



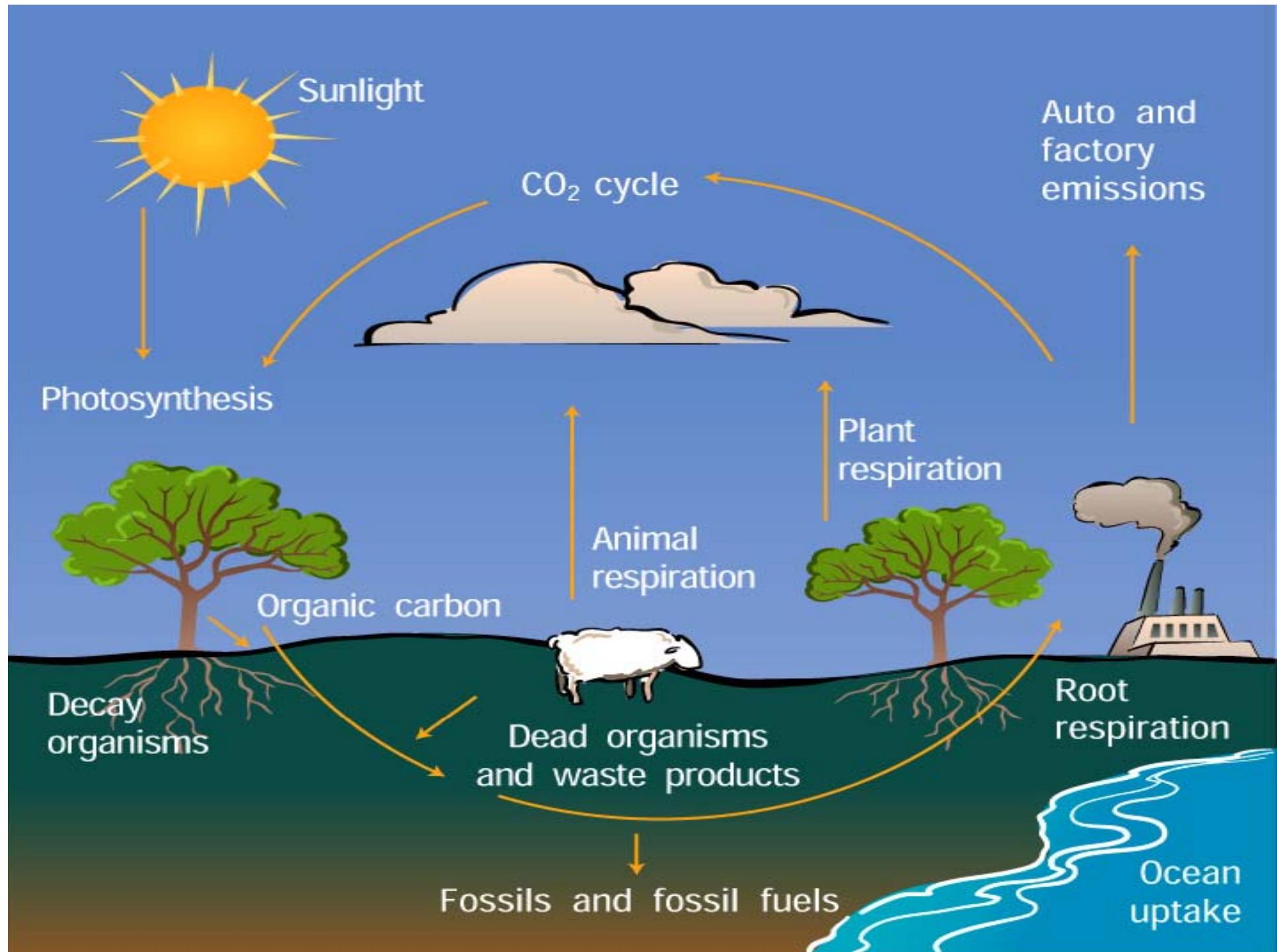
# Feeding the World in the 21<sup>st</sup> Century: the role of Genomics

Mike Bevan  
Venice, Sept 2009

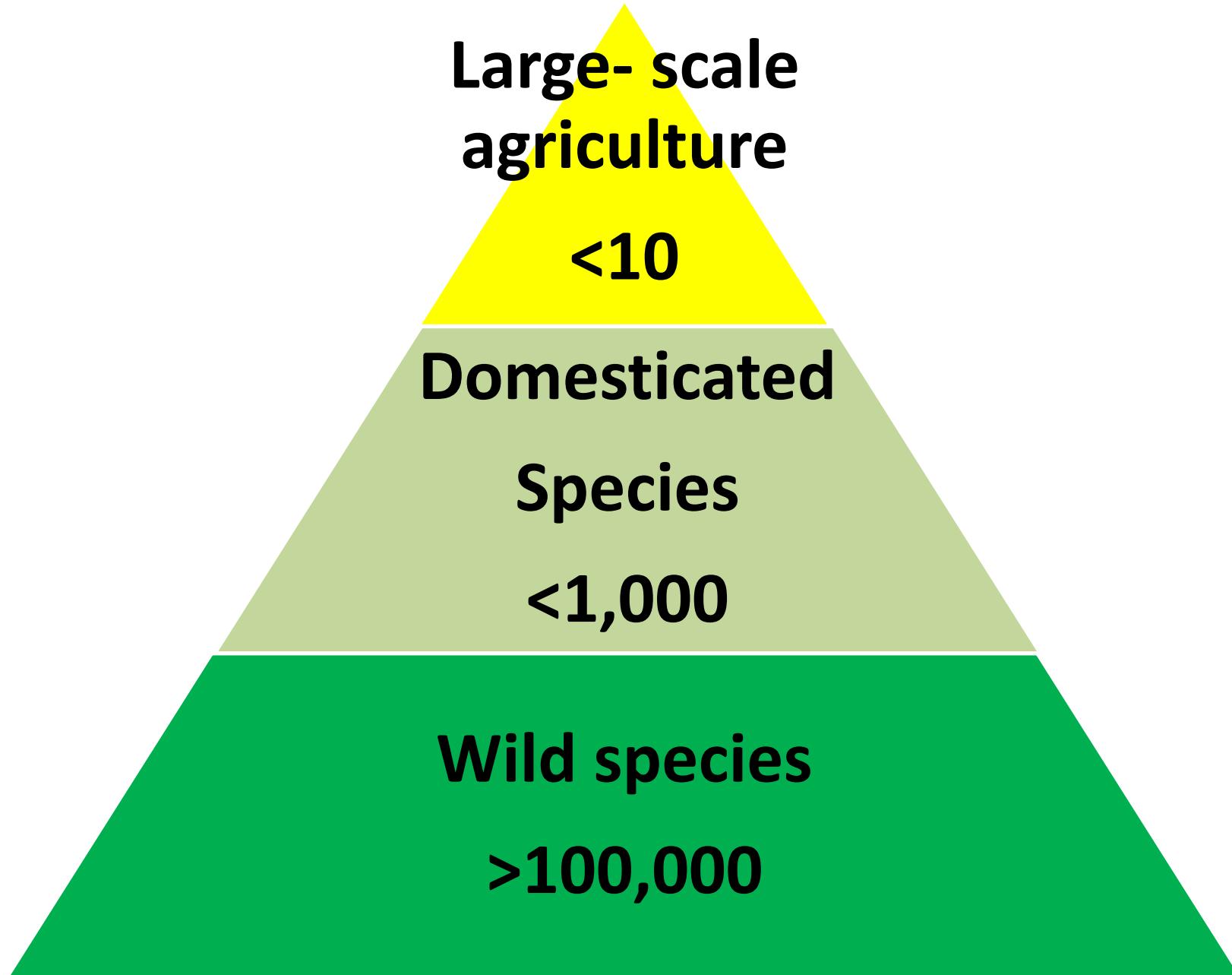




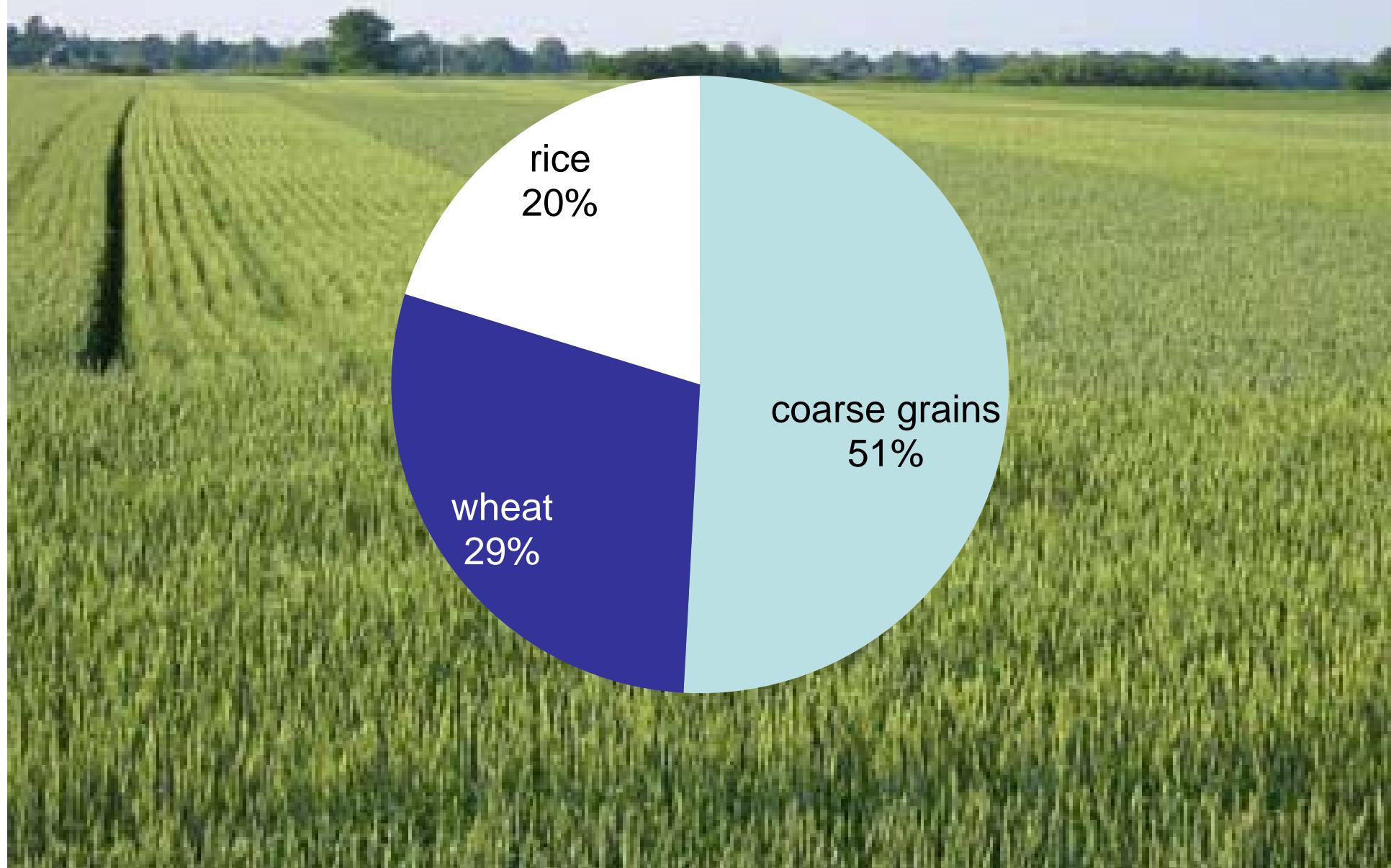
- Where does our food come from?
- What are the problems in producing sufficient food?
- How much will we need?
- Which technologies will be important?



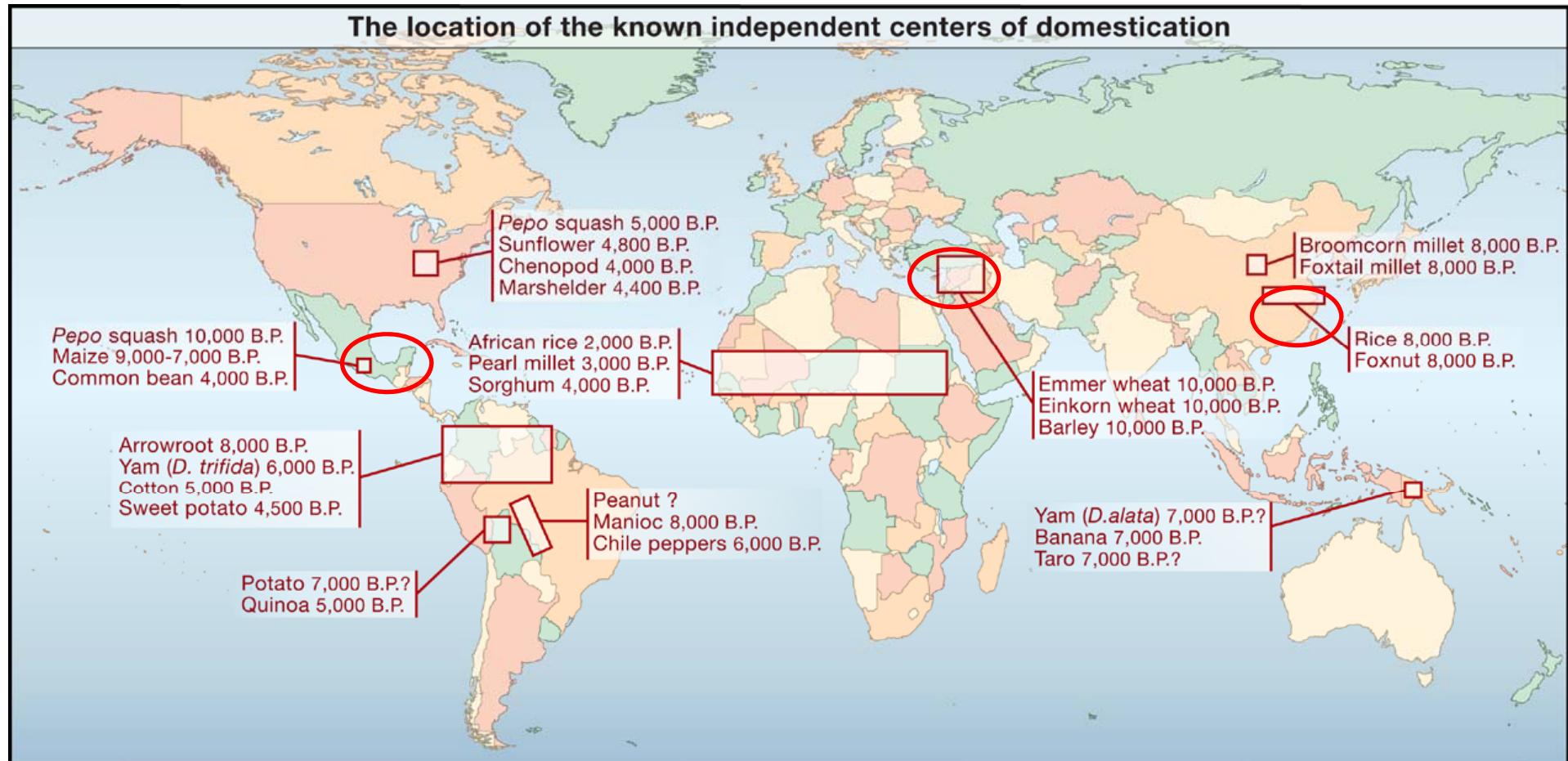
**Most of our food comes from a few domesticated species**



# Grain Production 2007/8



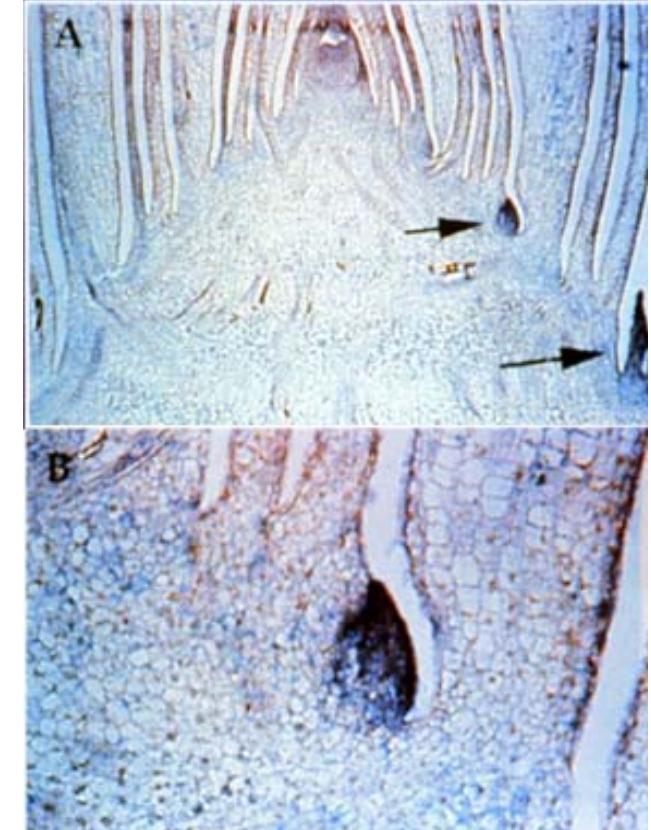
# Centres of crop domestication



# THE INTIMATE RELATIONSHIP BETWEEN CROP DOMESTICATION AND CIVILISATION

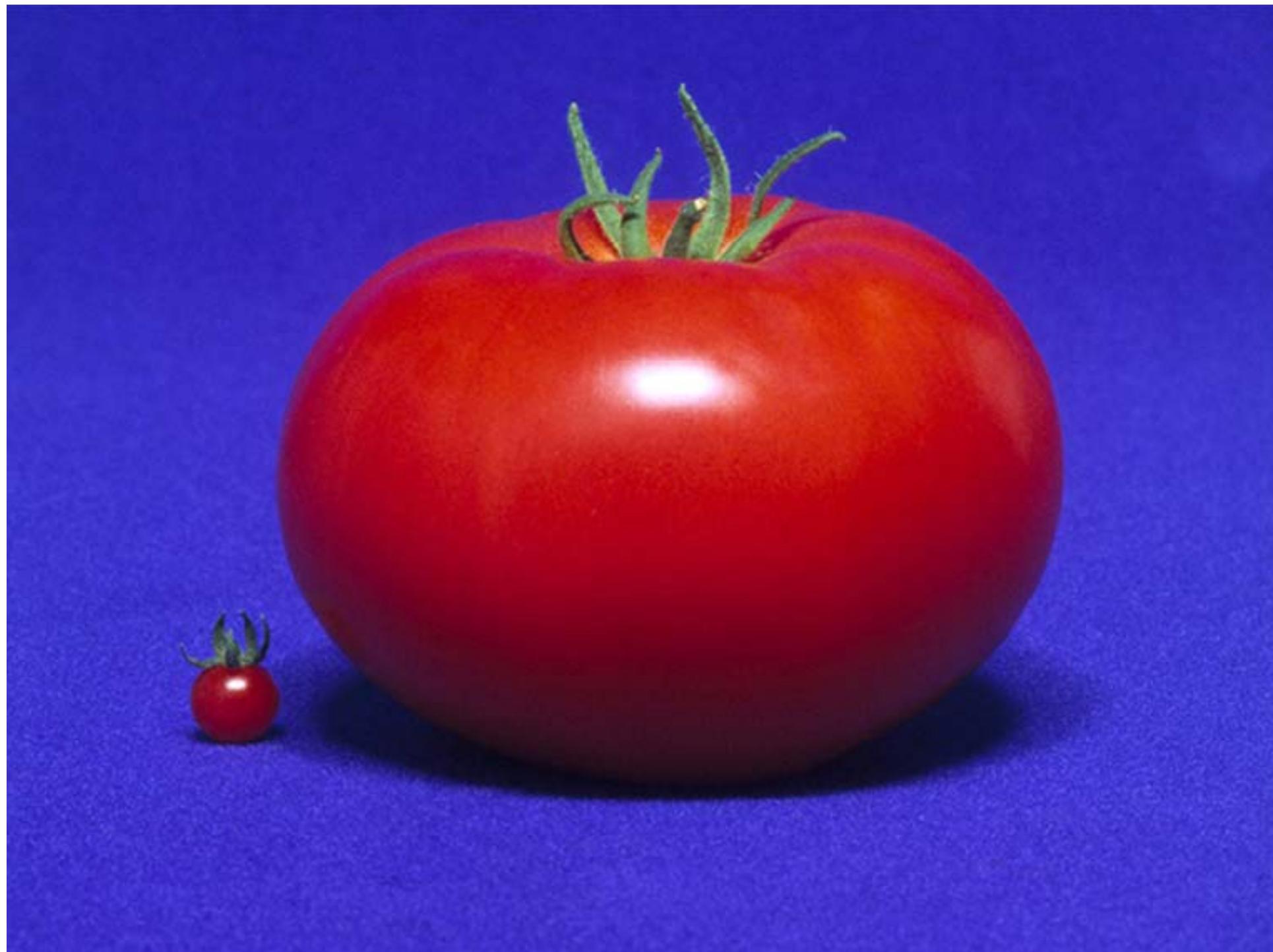


# What kinds of genes?



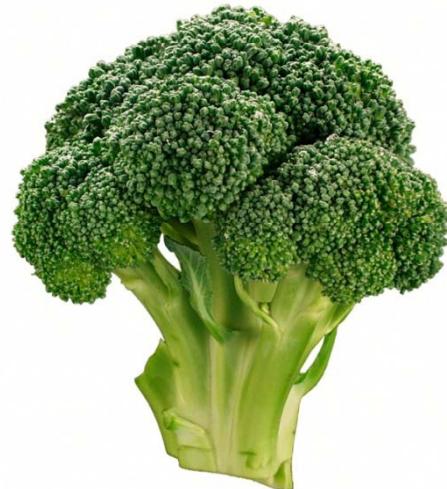
***Teosinte branched1 (tb1): a DNA binding transcriptional regulator that represses the outgrowth of lateral buds***

	BASIC	HELIX	LOOP	HELIX
TB1	RKDRHSKICTAGGM	RDRRMRLSLDVARKFFALQDMLGFDKASKTVQWLLNTSKSAIQEI		
PCF1	SSDRHSKV--AG--	RGRRVRIPAMVAARVFQLTRELGHRTDGETIEWLLRQAEPSIIAA		



# The Power of Artificial Selection

*Different selected versions of a single crop species (*Brassica oleracea*).*



# Simple Single Gene Inheritance

*Prostrate growth-1 (*Prog1*) - vegetative phase plant architecture.*

*Prog1 (dominant)*



*prog1 (recessive)*



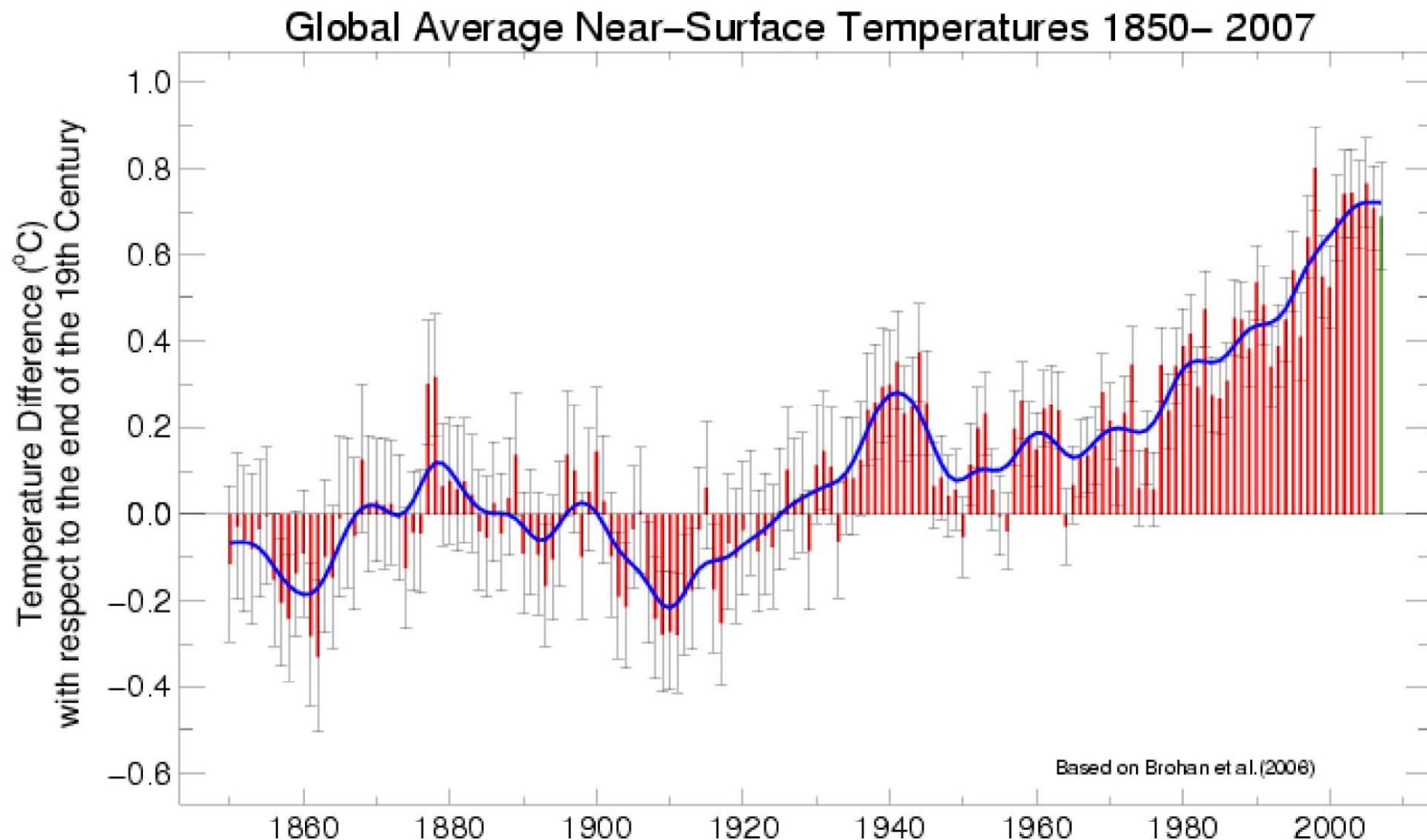
*Wild Rice.*

*Domesticated Rice*

# Nature of the Changes in the Genes

Crop	Gene	Class	Comment
Rice	qSH1	cis regulatory	altered CRE binding site
Rice	gif1	cis regulatory	restricted/reduced expression
Tomato	fw2.2	cis regulatory	heterochronic expression shift
Maize	tb1	cis regulatory	enhancer; up regulation
Tomato	fas	cis regulatory	down regulation
Maize	tga1	protein function	transcriptional repression
Rice	sha1	protein function	AA change in DNA binding domain
Rice	prog1	protein & cis-reg	multiple changes
Wheat	Q	protein & cis-reg	dimerization; message level; miRNA
Rice	sh4	protein & cis-reg	multiple changes
Barley	Vrs	Loss of function	frame shift or AA change
Rice	gn1a	LOF & cis-reg	multiple alleles / different lesions
Barley	nud	LOF	deletion of the entire gene (17 kb)

# THE WORLD IS GETTING WARMER





**POPULATIONS ARE INCREASING**

**GEO-4 2007**

**“Our Shrinking Earth”**

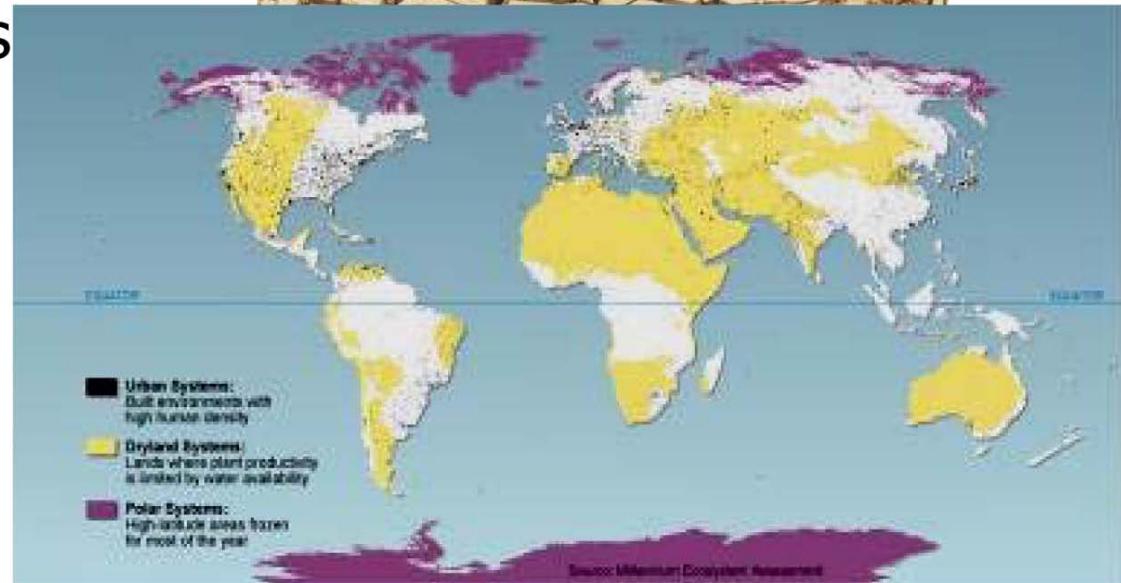
**Hectares of land per  
person from 1900 to  
2050:**

**7.9 to 1.6\***

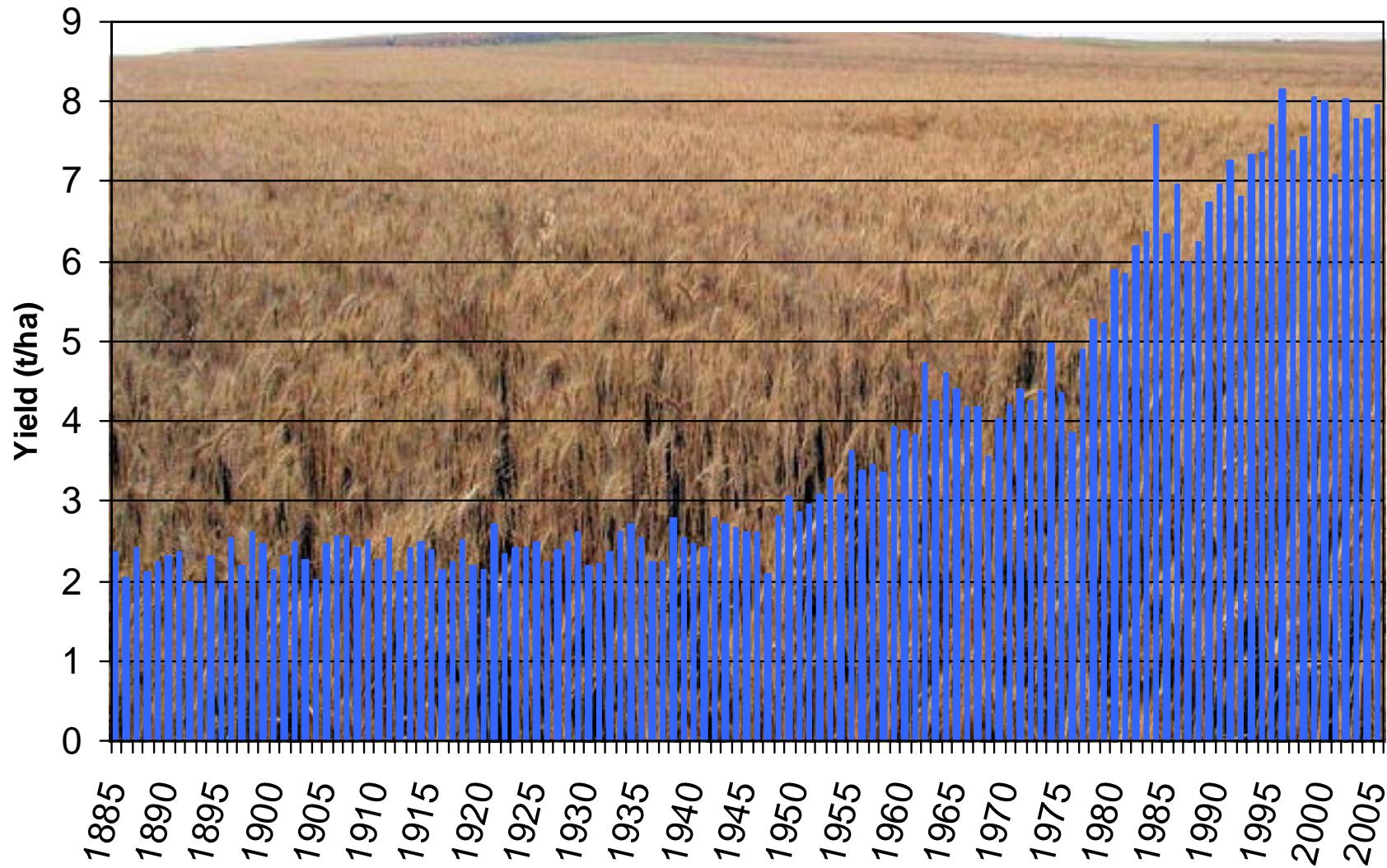
**128m x 128m = 4  
acres**

# WATER AND OTHER RESOURCES ARE LIMITING

- 40% of land surface and more than 2 billion inhabitants
- Lowest levels of human well-being
- 10-20% of drylands degraded
- Only 8% of renewable water supply

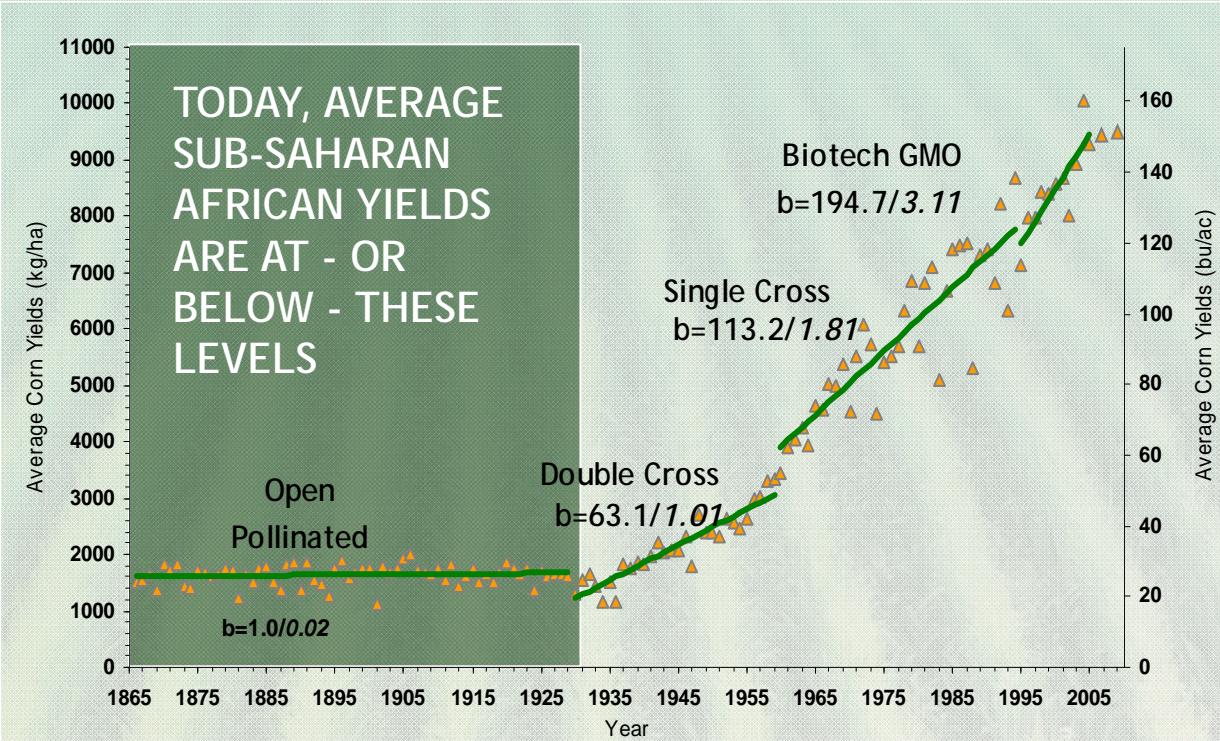


# UK Wheat Yield Trends



# Average Sub-Saharan African Corn Yields Are Equivalent to Average U.S. Yields in Late 1920s

YIELDS LAG DUE IN PART TO LIMITED TECH ADOPTION AND ADVANCES IN AG PRACTICES



THERE IS A REAL NEED FOR BETTER YIELD

IMPROVED AGRONOMIC PRACTICES, BREEDING AND BIOTECH CAN ALL PLAY A ROLE

Source: March 2006. Crop Science. Ref# 46:528-543

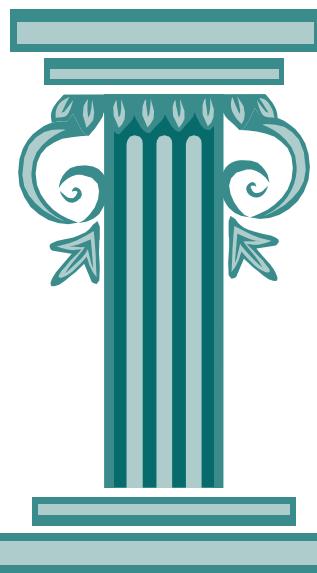
# THE FUTURE



Sir Roland Bifflin circa 1925

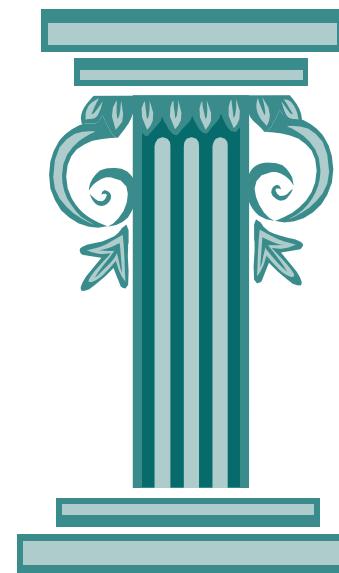
# The Three Pillars of Yield

## BREEDING



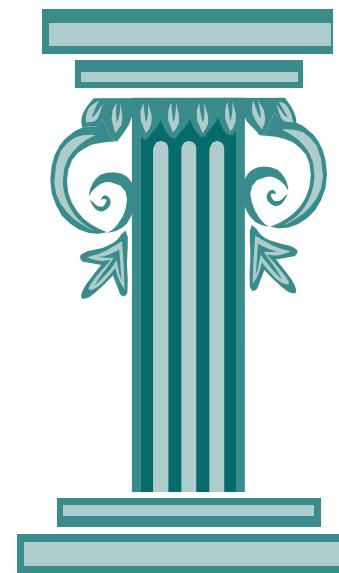
Strategically breed plants to create new, more robust seeds that perform better – and longer – in the field.

## AGRONOMICS



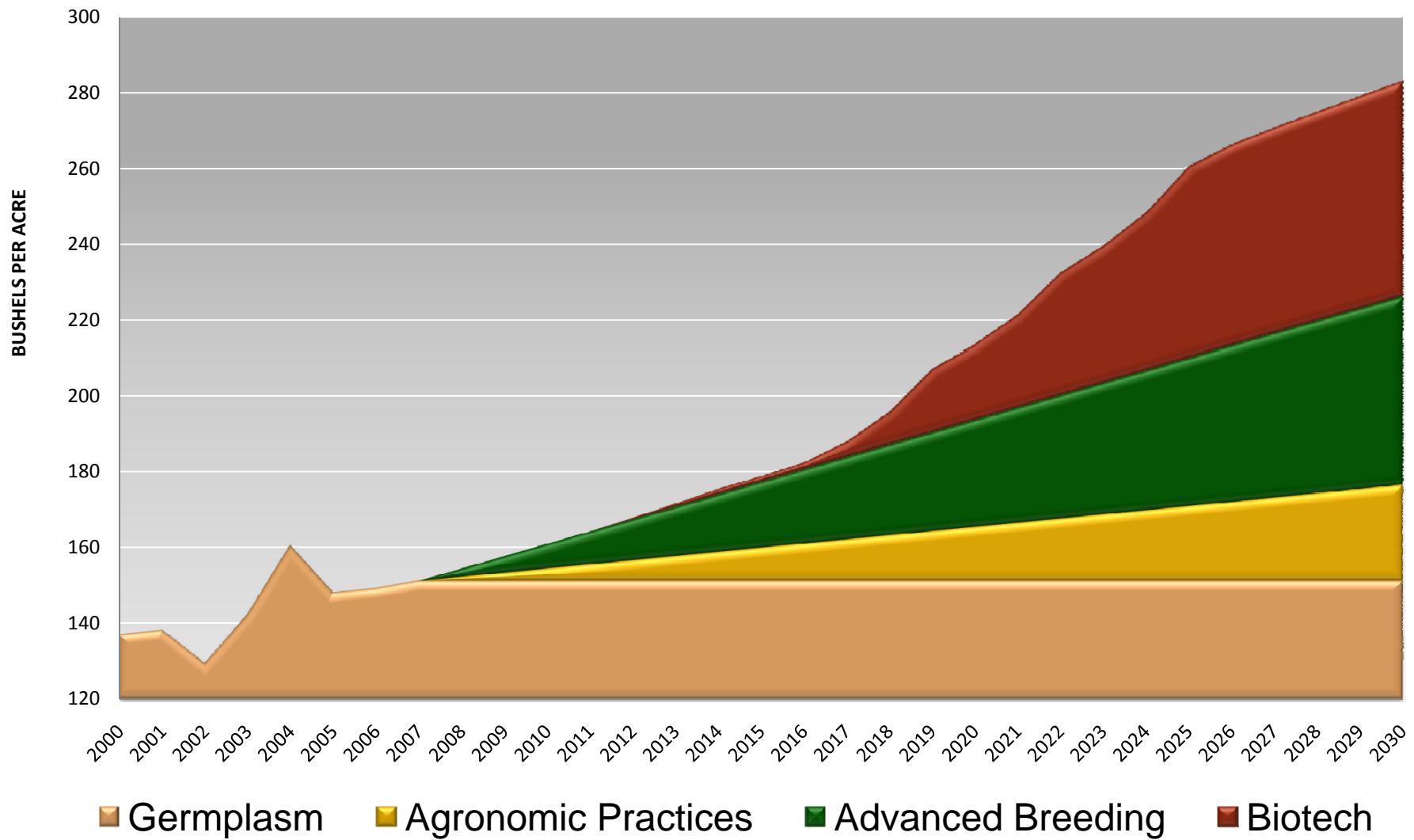
Use precision ag, planting density, plant health protection, and conservation tillage to make acres more productive.

## BIOTECHNOLOGY

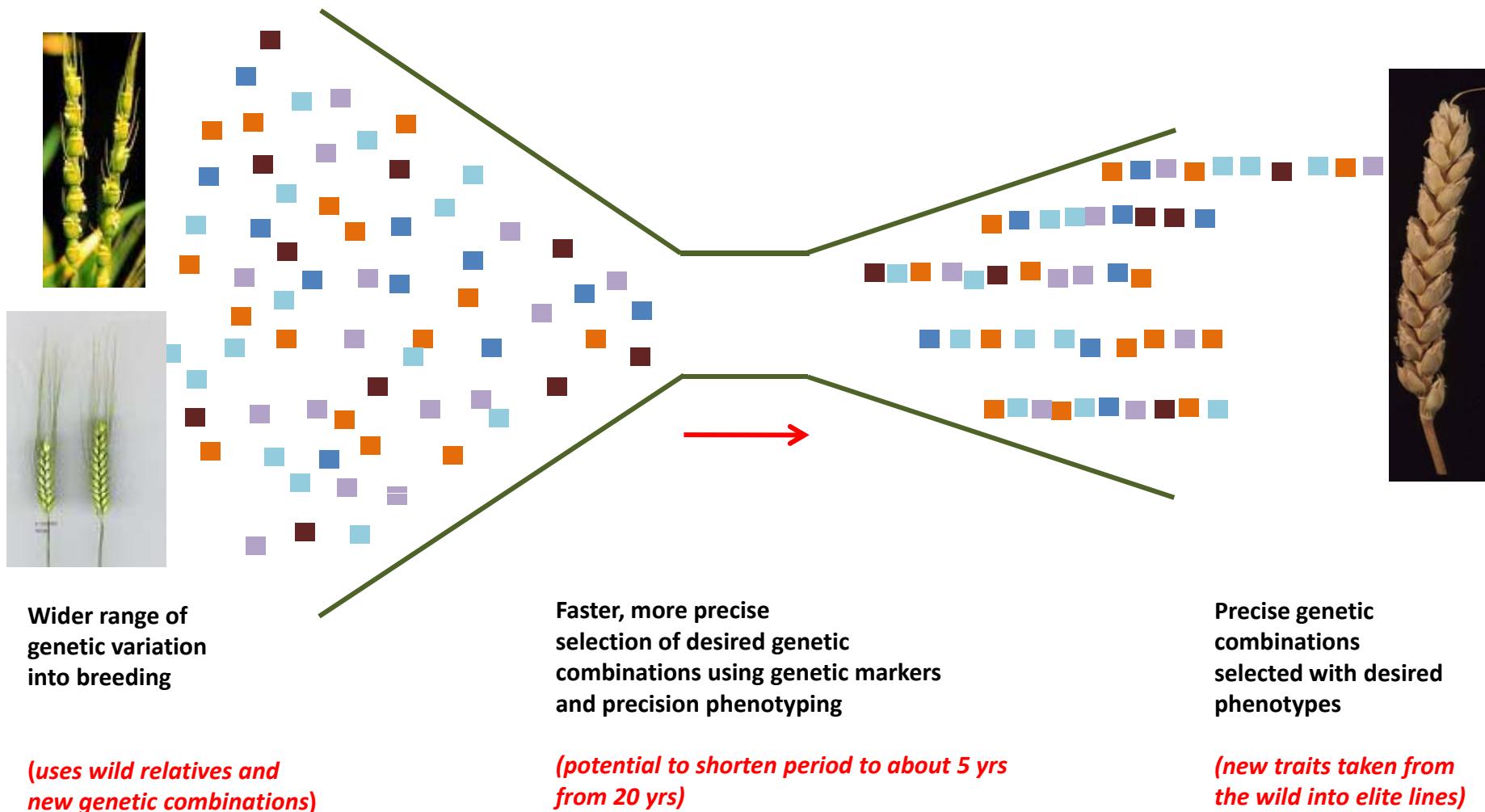


Supplement breeding advancements by adding special beneficial genes to the plant.

# The Combination of Maize Breeding, Agronomic Practice Improvements and Biotech Can Maximize Yield Gains



# Genomics can accelerate plant breeding using more diverse germplasm



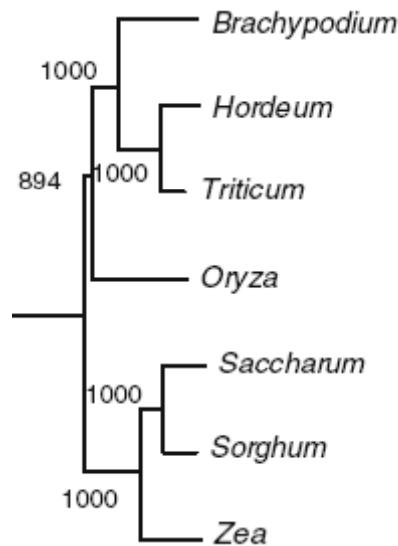
After Tanksley and McCouch. *Science* 277, 1063.

# The grass family (*Poaceae*)

## Ehrhartoideae

### Oryza

*Oryza sativa* (rice)



## Panicoideae

### Paniceae

*Panicum* (switchgrass)

### Andropogoneae

*Sorghum*

*Saccharum* (sugarcane)

*Zea* (maize)

*Miscanthus*

## Pooideae

### Aveneae

*Avena* (oat)

### Brachypodieae

*Brachypodium*

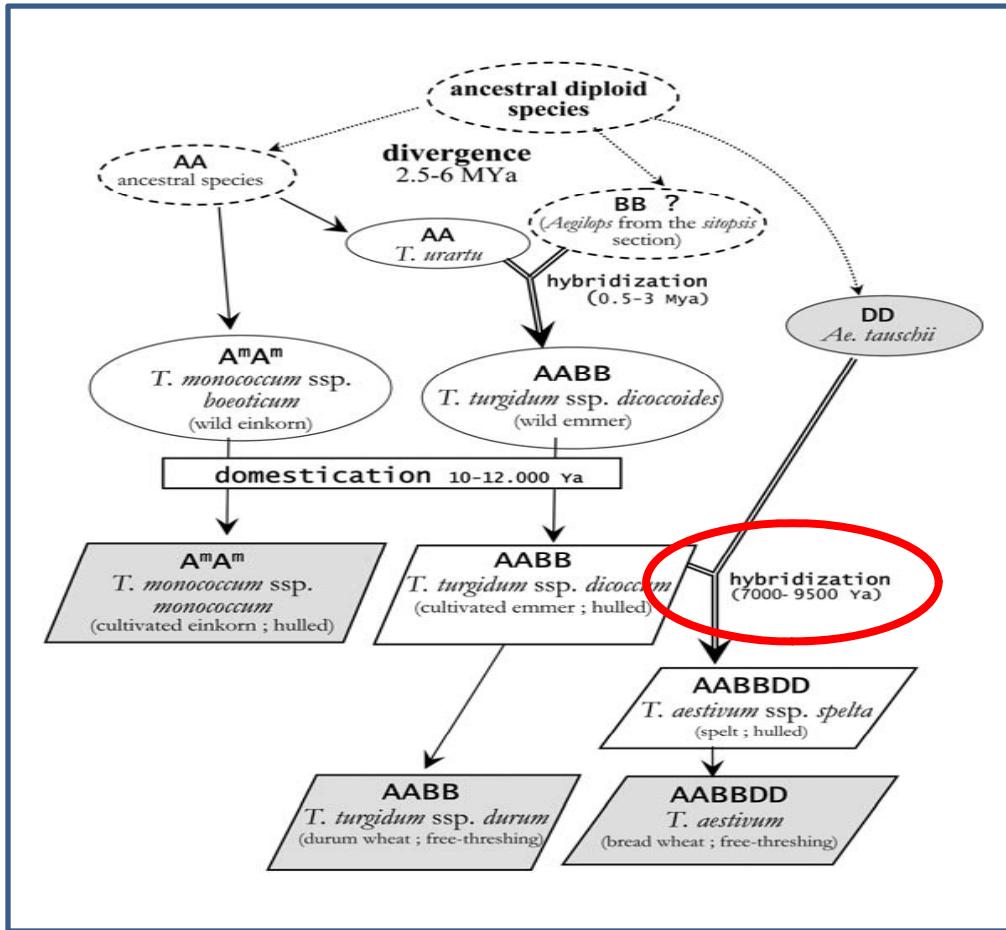
### Triticeae

*Hordeum* (barley)

*Secale* (rye)

*Triticum* (wheat)

# The wheat genome is a major challenge, but is feasible



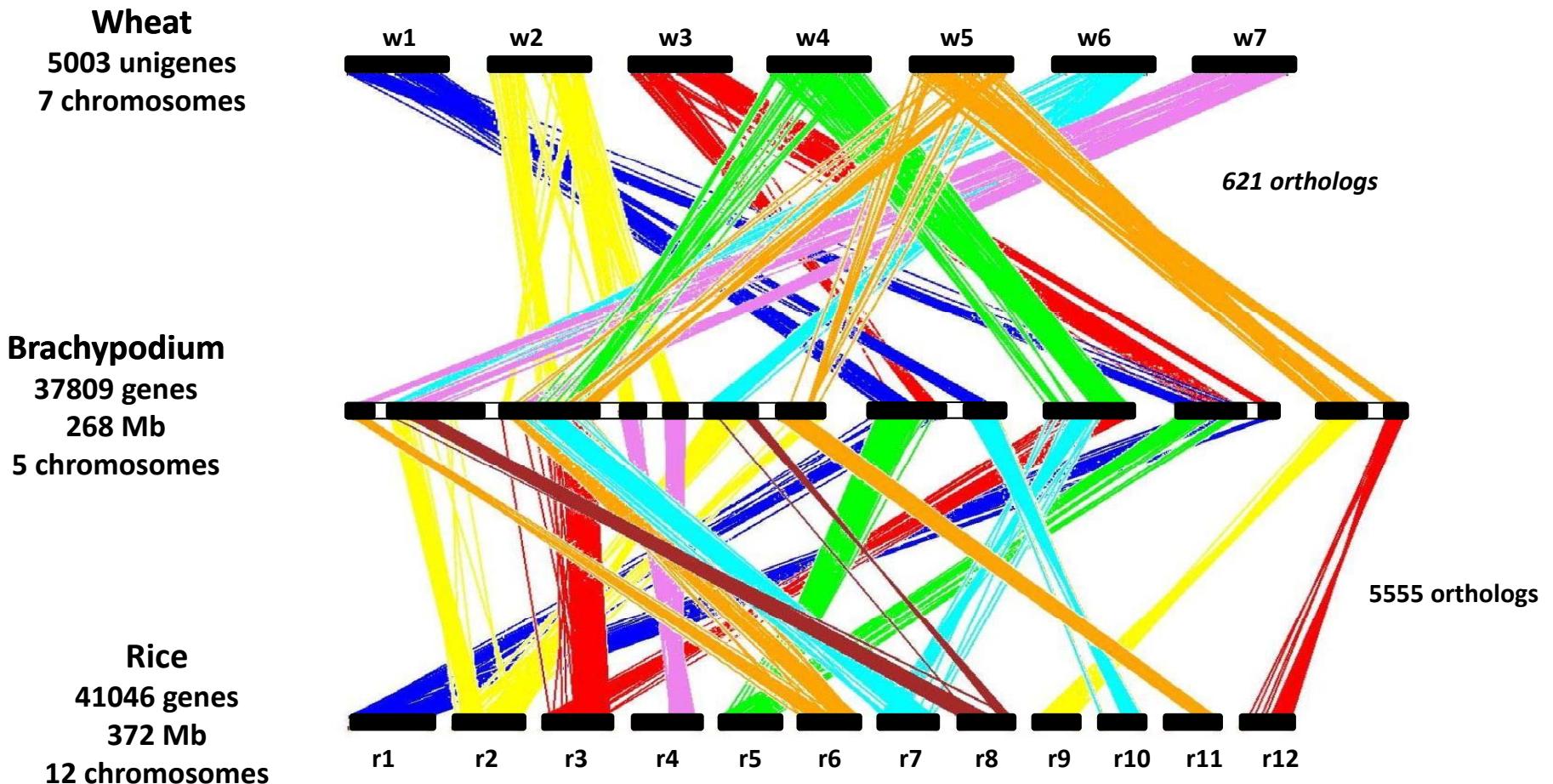
## **Genetics of Resistance to Wheat Leaf Rust, Stem Rust, and Powdery Mildew in *Aegilops sharonensis***

P. D. Olivera, E. Millet, Y. Anikster, and B. J. Steffenson

First and fourth authors: Department of Plant Pathology, University of Minnesota, St. Paul 55108; and second and third authors: Institute for Cereal Crops Improvement, Tel Aviv University, Ramat Aviv 69978, Israel.  
Accepted for publication 13 November 2007.



# Rice/Wheat/Brachypodium Synteny; guidelines for wheat



## Method

- Alignment criteria CIP CALP
- Statistical validation

Courtesy of Jerome Salse

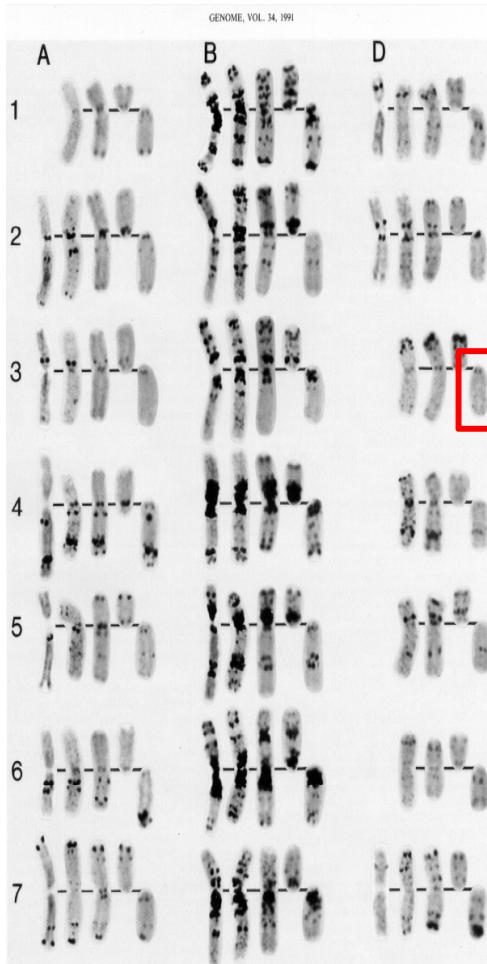
# Wheat genomics strategies

INTERNATIONAL CONSORTIUM

BBSRC (TGAC/JIC), CSHL

TGAC/EBI/JIC

## WHEAT ANEUPLOID LINES



3 INDIVIDUAL GENOMES  
5 TIMES HUMAN GENOME

## PURIFIED CHROMOSOMES



PHYSICAL MAP OF BACS

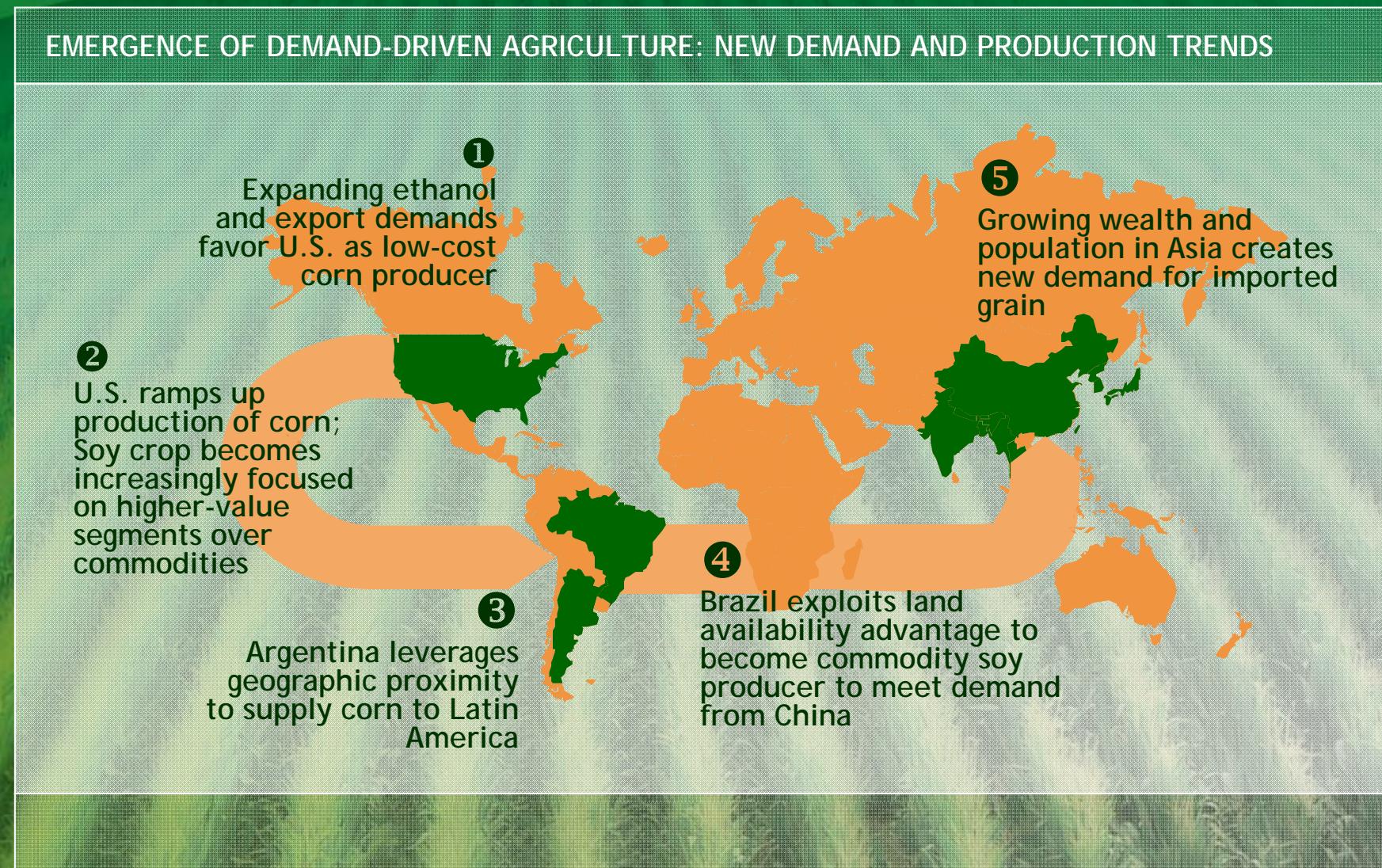
SEQUENCED FRAGMENTS

ASSEMBLY,  
ANALYSIS

TRANSCRIPTOME  
SEQUENCE

LOW COVERAGE  
WHOLE GENOME SEQUENCE

# Market Forces Are Changing Supply-Demand Patterns Globally, Creating a New Dynamic Across Agriculture



# Advanced crop breeding systems

- Genome sequencing of multiple lines
- High throughput genotyping
- Greater understanding of gene function using model systems such as *Arabidopsis* and *Brachypodium*
- Efficient gene transfer systems
- Exploiting new sources of genetic variation
- More efficient breeding pipeline from the lab to the field