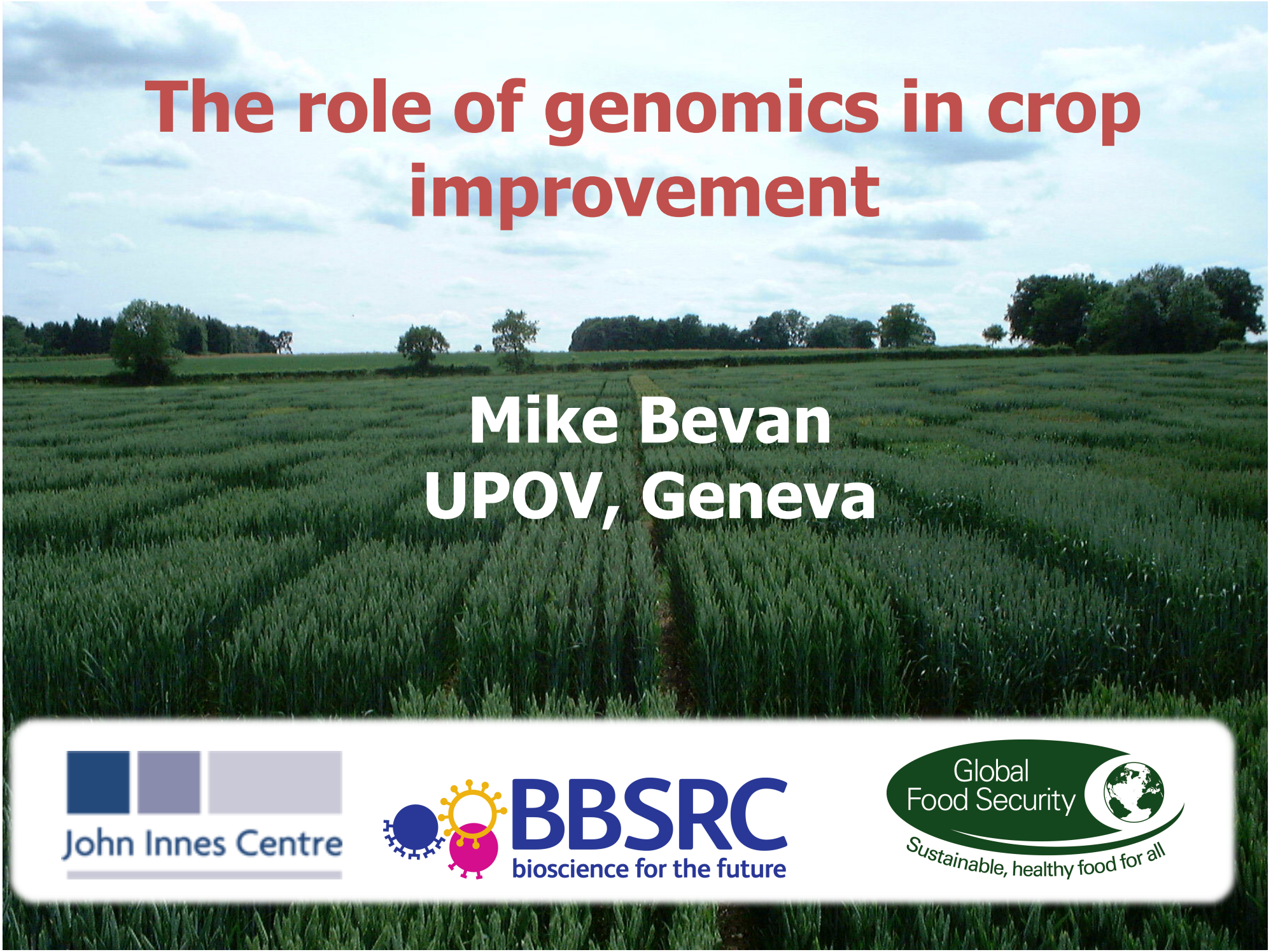
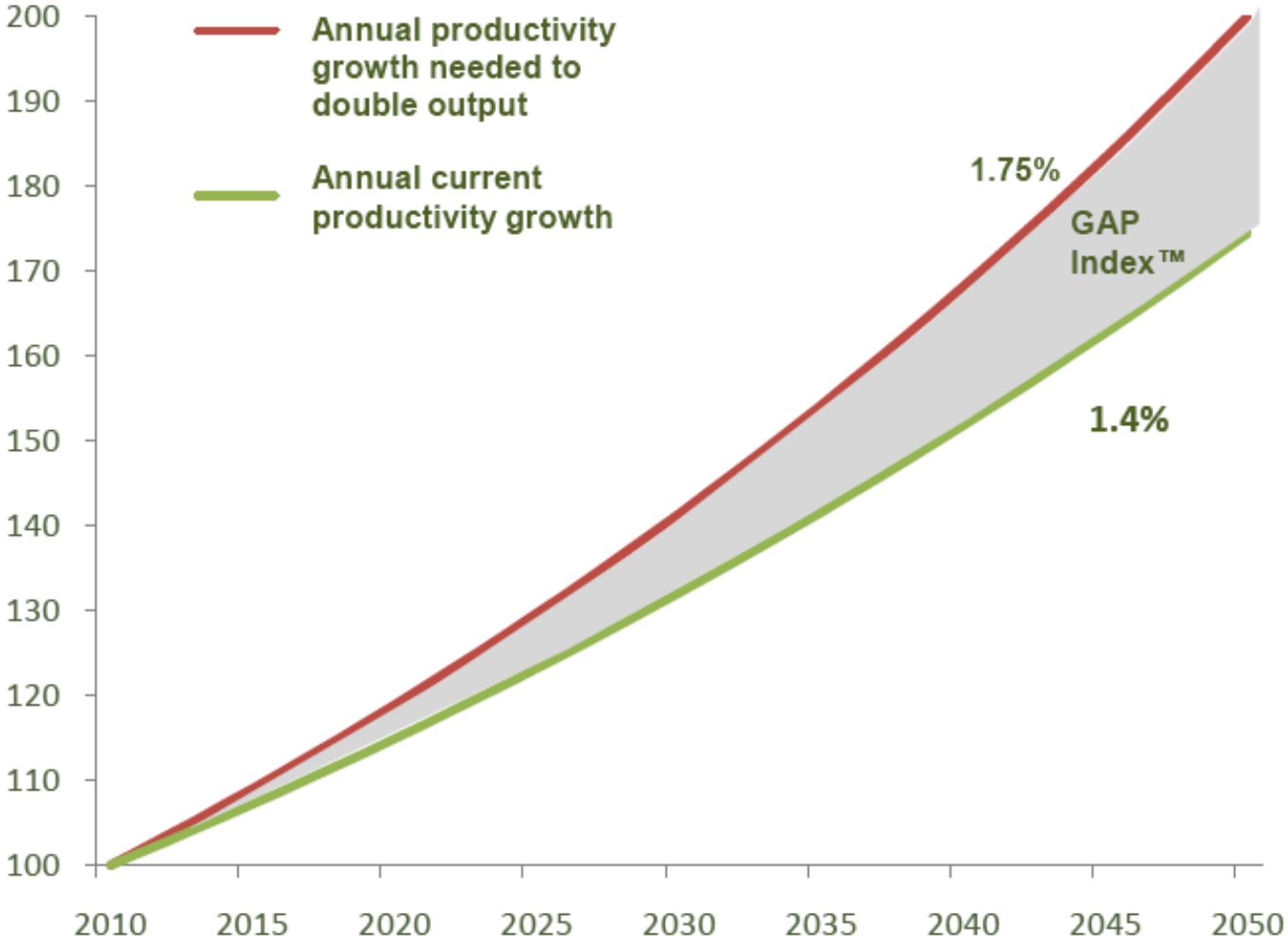

The role of genomics in crop improvement
Mike Bevan
UPOV, Geneva
John Innes Centre
BBSRC
bioscience for the future
Global Food Security
Sustainable, healthy food for all


•Supplying sufficient food in the 21 century
•What is sustainable agriculture?
•The key role of plant science and genomics

The Global Harvest Initiative

2010 GAP Report™

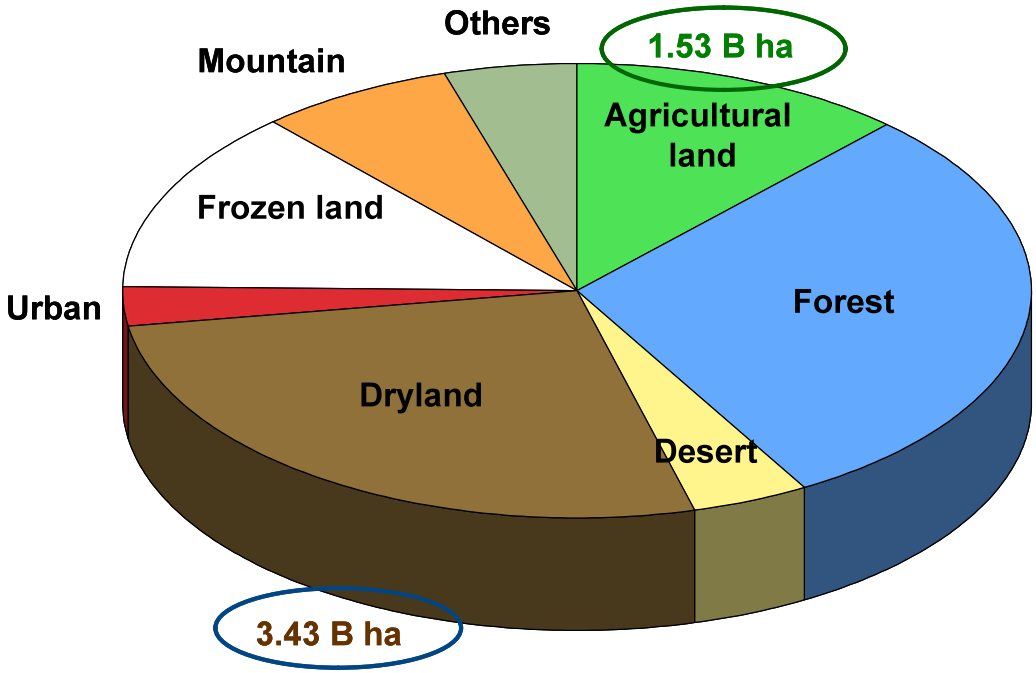
Measuring Global Agricultural Productivity



Source: Farm Foundation, NFP calculations (2010) based on USDA ERS data.

Land is a limiting resource for plant productivity

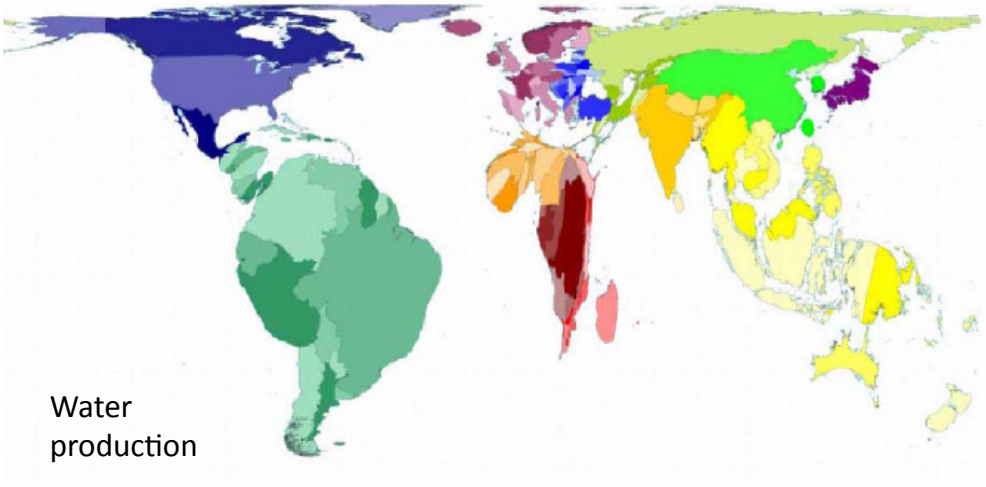
Total land on earth:
12.8 billion hectares



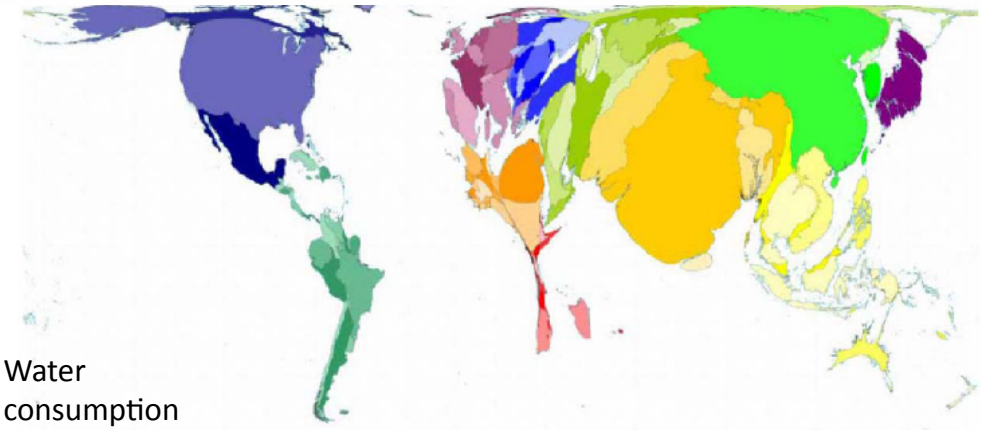
decline
from 0.38 hectares in 1970 to
0.15 hectares per person in 2050

Water is a limiting resource for plant productivity

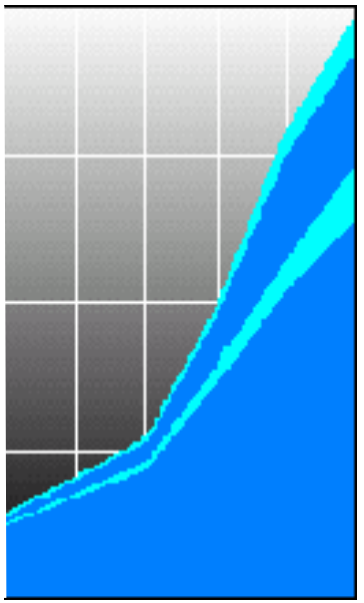
Worldwide, 70% of all water is used for agriculture



Water production



Water consumption



L/day/person used

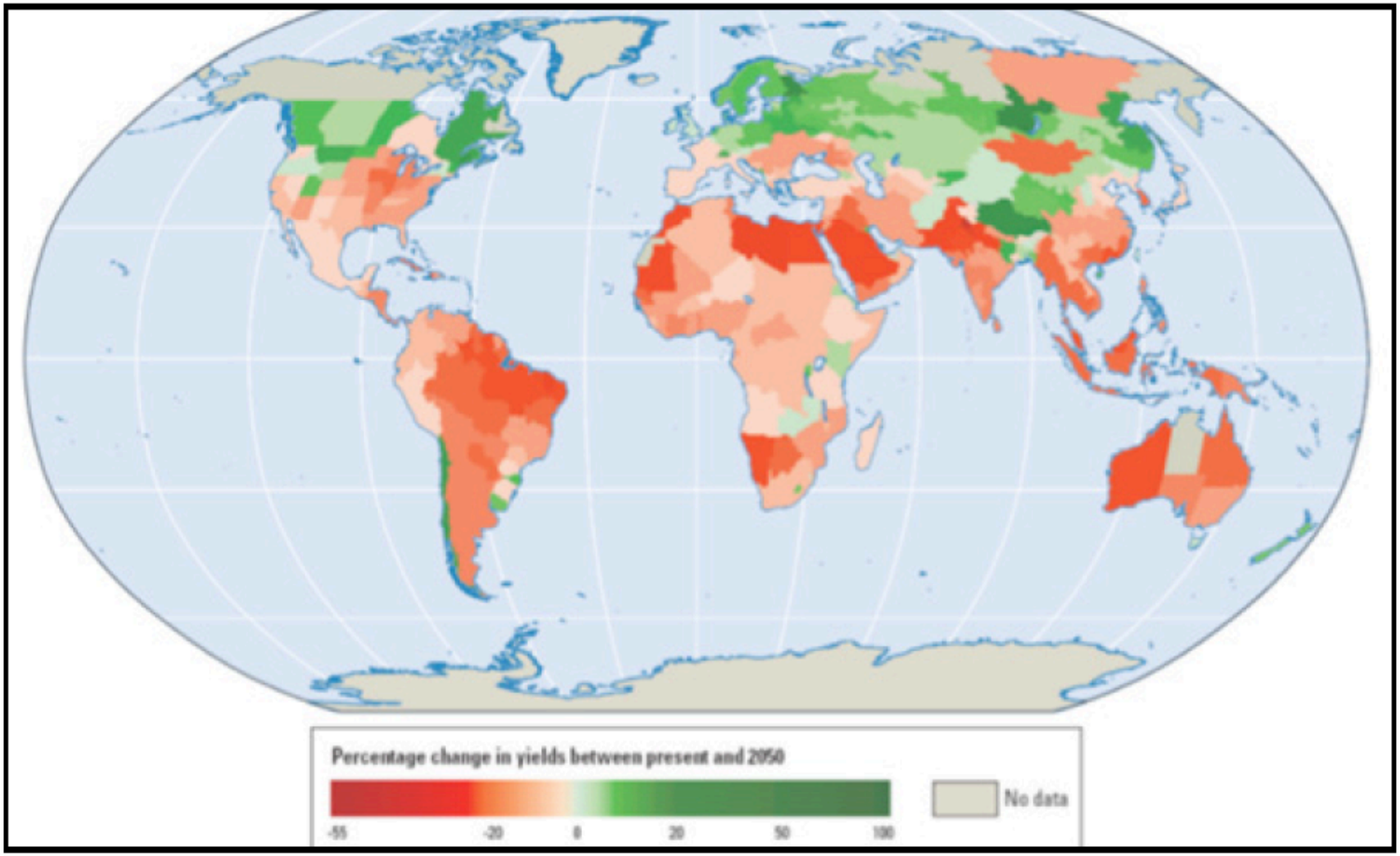
- AU 1,440
- USA 617
- EU 210
- Africa 48

- World water consumption doubled over the last 50 years
- Still 1.3 billion people do not get enough drinking water, by 2050 this number could double

Source: United Nations Environment Program 2005

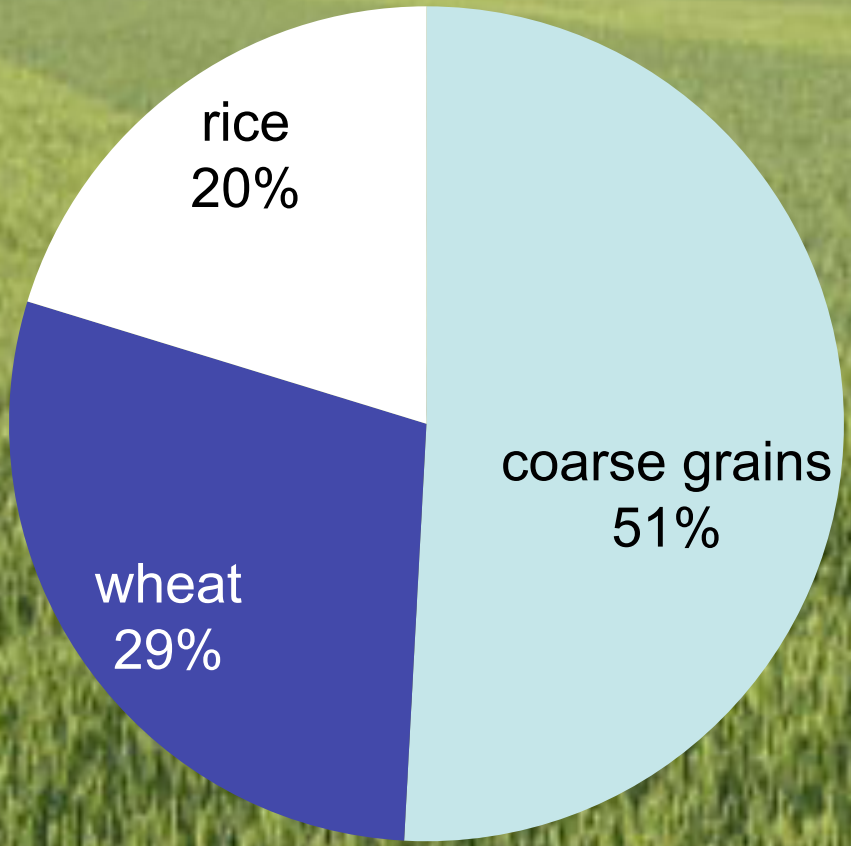
Predicted impact of global climate change on agricultural productivity

Figure 5.1. Impact of climate change on potential agricultural yields by 2050



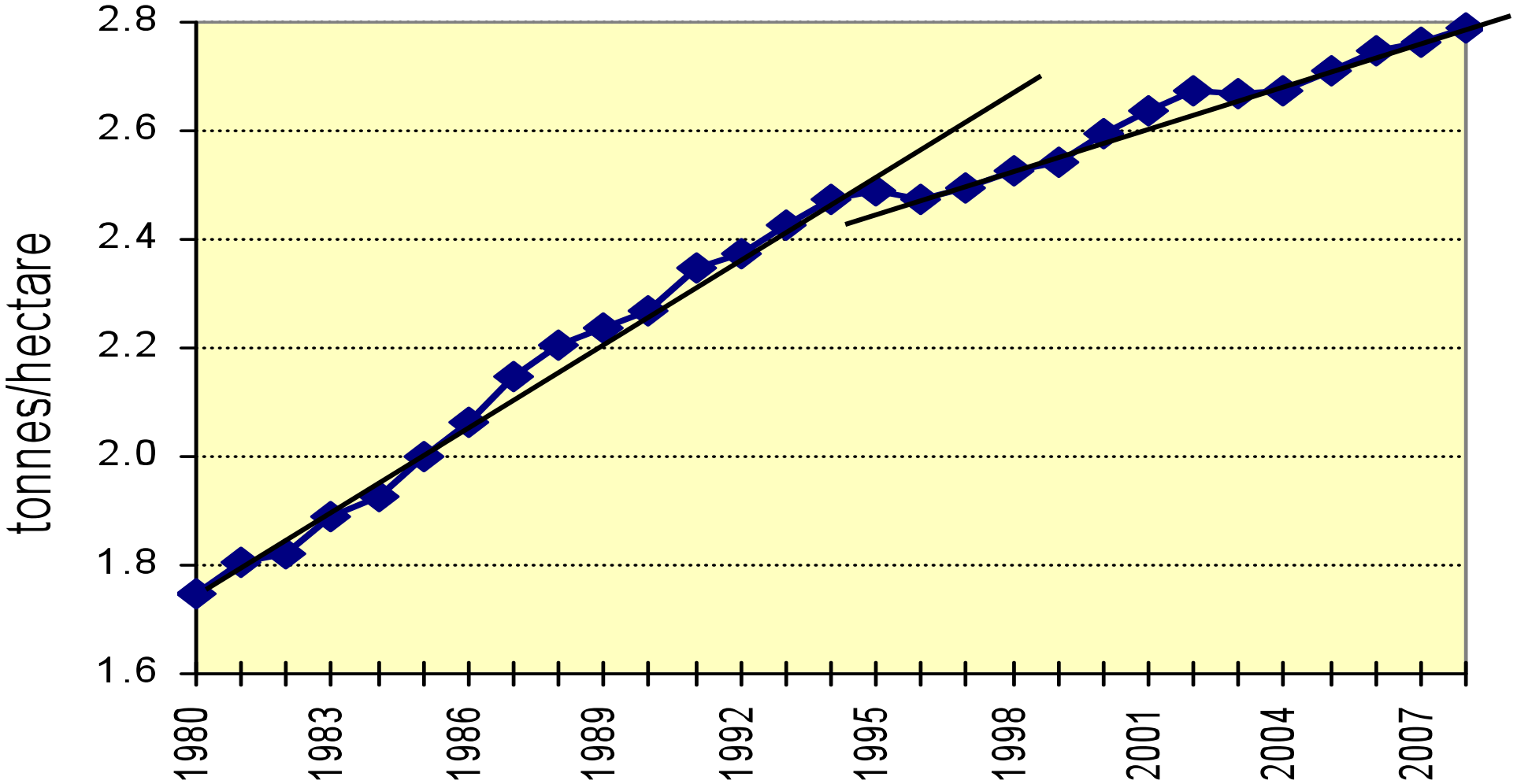
Source: World Bank 2009b

Grasses provide the bulk of human nutrition



WORLD WHEAT YIELD TRENDS

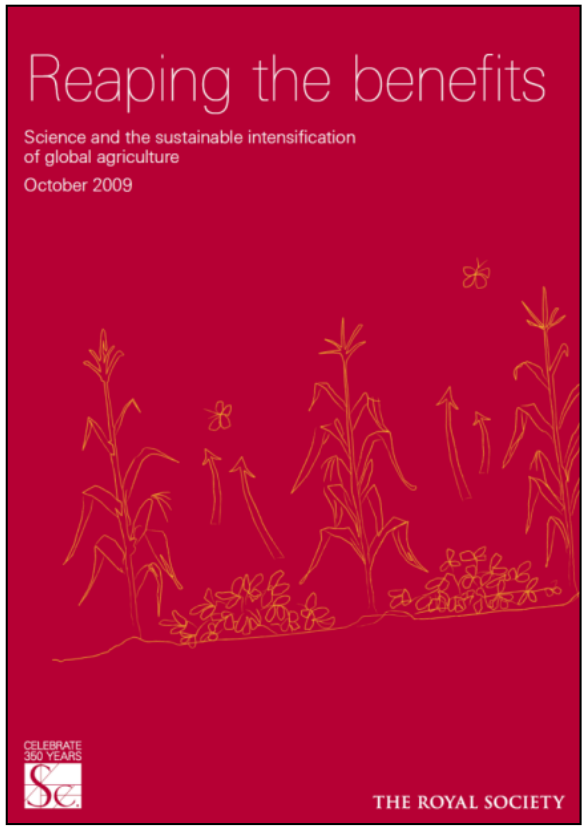
(5 Year Moving Average - tonnes/ha)



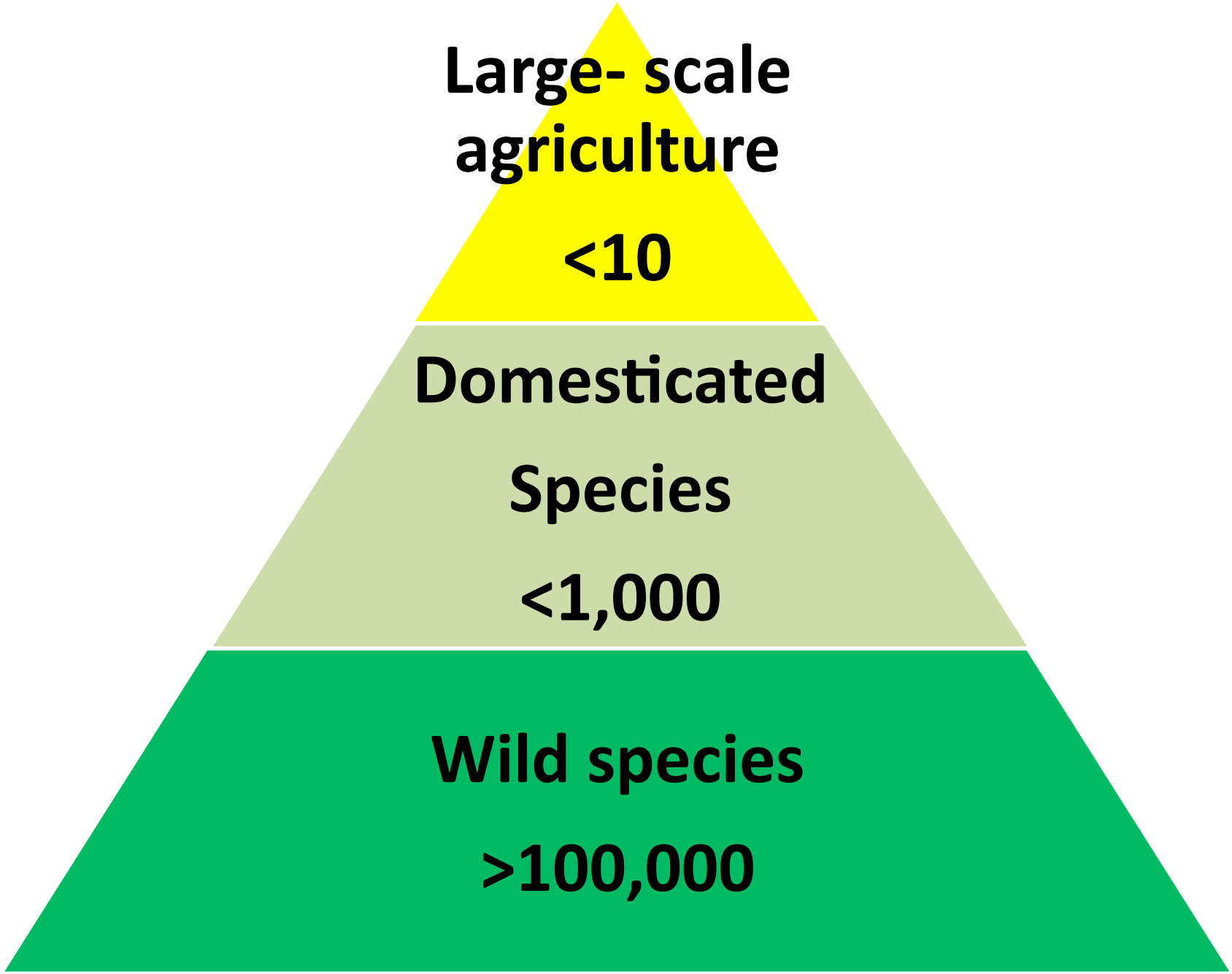
Source: Chudleigh, 2008

Understand to exploit

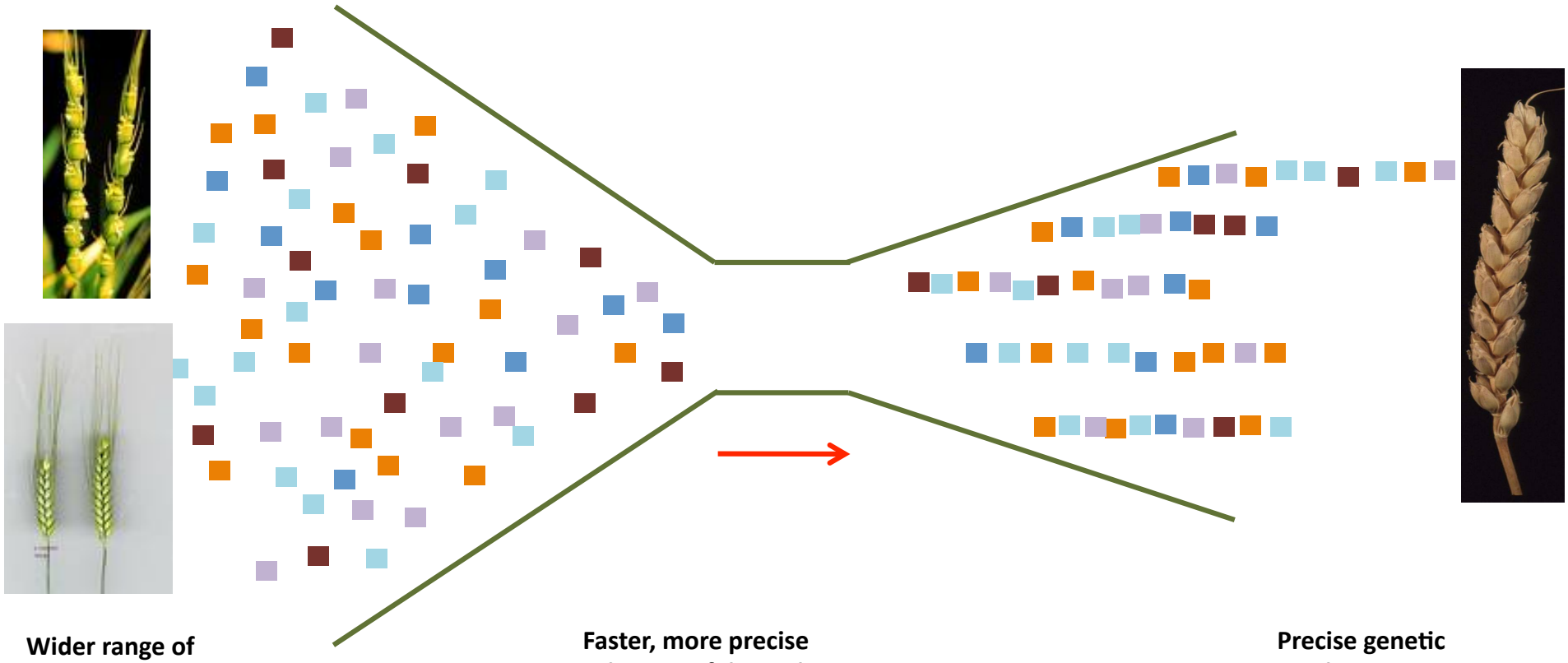
- More from less: 2x by 2050 (“Sustainable intensification”)



Most of our food comes from a few domesticated species



Genomics can accelerate plant breeding using more diverse germplasm



Wider range of genetic variation into breeding

(uses wild relatives and new genetic combinations)

Faster, more precise selection of desired genetic combinations using genetic markers and precision phenotyping

(potential to halve time taken to breed new varieties)

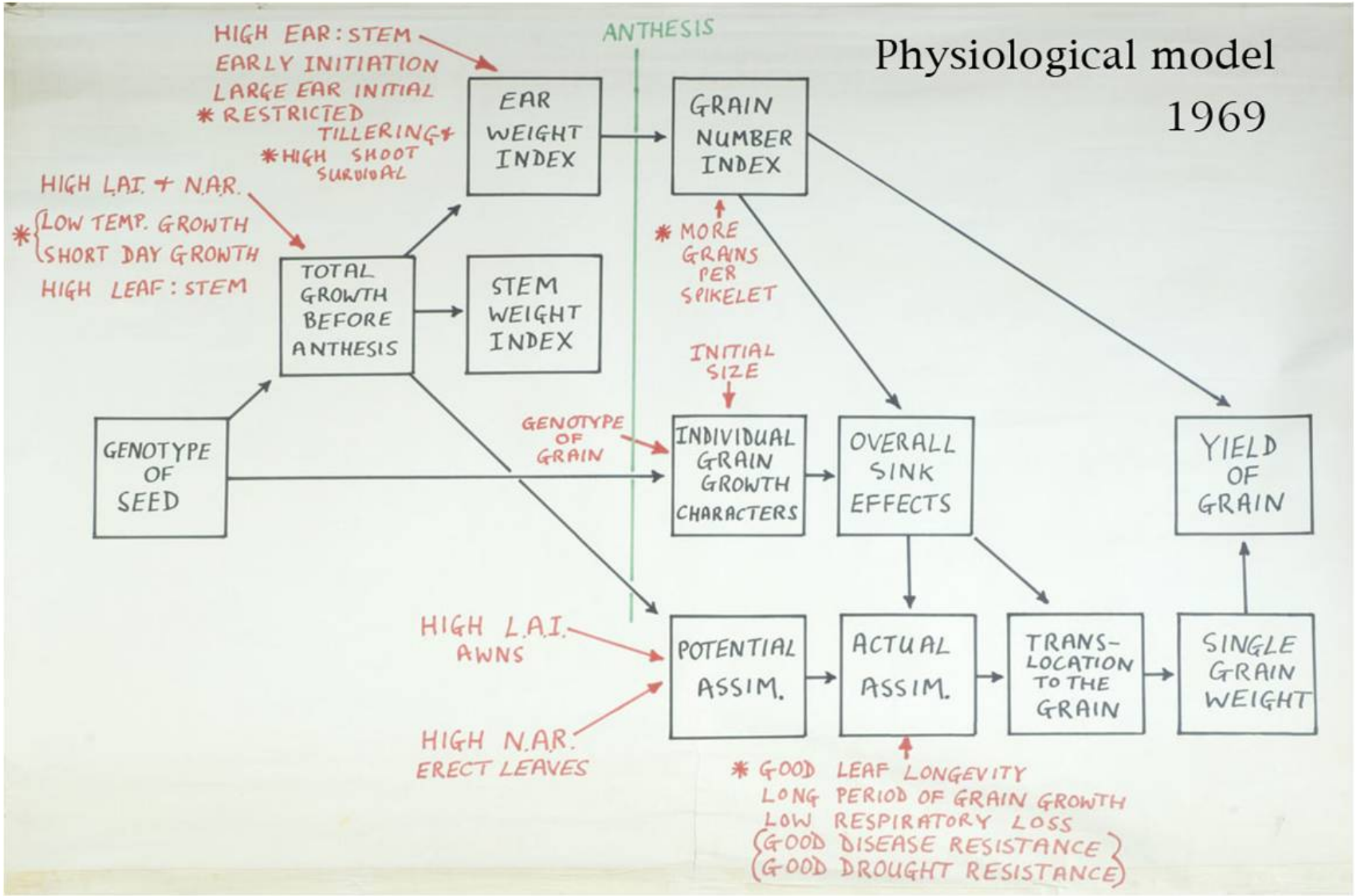
Precise genetic combinations selected with desired phenotypes

(new traits taken from the wild into elite lines)

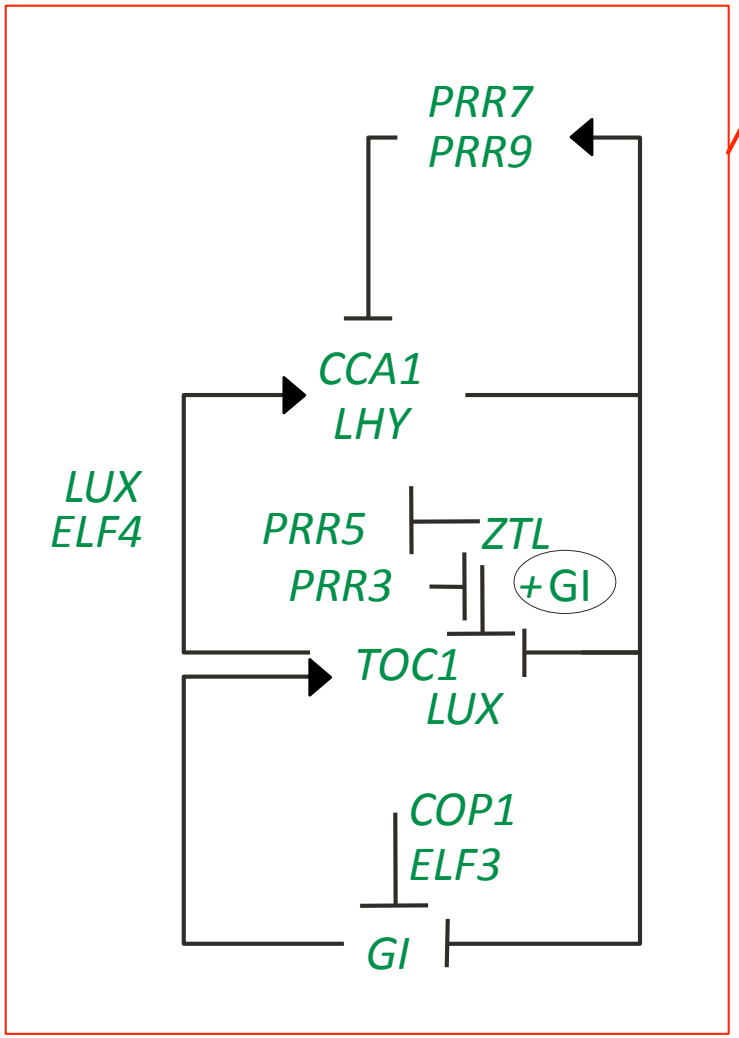
After Tanksley and McCouch. Science 277,1063.

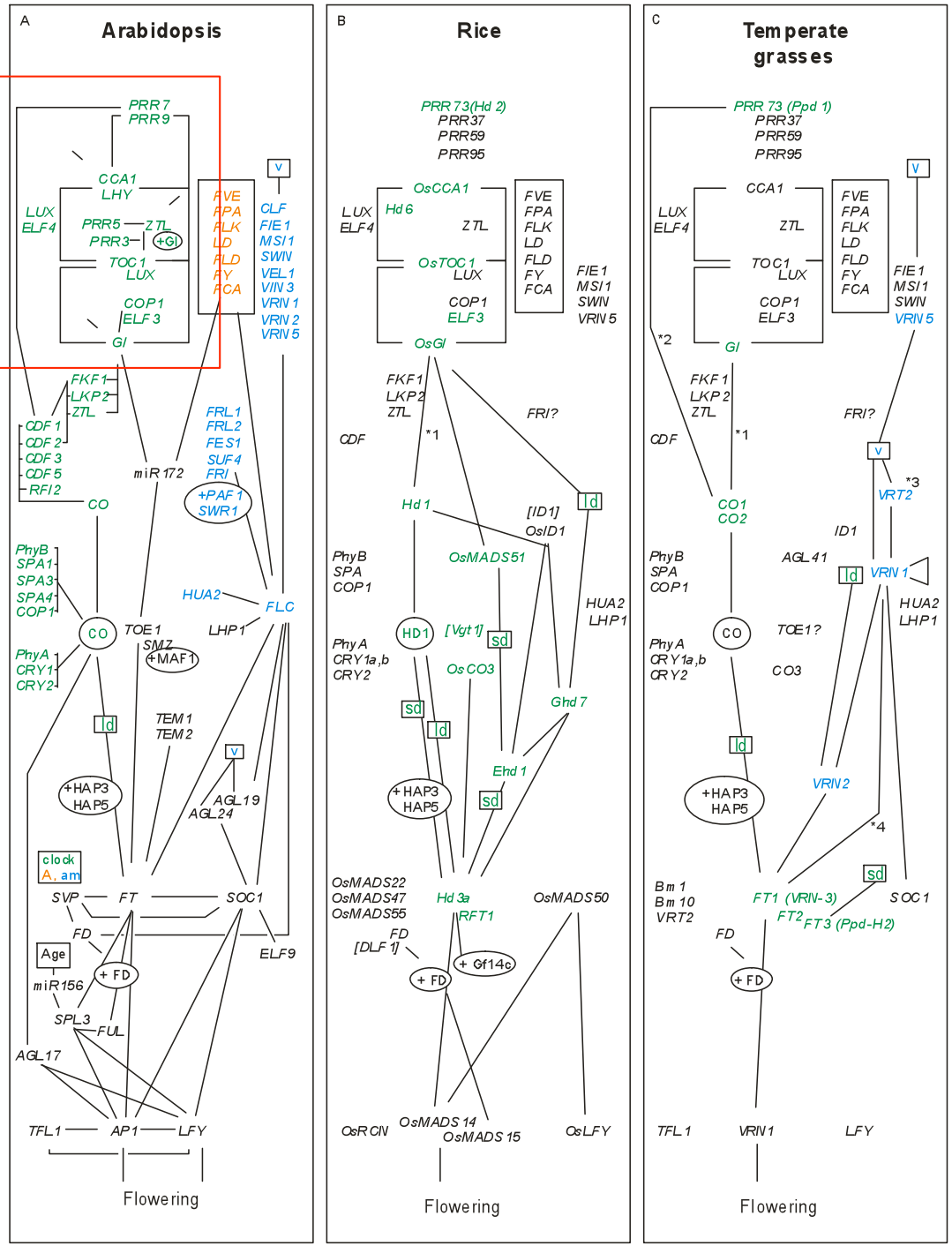
Advanced crop breeding systems

- 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


Physiological model
1969
ANTHESIS
HIGH EAR : STEM
EARLY INITIATION
LARGE EAR INITIAL
* RESTRICTED TILLERING +
* HIGH SHOOT SURVIVAL
EAR WEIGHT INDEX
GRAIN NUMBER INDEX
HIGH L.A.I. + N.A.R.
* LOW TEMP. GROWTH
SHORT DAY GROWTH
HIGH LEAF : STEM
TOTAL GROWTH BEFORE ANTHESIS
STEM WEIGHT INDEX
* MORE GRAINS PER SPIKELET
INITIAL SIZE
GENOTYPE OF SEED
GENOTYPE OF GRAIN
INDIVIDUAL GRAIN GROWTH CHARACTERS
OVERALL SINK EFFECTS
YIELD OF GRAIN
HIGH L.A.I.
AWNS
HIGH N.A.R.
ERECT LEAVES
POTENTIAL ASSIM.
ACTUAL ASSIM.
TRANS-LOCATION TO THE GRAIN
SINGLE GRAIN WEIGHT
* GOOD LEAF LONGEVITY
LONG PERIOD OF GRAIN GROWTH
LOW RESPIRATORY LOSS
GOOD DISEASE RESISTANCE
GOOD DROUGHT RESISTANCE

Genetic model 2009





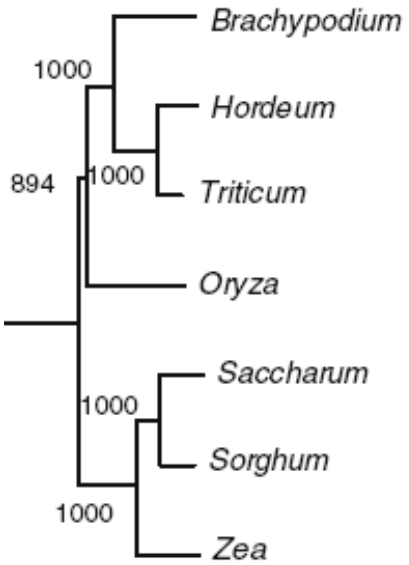
http://www.arabidopsisreactome.org

Economically significant grass sub-families

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)

Poeae

Lolium

Festuca

Source: http://beta.uniprot.org/taxonomy/

Genome analysis technology is changing

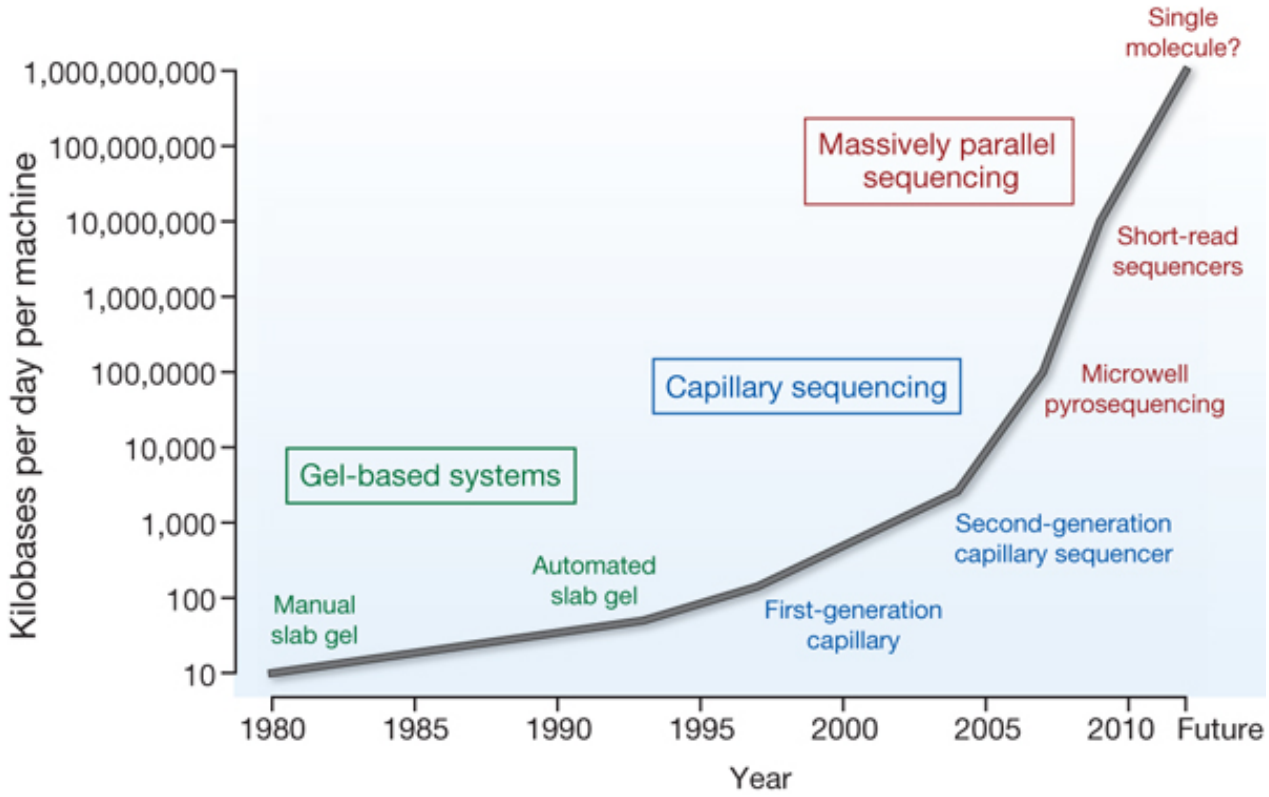
454 XLR

Illumina Hi Seq

SOLiD/ABI

bases/read	500	35	50
Read length	>750	120	50
Bases per run	500,000,000	2,000,000,000	5,000,000,000
cost/run	£4000	£3000	£6000
Cost/kb	£0.016	£0.003	£0.00012
Accuracy	Very Good	Excellent	Very Good

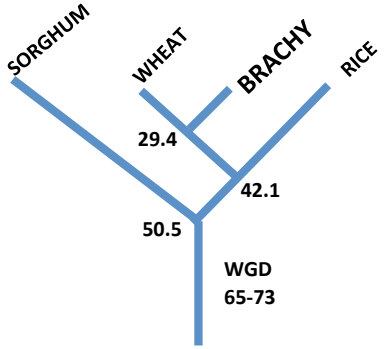
Improvements in the rate of DNA sequencing over the past 30 years and into the future.

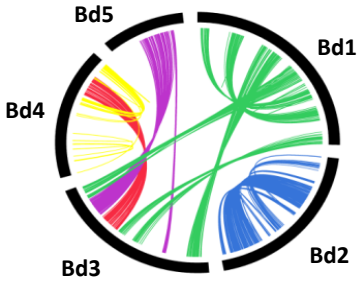


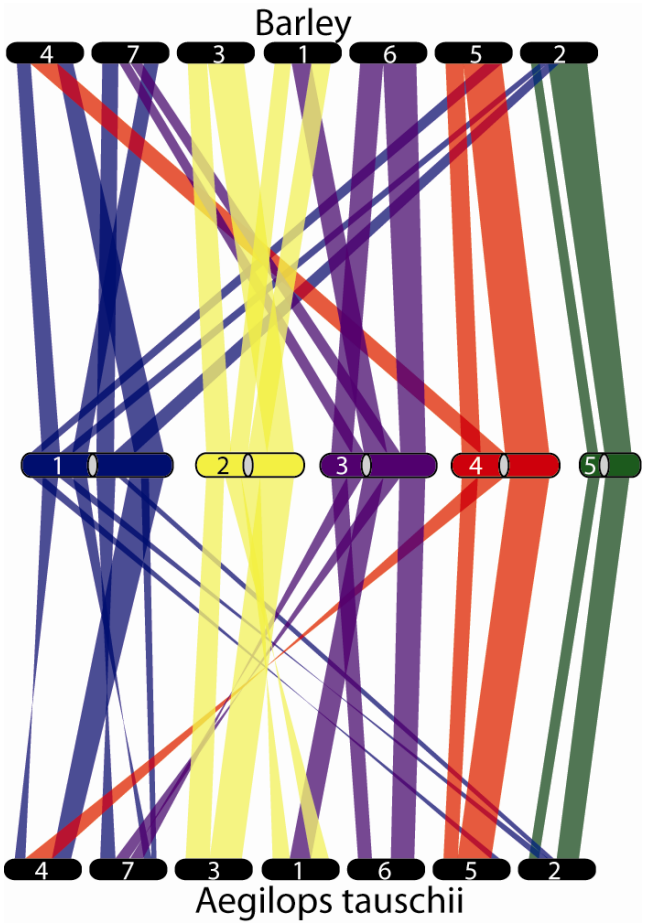
MR Stratton *et al. Nature* **458**, 719-724 (2009) doi:10.1038/nature07943

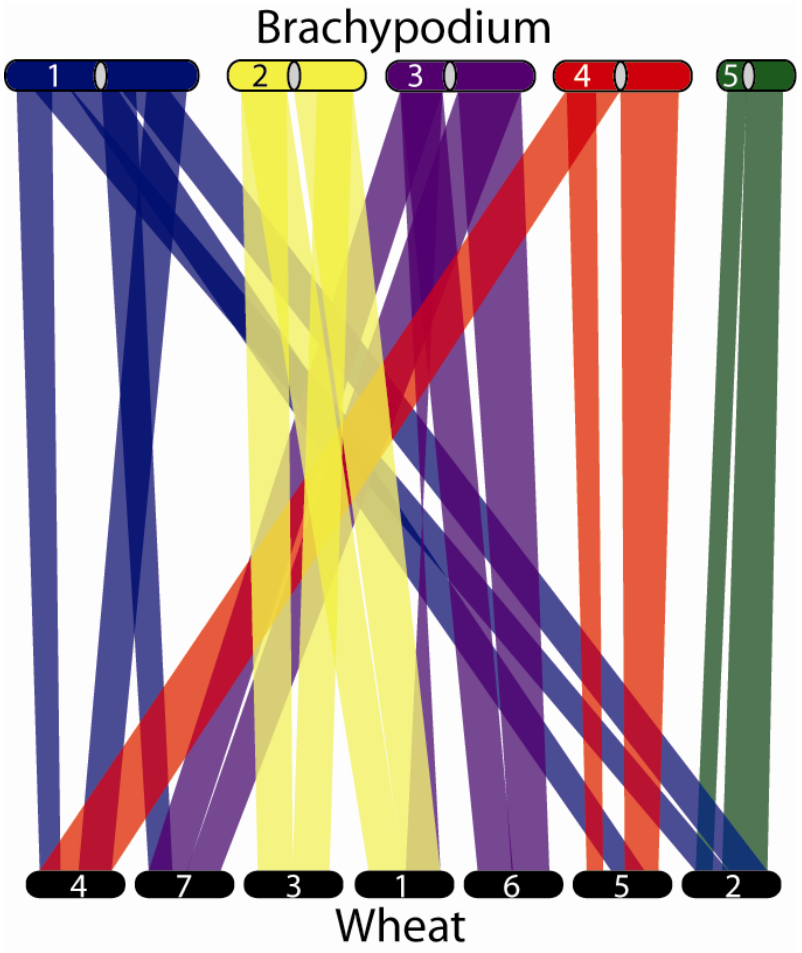
nature

Whole genome synteny analysis

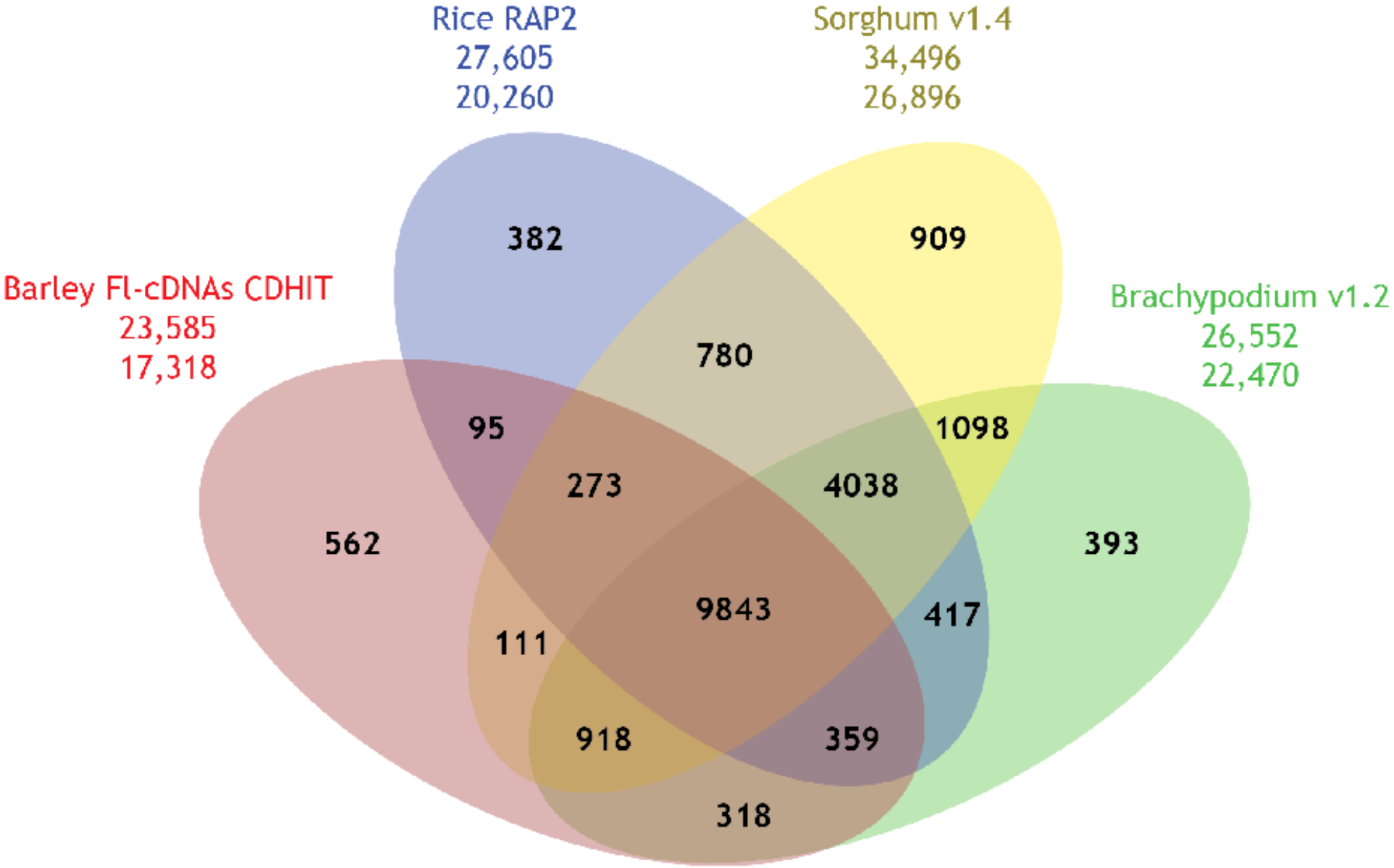


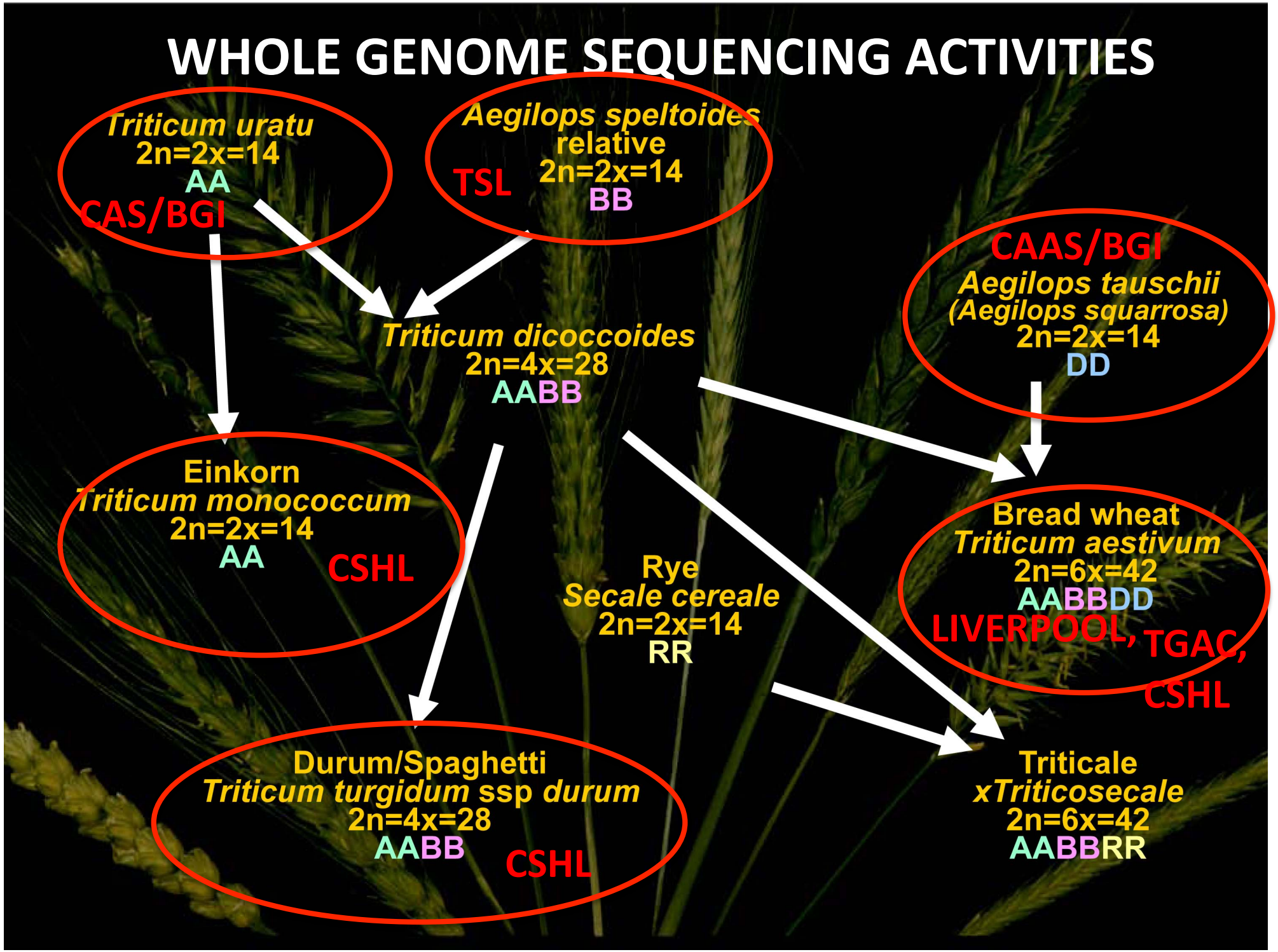




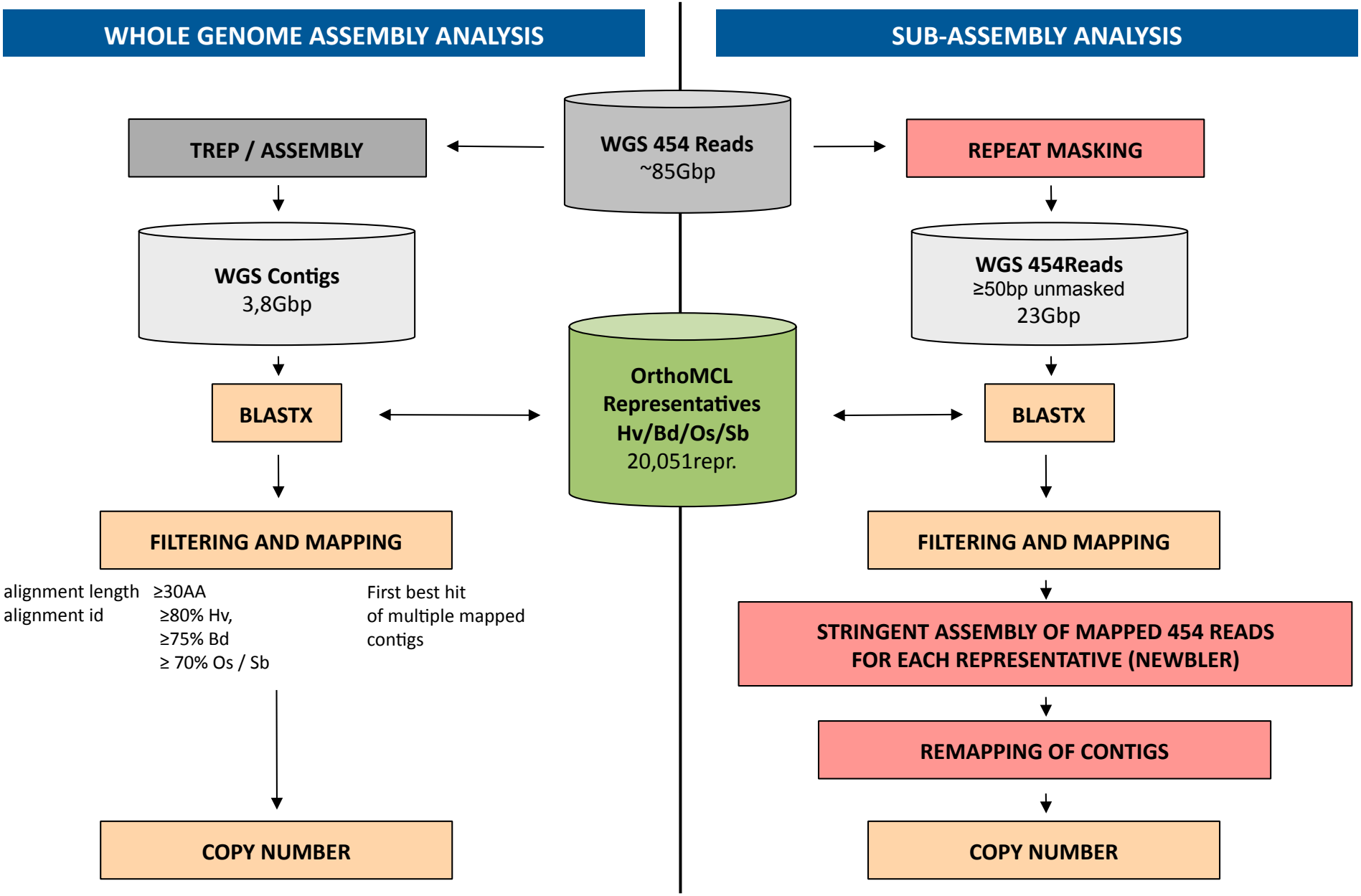


Defining an orthologous gene set for comparison

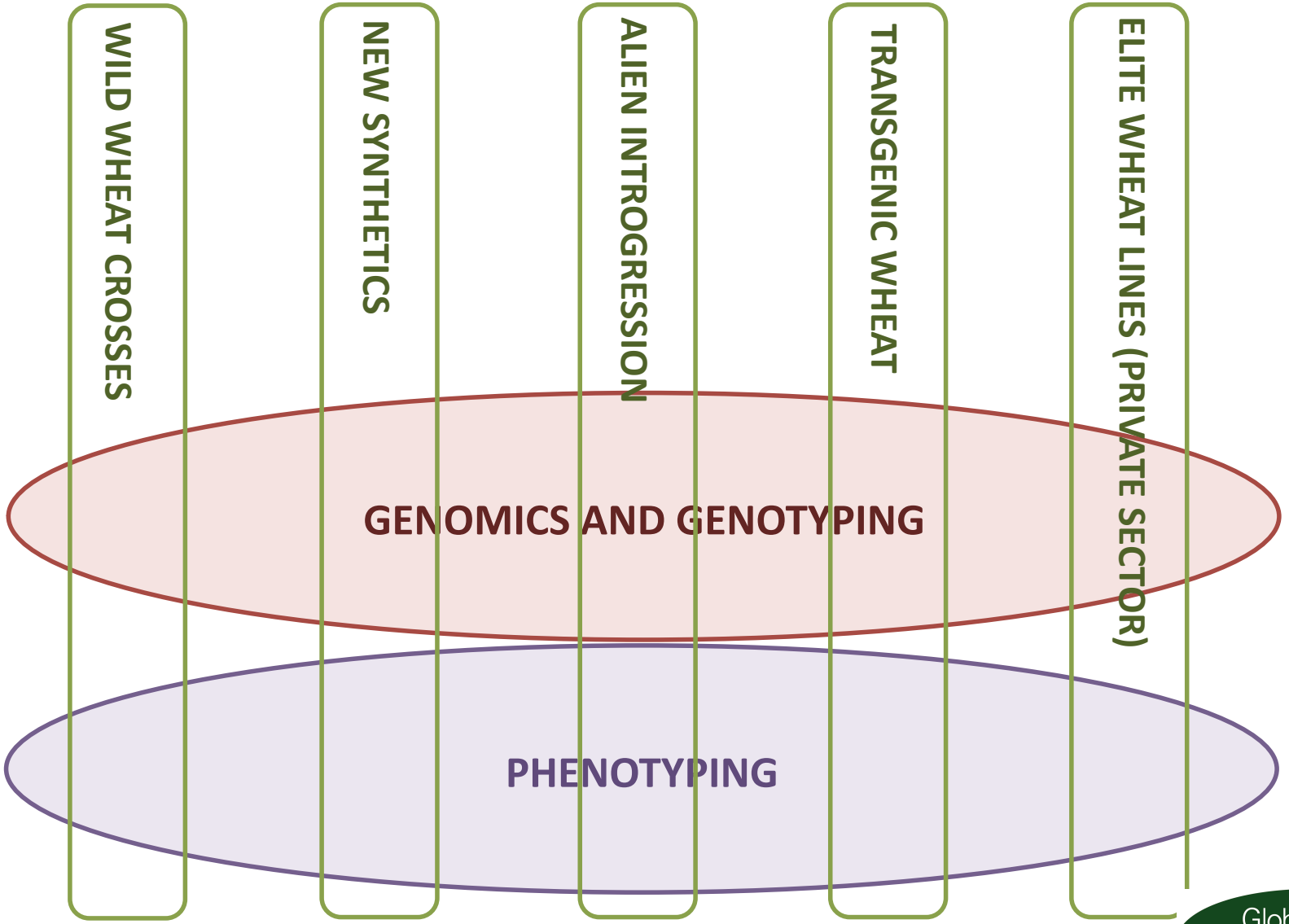



WHOLE GENOME SEQUENCING ACTIVITIES
Triticum uratu
2n=2x=14
AA
CAS/BGI
Aegilops speltoides
relative
2n=2x=14
BB
TSL
Triticum dicoccoides
2n=4x=28
AABB
CAAS/BGI
Aegilops tauschii
(Aegilops squarrosa)
2n=2x=14
DD
Einkorn
Triticum monococcum
2n=2x=14
AA
CSHL
Rye
Secale cereale
2n=2x=14
RR
Bread wheat
Triticum aestivum
2n=6x=42
AABBDD
LIVERPOOL, TGAC,
CSHL
Durum/Spaghetti
Triticum turgidum ssp durum
2n=4x=28
AABB
CSHL
Triticale
xTriticosecale
2n=6x=42
AABBRR

Analysis pipelines for genome sequence



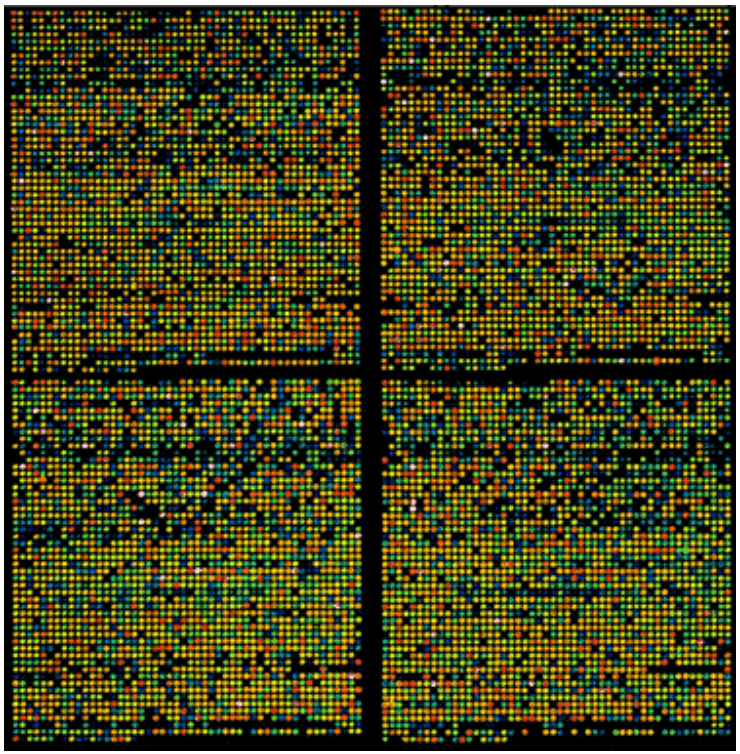
AN INTEGRATED WHEAT GERMPLASM IMPROVEMENT PROGRAMME

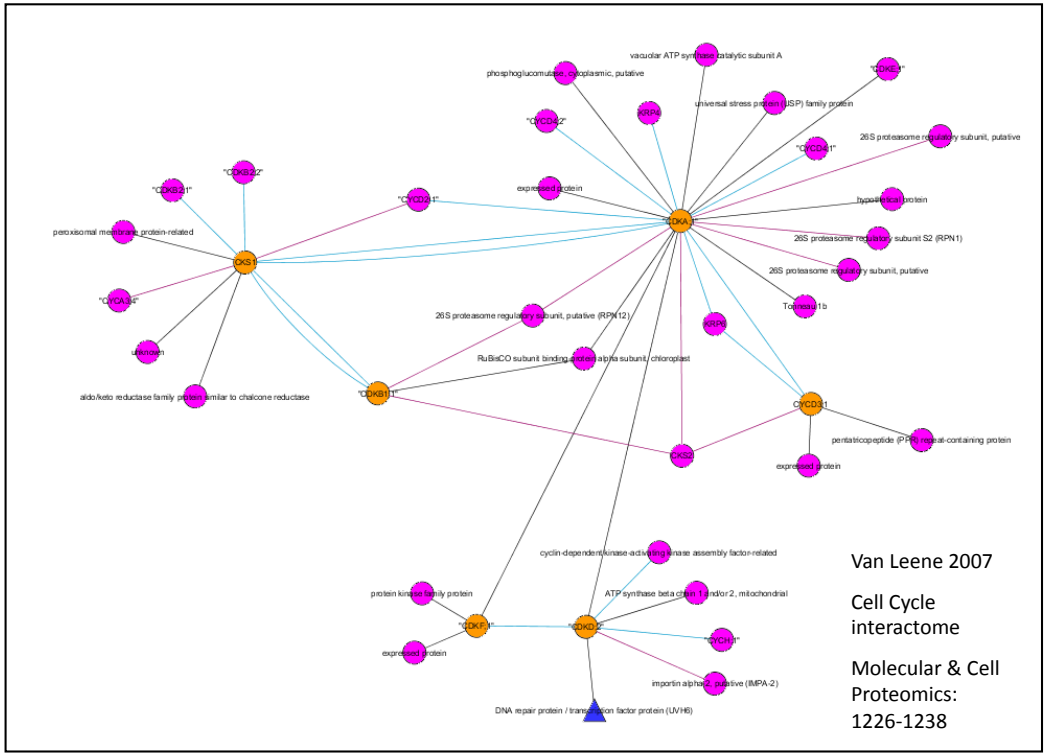


Graham Moore, JIC

Global Food Security
Sustainable, healthy food for all

GENE NETWORK ANALYSIS



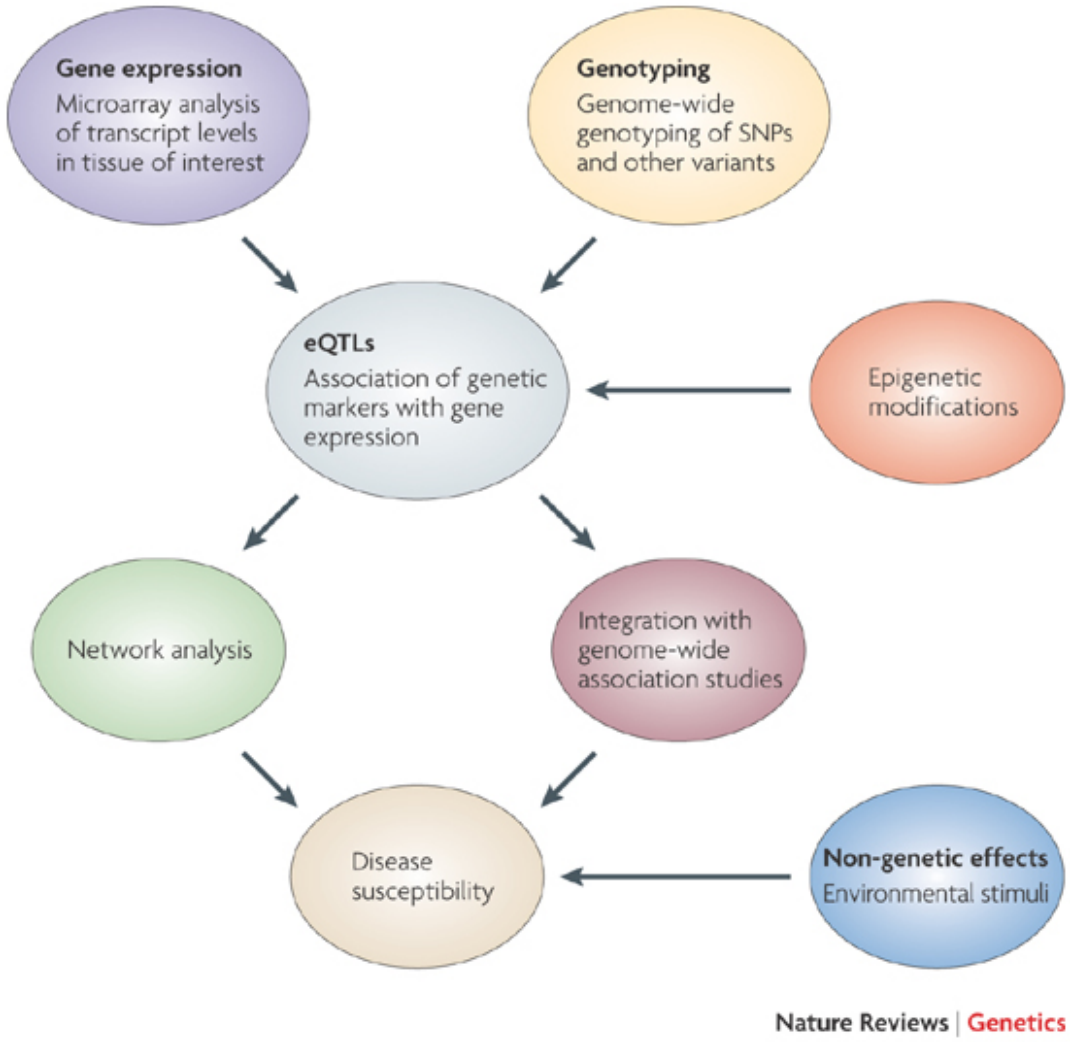


Van Leene 2007

Cell Cycle interactome

Molecular & Cell Proteomics: 1226-1238

Systems genetics analysis of complex traits



The Future – 2011-2015. A WAVE OF NEW & IMPROVED BIOTECH CROPS

ISAAA

- **Many new crop/trait** options will be ready before 2015
- **Drought tolerance**–principal trait–maize in US 2012/13
- **Biotech rice –** major crop, up to 1 billion beneficiaries
- **Quality traits** – Golden Rice in 2013, omega-3, others
- More biotech crops developed by countries from the South in public inst. – **more South-South cooperation**
- Biotech applications for **"Speeding the breeding"** – MAS and biotech crops, to provide a faster response to more severe and rapid changes in climate change
- **Asia will grow more in 2nd decade** than first decade

Source: Clive James, 2011

ISAAA Prediction for 2nd Decade, 2006-2015

	2006	2010	2015
# of Biotech Countries	22	29	~ 40
# of Farmers Planting Biotech Crops	10 Million	15.4 Million	~ 20 Million
Global Biotech Area m. hectares	100 Million Hectares	148 Million Hectares	~200 Million Hectares

Source: Clive James, 2011

Acknowledgements

- Neil McKenzie, Cristobal Uauy, Andreas Magusin (JIC)
- Jon Wright, Darren Waite, Mario Caccamo, Melanie Febrer, Jane Rogers (TGAC)
- Matthias Haimel, Paul Kersey, Ewan Birney (EBI)
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- Gary Barker, Keith Edwards (Bristol)
- Melissa de la Bastide, Dick McCombie (CSHL)
- Mincheng Luo, Jan Dvorak (UC Davis)
- Matthias Pfeifer, Manuel Spannangl, Klaus Mayer (H-Z Munich)