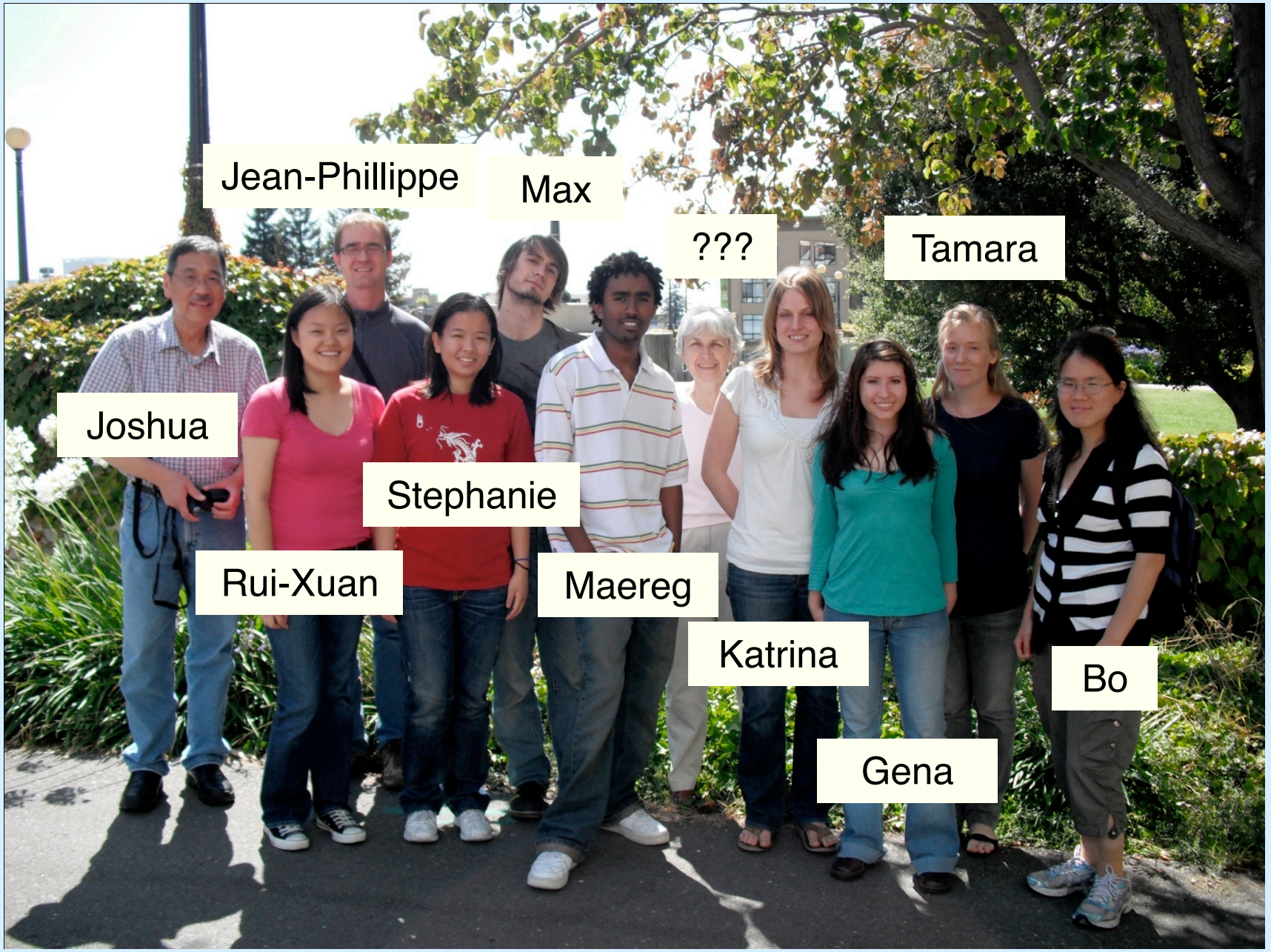
Is Farming Conventionally a Magic Bullet?



Is Farming Using Organic Practices a Magic Bullet?

As populations continue to increase, producing and distributing adequate food will become even more complex - requiring all skills and technologies available. The wise use of the best of each of these approaches offers a possible means to achieve sustainable food production to feed the world's populations.


For more information: see http://ucbiotech.org and Lemaux PG. *Annual Review of Plant Biology* 2008 and 2009




**2009 Summer UC Berkeley SORGHUM Crew**