Genetically Engineered Crops: Can India Benefit?

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Developing agriculture is the most effective and least objectionable route to achieving sustainable development.

Improving biological productivity of developing country farmers is critical to agricultural development.

Genetic enhancements have been and remain critical to improvements in agricultural productivity.

P.B. Thompson. 2009. **Can Agricultural Biotechnology Help the Poor?**
http://www.scienceprogress.org/2009/06/ag-biotech-thompson/

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
- No country has rapidly moved out of poverty without increasing agricultural productivity
- Nearly two-thirds of Indians are small-area farmers; many women with few resources

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

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

India has >100 million small farmers
With average farm size <1.2 hectares (slightly smaller than a football field)
Number of small farmers increased from 70% in 1971 to 80% in 1998; expected to be 83% by 2010

Small farm in Saswad, Maharashtra, India

U.S. aerial rice planting

NE Indian State, Assam, hand seeding rice

Technologies available for agriculture in many parts of India are different from those in the developed world…

Also crop productivity is different in India and other 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	>4X
Sorghum	1,230	1,455	797	3,910	5X
Rice	3,930	1,872	3,284	6,810	2X
Wheat	2,310	1,469	2,601	3.110	
Chickpea	314	1,026	814	7,980	10X

WHY?

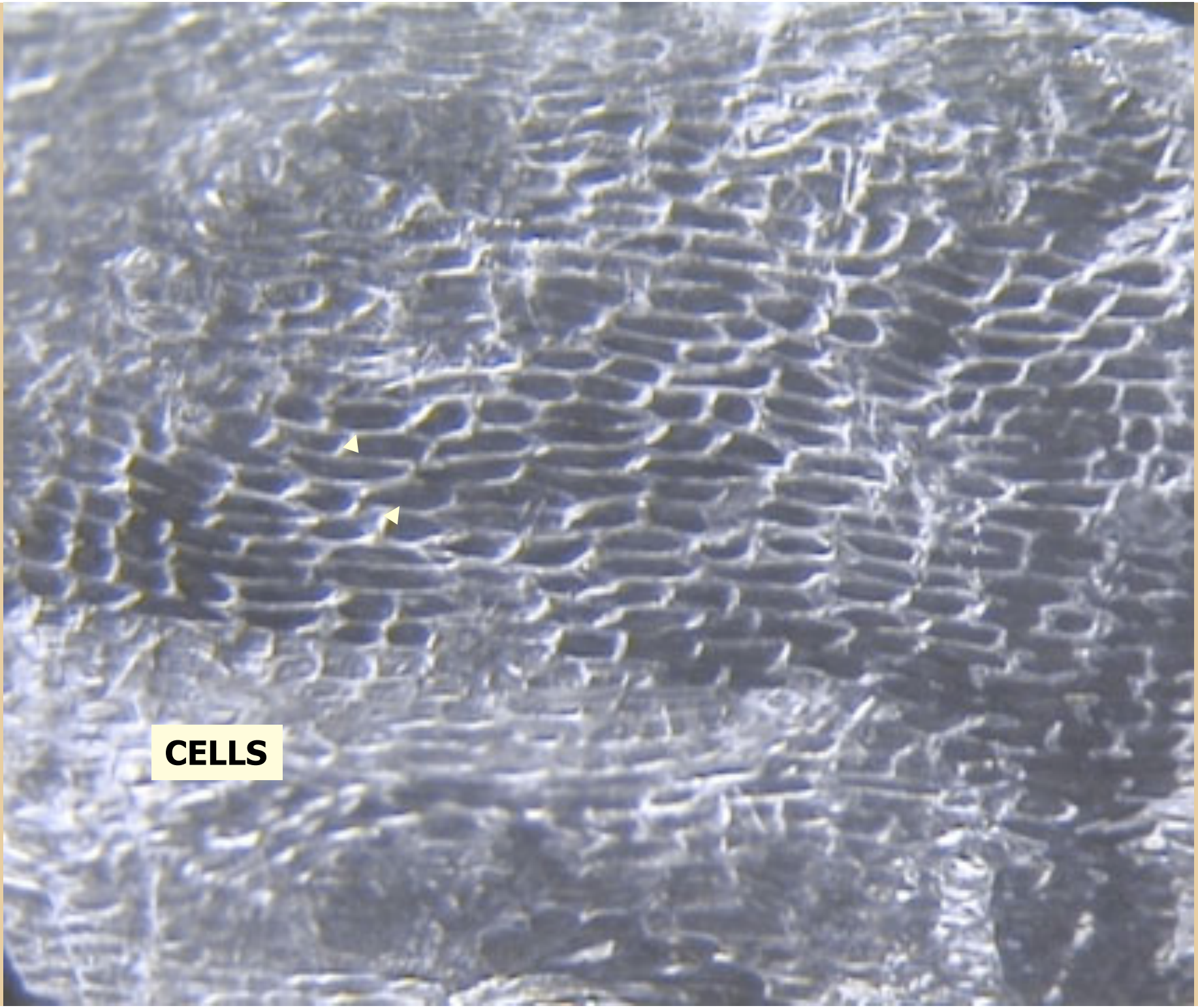
For many reasons…among them is that varieties giving higher yields are not genetically optimized for their agriculture.

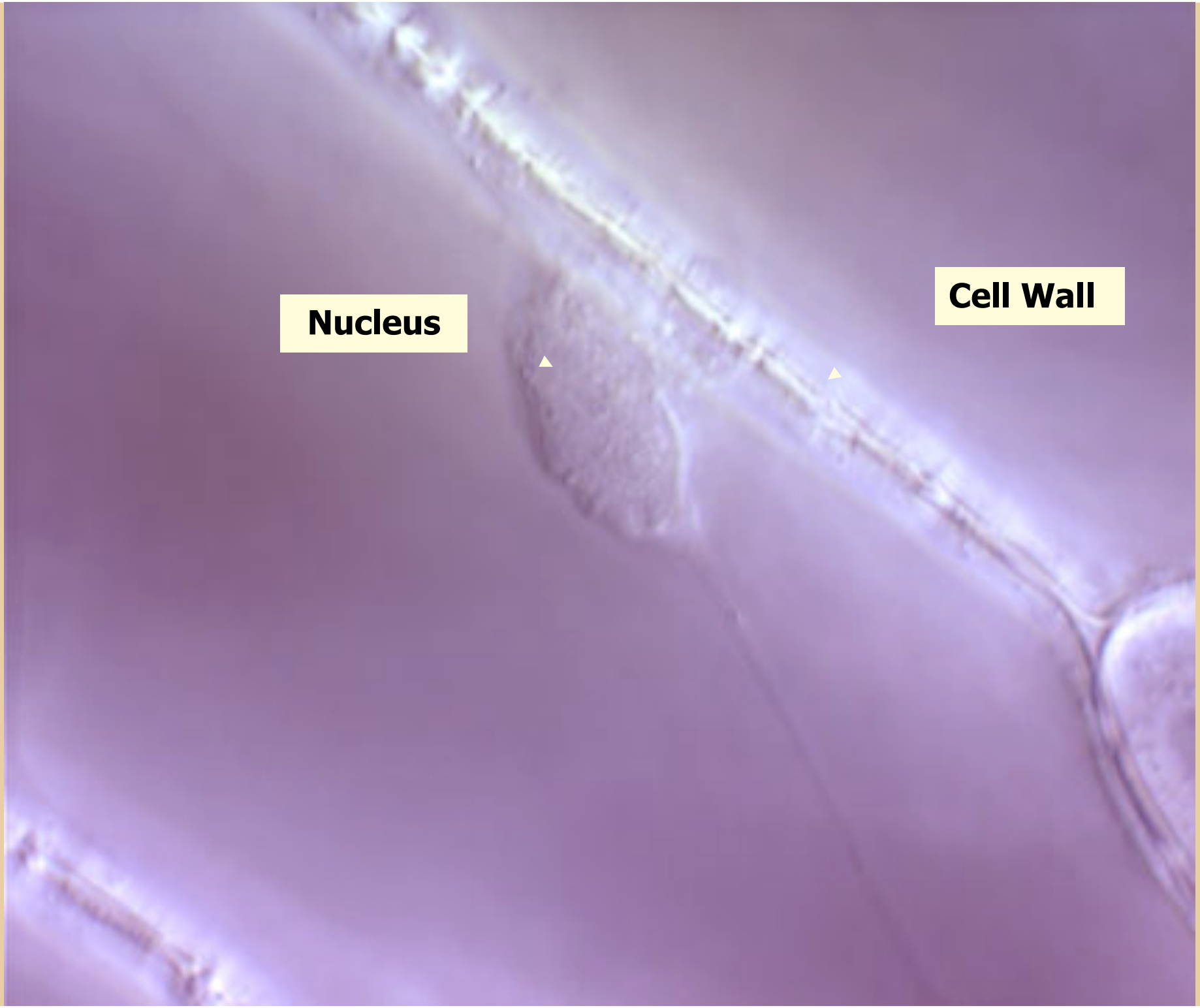
What are some genetic technologies that have been used to improve crops, like wheat?

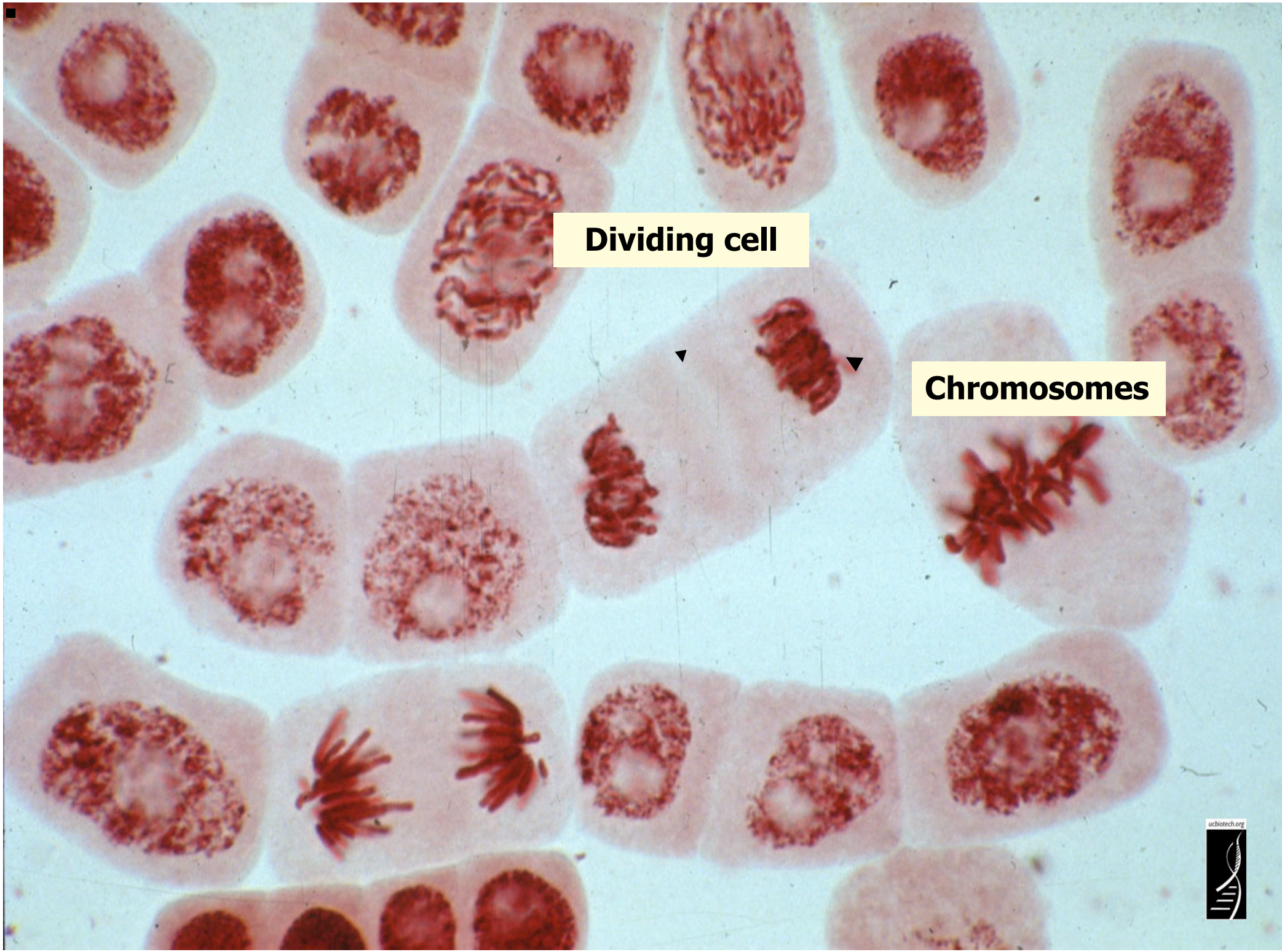
Triticum aestivum
Modern bread variety

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
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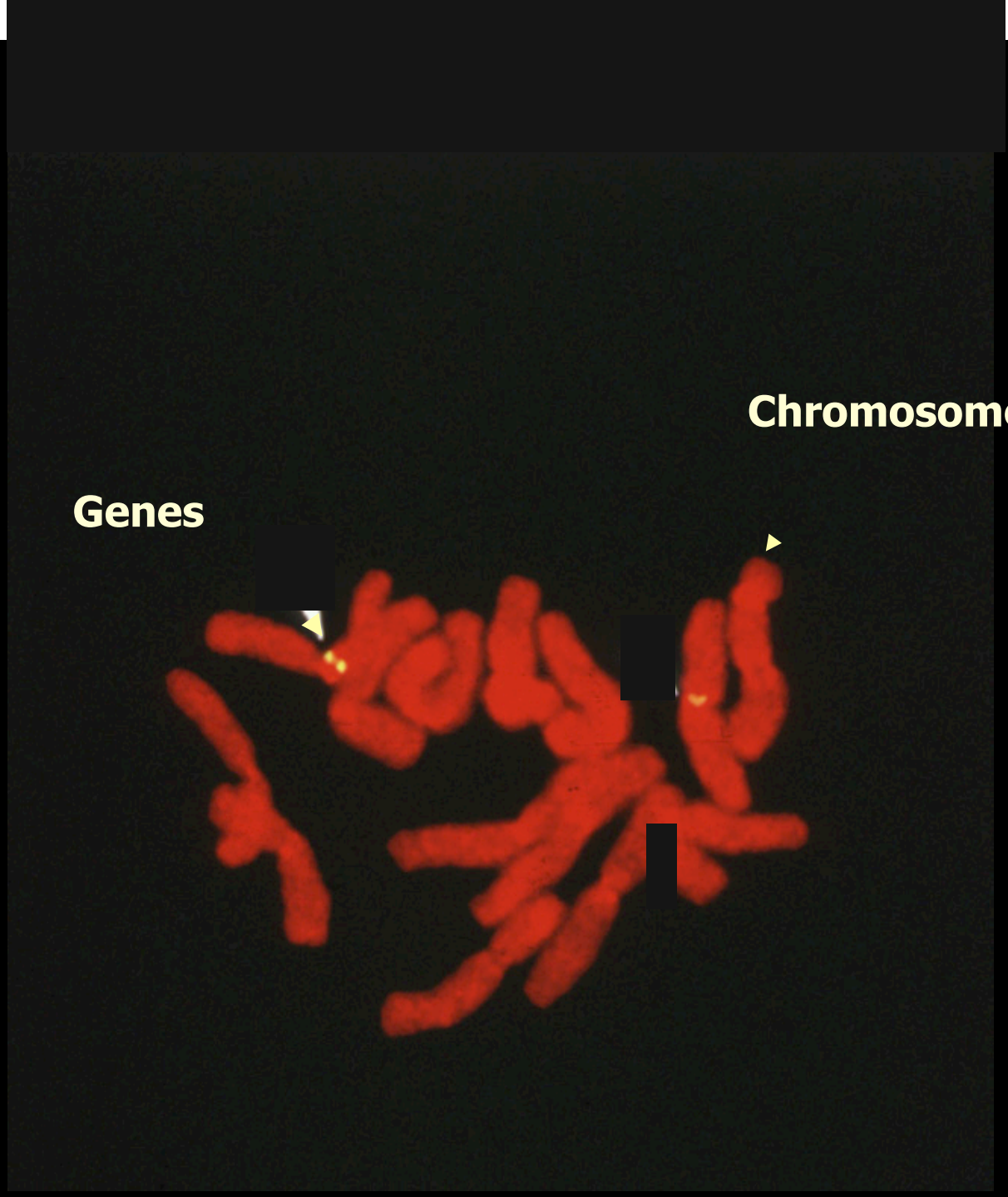
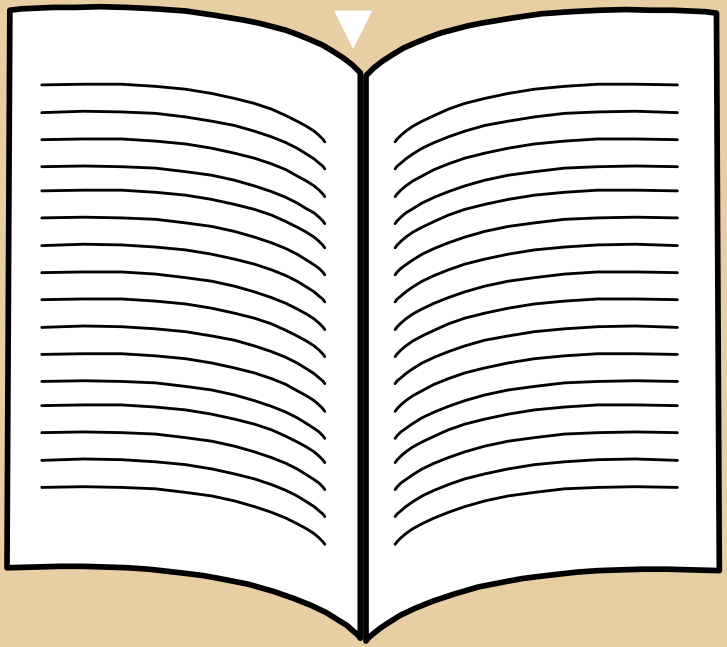

Chromosome
Genes

Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...



1700 books
1000 pages each

1700 books
(or 1.7 million pages)

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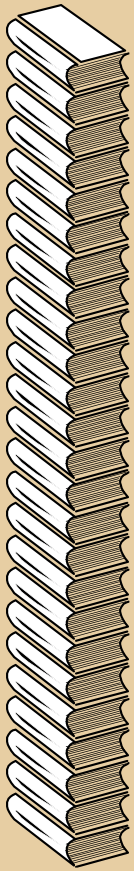
Hybridization or cross breeding of wheat

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



X

Random retention of information from each parent

1700 books (or 1.7 million pages)

1700 books (or 1.7 million pages)

1700 books (or 1.7 million pages)

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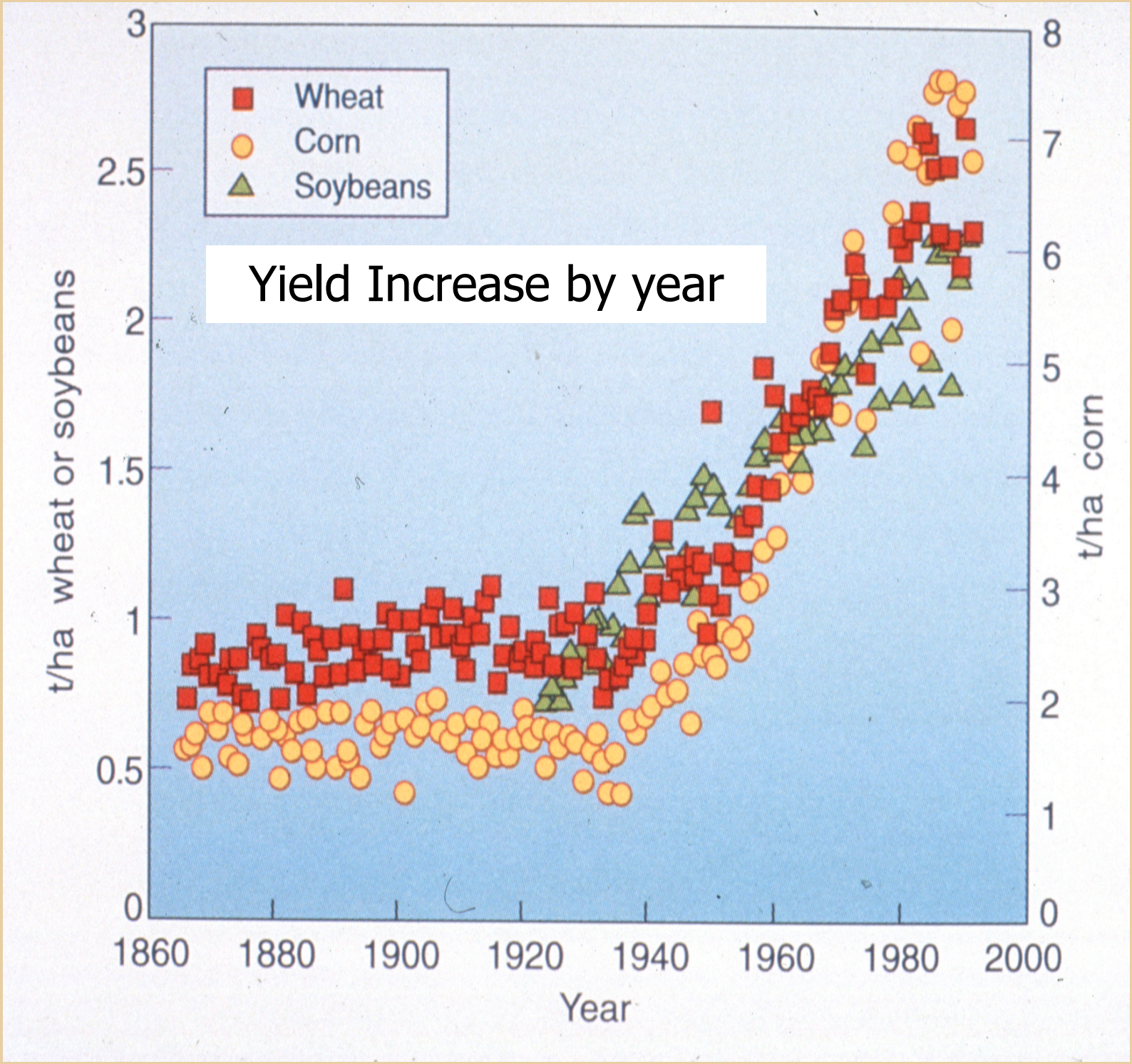
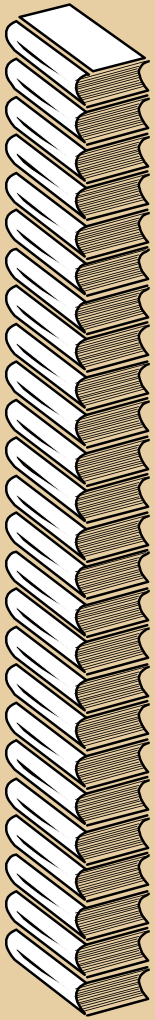

Wheat
Corn
Soybeans
Yield Increase by year
t/ha wheat or soybeans
t/ha corn
Year
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
1860
1880
1900
1920
1940
1960
1980
2000

Biotechnology or Genetic Engineering Methods



1700 books
(or 1.7 million pages)

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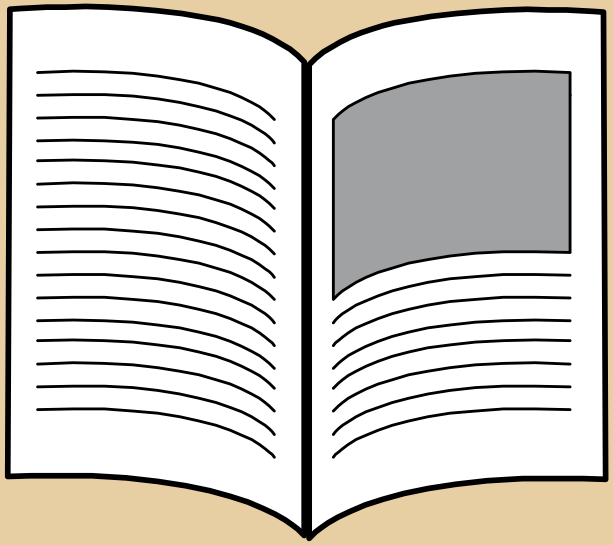
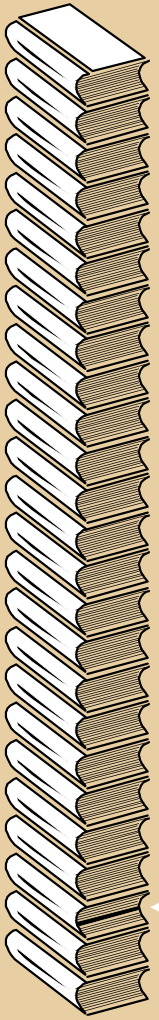


One-half page
equivalent to a gene



Inserts randomly in genome

Inserted gene(s)

1700 books
(or 1.7 million pages)

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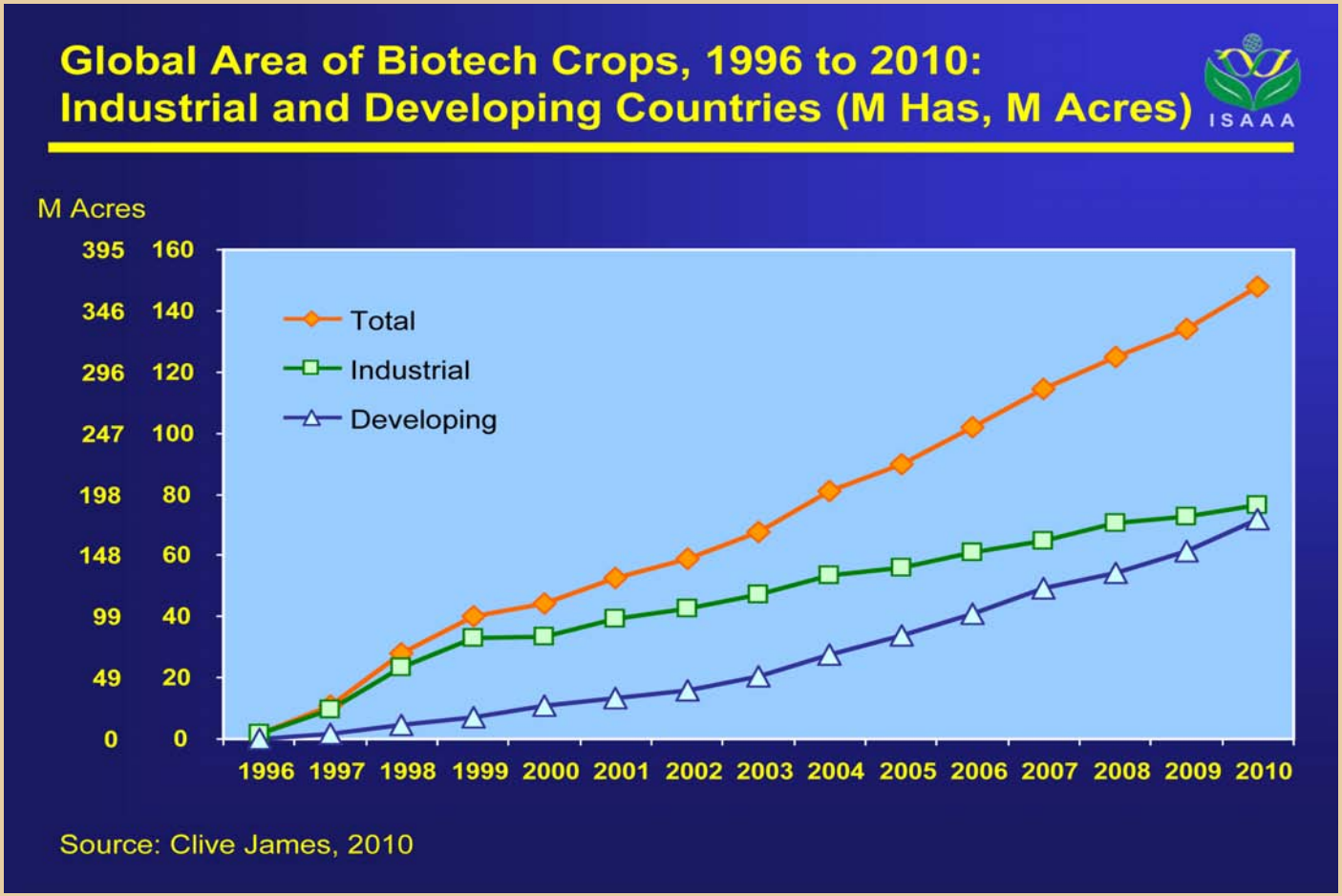
What questions are being asked about GE crops or GMOs?

- Are GE crops being grown in developing countries?
- Will they address small acreage farmers' needs?
- Is this a magic bullet for food security?

Are GE crops grown in developing countries?

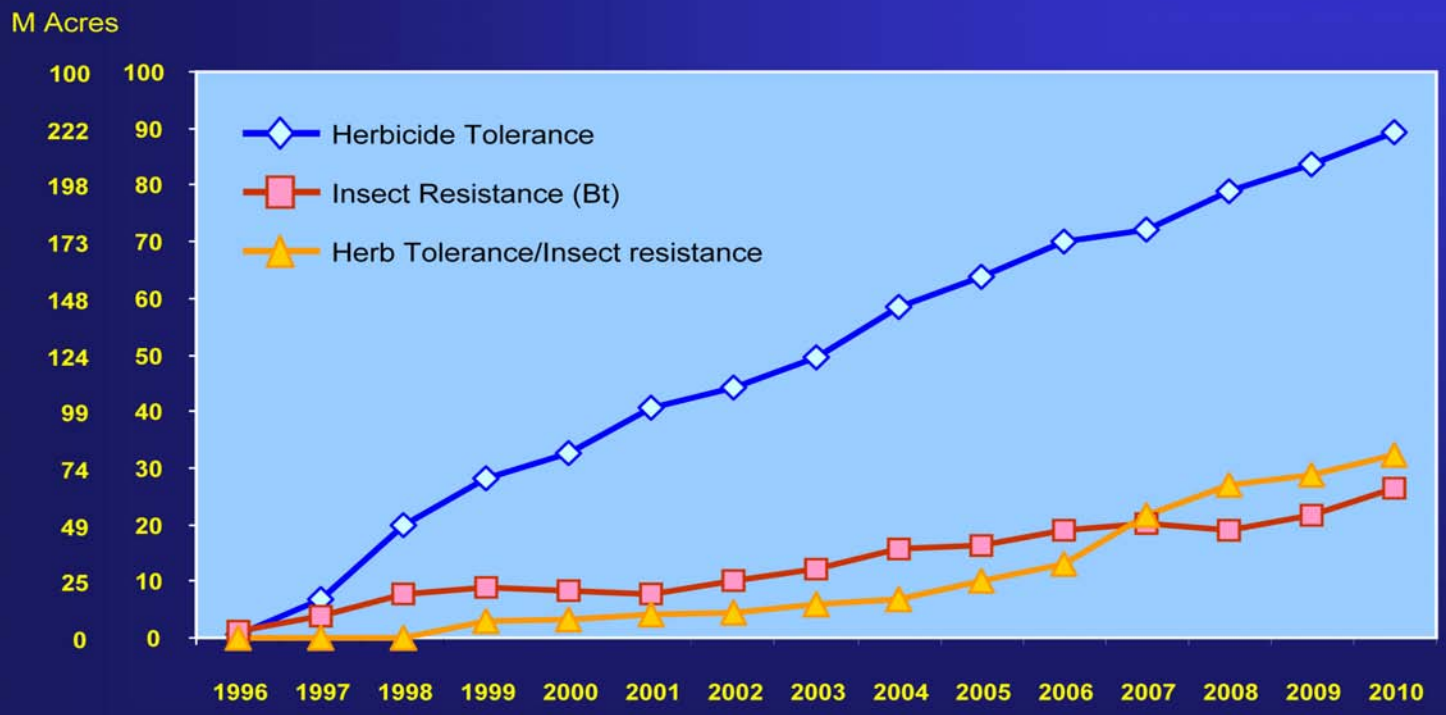


571,431 square miles worldwide in 2010 (equal to approximately half the area of India) in 29 industrial and developing countries

29 industrial and developing countries in order of acreage:

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

Global Area of Biotech Crops, 1996 to 2010: By Trait (Million Hectares, Million Acres)



Source: Clive James, 2010

But the variety of GE crops is limited to insect resistance (Bt), herbicide tolerance and both.

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

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GMO Eggplant Will Not Be Grown in India

Environment Minister Blocks First Genetically Modified Food Crop

Feb 10, 2010 ☆ Victoria Anisman-Reiner

Like

India's Environment Minister Blocks GMO Aubergine - *K. Connors, Morguefile*

In an unprecedented decision, India's Environment Minister has suspended the introduction of GMO "BT brinjal" eggplant due to public concerns about safety.

Concerns about the safety of genetically engineered foods are very common, but real action from today's governments to honor these concerns is something outside the ordinary. India is drawing attention for its precedent-setting decision to put GMO aubergine or eggplant on hold until further studies can prove the crop's safety to both the scientific community and the public.

GM Eggplant (BT Brinjal) Will Not Be Planted in India

Making news around the world, Environment Minister Jairam Ramesh has put the concerns of India's people first in making policy about genetically modified foods or GMOs (genetically modified organisms).

"Public sentiment is negative. It is my duty to adopt a cautious, precautionary, principle-based approach," Minister Ramesh told BBC reporter Geeta Pandey at a news conference in Delhi where his decision was made public on February 9, 2010.

TUESDAY, JUL 1, 2008 15:55 ET

Why Indian farmers lust after genetically modified eggplant

When you're going broke spraying pesticides that don't work, built-in resistance to nasty bugs starts looking mighty attractive.

BY ANDREW LEONARD | Like

In May, India's Genetic Engineering Approval Committee (GEAC) approved a request by the Maharashtra Hybrid Seed Co. (Mahyco) to begin "experimental seed production" of genetically modified Bt eggplant. (Thanks to GMO Pundit for the link.)

After China, India is the world's largest producer of eggplant, or brinjal, as it is known on the subcontinent. Primarily cultivated by small farmers, it is plagued by a devastating pest, the fruit and shoot borer. But Bt brinjal incorporates a variation of the cry1Ac gene, which works as potent built-in pesticide against the borer.

At the same meeting at which GEAC approved the production of Bt brinjal seeds, the committee heard testimony from Dr. P.M. Bhargava, who ran through a checklist of reasons why recklessly expanding the number and type of genetically modified crops planted in India might be imprudent. The committee dismissed his concerns, and we could have a nice long argument over whether it was wise to do so. Personally, How

Some in India have taken strong stands against, some for GE crops, leaving the public confused

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Genetically engineered crops for developing countries: some examples

Miscellaneous examples of GE crops of importance to developing countries

Development of Golden Rice (rice is 2nd most important crop in India)

SuperSorghum (Jowar) (sorghum is 3rd most important crop in India)

Genetically engineered crops for developing countries: some examples

Miscellaneous examples of GE crops of importance to developing countries

GE insect-resistant cotton generated not only higher income for rural workers but also more employment… about 424 million additional days of employment for female earners

SOURCE: Subramanian, A., Kirwan, K., Pink, D. and Qaim, M. 2010. GM crops and gender issue. Nature Biotechnology 28, Pages: 404–406.

Beetle-resistant Eggplant developed in India

SOURCE: "1st GM eggplant soon to be commercially grown in RP", The Philippine Star, 1/21/07

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Researchers develop protein-packed potato in India

SOURCE: http://www.reuters.com/article/idUSTRE68J45F20100920

Chakraborty, S. et al. 2010. Next-generation protein-rich potato expressing the seed protein gene AmA1 is a result of proteome rebalancing in transgenic tuber. PNAS published ahead of print September 20, 2010.

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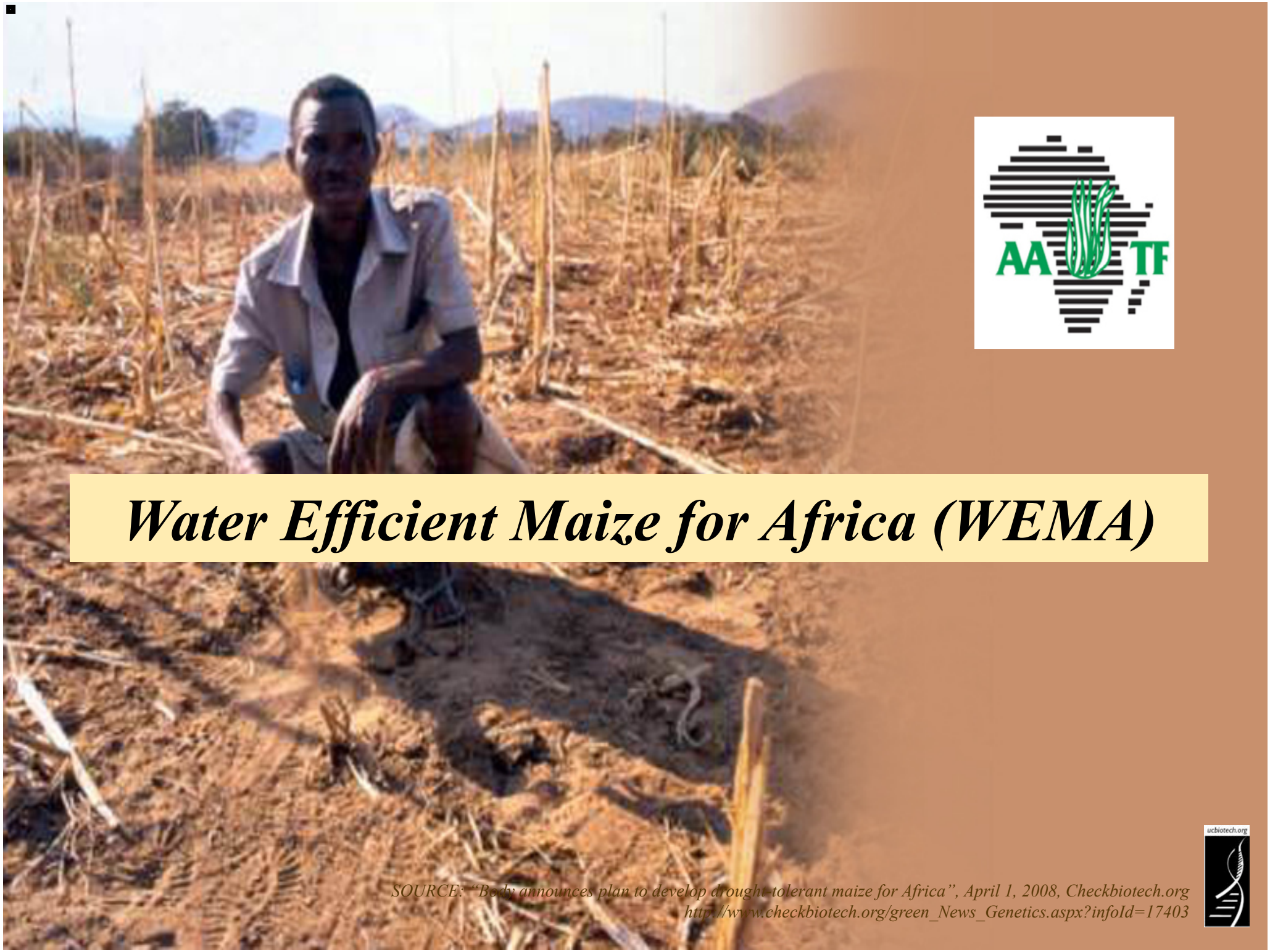

Water Efficient Maize for Africa (WEMA)

SOURCE: "Body announces plan to develop drought-tolerant maize for Africa", April 1, 2008, Checkbiotech.org
http://www.checkbiotech.org/green_News_Genetics.aspx?infoId=17403

GE maize variety resistant to maize streak virus for sub-Saharan Africa

SOURCE: Shepherd, D.N., Mangwende, T., Martin, D.P., Bezuidenhout, M., Kloppers, F.J., Carolissen, C.H., Monjane, A.L., Rybicki, E.P. and Thomson, J.A. 2007. Maize streak virus-resistant transgenic maize: a first for Africa. Plant Biotechnology Journal, online first (doi: 10.1111/j.1467-7652.2007.00279.x).

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GE sweet banana tested in Uganda for Black Sigatoka fungus resistance
SOURCE: http://allafrica.com/stories/200705150771.html
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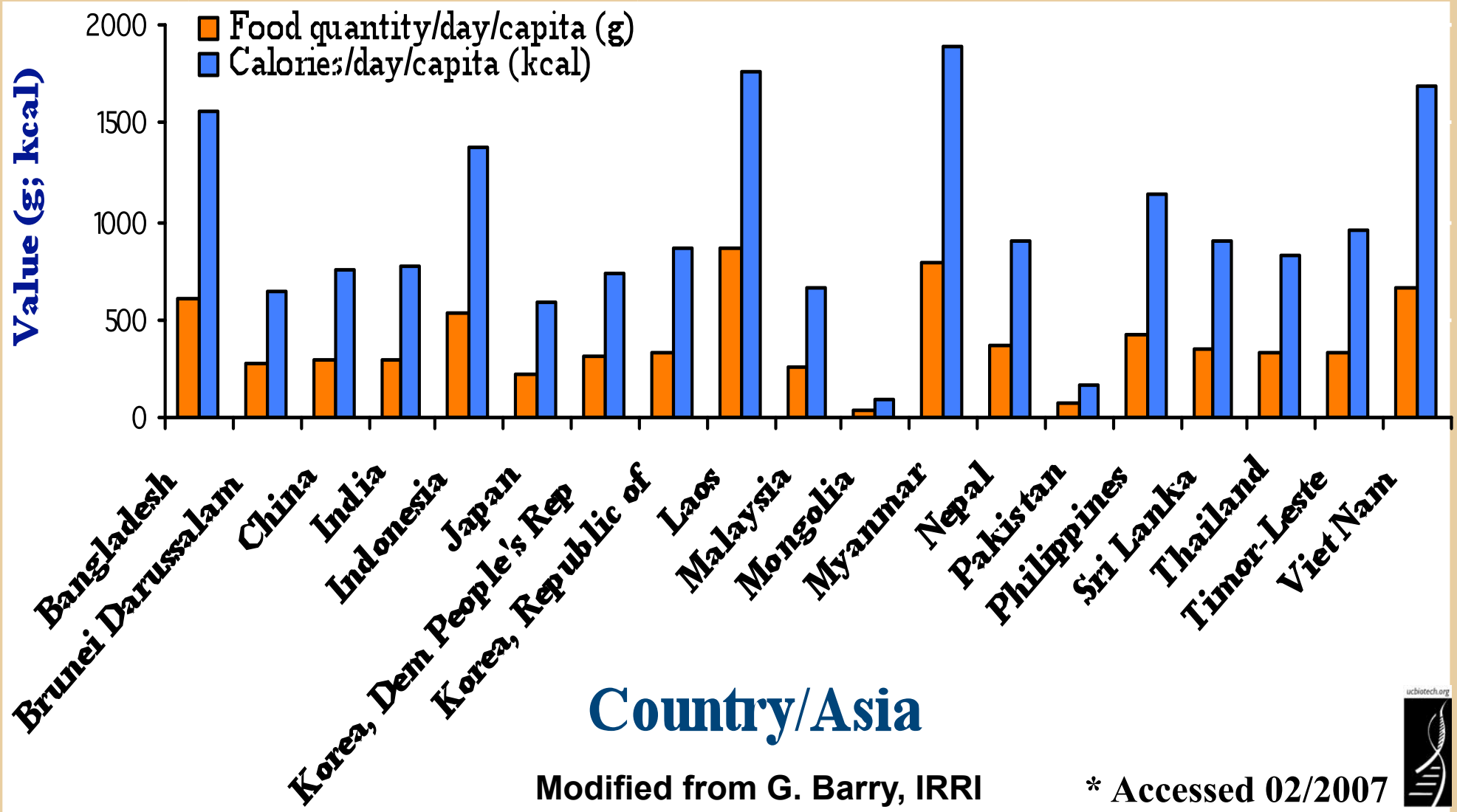
Genetically engineered crops for developing countries: some examples

Development of Golden Rice (rice is 2nd most important crop in India)

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

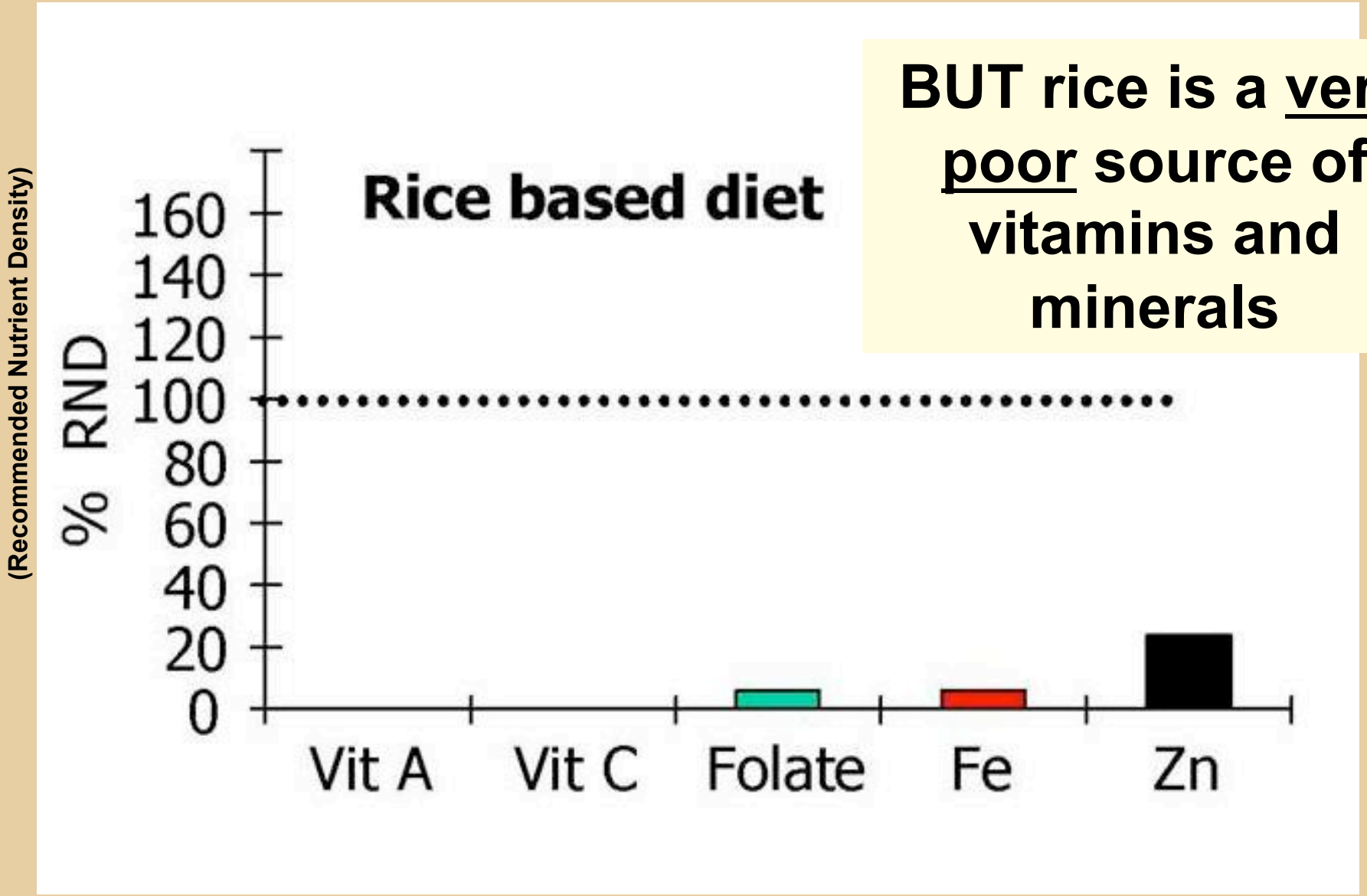
FAO Minimum Dietary Energy Requirement
= 1800 – 2000
(weighted average; kcal/person/day)



Modified from G. Barry, IRRI

* Accessed 02/2007

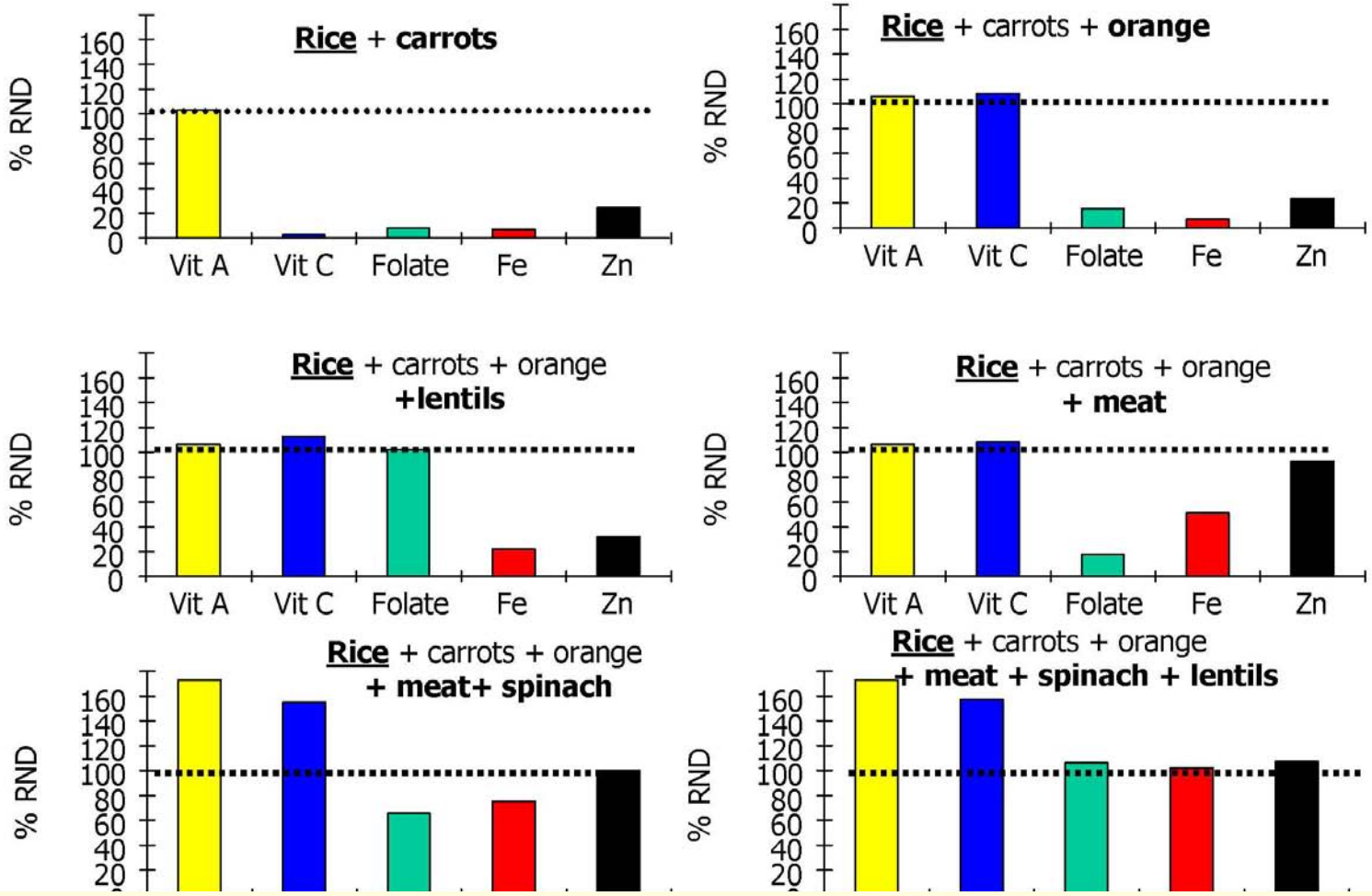
Rice Diet and Micronutrient Nutrition



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…

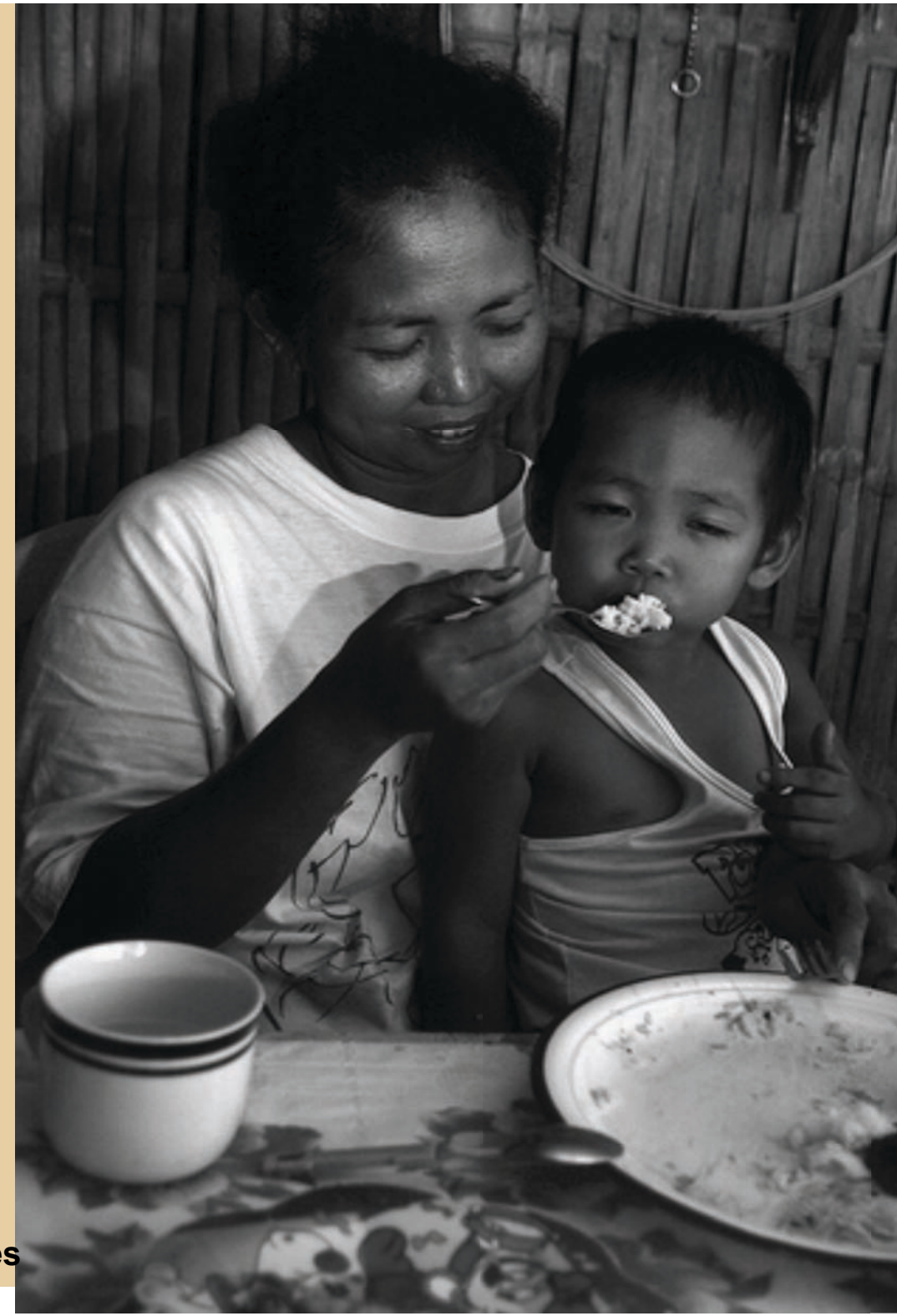
2 of 3 infants (6mos.-1yr) have iron-deficiency anemia

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

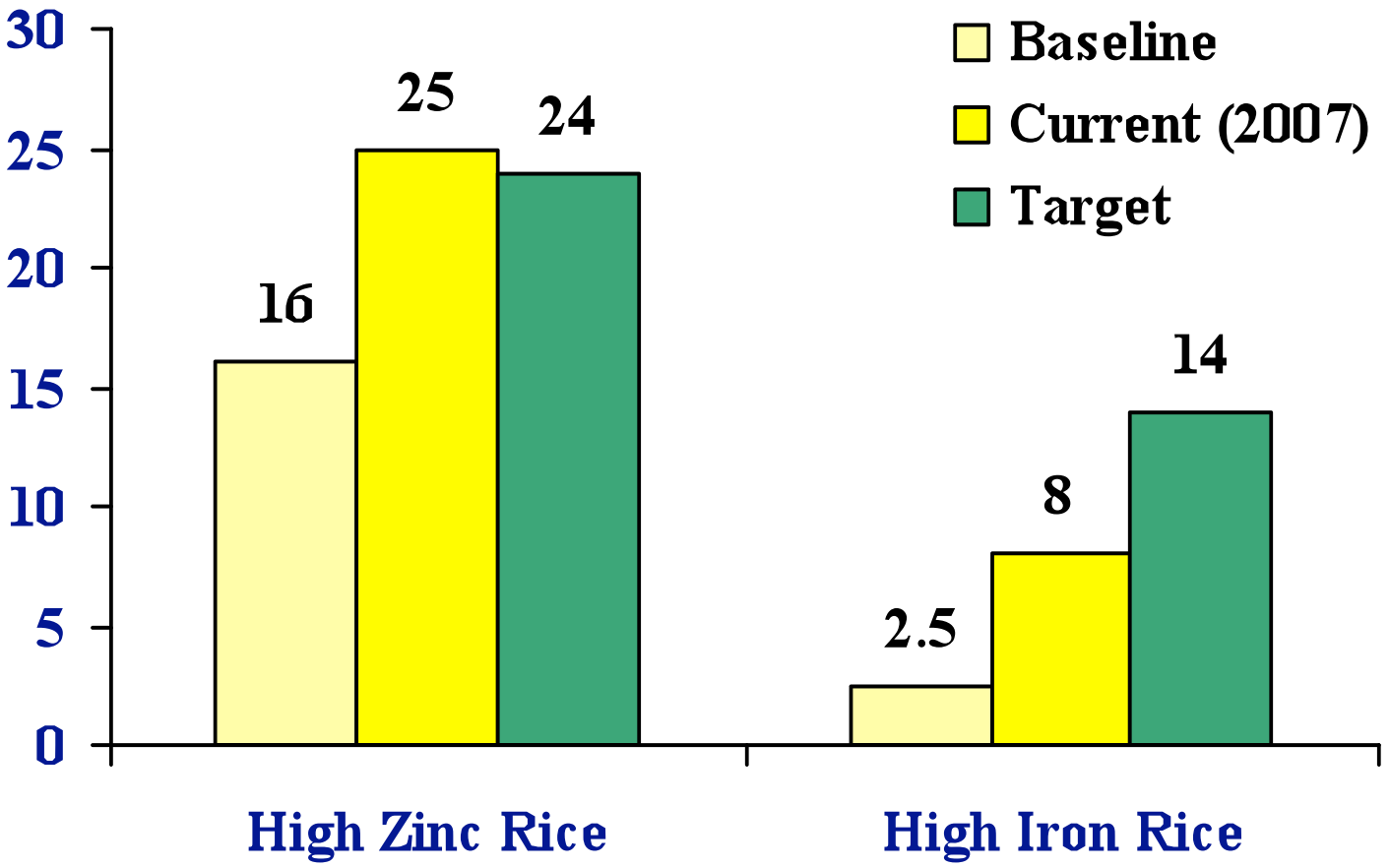
Biofortification

Dietary Diversity

Modified from G. Barry, IRRI

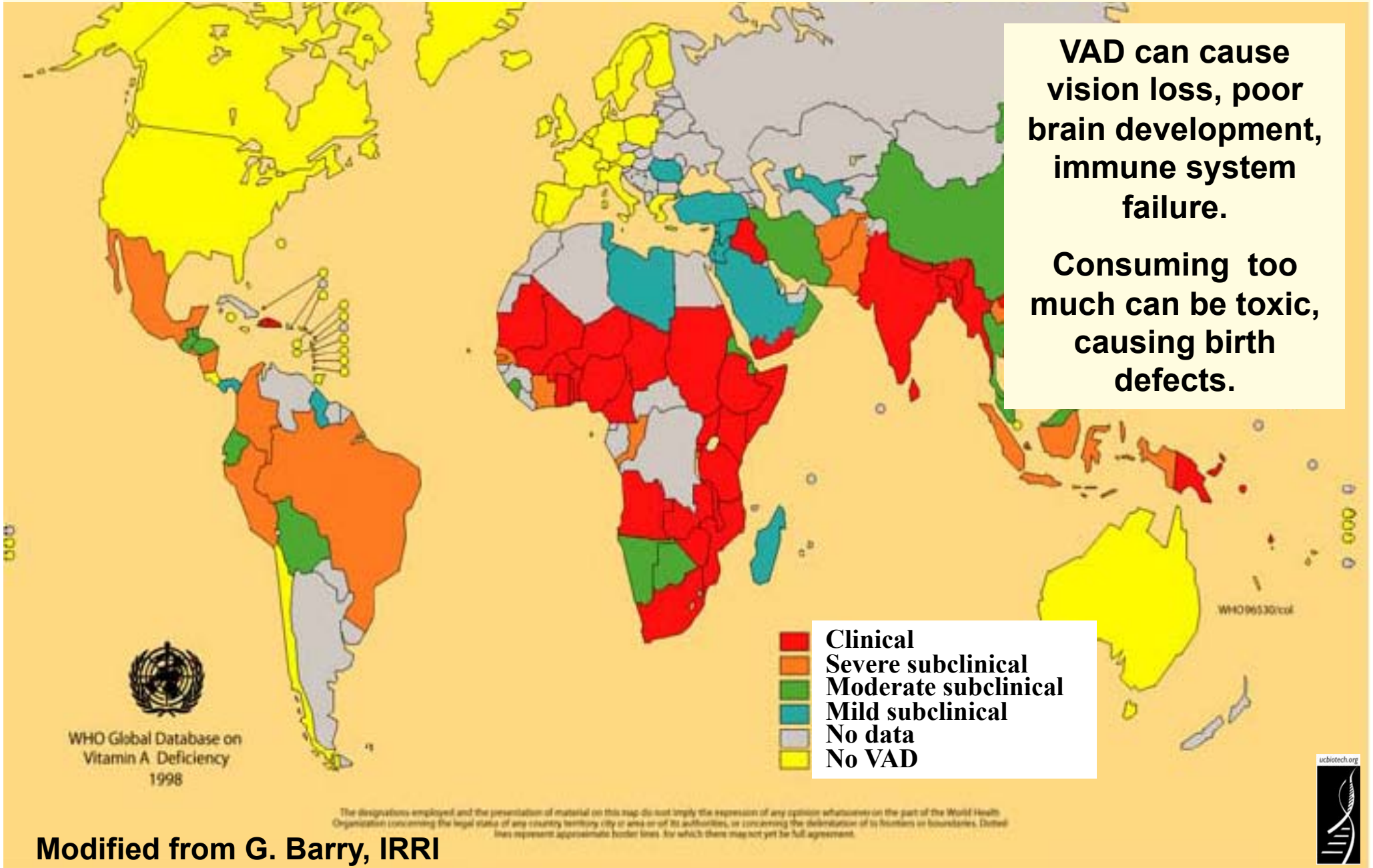
HarvestPlus
Breeding Crops for Better Nutrition

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
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

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

Modified from G. Barry, IRRI

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

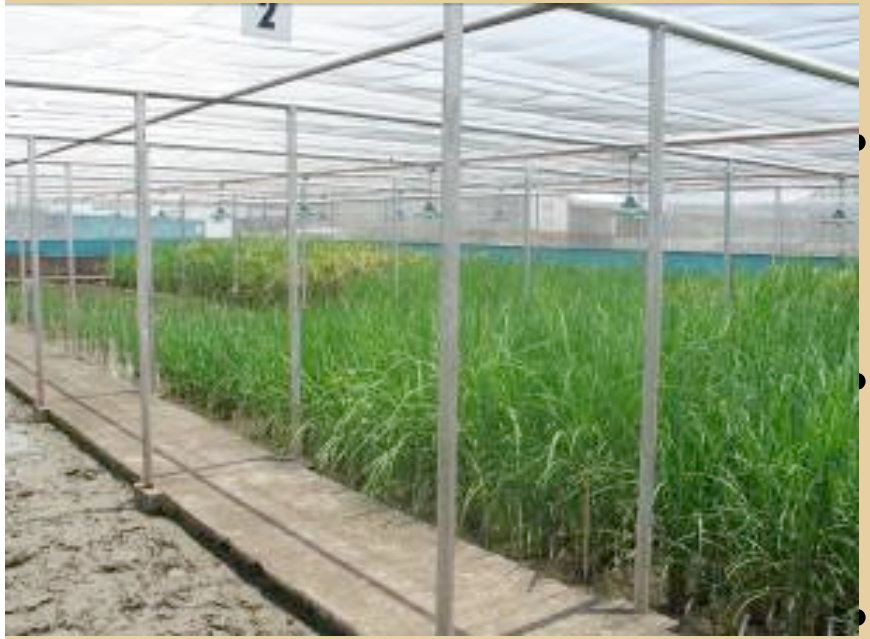
Golden Rice was engineered to have pro-Vitamin A

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

NO MAGIC BULLET

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)
- Parallel introgression breeding being done for **India, Vietnam,** and the **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

Genetically engineered crops for developing countries: some examples

SuperSorghum (Jowar)
(sorghum is 3rd most important crop in India)

Second cereal that is also nutritionally deficient in:
Vitamins
Minerals
Amino acids
(like most cereals)

but, uniquely, is also

Poorly Digested

What is this crop?

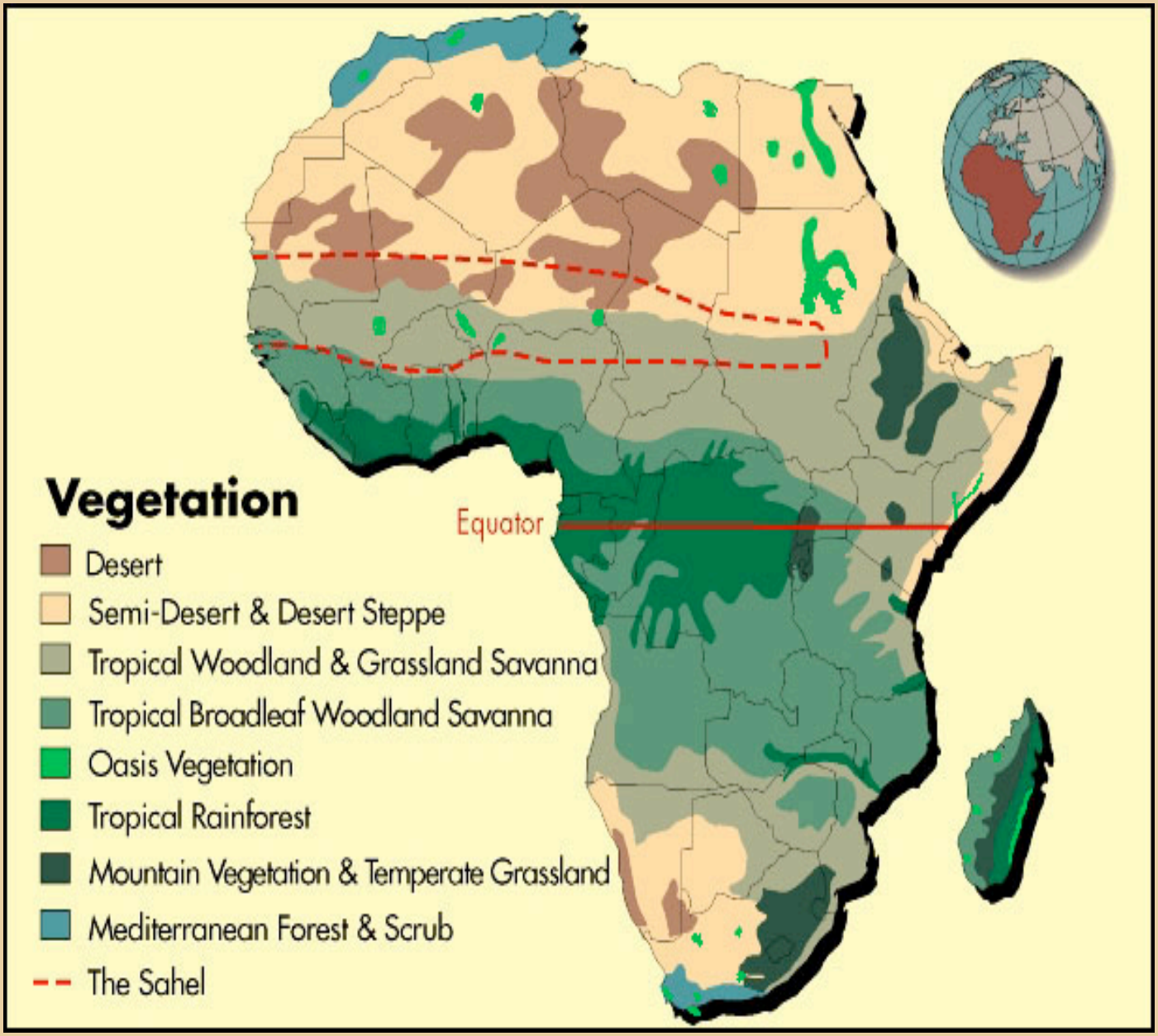
Why Pick Sorghum?

- 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 – it withstands both drought and water logging



Grand Challenges in Global Health - Microsoft Internet Explorer

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Address 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

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

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

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 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.

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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

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…

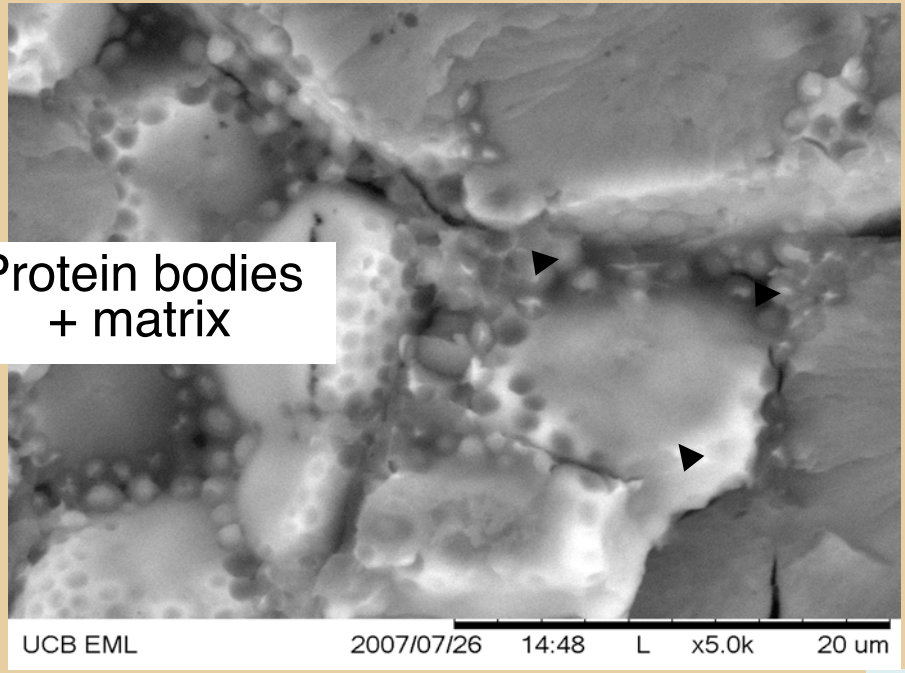
In Africa, 74% of sorghum is consumed at home as cooked porridge

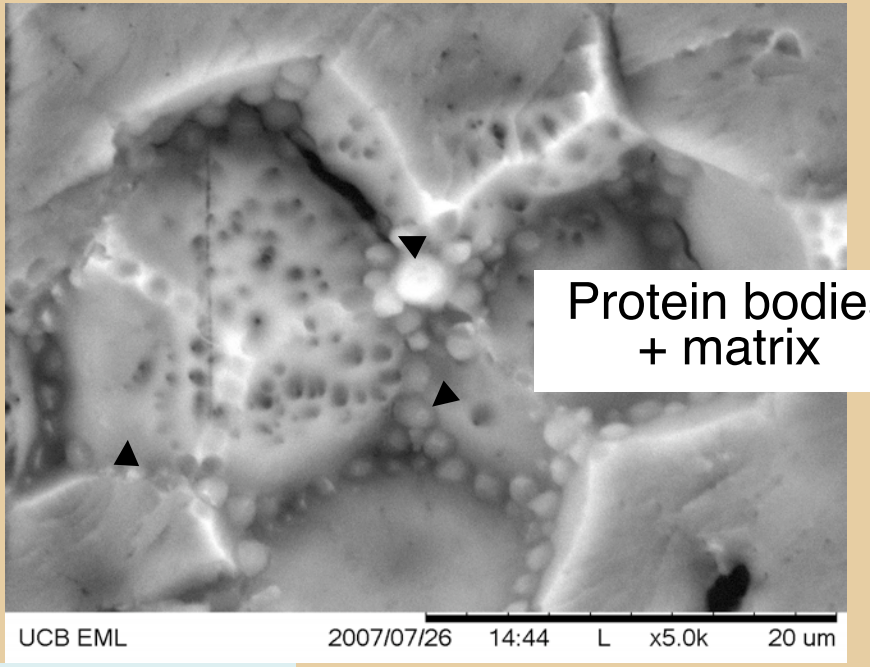
Elderly woman making cooked sorghum porridge

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.





Starch granules

Super Sorghum

NO MAGIC BULLET

But it can help!

2009 Summer UC Berkeley SORGHUM Crew

ucbiotech.org

SCIENCE-BASED INFORMATION & RESOURCES ON AGRICULTURAL BIOTECHNOLOGY

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know GMOS

This website, developed for the University of California Division of Agricultural and Natural Resources Statewide Biotechnology Workgroup, provides educational resources focused broadly on issues related to agriculture, crops, animals, foods and the technologies used to improve them. Science-based information related to these issues is available, as well as educational tools and information, which can be used to promote informed participation in discussions about these topics.

DISPLAY CARDS NOW IN SPANISH!

We now have Spanish cards available to distribute with both educational displays. Click here for more details!

BIOTECHNOLOGY INFORMATION

ANNUAL REVIEWS

Review articles: Focused on food, environmental and socioeconomic issues of GE crops and foods.

RESOURCES FOR OUTREACH & EXTENSION, RESEARCHERS & TEACHERS

Slide Archive: Extensive collection of PP slides on agriculture & biotechnology.

Available on loan:

Educational displays: "Genetics and Foods" and Genetic Diversity and

HELPFUL SITES

Seed Biotechnology Center Mobilizes research, education & outreach efforts in partnership with seed & biotechnology industries.

To Tell Grow: educational game to teach what foods come from what crops.

SEARCH • CONTACT • SITE MAP

For more information: ucbiotech.org and

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