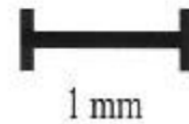


## Plant of the day: Marshelder

- Close relative of ragweed and sunflower
- Domesticated in eastern North America as an oilseed
- Domesticated form now extinct



Marshelder (*Iva*)



*Iva annua*

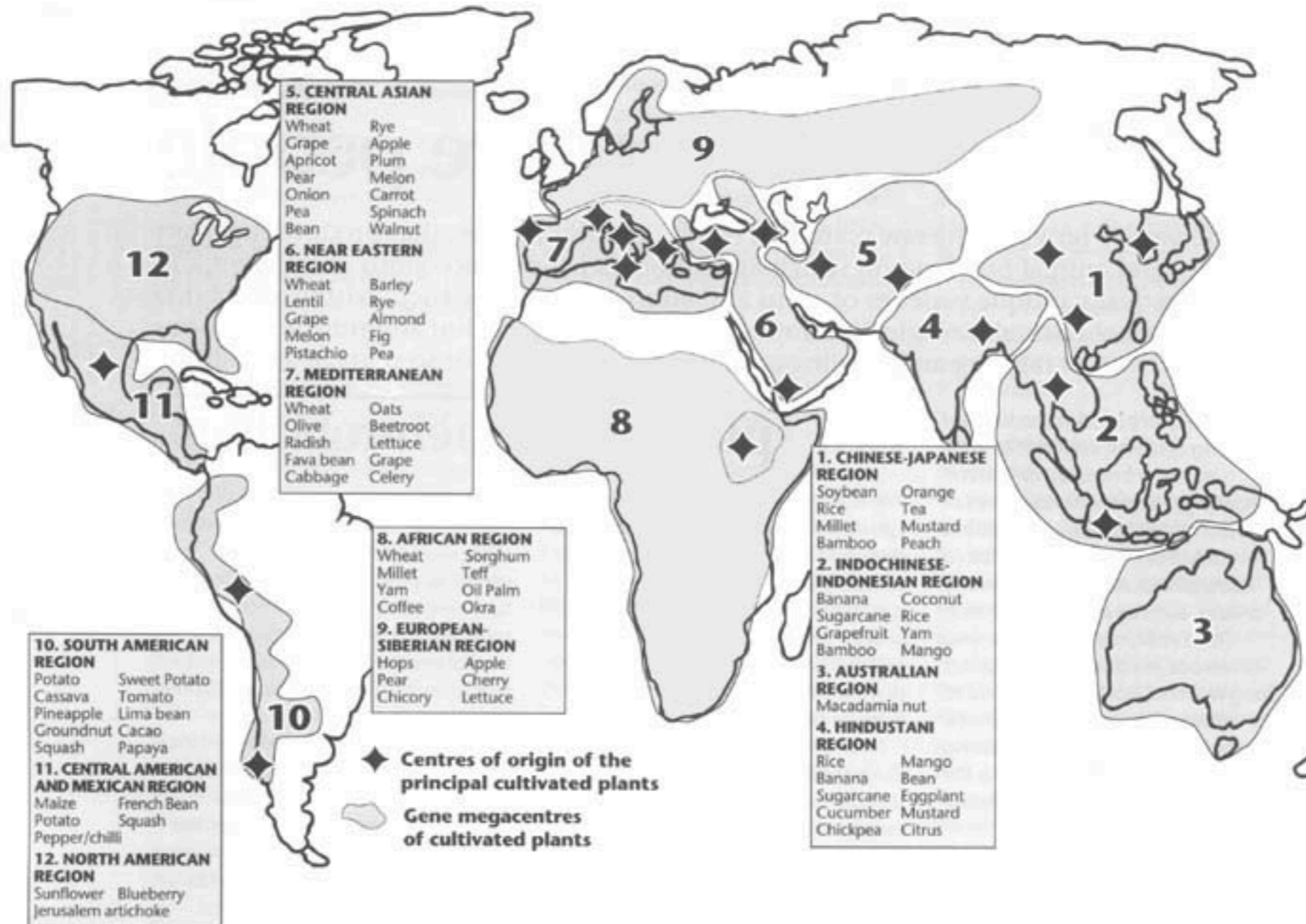
# Crop domestication



# Big Questions:

- Where, why and when were plants domesticated?
- What are domestication traits?
- What is the difference between domestication, diversification and improvement?
- What kinds of genetic changes are under selection during domestication?
- Do analyses of evolution under domestication inform us about evolution under natural selection?

# Centres of domestication



Archaeological evidence suggests that hunter-gatherers independently began cultivating food plants in at least 12 regions of the world (Doebley et al. 2006)

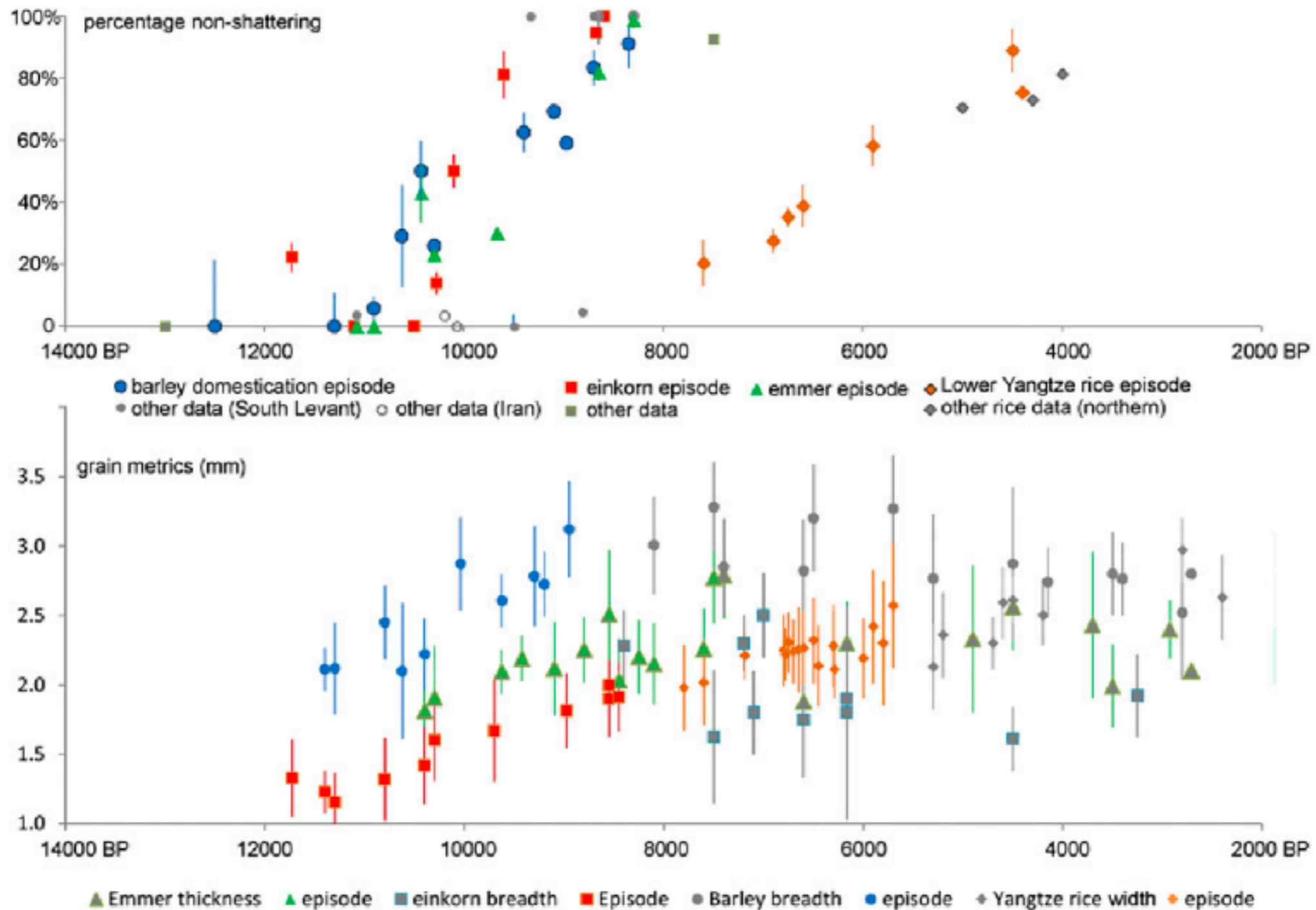
# Reasons for domestication

## **THINK - PAIR - SHARE**

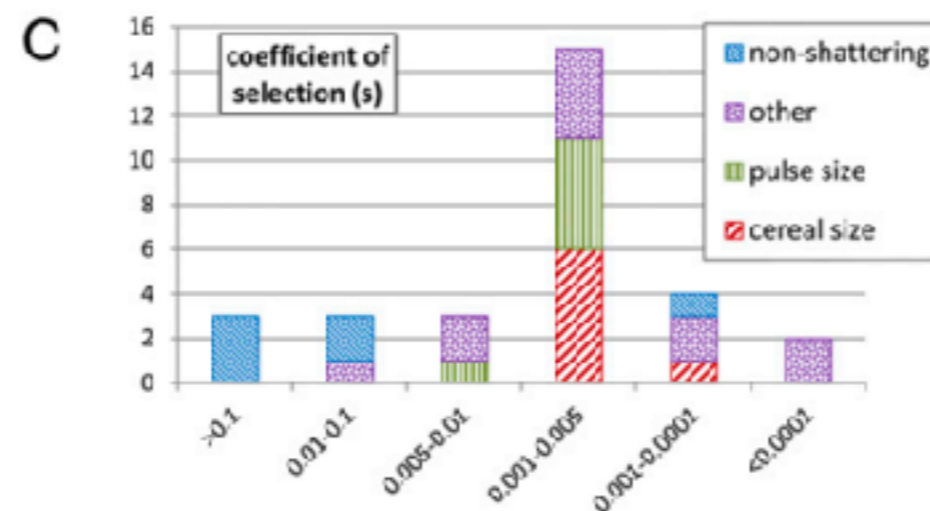
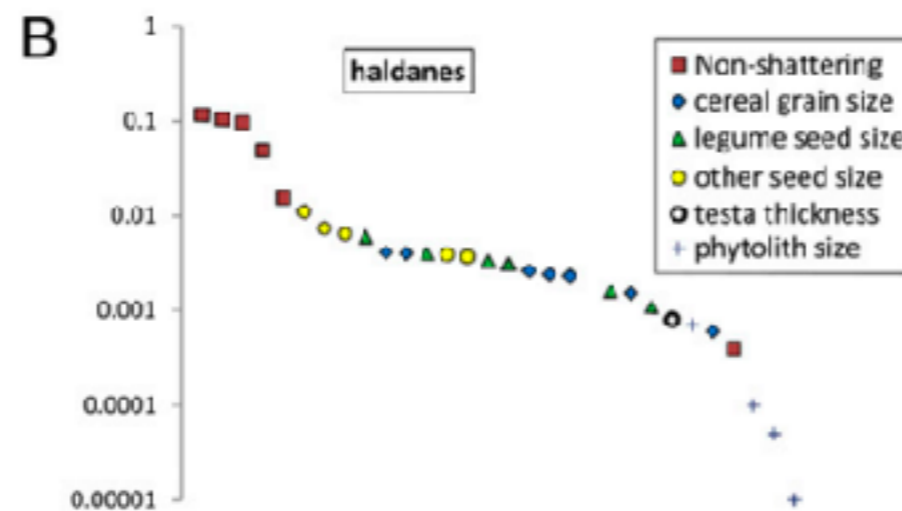
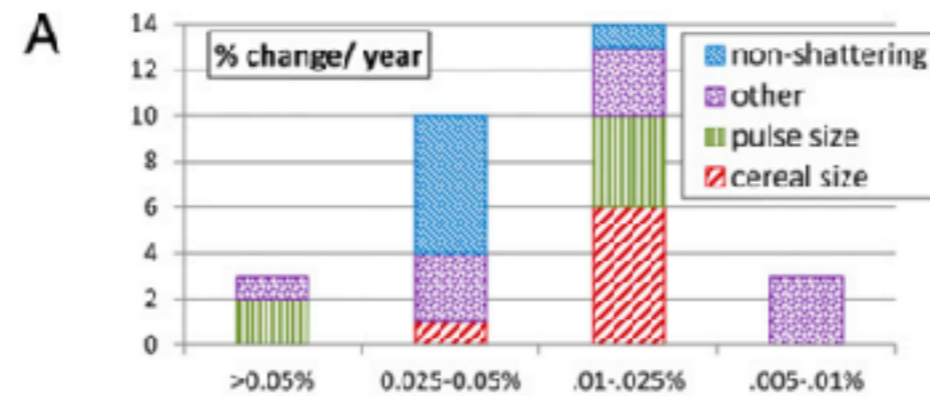
Why were plants domesticated?



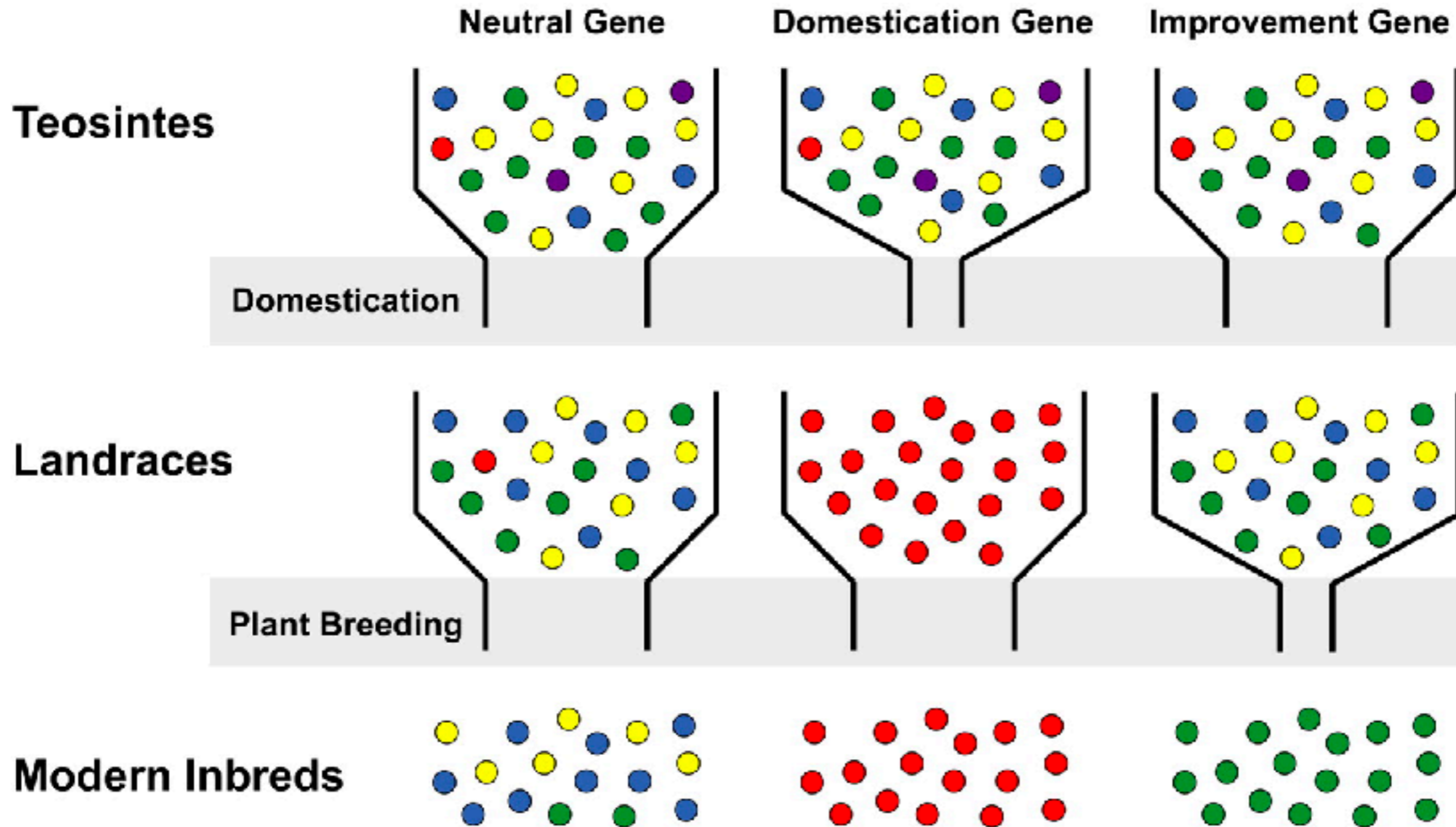
# Speed of domestication



# Speed of evolution



# Domestication bottlenecks





# Domestication Bottlenecks

- Breeding between cultivars or with wild progenitors can restore diversity.
- The level of bottleneck depends on the species and the level of domestication

# Domestication Syndrome

A domestication syndrome describes the properties that distinguish a certain crop from its wild progenitor.

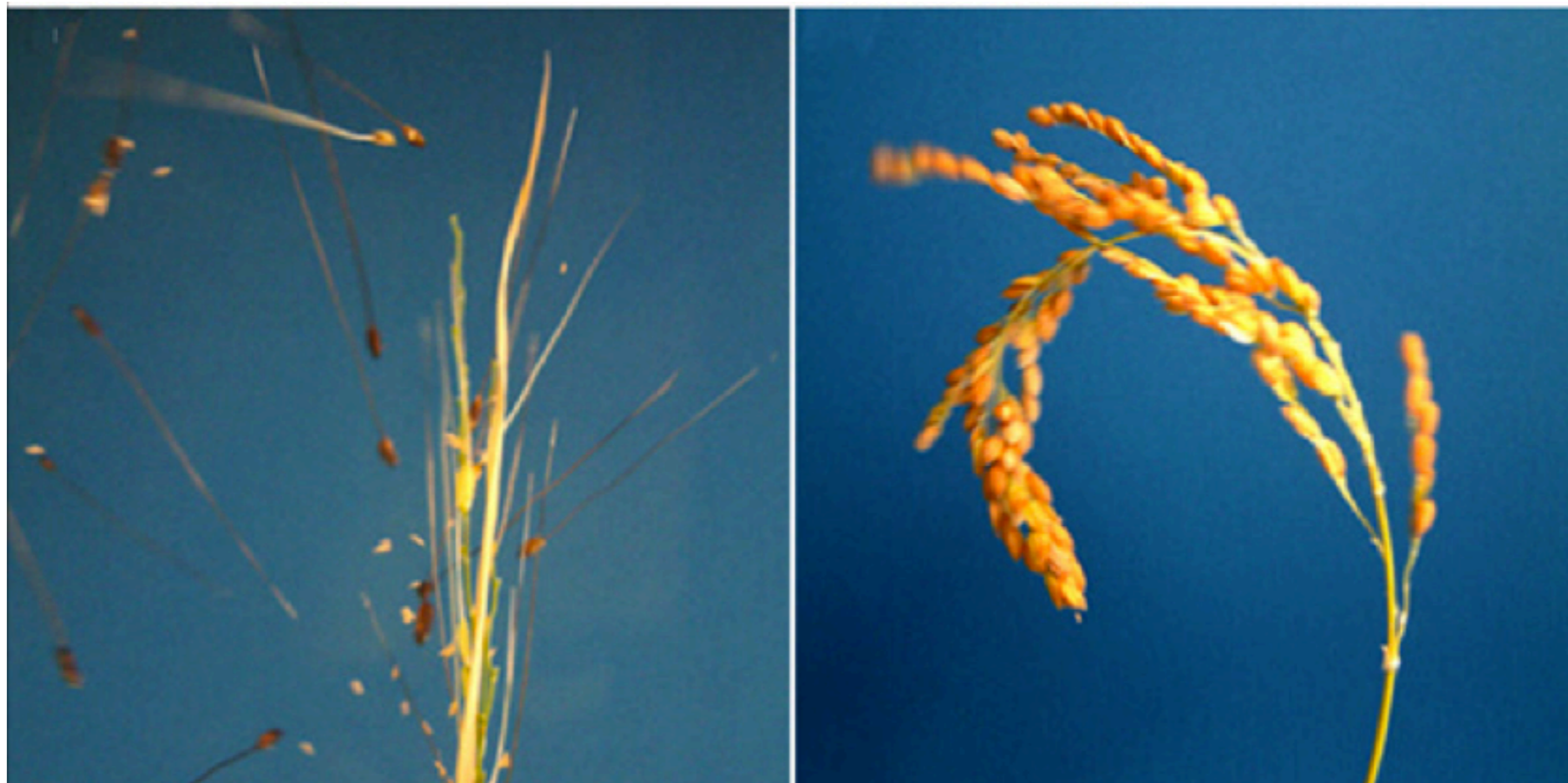
## **THINK - PAIR - SHARE**

What are some domestication traits?

What about for seed crops vs. root crops vs. fruit crops?

# Domestication traits

A lack of shattering





# Domestication traits

Less branching





# Domestication traits

Fewer larger fruits





# Domestication as a process

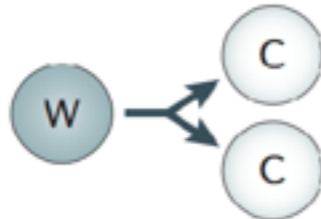
- The distinction 'domesticated' or 'not domesticated' is an oversimplification
- Some crops have moved further along this process further than others.
- We can recognize different levels of domestication
- How can we decide which level?

# Domestication process

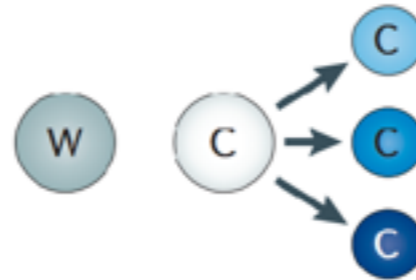
**a Stage 1:**  
Onset of domestication



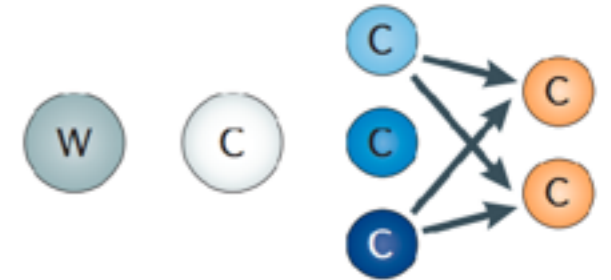
**b Stage 2:**  
*In situ* increase in frequency of desirable alleles



**c Stage 3:**  
Formation of cultivated populations that are adapted to new environments and local preferences



**d Stage 4:**  
Deliberate breeding



Domestication



Diversification



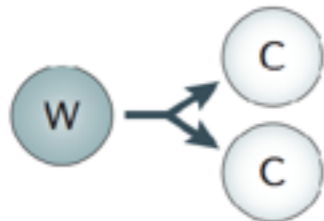
Improvement

# Domestication process

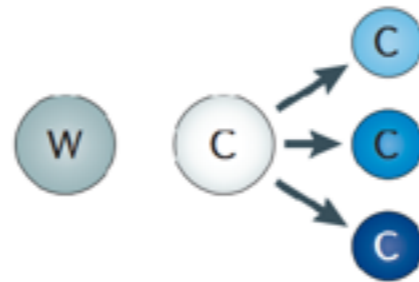
**a Stage 1:**  
Onset of domestication



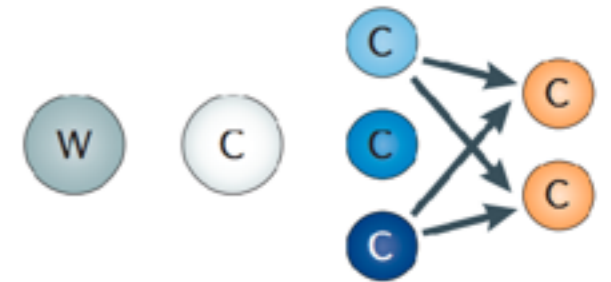
**b Stage 2:**  
*In situ* increase in frequency of desirable alleles



**c Stage 3:**  
Formation of cultivated populations that are adapted to new environments and local preferences



**d Stage 4:**  
Deliberate breeding



Domestication



Diversification



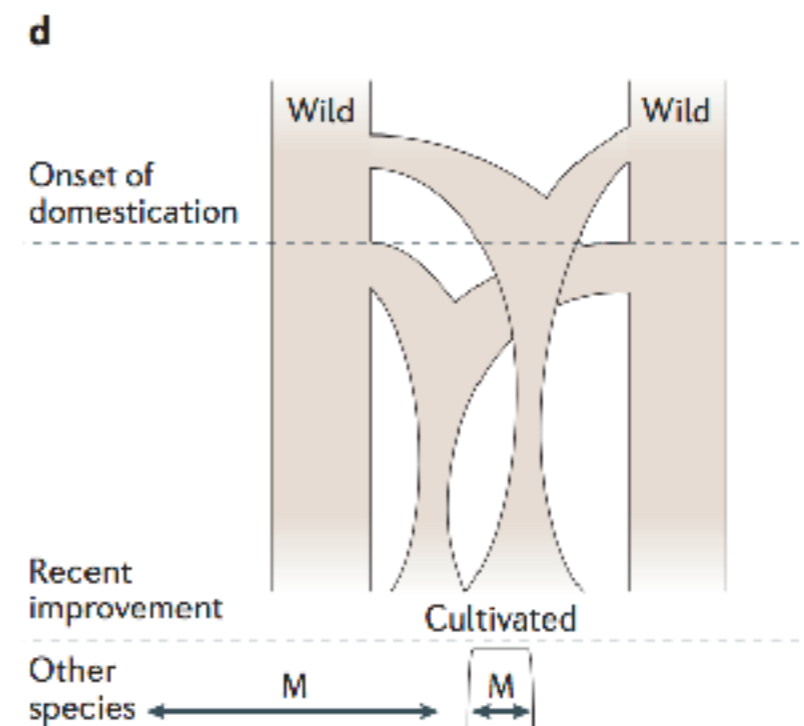
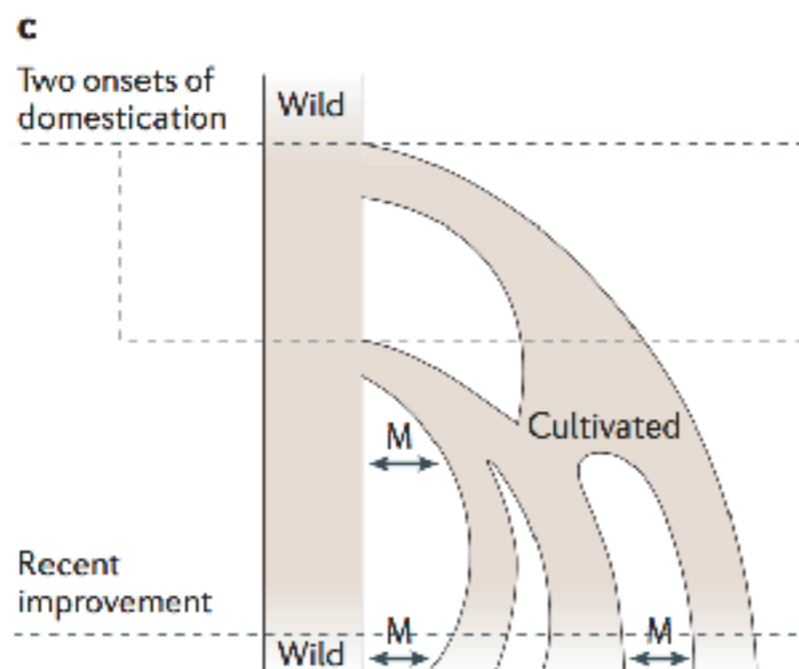
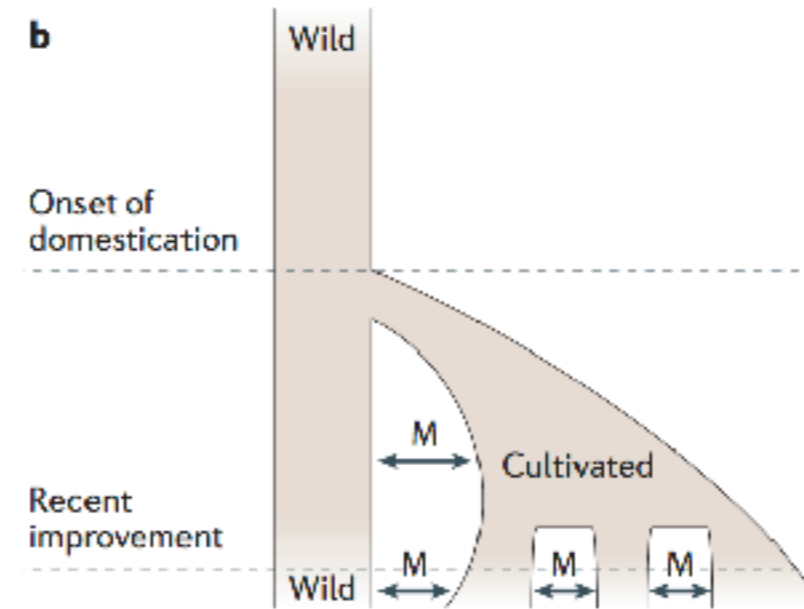
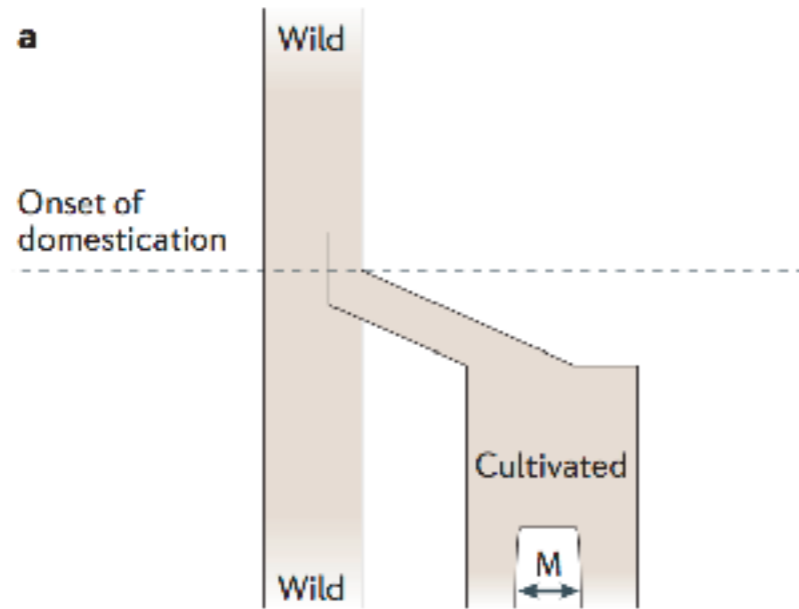
Improvement

**How might improvement traits be different from domestication traits?**



# Domestication process

Older view

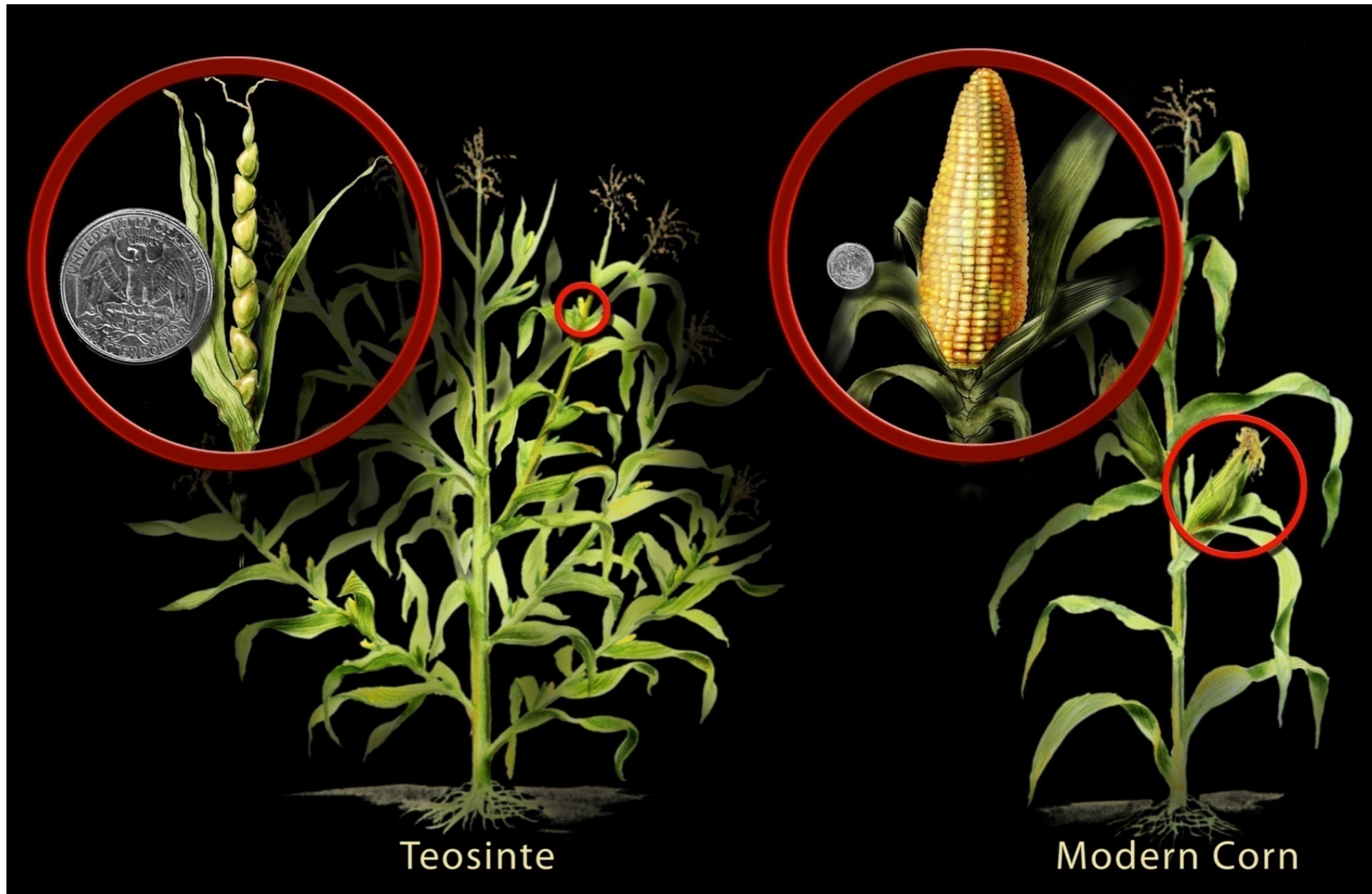


# Domestication process

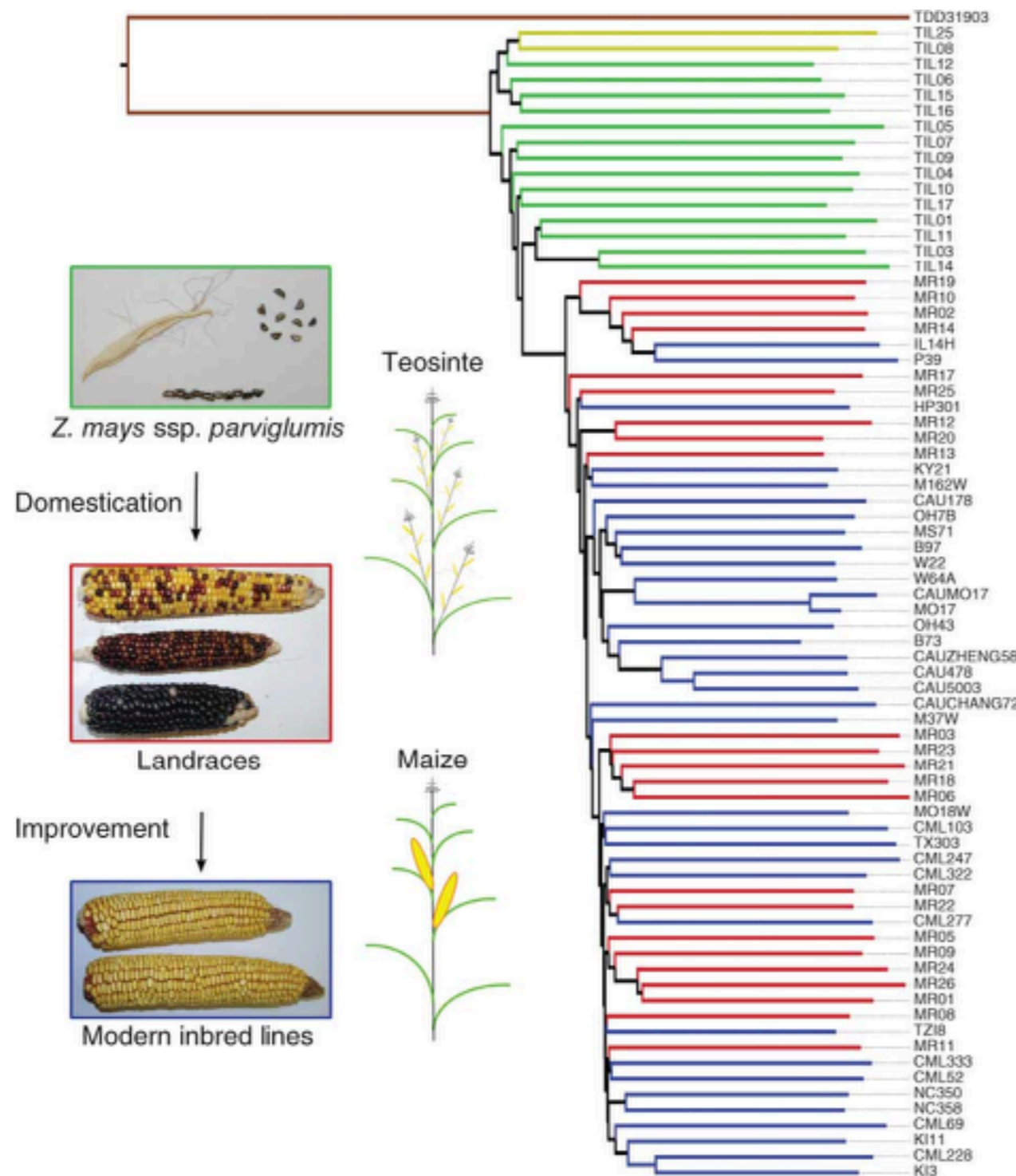
- Plants can have multiple origins of domestication
  - Barley, bottlegourd, coconut, common bean
- Gene flow between cultivate crops and wild progenitors during domestication is also possible



# Maize domestication



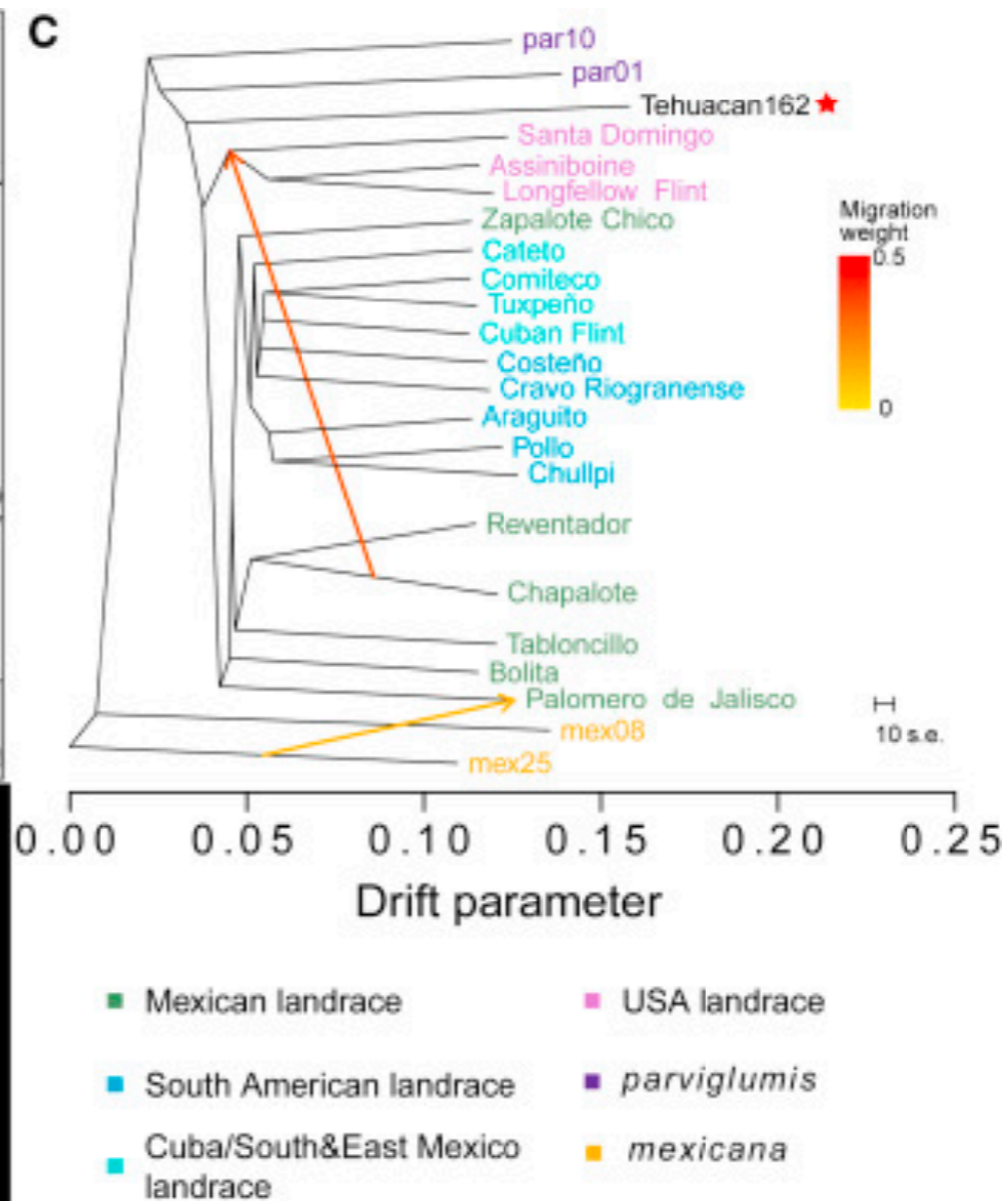
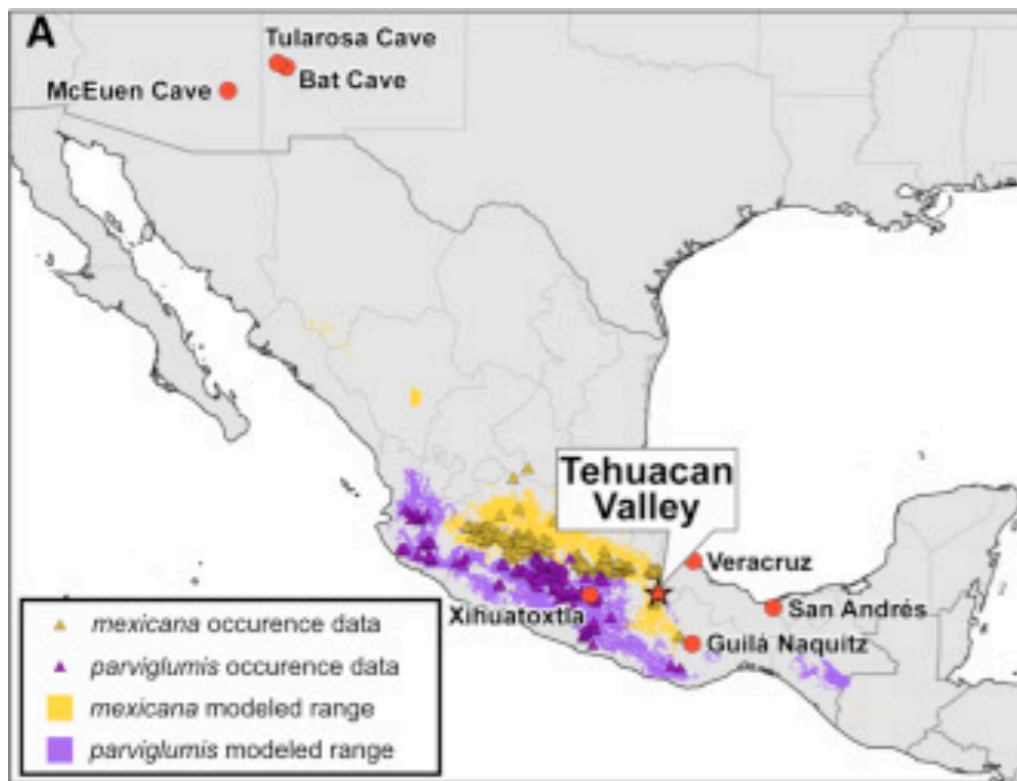
# Maize domestication



Single origin

Hufford *et al.* 2012

# Maize domestication

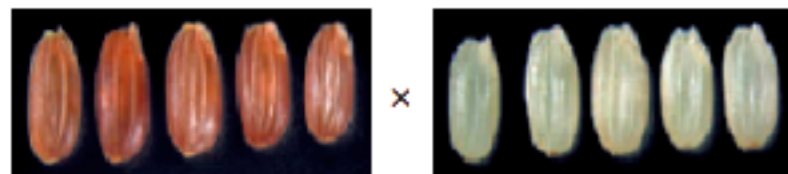


5310 year old maize cob! Ramos-Madrugal *et al.* 2016



# Detecting domestication genes

## a Discovery of domestication mutations that alter rice bran colour through fine mapping



Genetic mapping of the red bran trait provides a general location of the *Rc* locus

Fine mapping localizes *Rc* to a bHLH gene

Sequence analyses of 440 individual cultivars identify distinct *Rc* haplotypes, including a predominant 14-bp deletion

## b Candidate domestication-related genes discovered through resequencing

Whole-genome resequencing of many domesticated rice cultivars and *Oryza rufipogon* plants

### Selective-sweep mapping

Identify regions with significantly reduced diversity or high  $F_{ST}$  in domesticated rice but not in wild rice

Identify alleles that are fixed in cultivars

Near-complete fixation found in an unannotated gene, *09G0547100*

### GWASs

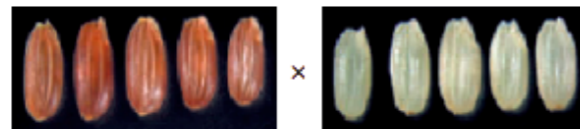
Generate a SNP map and phenotype data

Identify SNPs that are associated with grain width in a mixed linear model

High minor allele frequencies found in two SNPs: one in a known grain width locus and one in an unknown gene

# Detecting domestication genes

**a** Discovery of domestication mutations that alter rice bran colour through fine mapping



Genetic mapping of the red bran trait provides a general location of the *Rc* locus

Fine mapping localizes *Rc* to a bHLH gene

Sequence analyses of 440 individual cultivars identify distinct *Rc* haplotypes, including a predominant 14-bp deletion

**b** Candidate domestication-related genes discovered through resequencing

Whole-genome resequencing of many domesticated rice cultivars and *Oryza rufipogon* plants

## Selective-sweep mapping

Identify regions with significantly reduced diversity or high  $F_{ST}$  in domesticated rice but not in wild rice

Identify alleles that are fixed in cultivars

Near-complete fixation found in an unannotated gene, *09G0547100*

## GWASs

Generate a SNP map and phenotype data

Identify SNPs that are associated with grain width in a mixed linear model

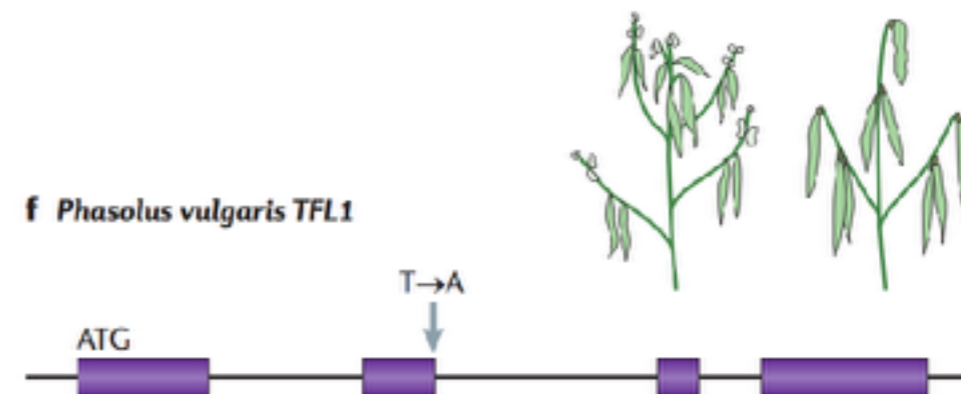
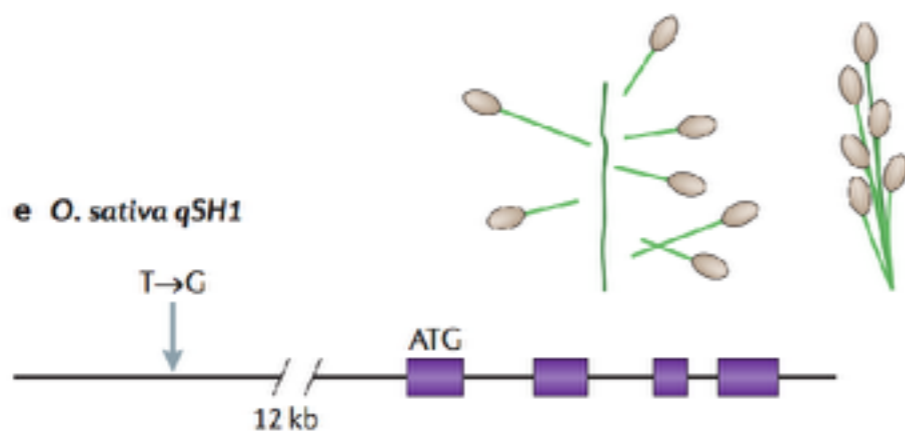
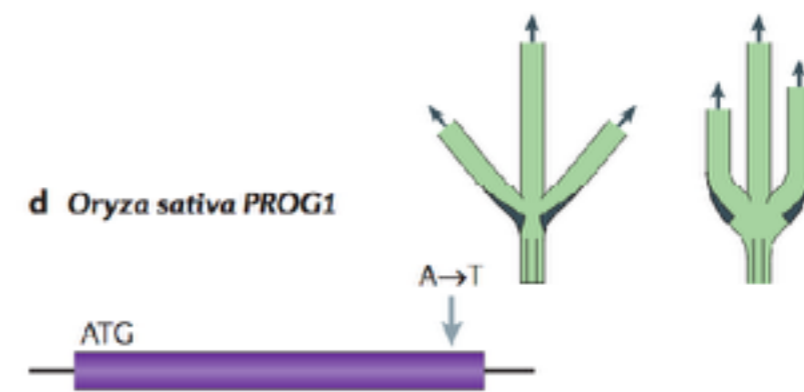
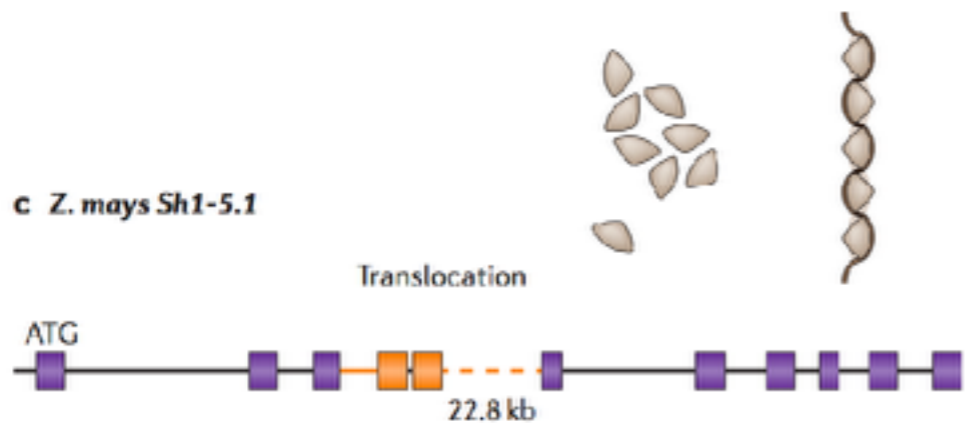
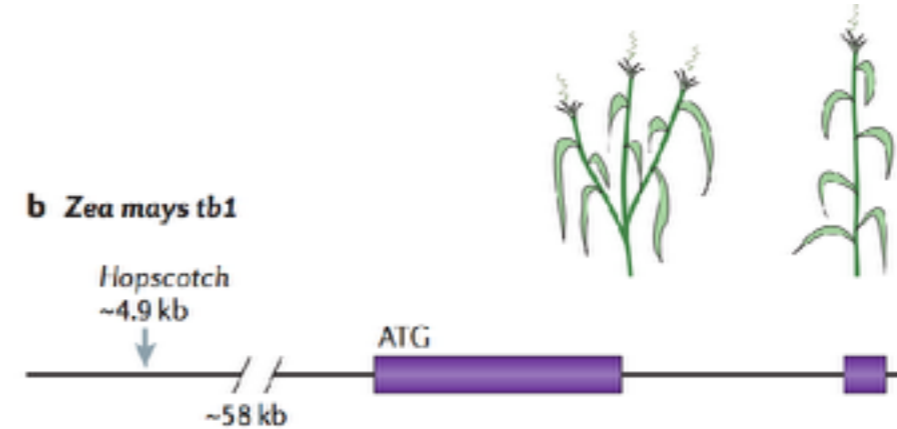
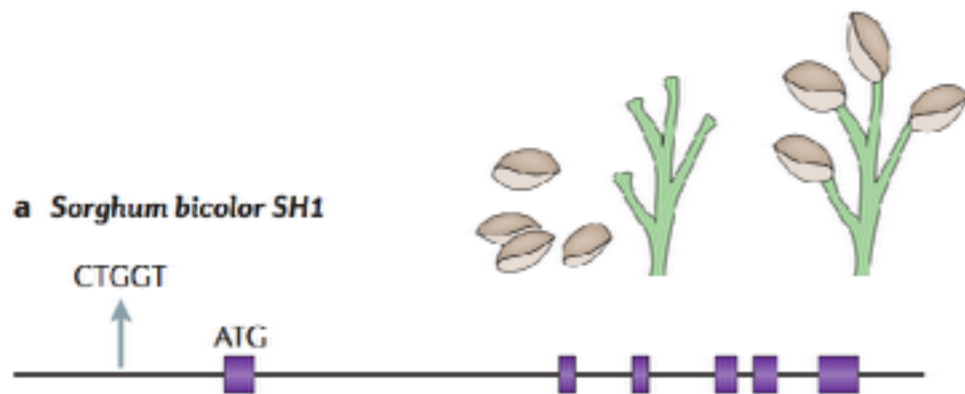
High minor allele frequencies found in two SNPs: one in a known grain width locus and one in an unknown gene

**THINK - PAIR - SHARE**

**What are some weaknesses of each method?**



# Domestication genes



# Domestication genes

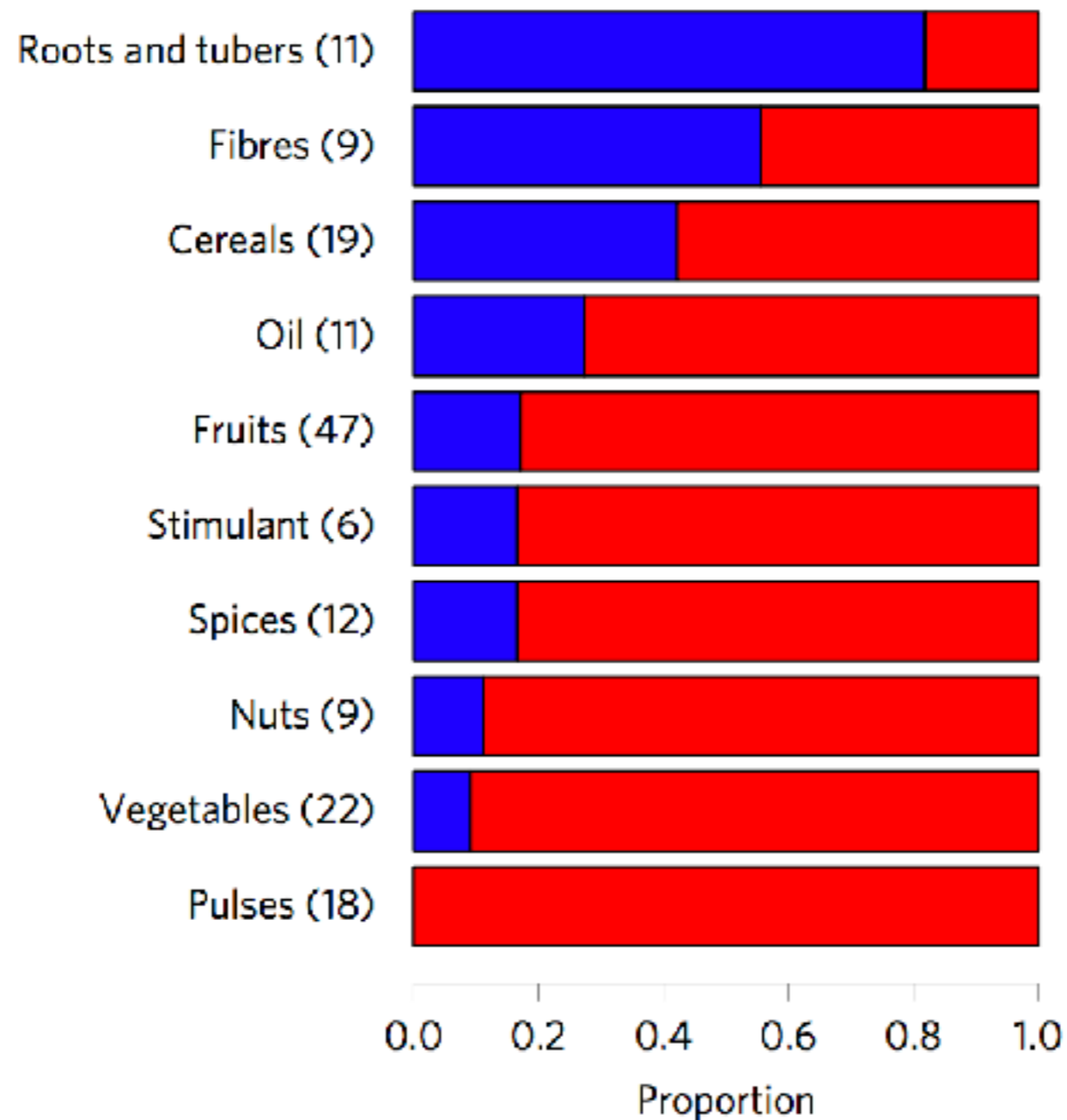
- A majority of domestication genes are transcription factors
- Are enriched for genes of large effect (loss of function alleles)
- Can be new mutations or be found in the wild progenitor

# Genetic parallelism

- Sticky rice is caused by a mutation in the WAXY gene
- Mutations in the same gene cause sticky varieties in broomcorn millet, foxtail millet and three *Amaranthus* spp. pseudocereals

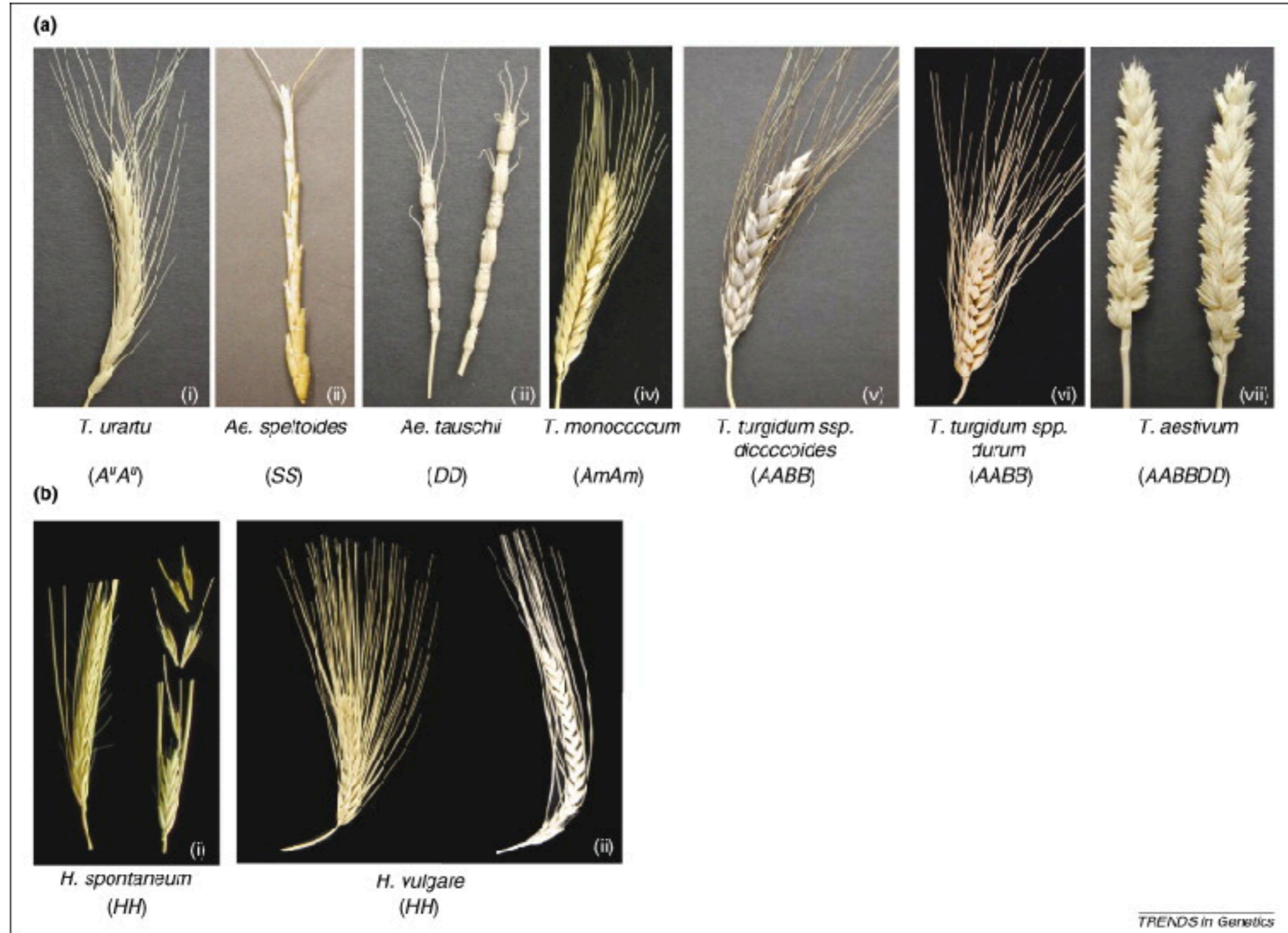


# Polyploidy and domestication



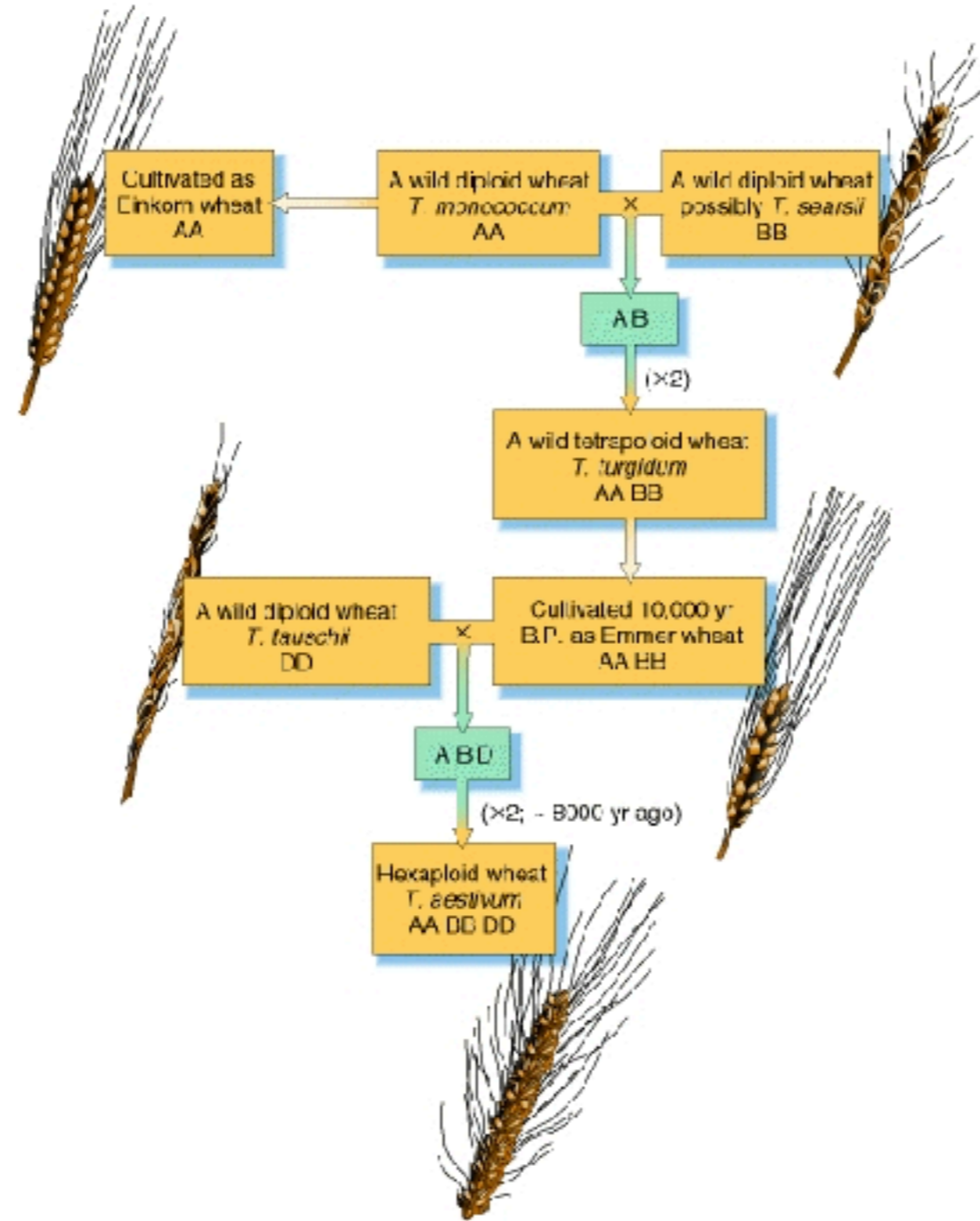


# Polyploidy and domestication

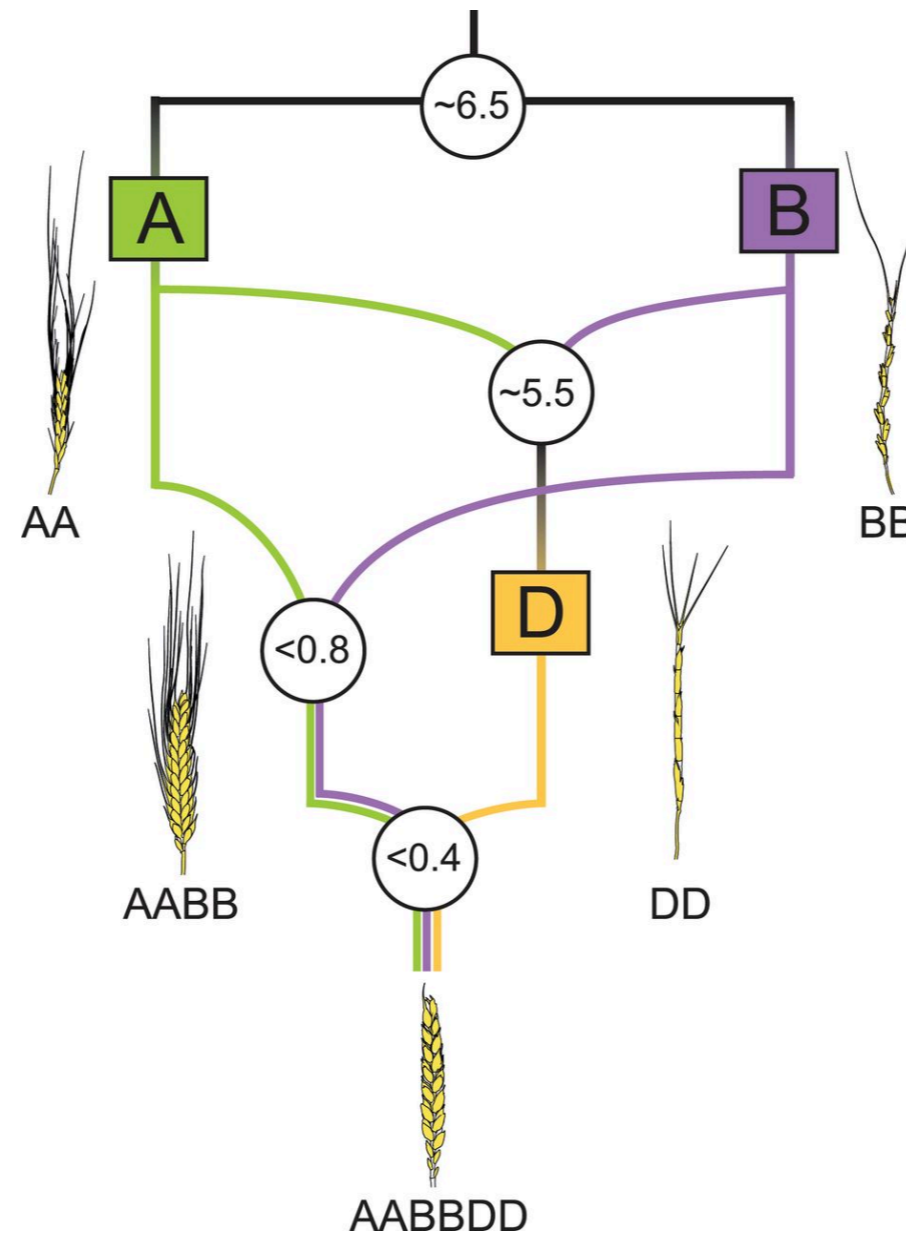




# Polyploidy and domestication



# Polyploidy and domestication



# Unanswered questions

- Why are some crops only weakly domesticated?
- Are the major effect domestication genes/mutations cloned so far representative of other crops/genes/mutations?
- What is the role of reproductive isolation in domestication? What about gene flow from wild relatives?
- Do domesticated plants carry high levels of genetic load?