Genetically Engineered Crops: Can Africa Really Benefit?

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Perspective on agriculture in developing countries…

How much will you spend on your lunch today?

- One billion of the world's poorest people live on ≤ $1 per day and depend on their own agriculture for food.
- 820 million people go to bed hungry each day
- Malnutrition leads to stunted physical/mental development, increased disease susceptibility
- No country has rapidly moved out of poverty without increasing agricultural productivity
- Two-thirds of Africans are small farmers; the majority are women who often have few resources

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

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

United States

Senegal

Technologies available for agriculture in many parts of Africa are different from that in the developed world…

"The farmers usually come on bicycles, sometimes they come on foot. Most people come from far distances, 10 km (six miles) away."

Mrs. Dinnah Kapiza, Agro-dealer, Mponela, Malawi

Mrs. Dinnah Kapiza has transformed her used clothing business into a full-line farming supply store in rural Malawi that is now critical to the success of poor farmers in her region. She opened her store in 2002 with an initial investment of MWK$20,000.00 (Malawian kwacha, equivalent to US$310.00).

http://www.agra-alliance.org/section/people/profiles#kapiza

Also crop productivity is different in developed vs. developing countries where yields are lower.

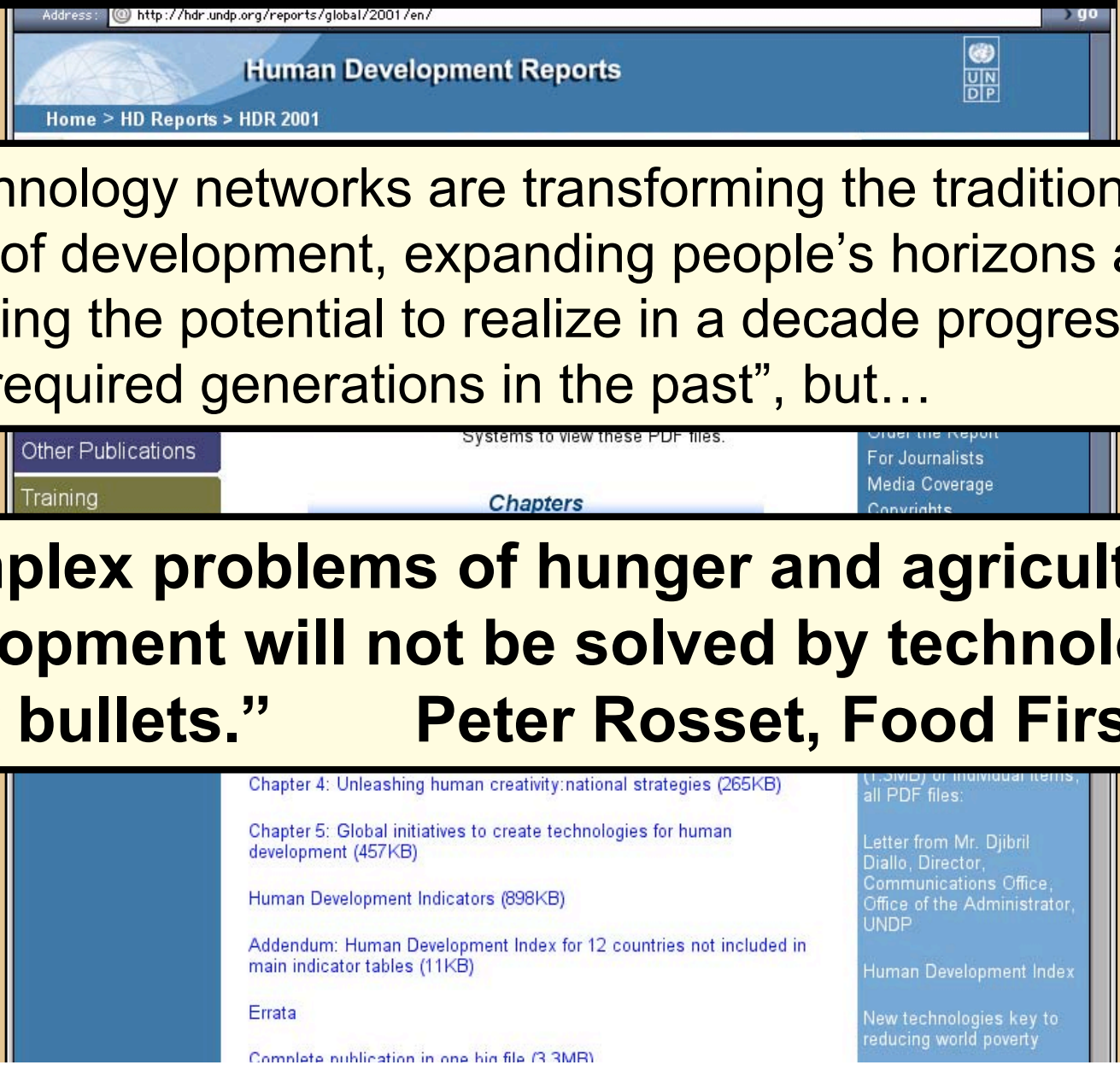
CROP	YIELD (kilograms per hectare)				
	Kenya	Ethiopia	India	Developed World	
Maize	1,640	2,006	1,907	8,340	5X
Sorghum	1,230	1,455	797	3,910	5X
Rice	3,930	1,872	3,284	6,810	~3X
Wheat	2,310	1,469	2,601	3.110	2X
Chickpea	314	1,026	814	7,980	25X

WHY?

For many reasons…among them is that varieties giving higher yields are not optimized genetically for their environments.

United Nations Development Programme

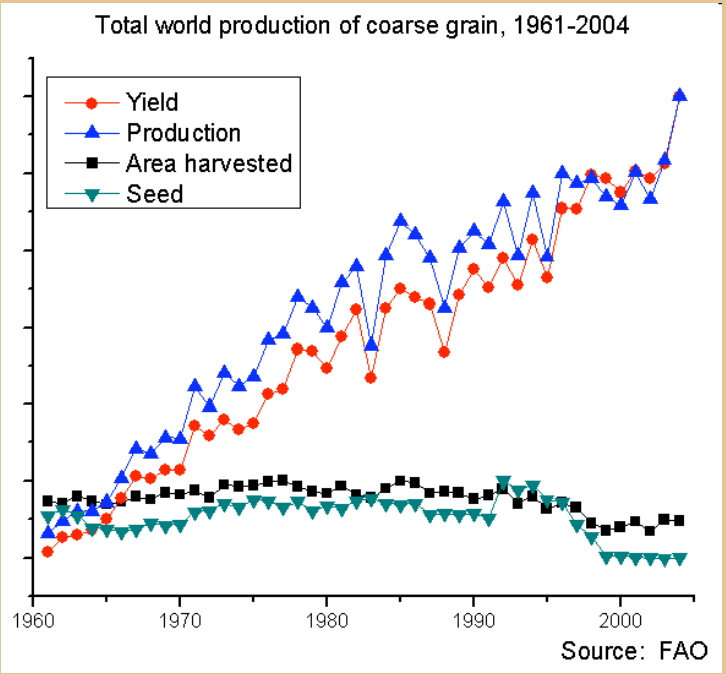
Two views of the role of technology…



"Technology networks are transforming the traditional map of development, expanding people's horizons and creating the potential to realize in a decade progress that required generations in the past", but…

"Complex problems of hunger and agricultural development will not be solved by technological silver bullets." Peter Rosset, Food First

Norman Borlaug, father of the Green Revolution, upon receiving the Congressional Gold Medal in 2006 for developing higher yielding rice and wheat varieties, said…



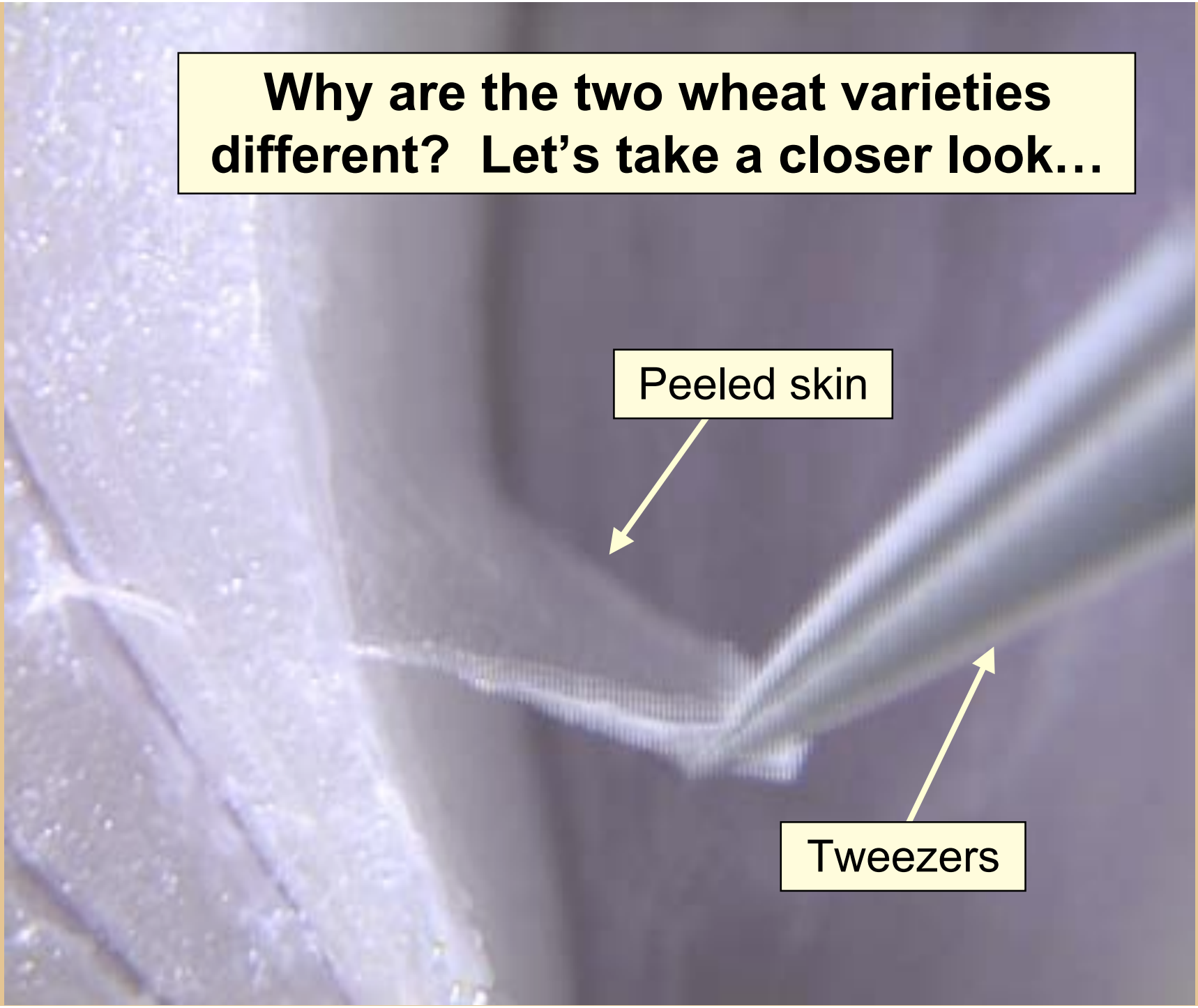
"The battle to ensure food security for hundreds of millions of miserably poor people is far from won. World peace will not be built on empty stomachs or human misery,"

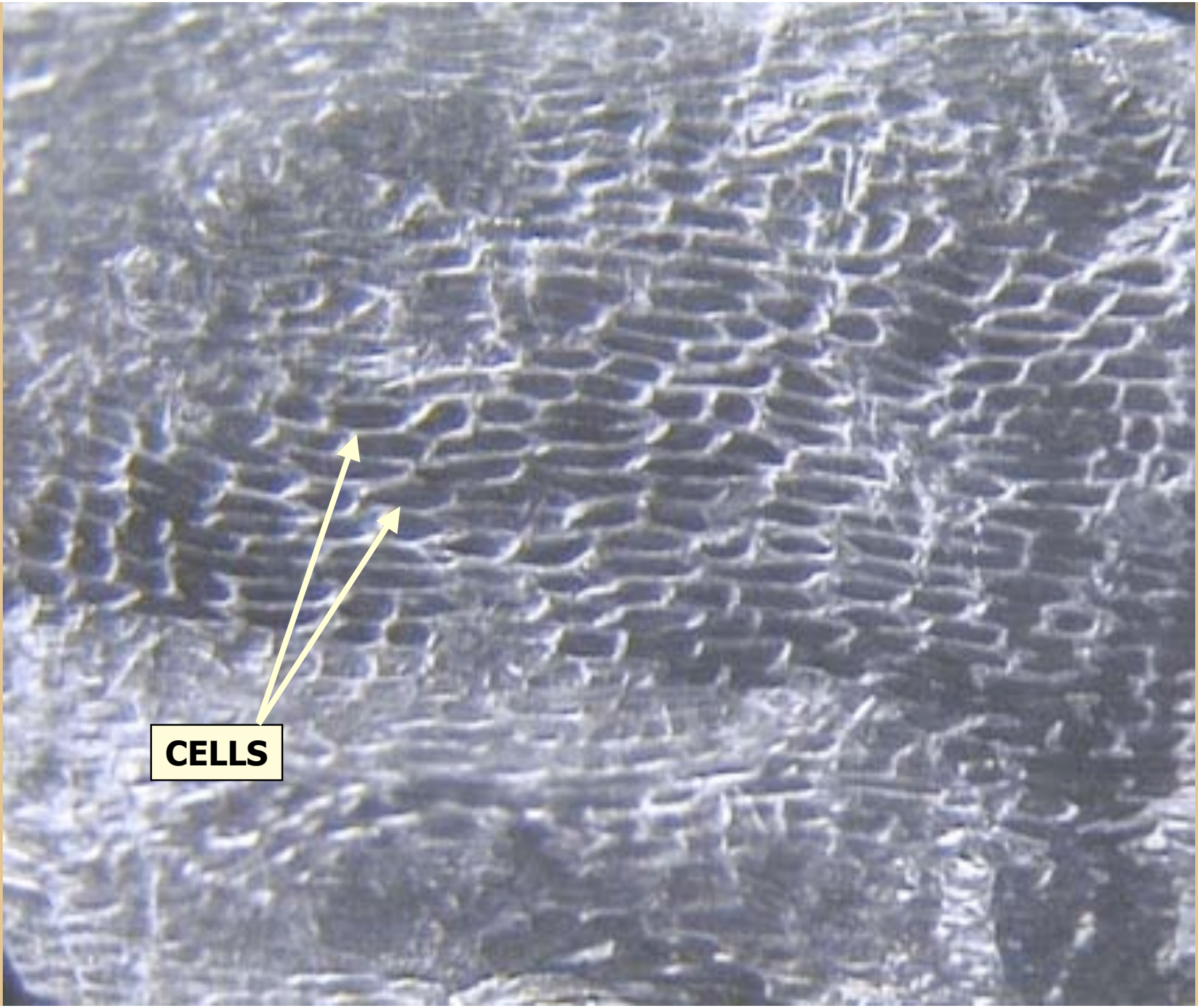
"It is within America's technical and financial power to help end this human tragedy and injustice, if we set our hearts and minds to the task."

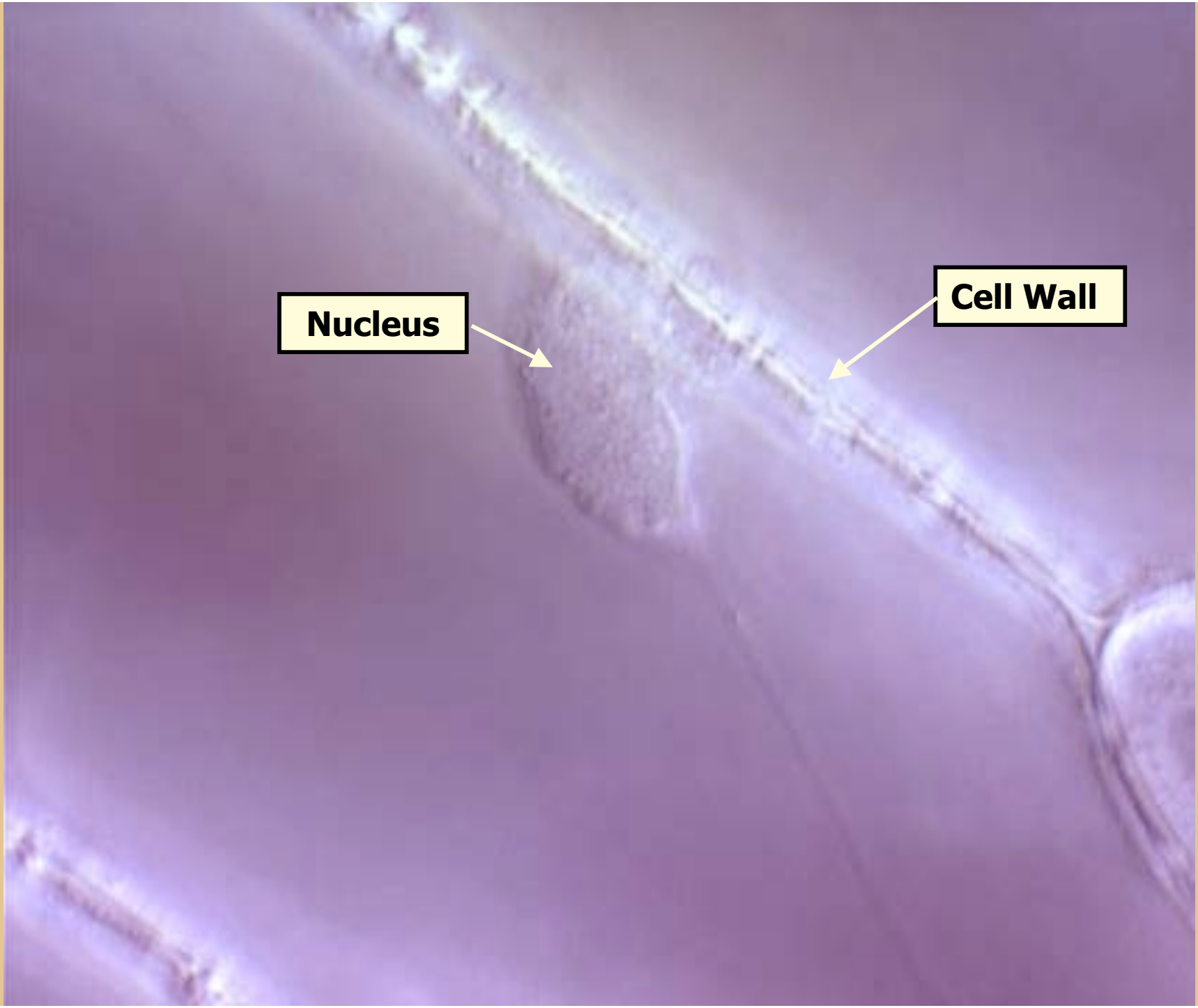
What are some genetic technologies that can be used to improve crops, like wheat?

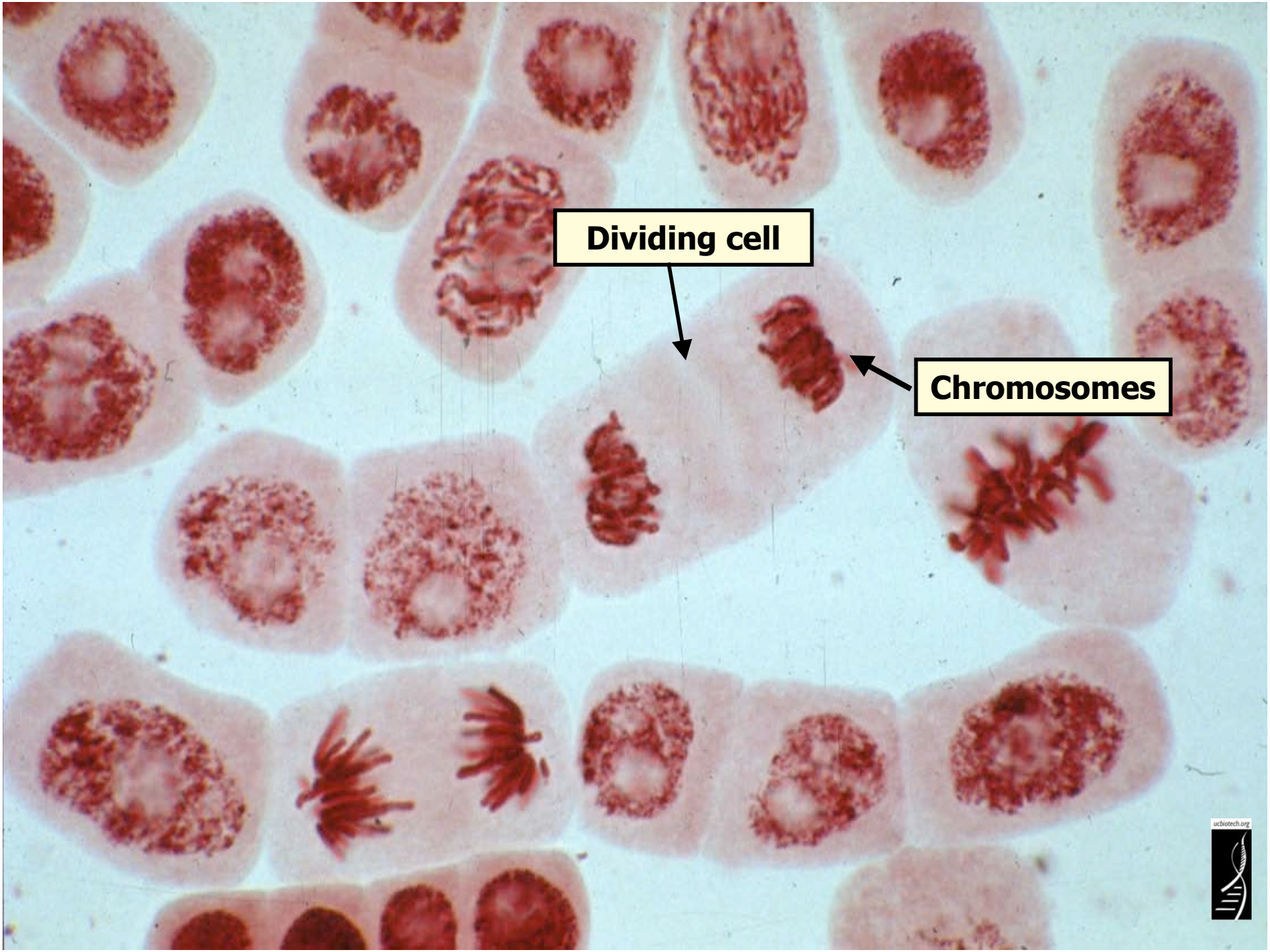
Triticum aestivum
Modern bread variety

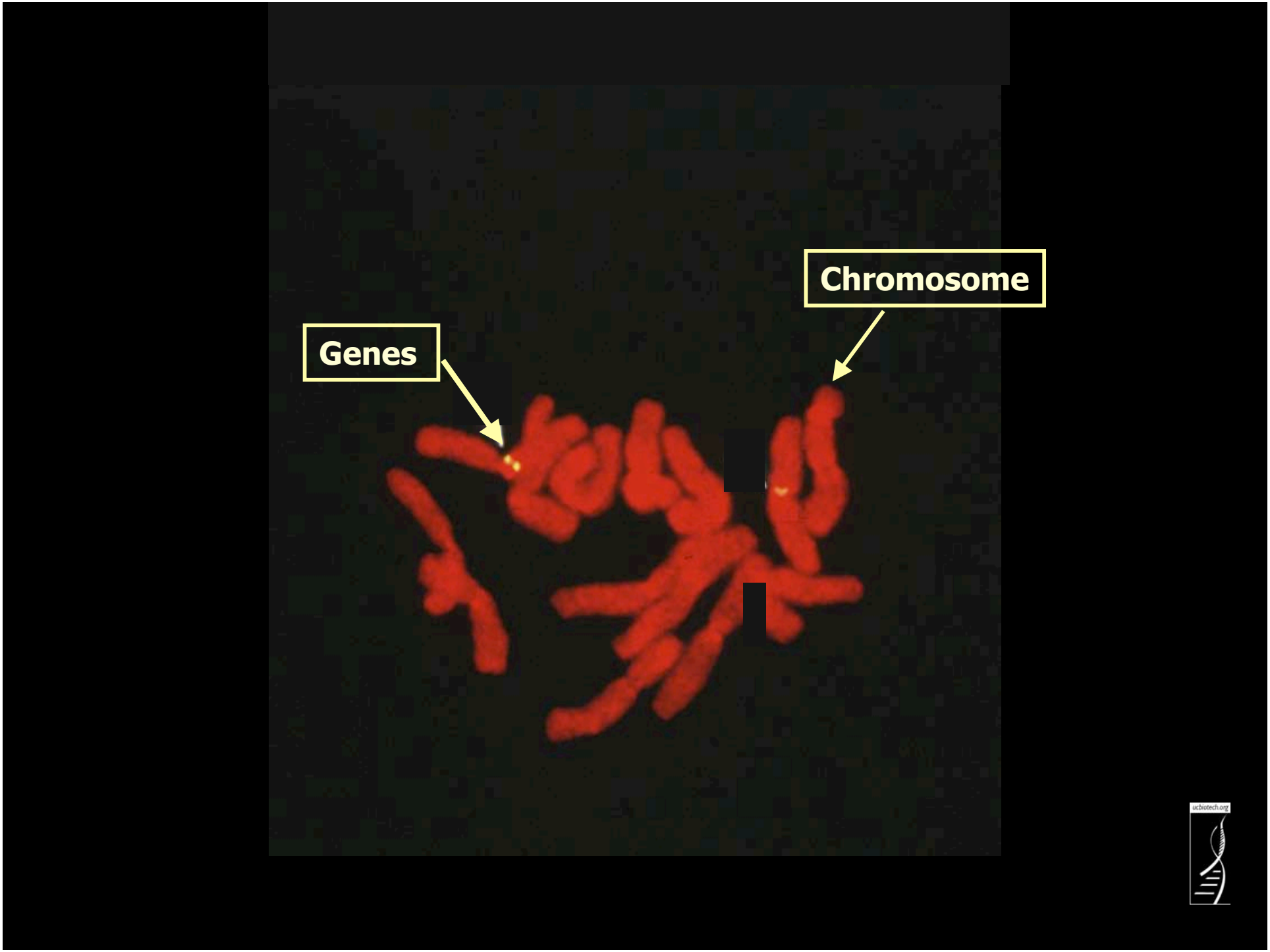
Triticum monococcum
Ancient variety


Why are the two wheat varieties different? Let's take a closer look…
Peeled skin
Tweezers


CELLS


Nucleus
Cell Wall


Dividing cell
Chromosomes
ucbiotech.org


Chromosome
Genes

Information in the wheat genome

Chemical units represented by alphabetic letters

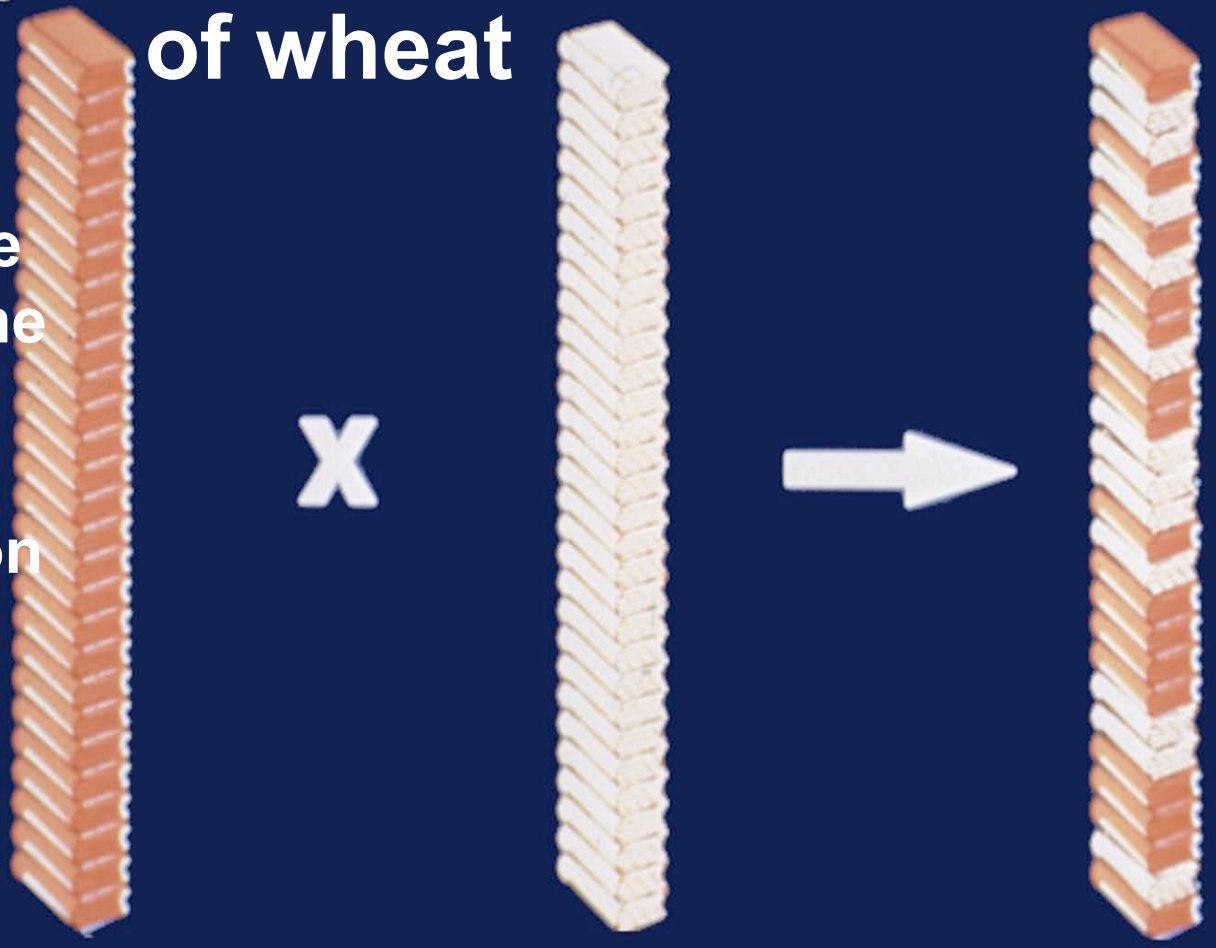
...CTGACCTAATGCCGTA...

1700 books
1000 pages each

1700 books
(or 1.7 milion pages)

Hybridization or cross breeding of wheat

Two varieties have some of the same and some different information contained in their books



Random retention of information from each parent

1700 books (or 1.7 million pages)

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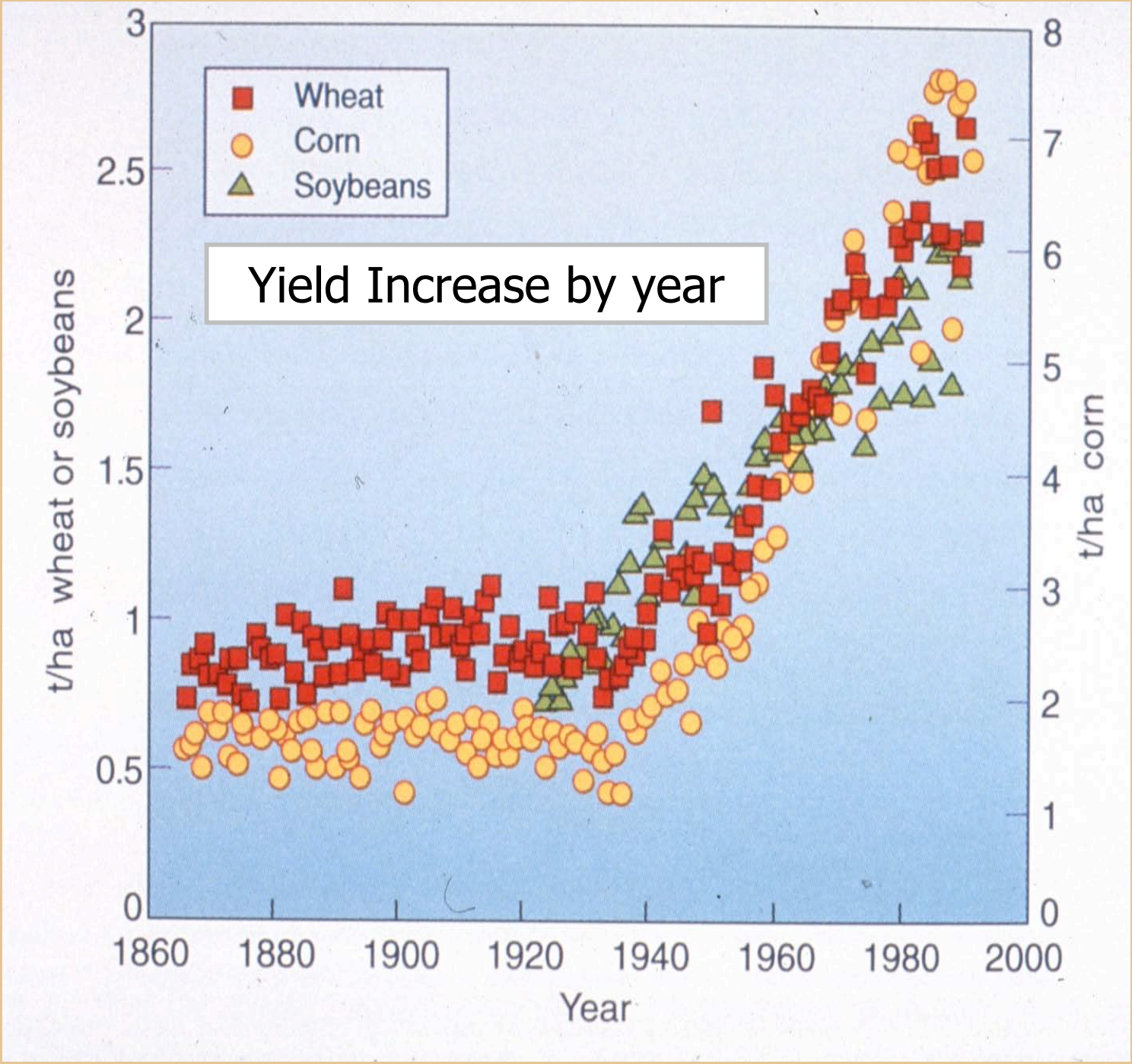
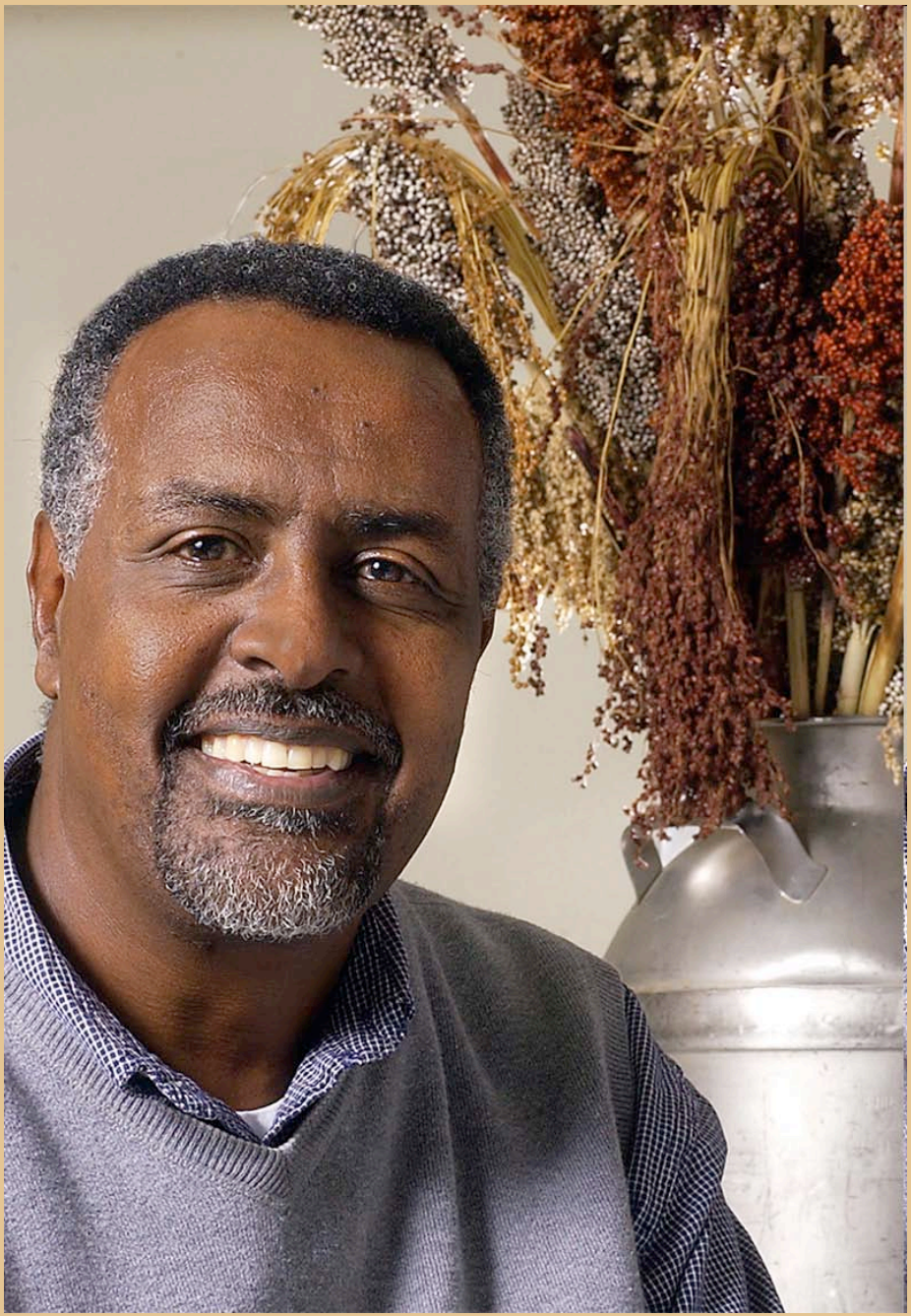
1700 books (or 1.7 million pages)

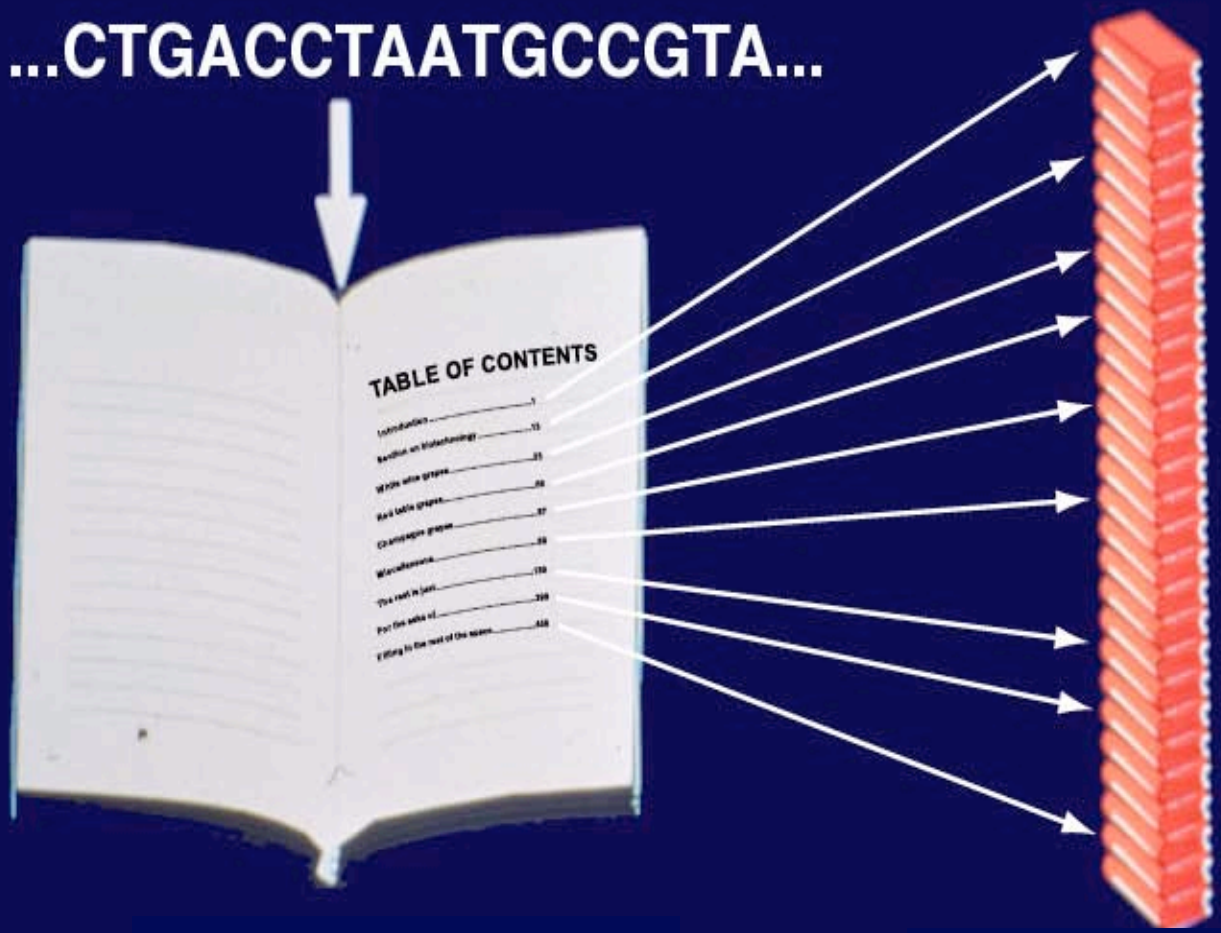

Wheat
Corn
Soybeans
Yield Increase by year
t/ha wheat or soybeans
t/ha corn
Year
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
1860
1880
1900
1920
1940
1960
1980
2000



The 2009 World Food Prize will be awarded to Dr. Gebisa Ejeta of Ethiopia, whose sorghum hybrids, resistant to drought and the devastating Striga weed, have dramatically increased production and availability of sorghum for the poor.

Table of contents for genes in wheat

...CTGACCTAATGCCGTA...



Used for Marker-Assisted Breeding

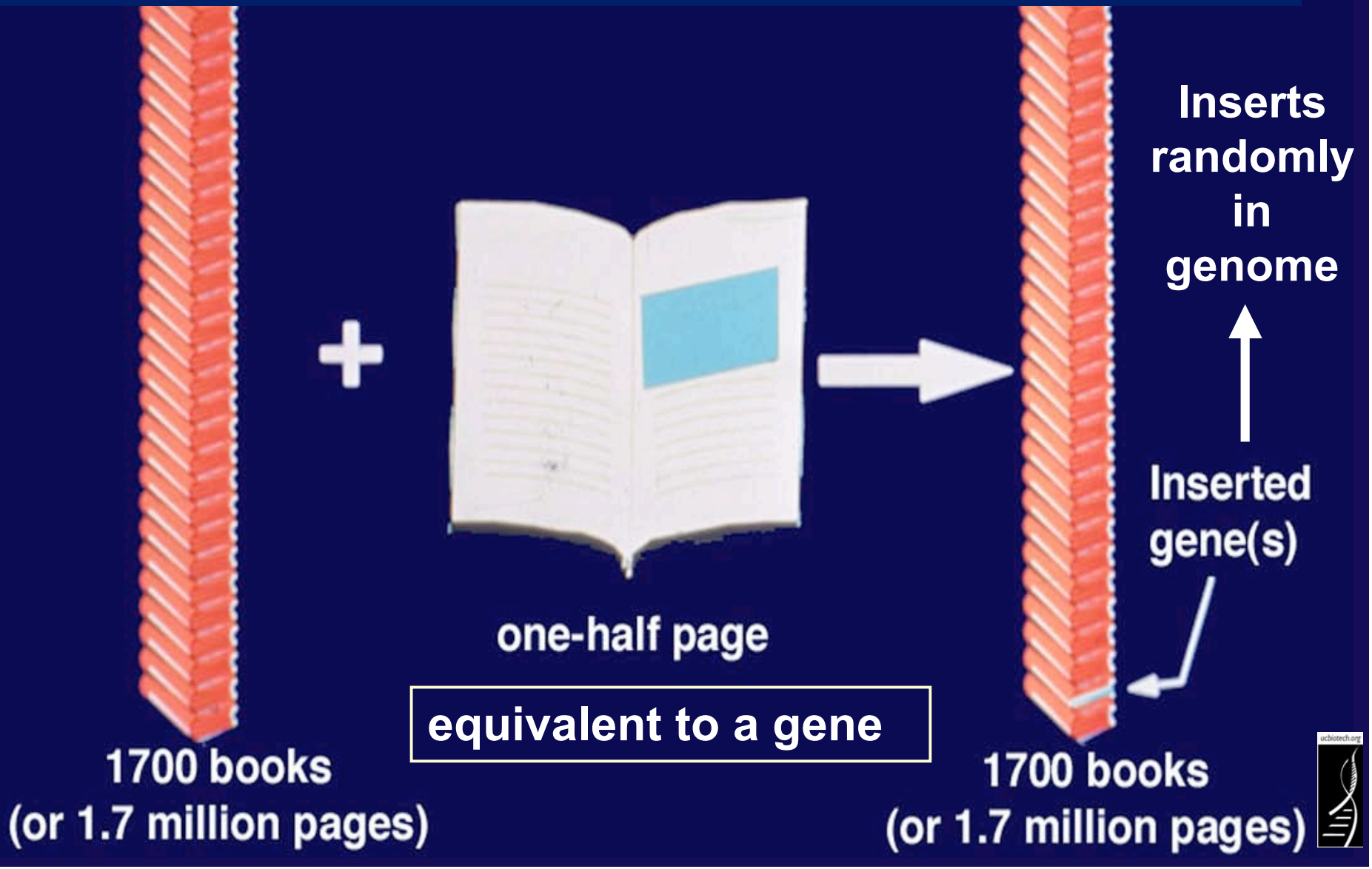
Genomics

1700 books
(or 1.7 million pages)

Water Efficient Maize for Africa (WEMA) uses marker-assisted breeding and biotechnology to develop African maize varieties

SOURCE: "Body announces plan to develop drought-tolerant maize for Africa", April 1, 2008, Checkbiotech.org

Biotechnology or Genetic Engineering Methods



Methods developed for genetic engineering are used in other ways besides just GMOs

Marker-assisted breeding led to new millet hybrid with powdery mildew resistance

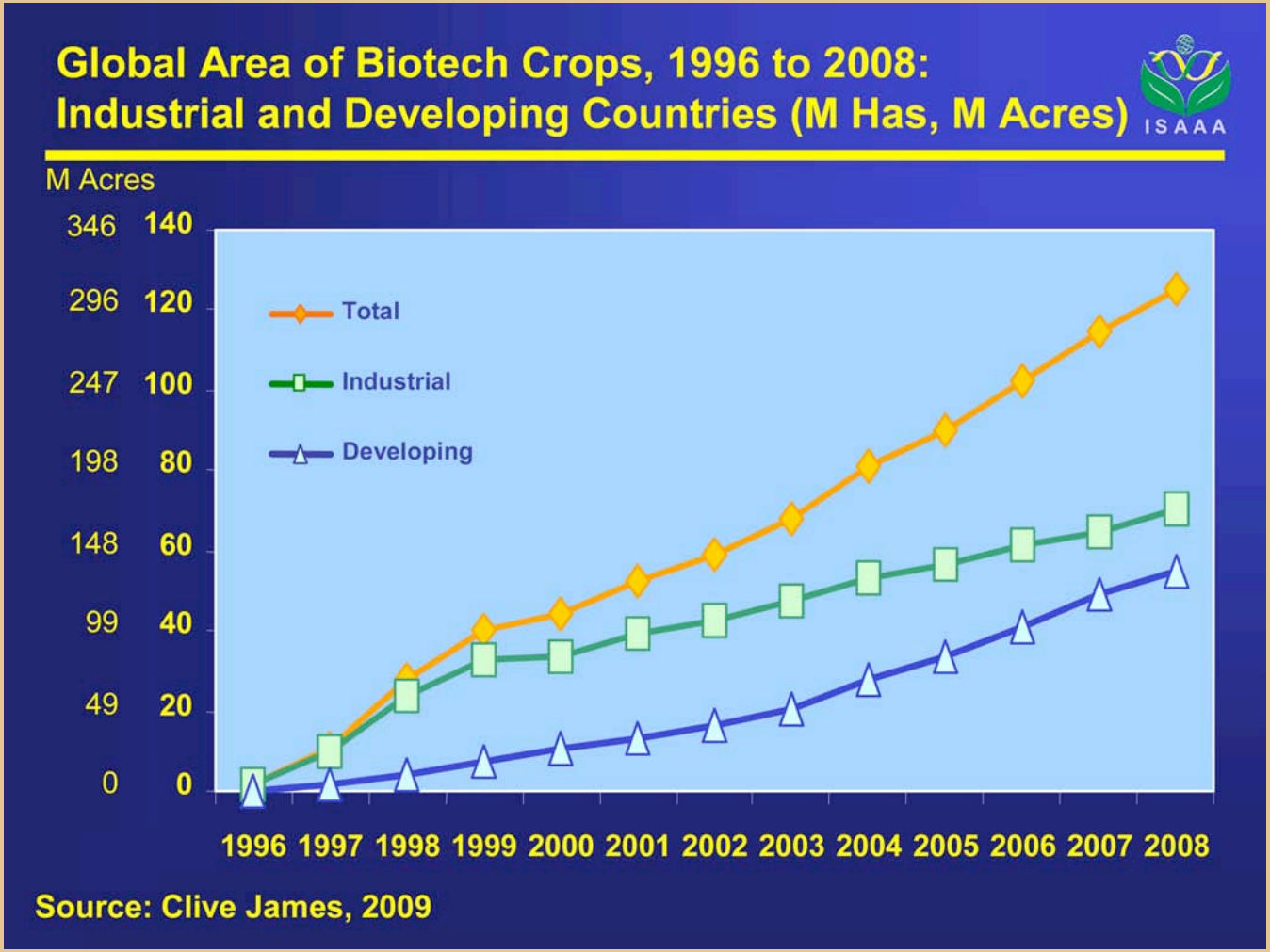
PCR for pest disease detection for bananas and papaya

Tissue culture methods of propagation for commercial production of banana, for example, rid the crop of viral disease. Female-managed companies in the Philippines give women a different role in agriculture and provide income

What questions are being asked about GE crops or GMOs?

- Are GE crops being grown in developing countries?
- Will they address small acreage farmers' needs?
- Why are they growing them?
- Are there regulatory and consumer acceptance issues??
- Is this a magic bullet for food security in Africa?

Are GE crops grown in developing countries?

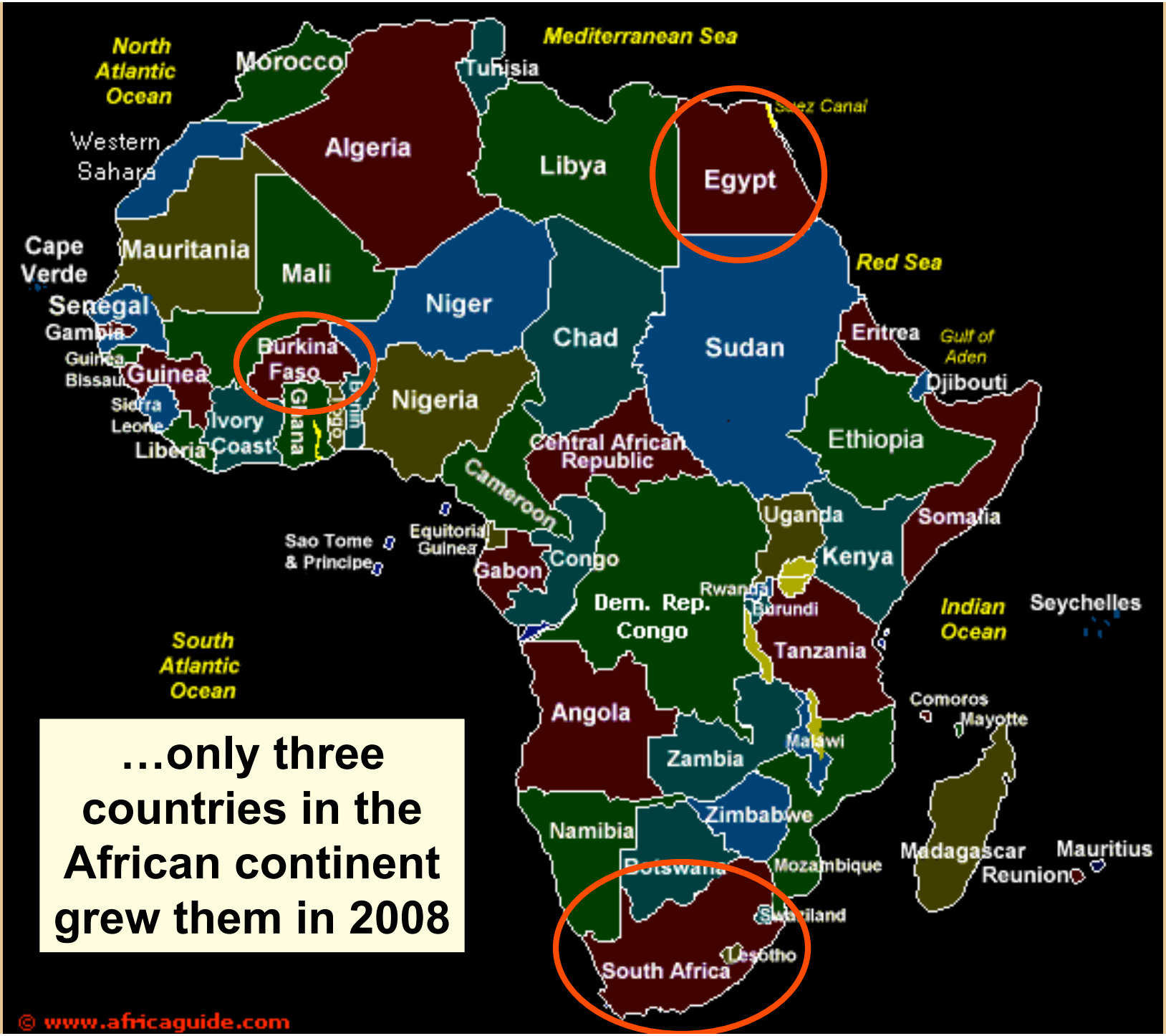


482,812 square miles worldwide in 2008 (equal to combined areas of CA, TX and NY) in 25 industrial and developing countries

But the variety of GE crops is limited and…

25 industrial and developing countries in order of acreage:

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



…only three countries in the African continent grew them in 2008

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*)

What does "pro-poor" mean?

How can this technology be pro-poor?

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 %**

Ref: : Qaim M and Zilberman D. 2003. **Science 299:900-902**

Another study, using data collected by researchers on field trials of 9000 farming families in India, found a 45-63% higher yield with Bt vs. nonBt cotton.

Ref: Bennett *et al*., 2006. *Rev Agric Econ* 28: 59-71

Reason for difference: Small-scale farmers suffer bigger pest-related yield losses due to technical and economic constraints

Yield indications for first research season for different survey areas.

Site	Variety	Mean yield (kg/kg)	*n*	Yield difference (kg/kg)	*t*-value	% yield difference
Avg. all farmers						
	Own seed	**63**				
	CRN seed	**187**	**175**	**59**	**8.679**	**32%***
	Bt seed	**246**				
Individual Sites:						
Northern Highveld						
	Own seed	32				
	CRN seed	90	33	56	4.490	62%*
	Bt seed	146				
Southern Highveld						
	Own seed	162				
	CRN seed	278	57	57	4.332	21%*
	Bt seed	335				
Hlabisa	Own seed	78				
	CRN seed	95	22	32	2.084	34%
	Bt seed	127				

*Yield difference statistically significant at a 95% level.

Following introduction, figures show small-scale farmers are getting increased yields and better quality with Bt maize.

Gouse et al., Three Seasons of Subsistence Insect-Resistant Maize in South Africa: Have Smallholders Benefited? *AgBioForum 9(1)-2*

Zimbabwe and Zambia stand united on GMOs

THE HERALD (Harare) Wisdom Mdzungairi
October 11, 2005

International scientists, including those from the United States, have praised Zimbabwe and Zambia for rejecting genetically-modified food donations from the West to feed scores of their rural folk facing drought-induced food shortages.

Some African countries have taken strong stands against, some for GE crops, leaving policymakers and the public confused

policymakers and the public because of lack of reliable information and guidance available to the groups."

Shouldn't African farmers and consumers make their own decisions on these issues?

Genetically engineered crops for developing countries: two examples

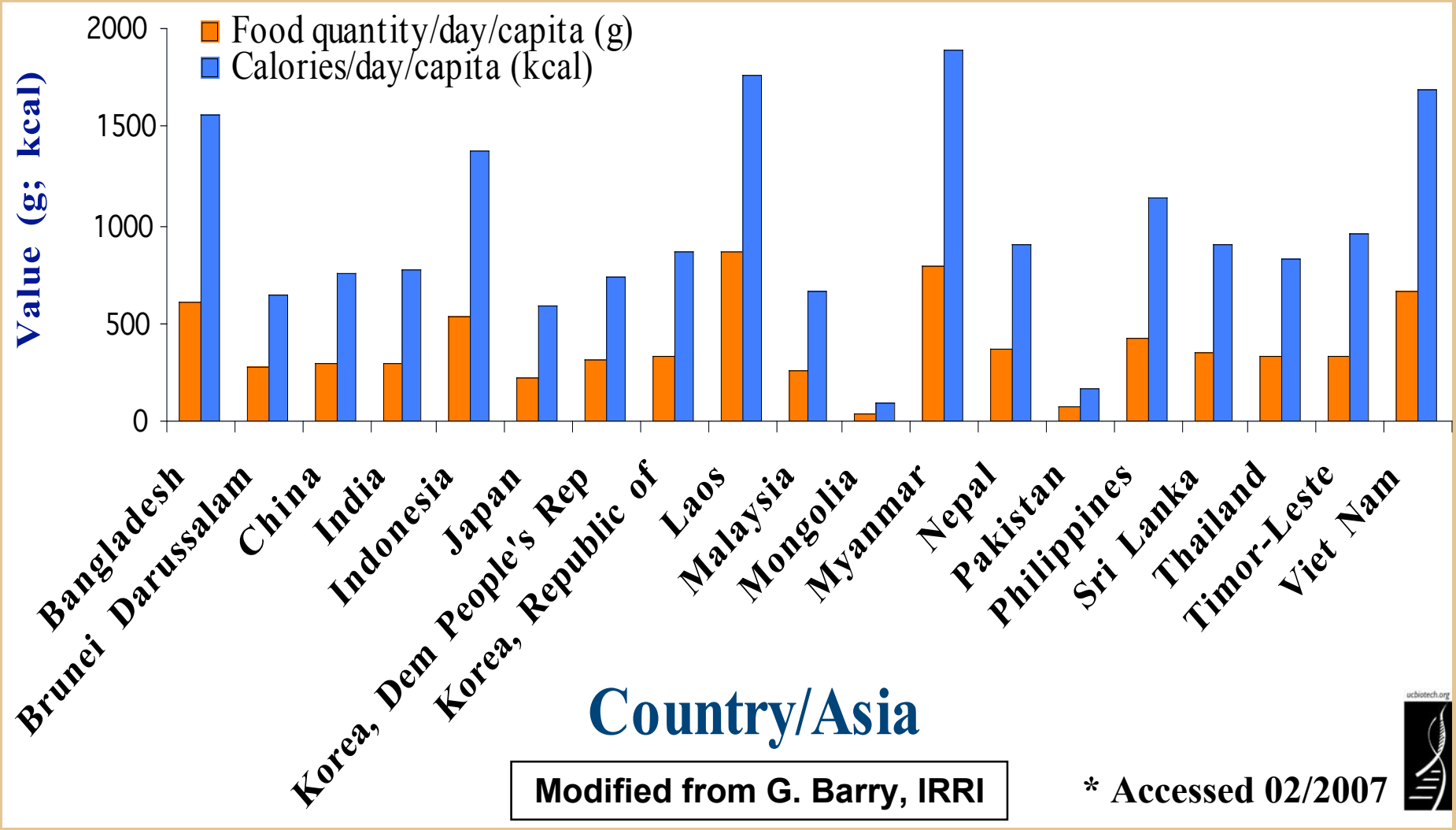
Public sector: Development of Golden Rice

Public-Private sector partnership: Development of SuperSorghum

Public sector: Development of Golden Rice

Rice: Critical Part of Many Diets
2004 (FAOSTAT)*

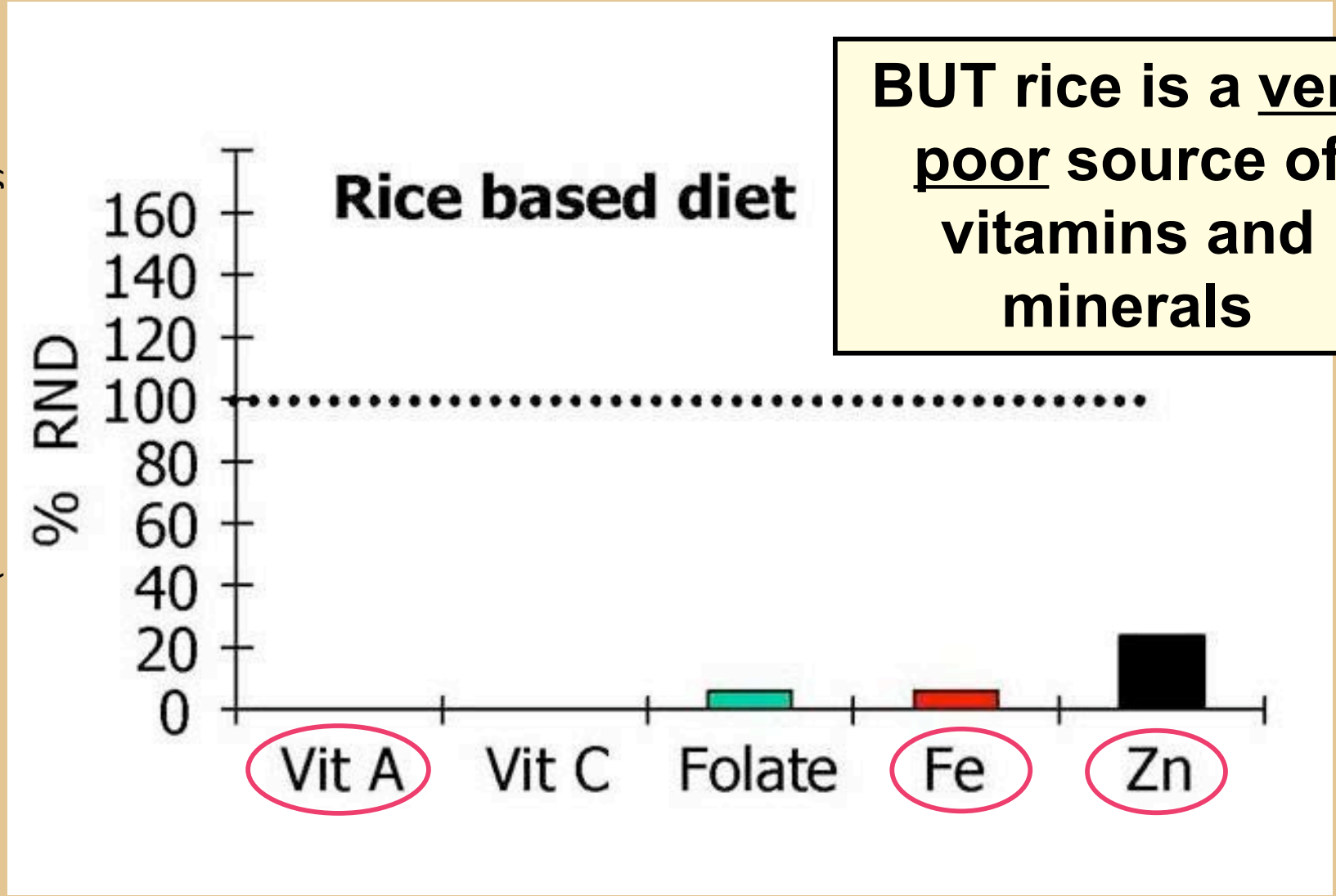
FAO Minimum Dietary Energy Requirement
= 1800 – 2000
(weighted average; kcal/person/day)



Modified from G. Barry, IRRI

* Accessed 02/2007

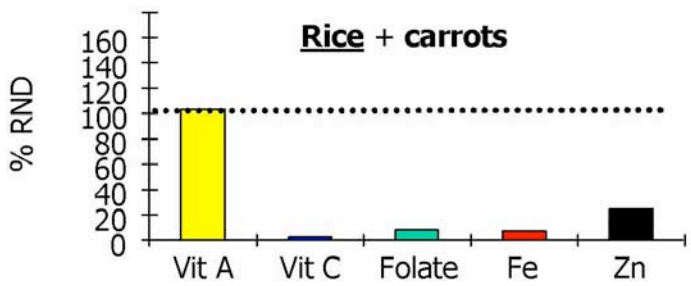
Rice Diet and Micronutrient Nutrition

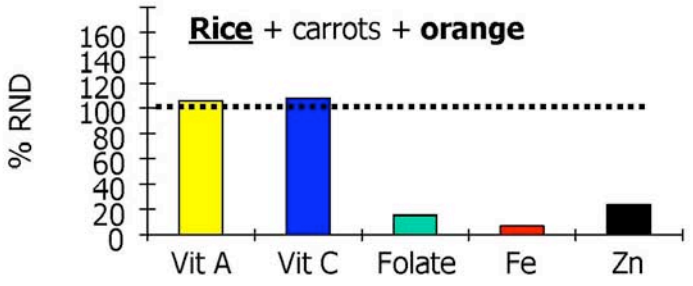


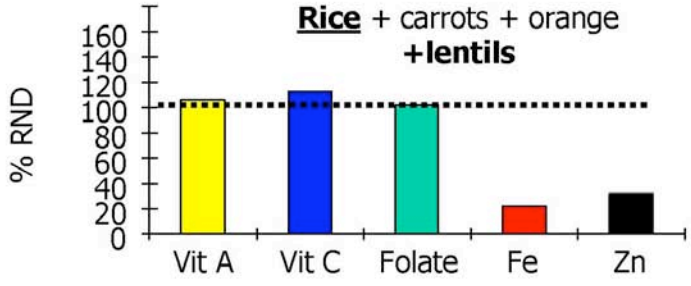
BUT rice is a <u>very poor</u> source of vitamins and minerals

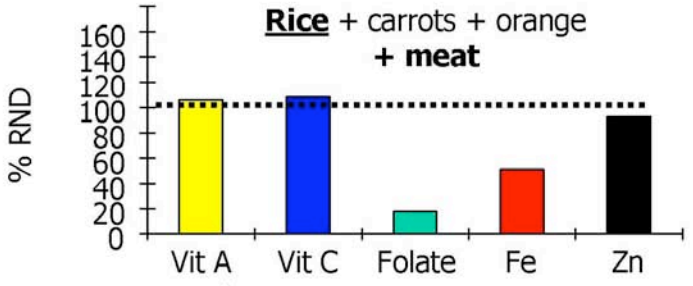
From: "Nutrition: A Cornerstone for Human Health and Productivity", Richard J. Deckelbaum. Seminar, Earth Institute of Columbia University, April 14, 2005

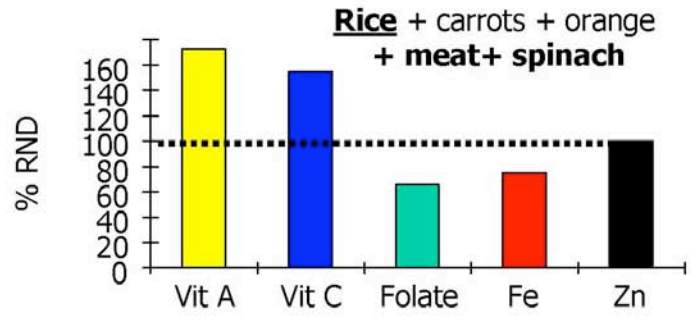
Modified from G. Barry, IRRI

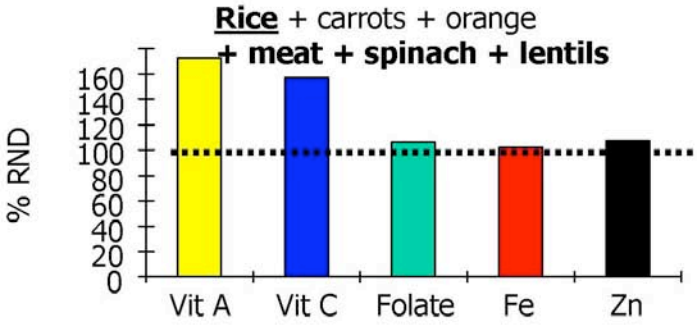












Rice diet can be supplemented with other fruits, vegetables and meat to acquire needed nutrients…but not everyone has that luxury

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

The FACTs in the Philippines are…

2 of 3 infants (6mos.-1yr) have iron-deficiency anemia

1 of 3 Filipinos are at risk of low zinc intake

4 of 10 children are vitamin A deficient

Numbers are increasing since 1990s

Micronutrient malnutrition is a serious public health problem

Emilia Boncodin, Fedl Budget Secy Manila Philippines

Biofortification can complement current interventions, all of which are needed.

Supplementation

Food Fortification

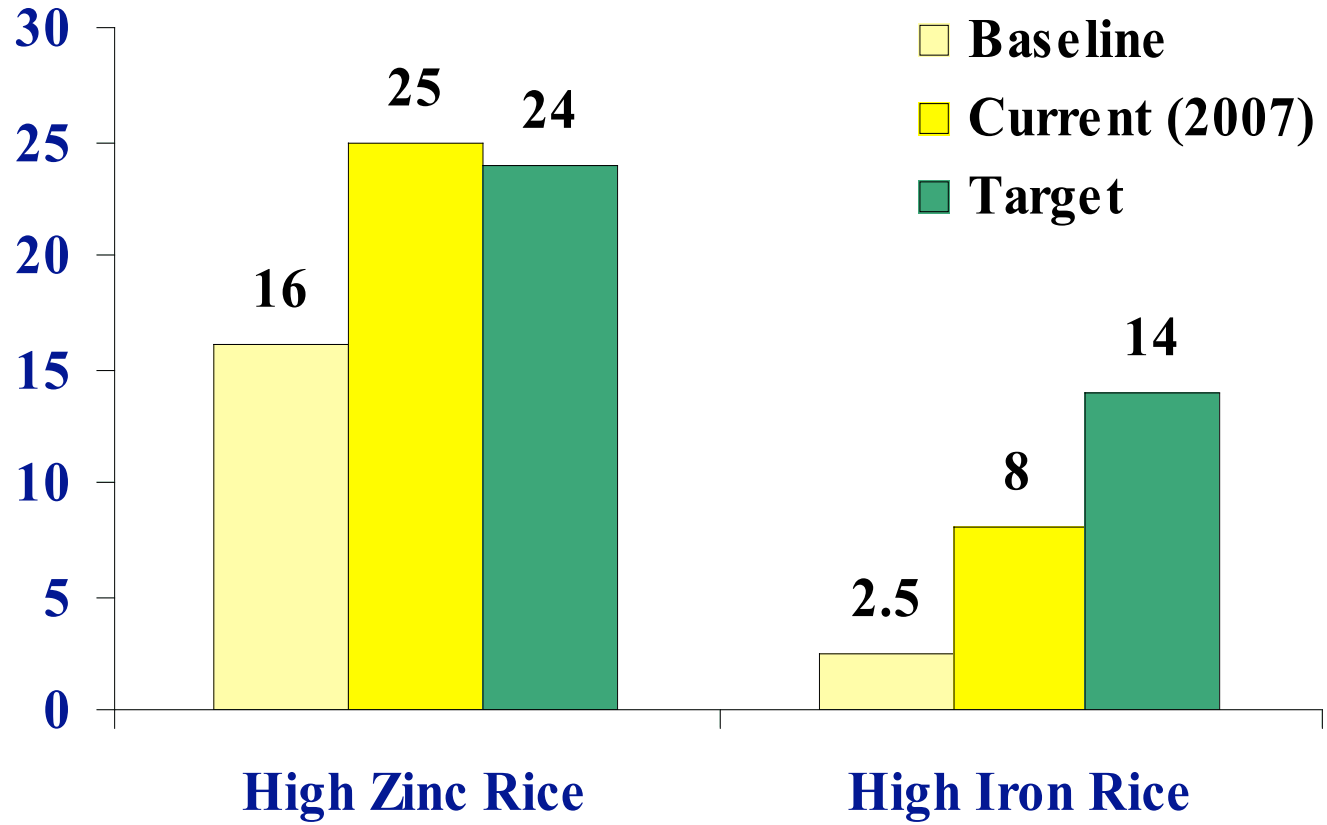
Dietary Diversity

Biofortification

Modified from G. Barry, IRRI

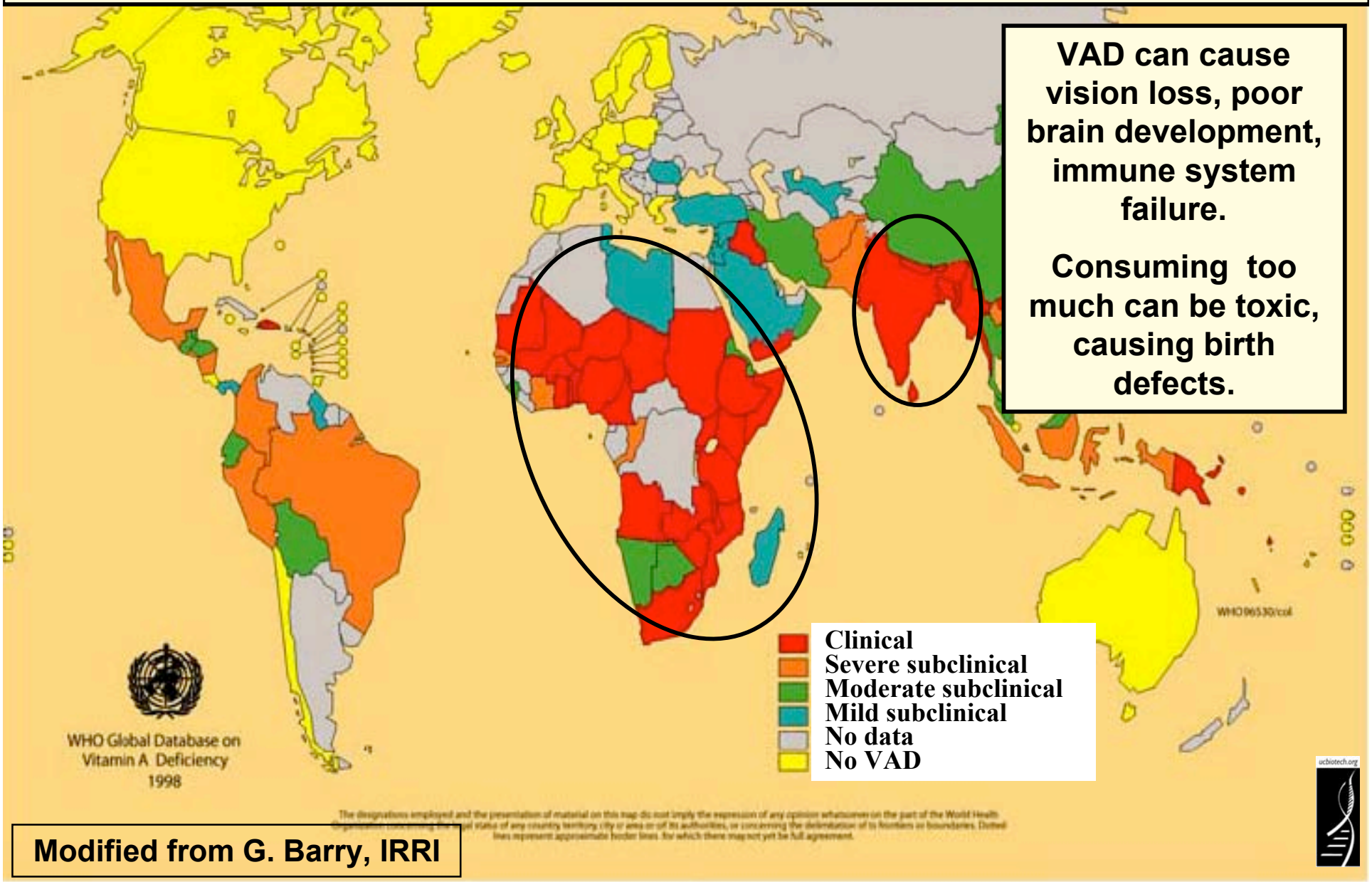
HarvestPlus
Breeding Crops for Better Nutrition

IRRI has made progress on iron and zinc biofortified rice…



E. Boncodin, Fedl Budget Secy Manila Philippines

Vitamin A deficiency (VAD): as judged by severity of health impact



Modified from G. Barry, IRRI

An estimate of the cost effectiveness for GR and VAD relief - India

Table 4. *The annual burden of VAD in India and the cost-effectiveness of GR*

Scenario	Low impact	High impact
Current burden of VAD		
Number of DALYs lost each year (thousands) (DALY = Disability Adjusted Life Years)	2,328	

2 million disability years lost in India to Vitamin A deficiency

71,000 lives lost each year in India to VAD

0.2-1.3 million disability years could be saved with Golden Rice

5,000- 40,000 lives could be saved each year with Golden Rice

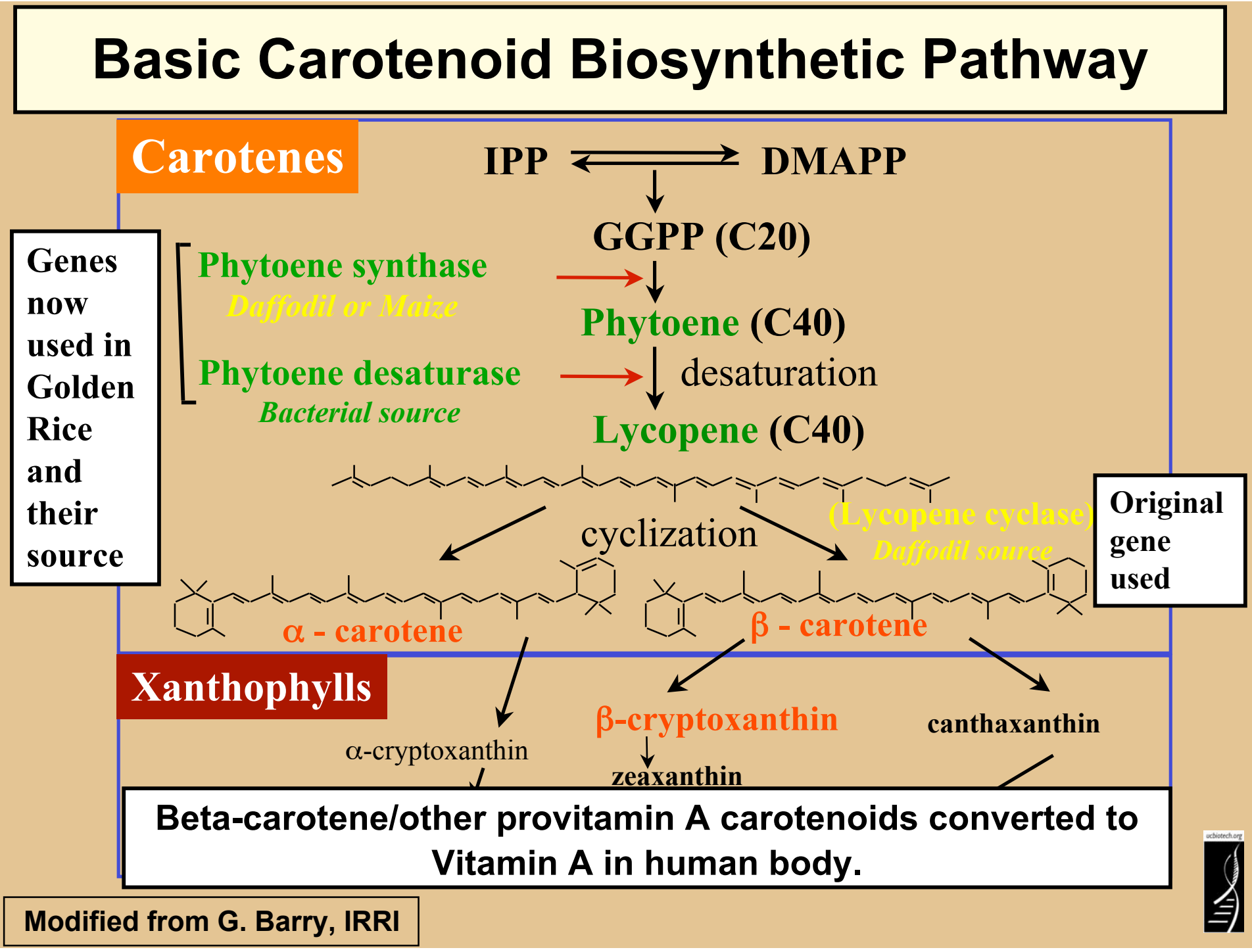
And it is cheaper than supplementation by 2- to 6-fold

World Bank cost-effectiveness standard for DALYs saved (U.S.$)	200
WHO standard for valuing DALYs (U.S.$)	620-1,860
Cost per DALY saved through supplementation (U.S.$)	134-599
Cost per DALY saved through industrial fortification (U.S.$)	84-98

Modified from G. Barry, IRRI

Stein *et al.* 2007 World Development – in press

Basic Carotenoid Biosynthetic Pathway



Golden Rice in 2000

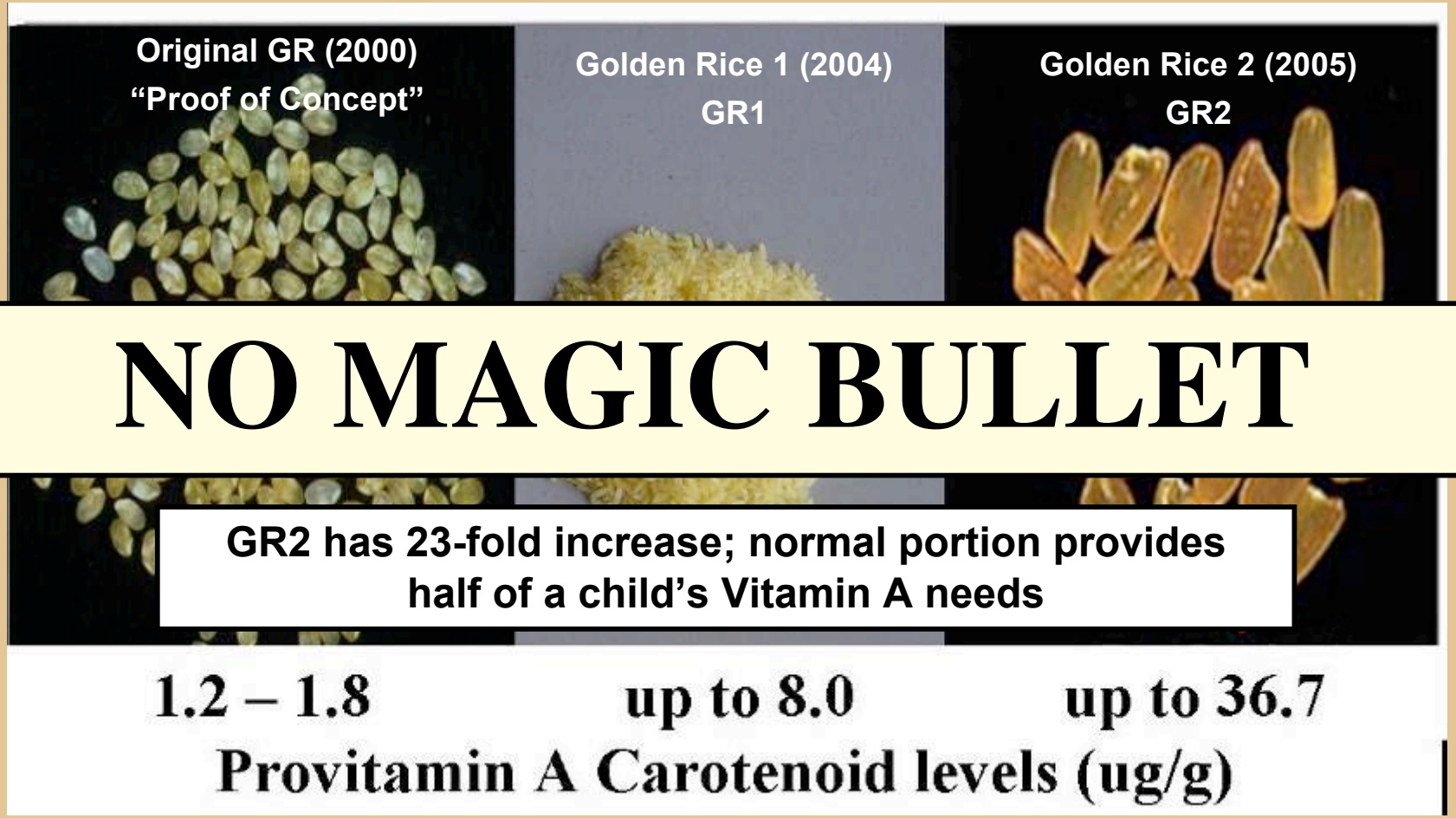
'Golden Rice', developed by Ingo Potrykus and Peter Beyer, was funded by Rockefeller Foundation, Swiss Federal Institute of Technology, European Union, and Swiss Federal Office for Education and Science.

Polished, original version of Golden Rice had measurable levels of β-carotene – to be used as a food-based approach to complement other approaches to reduce problem of Vitamin A Deficiency

Modified from G. Barry, IRRI

Types of Golden Rice

GR1 and GR2 developed by Syngenta, donated to GR Humanitarian Board for use in developing countries by GR Network

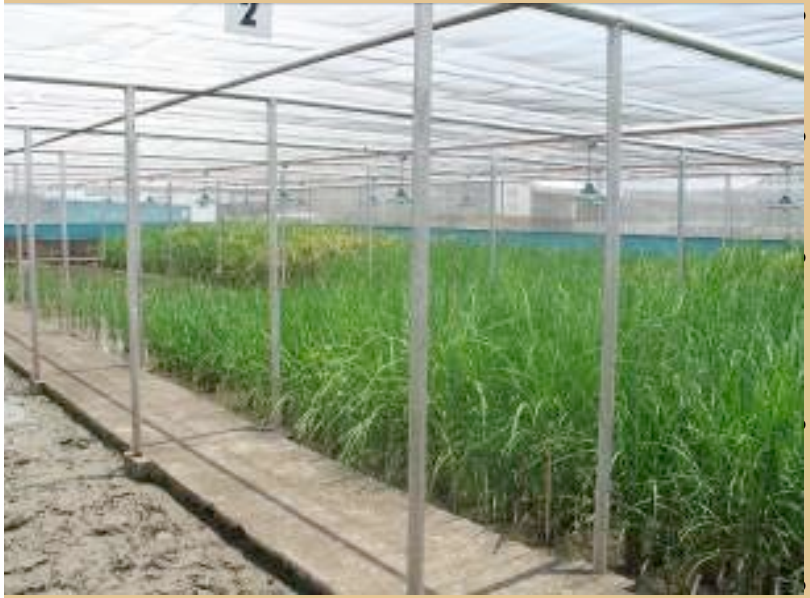


NO MAGIC BULLET

GR2 has 23-fold increase; normal portion provides half of a child's Vitamin A needs

Golden Rice is now a breeding project

Transferring Golden Rice traits into popular rice varieties at IRRI



IR64 & IR36: Mega-varieties with broad Asian coverage (GR1 & GR2)

BR29: The most popular and productive *boro* rice variety in **Bangladesh** (GR1 & GR2)

An IRRI-bred line released as PSB Rc82: the most popular rice variety in the **Philippines** (GR2)

Only one event will ever be released/go through full regulatory approval; **2011 first release**

Parallel introgression breeding being done by Golden Rice Network partners in **India, Vietnam, and the Philippines**

E. Boncodin, Fedl Budget Secy Manila Philippines

First Outdoor Trial of Golden Rice in Asia

IR64 GR1 event 309; 20 lines

Transplanting at IRRI April 2, 2008

May 30, 2008

April 10, 2008

E. Boncodin, Fedl Budget Secy Manila Philippines

Public-Private sector partnership:
Development of SuperSorghum

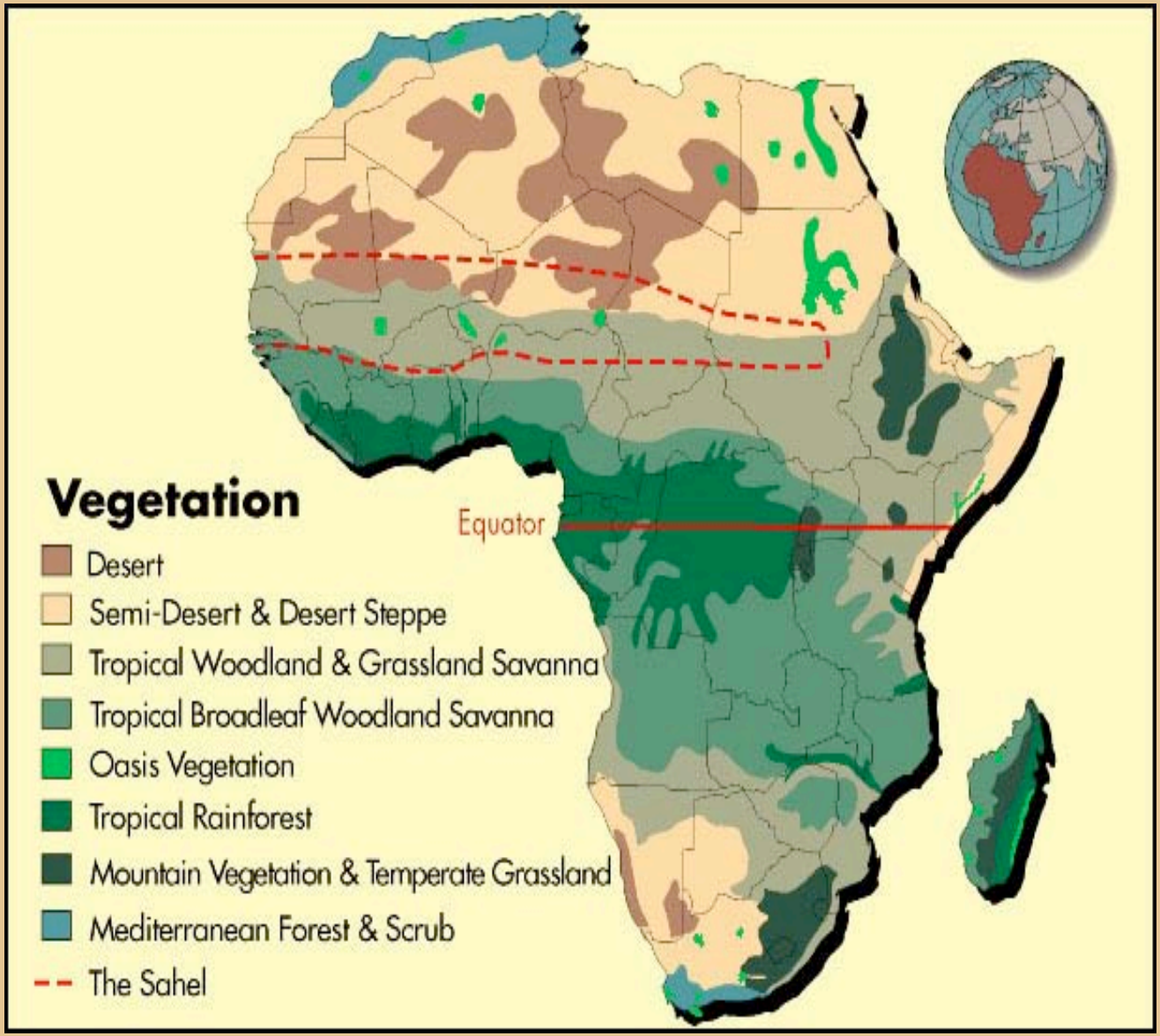
Why Pick Sorghum for Our Target?

- **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**

Cultivated sorghum

Wild outcrossing species

Sorghum is uniquely adapted to Africa's climate – it withstands both drought and water logging



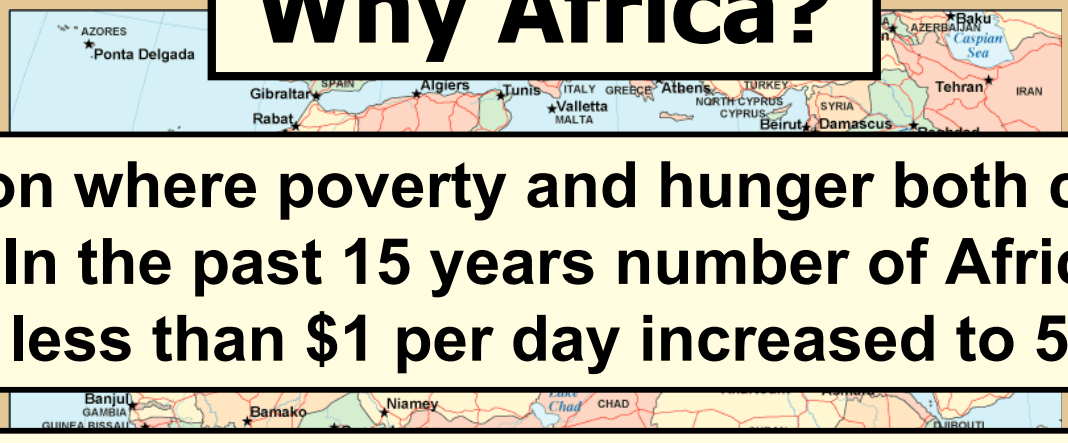
During prolonged drought in South Africa, sorghum thrived while maize struggled!

Maize

Sorghum

Potchestrom, South Africa Feb. 17, 2007

Why Africa?



Only region where poverty and hunger both continue to increase. In the past 15 years number of Africans living on less than $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.

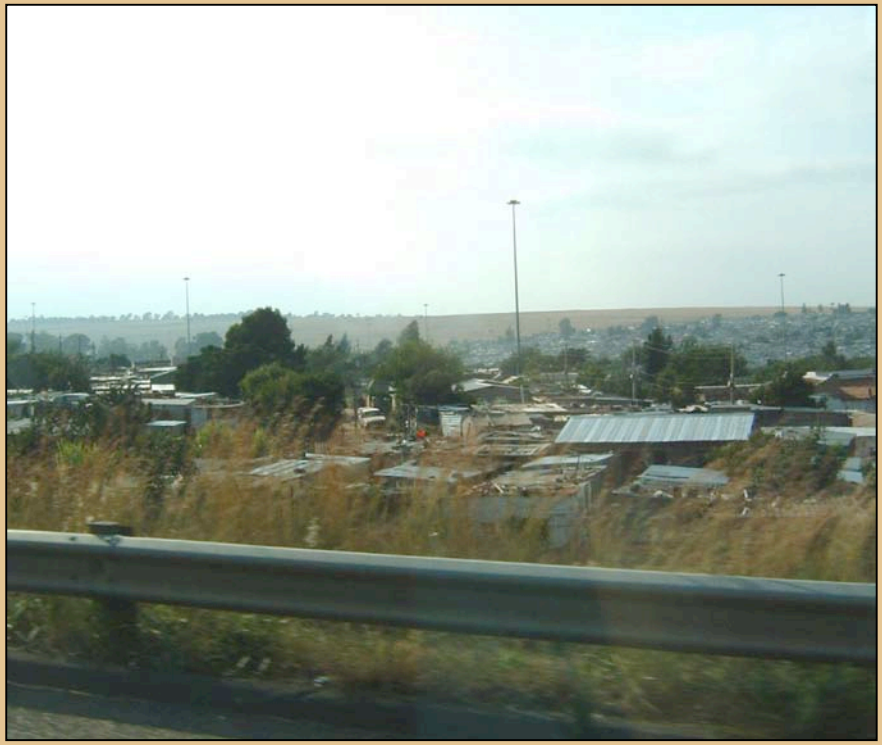
Africa's farms yielded 19% less agricultural production per capita in 2005 than they did in 1970.

In 2004 UN Development Programme said Africa as a whole would not reach its 2015 Millennium Development Goal for alleviating human poverty until 2147!

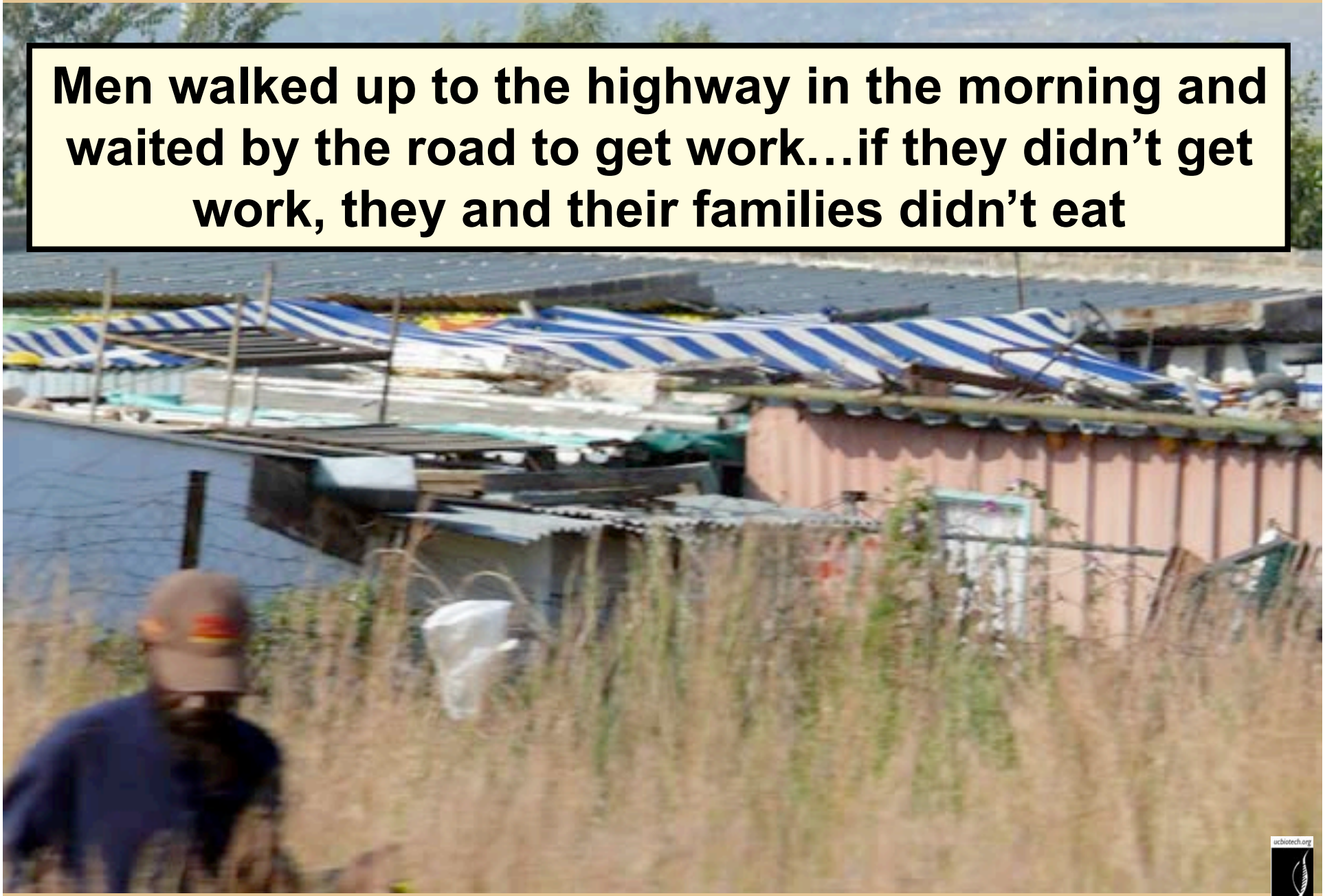
From "Starved for Science: How Biotechnology Is Being Kept out of Africa" by R. Parlberg 2008

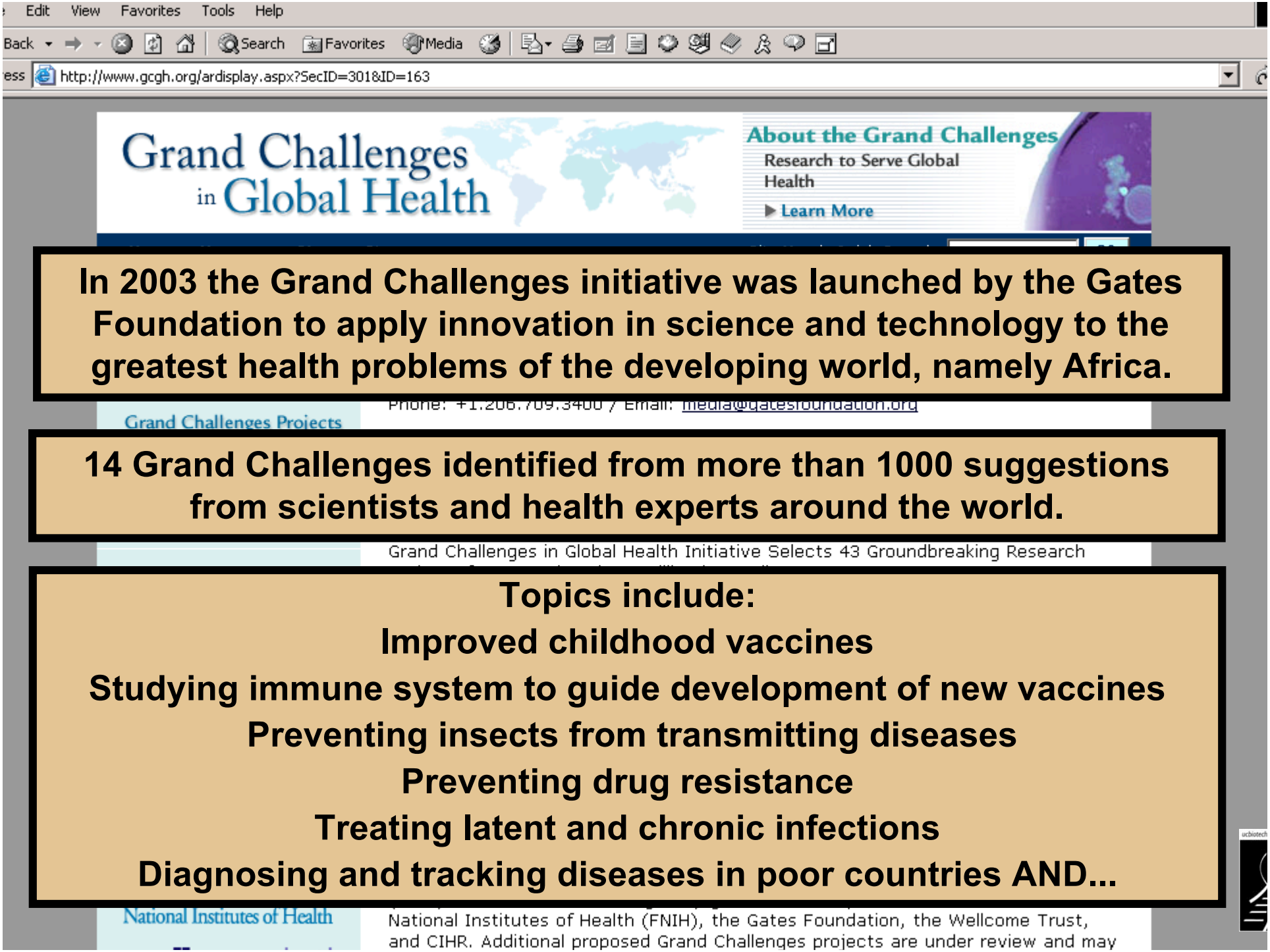

Homes in rural communities are not spacious, but at least there are small spaces to grow food

Just outside cities – often juxtaposed next to modern suburbs –as far as the eye could see were tiny huts crammed together with no place to raise crops.




The poverty was staggering – with whole families living in a place the size of our walk-in closets
ucbiotech.org


Men walked up to the highway in the morning and waited by the road to get work…if they didn't get work, they and their families didn't eat


Edit View Favorites Tools Help
Back Search Favorites Media
http://www.gcgh.org/ardisplay.aspx?SecID=301&ID=163
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, namely Africa.
Grand Challenges Projects
14 Grand Challenges identified from more than 1000 suggestions from scientists and health experts around the world.
Grand Challenges in Global Health Initiative Selects 43 Groundbreaking Research
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...
National Institutes of Health
National Institutes of Health (FNIH), the Gates Foundation, the Wellcome Trust, and CIHR. Additional proposed Grand Challenges projects are under review and may

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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."

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

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

Focused on 4 crops:

banana, cassava, rice and SORGHUM

Sorghum is a major food in these areas but is nutritionally deficient in:

Vitamins
Minerals
Amino acids
(like most cereals)

But, uniquely, it is

Poorly Digested

Can't they just eat something else to make up for deficiencies?

Addressing the nutritional challenge

Goal of Super Sorghum Project

Develop more nutritious, easily digestible, biofortified sorghum, containing higher levels of pro-vitamin A, vitamin E, iron, zinc, and deficient amino acids, lysine, tryptophan and threonine, for the arid and semi-arid tropical areas of Africa

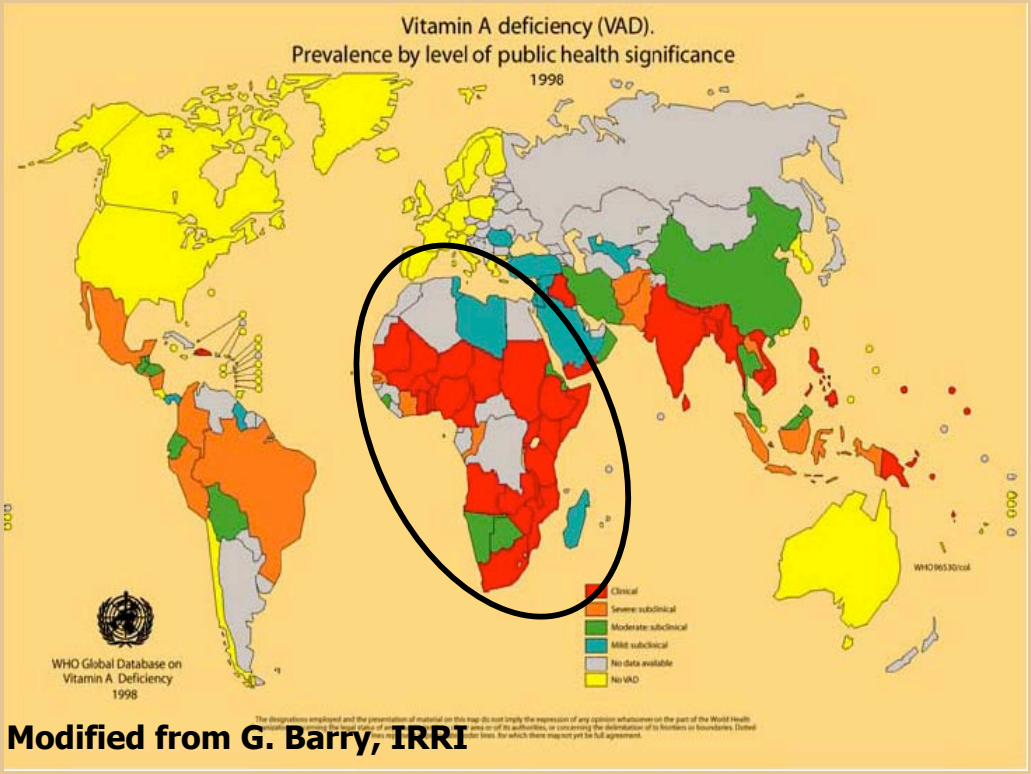
Focus of ABS Project: Food Quality

Aims

- ❖Increase levels of Vitamin A and E
- ❖Increase iron and zinc availability
- ❖Improve protein quality
- ❖Improve digestibility upon cooking

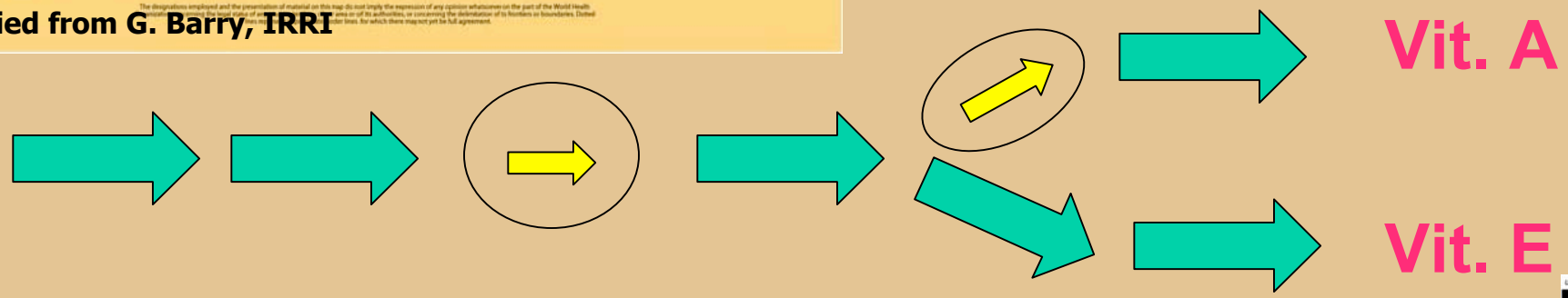
- ❖Earlier breeding efforts to improve some target traits unsuccessful
- ❖GE strategy needed to improve multiple target traits simultaneously
- ❖All genes from crop sources, except one from common microbe
- ❖All approaches validated in corn and other cereals

Vitamin A Deficiency: Severe Health Problem in Africa

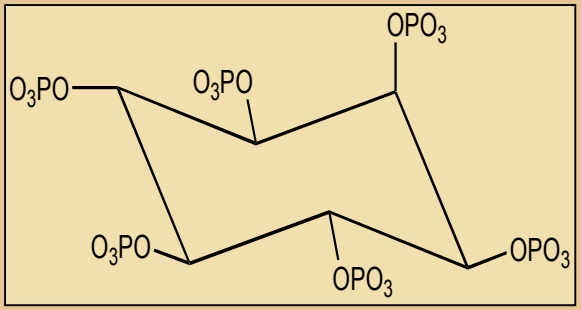


Modified from G. Barry, IRRI

- Sorghum grain - very low levels of Vit A and E
- Vit A critical for eyesight Vit E protects Vit A.
- Increase production by improving rate-limiting steps in biosynthesis



Improving Iron and Zinc Availability in Sorghum by Reducing Phytic Acid in Grain



Phytic Acid

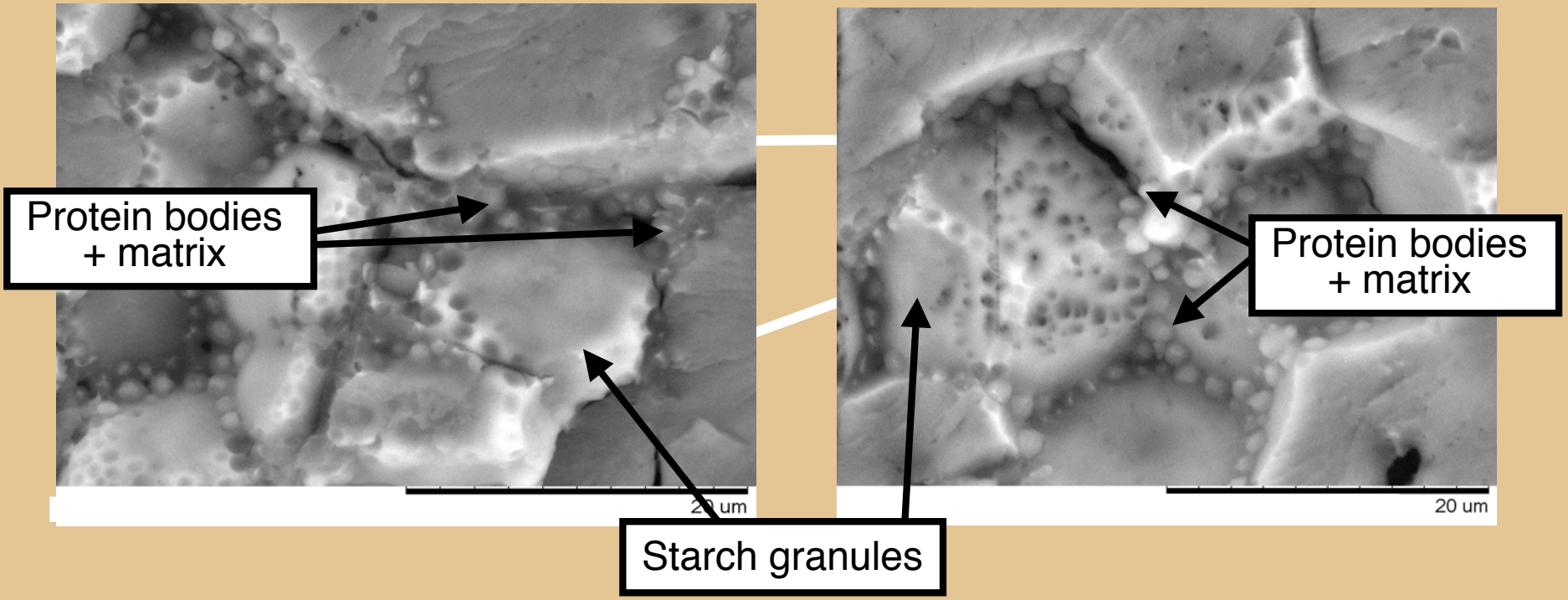
- **Phytic acid in the seed binds iron and zinc**
- **Reduce phytic acid by blocking production**
- **Lower phytic acid frees iron & zinc to be taken up from food**

Improving Protein Quality
UCB involvement

- **Improve Protein Quality**
  - Introduce new protein with increased Lys, Trp, Met, Thr
  - Decrease proteins with poor quality
- **Improve Protein Digestibility**
  - Decrease proteins negatively affecting digestibility
  - Alter digestibility of protein

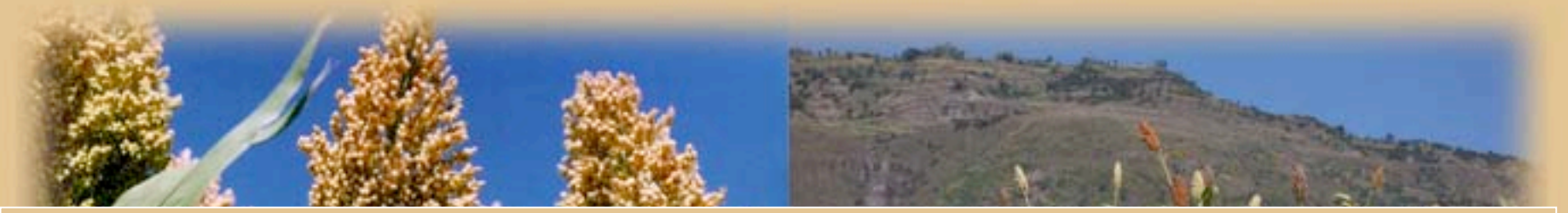
Improving Digestibility

Starch granules embedded in protein matrix



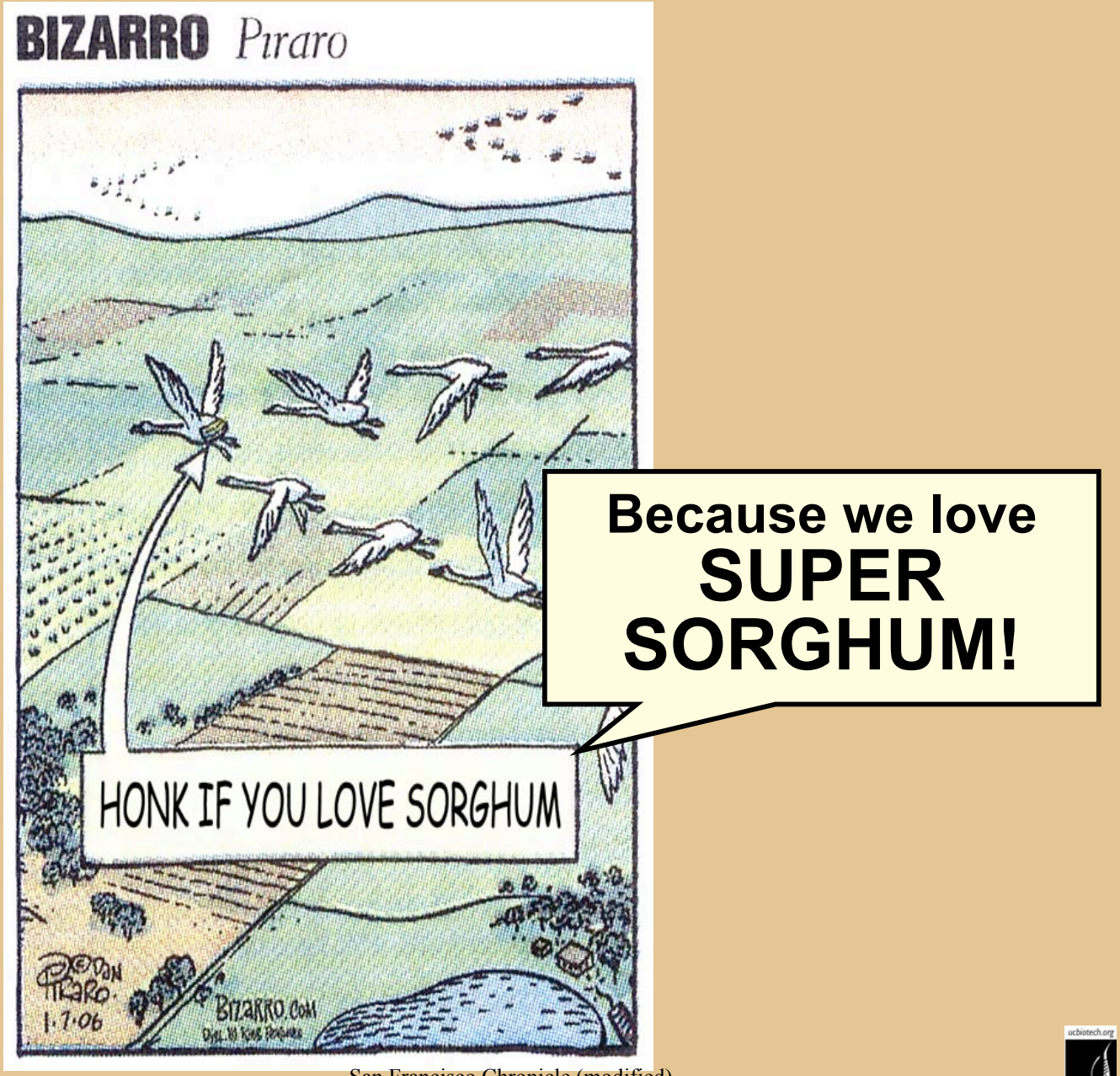
Disulfide bonds within and between kafirins hinder starch and storage protein digestibility upon cooking

Super Sorghum

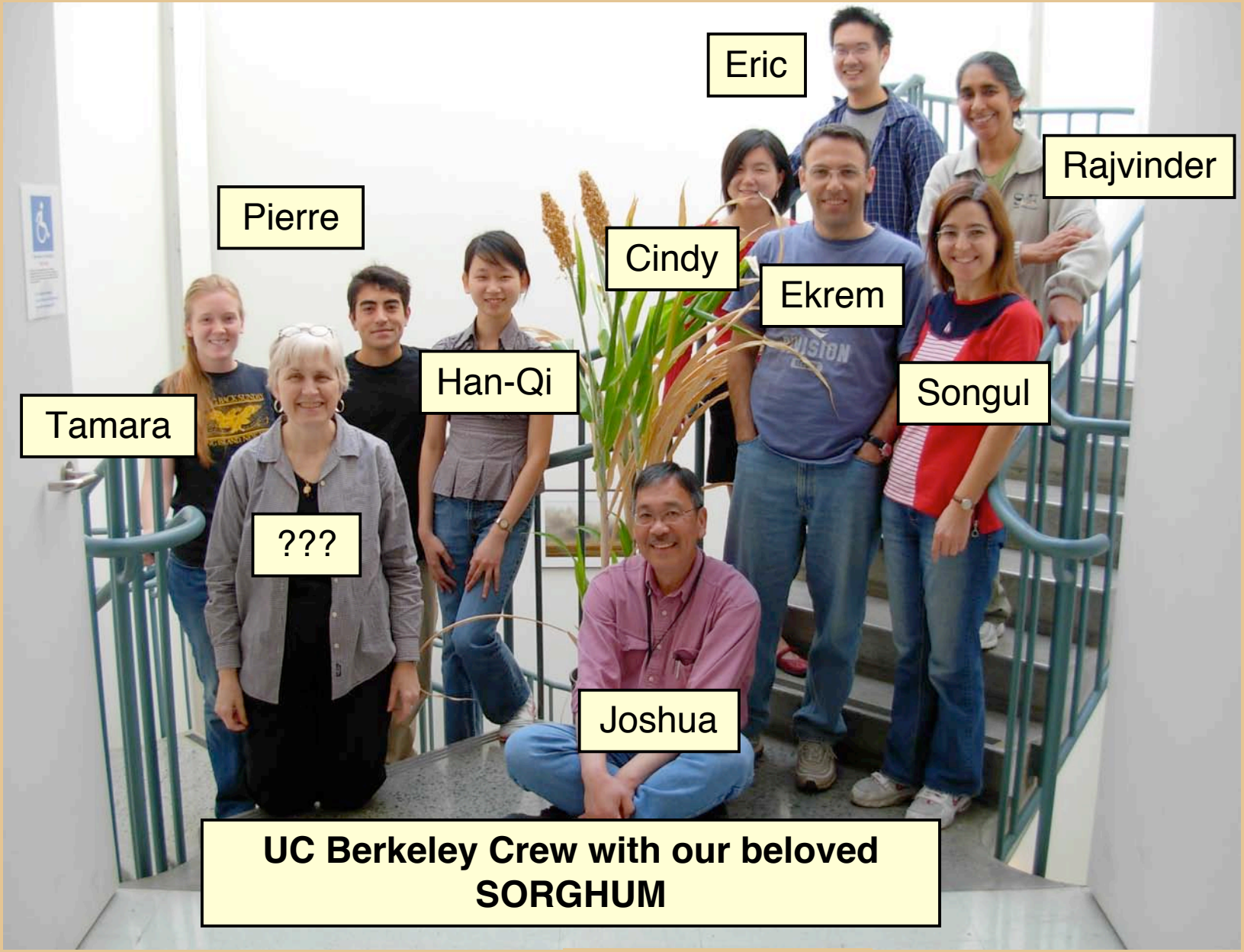


NO MAGIC BULLET

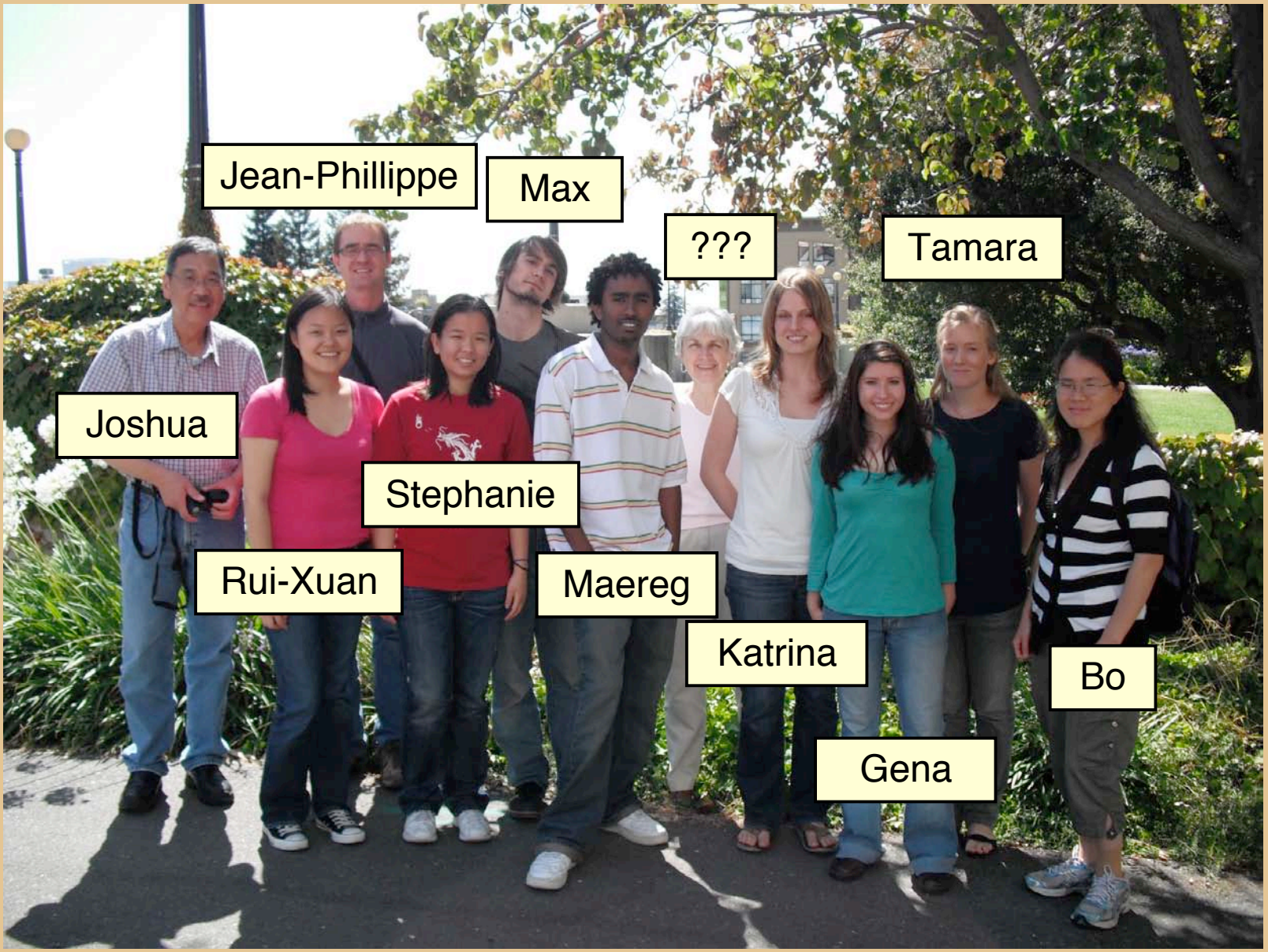
But it can help!



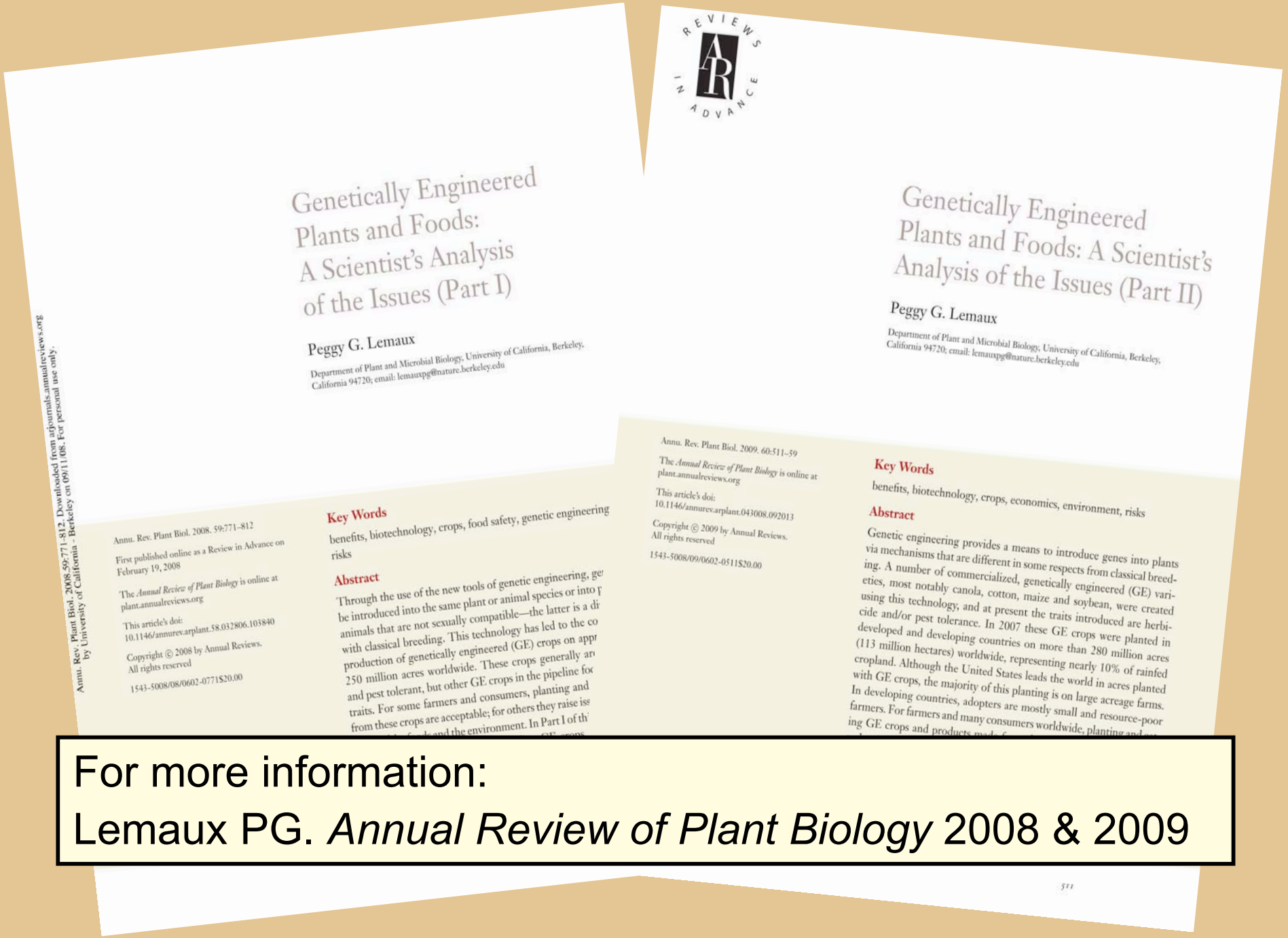
San Francisco Chronicle (modified)



UC Berkeley Crew with our beloved SORGHUM



2009 Summer UC Berkeley SORGHUM Crew



Genetically Engineered Plants and Foods: A Scientist's Analysis of the Issues (Part I)

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Key Words

benefits, biotechnology, crops, food safety, genetic engineering risks

Abstract

Through the use of the new tools of genetic engineering, ge be introduced into the same plant or animal species or into p animals that are not sexually compatible—the latter is a di with classical breeding. This technology has led to the co production of genetically engineered (GE) crops on appr 250 million acres worldwide. These crops generally ar and pest tolerant, but other GE crops in the pipeline fo traits. For some farmers and consumers, planting and from these crops are acceptable; for others they raise iss and the environment. In Part I of th

REVIEWS IN ADVANCE

Genetically Engineered Plants and Foods: A Scientist's Analysis of the Issues (Part II)

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Abstract

Genetic engineering provides a means to introduce genes into plants via mechanisms that are different in some respects from classical breeding. A number of commercialized, genetically engineered (GE) varieties, most notably canola, cotton, maize and soybean, were created using this technology, and at present the traits introduced are herbicide and/or pest tolerance. In 2007 these GE crops were planted in developed and developing countries on more than 280 million acres (113 million hectares) worldwide, representing nearly 10% of rainfed cropland. Although the United States leads the world in acres planted with GE crops, the majority of this planting is on large acreage farms. In developing countries, adopters are mostly small and resource-poor farmers. For farmers and many consumers worldwide, planting and ing GE crops and products

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For more information:

Lemaux PG. *Annual Review of Plant Biology* 2008 & 2009