New Technologies for Sustained Productivity Growth:
Plant Breeding

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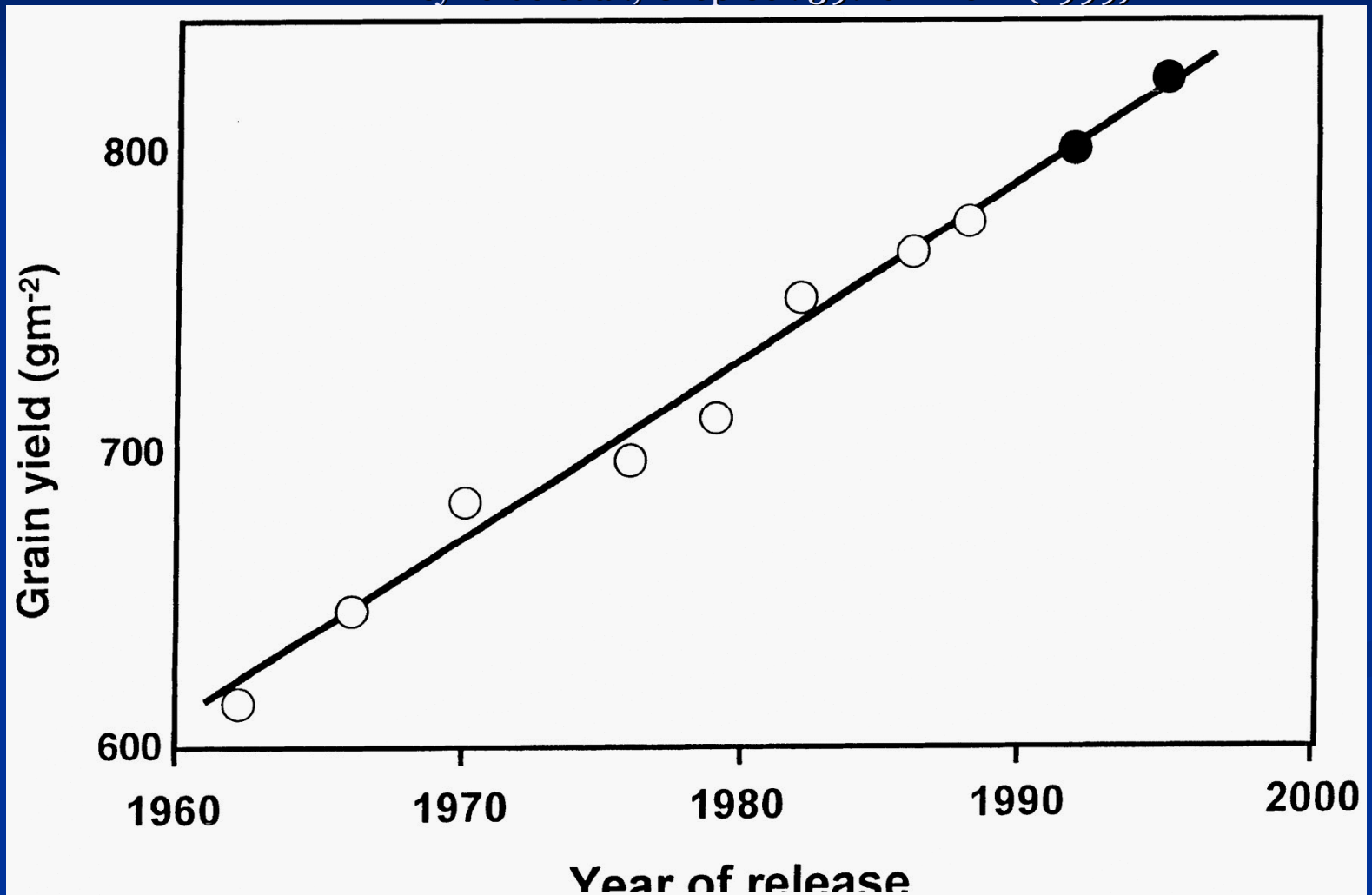
Past Achievements: Productivity

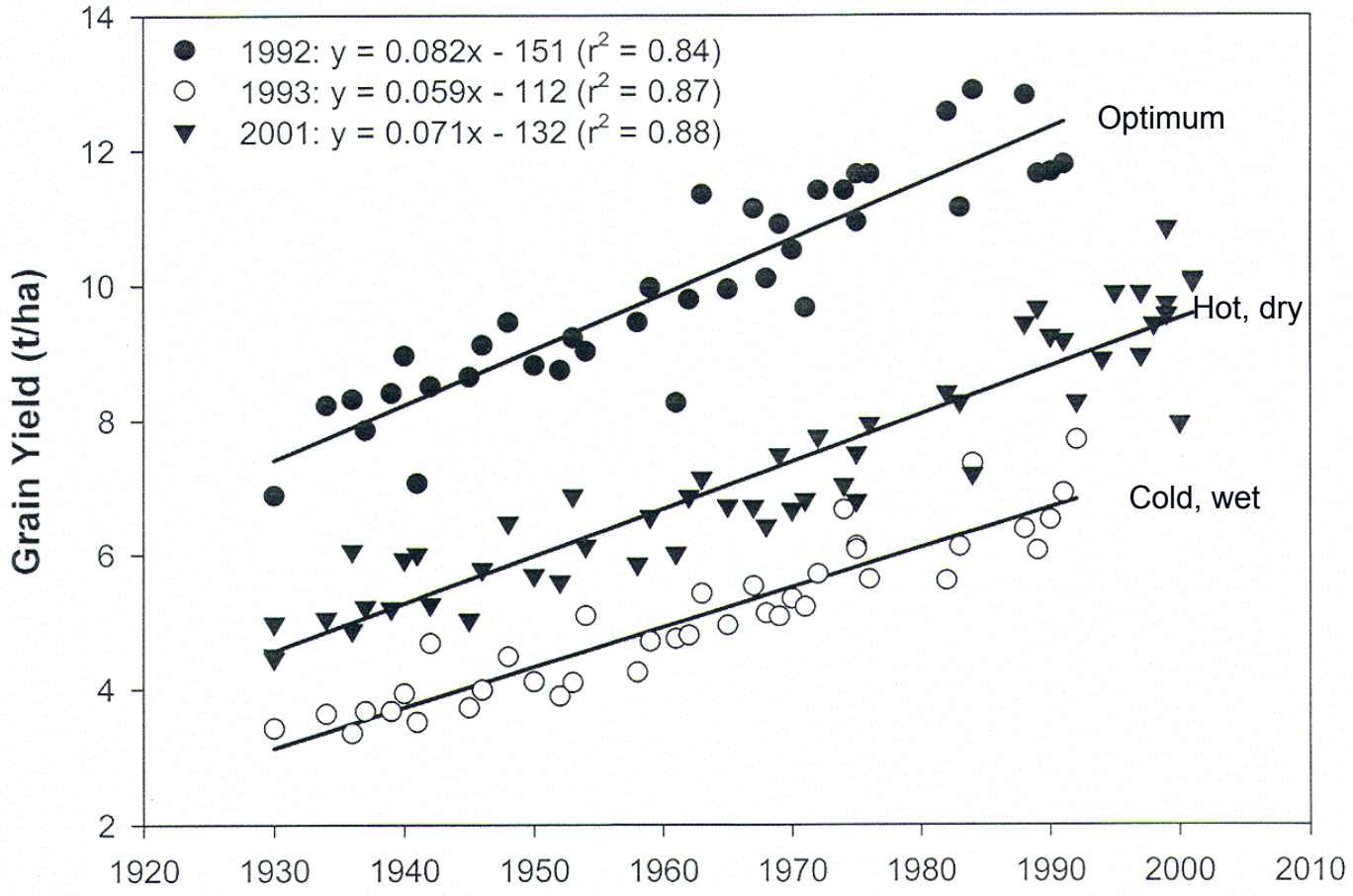
- Linear gains in yield for most field crops
  - 50% to management (e.g., fertilizers)
  - 50% to genetics (e.g., higher yield cultivars)
- Genetic yield gains are caused by:
  - Increased tolerance to abiotic and biotic stress (e.g., drought tolerance, disease resistance)
  - Increased efficiency of grain production (e.g., small tassels, short plants)
  - Conventional breeding did it all

Genetic gain in wheat: Mexico (CIMMYT)

Reynolds et al., Crop Sci. 39:1611-1621 (1999)



Increased Maize Yield in Good Years and Bad



Duvick et al., in *Plant Breeding Reviews* 24:109-151 (2004)

Past Achievements: Organizational

- Public sector (a): National, state, province
  - supported by tax payers*
- Public sector (b): IARCs (IRRI, etc.)
  - supported by tax payers indirectly **
- Private sector
  - supported by farmers***

- *Now supported by combination of restricted grants, royalties and the original sources
- **Now supported by combination of restricted grants, collaborations and the original sources
- ***Still supported by farmers

Potentials for Further Advance

- Genetic yield gains can continue at same pace for at least several more decades
  - Conventional plant breeding will continue as the essential foundation
- Biotechnology, via transgenics, can continue to add defensive traits
  - Must move beyond vertical (short-term) resistance to horizontal (durable) resistance

Potentials for Further Advance

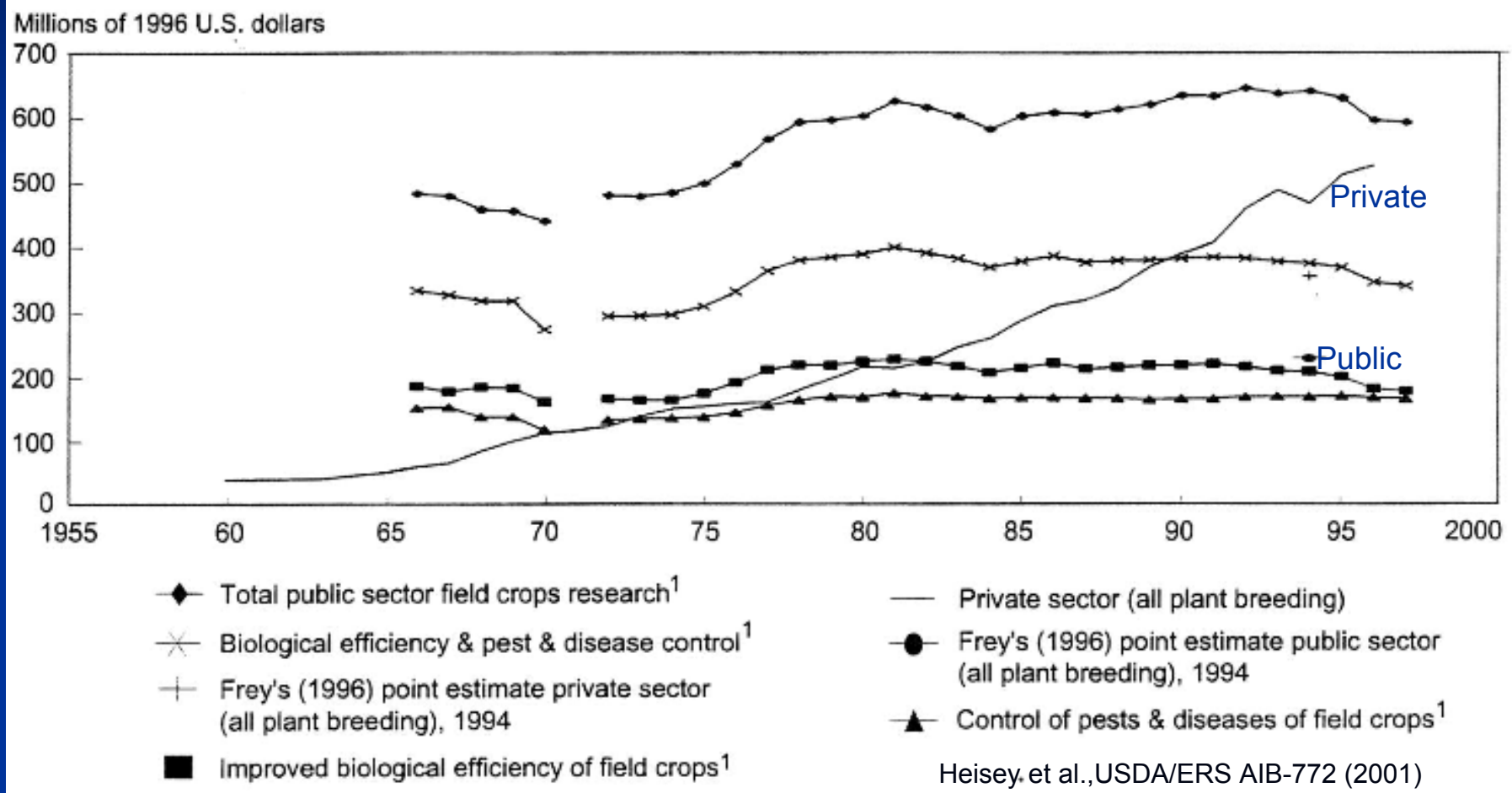
- In long-term, molecular biology insights can enable skillful, non-transgenic, improvement of native genomes
  - This will improve speed and precision of breeding for increased tolerance to biotic and abiotic stress, and therefore
  - Will increase yield and dependability
- This will be the most significant and long-lasting contribution of biotechnology

Complications: Public sector

- Funding amounts (U.S.) constant over the years, but increasingly less for cultivar development, more for biotechnology
- Consequently, less work in cultivar development than previously, in some crops and/or regions
- Reduced ability to train plant breeders to meet future needs.

Public and Private Expenditures in Plant Breeding, US

Figure 3
Real public and private sector expenditures on plant breeding, U.S. agricultural research deflator



Heisey et al.,USDA/ERS AIB-772 (2001)

[1] Data not available for 1971.

Complications: Private sector

- Consolidations: advantages and disadvantages
  - Economies of scale
  - Disruptions in management and organization
- Fears of monopoly
  - the norm for past 50 years
- Fluid ownership situation
  - the norm for past 50 years

Complications: Biotechnology

- Transgenic crops enthusiastically adopted by farmers, when allowed to do so
- Strong and effective opposition by some segments of society
  - Chief concerns: food safety, environmental health, concentration of power in private sector
- Consequent bans of transgenic crops or their products in some countries

Complications: Biotechnology (cont'd)

- High cost of research
  - Long-term until major payoff
- Can public sector funding stay the course?
  - Disaffection of public with agriculture and farmers
- Can private sector funding stay the course?
  - Cannot stop conventional research so need extra profits to pay for biotechnology research.
  - How much higher can seed prices go?

Complications: Developing Countries

- Farmers in developing countries are not well supplied by plant breeding (some exceptions)
  - Public sector generally poorly supported
  - Private sector usually absent because no markets for commercial seed sales
  - IARCs have made major contribution of improved cultivars for some crops, but
- IARC funding now reduced drastically
  - Directed away from plant breeding
  - Directed toward rural socio-economic development

Reduced Funds, IARCs

- *"Expenditures on agricultural research in the public sector, including the International Agricultural Research Centers (IARCs) have stagnated and in some cases, declined sharply in recent years."* (Maredia and Byerlee, Agricultural Economics 22:1-16. 2000)

Complications: Alternative Goals for Plant Breeding

"Plant breeding's primary goal should be to enhance environmental well-being"

- Breed for best performance in polycultures
  - Higher total yield
  - Better stability of performance
- Breed for perennial habit
  - Less plowing, less erosion
- Breed ground-cover crops
  - Prevent erosion in row crops

Complications: Alternative Goals for Plant Breeding (cont'd)

"Plant breeding's primary goal should be to enhance socio-economic well-being"

- Biotechnology will be bad for the poor and disadvantaged
  - Biotechnology is the tool of the private sector
  - Biotechnology will increase power of corporations
- Intellectual property rights for seeds is wrong
  - "Farmers' rights" should prevail
- Higher yields from plant breeding are not needed
  - Sufficient production already, if it is justly and equitably distributed.

Higher yields not needed

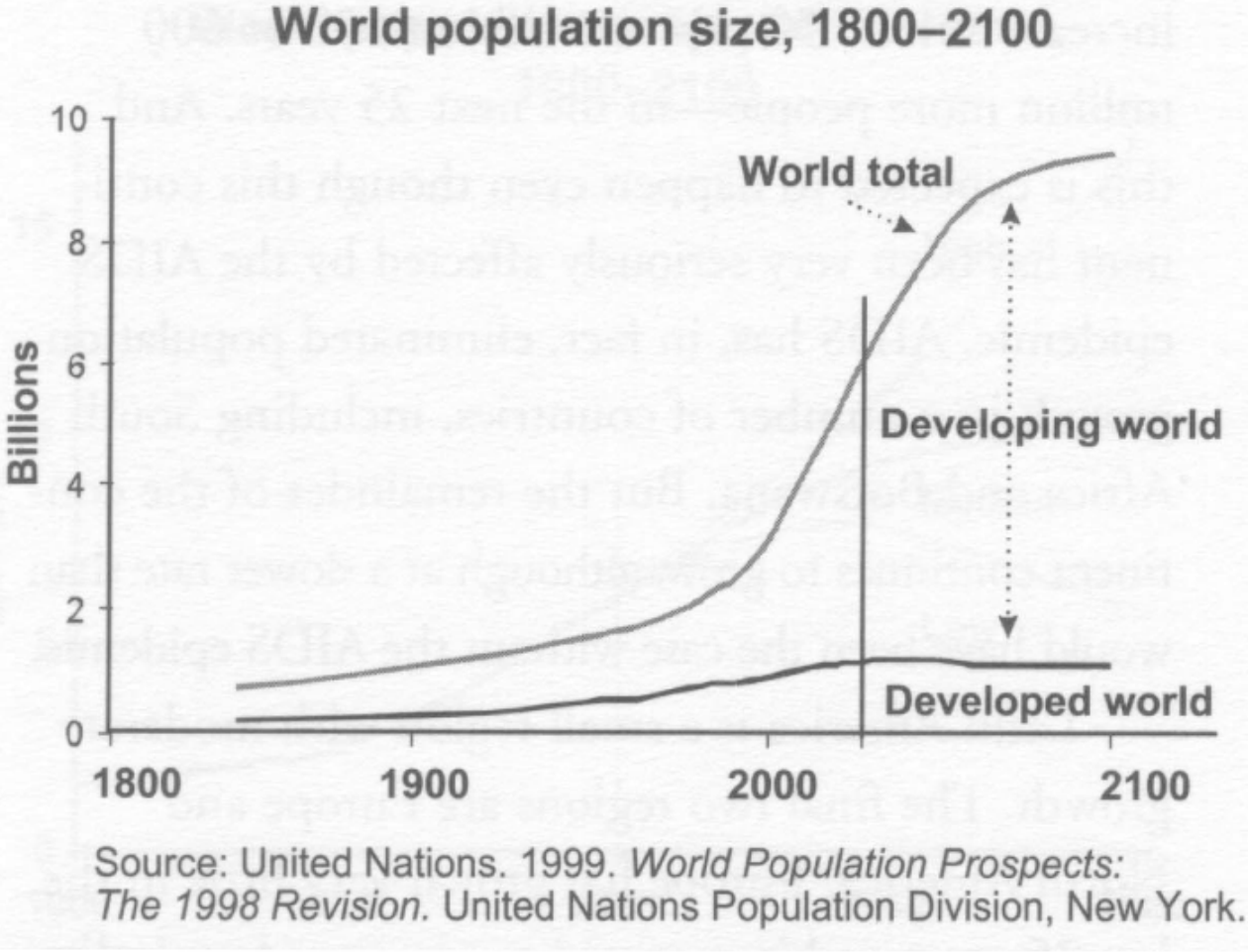
- *"Not only is there enough food in the world, but as long as we are only talking about food — how best to produce it — we'll never end hunger or create the communities and food safety we want."*
- *"Hunger is not caused by a scarcity of food but a scarcity of democracy."*

Frances Moore Lappe, *The Des Moines Register*, July 24,

Higher yields not needed

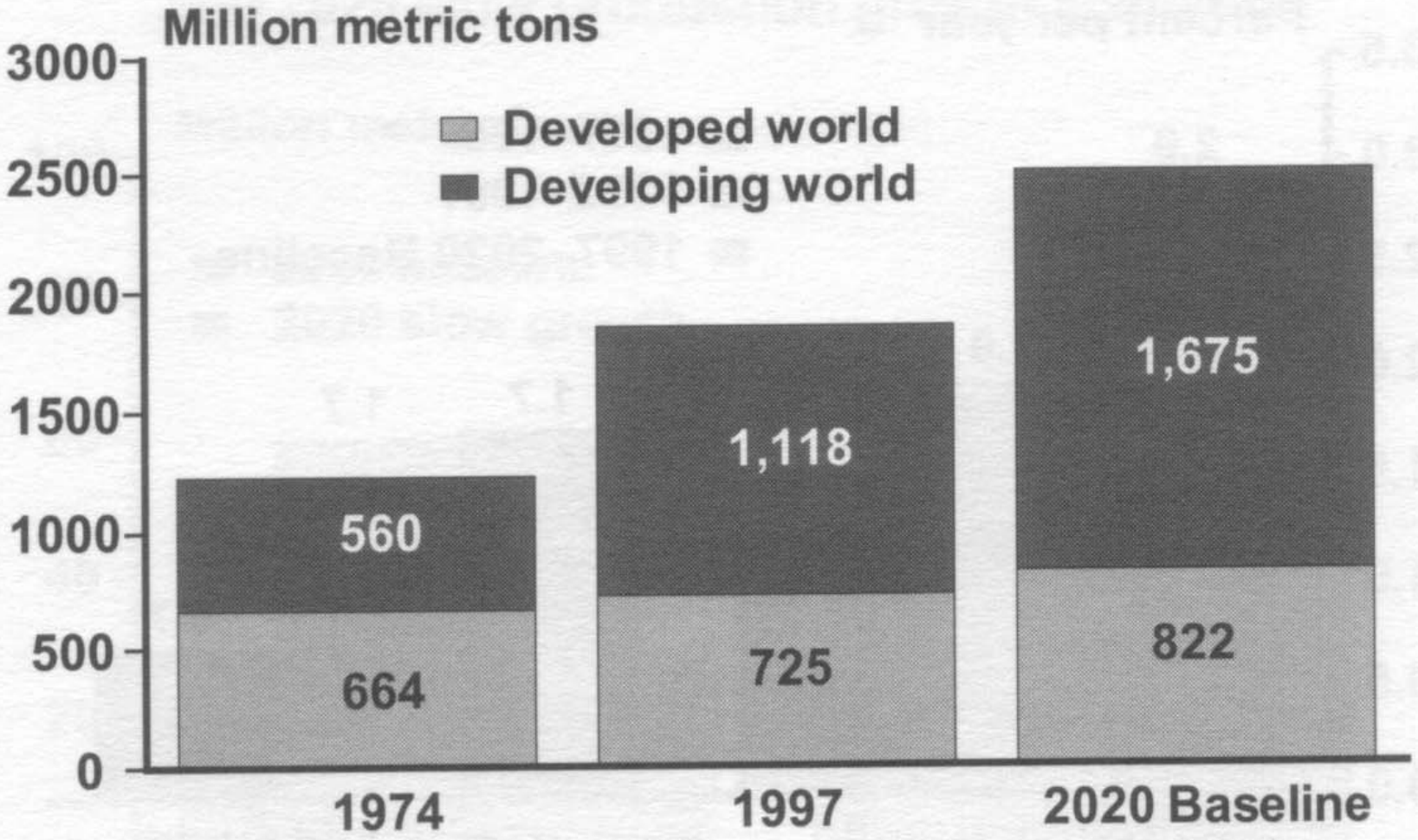
- *"The biotechnology industry claims it holds the answer to world hunger: high technology to increase production. But according to the United Nations Food and Agriculture Organization (FAO), this badly misstates the problem. There is no shortage of food in the world. Per capita food production has never been higher."* Advertisement in New York Times, October 11, 1999, by *Turning Point Project, a coalition of more than 60 non-profit organizations.*

Global Population Trends



Source: United Nations. 1999. *World Population Prospects: The 1998 Revision.* United Nations Population Division, New York.

Cereal demand, 1974, 1997, and 2020



Source: Rosegrant et al. 2001. *Global Food Projections to 2020: Emerging Trends and Alternative Futures.* International Food Policy Research Institute, Washington, DC.

Commentary: Genetic Engineering

- *"In reality, anxieties about genetically engineered crops are social rather than scientific. … Outrage at [concentration of wealth] rather than perception of serious objective risks, underlies much anti-GM activism."*

  John Postgate, book review, in TLS August 1, 2003

Predictions

- Plant breeding will continue to produce improved cultivars
- Biotechnology will be used increasingly, albeit at slower pace than expected
- Plant breeding of the future will seamlessly integrate conventional and molecular breeding
  - but probably will have a fancy new name, e.g., “biological enhancement”

Predictions

- Public and private sector plant breeding will come to resemble each other in some ways
  - Public sector, supported by check-off funds and/or royalties will breed for producers not adequately supplied by the private sector
  - Private sector will donate some of its basic research findings to public use

Predictions

- Private sector breeding for developing countries will increase in amount
  - Will grow in step with development of profitable commercial agriculture
  - Hybrid crops (maize, sorghum, rice)
  - Self-pollinated crops in regions where sound seed production is difficult or not possible
  - Small local companies and large international companies (and sometimes the public sector) will share the markets

Recommendations

- Public sector should be funded to do research in “environmental breeding”
  - Breed new crops for use in environmentally friendly and also profitable reinvented production systems (polycultures, etc.)
  - Breed current crops for use in environmentally friendly and also profitable modifications of current production systems (monocultures, etc.)

Recommendations

- Encourage development of “participatory plant breeding” where needed (and wanted)
  - The farmer pays
- Encourage “breeding for hire” by public sector, for crops/regions not adequately supplied by private sector
  - The farmer pays

Recommendations

- Increase efforts to maintain and increase genetic diversity of crop plants
  - Germplasm collection, conservation and characterization (“seed banks”)
  - Public sector breeders for niche crops and regions
  - Germplasm Enhancement of Maize (GEM) program, a collaboration of public and private sectors

In Conclusion

- Plant breeding can and will continue to help feed the world but adjustments will be needed to adapt its support and operations to current and future societal needs and norms
- Plant breeding — “planned evolution” — has itself evolved, and will continue to evolve in the years to come

A final comment …

"The laws governing inheritance are for the most part unknown. No one can say why the same peculiarity in different individuals of the same species … is sometimes inherited and sometimes not so … "

Charles Darwin (1859) "The Origin of Species"