FEAST, FAMINE and the FUTURE of FOOD

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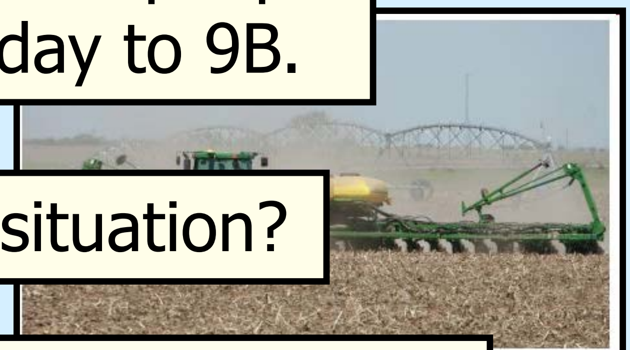
Images of our world today raise issues of population explosion and the food production required.

In less than 40 years number of people is to increase from 6.7B today to 9B.

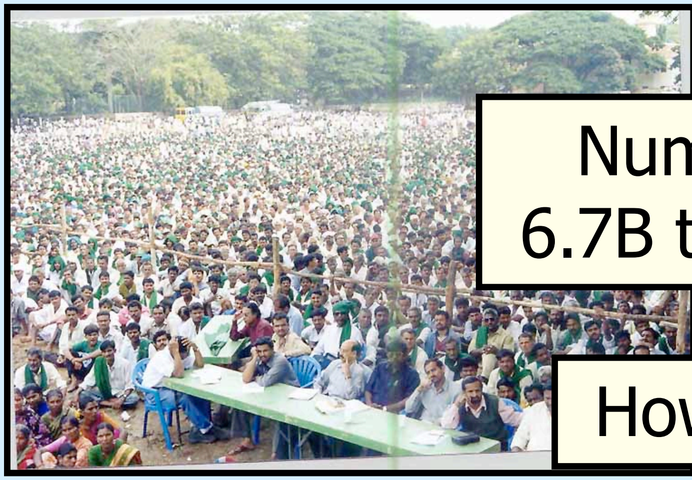


How did we get into this situation?

Increased food demand will require world ag production to rise by 50% in less than 20 years

What will we do about it?

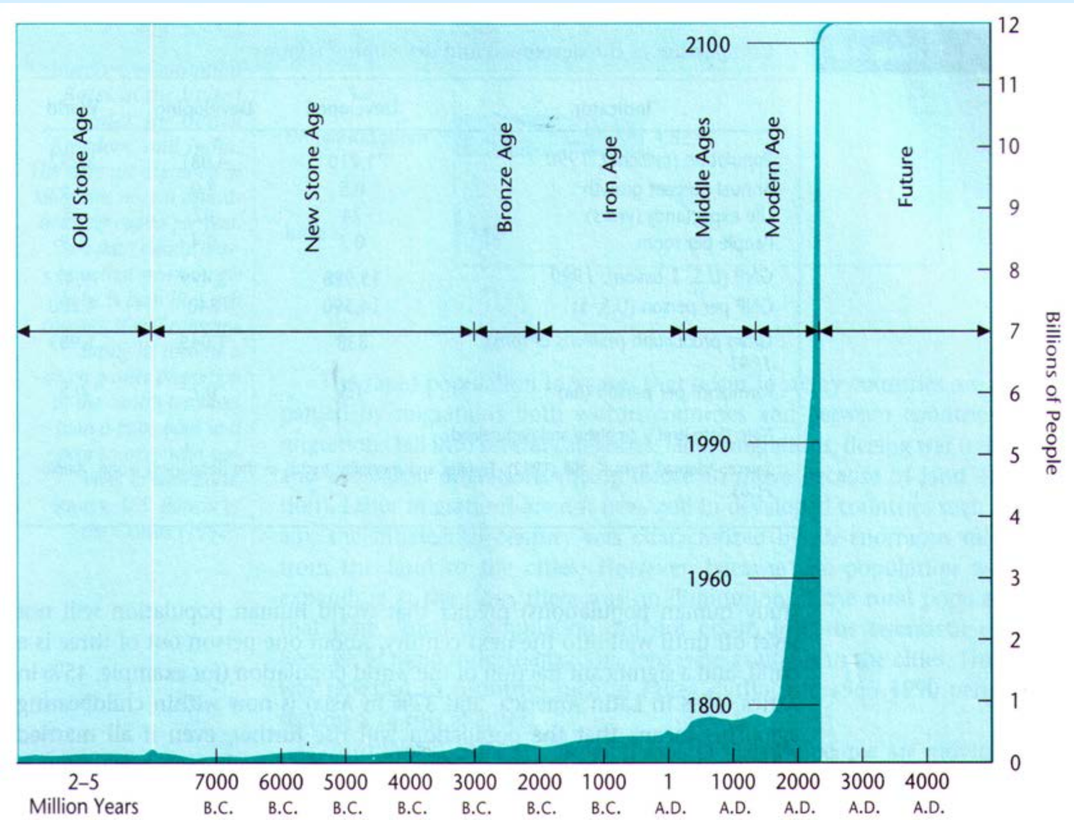
Images of our world today bring up issues of population explosion and food production required.



Number of people to increase from 6.7B today to 9B in less than 40 years.

How did we get into this situation?

2,000 years ago – there were 300 million people worldwide – that's approximately same as it is in just the U.S. today!



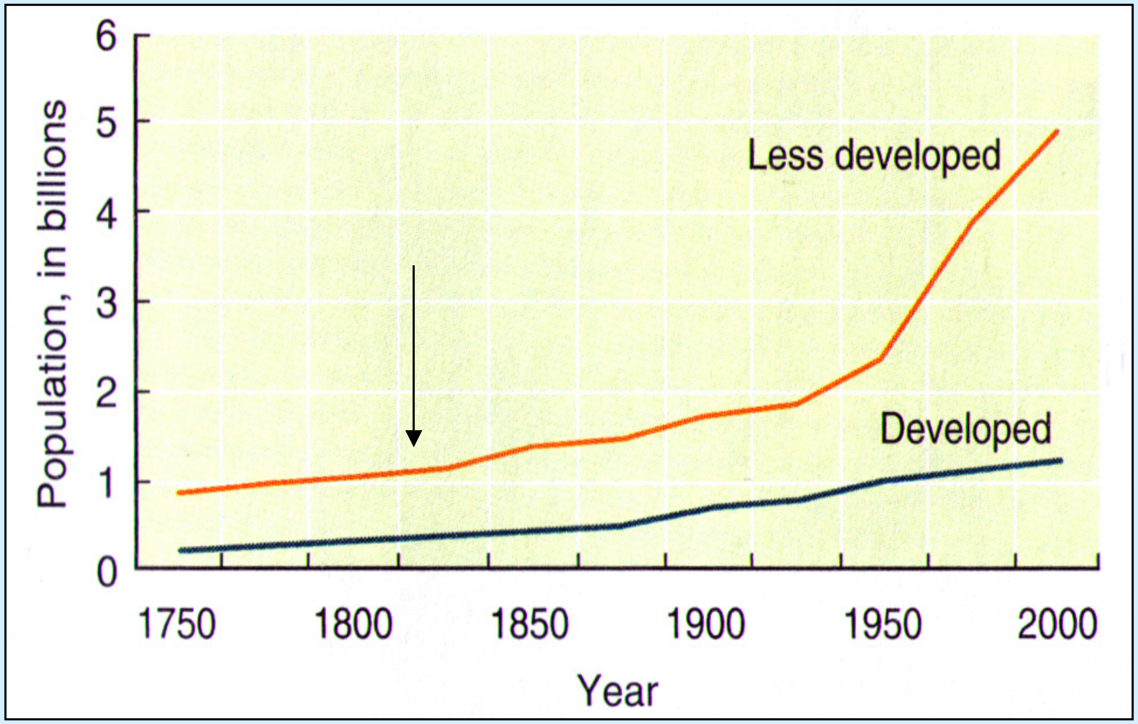
2000 years ago:
500 people were added to the world each day.

Today: 400 times more people per day are added: 200,000!

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

Long ago hunter/gatherer lifestyles led to moderately high birth and death rates.

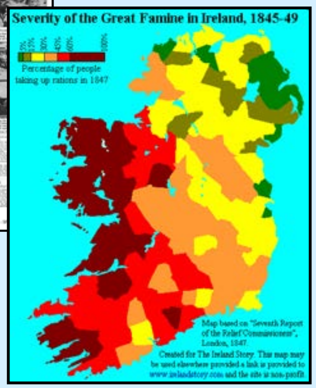
~10,000 years ago, agriculture began replacing hunting and gathering.



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

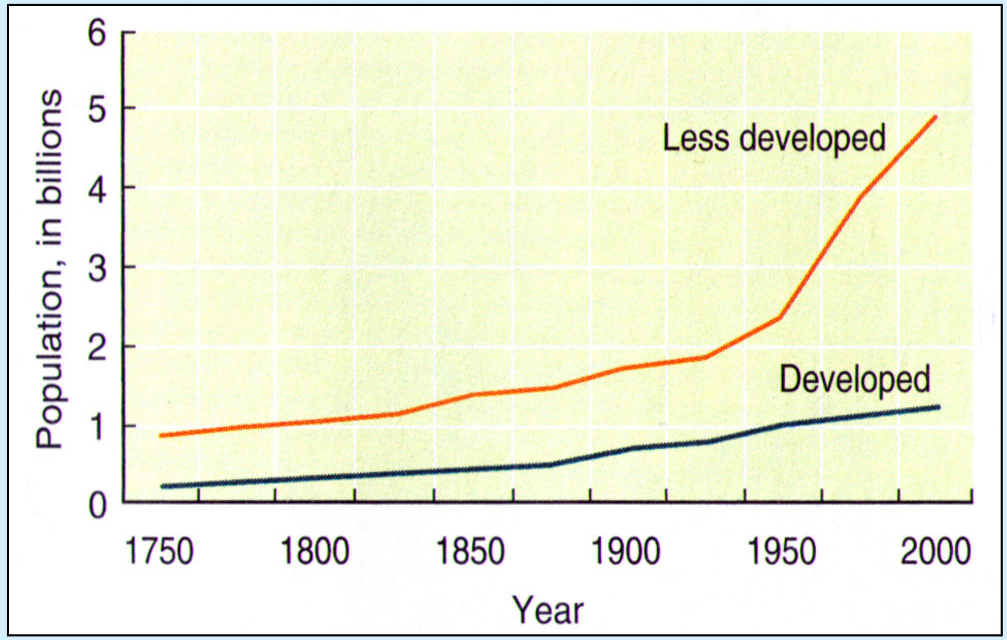
kept populations down

Dramatic population explosion in last 80 years.

Why?

Rising income = more people could buy food

Improved housing/ public hygiene = decrease in infectious disease



Food production more dependable due to improved transportation

Medical advances due to 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 hundreds of years

In Asia, Africa, Latin America, improvements happened "overnight" (last 50 years) with populations growing 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

This led to 16-fold increase in population in less developed countries

WHY?

But grain production did not keep up at 1.5-fold

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

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

to urban areas, as a result of industrialization.

This put increased pressure on agricultural systems

But that's not the whole story: types of foods eaten also affect 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.

Less developed countries' protein needs were satisfied by cereals + beans. Now shifting to milk and meat – affecting ag production. Why?

Transfer of energy efficiency from plants to humans through beef is ~1%!!

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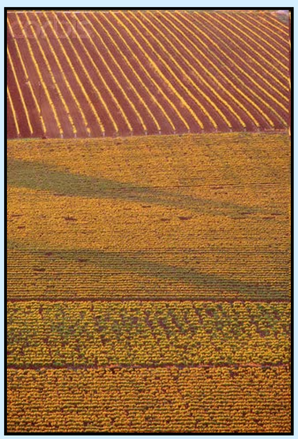
SOURCE: "Plants, Genes, and Agriculture", Chrispeels, M.J. and Sadava, D.E. (editors) 1994.

In the past 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 land size has remained steady, causing amount of cultivated land per person to drop by 25%.

This loss was compensated for by increased crop productivity.

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

What do farmers produce?

Globally 300 crops provide food…
24 supply most of the food and feed...
8 supply 85%!

Three account for over half of our food - directly or indirectly.

Wheat

Corn

Rice

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

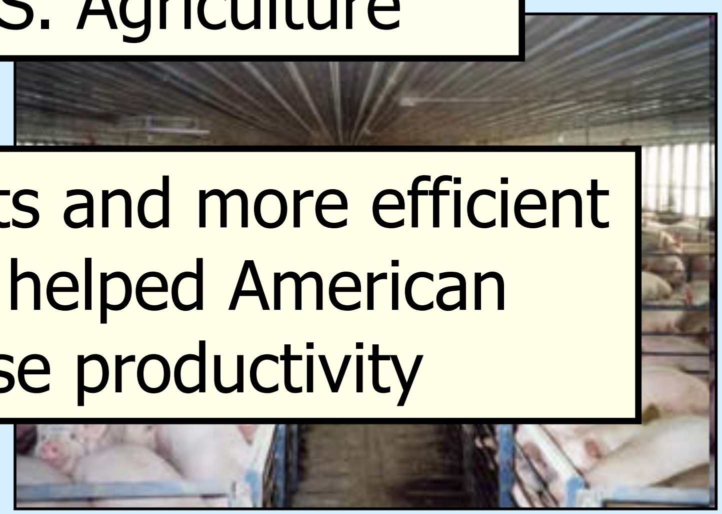
BOTH DECREASED

But productivity of average US farmer INCREASED…

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

At first it doesn't look good

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

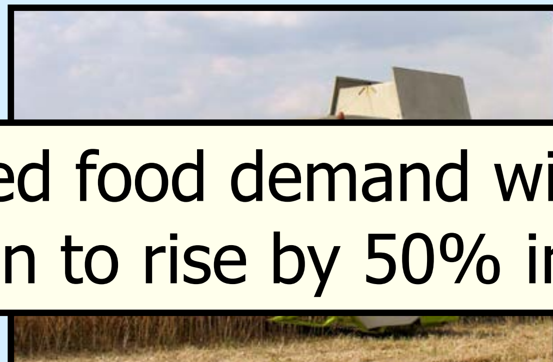


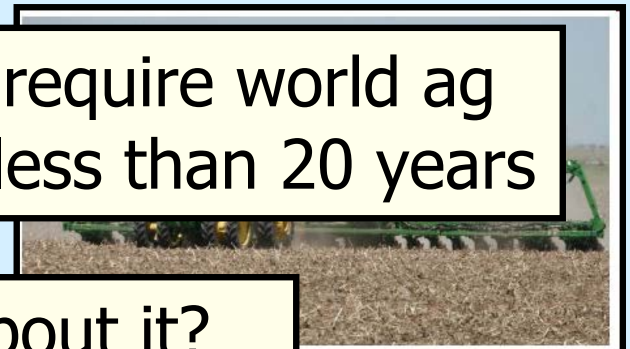
Genetic improvements and more efficient farming practices helped American farmers increase productivity

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

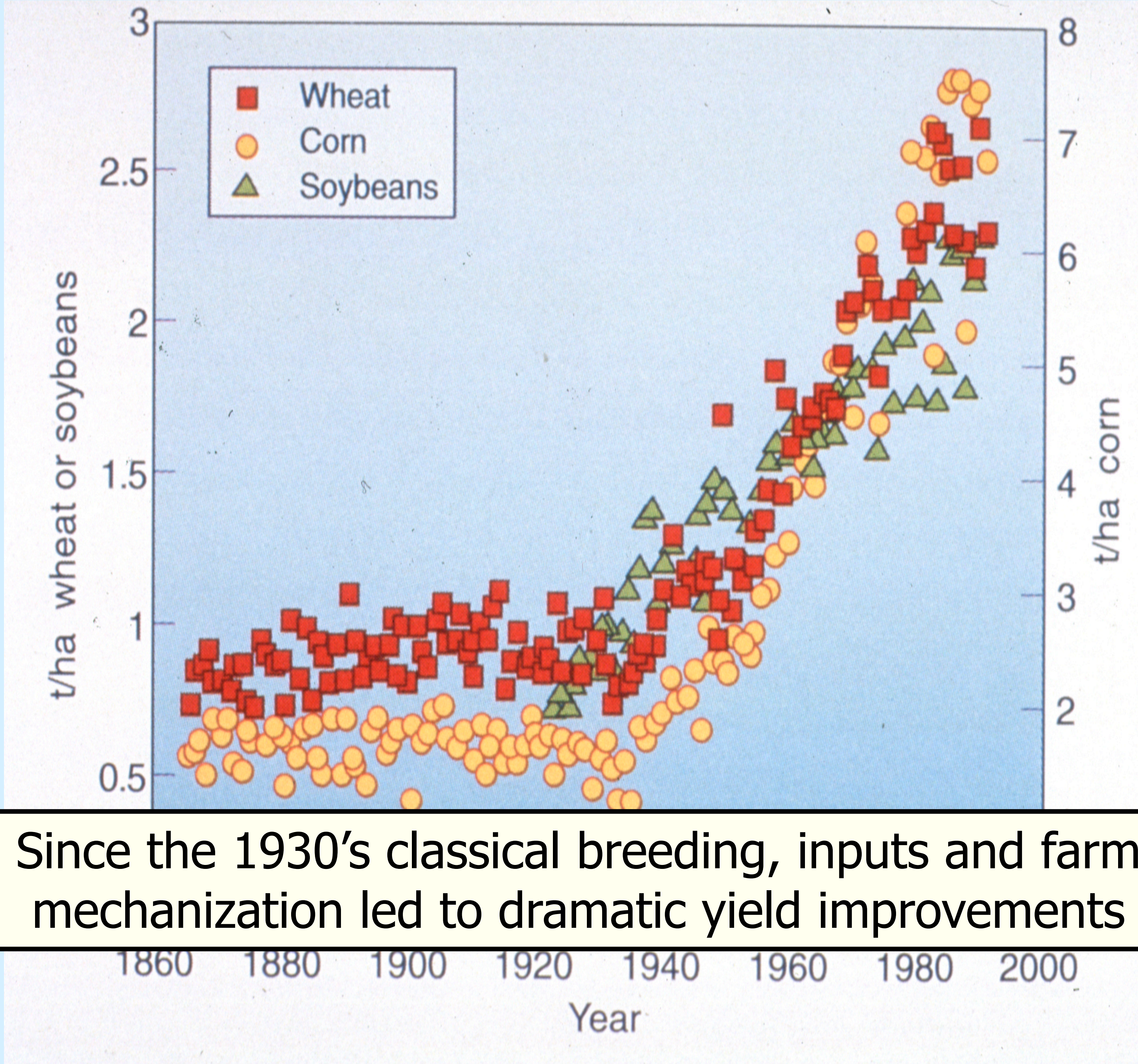
Images of our world today bring up issues of population explosion and food production required.





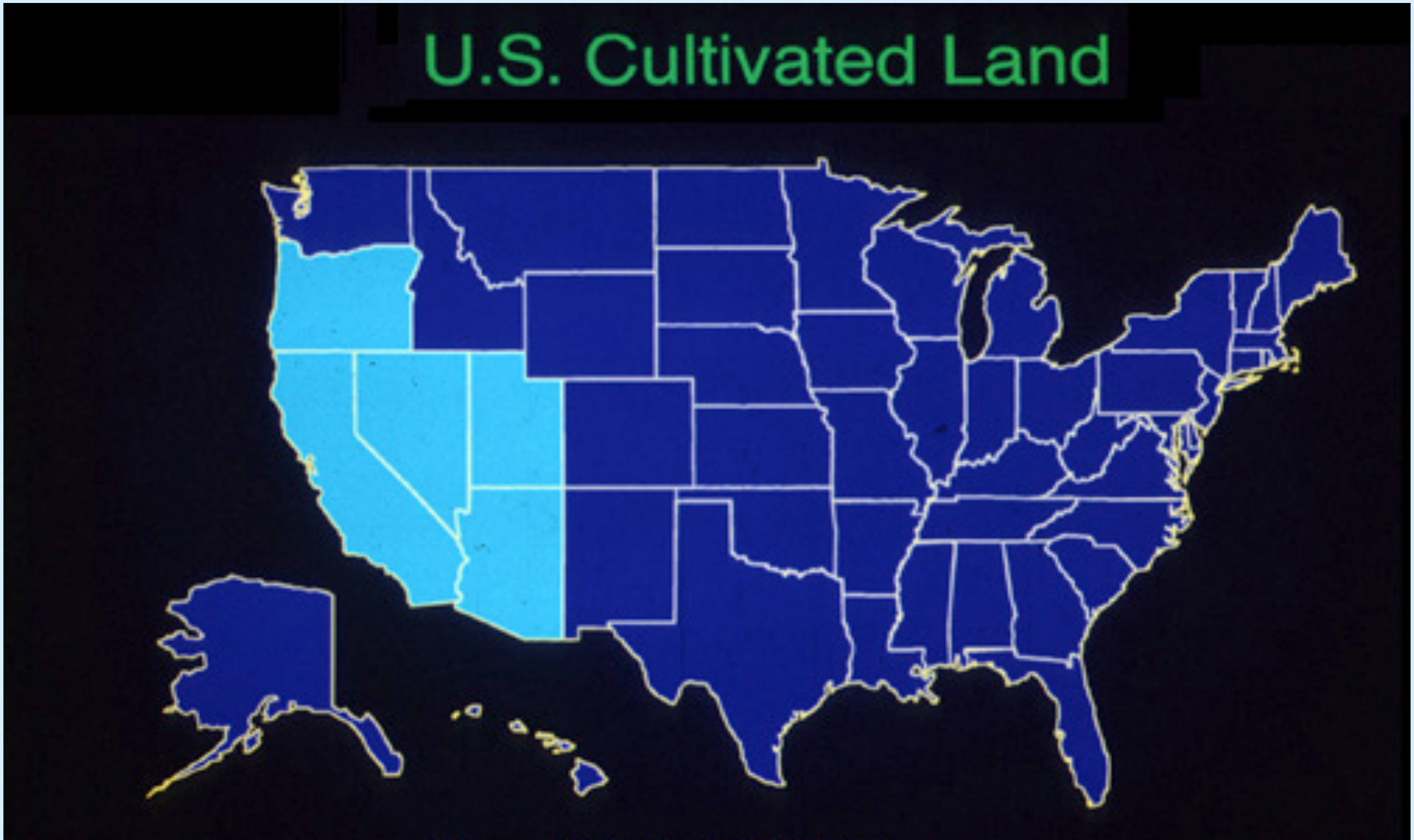
Increased food demand will require world ag production to rise by 50% in less than 20 years

What will we do about it?



Since the 1930's classical breeding, inputs and farm mechanization led to dramatic yield improvements

From the acreage that would have been needed to feed the U.S. at 1929 production levels to…



To that which is needed with 1987 production levels.

The problems are complex and require the best of a diverse number of approaches.

It is important to realize there is no one magic bullet for these challenges!

In the past how did we use genetics to create higher yielding varieties?

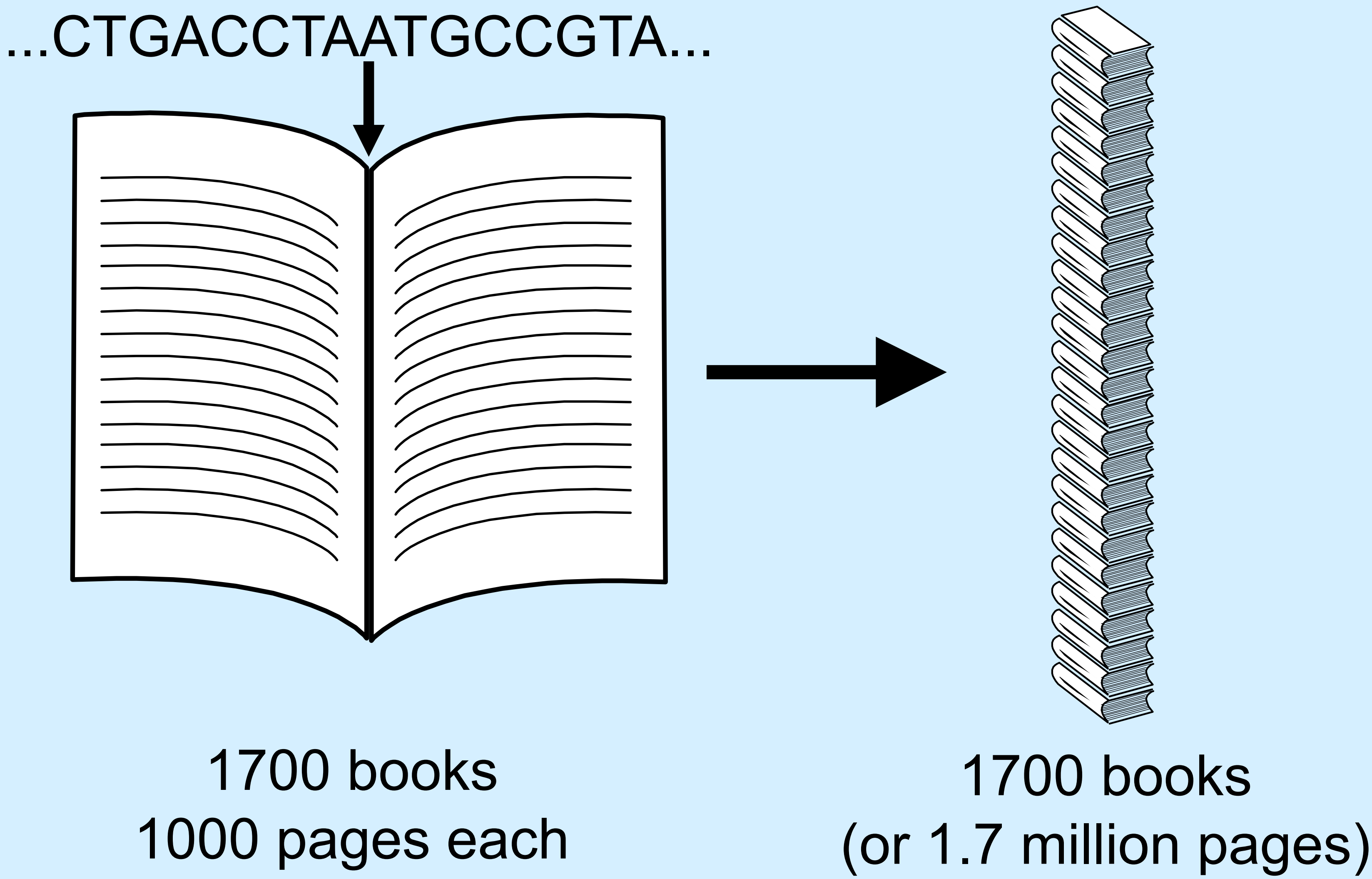
Classical breeding

Triticum aestivum
Modern bread variety

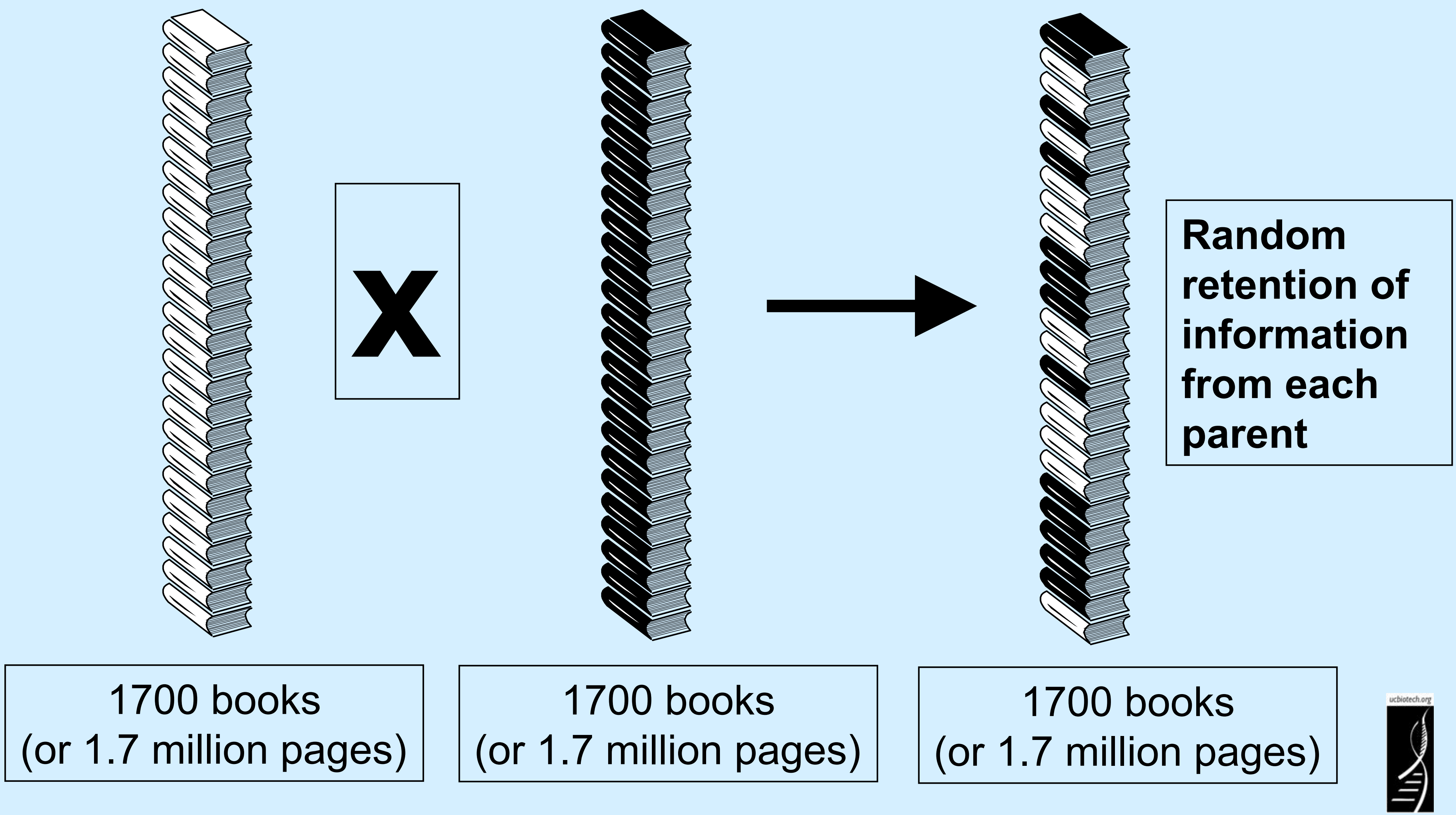
Triticum monococcum
Ancient variety

Information in the wheat genome

Chemical units represented by alphabetic letters



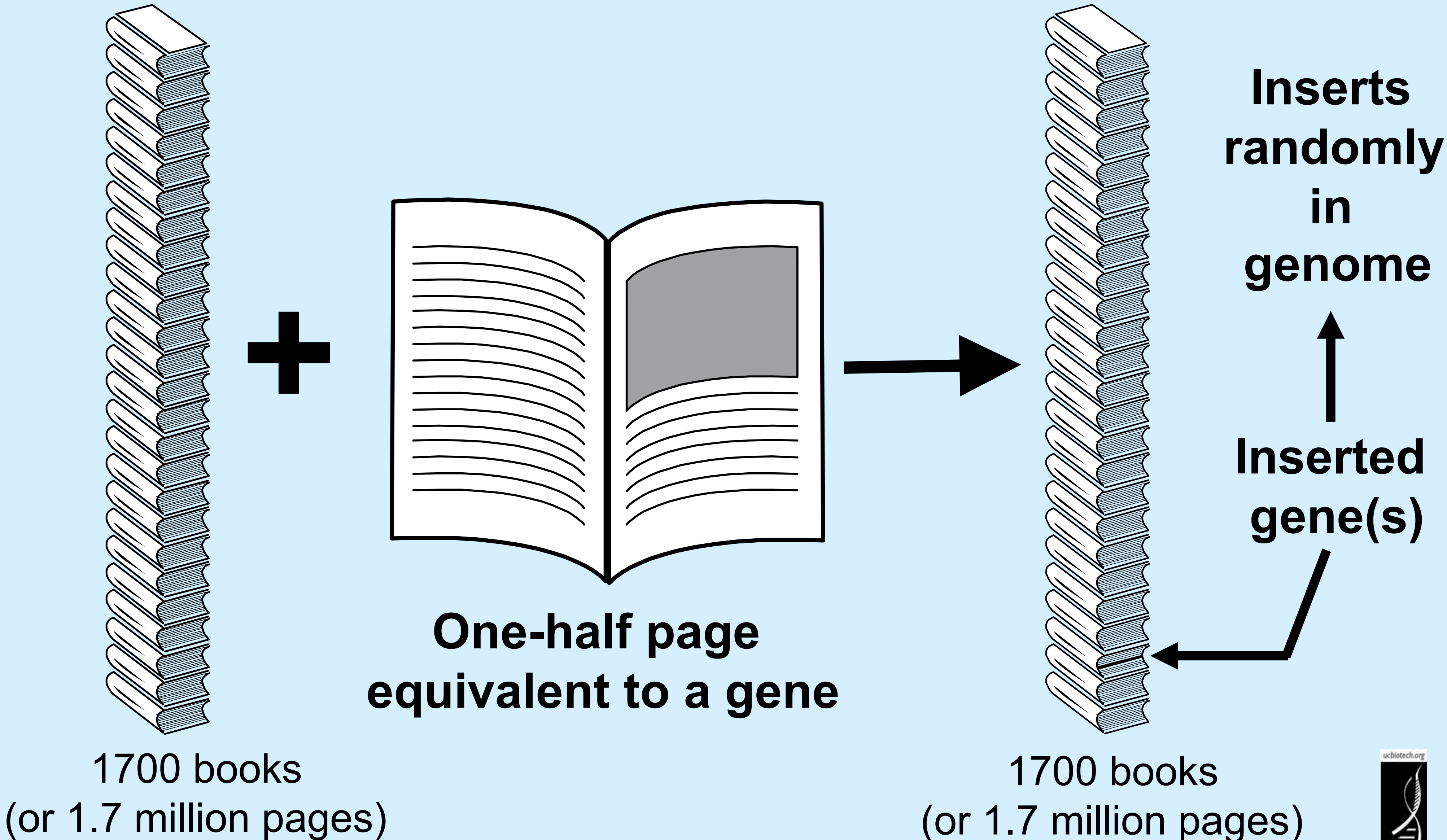
Hybridization or cross breeding of wheat



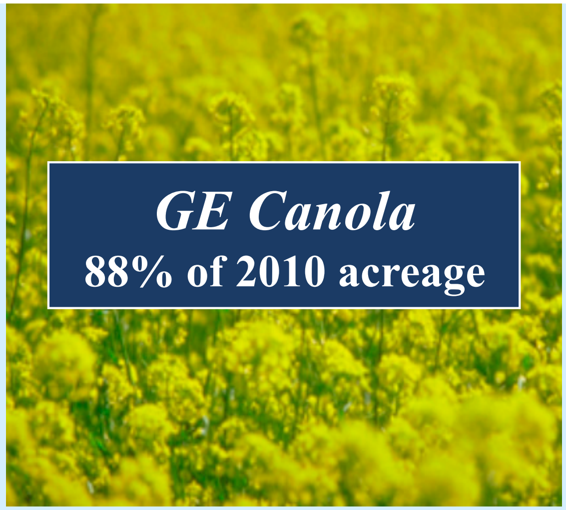
What about new genetic approaches being used to create crops?

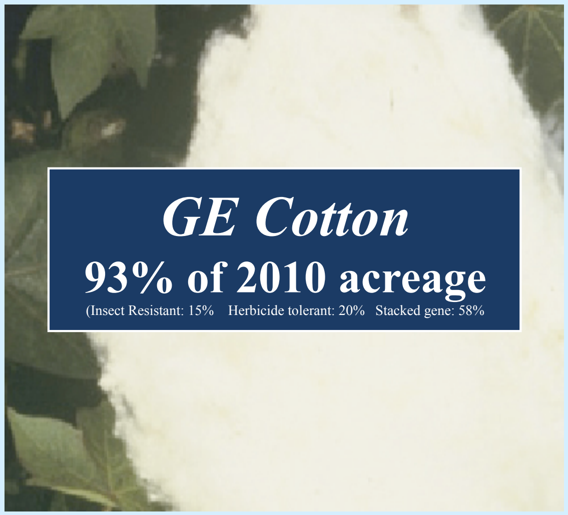
Genetic Engineering

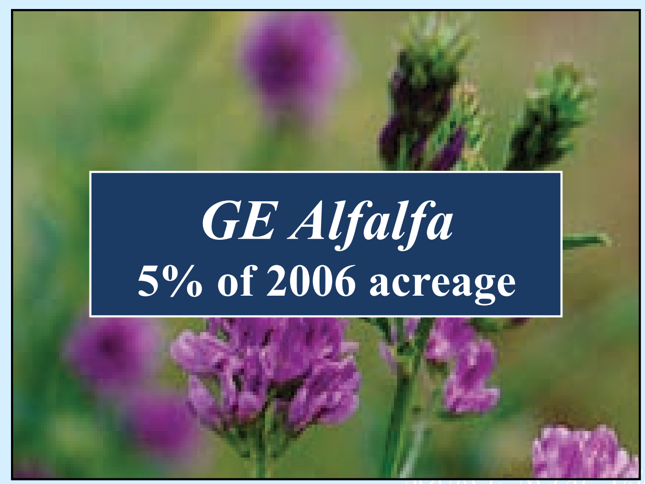
Genetic Engineering Methods



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



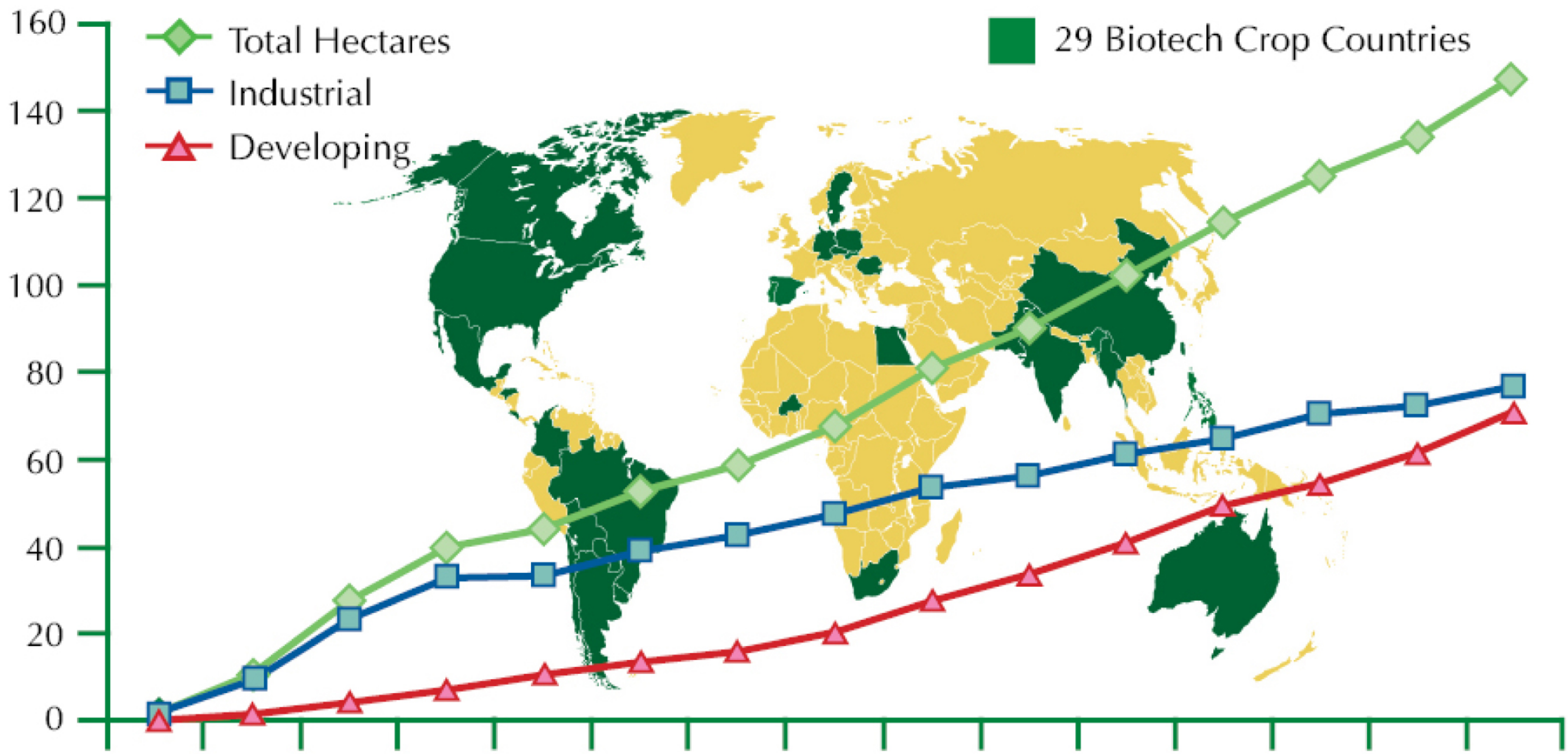




Only a few whole foods on the market are genetically engineered

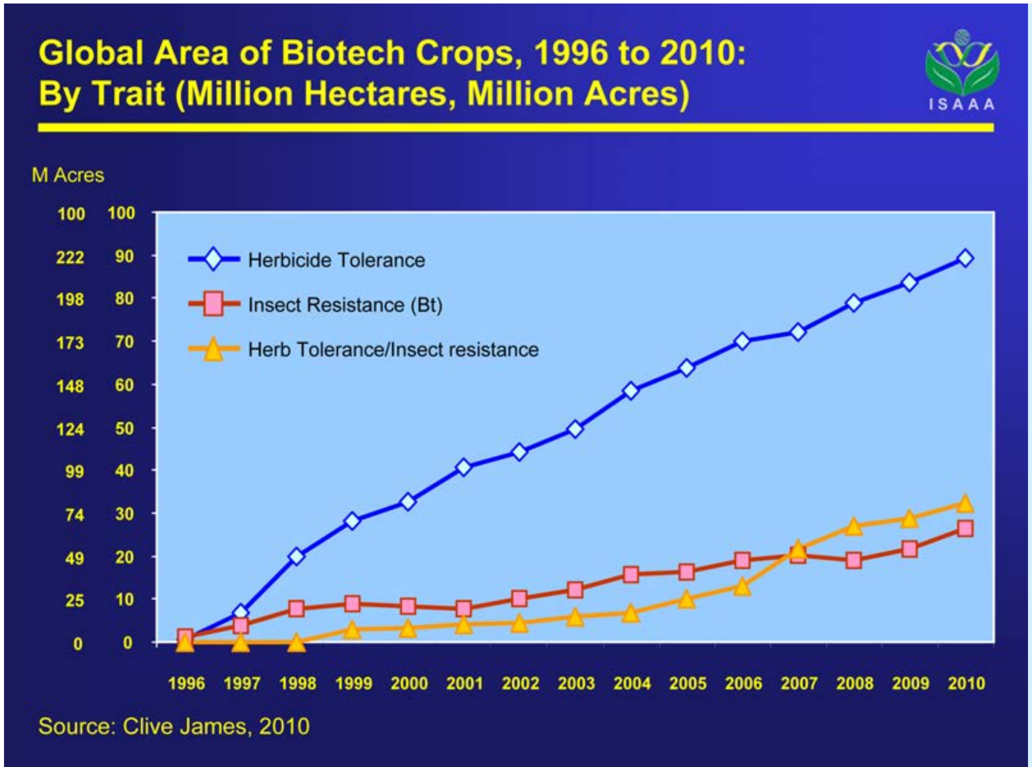
What is the situation with GE crops worldwide?

GLOBAL AREA OF BIOTECH CROPS
Million Hectares (1996-2010)



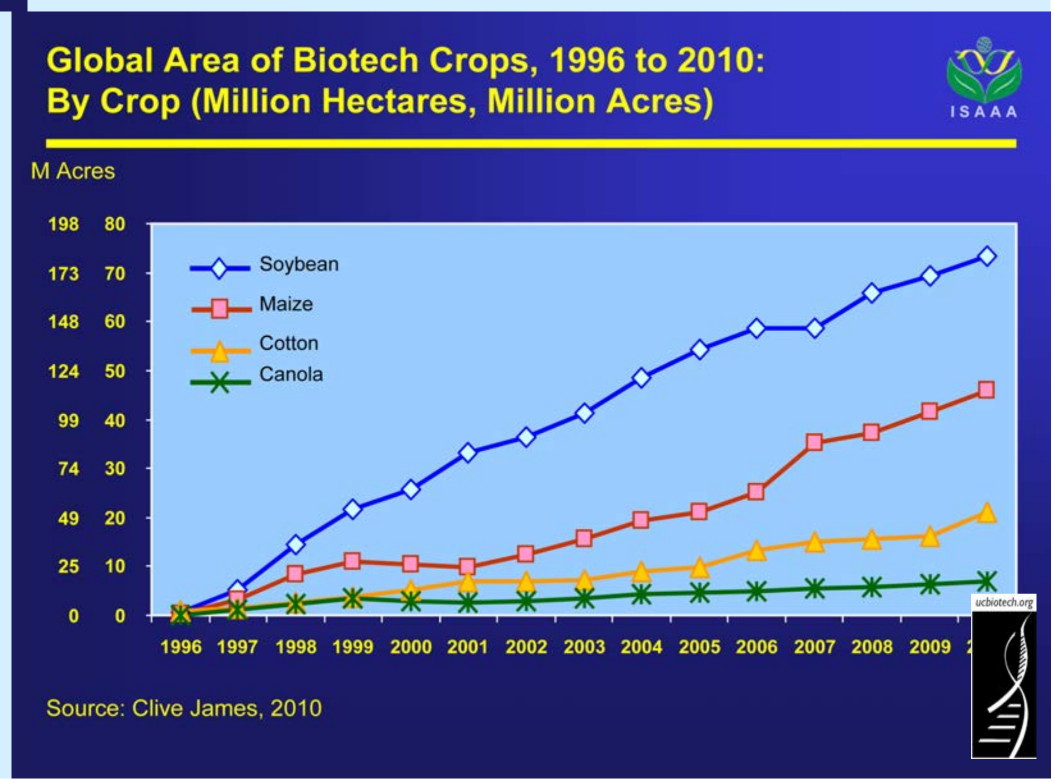
Recent figures indicated 15.4 million farmers in 29 countries planted 365M acres (~6X Oregon's size) – **over 90% were small resource-poor farmers in developing countries**

Source: Clive James, 2010.



But advances for these farmers are only in a limited number of crops – not necessarily those of most value to developing countries and…

…they have a limited number of traits. Does this really serve the needs of developing countries?



USA TODAY

More of world's crops are genetically engineered

By Elizabeth Weise, USA TODAY

February 23, 2011

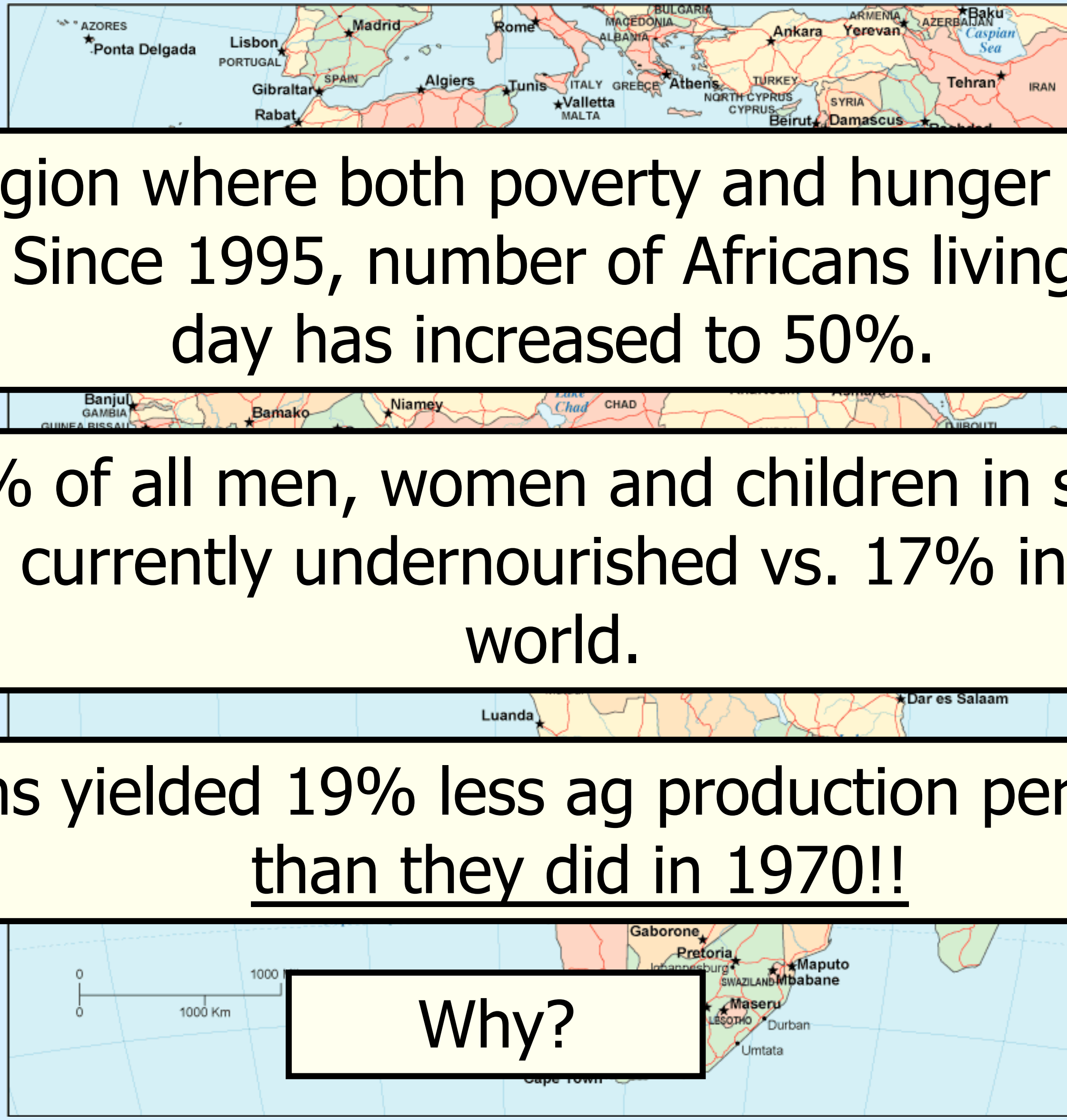
The amount of land devoted to genetically engineered crops grew 10% last year, and 7% in the year before, as farmers in major grain and soy exporting countries such

Lemaux says "because of the expenses involved, creating engineered crops for developing countries requires humanitarian contributions by philanthropists like (Bill) Gates and the Rockefeller Foundation, or perhaps by companies who see value in such endeavors."

And, although many academic scientists would like to play a meaningful role, they have limited resources to do so.

SOURCE: "More of world's crops are genetically engineered", USA Today, February 23, 2011. http://www.usatoday.com/tech/news/biotech/2011-02-22-biotech-crops_N.htm

The situation with agricultural production in less developed countries requires a different perspective. Why?
Let's look at the situation in Africa.



Only region where both poverty and hunger continue increasing. Since 1995, number of Africans living on <$1 per day has increased to 50%.

Nearly 33% of all men, women and children in sub-Saharan Africa are currently undernourished vs. 17% in developed world.

African farms yielded 19% less ag 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

And most Africans do not have access to the diversity of foods available in the developed world to satisfy their dietary needs.

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

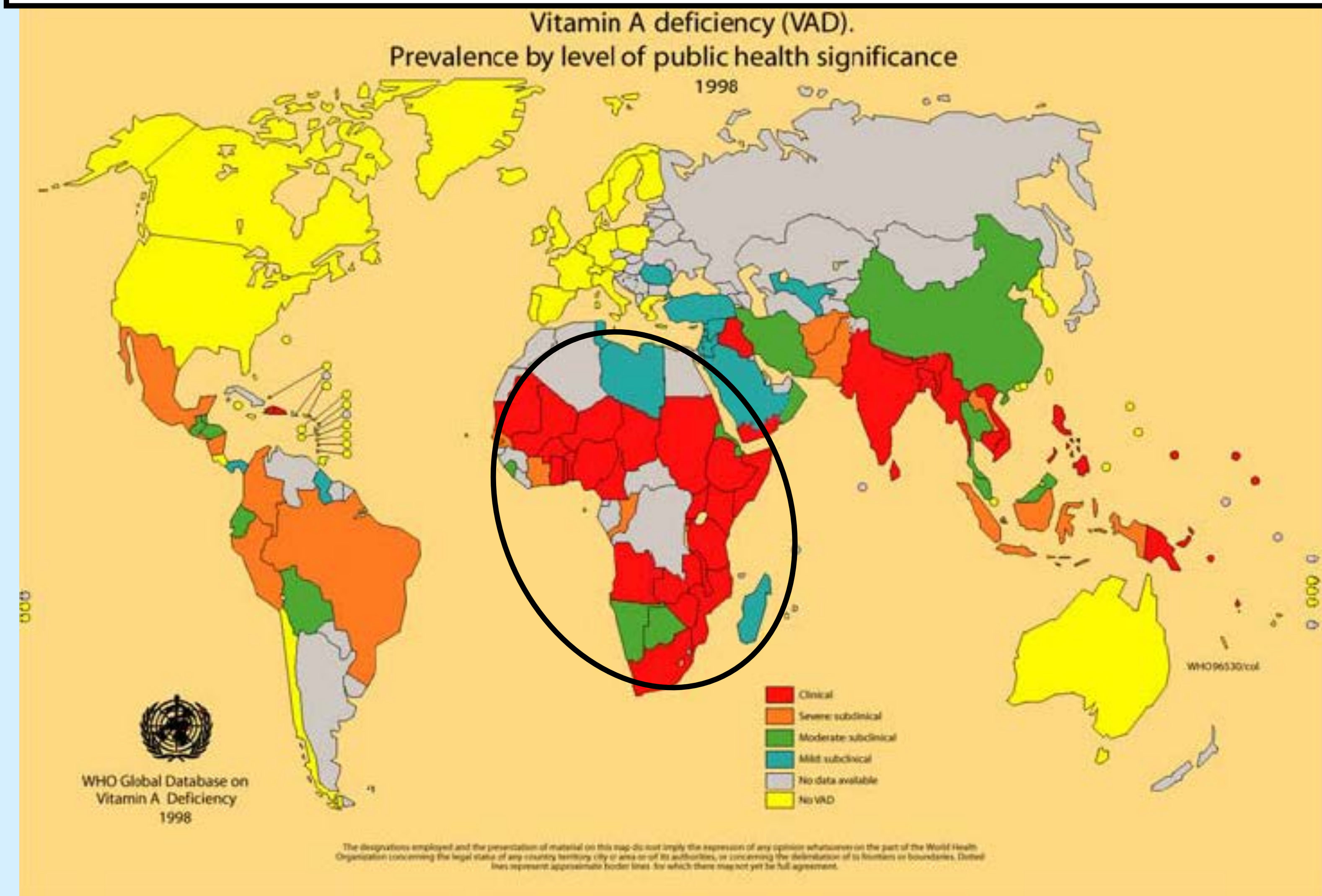
Can biological improvements in crops help?
Focus on Two Examples

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

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

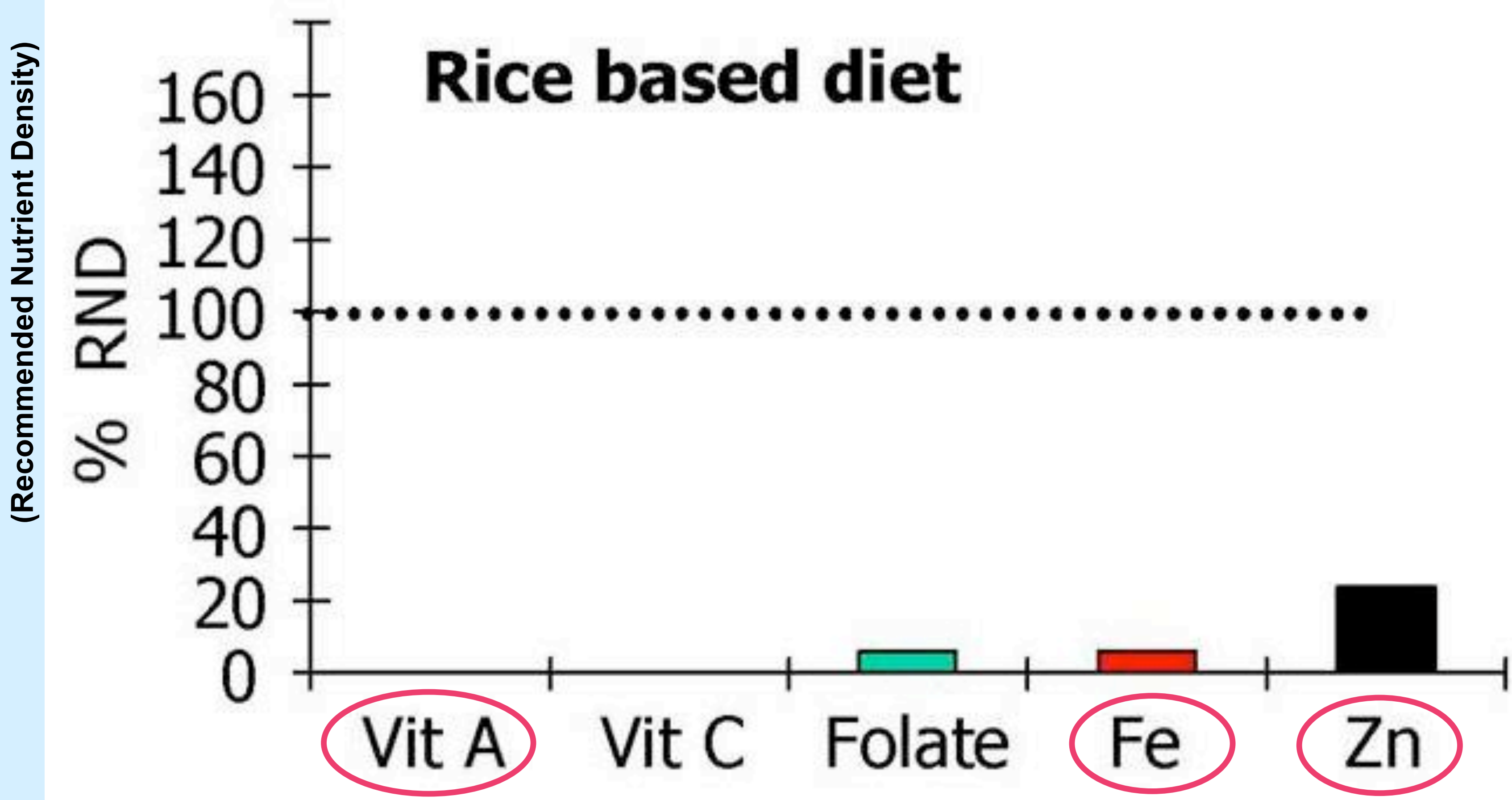
Vitamin A deficiency

Cause of severe health problems, vision loss, poor brain development, immune system failure.



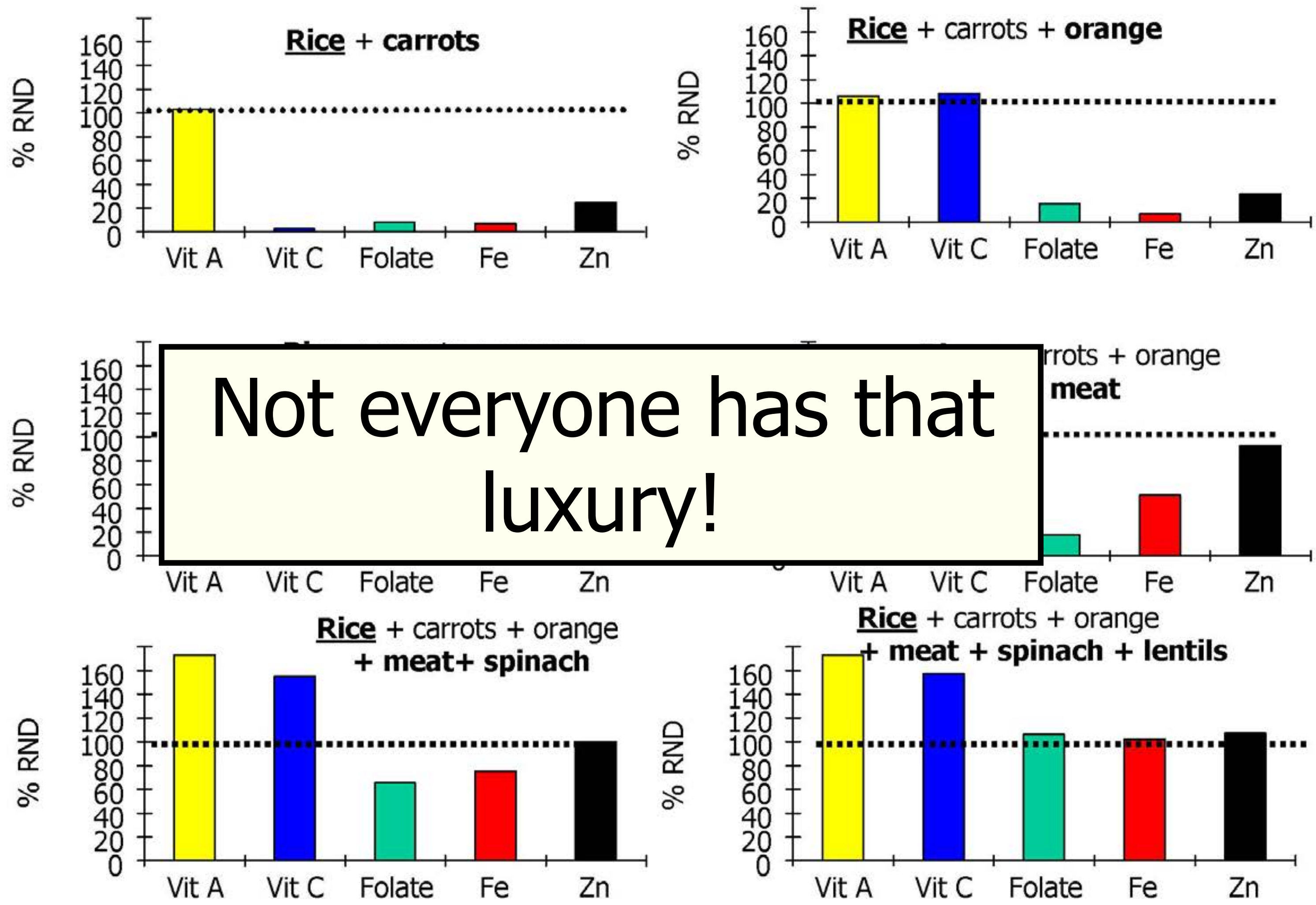
Modified from G. Barry, IRRI

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



Not everyone has that luxury!

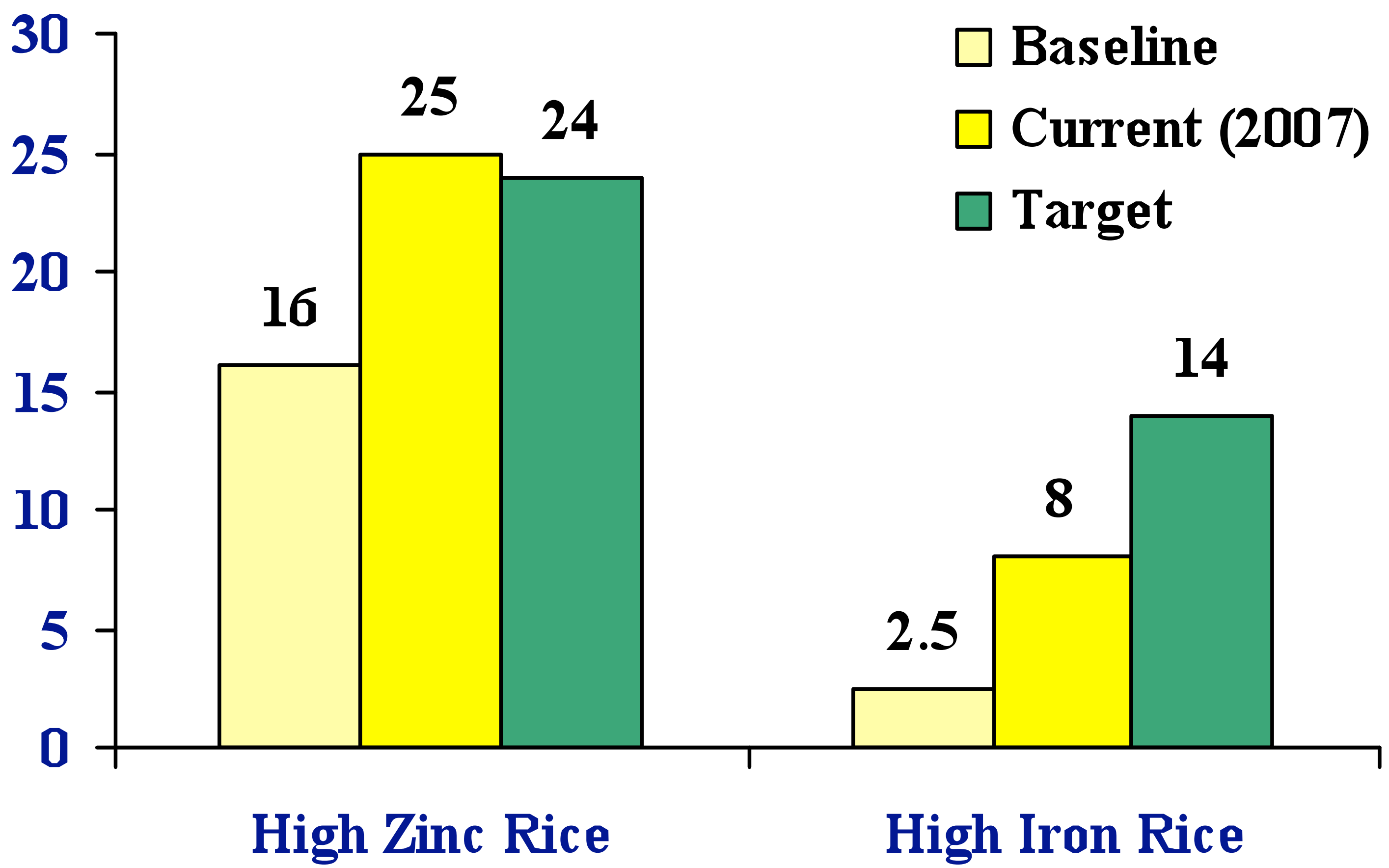
Can't rice diets just be supplemented with other fruits, vegetables and meat to add these nutrients?

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 classical breeding crosses 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

Basic Carotenoid Biosynthetic Pathway

Carotenes

Genes used to engineer rice to make provitamin A

IPP ⇄ **DMAPP**

↓

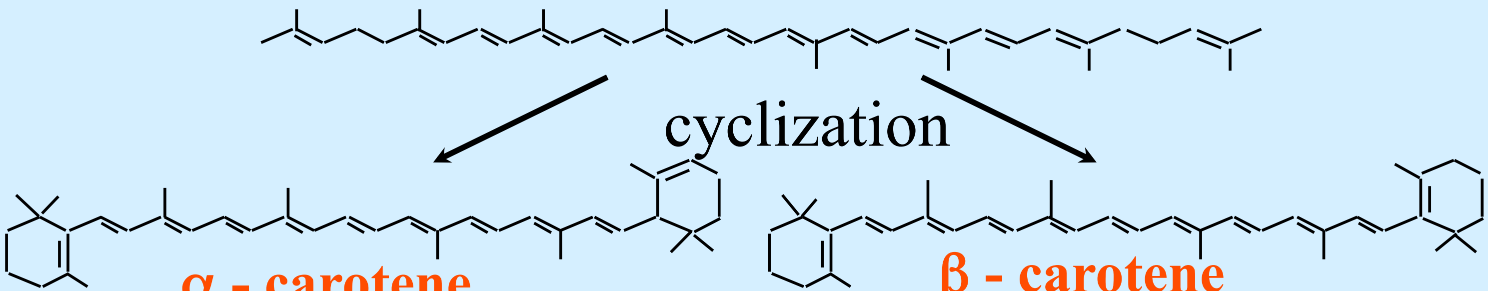
GGPP (C20)

Phytoene synthase → ↓
Maize

Phytoene (C40)

Phytoene desaturase → ↓ desaturation
Bacterial source

Lycopene (C40)



β-carotene/other provitamin A carotenoids are converted to Vitamin A as needed in the body.

Golden Rice was engineered to make provitamin A

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

NO MAGIC BULLET

Second cereal that is important in developing countries and also nutritionally deficient in:

Vitamins
Minerals
Amino acids
(like most cereals)

but, uniquely, 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

million people in Africa who rely on sorghum as a principal source of food.

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 to fund the work of Buchanan and co-researcher Peggy G. Lemaux, UC Berkeley Cooperative Extension specialist

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

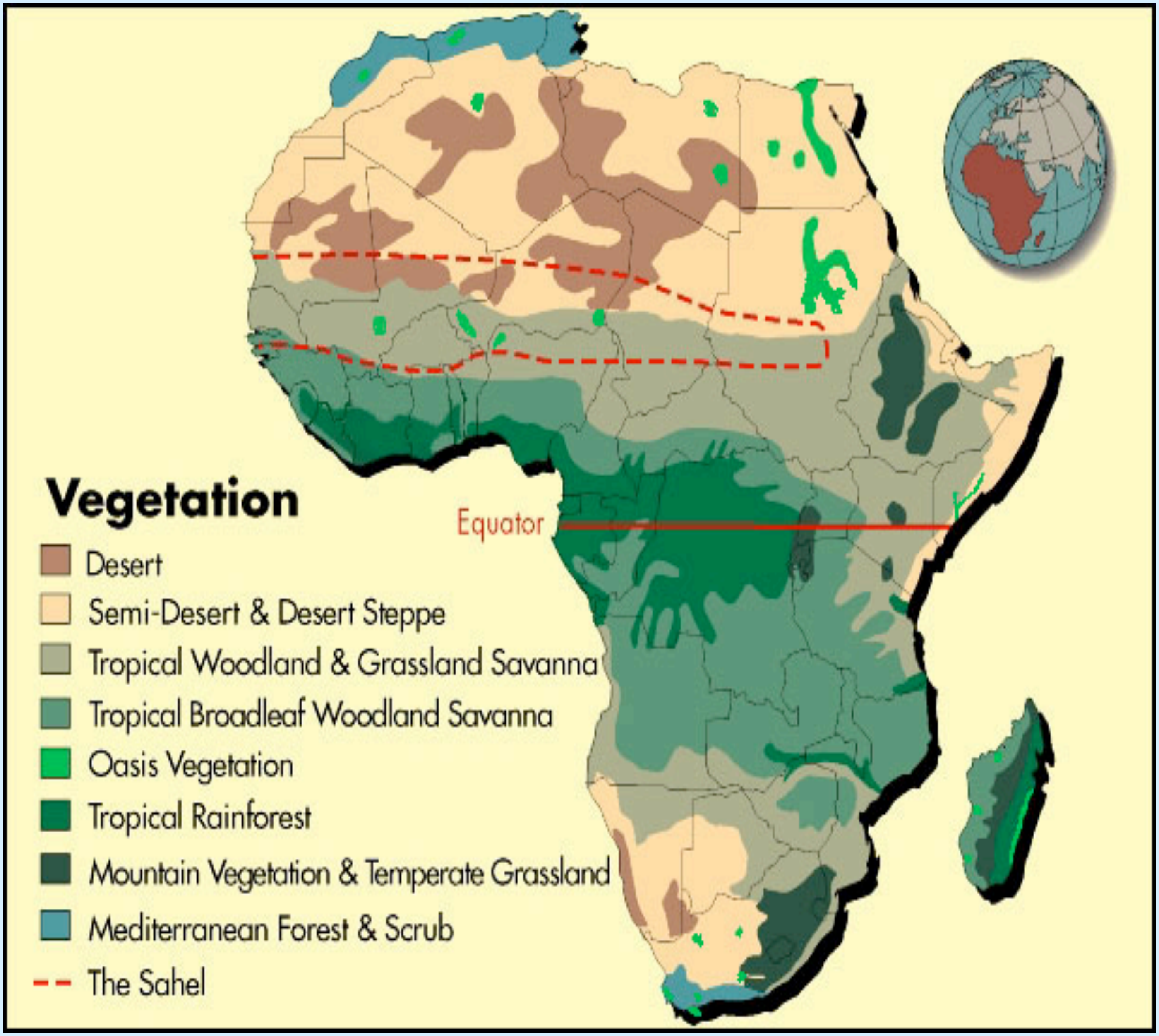
Why Pick Sorghum?

- 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



First successful nutritional improvement in sorghum was engineering to make provitamin A, 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…

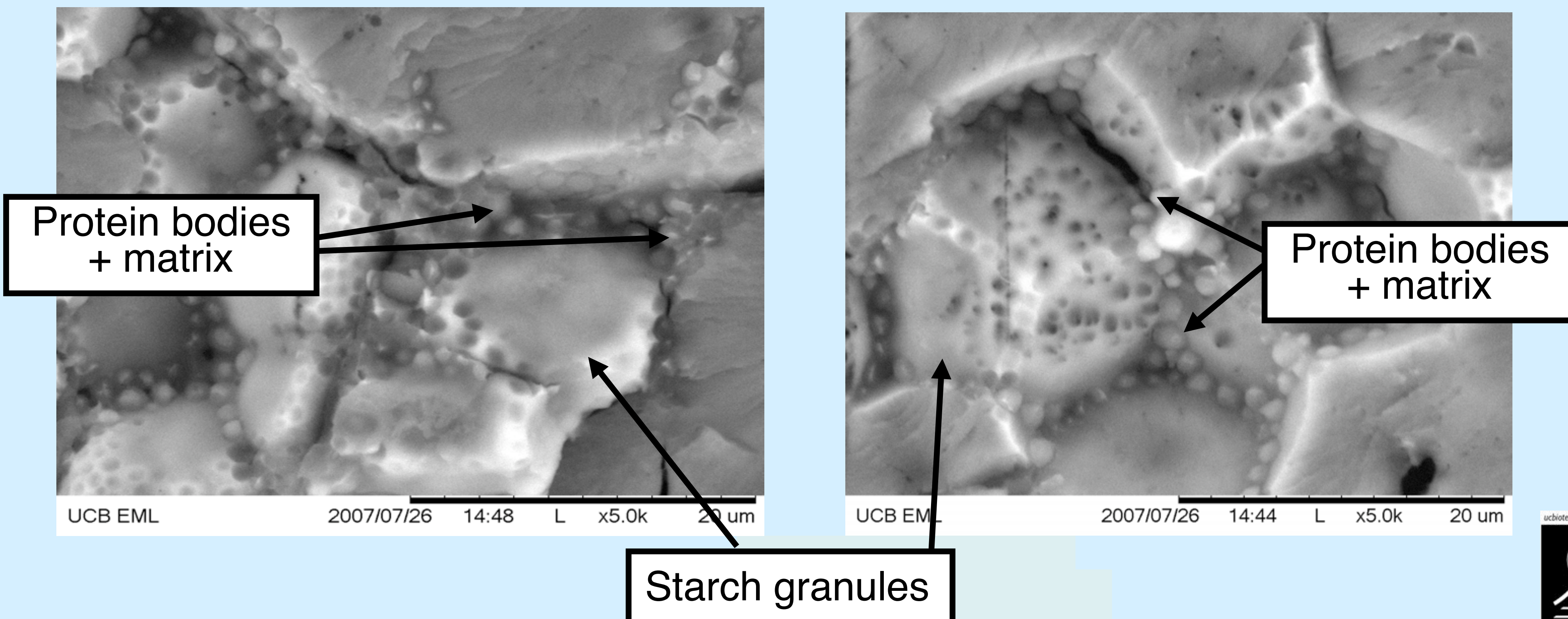
In Africa, 74% of sorghum is consumed at home as cooked porridge

Elderly woman making cooked sorghum porridge

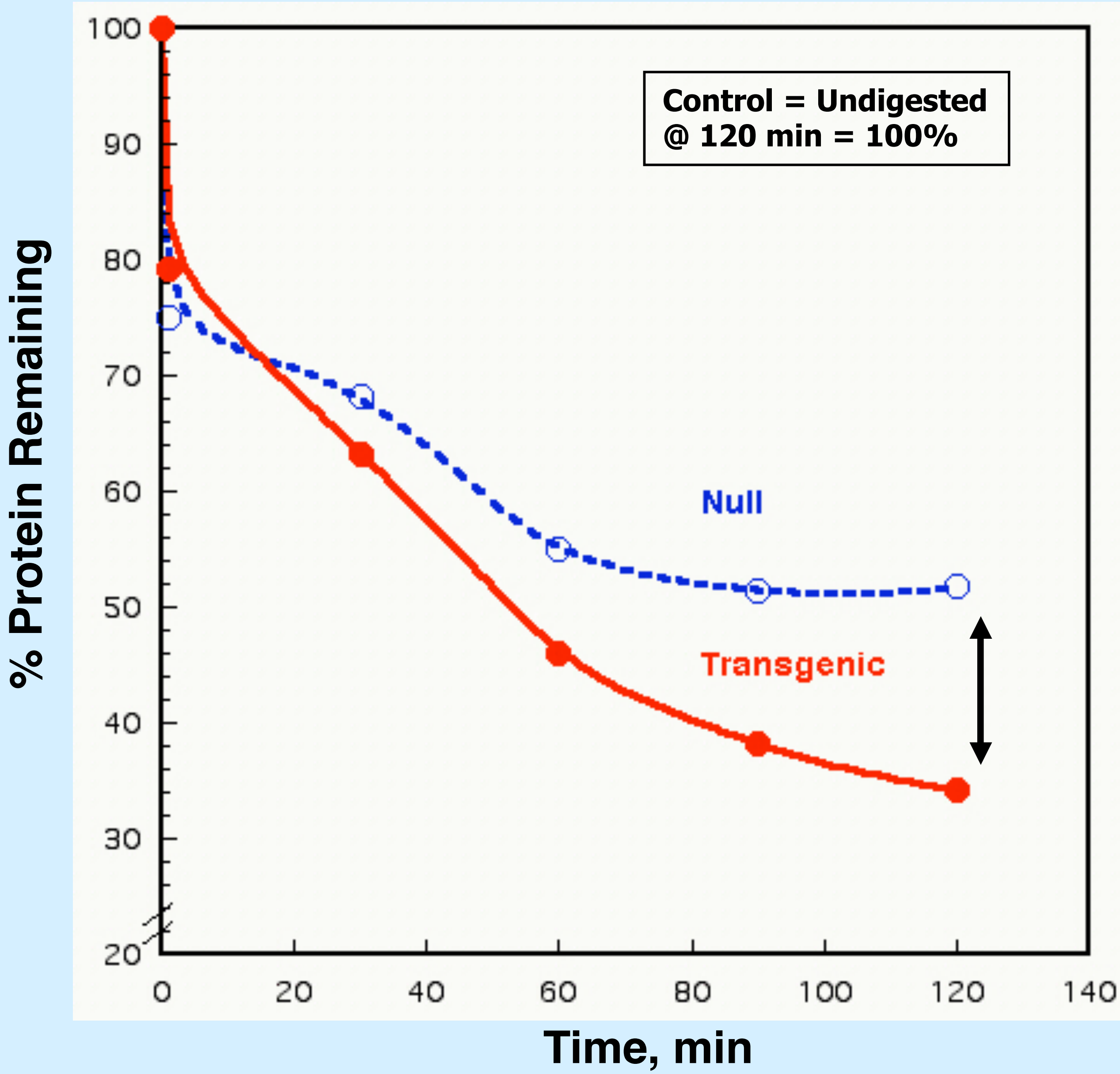
But, of major cereals, sorghum is the least digestible following cooking

	% 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.



In vitro Pepsin Digestion of Seed Storage Proteins in Sorghum Engineered with Innate Redox Protein



25% increase in digestibility in engineered line

Are Genetically Engineered Crops a Magic Bullet?

Is Farming Using Organic Practices a Magic Bullet?

Is Farming Conventionally a Magic Bullet?

Is Farming with Integrated Pest Management a Magic Bullet?

Future farming will be complex, requiring all skills and technologies available. Wise use of the best of each approach offers the best way of achieving sustainable food production to feed future populations.

For more information: See Resources and Biotechnology information sections at http://ucbiotech.org