How Much Did You Pay for Your Lunch Today?

Peggy G. Lemaux
University of California, Berkeley
http:/ucbiotech.org
http://pmb.berkeley.edu/~lemauxlab

What if I told you, I would give you $30 for lunch, would you take it?

But, it actually must pay for a month of lunches

and dinners and everything else you need to live – food, shelter, transportation, clothing!!

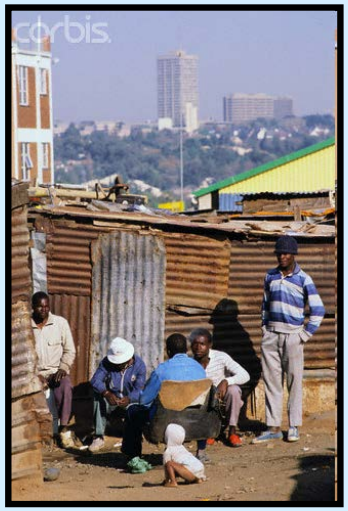
Maybe it would make you think differently about…

…growing your own food.

…the fact that average Americans spend <10% of their income on food, while in developing countries it is can be as much as 80%!

…how lucky we are to have the variety, quantity and quality of food to eat and most of us don't have to produce it!

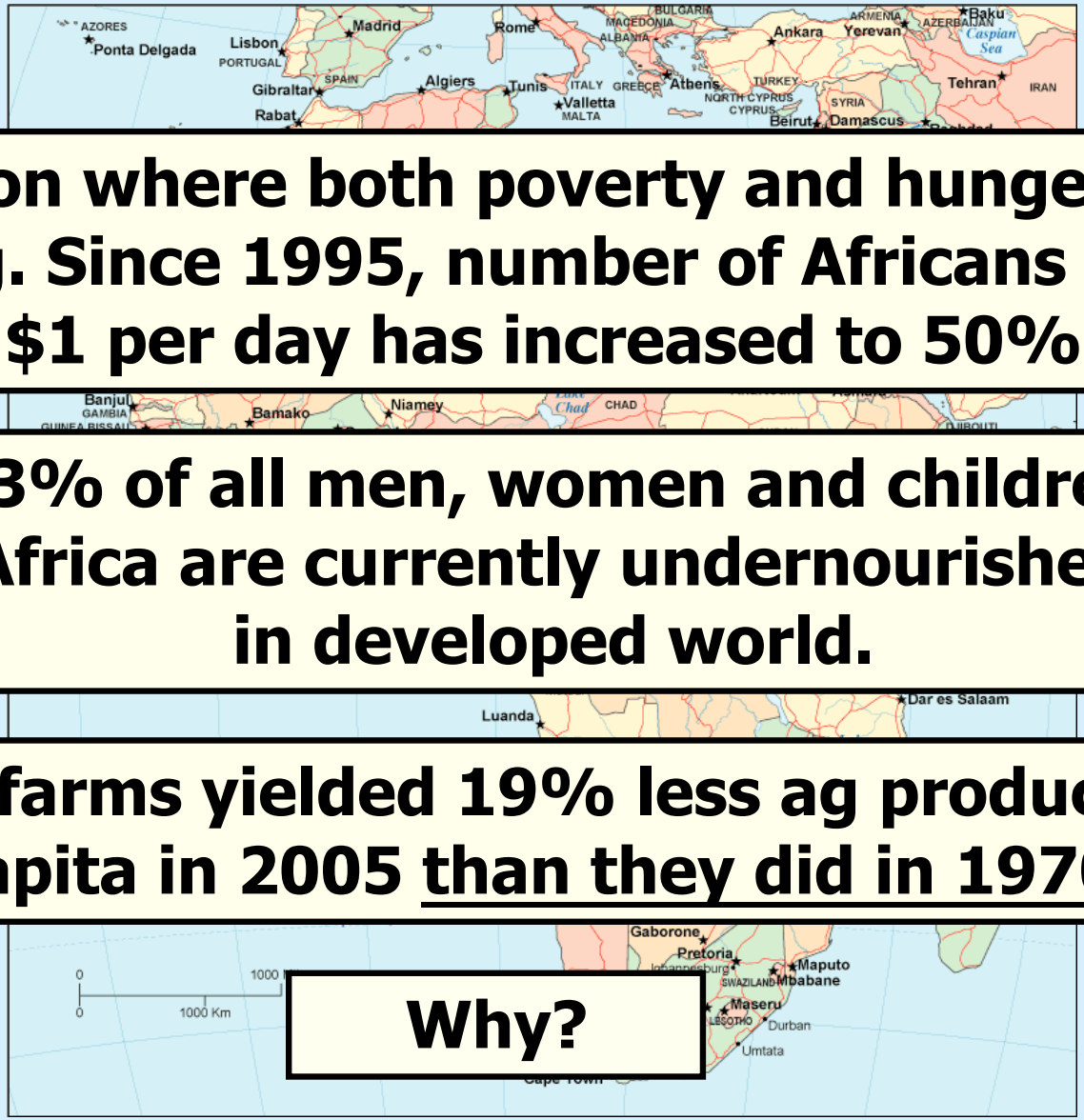
Now consider this…



- ❖ One billion of the world's poorest people live on ≤ $1 per day.
- ❖ 820 million people go to bed hungry each day
- ❖ Malnutrition leads to stunted physical/ mental development, increased disease suceptibility
- ❖ No country has risen rapidly from poverty without increasing agricultural productivity

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

But, the situation with agricultural productivity in less developed countries, like Africa, requires a different perspective. Why?



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 <u>than they did in 1970!!</u>

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…

And crop yields vary dramatically from the developed world

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

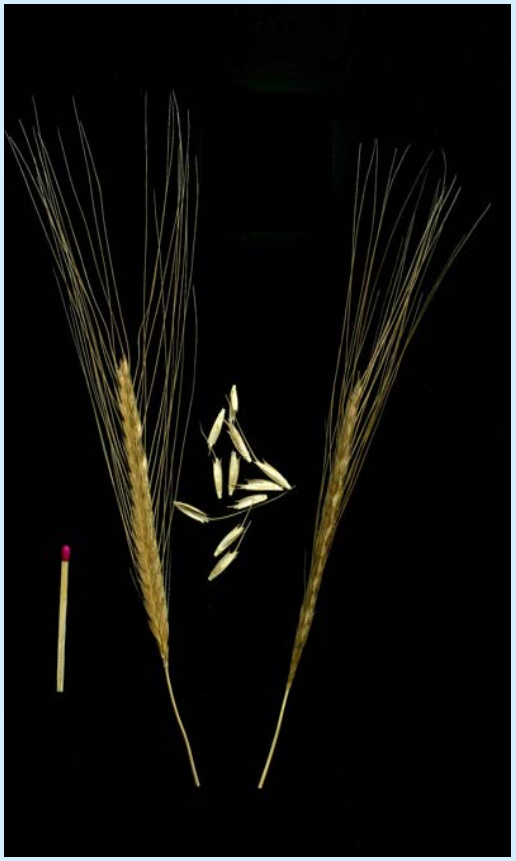
5X

3X

WHY?

Many reasons…but among them is lack of genetic improvement of varieties giving higher yields under their specific growing conditions.

How have we accomplished genetic improvements to increase yields?



Triticum monococcum

Ancient variety

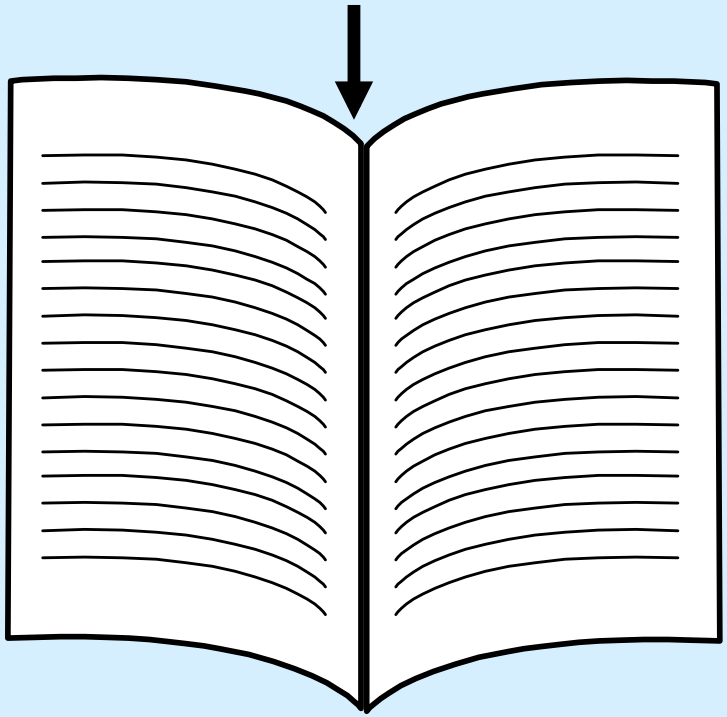
Triticum aestivum

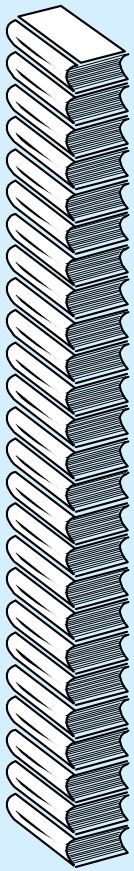
Modern bread variety

Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...



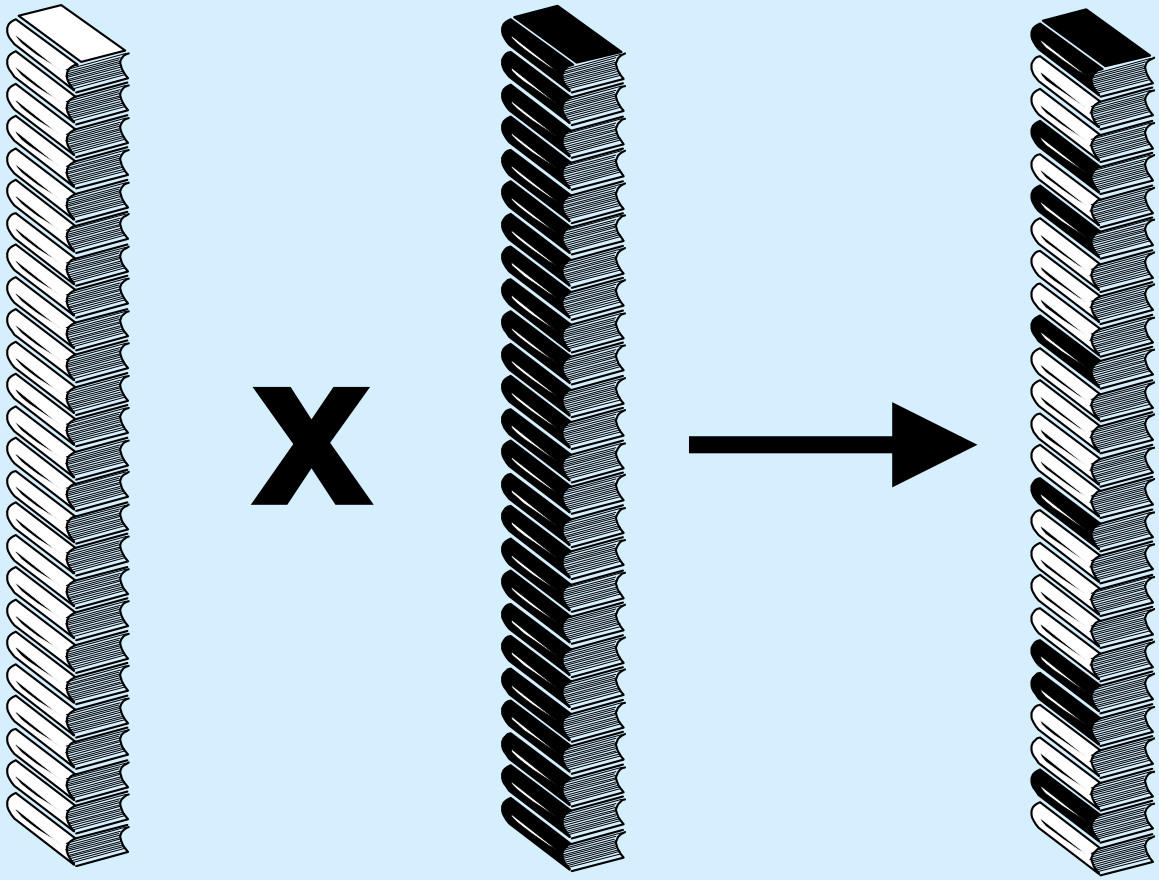


1700 books
1000 pages each

1700 books
(or 1.7 million pages)

Hybridization or cross breeding

Two wheat varieties with some of the same and some different information in their books

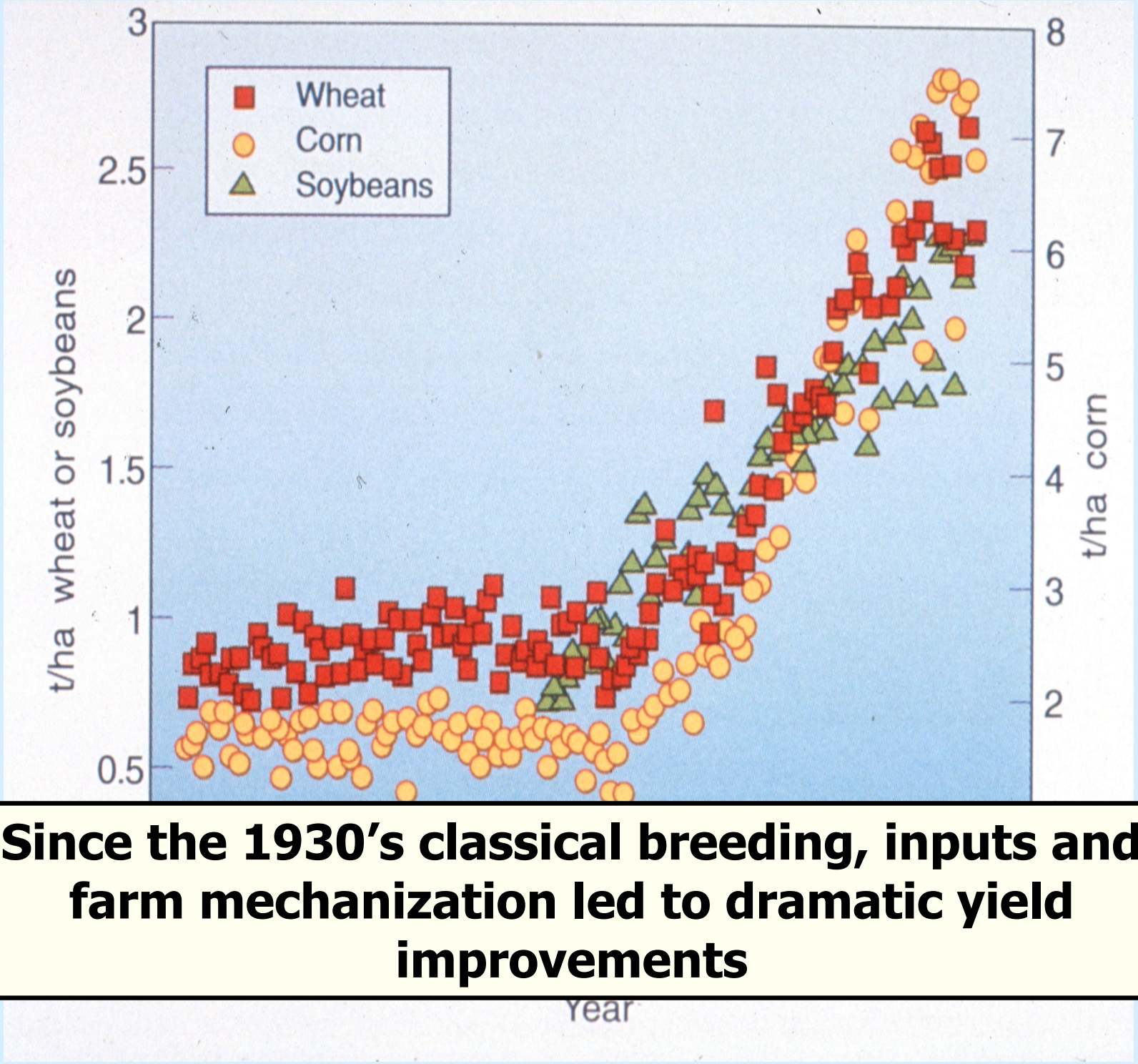


Random retention of information from each parent

1700 books (or 1.7 million pages)

1700 books (1.7 million pages)

1700 books (1.7 million pages)

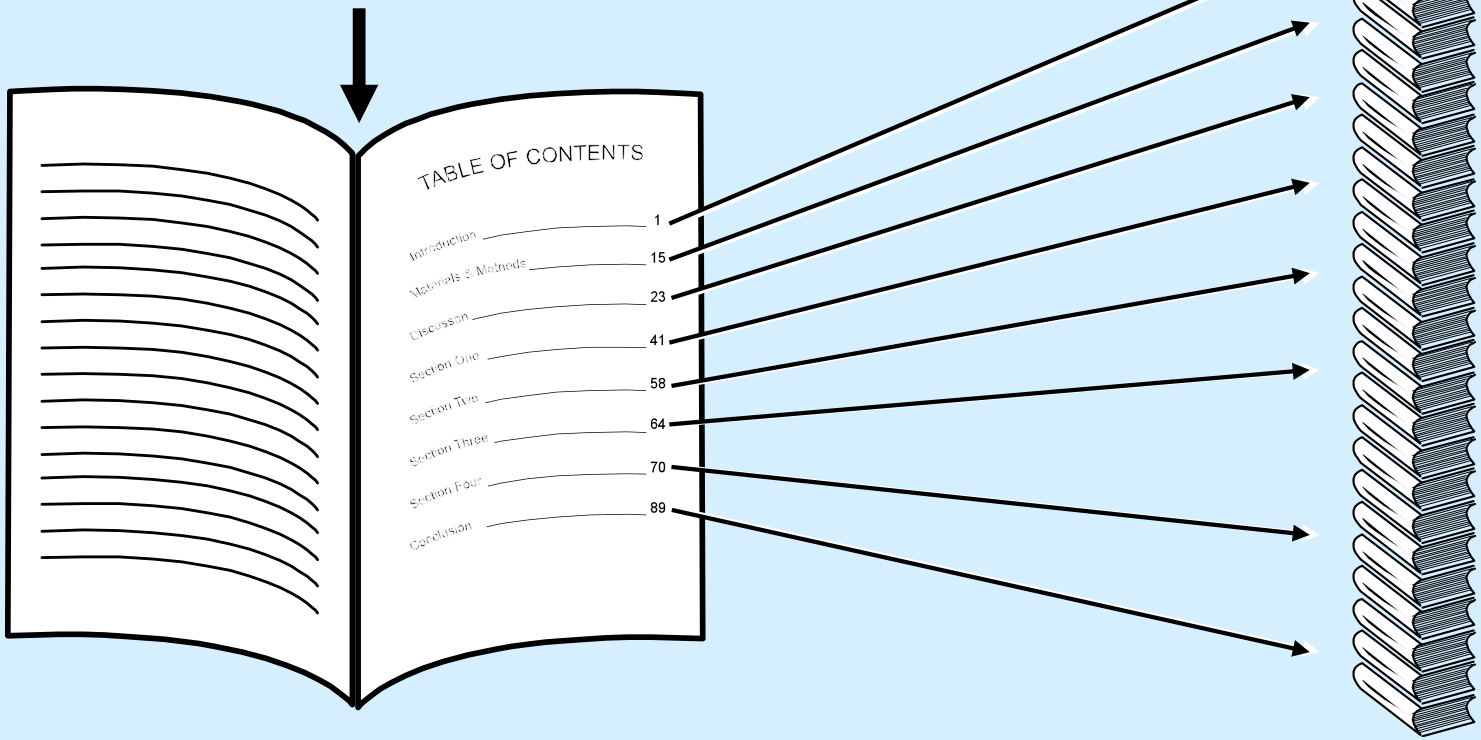


Since the 1930's classical breeding, inputs and farm mechanization led to dramatic yield improvements

But there are other ways to create new varieties through genetic modification

Table of contents for wheat genes

...CTGACCTAATGCCGTA...



Used for Marker-Assisted Breeding

Genomics

1700 books
(or 1.7 million pages)

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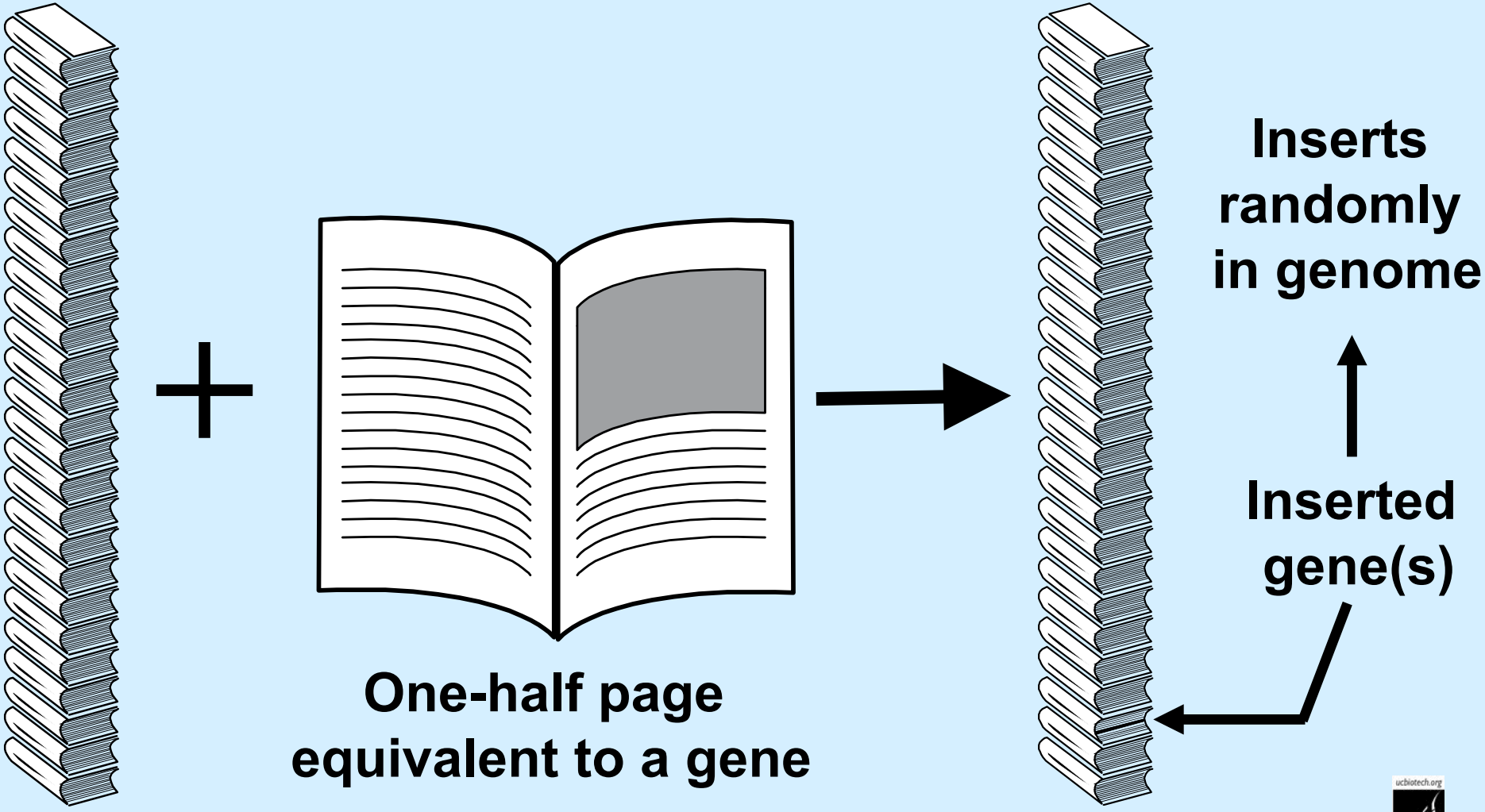
Marker-assisted selection used to protect rice against bacterial blight and blast disease

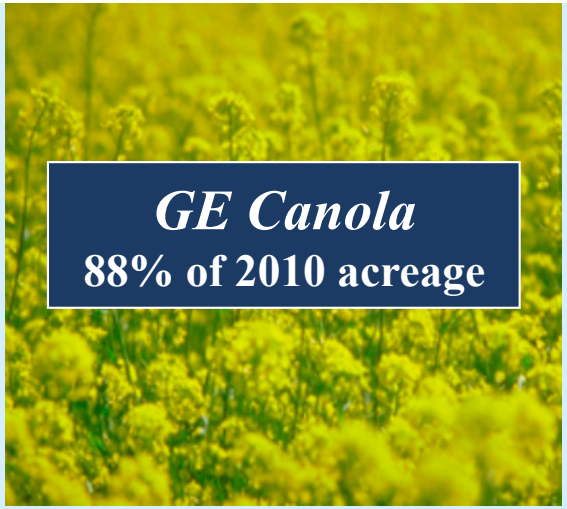
Limited to diversity in compatible relatives

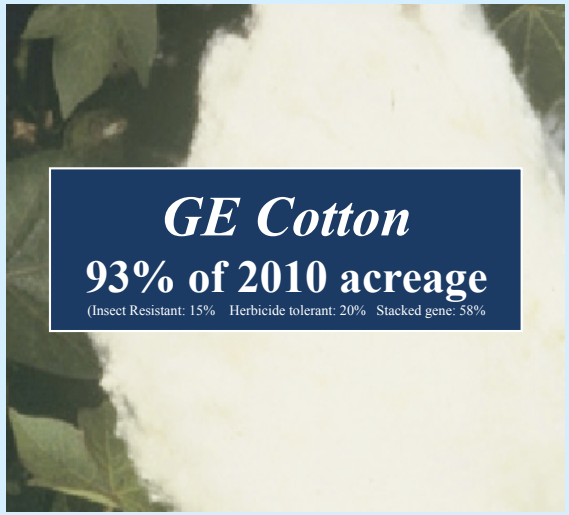
How can limitations be overcome?

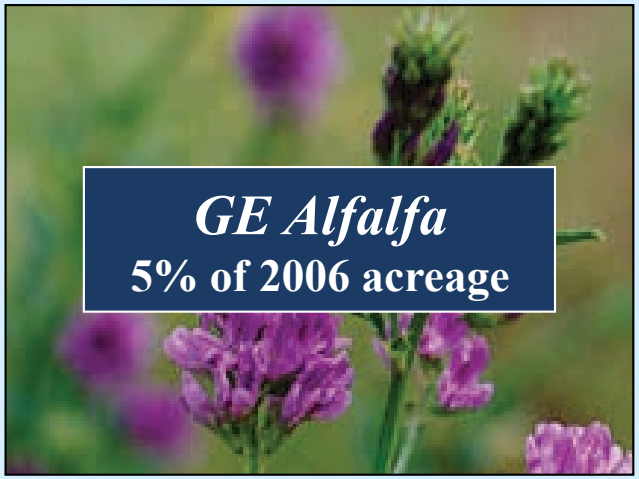
Biotechnology or Genetic Engineering Methods



What are the commercial GE varieties in the field in the U.S.?



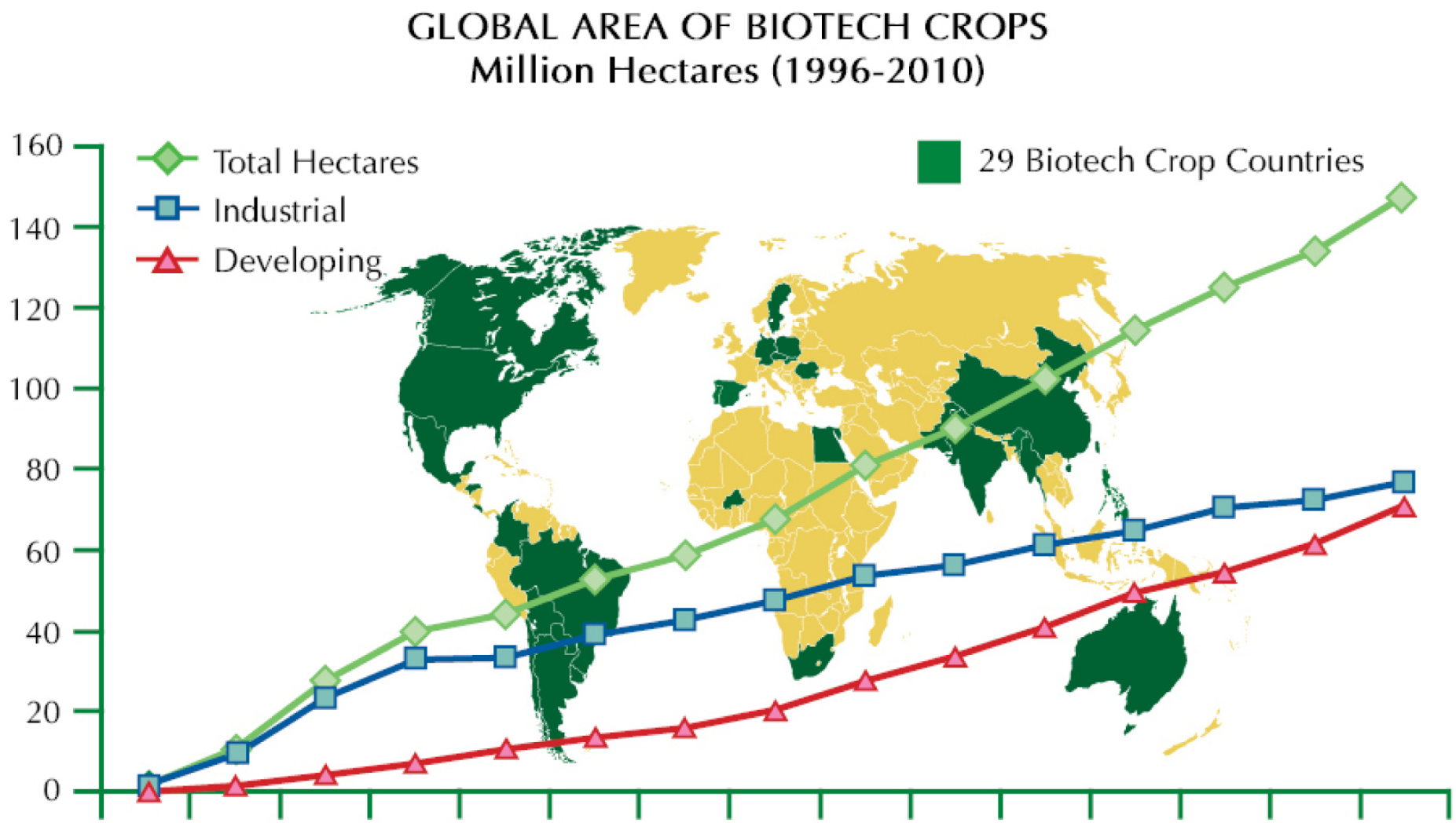




SOURCE: NCFAP; USDA ERS

Only a few whole foods on the market are genetically engineered

What is the situation with GE crops worldwide?

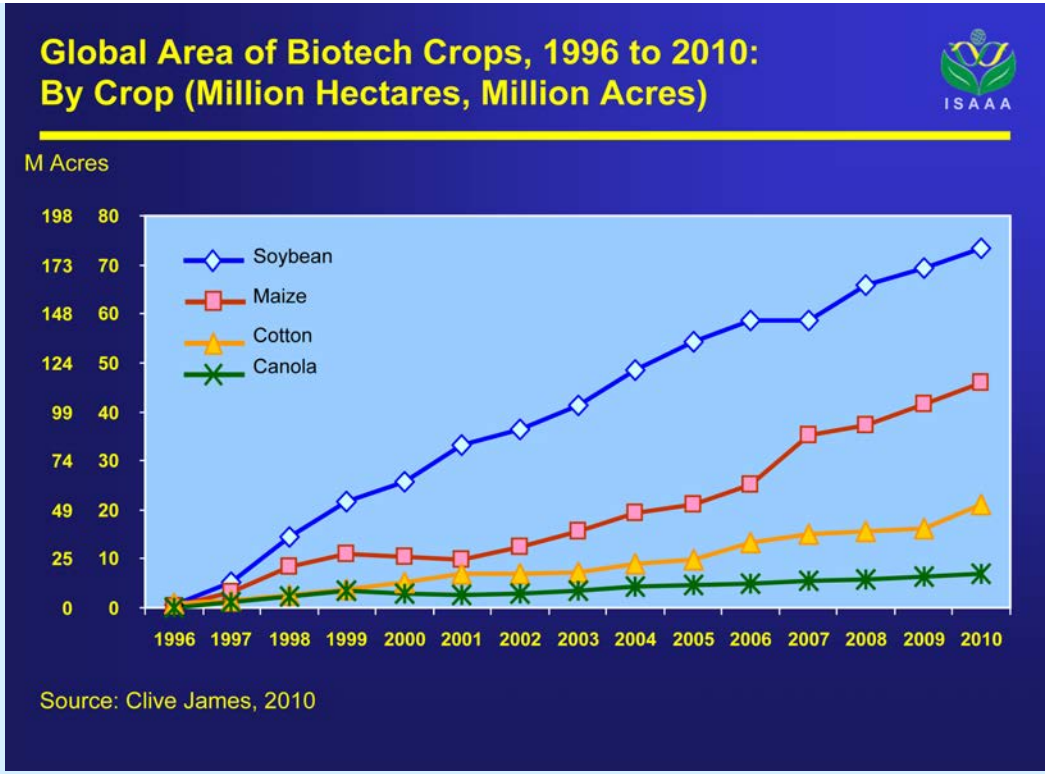


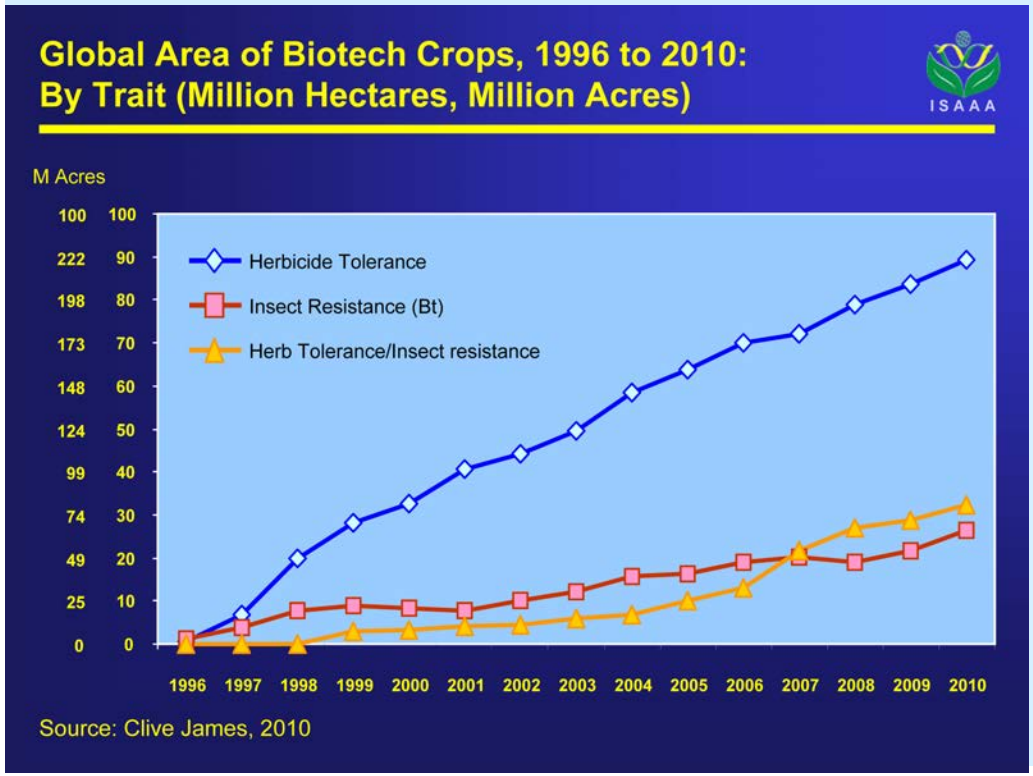
Recent figures indicated 15.4 million farmers in 29 countries planted 365M acres (~3X California) – over 90% were small resource-poor farmers in developing countries

Source: Clive James, 2010.

But only three countries in Africa are growing them at present – mostly insect-resistant maize

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.

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Private sector is developing insect-resistant or Bt maize

Is this needed?

"Maize is our staple food, and we have not identified any other source of income from plants to sell, so we continue planting maize."

Mrs. Bernadette Mwikali Kioko, Farmer, Ukambani, Kenya

http://www.agra-alliance.org/celebrating/people.html

What are some questions are being asked about such products?

Will only large agrochemical companies benefit?

Will GE crops really address small farmers' needs?

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Will only large agrochemical companies benefit?

Economic evidence also does not support that only multinational firms are capturing economic value created by transgenic crops (in developing countries). Benefits are shared by consumers, technology suppliers, adopting farmers

But likely large companies will not invest in crop improvements using GE unless they see a financial incentive

Institutional factors, like research capacity, environmental and food safety regulations, intellectual property rights and agricultural inputs are as important as technological capabilities in determining the level and distribution of economic benefits

(Raney T 2006. Curr Opinon Biotech 17:174-178)

Will GE crops address small farmers' needs?

"Economic evidence does not support misconception that transgenic crops only benefit large farms; evidence indicates technology might actually be 'pro-poor'" (Ruttan VW 2004. *Intl J Biotechnol 643-54*)

How can this technology be pro-poor?

Productivity: Evidence for Bt Cotton Gains

Bt cotton in:

- **United States yield increase 0 – 15%**
- **China yield increase 10%**
- **South Africa yield increase 20%-40%**
- **India yield increase 60 – 80 %**

WHY? Small-scale farmers suffer bigger pest-related yield losses because of technical/economic constraints

SOURCE: Qaim M and Zilberman D. 2003. Yield effects of genetically modified crops in developing countries. Science 299:900-902

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Bt maize

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But is this the best we can do for developing countries?

More of world's crops are genetically engineered

By Elizabeth Weise, USA TODAY

February 23, 2011

The amount of land devoted to genetically engineered

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 want 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

So, can these groups use genetic engineering to modify crops to benefit developing countries?

Two stories that focus on genetic engineering projects for developing countries:

Public sector:
Development of Golden Rice

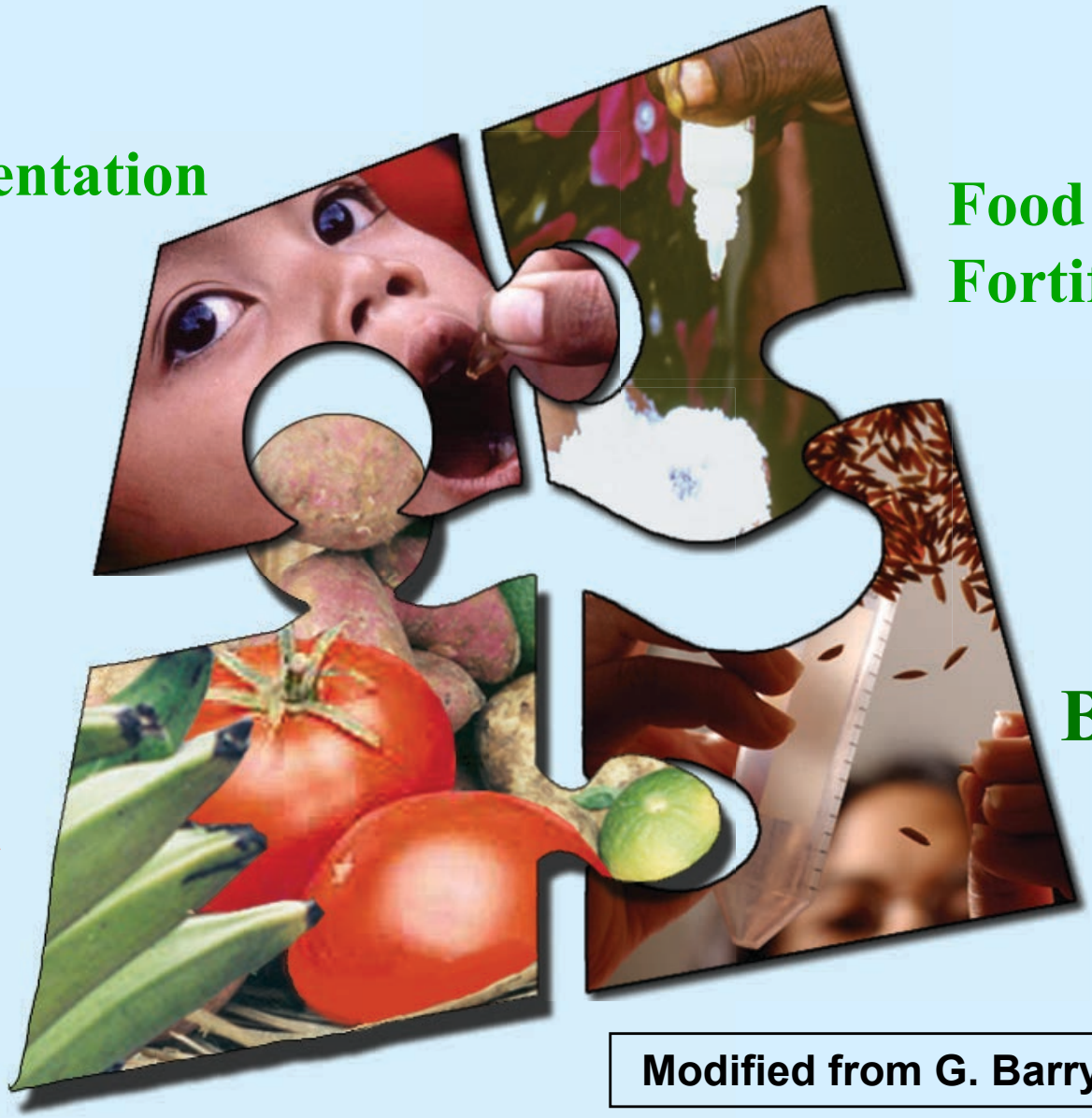
Public-Private sector:
Development of SuperSorghum

Public sector: Development of Golden Rice

Biofortification can provide additional options to combat persistent micronutrient deficiency.

Supplementation

Food Fortification



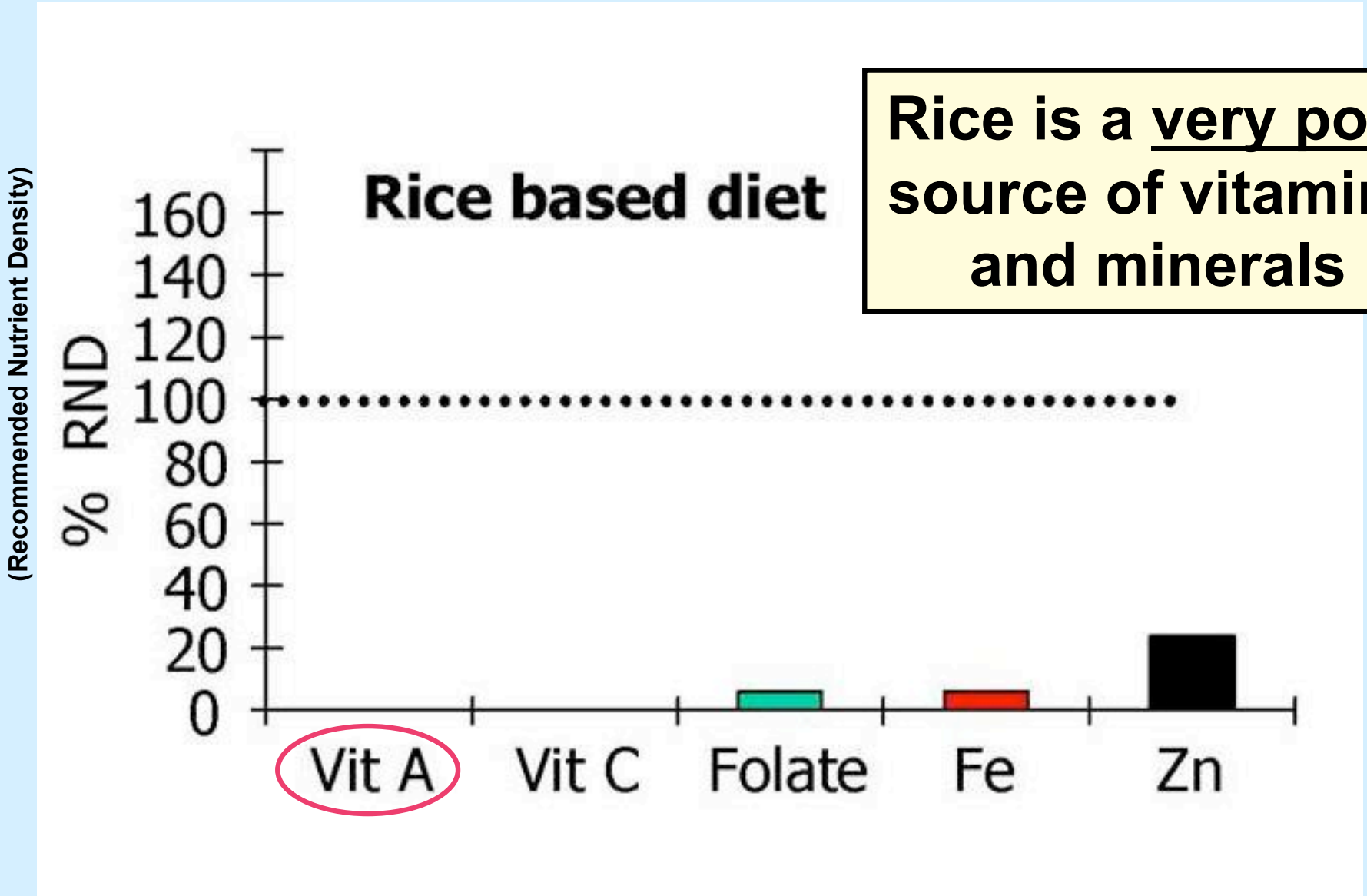
Biofortification

Dietary Diversity

Modified from G. Barry, IRRI

HarvestPlus
Breeding Crops for Better Nutrition

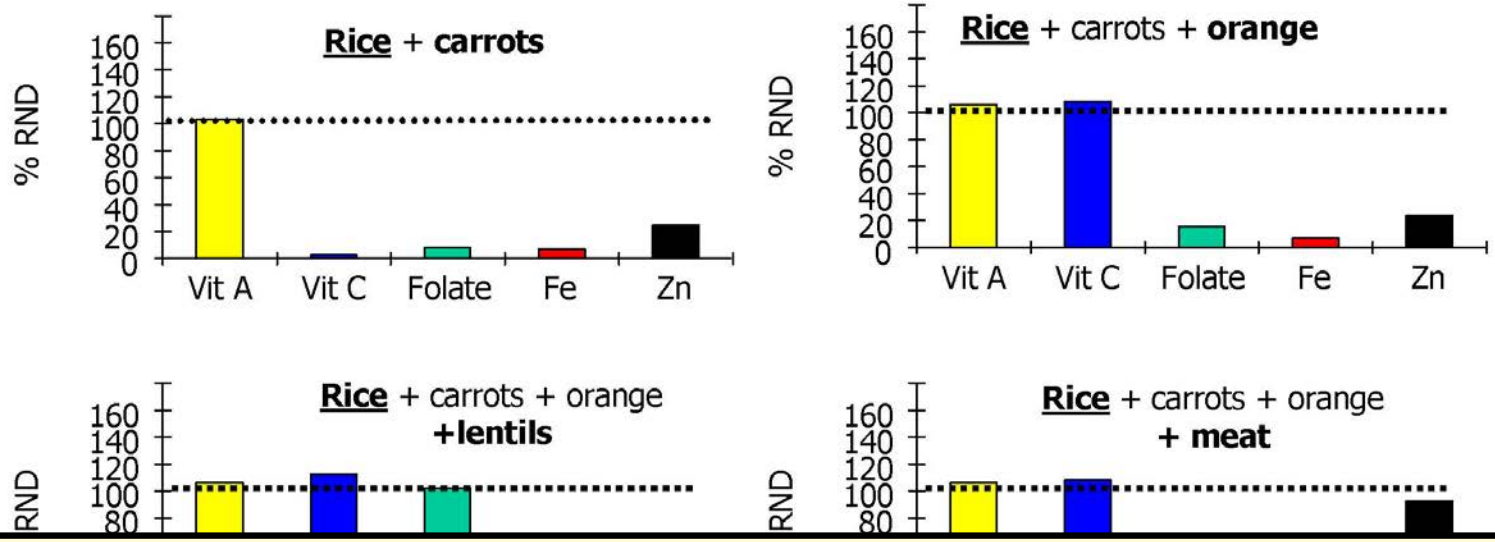
Rice Diet and Micronutrient Nutrition



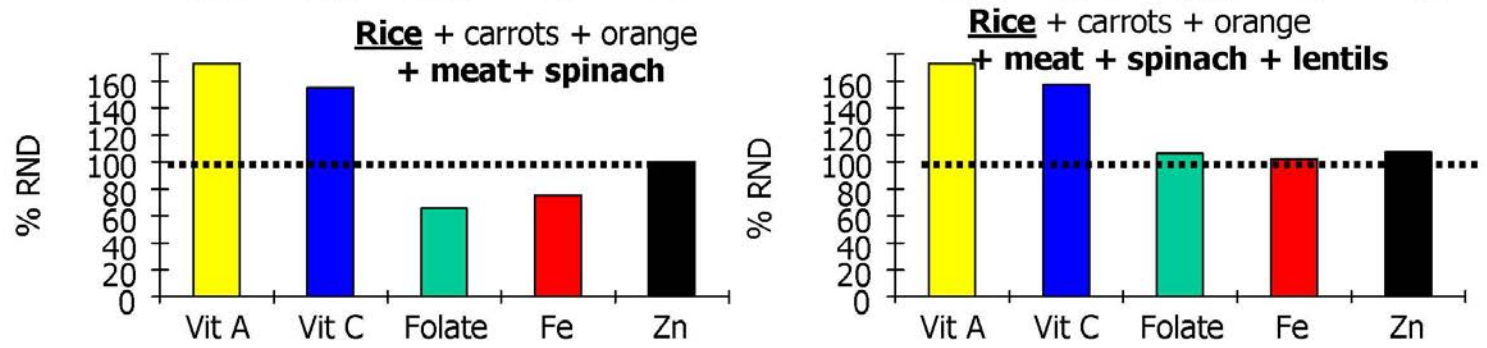
Rice is a <u>very poor</u> source of vitamins and minerals

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



…but not everyone has that luxury!!



Rice diet can be supplemented with other fruits, vegetables and meat to acquire needed nutrients…

Modified from G. Barry, IRRI

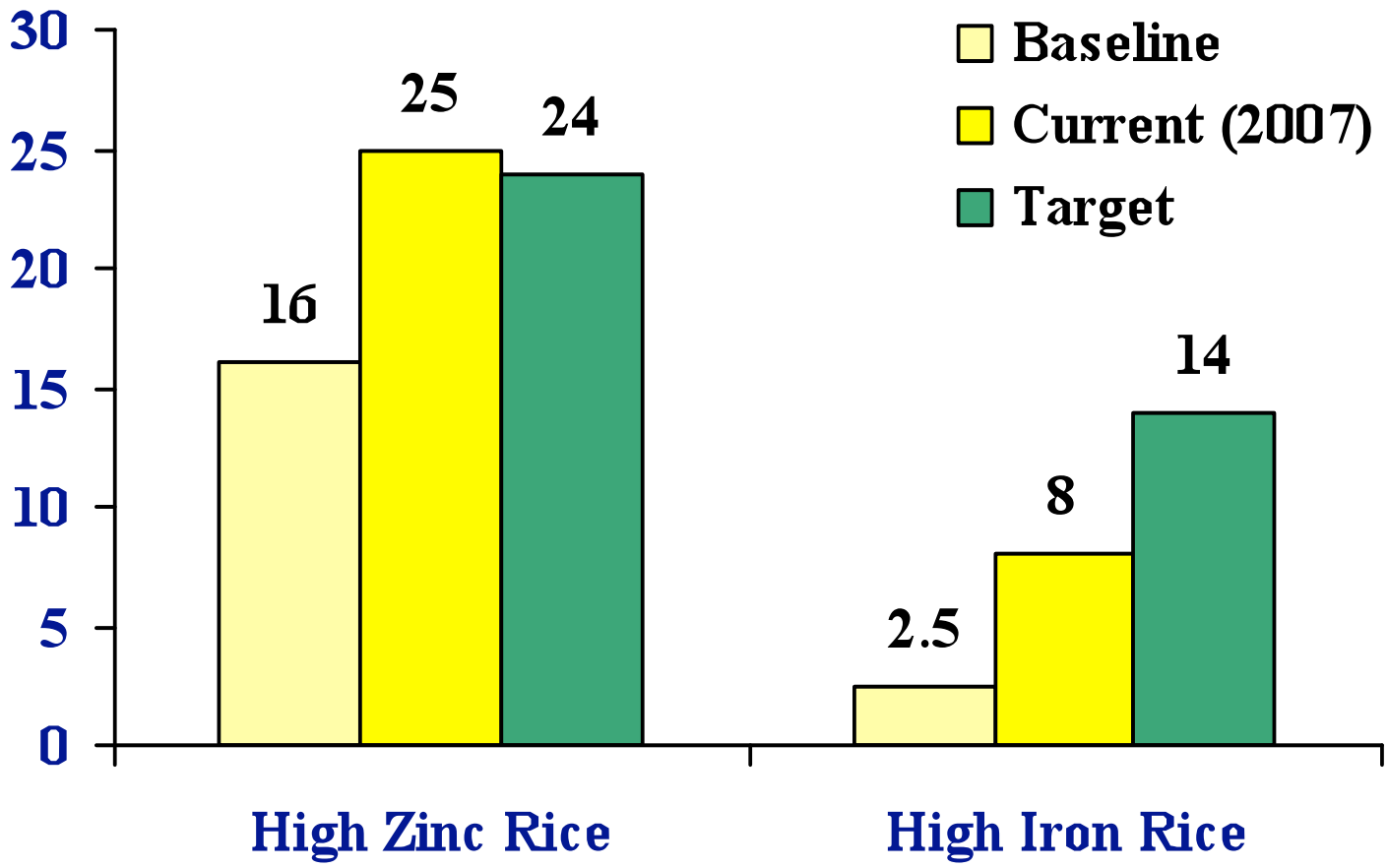
: "Nutrition: A Cornerstone for Human Health and Productivity", Richard J. Deckelbaum. Seminar at The Earth Institute of Columbia University, April 14, 2005

Can we biofortify rice with vitamins and minerals?

How?

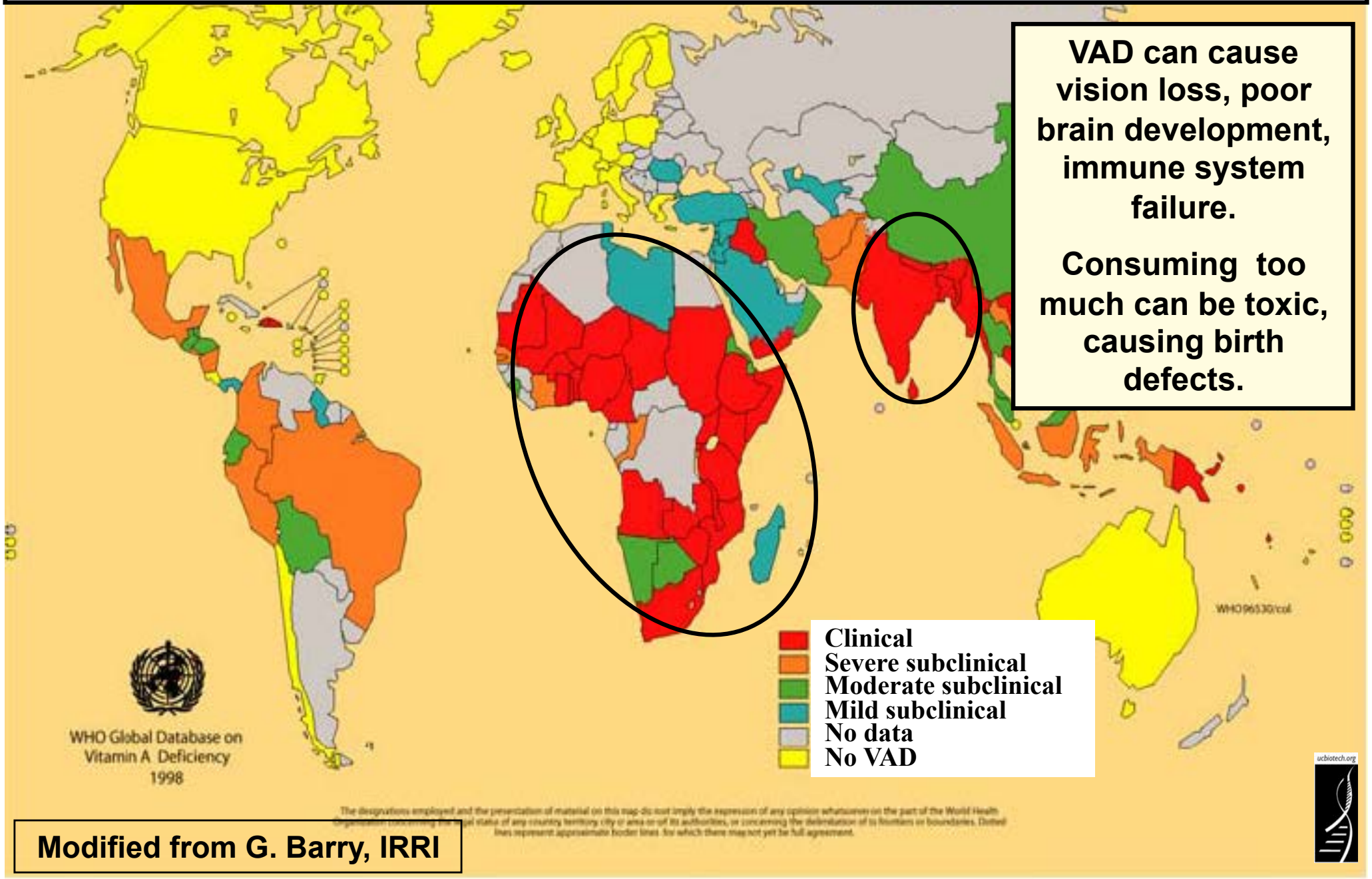
Rice was made with increased iron and zinc by crossing with other rice varieties that have these traits…

But this 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 (VAD): as judged by severity of health impact

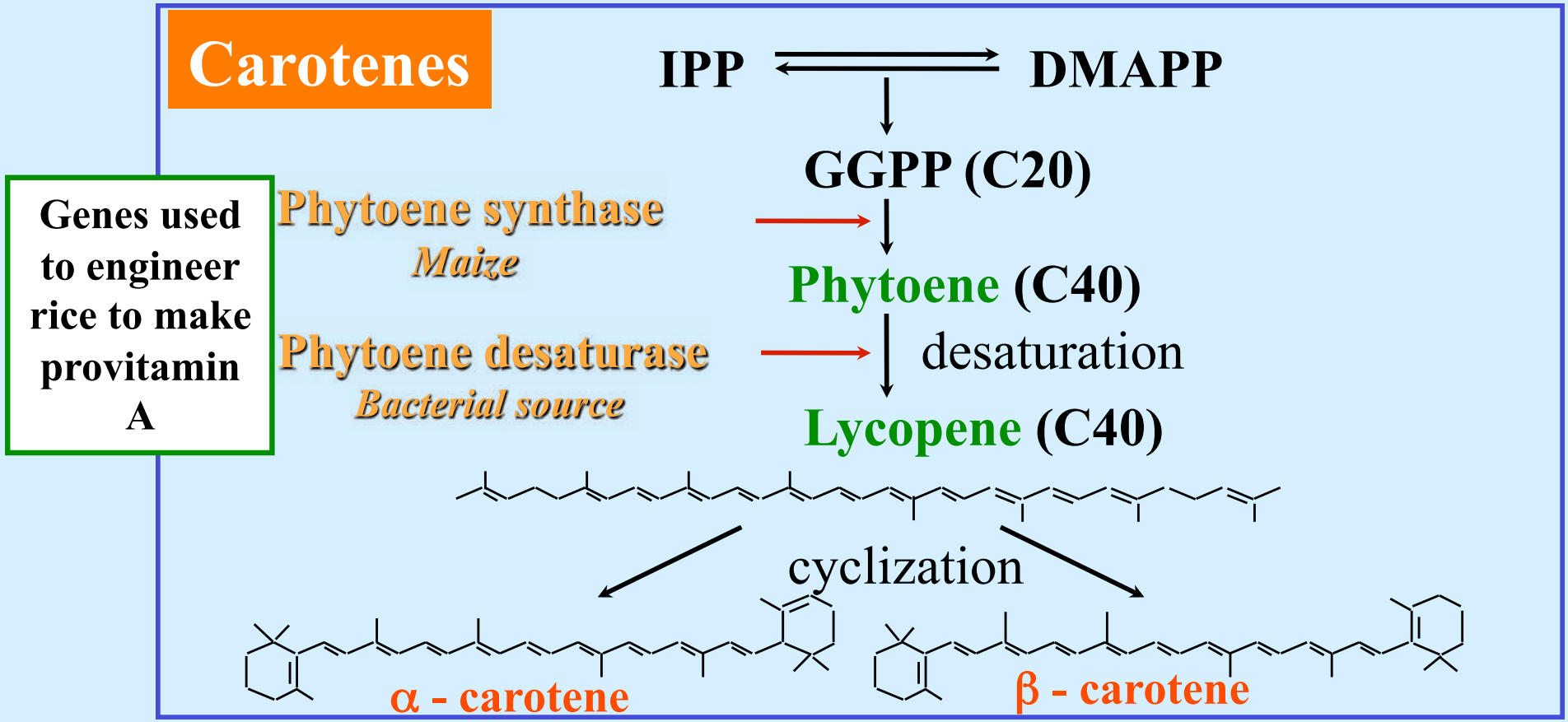


VAD can cause vision loss, poor brain development, immune system failure.

Consuming too much can be toxic, causing birth defects.

Modified from G. Barry, IRRI

Basic Carotenoid Biosynthetic Pathway



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

Public-Private sector partnership: Development of SuperSorghum

Another cereal important in developing countries is also nutritionally deficient in:

Vitamins
Minerals
Amino acids
(like most cereals)
but, uniquely, is also

Poorly Digested

What is this crop?

SORGHUM

Sorghum is a staple food for 300 million of the world's poor – many in Africa

Can improving sorghum make a difference in Africa?

Why did I become involved?

Part of my mandate as public sector scientist and CE specialist

The magnitude of the problem begs for solutions. This was something I wanted to do, but…

How did I become involved?

Capital Press
Agriculture Newspaper

Bill Gates defends focus on high-tech ag

Software magnate says biotech key to new 'green revolution'

By DONNA GORDON BLANKINSHIP
Associated Press

KIRKLAND, Wash. (AP) — Bill Gates has a terse response to criticism that the high-tech solutions he advocates for world hunger are too expensive or bad for the environment: Countries can embrace modern seed technology and genetic modification or their citizens will starve.

When he was in high school in the 1960s, people worried there wouldn't be enough food to feed the world, Gates recalled in his fourth annual letter, which was published online Tuesday. But the "green revolution," which

starvation and malnutrition for the poor.

Resistance to new technology is "again hurting the people who had nothing to do with climate change happening," Gates said.

Groups resistant to genetic modification and other hallmarks of modern agriculture, such as pesticides and petroleum-based fertilizers, generally object on two grounds — concerns about the environment and the high cost of the seed and chemicals used in modern farming.

Bill Freese, a science policy analyst for the Washington-based Center for Food Safety, said everyone wants to see things get better for hungry people, but genetically modified plants are more likely to make their developers rich than feed the poor.

Bill Gates made a bold move to support using genetic engineering to improve the nutritional quality of crops for Africa's poor. His reasoning: Countries can embrace modern seed technology or watch their citizens starve.

SOURCE: Capital Press, January 27, 2012
http://www.capitalpress.com/print/AP-US-Food-farm-Gates-012512

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Grand Challenges in Global Health - Microsoft Internet Explorer

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Grand Challenges in Global Health

About the Grand Challenges

Research to Serve Global Health

Learn More

In 2003 the Grand Challenges initiative was launched by the Gates Foundation to apply innovation in science and technology to the greatest health problems of the developing world.

Phone: +1.206.709.3400 / Email: media@gatesfoundation.org

Initiative supported by $450 million from Bill and Melinda Gates Foundation; $27.1 million from Wellcome Trust and $4.5 million from Canadian Institutes of Health.

Projects for More Than $436 Million in Funding

14 Grand Challenges identified from more than 1000 suggestions from scientists and health experts around the world.

Topics include: Improved childhood vaccines, Studying immune system to guide development of new vaccines, Preventing insects from transmitting diseases, Preventing drug resistance, Treating latent and chronic infections, Diagnosing and tracking diseases in poor countries AND...

Local intranet

SeedQuest - Central information website for the global seed industry - Microsoft Internet Explorer

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Address http://www.seedquest.com/News/releases/2006/april/15466.htm

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

Berkeley, California
April 10, 2006

Researchers at the University of California, Berkeley, are joining an ambitious project to improve nutrition for 300 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."

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 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."

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

Grand Challenge #9: Growing more nutritious staple crops to combat malnutrition

Focuses on 4 crops:

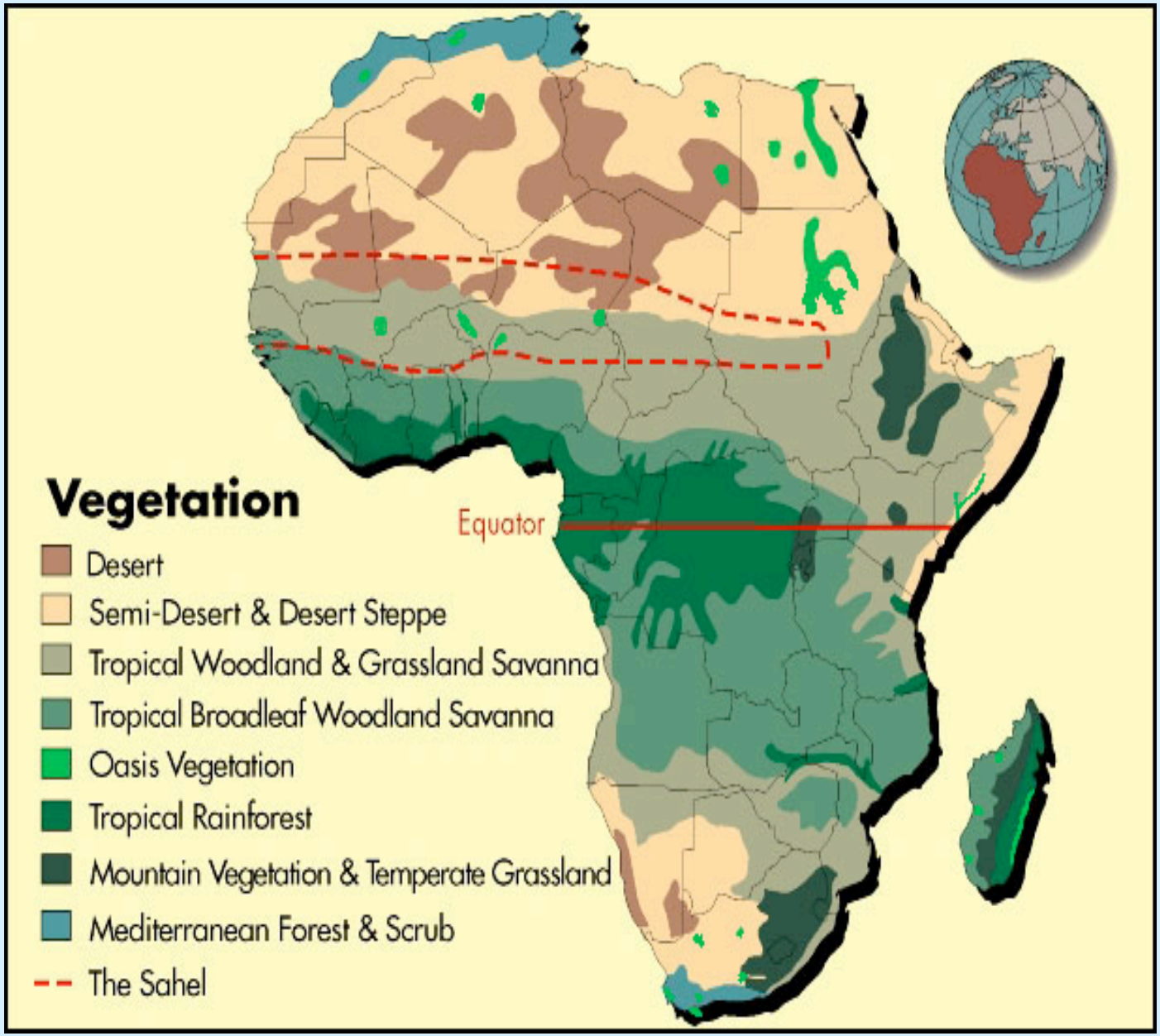
banana, cassava, rice and SORGHUM

Local intranet

Why Was Sorghum a Target?

- **Fifth most important food grain**
- **90% grown in Africa and Asia in arid and semi-arid regions**
- **Staple food for 300 million in Africa**
- **In Africa, 74% of sorghum is consumed at home as cooked porridge**

Sorghum is uniquely adapted to Africa's climate – it withstands 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.

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But digestibility remains a problem because…

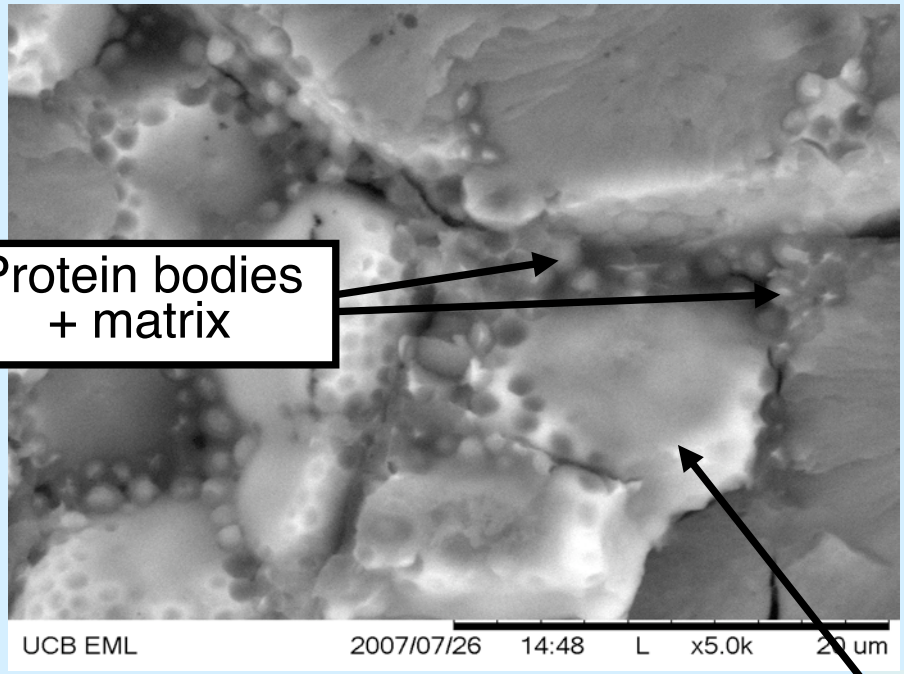
In Africa, 74% of sorghum is eaten at home as cooked porridge

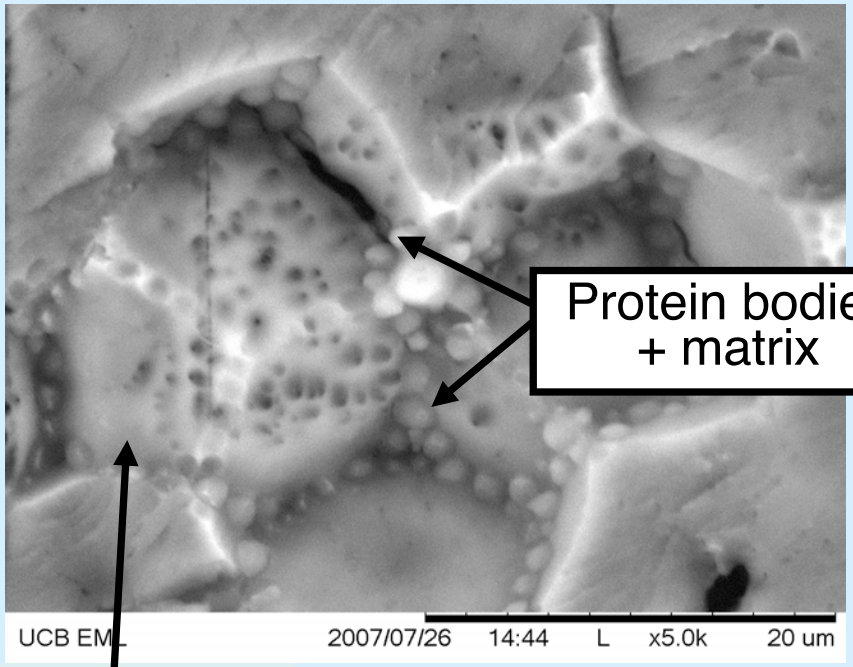
Elderly woman making cooked sorghum porridge

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.



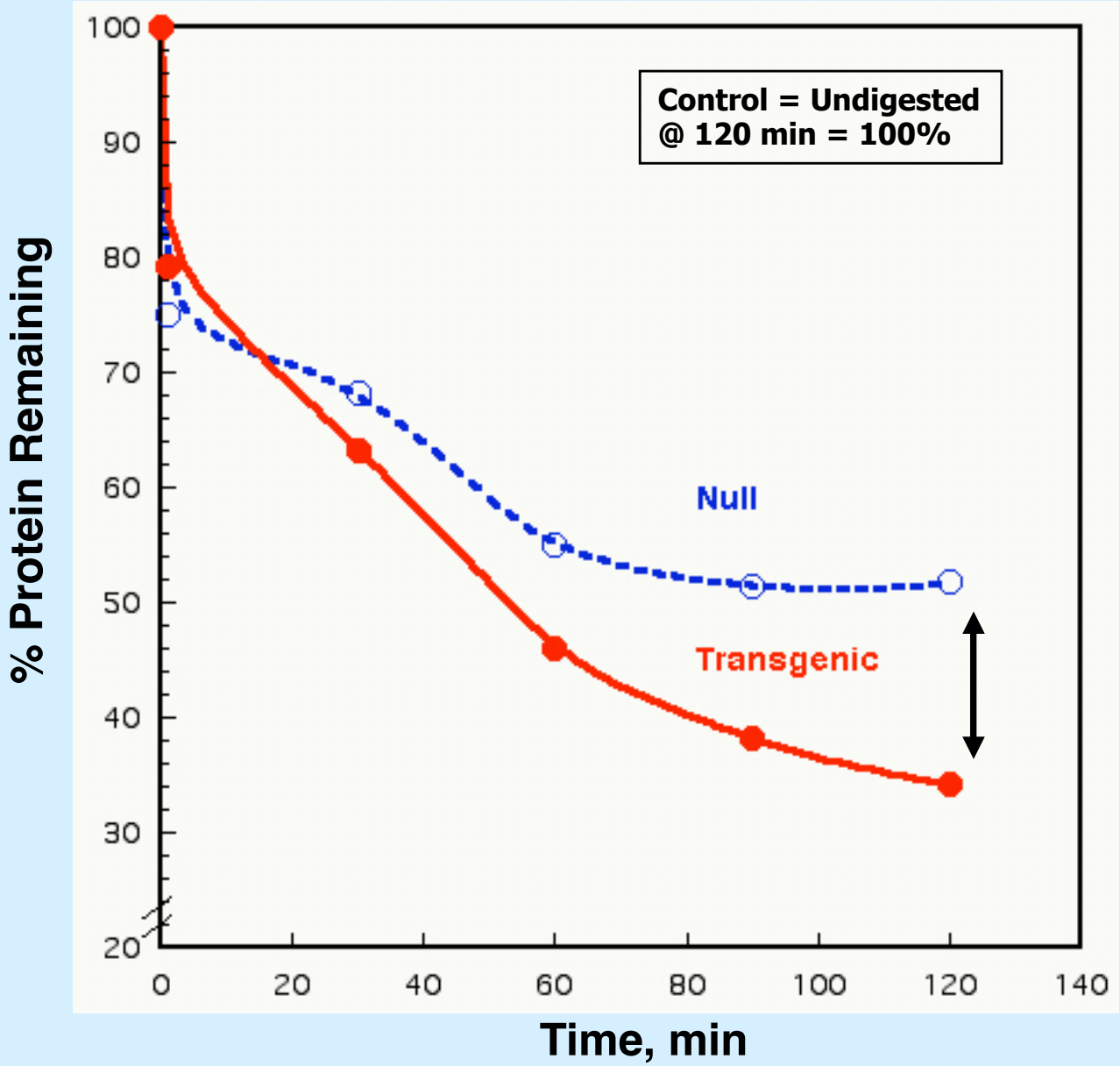


Protein bodies + matrix

Protein bodies + matrix

Starch granules

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



25% increase in digestibility in engineered line

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But could it help?

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